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The Influence of Precision Dripping Irrigation System on the Phenology and Yield Indices of Sweet Maize Hybrids

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Abstract: Sweet maize is an annual plant that is extremely useful and economical for planting and harvesting. However, maize stands are damaged quickly in the case of nutrient and water deficiency. This research was carried out under dripping irrigation conditions and control plots without irrigation, involving seven different maize hybrids. The obtained results showed no existing variation in the dry matter content of cob (DMC) between the irrigated and non-irrigated treatments. Correlation analysis showed that increasing DMC causes decreasing moisture content of cob (MC) of sweet maize with irrigated and non-irrigated treatments. DMC and MC are important factors in the yield index on irrigation treatments. Biplots showed that the Dessert R72 (10.82) hybrid had maximum yield and effect on Brix/Abbe and Brix/Atago Pal-1, while the Messenger hybrids (42.96) had maximum effect on MC. It was also shown that DMC and MC are important factors in the yield index on irrigation treatments on hybrids. The Noa (37.97) and Honey hybrids (27.88) had minimum effect and performance on non-irrigation and irrigation treatments. The Messenger (11.25) and SF1379 hybrids (10.5) had a maximum performance on Brix Abbe and Brix Pal in the irrigation treatment and Dessert R78 (13.5), the Messenger hybrid (11.8) had a maximum performance on Brix/Abbe and Brix/Atago Pal-1 in non-irrigation treatment. The Dessert R78 (13.5) is the best-performing hybrid in terms of the yield of Brix/Abbe and Brix/Atago Pal-1 in the performed irrigation treatments.

Keywords: dry matter content of cob; drought stress; maize hybrids; Brix

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Citation: Illés, Á.; Szabó, A.; Mousavi, S.M.N.; Bojtor, C.; Vad, A.; Harsányi, E.; Sinka, L. The Influence of Precision Dripping Irrigation System on the Phenology and Yield Indices of Sweet Maize Hybrids. *Water* **2022**, *14*, 2480. https://doi.org/10.3390/w14162480

Academic Editors: Sara Álvarez and Cristina Romero-Trigueros

Received: 6 July 2022
Accepted: 9 August 2022
Published: 12 August 2022

1. Introduction

On a global scale, the cultivation of sweet maize has increased significantly (60%) in the last 25 years. Sweet maize is rich in sugar, protein, vitamins and microelements [1]. Hungary is in the first place among the most significant producers in the European Union, producing almost the same amount (since 2002, it is in the first place in the statistics according to the sown area) as France. Sweet maize is the largest vegetable crop grown in Hungary and the number one industrial vegetable [2,3]. China is one of the largest maize growing countries in the world.

Sweet maize is characterised by excellent content values such as high sugar content, unique taste and aroma [4]. The utilisation of maize is widely researched in nutritional science and it is consumed both in frozen and raw forms. Pasta, baby food and chips are made from dry grains of sweet maize [5].

Dripping irrigation causes effective soil ventilation and provides suitable and usable moisture in the soil. Considering the possibility of using fertilisers and toxic materials along with irrigation water and reducing their consumption, experts have mentioned the reduction of groundwater pollution as one of the advantages of reducing the consumption of fertilisers and toxic materials. Improving the efficiency of modern irrigation, optimising water consumption, creating fundamental changes in the irrigation method and developing irrigation under pressure at the level of gardens and farms to increase the productivity of production resources are considered among the best and most advanced methods [6]. Precision agriculture plays a significant role in cost- and energy-efficient methods, with the aim of facilitating farmers' decision-making in cultivation technology. Dripping precision irrigation system can provide reliable irrigation to the entire land, such as corners and irregular shaped plots, which is not practical in other irrigation systems. Accurate water delivery through dripping precision irrigation systems has allowed researchers to improve the selection and identification of drought-resistant plant species. It is possible to precisely control the volume and time of nitrogen delivered to maize to improve the nitrogen efficiency used in precision irrigation systems [7]. In addition, the use of precision irrigation plays an important role in achieving higher yields [8]. Unpredictable precipitation distribution also has a significant impact on the cultivation of sweet maize. Sweet maize production without irrigation is inconceivable. The crop's greatest water demand is present from tasselling to grain-filling [9,10]. Weather conditions can also significantly affect yield, grain weight, and the length of the growing season [11].

According to Nagy [12], under irrigated conditions, ears were 20–23% longer compared to the control treatment, however, the ear lengths were not affected by fertilisation during the irrigated treatment. Irrigation significantly affected the yield of sweet maize cobs. Significantly higher green cob yield (16.93 t ha^{-1}) was obtained for the 0.8 Epan drip irrigation, which was 27.97% higher than the 0.4 Epan drip, introduced to a higher moisture stress in the drip irrigation system between irrigation treatments [13]. Averaged over two years, the highest ear yield was obtained at 100% (14.46 t ha^{-1}), and the minimum fresh ear yield was obtained at 70% of Epan (8.9 t ha^{-1}) [14].

Based on the experiment performed by Dagdelen et al. [15], water deficiency significantly affected maize yield and reached the highest maize yield in irrigated (100%) treatments. Oktem [14] reported that ear ear length was affected by the lack of water, as well as its increase. In this experiment, the longest ears were measured in the full-irrigated treatment (100% Epan) and the shortest in the 70% Epan treatment. Water stress had 50% impact on grain yield, 40% impact on the thousand grain weight, and 30% impact on cob length, as well as the sweet maize growth characteristic [16]. In agreement with Moosavi [17], water stress had a negative effect on ear diameter and ear length. The increased amount of time between the two irrigation rounds significantly decreased the following parameters: plant height (14.6%), leaf area index (12.9%), number of rows per ear (10.1%) and number of grains per ear (29.8%), thousand grain weight (6.9%), and grains (33.8%) [18], number of kernel rows per ear, number of kernels per ear (all at $p \leq 0.01$), and fresh ear weight ($p \leq 0.05$) [19,20]. Deficit irrigation significantly reduced ear length, diameter, number of grains per ear, and yield [19,21,22].

Rivera-Hernández et al. [21] reported in their experiment that the best result was obtained in the case of the −30 kPa moisture-tension treatment, as they achieved ear yield of 27 kg ha^{-1} per millimetre irrigated. The variables characterising the morphological quality in sweet maize ears, i.e., length, fresh weight, and number of grains per ear increased by about 40%. The maximum grain yield was reached with full irrigation, 9.35 t ha^{-1} [19]. The obtained results showed that the highest yield was achieved with a 2-day irrigating frequency, 13.66 t ha^{-1} in 1998 and 13.19 t ha^{-1} in 1999. When the frequency of irrigation decreased, yield has dropped by almost half, a decreasing trend can be seen, 8.55 t ha^{-1} in 1998 and 7.29 t ha^{-1} in 1999. According to the performed experiment, the applied irrigation method and nitrogen supply had a significant effect on maize growth characteristics.

With flat bed irrigation, grain and stover yields of 4917 and 8018 kg ha^{-1} were achieved, respectively [23].

In the case of deficit irrigation treatment, the decrease in grain yield was manifested primarily in the number of grains and secondarily in grain weight. Water stress was applied in the reproductive stage. The efficiency of water use increased in the treatment and it was affected by the increased nitrogen dose, indicating that it is sensitive to water stress and highlighting the importance of applying the optimal amount of nitrogen under Sahelian environment [24].

According to Ertek and Kara [25], the highest yields were observed in the case of I100 and I85 treatments, and the sugar and protein content in the case of the I70 irrigation treatment was the average of the two years (I100 = full irrigation; I85 = 15% deficit; 70 = 30% deficit). The highest sugar content was measured under moderate irrigation conditions, however, a statistically inverse relationship was found between protein and sugar content (r2 = −0.71 ** [16]. Water deficient stress significantly ($p \leq 0.01$) increased glucose, fructose and sucrose content, and decreased protein content [19]. Mohammadkhani and Heidari [26] found that the sugar increased, however, starch content decreased under water stress. Deficit irrigation produced higher sucrose levels. As regards sugar content, irrigation had no significant effect in any of the examined years, under biennial experiment [27].

In the full irrigation treatment and as a result of applying 80% of the required irrigation water, the highest values of grain yield, DMC and water use efficiency were obtained. DMC and grain yield were significantly increased by the applied irrigation doses ($p < 0.01$) [22]. Water deficit had an effect on DMC accumulation [15]. The amount of water contributed to the reduction of DMC accumulation and the partitioning of grains. Water deficit reduced DMC by an average of 35% ($p < 0.01$). Irrigated conditions contributed to yield. Grain yield was reduced by 37% ($p < 0.01$) and seed number by 10% due to water stress conditions [28]. The frequency of drip irrigation periods positively stimulated crop parameters, increasing the total DMC by 44% and the yield components by 32% [29]. DMC yield increased with increasing evapotranspiration as full irrigation treatment contributed to dynamic vegetative growth under semi-arid conditions for maize [15].

Farsiani et al. [30] determined that moderate irrigation water level can be applied without a significant reduction in grain yield. Ear diameter and length contributed the most to the ear yield; moreover, there was a statistically positive correlation between ear yield and ear length (0.74) [31]. In conclusion, the importance of irrigation is essential for sweet maize for abundant and quality yields [25]. Our experiment investigated seven sweet maize genotypes under irrigated and non-irrigated conditions. The main goal of our research was to determine the difference between the effect of the irrigated and non-irrigated treatments on the main quantitative parameters (e.g., ear length, net ear length/covered with kernels/, ear weight, number of kernel rows), furthermore on some qualitative parameters (e.g., Brix, moisture content of cob and dry matter content of cob). The above study was conducted considering the increase in the area under maize cultivation in Hungary and the lack of water in the summer season, which is the limiting factor for the production of maize. In order to obtain the most reliable results, we evaluated our data using various statistical methods.

2. Materials and Methods

2.1. Experimental Design

The examinations were performed at the experimental station of the University of Debrecen, Böszörményi street (47°55′ N, 21°60′ E, 121 m asl). The experimental station has leached chernozem-type soil with excellent properties. Four replications were performed. The soil has 90 cm width A layer. The soil pH was 7.46 and the soil texture was clay loam, according to the Arany-type soil plasticity index of 44. The total organic matter was around 2.4% in the upper surface layer of the soil (0–30 cm). Average macro-, micro and secondary nutrient contents of the soil were as follows: nitrogen: 2.04 mg kg^{-1}; potassium: 160.57 mg kg^{-1}; phosphorus: 162.26 mg kg^{-1}; magnesium: 646.53 mg kg^{-1}; sulphur:

1.81 mg kg^{-1}; sodium: 40.66 mg kg^{-1}; copper: 1.52 mg kg^{-1}; manganese: 25.65 mg kg^{-1}; zinc: 3.11 mg kg^{-1}. The soil moisture content (M) of the 0–100 cm layer was measured before the growing season (8 March 2021). The average of the total water volume in the wide examined ratio (0–100 cm) was 20.02%. The highest amount (23.42%) of water was located between 10–40 cm depth. In the deeper region (50–100 cm) of the soil, the moisture content was lower (18.46%) than the soil surface (0–50 cm). Soil samples were dried at 105 °C for 5 days in a drying chamber. The climate was measured by the weather station installed on the experimental site.

The applied macronutrients were 90 kg ha^{-1} N, 23 kg ha^{-1} CaO, 16 kg ha^{-1} MgO on 30 March 2021. Following the application of fertiliser, soil cultivation with a combinatory treatment was performed on the same day, on 30 March 2021. The test plants were different sweet maize hybrids (H1—Noa, an early maturity (73–74 days) super sweet maize variety; H2—Dessert R78, a middle maturity, extremely tasty virus-resistant variety. H3–Dessert R72, a very early maturing super sweet hybrid, H4—Messenger, a semi-early sweet maize hybrid, reaching maturity in about 85–87 days; H5—SF1379, a middle-maturing (75–77 days) super sweet maize; H6—Honey, a super early maturity sweet maize with excellent sweet taste; H7—GSS5649, a hybrid characterised by an extratimpurian maturity of about 75 days and a super sweet taste).

Herbicide containing weed killer (37.5 g L^{-1} mesotrione, 375.0 g L^{-1} S-metolachlor and 125.0 g L^{-1} terbuthylazine) was applied on 21 May 2021 at a dose of 5 L ha^{-1}.

2.2. Irrigation Process

2.2.1. Irrigation Schedule

The experiment was carried out under dripping irrigation conditions and on control plots without irrigation. The dripping irrigation system was controlled by the database of the soil moisture sensor and the weather station. Irrigation was based on the measurement of a pre-calibrated Delta T humidity sensor placed at a depth of 35 cm. The soil moisture sensor was calibrated using thermometric moisture calibration, with soil samples taken from different soil layers. Fresh, wet soil from the layer of the sensor was weighed, dried until constant weight at 105 °C, then the dry soil was weighed again, making possible the calculation of the exact soil moisture content and the reliable use of the sensor. Irrigation was adjusted to 45% soil moisture content by volume. Irrigation was performed under the control of the Hydrawise smart remote-controlled application. The total applied amount of water was 283.78 mm under the growing season.

During the growing season, the soil moisture content was low in the non-irrigated plots. In the first part, it was below 40% and the second part after flowering during the grain filling period, it was below 35% until harvest. The low soil moisture content was mitigated by the dripping irrigation system in the irrigated plots (Figure 1).

2.2.2. Analysis of the Irrigation Water

The pH of the irrigation water used for our experiment was 7.42, i.e., slightly alkaline (Table 1). The pH of natural waters ranges from 6.0 to 8.0 depending on the origin of the water. The most important nutrients are optimally soluble in the range of pH 5.6–6.8 for the majority of the cultivated plants.

Table 1. Quality parameters of water used for irrigation.

pH	EC	TDS	SAR	Na%	Mg%	HCO_3^-	Cl^-
	µS cm^{-1}	mg L^{-1}		%	%	mgmol L^{-1}	mgmol L^{-1}
7.42	0.51	326.40	0.67	18.30	30.34	3.67	0.10

Note: EC = Electrical Conductivity, TDS = Total Dissolved Solids, SAR (Sodium Adsorption Ratio), Na (Sodium), Mg (Magnesium), HCO (Bicarbonate), Cl (Chlorine) where EC = Electrical Conductivity, TDS = Total Dissolved Solids, SAR (Sodium Adsorption Ratio) = $\frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$, Na% = $\frac{Na^+}{Ca^{2+}+Mg^{2+}+Na^++K^+} * 100$, Mg% = $\frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}} * 100$.

Source: Central Laboratory of the Research Institute of Karcag, Hungarian University of Agriculture and Life Sciences.

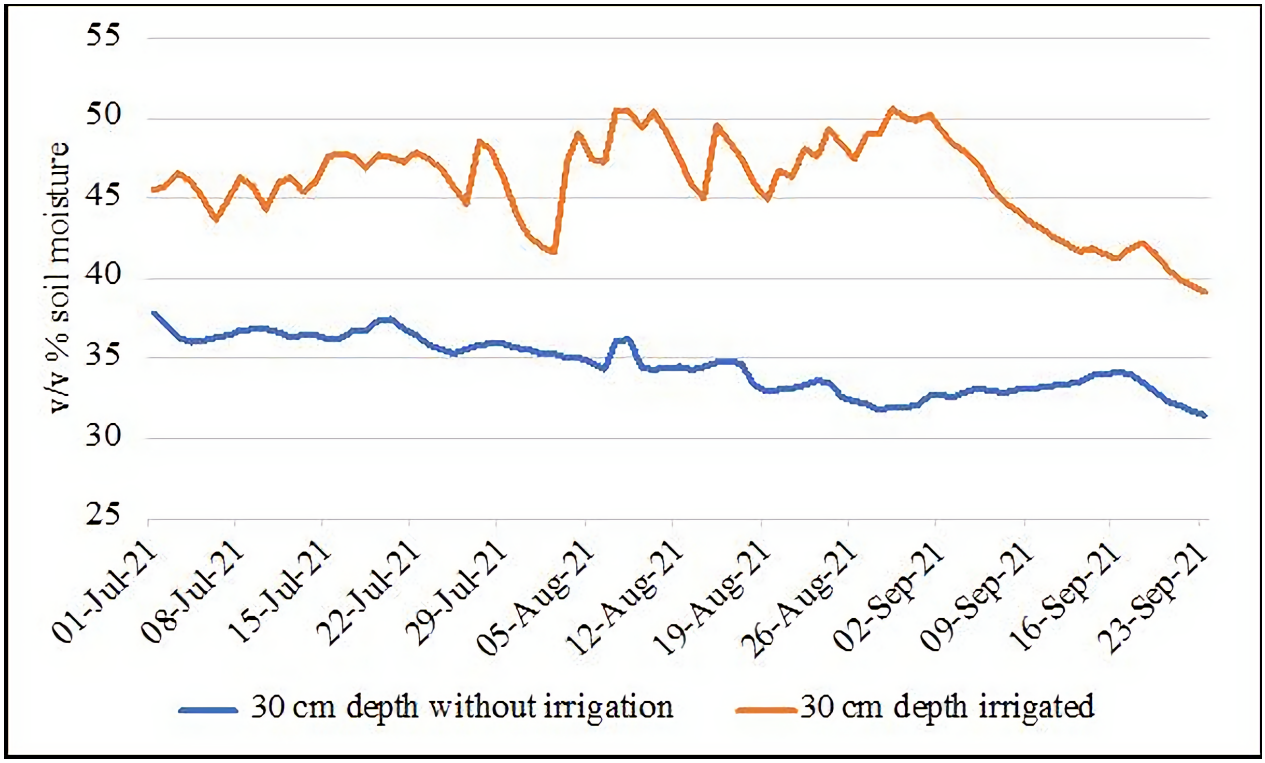

Figure 1. Soil moisture content in the important phenological stages during the growing season under irrigated and non-irrigated conditions.

The salinizing effect of the irrigation water was investigated based on 3 derived values, namely the total dissolved salt content (TDS), the relative amount of Na ion (Na%), and the calculated sodium adsorption ratio (SAR) value. The irrigation water was not saline with its 326.40 mg L^{-1} TDS, which is below the upper limit of the suitability for irrigation (500 mg L^{-1}). The SAR value expresses the salinizing effect of Na. If the SAR value is between 0 and 3, and the Electric Conductivity (EC) of the irrigation water is below 0.7 µS cm^{-1}, it does not endanger the soil and does not impair its fertility [32]. The SAR value of the applied irrigation water was 0.67, while the EC was 0.51 µS cm^{-1}. For the relative amount of sodium ion, the acceptable limit is 40%. According to Zsembeli and Szűcs [33], the higher the proportion of Na cations, the less suitable the water is for irrigation, especially on soils with unfavourable conditions and with the risk of secondary salinisation [34,35]. The Na% of the irrigation water was 18.30%. Based on these parameters, it can be concluded that the irrigation water we used in the experiment had no salinizing effect under the given conditions as all the parameters expressing the degree of salinizing effect were under the thresholds.

Significant amounts of Mg ions can be bound to the soil colloids from irrigation water with a high magnesium content, which adversely affects the physical and water management properties of the soil. Therefore, for the classification of irrigation water, it is advisable to take the Mg^{2+} $(Ca^{2+} + Mg^{2+})^{-1}$ ratio into account, which is considered favourable if lower than 1:1 [36]. The Mg ratio of the well water used in our experiment met this criterion as it was under 50% (30.34%, respectively).

Based on the results of Terbe et al. [37], water with bicarbonate content less than 5.0 milliequivalents L^{-1} and chlorine content less than 1.5 milliequivalents L^{-1} is ideal for irrigation. The examined irrigation water had 3.67 milliequivalents L^{-1} bicarbonate and 0.10 milliequivalents L^{-1} chlorine content. Waters characterised by such parameters can be recommended for all cultivation technologies. It can be stated for all examined parameters that the applied irrigation water proved to be suitable for irrigating sweet maize under the given conditions.

2.3. Determination of the Total Soluble Solids (TSS) of Kernels

The TSS (°Brix) was determined by using an Abbe refractometer and a digital refractometer (Atago Pal-1®, Tokyo, Japan). The Abbe refractometer has two scales: the refractive index of the measured substance can be read on one of the scales of the refractometer, while on another scale the percentage of total soluble DMC of the same substance can be read in the range of 0–85% (at 20 °C). The Pal-1 digital refractometer can measure the °Brix of a substance in the range of 0–53% with temperature compensation from 10 to 100 °C [38]. 1 °Brix is the sugar content of a solution of 100 g containing 1 g sucrose. Before the measurements, the instruments were calibrated with deionized water. The results were derived from the averages of 4 repetitions.

2.4. Statistical Analysis

Analysis of variance (ANOVA) is a collection of statistical models and their associated estimation procedures used to analyse the differences between mean values. The Pearson torque correlation coefficient, commonly called the Pearson correlation is probably the most widely used statistical index of bivariate correlation. Pearson coefficient shows the extent to which there is a linear relationship between quantitative variables [39,40]. Principal Component Analysis (PCA) is a multivariate technique whose main purpose is to reduce a multivariate data set (i.e., the number of variables) as much as possible to explain the changes of the primary variables in the data set. Additive Main effects and Multiplication Interaction (AMMI) is one of the important methods of PCA [41,42]. All analyses were performed with Minitab and Genstat software.

3. Results

Variance analysis showed that irrigation treatments had a significant effect on ear length, net ear length, ear weight, Brix/Atago Pal-1, Brix/Abbe, and MC. Irrigation treatments had no significant effect on DMC. Hybrids had a significant effect on ear length, net ear length, ear weight, number of kernel rows, Brix/Atago Pal-1, Brix/Abbe, MC, and DMC. Irrigation in hybrid interaction had a significant effect on ear length, net ear length, ear weight, number of kernel rows, Brix/Atago Pal-1, Brix/Abbe, and MC, and DMC (Table 2).

Correlation analysis showed that ear length had a positive correlation with the net ear length (0.635). Brix/Atago Pal-1 positively correlated with Brix/Abbe (0.978). Moisture negatively correlated with DMC (−0.897). The DMC had a negative correlation with MC (0.803). Other parameters do not have any significant correlation together (Table 3).

AMMI analysis showed that IPCA 1 and IPCA 2 covered 92 percent of all data concerning irrigation in hybrid interaction. IPCA1 covered 65.60 percent of all data, and IPCA2 covered 26.88 of all data. IPCA1 and IPCA 2 significantly affected AMMI based on the performed variance analysis (Table 4).

Table 2. Variance analysis on parameters in different irrigation schemes with different maize hybrids.

	Source	DF	F-Value	*p*-Value
Ear length	Irrigation	1	45.12	0.000
	Hybrid	6	5.96	0.000
	Irrigation x Hybrid	6	3.52	0.007
Net ear length (covered with kernels)	Irrigation	1	10.35	0.002
	Hybrid	6	3.37	0.008
	Irrigation x Hybrid	6	2.72	0.026
Ear weight	Irrigation	1	48.69	0.000
	Hybrid	6	4.93	0.001
	Irrigation x Hybrid	6	3.42	0.008
Number of kernel rows	Irrigation	1	1.23	0.273
	Hybrid	6	7.20	0.000
	Irrigation x Hybrid	6	3.52	0.007
Brix/Atago Pal-1	Irrigation	1	16.96	0.000
	Hybrid	6	5.64	0.000
	Irrigation x Hybrid	6	4.45	0.001
Brix/Abbe	Irrigation	1	12.53	0.001
	Hybrid	6	3.19	0.011
	Irrigation x Hybrid	6	3.90	0.003
MC	Irrigation	1	11.19	0.002
	Hybrid	6	28.47	0.000
	Irrigation x Hybrid	6	4.73	0.001
DMC	Irrigation	1	1.42	0.239
	Hybrid	6	114.45	0.000
	Irrigation x Hybrid	6	3.65	0.001

Note: MC is moisture content of cob, DMC is dry matter content of cob.

Table 3. Correlation of parameters in different irrigation treatments with different maize hybrids.

	LC	LCL	WC	NSR	Brix/Atago Pal-1	Brix/Abbe	M	DM
LCL	0.635 *							
WC	0.470	0.409						
NSR	0.220	0.217	0.415					
Brix/Atago Pal-1	−0.039	−0.103	0.461	0.103				
Brix/Abbe	−0.001	−0.100	0.434	0.096	0.978 **			
M	−0.483	−0.186	0.086	−0.066	0.254	0.238		
DM	−0.493	−0.252	0.271	0.027	0.469	0.422	−0.897 **	
MC	−0.450	−0.149	0.006	−0.100	0.153	0.150	0.984 **	−0.803 **

Note: * and ** significant at 5%, 1%. Where LC is ear length, LCL is net ear length, WC is ear weight, NSR is the number of kernel rows, M is soil moisture content, DMC is dry matter content of cob, and MC is moisture content of cob.

AMMI biplot showed that hybrids Dessert R78 and Dessert R72 had the highest stability and effect on irrigation in the hybrid interaction-based IPCA1. Also, SF1379, Honey and Dessert R72 hybrids had desirable stability and effect on irrigation in the hybrid interaction-based IPCA2. Brix/Atago Pal-1, Brix/Abbe, ear length, net ear length had the highest effect based on IPCA 2 and IPCA1 (Figure 2).

Table 4. AMMI analysis parameters in different irrigation with different maize hybrids.

Source	df	SS	MS	F	%	F_prob
Total	503	6052	12.03	*		*
Treatments	62	5797	93.51	153.80		0.00000
Genotypes	6	58	9.61	15.81		0.00000
Irrigation	8	5647	705.84	6844.64		0.00000
Block	27	3	0.10	0.17		1.00000
Interactions	48	93	1.94	3.19		0.00000
IPCA1	13	61	4.73	7.77	65.60	0.00000
IPCA2	11	25	2.29	3.77	26.88	0.00004
Residuals	24	6	0.27	0.44		0.99138
Error	414	252	0.61	*		*

Note: * significant at 5%. IPCA (interaction of principal component analysis), df (Degrees of freedom), SS (sum of square), MS (means of square).

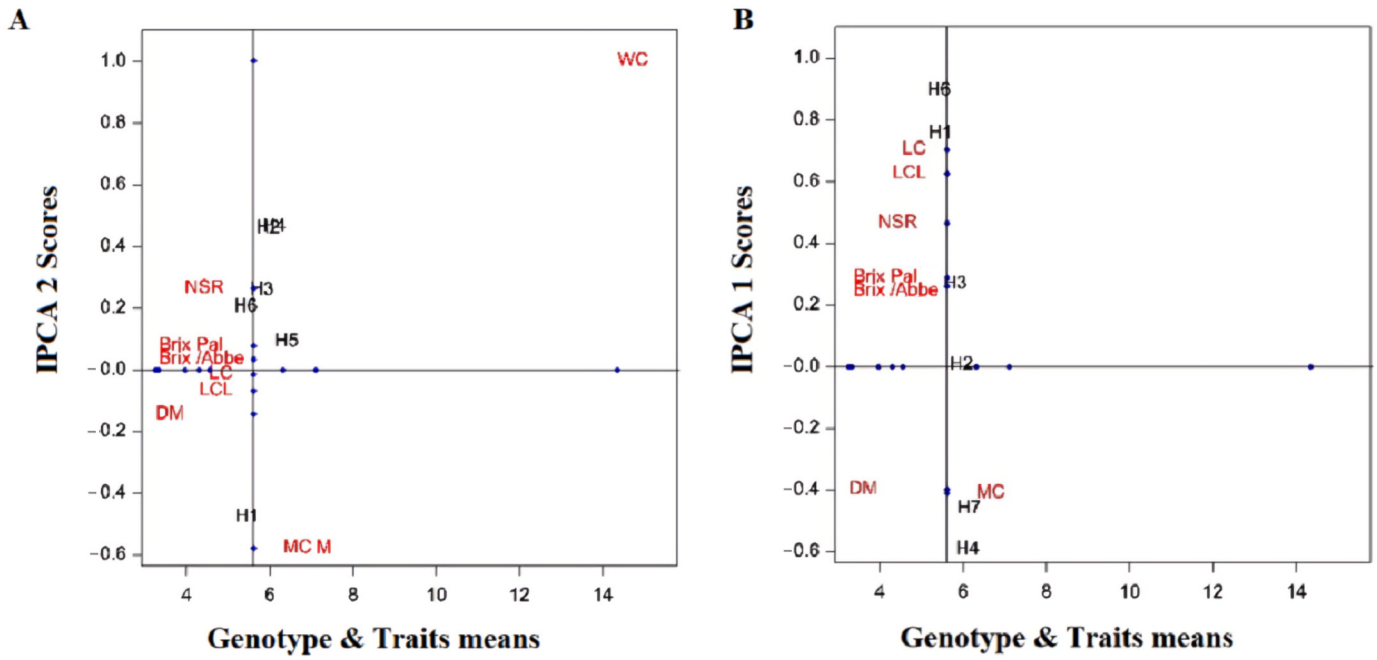

Figure 2. AMMI biplot on IPCA 2 ((**A**) comparison based on the traits) and IPCA 1 ((**B**) comparison based on the genotype) on different maize hybrids in non-irrigated and irrigated treatments. Ear length (LC), net ear length (LCL), ear weight (WC), number of kernel rows (NSR), Brix/Atago Pal-1, Brix/Abbe, soil moisture (M), dry matter content of cob (DM), moisture content of cob (MC). (H1: Noa, H2: Dessert R78, H3: Dessert R72, H4: Messenger, H5: SF1379, H6: Honey, H7: GSS5649).

The non-irrigation biplot showed that dry matter content, soil moisture content, and moisture content of cob had maximum stability on the hybrid in yield indices interaction based on the hybrid in yield indices interaction. Also, SF1379, Messenger, GSS5649, Dessert R78, and Dessert R72 hybirds had the highest performance and stability on yield indices. The first principal component covered 83.77 percent of all data, and the second principal component covered 6.39 percent of all data (Figure 3).

DMC, Brix/Atago Pal-1, Brix/Abbe and soil moisture content had maximum stability on the hybrid in the yield indices interaction based on the irrigation biplot analysis. Also, Messenger, SF1379, GSS5649 hybrids had maximum performance and stability on the hybrid in the yield indices interaction. The first principal component covered 73.49 percent of all data, and the second principal component covered 19.80 percent of all data (Figure 4).

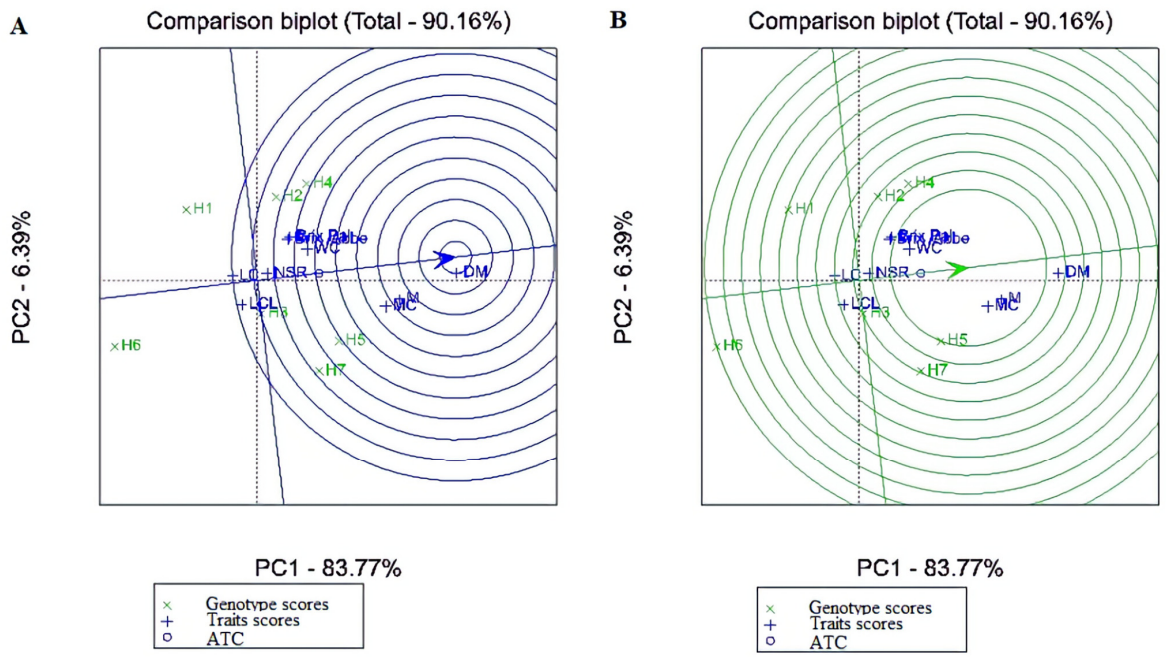

Figure 3. Biplot on different maize hybrids in non-irrigated treatment. (**A**) comparison based on the traits, (**B**) comparison based on the genotype. Ear length (LC), net ear length (LCL), ear weight (WC), number of kernel rows (NSR), Brix/Atago Pal-1, Brix/Abbe, soil moisture content (M), dry matter content of cob (DM), moisture content of cob (MC). (H1: Noa, H2: Dessert R78, H3: Dessert R72, H4: Messenger, H5: SF1379, H6: Honey, H7: GSS5649).

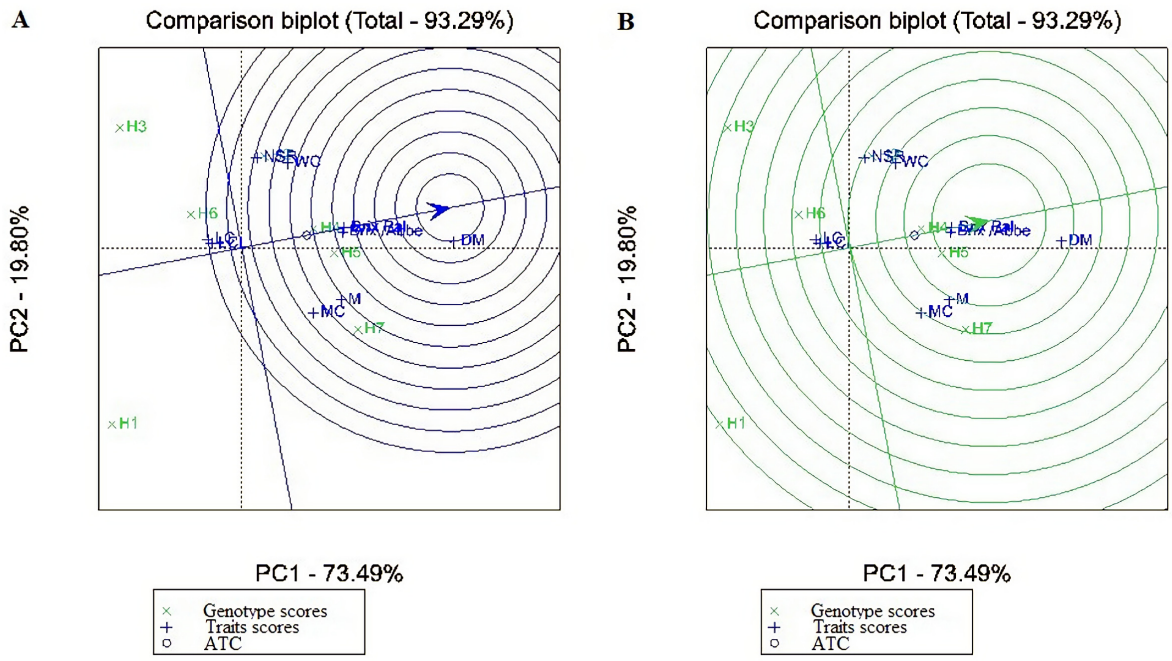

Figure 4. Biplot on different maize hybrids in irrigation treatment. (**A**) comparison based on the traits, (**B**) comparison based on the genotype. Ear length (LC), net ear length (LCL), ear weight (WC), number of kernel rows (NSR), Brix/Atago Pal-1, Brix/Abbe, soil moisture content (M), dry matter content of cob (DM), moisture content of cob (MC). (H1: Noa, H2: Dessert R78, H3: Dessert R72, H4: Messenger, H5: SF1379, H6: Honey, H7: GSS5649).

4. Discussion

The result of this study showed no existing variation in the DMC in irrigation and non-irrigation treatment. At the same time, the study highlighted variation in yield indices. Consequently, the obtained results showed that irrigation treatments are an important factor and affect yield indices on sweet maize. This study showed that the effect of the hybrid varied on phenology and yield indices. Also, the hybrids in irrigation interaction varied on phenology and yield indices. Ertek and Kara [25], examining different irrigation levels on sweet maize yield, stated that the highest yield in the optimal irrigation treatment and the lowest yield in the treatment of 60% of plant water requirement was 14.8 and 11.5 tons per hectare, respectively. Results showed that increasing dry matter causes decreasing moisture. Akhavan et al. [43] reported that the highest grain yield had 125% of the plant water requirement of about 8.23 tons per hectare, and the lowest grain yield had only 50% of the water requirement of about 5.02 tons per hectare in sweet maize. Tagheian Aghdam et al. [44], by reporting the effect of different irrigation levels on the quantitative and qualitative yield of sweet maize, concluded that the different levels of irrigation had a significant effect on yield components. Siadat et al. [45] reported the production of sweet maize under low irrigation stress that drought stress reduced ear weight and grain yield compared to the control plots. Correlation analysis showed that increasing DMC causes decreasing moisture content on sweet maize with irrigated and non-irrigated treatments. In drought stress, reducing the transfer of nutrients affects the development of stem and leaf cells, and as a result, leads to a decrease in plant height, leaf area and grain protein content, and finally, a decrease in DMC accumulation in the seeds [46]. The ear length, number of seeds per ear, and grain yield showed maximum correlation in sweet maize [47]. Simple and multiple regression analysis methods, variance correlation, principal components analysis are used for yield components on crop production [48]. Biplots showed that the Dessert R72 hybrid had maximum yield and effect on Brix/Abbe and Brix/Atago Pal-1 and GSS5649, and the Messenger hybrid had maximum effect on moisture content. It was also shown that DMC and moisture are important factors, as well as yield index on irrigation treatments in the case of the examined hybrids. The Noa and Honey hybrids had minimum effect and performance on non-irrigated and irrigated treatments. The Messenger and SF1379 hybrids had a maximum performance on Brix/Abbe and Brix/Atago Pal-1 with irrigation treatment and Dessert R78, Messenger hybrids had a maximum performance on Brix/Abbe and Brix/Atago Pal-1 in the non-irrigated treatment. The Dessert R78 is the best hybrid concerning yield on Brix/Abbe and Brix/Atago Pal-1 in irrigation treatments. Some researchers reported that water stress was effective in the grain filling stage in maize, i.e., this period was 13–3 days long, in the case of different hybrids, respectively [49,50]. One of the most important factors affecting crop grain yield is hybrids, which effectively influences hybrids in different climates, temperatures and radiation [50]. Ghazian Tafrishi et al. [51] reported decreasing number of seeds per cob in the yield of different sweet maize under water stress conditions. The reproductive growth stage in sweet maize has been introduced as one of the sensitive stages to water stress; As the stress of dehydration before silking leads to a sharp decline in grain yield through a negative impact on growth and reproductive development, including the embryonic sac and organ development [46]. Also, there is a variation on yield indices parameters on hybrids and irrigation and hybrid in irrigation interaction. Nemeskéri et al. [9] reported a decrease in yield due to water stress at this stage, resulting in a 22.1 to 15.1 percent loss compared to normal conditions. Many researchers consider the leaf surface development stage (vegetative growth stage) to be one of the most sensitive stages of sweet maize growth to water scarcity stress (hence the importance of providing adequate moisture [30,52]. Dessert R78 and Dessert R72 hybrids had stability on non-irrigation; these hybrids had good performance on non-irrigation condition. The SF1379 and Honey hybrid had suitable performance in precision irrigation. DMC and MC had maximum effect on hybrids in precision irrigation. Weight of cob had more effect on hybrids in non-irrigation. This study showed that weight of cob is important plant part in non-irrigation condition. The weight of cob can help to increase the

performance of maize in non-irrigation conditions. In general, irrigation water treatments significantly affected maize performance and its quantitative characteristics, including ear length, net ear length, ear weight, number of the kernel, Brix/Atago Pal-1, and Brix/Abbe. The result based on the hybrids in irrigation showed that the response of the hybrids had variation based on the irrigation and non-irrigation because of different root systems. In addition, the examined hybrids reacted and responded differently based on irrigation to change to non-irrigation. Adequate moisture supply from the granulation stage is very important. If the plant has no water stress in any form (under-irrigation or cessation of irrigation) before the flowering stage, it will be able largely to have the best performance. If there is stress in the granulation stage, severe performance decline can be prevented. Also, according to the available reports, the greatest effect of moisture stress in the grain filling stage is on the grain yield and the stresses that occur after silking lead to smaller grain size [53].

5. Conclusions

Sweet corn is a water-demanding crop. This rapid increase in crop water use can catch growers out and reduce yield and quality. Based on the AMMI biplot analysis, DMC and moisture are important factors and the yield index on irrigation treatments on hybrids. Hybrids Noa and Honey had minimum effect and performance on non-irrigated and irrigated treatments. The Dessert R78 is the best-performing hybrid in terms of the yield of Brix/Abbe and Brix/Atago Pal-1 in irrigation treatments.

Author Contributions: Data curation and formatting, A.S. and L.S.; formal analysis, methodology and conceptualization, S.M.N.M.; writing—review and editing, C.B.; resources, A.V.; supervision, E.H.; project administration, Á.I. All authors have read and agreed to the published version of the manuscript.

Funding: Project no. TKP2020-IKA-04 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the 2020-4.1.1-TKP2020 funding scheme.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data supporting the conclusions of this article are included in this article.

Conflicts of Interest: The authors declare no conflict of interest.

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