DOI: 10.29050/harranziraat.822395
Harran Tarım ve Gıda Bilimleri Derg. 2021, 25(1): 100-108

Research Article/Araştırma Makalesi

Effects of irrigation termination dates on grain yield, kernel moisture at harvest and some agronomic traits of maize

Sulama sonlandırma zamanlarının mısırın (Zea mays L.) tane verimi, hasatta tane nemi ve bazı tarımsal özellikleri üzerine etkilerinin belirlenmesi

Erdal GÖNÜLAL[1*], Süleyman SOYLU[2], Mehmet ŞAHİN[3]

[1]Bahri Dagdas International Agriculture Research Institute, 42010, Konya-Turkey
[2]Selcuk University Agricultural Faculty, Department of Field Crops, 42031, Konya-Turkey.
[3]Selcuk University Agricultural Faculty, Department of Department of Agricultural Structures and Irrigation, 42031, Konya-Turkey.

To cite this article:
Gönülal, E., Soylu, S. & Şahin, M. (2021). Effects of irrigation termination dates on grain yield, kernel moisture at harvest and some agronomic traits of maize. Harran Tarım ve Gıda Bilimleri Dergisi, 25(1): 100-108.
DOI: 10.29050/harranziraat.822395

Address for Correspondence:
Erdal GÖNÜLAL
e-mail:
erdalgonulal@hotmail.com

Received Date:
06.11.2020
Accepted Date:
30.12.2020

ABSTRACT

This study was conducted to investigate the effects of different irrigation termination dates on maize grain yield, kernel moisture at harvest and some other agronomic traits. The relationships between irrigation termination dates and investigated traits were visually assessed through biplot analysis. Experiments were conducted for two years (2016 and 2017) with three replications in Konya-Karapınar ecological condition. Irrigations were terminated at eight different dates (S_1: R2 blister stage; S_2: R3 early milk stage; S_3: R3 milk stage; S_4: R3 late milk stage; S_5: R4 dough stage; S_6: R5 early dent stage; S_7: R5 dented stage; S_8: R5 late dent stage). The amount of irrigation water applied to the subjects in the study varied between 458-475 mm (S_1) and 738-744 mm (S_8). Irrigation water amount has been important in differences between subjects. As a result of the study, early irrigation termination date (S1: 1046 kg / da yield and 11.7% moisture) has low harvest moisture and grain yield. However, despite high yield levels, late irrigation termination dates had high kernel harvest moisture levels (S_7:16100 kg ha^{-1} grain yield; and 18.8% moisture; S_8:16240 kg ha^{-1} grain yield and 19.6% moisture). In terms of grain yield and harvest moisture, S_4 (14050 kg ha^{-1} grain yield and 14.2% harvest moisture), S_5 (14170 kg ha^{-1} grain yield and 15.0% moisture) and S_6 (14880 kg ha^{-1} grain yield and 16.1% moisture) treatments had similar values and were considered to be as the most appropriate irrigation termination dates.
Kernel weight per ear varied between 150.6 (S_1) and 238.7 g (S_7); number of kernels per ear varied between 677 (S_1) and 741 kernels (S_5), ear lengths varied between 16.7 (S_1) and 24.1 cm (S_4), thousand-kernel weights varied between 271 g (S_1) and 381 g (S_8), hectoliter weights varied between 74.3 (S_1) and 78.1 kg (S_4) and number of days to physiological maturity varied between 112.5 (S_1) and 124.5 days (S_8).

Key Words: Biplot analysis, Corn, Irrigation, Last irrigation, Water stress

ÖZ

Bu çalışma, farklı sulama sonlandırma tarihlerinin mısır tane verimi, hasatta tane nemi ve diğer bazı tarımsal özellikleri üzerindeki etkilerini araştırmak için yürütülmüştür. Sulamanın sona erme tarihleri ile incelenen özellikler arasındaki ilişkiler, biplot analizi yoluyla görsel olarak değerlendirilmiştir. Çalışma Konya-Karapınar ekolojik koşullarında iki yıl (2016 ve 2017) süreyle üç tekerrürlü olarak yürütülmüştür. Sulamalar sekiz farklı tarihte sonlandırılmıştır (S_1: R2 blister aşaması; S_2: R3 erken süt olum dönemi; S_3: R3 süt olum dönemi; S_4: R3 geç süt olum dönemi; S_5: R4 hamur olum dönemi S_6: R5 erken diş olum dönemi; S_7: R5 diş olum dönemi; S_8: R5 geç diş olum dönemi). Araştırmada konulara uygulanan sulama suyu miktarı 458-475 mm (S_1) ile 738-744 mm (S_8) arasında değişmiştir. Konular arasındaki farklılıklarda sulama suyu miktarı önemli olmuştur. Erken sulama sonlandırma tarihlerinde hasatta tane nemi ve tane verimi düşük olmuştur (S_1: 10460 kg ha^{-1} tane verimi; % 11.7 nem). Ancak, yüksek tane verimi

seviyelerine rağmen, geç sulama sonlandırma tarihleri yüksek tane nemine sahip olmuştur (S_7: 16100 kg ha^{-1} tane verimi; ve % 18.8 nem; S_8: 16240 kg ha^{-1} tane verimi ve% 19.6 nem). Tane verimi ve hasat nemi açısından S_4 (14050 kg ha^{-1} tane verimi ve% 14.2 hasat nemi), S_5 (14170 kg ha^{-1} tane verimi ve % 15.0 nem) ve S_6 (14880 kg ha^{-1} tane verimi ve % 16.1 nem) uygulamaları benzer değerlere sahip olmuş ve en uygun sulama sonlandırma tarihleri olarak belirlenmiştir.
Koçanda tane ağırlığı 150.6 (S_1) ve 238.7 g (S_7) arasında; koçanda tane sayısı 677 (S_1) ve 741 (S_5) arasında, koçan uzunlukları 16.7 (S_1) ve 24.1 cm (S_4) arasında, bin tane ağırlıkları 271 g (S_1) ve 381 g (S_8) arasında, hektolitre ağırlıkları 74.3 (S_1) ve 78.1 kg (S_4) arasında ve fizyolojik olum gün sayısı 112.5 (S_1) ile 124.5 gün (S_8) arasında değişmektedir.

Anahtar Kelimeler: Biplot analizi, Mısır, Sulama, Son sulama, Su stresi

Introduction

Maize is a warm-season crop. Among the cereals, maize ranks third in cultivated lands and the first in production quantity in the worldwide. According to statistics of the year 2019, maize is cultivated over 638 828 ha land area in Turkey and about 6 million tons of production was realized (Anonymous, 2019). Konya province has the greatest maize cultivation lands (124.535 ha) and together with Karaman and Aksaray provinces with a similar climate became an important grain maize production basin of the country (Anonymous, 2019). Maize has quite a high adaptation capacity, thus is produced in several regions (Kırtok, 1998). In Turkey, maize is grown under rain-fed conditions without irrigation in some regions, but irrigation is essential in Konya and the other provinces with similar ecologies. Efficient water use in maize plants is negatively influenced by climate change and such an efficient use of water is a significant issue for sustainability of water resources and agricultural activities (Xu and Hsiao, 2004). Konya basin has 1.8 billion m^3 available ground and surface water potential, but annual amount of irrigation water used in the region is around 2.6 billion m^3. Therefore, there are important water shortages in the region and such a case exerts serious threats on sustainability of water resources (Anonymous, 2009). Additionally considering the irrigation costs in region, it is seen that the irrigation termination dates is important.

In present research area, maize cultivation has achieved a serious progress with the aid of agricultural technologies and extension efforts. Various innovations, especially drip irrigation technologies, are used in the region at a level above the country averages. Mazie growing season of the region is shorter than the other regions. Such shorter growing seasons should be taken into consideration while selecting cultivars to be grown and designating sowing and harvest dates and kernel moisture level at harvest (Vartanlı and Emeklier, 2007). Prices are lower for high kernel moisture at harvest levels and such high moistures also generate serious problems in storage of maize kernels. Therefore, maize is generally harvested toward the end of November in the region (Sade et al., 2007). Such a case then increases harvest losses and costs and results in less time left for soil tillage for subsequent plants. The ideal kernel moisture level is between 13-16% to have less harvest losses, no problems in marketing and storage (Vartanlı and Emeklier, 2007).

Although there are several studies about maize cultivation both in the region and in Turkey, number of studies about the effects of irrigations and especially of the irrigation termination dates on kernel moisture at harvest, yield and the other agronomic traits is quite limited. Therefore, present study aimed to identify optimal irrigation termination dates in maize cultivation.

Material and Methods

This study was conducted under ecological conditions of Konya-Karapınar (37˚ 41' 14.40" N and 33˚ 30' 13.12" E) for two years (2016 and 2017). Present research site has the greatest grain maize cultivation production in Konya province. The research area had a dominant terrestrial climate with long-term average annual precipitation of less than 300 mm. Majority of this precipitation falls in winter months out of the maize growing season. When the monthly precipitations between April – September were evaluated (Table 1), it can be seen that the research site was a marginal region in terms of precipitation total and distribution.

Table 1. Some meteorological data of the experimental area

		Av.temp.(°C)	Max.Temp.(°C)	Min.Temp.(°C)	Precipitation (mm)
May	2016	16.0	30.7	3.0	2.7
	2017	15.5	30.6	3.3	33.0
	1963-2017	15.4	30.5	0.9	35.4
June	2016	21.8	35.0	7.7	25.0
	2017	21.0	34.4	8.0	15.6
	1963-2017	19.6	34.0	5.6	25.3
July	2016	24.0	37.8	9.9	8.3
	2017	24.3	37.9	13.9	0.0
	1963-2017	22.8	36.6	8.9	8.1
Augst	2016	24.4	36.7	13.2	3.4
	2017	23.3	36.5	7.9	29.4
	1963-2017	22.1	32.0	5.1	4.1
September	2016	17.5	32.0	5.1	26.4
	2017	20.5	35.2	5.9	0.0
	1963-2017	17.5	33.1	4.9	10.1

Besides climate data, the region has also exceptional soil characteristics. Experimental soils were poor in organic matter and had high lime contents. Soils were unsaline and had high pH levels. Upper layers were sandy in texture (Table 2).

Table 2. Some soil properties of the experimental area

Depth (cm)	Structure	Field Capasity (%)	Wilting Point (%)	Bulk density (g cm^{-3})	pH	EC (dSm^{-1})	Lime (%)	Organic carbon (%)
0-30	SCL	20	9.6	1.37	7.8	0.42	33.5	0.75
30-60	C	24.5	12.6	1.30	8.1	0.45	28.7	0.64
60-90	C	28	15.4	1.22	8.2	0.44	29.4	0.35

The maize cultivar of DKC 5741 in FAO 500 maturity group, commonly grown in the region, was used as the plant material of the study. Experiments were conducted in randomized blocks design with three replications. Eight different irrigation termination dates (S_1: R2 blister stage; S_2: R3 early milk stage; S_3: R3 milk stage; S_4: R3 late milk stage; S_5: R4 dough stage; S_6: R5 early dent stage; S_7: R5 dented stage; S_8: R5 late dent stage) were investigated. 24 plots were generated for 8 irrigation termination dates and 3 replicates. Each plot was 5 m long and had 6 rows, row spacings were 70 cm and on-row plant spacings were 18 cm. Sowing was performed on 30th of April in 2016 and 2nd of May in 2017. Based on soil analysis, 100 kg ha^{-1} phosphorus (P) was applied at sowing as triple superphosphate (20% P) and 250 kg ha^{-1} nitrogen (N) fertilizer was applied as three splits. Ammonium sulfate (21% N) was used as a nitrogen source. Soil moisture was monitored with gravimetric method and soil moisture was brought to field capacity in each irrigation with pressure-regulated drip irrigation. In study, laterals that have 33 cm dripper spacing and 2 L h^{-1} dripper discharge were used. According to the results of soil samples taken at a depth of 90-120 cm after irrigation, it was observed that there was no deep infiltration. Amount of irrigation water, precipitation, change in soil water and evapotranspiration applied in each treatment are provided in Table 3.

Evapotranspiration was calculated according to

Equation 1, considering the moisture content in the 90 cm soil profile (Doorenbos and Kassam, 1979).

$$ET = I + P - Dp \pm CSW \quad (1)$$

In eguation 1; ET= Evapotranspiration (mm), I= Irrigation water quantity (mm), P= Precipitation (mm), Dp= Deep percolation (mm), CSW: Change in soil water storage (mm) between planting and harvest.

Table 3. Amount of irrigation water, precipitation, change in soil water and evapotranspiration applied at treatments

Years	Irrigation Levels	Irrigation Number	Irrigation water (mm)	Precipitation (mm)	Change in soil water (mm)	Evapotranspiraiton (mm)
2016	S_1	7	458	36.0	55.9	549.9
	S_2	8	495	36.0	57.6	588.6
	S_3	9	542	39.4	40.6	622.0
	S_4	10	573	39.4	35.8	648.2
	S_5	11	623	39.4	29.7	692.1
	S_6	12	658	39.4	28.9	726.3
	S_7	13	701	44.6	21.9	767.5
	S_8	14	738	47.2	22.4	807.6
2017	S_1	8	475	48.6	59.8	583.4
	S_2	9	523	48.6	54.3	625.9
	S_3	10	563	59.8	48.6	671.4
	S_4	11	589	63.7	39.4	692.1
	S_5	12	636	63.7	33.8	733.5
	S_6	13	674	78.0	35.5	787.5
	S_7	14	713	78.0	29.5	820.5
	S_8	15	744	78.0	27.6	849.6

* S_1: R2 blister stage; S_2: R3 early milk stage; S_3: R3 milk stage; S_4: R3 late milk stage; S_5: R4 dough stage; S_6: R5 early dent stage; S_7: R5 dented stage; S_8: R5 late dent stage

In all treatments, initial irrigation was performed through sprinkler irrigation to bring the soil moisture to field capacity. Drip irrigation system was used in the study. The last irrigations were practiced between 1st of August (S_1) and 5th of September (S_8) in 2016 and between 3rd of August (S_1) and 7th of September (S_8) in 2017. Harvest was performed manually on 28th of October in 2016 and 1st of November in 2017. Harvested ears were threshed in a thresher and weighed to get yield per hectare. Besides grain yield, kernel moisture at harvest, thousand-kernel weight, hectoliter weight, number and weight of kernels per ear and number of days to physiological maturity were determined in accordance with the methods specified by Eichelberger et al. (1989). Experimental data were subjected to analysis of variance with JMP 11.2.1 statistical software. Significant means were compared with the aid of LSD test. GGE-biplot software was used for visual assessment of the relationships between irrigation termination dates and the investigated traits over the average of two years (Yan, 2014).

Results and Discussion

In the experiment, the differences between the irrigation termination dates were found to be significant ($p < 0.01$) for all traits, except for hectoliter weight.

Grain yield and kernel moisture at harvest

The earliest irrigation termination date S_1 (10460 kg ha^{-1}) coincided with the end of pollination and thus resulted in a sharp decline in grain yield. Previous researchers worked on deficit irrigation in maize and indicated that at the end of pollination and right after pollination as the most sensitive periods against water stress (Eck, 1984). Similar with the present findings, previous researchers working on deficit irrigation also reported decreasing maize grain yields with earlier irrigation termination dates (Yerdogan and Gozubenli, 2015; Sahin, 2016).

Grain yields increased with delaying of the last irrigation and the greatest grain yield were obtained at S_8 (16240 kg ha^{-1}) treatment.

However, such late irrigations may be disadvantageous in terms of kernel moisture at harvest (Table 4). Irrigation water amount has been important in differences between subjects in terms of grain yield.

Table 4. Grain yield, kernel moisture at harvest, hectoliter weight and thousand kernel weight values obtained at different irrigation termination dates

ITD	Grain yield (kg ha^{-1})**			Kernel moisture at harvest (%)**			Thousand-kernel weight (g)**		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
S_1	11270	9640	10460 d	13.5 e	10.0 f	11.7 e	280	222	271 d
S_2	11440	11340	11390 d	13.0 e	14.0 d	13.5 d	334	299	317 c
S_3	12850	12400	12630 c	15.8 c	13.0 e	14.4 c	350	323	336 bc
S_4	13100	14990	14050 b	14.1 d	14.2 d	14.2 c	372	344	358 ab
S_5	13810	14520	14170 b	15.7 c	15.3 c	15.0 c	402	352	377 a
S_6	14550	15200	14880 b	16.2 c	16.0 c	16.1 b	382	355	369 a
S_7	15770	16430	16100 a	20.5 a	17.1 c	18.8 a	406	351	379 a
S_8	15850	16620	16240 a	21.4 a	17.8 b	19.6 a	411	352	381 a
Mean	13580	13890	13740	16.3	14.7	15.5	367 a	330 b	349
LSD(%5)	Year:ns Year x ITD:ns ITD:1050			Year:ns Year x ITD:1.97 ITD:1.39			Year:12.8 Year x ITD:ns ITD:25.6		
CV	6.5			7.5			6.2		

S_1: R2 blister stage; S_2: R3 early milk stage; S_3: R3 milk stage; S_4: R3 late milk stage; S_5: R4 dough stage; S_6: R5 early dent stage; S_7: R5 dented stage; S_8: R5 late dent stage, ITD: Irrigation termination dates, ns: non-significant; ** significant at P ≤ 0.01

Kernel moistures at harvest varied with the irrigation termination dates and applied irrigation water quantities. The lowest moisture ratios were observed in S_1 (11.7%) treatments. The highest kernel moistures were observed in later irrigation termination dates (S_7 and S_8) (Table 4). High kernel moistures observed in S_7 and S_8 are not desired in grain maize cultivation (Vartanlı and Emeklier, 2007). In Central Anatolia-like regions with limited vegetation period, grain yields should be assessed together with kernel moisture and harvest moisture levels should also be taken into consideration in all the other agronomic practices. Therefore, as can be seen in Table 5, S_4 (14050 kg ha^{-1} yield and 14.2% moisture) and S_5 (14170 kg ha^{-1} yield and 15.0% moisture) treatments seemed to be the best periods for termination of irrigations in terms of both the grain yield and moisture content at harvest. Supporting present findings, Klocke et al. (1996) indicated optimum irrigation termination period in maize cultivation as 2-4 weeks before physiological maturity. Similar with the present findings on kernel moisture at harvest, Sahin (2016) also reported high moisture levels at late irrigation terminations.

Thousand-kernel weight

As it was in grain yield and kernel moisture at harvest, irrigation termination dates also influenced thousand-kernel weights. The lowest value was observed in S_1 (271 g) treatment and greatest value was observed in S_8 (381 g) treatment (Table 4). Average thousand-kernel weight was measured as 349 g and this value was similar with the values reported by Sakin et al. (2016). Similar with the present findings, Yerdogan and Gozubenli (2015), Sahin (2016) also reported that the lowest thousand-kernel weights at early irrigation termination dates and increasing values with the late irrigation termination dates.

Number of kernels per ear

As it was in grain yield and the other yield-related parameters, early irrigation termination dates negatively influenced number of kernels per ear. The lowest value was observed at S_1 (677 kernels) treatments and the highest value was observed at S_8 (739 kernels) treatment (Table 5).

Table 6. Kernel weight and number per ear and ear length values in obtained from different irrigation termination dates.

ITD	Kernel weight per ear(g)**			Number of kernel per ear **			Ear lenght (cm)**		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
S_1	174.1 c	127.2 d	150.6 d	688	666	677 e	16.1	17.2	16.7 e
S_2	171.5 c	207 a-c	189.2 c	720	700	710 d	18.4	18.6	18.5 d
S_3	204.2 b	183.4 c	193.8 c	738	715	726 c	20.1	20.3	20.2 c
S_4	196.7 bc	216 ab	206.4 bc	746	724	735 b	23.1	25.0	24.1a
S_5	210.1 b	202 bc	206.0 bc	752	730	741 a	22.7	23.4	23.1 a
S_6	221.4 ab	224.9 ab	223.2 ab	751	729	740 a	22.2	24.0	23.1 a
S_7	239.9 a	237.4 a	238.7 a	741	728	735 b	22.7	24.5	23.6 a
S_8	241.2 a	231.6 ab	236.4 a	750	728	739 ab	22.3	23.9	23.2 a
Mean	207.4	203.7	205.5	736 a	715 b	725	21	22.1	21.6
LSD(5%)	Year:ns Year x ITD:27.1 ITD:19.1			Year:2.5 Year x ITD: ns ITD:5.1			Year:0.87 Year x ITD:ns ITD:1.74		
CV	7.9			1.2			4.6		

S_1: R2 blister stage; S_2: R3 early milk stage; S_3: R3 milk stage; S_4: R3 late milk stage; S_5: R4 dough stage; S_6: R5 early dent stage; S_7: R5 dented stage; S_8: R5 late dent stage, ITD: Irrigation termination dates, ns: non-significant; ** significant at P ≤ 0.01

Maize plants have the greatest water requirement just beforetasseling period and subsequent 15-20 days (Kirtok, 1998; Gonulal and Soylu, 2019) and water deficits in these periods together with increasing temperatures reduces both the yield and number of kernels per ear.

Kernel weight per ear

Kernel weight per ear is directly related to thousand-kernel weight and number of kernels per ear (Kirtok, 1998) and it was negatively influenced by early irrigation termination dates. The lowest value was observed at S_1 treatments (150.6 g) and the greatest values were observed at S_7 (238.7 g) treatments. The S_6 treatment (223.2 g), recommended for grain yield and kernel moisture at harvest, was also in the same statistical group and had high kernel weight per ear (Table 4 and 5). Kernel weight per ear is a significant parameter for grain yield in maize and greatly influenced by water deficits at tasseling and early kernel filling periods (Kirtok, 1998). Present findings on kernel weight per ear comply with the findings of Yerdogan and Gozubenli (2015) and Sahin (2016).

Ear length

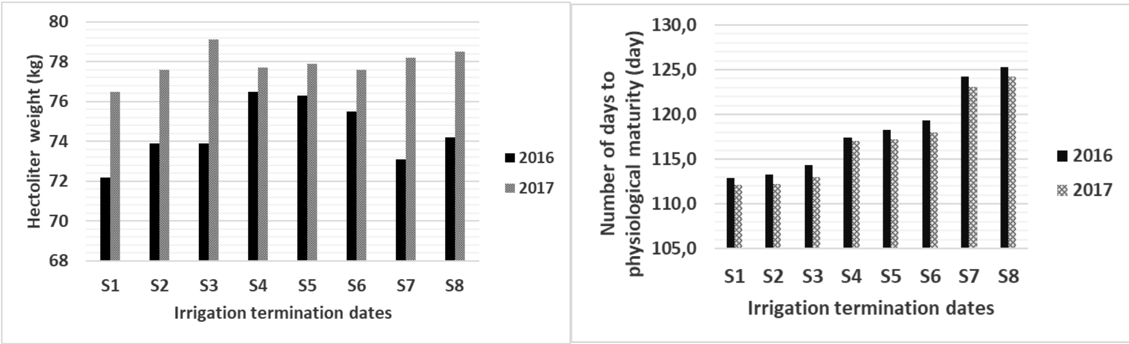
In study the lowest values were observed in S_1 (16.7 cm) treatment and the greatest values were observed in S_7 (23.6 cm) treatment (Table 5). Ear length is related to number of kernels per ear and the factors reducing number of kernels per ear also reduced ear lengths. Supporting present findings, previous studies on the last irrigation in maize cultivation (Yerdogan and Gozubenli, 2015; Sahin, 2016) indicated that irrigation termination at tasseling and early kernel formation periods decreased ear lengths.

Hectoliter weight.

The average hectoliter weight was measured as 74.5 kg in 2016 and as 77.9 kg in 2017. The average value was 76.2 kg. Present findings comply with the values reported by Gur and Kara (2019) and Saygı and Toklu (2017). The differences between hectoliter weights of irrigation termination dates were not found to be significant. The lowest value was observed at the earliest irrigation termination date of S_1 treatment (74.3 kg) and S_3-S_8 treatments (76.5 kg - 76.4 kg) had similar and closer values to each other (Fig.1 a). Similar with the present findings, Yerdogan and Gozubenli (2015) also reported the lowest hectoliter weight of flint corn for the earliest irrigation termination date.

Number of days to physiological maturity

Number of days to physiological maturity increased with the delaying of irrigation termination dates. As the average of two years, number of days to physiological maturity was identified as 117.5 days. The lowest values were observed in early irrigation termination dates (S_1: 112.5 days, S_2: 112.5 days and S_3: 113.5 days, respectively) and the greatest values were observed at late irrigation termination dates (S_7: 123.5 days and S_8: 124.5 days) (Fig. 1 b).

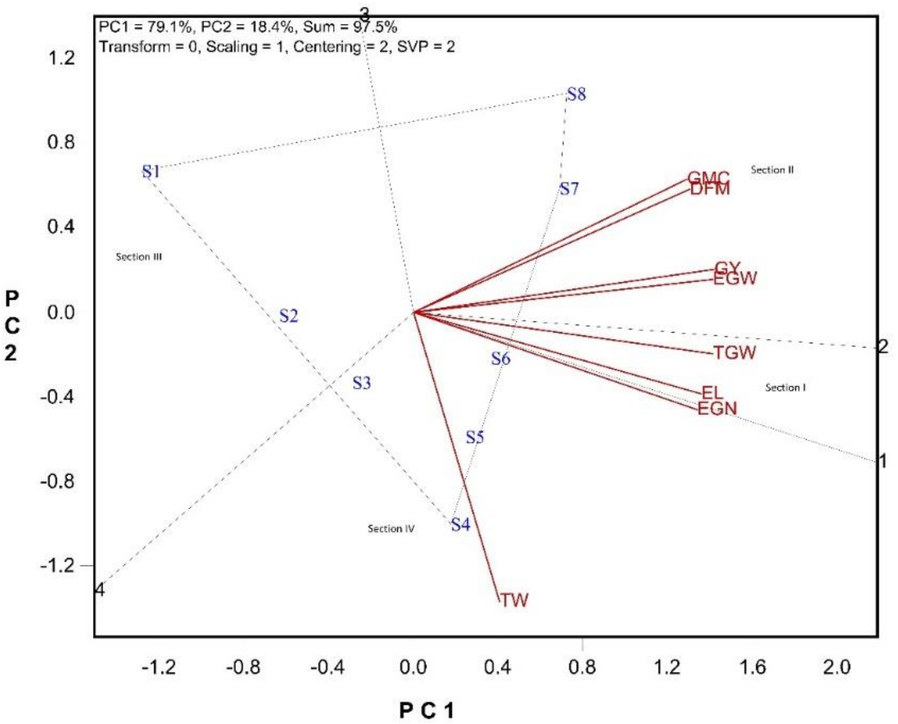


(a) (b)

Figure 1. Hectoliter weight (a) and number of days to physiological maturity values in obtained at different irrigation termination times (b).

Biplot assessments for the relationships between irrigation termination dates and investigated traits.

Biplot graph generated over two-year averages for visual assessment of the relationships between irrigation termination dates and investigated traits was presented in Figure 2.



GY: Grain yield; **GMC**: Kernel moisture at harvest; **TW**:Hectoliter weight; **TGW**: Thousand-kernel weight; **EGW:** Kernel weight per ear; **EGN:** Kernel number per ear; **EL**: Ear lenght**; DFM:** Number of days to physiological maturity

Figure 2. Biplot graph generated over two-year averages for visual assessment of the relationships between irrigation termination dates and investigated traits.

Biplot allows visual assessment of the relationships between irrigation termination dates and investigated traits on a single graph (Yan and Frégeau-Reid, 2008). The first component explained 79.4% and the second component explained 18.4% of total variation (Figure 2). Such high explanation rates are desired in GGE biplot graphs (Fırıncıoglu et al., 2012) and reliable interpretations can be made by the researches at these high explanation rates (Yan et al., 2007). In general, diagonal genotypes are considered to be superior over the others in the same sector (Yan and Kang, 2003). Present biplot had 4 sectors and 4 diagonals (S_1, S_4, S_7, S_8). The second sector with S_7 and S_8 diagonal treatments included GY, DFM, GMC and EGW parameters (Figure 2). These traits have high correlations among them and had high value in late irrigation termination dates (S_7 and S_8 treatments) (Table 5 and 6). Similar with the present findings, Sahin (2016) reported increased grain yield and kernel moisture at harvest levels in maize with late irrigation terminations. In biplot graph, TW and EGN traits were placed into the 4th sector with diagonal S_4 treatment. The greatest TW values were observed in S_4 and S_5 treatments and the greatest EGN values were observed in S_5 and S_6 treatments. There were not any traits in the 3rd sector of the graph and the first sector included TGW and EL traits (Figure 2). In this sector, there were not any diagonals. The greatest TGW values were observed in S_8 and S_7 treatments and the greatest EL value was observed in S_4 treatment.

Conclusion

The present experimental site is the largest grain maize production region of Turkey and also the driest section of the country. In this region and similar ecologies, several studies were conducted on maize growing techniques and various techniques were put into practice at the end of these studies. However, number of studies about marketing and storage of grain maize, about irrigation termination dates with a significant effect on kernel moisture at harvest and grain yields is quite limited. Therefore, this study was conducted to investigate the effects of different irrigation termination dates on grain yield, kernel moisture at harvest levels and some other agronomic traits of maize in Central Anatolia with limited vegetation period and water resources. Present findings revealed the significance of irrigation termination dates in maize cultivation.

Number of days to physiological maturity increased with delaying the irrigation termination dates. The lowest values were observed at S_1 (112.5 days) treatment and the highest values were observed in S_8 (124.5 days) treatment.

When the grain yields and kernel moisture contents at harvest were assessed together, it was observed that S_4 (14050 kg ha^{-1} grain yield and 14.2% kernel moisture), S_5 (14170 kg ha^{-1} grain yield and 15.0% kernel moisture) and S_6 (14880 kg ha^{-1} grain yield and 16.1% kernel moisture) treatments were appropriate irrigation termination dates.

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

Author Contribution: Erdal GÖNÜLAL designed the study and set up the experiments, Erdal GÖNÜLAL, Süleyman SOYLU and Mehmet ŞAHİN conducted the study. Erdal GÖNÜLAL analyzed the data, and Erdal GÖNÜLAL, Süleyman SOYLU and Mehmet ŞAHİN wrote the article.

References

Anonymous (2009). Problems of Konya closed basin groundwater and solutions. Konya Chamber of Geological Engineers publications. Retrieved from: https://www.jmo.org.tr/resimler/ekler/dcfee25dedf7c8e_ek.pdf?dergi=HABER%20B%DCLTEN%DD .

Anonymous (2019). Crop production statistics. Retrieved from: www.tuik.gov.tr.

Doorenbos, J., & Kassam, A. H. (1979). Yield response to water. *Journal of Irrigation and Drainage*, 33, 193.

Eck, H. V. (1984). Irrigated corn yield response to nitrogen and water. *Agronomy Journal*, 76, 421-428.

Eichelberger, K. D., Lambert, R. J., Below F. E., & Hageman, R. H. (1989). Divergent phenotypic recurrent selection for nitrat reductase activity in maize. II. efficient use of fertilizer nitrogen. *Crop Science*, 29,1398 – 1400.

Fırıncıoglu, H. K., Unal, S., Pank, Z., & Beniwal, S.P.S. (2012). Growth and development of narbon vetch (*Vicia Narbonensis* L.) genotypes in the semi-arid central Turkey. *Spanish Journal of Agricultural Research,*10, 430-442.

Gur, I., & Kara, B. (2019). Performances of some hybrid dent corn cultivars (Zea mays indentata Sturt) in Trabzon ecological conditions. *Black Sea Journal of Agriculture*, 2, 103-108.

Kırtok, Y. (1998). *Production and Use of Maize*. Istanbul: Kocaoluk Press, 202-240.

Klocke, L.N., & Hergert, W.G. (1996). How soil holds water. *Cooperative Extension. Institute of Agriculture and*

Natural Resources University of Nebreska. *https://core.ac.uk/download/pdf/188046144.pdf* (Cited 2020 March 26).

Sade, B., Ogut, H., & Soylu, S. (2007). Maize in the World and Turkey. *Journal of Biofuel*, 10, 32-41.

Sakin, M.A., Bozdag, M., & Cakar, S. (2016). Determination of yield and its related traits of hybrid dent corn varieties (*Zea mays indentata* L.) in Tokat Kazova and Zile under main crop conditions. *Journal of Field Crops Central Research Institute*, 25 , 87-93.

Saygı, M., & Toklu, F. (2017). Evaluation of some dent corn (*Zea mays indentata* Sturt.) varieties grown in the main crop conditions in Cukurova region conditions for grain yield, several plant traits and phenotypic correlation coefficients. *KSU Journal of National Science*, 20, 308-312.

Sahin, M.D. (2016). *Effects of different sowing time and different water cutting times ın generative stage on the yield of corn under the Harran plain conditions* (Un published MSc Thesis). Kahramanmaras Sutcu Imam University Graduate School of Natural and Applied Sciences, Kahramanmaraş.

Vartanlı, S., & Emeklier, H. Y. (2007). Determination of the yield and quality characteristics of hybrid maize varieties under Ankara conditions. *Journal of Agriculture Sciences*, 13, 95-202.

Yan, W., & Kang, M. S. (2003). *GGE Biplot Analysis: A Graphical Tool for Breeders,Geneticists, and Agronomists*. Boca Raton: CRC Press, 288.

Yan, W., Kang, M. S., Manjit, B., Woodsc, S., & Corneliusd, P. L. (2007). GGE Biplot vs. AMMI Analysis of Genotype by- Environment Data. *Crop Science*, 47: 643-653.

Yan, W., & Frégeau-Reid, J. (2008). Breeding line selection based on multiple traits. *Crop Science*, 48, 417–423.

Yan, W. (2014). *Crop Variety Trials: Data Management and Analysis*. John Wiley Sons Press, 349.

Yerdogan, K., & Gozubenli H. (2015). Determination of irrigation termination time effects on popcorn grain yield, and some quality characteristics. *11. Field Crops Congress*, (pp.112), 7-10 September 2011, Canakkale, Turkey.

Xu, L., & Hsiao, T.C. (2004). Predicted versus measured photosynthetic water-use efficiency of crop stands under dynamically changing field environments. *Journal of Experimental Botany*, 55, 2395-2411.