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Determination of Changes in Some Factors Affecting Grain Yield in Maize (*Zea mays* L.) Crops Grown at Different Densities

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ABSTRACT

In this study, it was tried to determine the effects of different plant densities on yield and some agricultural characteristics of some maize varieties. The experiment was conducted in Konya-Karapınar conditions in 2015 and 2016. The experiment was set up in a randomized block split plot design with 3 replications. In the study, 3 varieties (Pionner 0537, DKC 5783, KWS 6565) widely cultivated in the region were used as the main subject. As a sub-topic, with fixed row spacing (70 cm) 6 different row spacings (12, 14, 16, 18, 20, 22, 24 cm) and cross double row (50x24) were used. The study consisted of a total of 63 plots, 3 types x7 row spacing x3 replications. As a result of the study, it was determined that different plant densities affected grain yield and some agronomic traits in maize. It was observed that grain yield increased with increasing plant density, but stem diameter decreased. It was observed that although the yield was high especially in double row cross sowing, the stem diameter value was very low. This situation causes lodging and crop losses especially in Konya region where strong winds are observed at harvest time. From this point of view, row spacings of 14 and 16 cm were found to be more suitable considering both yield and stem diameter. At the same time, it was observed that the plant density was also affected by the yield according to the varieties, and it was seen that upright-leaved varieties were more suitable for dense planting.

Farklı Sıklıklarda Yetiştirilen Mısır (*Zea mays L.*) Bitkisinde Tane Verimine Etki Eden Bazı Faktörlerin Değişimlerinin Belirlenmesi

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ÖZET

Bu çalışmada bazı mısır çeşitlerinde farklı bitki sıklıklarının verim ve bazı tarımsal özelliklere etkileri belirlenmeye çalışılmıştır. Deneme, Konya/Karapınar şartlarında 2015/2016 yıllarında yürütülmüştür. Deneme tesadüf bloklarında bölünmüş parseller deneme desenine göre 3 tekrarlamalı olarak kurulmuştur. Çalışmada bölgede yaygın olarak yetiştirilen 3 çeşit (Pionner 0537, DKC 5783, KWS 6565) ana uygulama olarak kullanılmıştır. Alt uygulamalar olarak sabit sıra aralığı (70 cm) ve 7 farklı sıra arası (12, 14, 16, 18, 20, 22 cm) ve çapraz çift sıra (50x24) kullanılmıştır. Çalışma 3 çeşit x 7 sıra arası x 3 tekrar olmak üzere toplam 63 parselden oluşmuştur. Çalışmada farklı bitki sıklıklarının tane verimi ve bazı tarımsal özellikleri etkilediği belirlenmiştir. Bitki sıklığı arttıkça tane veriminin arttığı fakat sap çapının azaldığı görülmüştür. Özellikle çift sıra çapraz ekimde verimin yüksek olmasına rağmen sap çapı değerinin çok düşük olduğu görülmüştür. Hem verim hem de sap kalınlığı dikkate alınarak 14 ve 16 cm sıra aralıklarının daha uygun olduğu görülmüştür. Aynı zamanda bitki sıklıklarının çeşitlere göre de verimin etkilediği görülmüş olup, dik yapraklı çeşitlerin sık ekime daha uygun olduğu görülmüştür.

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INTRODUCTION

Maize is among the most widely used plants worldwide in human nutrition and animal feeding. Maize could accumulate high quantities of dry matter and store high quantity of energy in its structure (Çelik et *al*., 2008; Karadavut, et *al*., 2010a). It is one of the most preferred plants both in our country and in the world due to its high grain yield per unit area and the use of its green parts (Sümbül and Soylu, 2022). Inherently, based on available growing conditions, plant heights may reach to 2-3 meters and number of kernels per cob may reach up to 750-800 (Kırtok, 1998). Potential uses of maize plants vary from one country to another. While it is used as animal feed in some developed countries, it is used in human nutrition in the other countries. In Türkiye, ¼ of maize cultivation is used in human nutrition and the rest is used in animal feeding (TÜİK, 2019). Worldwide, maize is cultivated over 191 630 000 hectares and annual production is around 1 102 164 000 tons. Average yield per hectare is 5.75 tons. In terms of maize cultivated lands of the world, China (22%), the USA (18%), Brasil (10%), India (5%) and European Union Countries (5%) have the first five places. In Türkiye, maize is cultivated over 5 919 000 da land area, annual production is 5.900.000 tons and average yield is 963 kg/da. Top 10 provinces where corn is grown; Konya (19%), Adana (15%), Mardin (8%), Osmaniye (6%), Karaman (5%), Sakarya (5%), Manisa (5%), Şanlıurfa (4%), Diyarbakır (4%) and Kahramanmaraş (4%), and these provinces provide 75% of Türkiye corn production.

Maize is an important crop for Turkish farmers and constitutes a source of income for quite a large portion of farmers. Maize is also a strategic crop in reduction of foreign dependency. However, desired yield levels have not been achieved yet. Therefore, research on maize should focus on yield increases. Agronomic studies focus on arrangement of row spacing and thus number of plants per unit area to improve yield levels in maize cultivation. Besides parallel with the development of animal husbandry in our country, the demand for maize is also increasing in order to meet the increasing feed demand, and studies on the performance of newly developed maize varieties with different characteristics should be carried out continuously (Erdurmuş and Soylu, 2023). Plant density, of course, vary based on cultivar characteristics, climate and soil conditions. Besides growing techniques, plant density, fertilization and harvest like practices, maize yields are also largely influenced by regional climate, financial conditions of the farmers and several other factors (Kırtok, 1998). On-row plant spacing is among the most significant factors designating maize yield. It designates type of growth in growing ambient, excessive density and infrequence negatively influence yield and quality (Daynard and Muldoon, 1983; Palta et *al*., 2011).

Physiologically, maize is a C4 plant and able to use carbon dioxide, solar radiation and water more efficiently than the C3 plants. Agronomic practices with a great impact on dry matter accumulation should not be considered separately from irrigation water use efficiency (Karadavut et *al*., 2010a). However, maize is quite sensitive to water stress to be encountered in any growth stages throughout the growing season. Therefore, maize response to potential water stress is quite high (Gönülal and Soylu, 2019). Maize response to water deficits may vary based on growth stages (Çakır, 2004). The ideal precipitation in maize farming is defined as between 500–1200 mm (Belfield and Brown, 2008). It is expected that recent drought and increasing prospective droughts will greatly influence plant production. Therefore, efficient water use programs should urgently be developed. In this sense, newly developed cultivars are expected to have high water use efficiencies. Passioura and Angus (2010) defined irrigation water use efficiency as the yield per unit of water consumption.

Çokkızgın (2002) pointed out that initially proper agronomic conditions should be provided to increase yields in maize. Karadavut et *al.* (2010b) pointed out significance of number of plants per unit area in growth and development of silage maize. Maize has a high physiological adaptation capability and genotype x environment interactions should definitely be taken into consideration in regional production planning (Karadavut and Akıllı, 2012). Palta et *al*. (2011) indicated that water and nitrogen use efficiencies especially in cob formation and grain-fill stages designated maize yields. Konuşkan and Gözübenli (2001) pointed out that with increasing planting density, plant height and tassel flowering time increased, while stem thickness and grain weight per cob decreased. It has been determined that as plant density increases, single plant yield decreases, but the yield per unit area increases up to a certain limit, and if the plant density is higher than normal, a decrease in yield is observed due to the presence of cobless plants. Taş et *al. (2016)* reported that with increasing plant density, plant height and biomass yield increased, but stem diameter decreased.

In this study, effects of different plant densities on yield and yield components of maize cultivars commonly grown under irrigated conditions of Central Anatolia.

MATERIALS AND METHODS

The experiments were conducted over the experimental fields of Soil and Water Resources and Combating Desertification Research Institute, Karapınar Erosion Research Center for two years in 2015 and 2016 maize growing seasons. Experiments were implemented in randomized blocks – split plots experimental design with 3 replications. In present experiments, commonly grown 3 maize cultivars of the region (Pionner 0537, DKC 5783, KWS 6565) were used as the main treatments and 6 different on-row plant spacings (12, 14, 16, 18, 20, 22 cm) with a constant row spacing (70 cm) and (CDR) cross double row (50*24 cm) were used as sub-treatments. There were 63 plots (3 cultivars x 7 on-row plant spacing x 3 replications). Amount of fertilizers to be applied throughout the vegetation period was determined based on soil analysis results and fertilizers were applied as to complete the soil nutrients to 25 kg/da nitrogen, 8 kg/da phosphorus and potassium. All of the phosphorus fertilizer and 3 kg of nitrogenous fertilizer in DAP (18-46) form were applied at sowing and remaining portion of nitrogenous fertilizer was applied in portions through fertigation method of drip irrigation system. Experimental fields were prepared for sowing through soil tillage with moldboard plow, rototiller and harrow. Sowing was performed manually at 5 cm depth on 3rd of May in 2015 and 5th of May in 2016. Plot size was 2.80 x 5.00=14 m^2 at sowing and 1.40 x 3=4.2 m^2 at harvest considering the side effects (4 rows were harvested from each plot).

Karapınar, where the study was carried out, has an arid and semi-arid climate (Armağan and Işık, 2022), long-term averages for climate parameters are provided in Table 3.2. Average temperature of Karapınar town is 11.0^{o}C with the greatest average temperature (22.8^{o}C) in July and the lowest average temperature (-0.7 ^{o}C) in January. Considering the growing season of maize, average temperature is 10.6^{o}C in April, 15.4 ^{o}C in May, 19.6^{o}C in June, 22.8^{o}C in July, 22.1^{o}C in August and 17.5 ^{o}C in September. Long-term annual average temperature is 291.2 mm and 118.8 mm is falling during the growing seasons of maize (April/September). In the first year of the study (2015), annual total precipitation was 186.3 mm which was quite below the long-term average and 97 mm was falling between April/September. In the second year (2016), annual total precipitation was 286.2 mm and 98.6 mm was falling between April/September. (Table 1).

Table 1 *Some Climate Data of Karapınar District where the Research was Conducted*

Year	Months	January	February	March	April	May	June	July	August	September	October	Novomber	October	Ave./Total
Long years 1963-2015	Ave.Tem. (°C)	-0,7	0,8	5,1	10,6	15,4	19,6	22,8	22,1	17,5	11,6	5,5	1,5	11
	Max.Tem.(°C)	13,9	16	21,4	26,9	30,5	34	36,6	36,5	33,1	28,8	20,8	15,2	26,1
	Min.Tem..(°C)	-15,5	-15,9	-10,5	-3,9	0,9	5,6	8,9	7,9	2,0	-3,3	-9,0	-14,0	-3,9
	Rain (mm)	29,9	27,1	27,2	35,9	35,4	25,3	8	4,1	10,1	23,6	27,4	37,2	291,2
2015	Ave.Tem. (°C)	0,7	2,8	6,6	8,6	15,4	16,6	23	23,4	20,6	13,8	5,4	-2,6	11,2
	Max.Tem.(°C)	16,1	18,6	21,6	25,8	31,6	28,8	37	35,1	35,9	37,2	18	7,3	25,3
	Min.Tem..(°C)	-20,3	-16,7	-8,5	-8,4	0,7	6,2	7,7	9,2	5,6	0,5	-14,4	-13,5	-4,3
	Rain (mm)	13,2	24,9	45,4	16,6	28	46,4	0	5,2	0,8	3,6	1,6	0,6	186,3
2016	Ave.Tem. (°C)	0,2	6,5	7,7	14,2	16	21,8	24	24,4	17,4	13,1	4,9	-2,3	12,3
	Max.Tem.(°C)	16,3	21,4	25,3	28,1	30,7	35	37,8	36,3	32,0	28,2	21,8	9,4	26,9
	Min.Tem..(°C)	19,2	-10	-7,4	-1,9	3	7,7	9,9	11,1	5,1	2,1	-7,6	-17,6	1,1
	Rain (mm)	40,8	7,2	34,4	8,1	27,7	25	8	3,4	26,4	0,4	4,8	100	286,2

Climate data were taken from Konya Soil, Water and Deserting Control Research Institute

Soil samples were taken from 0 – 30 cm soil profile of experimental fields. Experimental soils were sandy-clay-loam (SCL) in texture at 0 – 30 cm soil layer, which was prone to erosion and clay (C) after 30 cm depth. Soil bulk density was 1.37 g/cm^3 in upper layer and 1.22 g/cm^3 in lower layer. Soil infiltration rate was measured as 10 mm/h. Soils were poor in organic matter, high in lime content. Soil pH values varied between 7.8–8.2 and there was no salinity problem (Table 2).

Table 2 *Analysis Results of Some Soil Characteristics of the Research Site*

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Taxture	FC (%)	FP (%)	volume weight (g/cm^3)	pH	EC (dSm^{-1})	Lime (%)	Organic Matter (%)	P_2O_5 (kg/da)	K_2O (kg/da)
0-30	58,1	22,8	19,1	SCL	20	9,6	1,37	7,8	0,42	33,5	1,3	14,5	33
30-60	30,1	20,3	49,6	C	24,5	12,6	1,30	8,1	0,45	28,7	1,1	5,7	26
60-90	16,0	24,4	59,6	C	28	15,4	1,22	8,2	0,44	29,4	0,6	2,6	24

Konya Soil, Water and Deserting Control Research Institute Laboratory

Irrigations were performed through drip irrigation system. Amount of applied irrigation water was measured as 690 mm in 2015 and 680 mm in 2016. Following the physiological maturity, kernel harvest was performed manually on 25th of October in 2015 and 1st of November in 2016. Plot yields were corrected based on 15% moisture content and yield per decare was calculated (Gönülal and Soylu, 2020). Besides kernel yield, cob diameter, plant height, number of kernels per cob, kernel weight per cob, thousand-kernel weight, cob height and lead angle parameters were also investigated. The methods specified in Anderson et *al*. (1984), Eichelberger et *al*. (1989) and Gönülal and Soylu (2019) were used in analysis of investigated parameters. Irrigation water use efficiency (IWUE) was calculated with the use of Equation 1 (Howell et *al*., 1990):

$$IWUE: Y/I (1)$$

$where;$

$IWUE: Irrigation\ water\ use\ efficiency\ \left(\frac{\frac{kg}{da}}{mm}\right),$

$Y: Kernel\ yield\ (kg\ da - 1),$

$I: Irrigation\ water\ quantity\ (mm)$

Statistical analyses were conducted with the use of MINITAB 18 statistical analysis software. Analysis of variance was conducted to determine the significance of differences between the treatments and between the cultivars. Significant means were compared with the use of LSD test to identify which treatment or treatments, cultivar or cultivars resulted in such differences in significant treatments and cultivars. Pearson correlation analysis was conducted to identify the relationships between the investigated parameters.

RESULT AND DISCUSSION

Yields at 7 different sowing densities are provided in Table 3. As can be inferred from the table, significant differences were not observed in yields of the cultivars. On the other hand, sowing density treatments significantly influenced the yields. The greatest yield (1765.3 kg da^{-1}) was obtained from cross double row (CDR), it was followed by 12 cm spacing (1663.8 kg da^{-1}) and the lowest yield (1024.3 kg da^{-1}) was obtained from 22 cm spacing. Cultivar x density interactions were found to be significant. In terms of the yields of interactions, the greatest value (1779.6 kg da^{-1}) was obtained from CDR of Pionner 0537 cultivar, followed by CDR of DKC 5783 cultivar (1779.3 kg da^{-1}). Plants got into competition for light with increasing densities. Plants then had taller heights accordingly. Kırılmaz and Marakoğlu (2018), reported that the highest grain yield was double row with 2233 kg da^{-1} and the lowest grain yield from 16 planting density with 1526 kg da^{-1}. Present findings comply with the results of, Ogunlela et *al.* (1988), Aydın (1991), Sezer and Yanbeyi (1997) reporting increasing plant heights with increasing sowing densities. Russsel and Balko (1980), Gözübenli (1997), Simenov and Tsankova (1990), Kaplan and Aktaş (1993), Uslu ve Karaaltın (1999) and Çokkızgın (2002) indicated that agronomic practices were not solely sufficient in yield increases, sufficient nutrient supply should also be provided for yield increases.

Table 3 *Cultivar, Density and Cultivar x Density İnteractions for Yield (kg da^{-1})*

Density	***Cultivars***			
	Pionner 0537	**KWS 6565**	**DKC 5783**	**Density means**
12	1684.2 b	1660.7 b	1646.4 b	***1663.8 AB***
14	1681.9 b	1547.4 c	1628.6 b	***1619.3 B***
16	1397.2 d	1520.4 c	1493.8 c	***1470.4 C***
18	1215.2 e	1257.1 e	1258.8 e	***1243.7 D***
20	1120.5 f	1204.6 g	1212.5 g	***1179.2 D***
22	985.8 ı	1081.8h	1005.4 hı	***1024.3D***
CDR	1779.6 a	1737.0 a	1779.3 a	***1765.3 A***
Cultivar means	***1409.2 A***	***1429.8 A***	***1432.1 A***	

*CDR: Crosss double row (50*24 cm)   * significance at p<0.05 level*

1000 grain weight of the cultivars at different sowing densities are provided in Table 4. Differences in thousand-kernel weights of the cultivars were not found to be significant. The greatest thousand-kernel weight (268.91 g) was obtained from Pionner 0537 cultivar, respectively followed by KWS 6565 cultivar (265.61 g) and DKC 5783 cultivar (256.05 g). However, significant differences were observed in 1000 grain weight at different sowing densities. The greatest 1000 grain weight (281.74 g) was obtained from 22 cm spacing, followed by 20 cm spacing (276.23 g). The lowest value (224.9 g) was obtained from 12 cm spacing. For 1000 grain weight, cultivar x density interactions were found to be significant. The greatest value (302.7 g) was obtained from 20 cm spacing of KWS 6565 cultivar and the lowest (211.5 g) from 12 cm spacing of DKC 5783 cultivar. Significance of cultivar x density interaction was resulted from the changing number of plants per unit area with changing density and resultant effects of such changes on physiological development accordingly. According to present findings, ideal on-row plant spacing was identified as 20 cm for KWS 6565 cultivar, 14 cm for Pionner 0537 cultivar and 18 cm for DKC 5783 cultivar. Taş (2010) investigated the effect of different row spacing (10, 14, 18, 22, 26 cm) on yield and factors affecting yield in Harran Plain conditions and reported that cob length, cob diameter, cob weight and thousand grain weight decreased as plant density increased.

Table 4 *Cultivar, Density and Cultivar x Density İnteractions for Yield (kg da^{-1})*

Density	***Cultivars***			
	Pionner 0537	**KWS 6565**	**DKC 5783**	***Density means***
12	237.4 e	225.9 ef	211.5 f	***224.9 B***
14	285.9 ab	245.2 de	249.9 cde	***260.3 AB***
16	269.8 bc	290.4 a	261.9 c	***274.0 A***
18	260.6 c	269.6 bc	278.7 b	***269.9 A***
20	269.4 bc	302.7 a	258.1 c	***276.23 A***
22	281.3 b	286.9 ab	277.1 b	***281.74 A***
CDR	278.0 b	238.6 e	255.2 cd	***257.9 AB***
Cultivar means	***268.91 A***	***265.61 A***	***256.05 A***	

*CDR: Crosss double row (50*24 cm)   * significance at p<0.05 level*

In terms of kernel weight per cob, cultivars, densities, cultivar x density interactions were found to be significant. In terms of kernel weight per cob of cultivars, the greatest value (179.61 g/cob) was obtained from KWS 6565 cultivar and the lowest value (168.63 g/cob) from Pionner 0537 cultivar (Table 5). In terms of sowing densities, the greatest value (192.4 g/cob) was obtained from 22 cm spacing, it was followed by 20 cm spacing (185.6 g/cob) and the lowest value (152.9 g/cob) was obtained from 12 cm spacing. In terms of cultivar x density interactions, the greatest value (201.9 g/cob) was obtained from 22 cm spacing of KWS 6565 cultivar and the lowest value (151.5 g/cob) was obtained from 12 cm spacing of KWS 6565 cultivar. Kernel weight per cob decreased with decreasing on-row plant spacings. In this sense, it could be stated that decreasing plant spacings hindered cob development. Especially at dense sowings, plants are not able to get sufficient light and wind and together with the other environmental factors, plants get into competition and such competitions hinder physiological development of the plants. Gözübenli (1997), Nimje and Seth (1988), Hutchinson et *al*. (1988) and Çokkızgın (2002) indicated that density did not have significant effects on cob characteristics in cases where sufficient nutrient supply was not provided, but reduction of on-row plant spacing might be effective in yield increases provided that sufficient nutrient supply was provided. Present findings in this sense comply with those earlier ones.

Table 5 *Cultivar, Density and Cultivar x Density İnteractions for Kernel Weight Per Cob (g)*

Density	***Cultivars***			
	Pionner 0537	**KWS 6565**	**DKC 5783**	***Density means***
12	155.6 d	151.5 d	151.6 d	***152.9 D***
14	185.1 b	166.9 cd	182.5 bc	***176.9 BC***
16	170.9 c	191.9 ab	189.0 b	***183.9 AB***
18	171.9 c	177.2 bc	186.7 b	***178.6 ABC***
20	173.5 c	186.7 b	196.7 a	***185.6 AB***
22	182.5 bc	201.9 a	196.7 a	***192.4 A***
CDR	171.3 c	164.8 cd	171.5 c	***169.2 C***
Cultivar means	***168.63 B***	***179.61 A***	***174.60 AB***	

*CDR: Crosss double row (50*24 cm)*   ** significance at $p<0.05$ level*

In terms of number of kernel per cob, cultivars and cultivar x density interactions were found to be significant, but density treatments were not found to be significant. Differences in number of kernels per cob of the cultivars were significant. The greatest number of kernels per cob (746.3) was obtained from DKC 5783 cultivar and the lowest (685.3) from Pionner 0537 cultivar. On-row plant spacings did not have significant effects on number of kernels per cob. The greatest value (722.6) was obtained from 22 cm spacing and the lowest (699.7) from CDR (Table 6). In terms of the number of kernels per cob of the interactions, the greatest value (806.2) was obtained from 20 cm spacing of DKC 5783 cultivar, it was followed by 16 cm spacing of DKC 5783 cultivar (762.7) and the lowest value (654.4) was obtained from 20 cm spacing of KWS 6565 cultivar. Present findings revealed that cultivar response varied with the densities probably because of genotypic characteristics of the cultivars. Each genotype should be supplied with ideal environmental conditions identified in breeding programs. A successful practice is only possible with the supply of desired requirements. Farmers should be informed about this issue and ideal or close to ideal conditions should be supplied. Supporting present findings, Lemcoff and Loomis (1986), Nimje and Seth (1988), Kaplan and Aktaş (1993), Paradkar and Sharma (1993) and Tüfekçi and Karaltın (2001) reported a fair amount of increase in number of kernels per cob with increasing densities, but indicated that without fertilization, it would be impossible to achieve high increases. Researchers indicated thsağlamat nitrogenous fertilizers increased number of kernels per cob and on-row plant spacing was not alone sufficient to increase number of kernels per cob.

Table 6 *Cultivar, Density and Cultivar x Density Interactions for Number of Kernels Per Cob*

Density	***Cultivars***			
	Pionner 0537	**KWS 6565**	**DKC 5783**	***Density means***
12	695.6 cd	712.7 cd	744.2 bc	***717.5 A***
14	684.7 de	726.0 c	758.0 b	***722.9 A***
16	684.7 de	706.7 cd	762.7 b	***718.0 A***
18	703.6 cd	695.3 cd	709.1 cd	***702.7 A***
20	683.1 de	654.4 de	806.2 a	***714.6 A***
22	688.9 d	745.1 b	734.0 bc	***722.6 A***
CDR	656.5 de	732.5 bc	710.2 cd	***699.7 A***
Cultivar means	***685.3 B***	***710.4 AB***	***746.3 A***	

*Density and Cultivar x density interactions are not significant, CDR: Crosss double row (50*24 cm)*

For stem diameters, density and cultivar x density interactions were found to be significant, but cultivars were not found to be significant (Table 7). The greatest stem diameter (29.2 mm) was obtained from KWS 6565 cultivar and the lowest (27,6 mm) from DKC 5783 cultivar. In terms of on-row plant spacing (density), the greatest value (32.8 mm) was obtained from 22 cm spacing and the lowest (24.1 mm) from CDR. For cultivar x density interactions, the greatest value (35.5 mm) was obtained from 22 cm spacing of KWS 6565 cultivar and the lowest (23.3 mm) from CDR of KWS 6565 cultivar. Generally increasing stem diameters were observed with increasing on-row plant spacings. It is an expected case since plants get into more competition for light and nutrients as the on-row plant spacings decreased. Plants try to increase their heights to compete, thus stem diameter decreased as the plant height increased. Stem diameters changes with the spacings. Especially in sparse sowing, plants had more available growth ambient, thus exhibited faster growth. Stem diameters therefore increased in plants not getting into competition. Eskandarnejad et al. (2013) reported that double row planting increased grain yield and the amount of grain per cob, but the cob length and stem diameter reduced. Present findings on stem diameters comply with the findings of Dostolek and Hruska (1985), Aydın (1991), Öktem (1996) and Uslu and Karaltın (1999).

Table 7 *Cultivar, Density and Cultivar x Density Interactions for Stem Diameter (mm)*

Density	*Cultivars*			
	Pionner 0537	**KWS 6565**	**DKC 5783**	***Density means***
12	25.7 cd	27.9 bc	24.6 cd	***26.0 C***
14	26.6 bc	27.9 bc	28.1 b	***27.5 BC***
16	26.2 bcd	28.7 ab	27.3 bc	***27.4 BC***
18	29.8 a	30.2 a	28.6 ab	***29.5 B***
20	29.1 ab	31.3 a	30.8 a	***30.4 AB***
22	32.4 a	35.5 a	30.4 a	***32.8 A***
CDR	24.9 ab	23.3 bc	24.0 b	***24.1 BC***
Cultivar means	***27.8 A***	***29.2 A***	***27.6 A***	

*CDR: Crosss double row (50*24 cm)*   ** significance at p<0.05 level*

The differences in plant heights of the cultivars were not found to be significant (Table 8). The greatest plant height (264.9 cm) was obtained from Pionner 0537 cultivar and the lowest (257.0 cm) from KWS 6565 cultivar. Significant differences were observed in plant heights of densities. The greatest value (284.1 cm) was obtained from CDR, it was followed by 22 cm spacing (265.0 cm) and the lowest (265.0 cm) values (251.6 cm) was obtained from 20 cm spacing. However, plant heights at 20 cm spacing were not significantly different from the plant heights at 12, 14, 16 and 18 cm spacings. It was expected herein that plants should have taller heights at denser sowings. However, limited number of irrigations and soil nutrients result in significant competitive losses in plant especially in dense sowings. Dense sowing put the plants into a competition for sunlight, then taller plants are encountered. Present findings comply with the results of, Ogunlela et al. (1988), Aydın (1991), Sezer and Yanbeyi (1997), Özata et al. (2016) and Bayram (2017) indicating taller plants with increasing densities.

Table 8 *Cultivar, Density and Cultivar x Density Interactions for Plant Height (cm)*

Density	***Cultivars***			
	Pionner 0537	**KWS 6565**	**DKC 5783**	***Density means***
12	258.8 bc	256.9 bc	255.9 bc	***256.2 BC***
14	262.1 b	255.1 bc	253.1 bc	***255.4 BC***
16	261.9 b	255.1 bc	253.6 bc	***256.9 BC***
18	253.6 bc	248.8 c	258.6 bc	***253.6 BC***
20	251.1 bc	250.8 c	248.8 c	***251.6 C***
22	267.8 b	260.7 b	266.7 b	***265.0 B***
CDR	295.6 a	275.7 ab	281.1 a	***284.1 A***
Cultivar means	***264.9 A***	***257.0 A***	***259.7 A***	

*CDR: Crosss double row (50*24 cm)   * significance at p<0.05 level*

Cob heights were influenced by plant height. Increasing cob heights are encountered with increasing plant heights. Cob heights of the experimental treatments are provided in Table 9. In terms of cob heights, cultivars, densities and cultivar x density interactions were all found to be significant. For cob heights of the cultivars, the greatest value (104.3 cm) was obtained from DKC 5783 cultivar and the lowest (81.6 cm) from KWS 6565 cultivar. In terms of on-row plant spacings, the greatest cob height (116.4 cm) was obtained from CDR and the lowest (78.9 cm) from 20 cm spacing. For interactions, the greatest value (123.3 cm) was obtained from CDR of Pionner 0537 cultivar and the lowest (62.1 cm) from 18 cm spacing of KWS 6565 cultivar. In terms of cob height, 12 cm spacing was remarkable. Plant, trying to increase plant height, also try to increase cob heights. The first cob height of the experimental treatments varied between 50.1-98.6 cm. Present findings on cob heights comply with the findings of previous studies (Ülger et *al.*, 1986; Gözübenli, 1997; Sezer and Yanbeyi, 1997; Uslu ve Karaaltın, 1999; Çokkızgın 2002). Increasing number of plants per unit area resulted in having greater cob heights. The first cob heights increased parallel to increasing plant heights.

Table 9 *Cultivar, Density and Cultivar x Density Interactions for Cob Height (cm)*

Density	***Cultivars***			
	Pionner 0537	**KWS 6565**	**DKC 5783**	***Density means***
12	104.2 ab	94.7 c	115.9 a	***104.9 AB***
14	98.7 bc	89.0 cd	103.1 ab	***96.9 BC***
16	100.8 bc	86.7 cd	103.0 abc	***96.8 BCD***
18	87.8 cd	62.1 e	101.8 abc	***83.9 CD***
20	84.8 d	94.764.1	87.8 cd	***78.9 D***
22	91.1 cd	69.3 e	98.1 bc	***86.2 CD***
CDR	123.3 a	105.4 ab	120.6 a	***116.4 A***
Cultivar means	***98.7 A***	***81.6 B***	***104.3 A***	

*CDR: Crosss double row (50*24 cm)   * significance at p<0.05 level*

Leaf growth and development designate plant growth and development. Position of leaves, the primary source of photosynthesis, may influence photosynthetic activity. Photosynthesis ability decreases in leaves developing perpendicular to the light and increases in leaves developing horizontal to light. In present study, leaf angles were tried to be identified. Resultant values are provided in Table

10. In terms of leaf angles, on-row plant spacings were not found to be significant, but cultivar x density interactions were found to be significant. The greatest leaf angle (61.51 °C) was observed in Pionner 0537 cultivar and the lowest (55.41 °C) in KWS 6565 cultivar. Therefore, it could be stated that KWS 6565 cultivar had less photosynthesis potential than the other two cultivars. For on-row plant spacings, the greatest leaf angle (63.4 °C) was obtained from CDR and the lowest value (54.9 °C) was obtained from 18 cm spacing. Similar findings were also reported by Sağlamtimur et al. (1989) and Swason and Zuber (1996). Supporting present findings, Saruhan and Şireli (2005) and Bahadur et al. (1999) reported decreasing number of leaves with increasing plant densities. Decrease in number of leaves then changed leaf angles based on plant density and solar radiation. Contrary to present findings, Emeklier and Kün (1988) reported increasing number of leaves with increasing plant densities. Such differences were attributed to genotypes and ecological conditions effective throughout the growing season.

Table 10 *Cultivar, Density and Cultivar x Density Interactions for Leaf Angle*

Density	***Cultivars***			
	Pionner 0537	**KWS 6565**	**DKC 5783**	***Density means***
12	62.3 a	55.7 ab	59.8 ab	***59.26 A***
14	61.3 a	55.1 b	62.3 a	***59.57 A***
16	62.1 a	55.8 ab	59.8 ab	***59.23 A***
18	60.8 a	54.9 b	61.6 a	***59.10 A***
20	60.8 a	55.1 b	62.1 a	***59.33 A***
22	59.8 ab	55.0 b	61.6 a	***58.80 A***
CDR	63.4 a	56.5 ab	60.7 a	***60.21 A***
Cultivar means	**61.51 A**	**55.41 B**	**61.13 A**	

CDR: Crosss double row (50*24 cm) * significance at p<0.05 level

In terms of irrigation water use efficiencies, cultivars were not found to be significant, but on-row plant spacings and cultivar x spacing interactions were found to be significant. Irrigation water efficiencies of the cultivars were quite close to each other. The greatest value (2.30 kg/da/mm) was obtained from KWS 6565 cultivar and the lowest (2.27 kg/da/mm) from Pionner 0537 cultivar. In terms of on-row plant spacings, the greatest value (2.87 kg/da/mm) was obtained from CDR and the lowest (1.63 kg/da/mm) from 22 cm spacing (Table 11). On-row plant spacings slightly influenced irrigation water efficiencies. Since irrigation water efficiency is directly related to physiology of the cultivars, it could be stated that on-row plant spacings had limited effects on physiological processes. Considering the interactions, the greatest value (2.9 kg/da/mm) was observed in Pionner 0537 and DKC 5783 cultivars and the lowest value (1.6 kg/da/mm) was observed in 22 cm spacing of the same cultivars. Caldwell et al. (1994) reported water consumption of drip-irrigated maize plants as between 746–801 mm, Uzunoğlu (1991) reported the same values as between 440–809 mm.

There were significant negative correlations between yield and kernel weight per cob (*r*=-0,464**) and between yield and stem diameter (*r*=-587**). There were significant positive correlations between yield and plant height (*r=0*,332**) and between yield and cob height (*r*=0,609**). However, the correlations between thousand-kernel weight and kernel weight per cob were quite remarkable. Thousand-kernel weight and kernel weight per cob had significant negative correlations with irrigation water use efficiencies. In other words, decreasing kernel yields and weights were observed with increasing irrigation water use efficiencies. As expected, there were significant positive correlations between plant height and cob height (*r*=0,569**).

Table 11 *Cultivar, Density and Cultivar x Density İnteractions for Irrigation Water Use Efficiency (IWUE)*

Density	*Cultivars*			
	Pionner 0537	**KWS 6565**	**DKC 5783**	***Density means***
12	2.7 a	2.7 a	2.6 ab	***2.67 AB***
14	2.7 a	2.6 ab	2.6 ab	***2.59 B***
16	2.2 bc	2.4 b	2.4 b	***2.33 C***
18	2.0 bc	2.0 bc	2.0 bc	***2.00 D***
20	1.8 bcd	1.9 bc	1.9 bc	***1.87 D***
22	1.6 cd	1.7 bcd	1.6 cd	***1.63 E***
CDR	2.9 a	2.8 a	2.9 a	***2.87 A***
Cultivar means	***2.27 A***	***2.30 A***	***2.29 A***	

*CDR: Crosss double row (50*24 cm)*

CONCLUSION

In Turkey, maize farming is practiced in irrigated lands. In arid and semi-arid climate zones, insufficient precipitation or irregular distribution of the precipitations may put maize farming into trouble. Therefore, irrigation designate the yields in maize farming. Despite increasing significance of irrigation, water resources used in agriculture are continuously decreasing, but demands for irrigation water in arid and semi-arid regions are also increasing. Irrigation water use efficiencies thus should be improved for high yields. In this sense, the balance between plant water consumption and dry matter production should be well-established in irrigation practices.

Besides sufficient supply of water requirement, efficient use of water is also a significant issue in maize farming. Therefore, efficient water using cultivars should be selected and agronomic practices facilitating efficient water use should be performed. The primary objective of the present study was to identify the best cultivar and on-row plant spacing for efficient water use in maize farming. Present findings revealed that cultivars did not exhibit significant differences in irrigation water use efficiencies, but significant differences were observed in irrigation water use efficiencies at different on-row plant spacings. The most appropriate on-row plant spacing was identified as CDR. However, method of irrigation is more effective than irrigation water quantity in identification of irrigation water use efficiency. Therefore, irrigation water use efficiencies of flooding, sprinkler or drip irrigation methods should be taken into consideration.

As a result of the study, it was determined that different plant densities affected grain yield and some agronomic traits in maize. It was observed that grain yield increased with increasing plant density but stem diameter decreased. It was observed that although the yield was high especially in double row cross sowing, the stem diameter value was very low. This situation causes lodging and crop losses especially in Konya region where strong winds are observed at harvest time.

From this point of view, row spacings of 14 and 16 cm were found to be more suitable considering both yield and stem diameter. At the same time, it was observed that the plant density was also affected by the yield according to the Cultivars, and it was seen that upright-leaved Cultivars were more suitable for dense planting

Author Contribution

Research Design (CRediT 1) Erdal GÖNÜLAL (%70) – Çetin PALTA (%30)

Data Collecting (CRediT 2) Erdal GÖNÜLAL (%60) – Çetin PALTA (%40)
Research - Data Analysis - Validation (CRediT 3-4-6-11) Erdal GÖNÜLAL (%50) – Çetin PALTA (%50)
Writing the Article (CRediT 12-13) Erdal GÖNÜLAL (%65) – Çetin PALTA (%35)
Editing and Development of the Text (CRediT 14) Erdal GÖNÜLAL (%80) – Çetin PALTA (%20)

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