***Pak. J. Bot.*, 54(2): DOI: http://dx.doi.org/10.30848/PJB2022-2(18)**

PLANTING DENSITIES IMPART VARIANCE IMPACT ON KERNEL PROPERTIES AND SOME QUALITY PARAMETERS FOR SOME MAIZE (*ZEA MAYS* L.) HYBRIDS

ÖMER KONUSKAN[1*], DILSAT BOZDOGAN KONUSKAN[2], CELALEDDIN BARUTÇULAR[3], NIZAMETTIN TURAN[4] AND AYMAN ELSABAGH[4,5*]

[1]Department of Field Crops, Faculty of Agriculture, Mustafa Kemal University, Turkey
[2]Depertment of Food Engineering, Faculty of Agriculture, Mustafa Kemal University, Turkey
[3]Department of Field Crops, Faculty of Agriculture, University of Çukurova, Turkey
[4]Depertmant of Field Crops, Faculty of Agriculture, Siirt University, Turkey
[5]Department of Agronomy, Faculty of Agriculture, Kafrelsheikh University, 33156 Kafrelsheikh, Egypt
**Corresponding author's email: okonuskan@mku.edu.tr $ ayman.elsabagh@agr.kfs.edu.eg*

Abstract

Climate change scenario has revitalized necessity to optimize agronomic management practices for boosting cereals productivity and nutritional quality. To observe the growth and quality attribute of maize hybrids under various planting densities and in order to sort out the most suitable plant population, a field experiment was conducted at the Research Farm, Faculty of Agriculture, Mustafa Kemal University during 2018. Six maize hybrids viz. DKC 6589, Carella, Pioneer 1921, 70 May 82, Cadiz and Bolson were grown using five planting densities (9, 10, 11, 12, and 13 plants m^2). The experiment was laid out in split plot arrangement with three replications. Maize hybrids and planting densitides were placed in main plots and sub plots, respectively. Growth characteristics like ear length, weight and diameter, and quality trauts like protein, stach and oil content in grains were determined as response variables. The results revealed that increasing plant densities gradually reduced the growth paramters including ear length, weight and diamter. While, quality traits such as starch and oil contents of basal, middle and tip kernels were increased with the increase in plant densities, but the protein ratio was decreased. The genotypes mean values indicated that 70 May 82 and Carella remained superior for ear length, weight and ear dimater respectively. In contrast, Pioneer 1921 and Bolson outformed other hybrids as far as starch and oil contents were concerned.

Key words: Grain quality, Grain yield, Maize, Plant density.

Introduction

Changing climate scenario has necessitated reinvetigating production technology packages of cereal crops to ensure nutrtional security of rising population (EL Sabagh *et al*., 2019; Saboor *et al*., 2021). Global food insecurity has emergd as one of the most serious issues, while improper crop management coupled with low yielding crop varieties are contributing to low yields and slicing of econmic turn outs (Iqbal *et al*., 2018; Maqsood *et al*., 2020). Moreover, high population growth is putting pressure to increase farm outputs for ensuring food security to meet future needs (FAO, 2015). Among cereals, maize (*Zea mays* L.) occupies pivotal position globally due to having a wide range of uses on commercial and subsistence levels (Iqbal *et al*., 2017; EL Sabagh *et al*., 2020; Wasaya *et al*., 2021). It ranks first among cereal crops by occupying 24% of the farmlands worldwide (Okweche *et al*., 2013; IPBO, 2017). Suboptimal agronomic management practices and low yielding cultivars are the leading causes of lower yield and nutrtional value of maize which have compromised the economic security of growers and nutrtional security of populace (Iqbal *et al*., 2018; Molla, *et al*., 2019; Ghosh *et al*,. 2020). Therefore, best agronomic practices need to be ivestigated keeping in view the pedo-climatic conditions along with the use of high yielding modern crop cultivars having higher yield potential (Sariyev *et al*., 2020; Ahmad *et al*., 2021). Among agronomic practices, optimum plant desity imparts a significant influence on the maize productivity (Jia *et al*., 2018; Haarhoff & Swanepoel, 2020). Recently, it has been reported that planting density was a crucial contributor and biologically viable strategy for improving maize yield (Konuskan & Gozubenli, 2001; Iqbal *et al*., 2019, 2019a; Konuskan & Kılınc, 2019; Wei *et al*., 2019). Maize grain yield is the product of the number of plants per hectare, kernels per plant, and kernel weight which are primarily influenced by the seeding rates (Bernhard & Below, 2020).

Along side planting patterns, maize grain yield has been attributed to superior genetic potential which ensures utilization of farm resources with greater efficacy (Duvick, 2005). Maize genotypes interact with crop management practices in producing yield, and hence, understanding the dynamics of this intraction will provide the opportunity to maximize yield potential of a hybrid through optimization of agricultural management system (Iqbal *et al*., 2018; Mastrodomenico *et al*., 2018). Planting patterns, such as narrow spacing (Gozubenli *et al*., 2003), wide–narrow rows (Gozubeli *et al*,. 2004) have been developed for maize to achieve higher grain yields under Mediterenean conditions. Maize yield also depends on the ability of hybrids to utilize resources more efficiently when grown under greater plant densities (Tollenaar & Lee, 2002; Iqbal *et al*., 2017a). The increase in plant density needs to be optimized with respect to particualr crop variety as different cultivar respond differently to spatial arrangements (Ruffo *et al*., 2015; Iqbal *et al*., 2018a). There is a general positive trend between higher plant populations and higher yields that has been observed over the past 60 years (USDA-NASS, 2017). In maize, planting density has important effects on the dry matter partitioning between vegetative and reproductive organs (Rossini *et al*., 2012). Breeding efforts have already been made to select hybrids that possess characteristics associated with tolerance to higher plant populations such as reduction in plant height and ear length, decrease in lodging potential, increase in more upright leaves, and decrease in tassel size.

However, considerable research gap exists pertainingt to maize hybrids response to different planting densities (Duvick *et al.*, 2004; Bernhard & Below, 2020), especially under Mediterrenean conditions. It was hypothesized that maize hybrids vary in their potential for growth and nutrtional quality, and thus may respond differently to varing planting densities. Thefore, the study was conducted to optimize planting density for maize hybrids leading to sort out the superior hybrid for boosting maize productivity and nutrtional quality.

Materıals and Methods

Location and growing conditions: The experiments were conducted at the Research Station of Mustafa Kemal University, Hatay, located at 36°15' N and 36°30' E in the Eastern Mediterranean region of Turkey during 2018. The soil of the experimental site has developed from alluvial deposits of river terraces, and is characterized to be typical for the Eastern Mediterranean region of Turkey, having relatively high clay content with the predominant clay minerals smectite and kaolinite. The soil of experimental plots was a clay silt loam with pH of 7.12, having 1.93% organic matter and 0.51 cm^3 of water holding capacity, and low in available phosphosus (7.41 kg/ha^{-1}).

Fertilizer N was applied as urea (240 kg N ha^{-1}) along with K_2O and P_2O_5 (80 kg ha^{-1} each). Both P and K containing fertilizers were applied at planting, while half of urea was applied at planting as a band close to the seed with a combine drill, and the other half was added by broadcasting when the plants were about 50 cm high. Plants were irrigated periodically as needed about every 10-15 days to eliminate any growth restrictions due to water deficit condition. Grain yield (adjusted to 15% moisture), and other treits were determined in the centre two rows of each sub-plot. Mean temperature and precipitation in the growing season are presented in (Table 1).

Experimental design and treatments: Field study was arranged as a split plot arrangement with three replications. Main plots contained maize hybrids (DKC 6589, Carella, Pioneer 1921, 70 May 82, Cadiz and Bolson), and sub-plots had twin row densities of 9, 10, 11, 12, 13, plants m^{-2}. Twin rows were 20 cm apart while 55 cm was the distance between row pairs. The center two rows of each plot were harvested by hand at maturity to determine ear and kernel quality. Seeds of maize hybrids were sown in May 2018 by using a combine drill. All the agronomic management practices except those under study were uniformly employed to all treatments plots in all replications.

Sampling and data collection: Ears from each genotype were harvested by hand. Seed from each genotype was separated into three groups (top, middile and buttom) on the basis of position on kernel. At harvesting time, data pertaining to experimental variables were collected by using standard procedures.

Grain quality analysis: Protein, starch, and oil contents were determined using Perten DA 7250 NIR Spectrometer (Near Infrared Reflectometer).

Statistical analysis

All collected data were analysed by employing analyses of variance (ANOVA) as suggested by Gomez & Gomez (1984). Significant means were separated by the Least Significant Difference (LSD) test at the 0.05 significance level ($p \leq 0.05$). The estimation of correlation for traits under study was calculated by MSTAT-computer software package.

Result and Dıscussıon

The statistical analysis of yield attributes including ear length, ear weigth and ear diameter depicted significance of cultivars (C) and density (D) and their interaction effects (Table 2).

Ear length (cm)*:* The ear length of maize cultivars was significantly influenced by planting densities as DKC 6589 showed the longest ear length (20.0 cm) under the planting density of 9 plant m^{-2}, which was statistically identical to 70 May 82 cultivar under planting density of 10 plant m^{-2}(Table 3). Maize cultivar Cardiz recorded the minimum ear length especially unde the planting density of 13 plants m^{-2}. Overall, lower plant density promoted higher ear lenght for all maize cultivars in this study. Previous rsearch finding also reported significant variations among maize genotypes in terms of yield attributes depending on their gentic potential and crop managment practices especially the planting densities (Szymanek *et al.*, 2012). The use of high populations heightens interplant competition for light, water and nutrients which hamper maize growth and reproductive organs development (Iqbal *et al.*, 2019; Thapa *et al.*, 2020). However, it has been infered that this may be detrimental to grain yield because it stimulates apical dominance, induces barrenness, and ultimately decreases the number of ears per plant and kernels set per ear (Sangoı & Salvador, 1998).

Ear weigth (g): Ear weigth was significantly differed by the interaction effect of plant density and cultivars (Table 4). The results rvealed that the cultivar 70 May 82 produced the highest ear weight under all planting densities especially 9 plants m^{-2} which was followed by Carella, Pioneer 1921, Bolson and DKC 6589. The most inferior performance in terms of ear weight was recorded for Bolson under all planting densities. These findings highlighted the importance of the plant population and high yielding genotypes for sustainable production of nutritionally rich maize grains (Wei *et al.*, 2017). These findings are also in agreement with those of Iqbal *et al.*, (2019) and Sher *et al.*, (2017), where high plant population imparted negative influence on the yield components of maize by reducing the number of ears $plant^{-1}$, kernels ear^{-1} and kernel weight (Gozubeli *et al.*, 2003). Moreover, higher plant population was reported to increase plant sterility and the interval between male and female blooms, and decreased the number of grains ear^{-1} (Liu *et al.*, 2004).

Table 1. Climatological conditions during the present study and long years.

Locations	Mean heat (ºC)		Precipitation (mm)		Humidity (%)	
	1940-2018	2018	1940-2018	2018	1940-2018	2018
May	21.2	23.8	14.2	11.8	63.1	61.2
June	24.8	26.5	1.5	16.4	63.2	62.2
July	27.1	30.1	0.1	0	64.0	49.6
August	28.8	29.3	0.1	0	63.2	61.3
September	26.4	28.4	9.9	0	61.0	57.1
October	21.4	22.7	29.5	24.6	59.2	62.8

Table 2. Analysis of variance (ANOVA) for ear paremeters of maize hybrids sown uner varying planting densities.

SOV	D.F.	F values		
		EL	EW	ED
Replication	2	2.207ns	4.49ns	0.77ns
Cultivars (C)	5	210.79**	16.42**	105.7**
Density (D)	4	94.11**	55.80**	34.03**
C X D	20	5.20**	4.16**	2.76**
Total	89			
CV (%)		2.63	6.49	1.74

SOV: Source of varions, DF: Degrees of freedom, ns: not significant, CV: Coefficient of variation, EL: Ear length, EW: Ear weigth, ED: Ear diameter; *: Ssignificant at $p<0.05$ level, **: Significant at $p<0.01$ level

Ear diameter: Significant variation in ear diameter of maize hybrids was caused by the interaction effect of plant densities and cultivars (Table 5). However, the highest ear diameter was obtained from Carella cultivar sown under planting densities of 9 and 10 plants m^{-2}.

Maize cultivar 70 May 82 remained inferior to other cultivars under all planting densities as far as ear dimater was concerned. It might be correlated to prvious findings whereby planting density remained more effective compard to hybrid type in determining the growth and yield attributes of maize (Iqbal *et al.*, 2019a). Ear diameter decreased with increasing plant densities (Gozubenli *et al.*, 2004; Fan *et al.*, 2020). Moreover, planting density was reported to influence the accumulation of carbohydrates, and thus influenced the yield attributes of maize (Lee & Tollenaar, 2007).

Nutrtional quality : The statistical analysis of rcorded data for kernels (basal, middle and tip) protein, starch and oil contents exhibited significant effect of cultivars, planting density and their interactions (Table 6), which are in agreement with the conclusions of Bänziger & Cooper (2001), and Haarhoff & Swanepoel (2020).

Table 3. Effects of plant densities on the ear length (cm) of maize hybrids.

Plant/m^2	Cultivars						Density mean
	DKC 6589	Carella	Pioneer 1921	70 May 82	Cadiz	Bolson	
9	20.0 a	18.2 d-g	18.2 d-g	19.2 bc	21.2 a	17.5 g-ı	**18.1 x**
10	18.8b-d	18.8 b-d	18.4 d-f	19.3 bc	15.7 mn	17.0 ı-k	**18.0 x**
11	17.7 f-ı	16.7 jk	18.4 d-f	19.2 bc	15.9 l-n	16.3 k-m	**17.3 y**
12	18.3 d-f	16.3 k-m	17.4 h-j	18.5 c-e	13.8 p	15.9 l-n	**16.7 z**
13	16.5 kl	15.7 mn	14.9 o	17.9 e-h	13.5 p	14.9 o	**15.6 t**
Genotypes mean	**18.3 B**	**17.1D**	**17.5 C**	**18.8 A**	**14.8 F**	**16.3 E**	
LSD	genotypes: 0.31, densities: 0.30, genotypes-densities interaction; 0.74						

A-C for each parameters different letters for the same cultivars indicate statically signifacant differences ($p≤0.05$) between cultivars, a-c for each parameters different letters for the cultivars densitty interaction indicate statically signifacant differences ($p≤0.05$) between cultivars density interaction, and x-y for each parameters different letters for the same density indicate statically signifacant differences ($p≤0.05$) between density

Table 4. Effects of plant densities on the ear weight (g) of maize hybrids.

Plant/m^2	Cultivars						Density mean
	DKC 6589	Carella	Pioneer 1921	70 May 82	Cadiz	Bolson	
9	171.6 a-f	195.4 a-d	172.7 a-f	203.3 a	159.7 d-h	198.3 a-c	183.5 x
10	156.6 e-h	203.6 a	173.0 a-f	189.0 a-e	150.5 f-ı	200.2 ab	178.8 xy
11	156.1 e-h	164.2 b-g	176.6 a-f	195.5 a-d	156.1 e-h	183.3 a-f	172.0 xy
12	167.9 a-g	159.3 d-h	172.1 a-f	179.2 a-f	156.8 e-h	155.8 e-h	165.2 y
13	127.7 h-j	131.7 g-j	115.8 ıj	171.1 a-f	100.5 j	163.8 c-h	135.1 z
Genotypes mean	156.0 DE	170.8 BC	162.0 CD	187.6 A	144.7 E	180.3 AB	
LSD	genotypes: 12.33, density: 14.8, genotypes-densities interaction: 36.31						

A-C for each parameters different letters for the same cultivars indicate statically signifacant differences ($p≤0.05$) between cultivars, a-c for each parameters different letters for the cultivars densitty interaction indicate statically signifacant differences ($p≤0.05$) between cultivars density interaction x-y for each parameters different letters for the same density indicate statically signifacant differences ($p≤0.05$) between density

Table 5. Effects of plant densities on the ear diameter (mm) of maize hybrids.

Plant/m^2	Cultivars						Density mean
	DKC 6589	Carella	Pioneer 1921	70 May 82	Cadiz	Bolson	
9	42.03 kl	48.04 a	45.55 b-e	43.66 h-j	46.57 bc	44.81 e-h	45.11 x
10	41.43 l	48.98 a	45.37 c-g	43.60 h-j	45.65 b-e	45.23 d-g	45.05 x
11	42.03 kl	46.27 b-d	45.27 d-g	43.01 ı-k	45.47 b-f	44.25 f-ı	44.38 y
12	41.36 l	46.67 b	45.21 d-g	42.06 kl	45.53b-e	43.47 ıj	44.05 y
13	39.49 m	44.81 e-h	41.97 kl	42.07 kl	42.48 j-l	44.18 g-ı	42.50 z
Genotypes mean	41.27 E	46.95 A	44.67 BC	42.88 D	45.15 B	44.39 C	
LSD	genotypes: 0.6, density: 0.51, genotypes-densities interaction: 1.3						

A-C for each parameters different letters for the same cultivars indicate statically signifacant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars densitty interaction indicate statically signifacant differences ($p \leq 0.05$) between cultivars density interaction, andx-y for each parameters different letters for the same density indicate statically signifacant differences ($p \leq 0.05$) between density

Table 6. Analysis of variance (ANOVA) for kernel characteristics.

SOV	d.f	F values								
		BKPR	BKSR	BKOR	MKPR	MKSR	MKOR	TKPR	TKSR	TKOR
Replication	2	2.32	0.19	5.0	21.53	1.29	3.32	0.34	19.54	3.6
Cultivars (C)	5	1608.6**	2866.7**	388.4**	3263.2**	5873.4**	261.86**	2294.45**	12121.5**	246.18**
Density (D)	4	46.89**	12.78**	15.11**	181.53**	290.16**	35.35**	151.94**	194.6**	49.00**
C X D	20	71.12**	179.9**	21.17**	122.35**	191.5**	18.42**	79.44**	240.45**	13.98**
Total	89									
CV (%)		0.87	0.13	1.6	0.78	0.1	1.76	0.81	0.1	1.89

*: significant at $p<0.05$, **: significant at $p<0.01$ levels, ns: not significant; CV: Coefficient of variation, BKPR: Basal kernel protein ratio, BKSR: Basal kernel starch ratio, BKOR: Basal kernel oil ratio, MKPR:Middle kernel protein ratio, MKSR: Middle kernel starch ratio, MKOR: Middle kernel oil ratio, TKPR; tip kernel protein ratio, TKSR: Tip kernel satarch ratio, TKOR; Tip kernel oil ratio

Table 7. Effects of plant density on protein content (%) of basal, middle and tip kernels of maize cultivars.

Plant densities	Cultivars						Densities
	DKC 6589	Carella	Pioneer 1921	70 May 82	Cadiz	Bolson	
plant/m^2	Basal kernels						
9	8.76 de	7.56 kl	7.36 m	8.76 de	7.20 n	9.00 ab	8.11 y
10	8.73 de	7.50 l	7.60 kl	8.83 cd	7.53 kl	7.56 kl	7.96 t
11	8.93 bc	7.50 l	7.97 h	9.06 a	7.77 ı	8.10 g	8.22 x
12	8.70 e	7.37 m	7.77 ı	8.47 f	7.73 ıj	7.73 ıj	7.96 t
13	8.83 cd	7.63 jk	7.77 ı	8.03gh	8.03 gh	7.77 ı	8.01 z
Mean	8.79 A	7.51 E	7.69 D	8.63 B	7.65 D	8.03 C	
LSD	genotypes;0.04, density; 0.05, genotypes density interaction; 0.12						
	Middle kernels						
9	8.27 fg	8.03 ı	7.33 op	8.87 c	7.47 mn	9.73 a	8.28 x
10	8.43 e	7.33 op	7.47 mn	9.37 b	7.47 mn	8.00 ı	8.01 y
11	8.70 d	7.63 kl	7.37 n-p	9.47 b	7.67 k	8.83 c	8.28 x
12	8.17 gh	7.27 p	7.57 k-m	8.67 d	7.67 k	8.07 hı	7.90 z
13	8.33 ef	7.53 lm	7.40 no	8.27 fg	7.87 j	7.87 j	7.88 z
Mean	8.38 C	7.56 E	7.42 F	8.93 A	7.63 D	8.50 B	
LSD	genotypes; 0.04, density;0.04, genotypes density interaction;0.1						
	Tip kernels						
9	8.73 f	8.27 h	7.77 no	9.13 d	8.07 jk	9.93 a	8.65 x
10	8.87 e	7.87 l-n	7.67 op	9.27 c	7.83 mn	8.70 f	8.37 y
11	9.57 b	8.23 hı	7.67 op	9.57 b	8.07 jk	8.97 e	8.68 x
12	9.17 cd	7.60 p	7.87 l-n	8.63 fg	7.93 lm	8.57 g	8.29 z
13	8.87 e	7.97 kl	7.93 lk	8.57 g	8.13 ıj	8.13 ıj	8.27 z
Mean	9.04 A	7.99 C	7.78 D	9.03 A	8.01 C	8.86 B	
LSD	genotypes; 0.04, density; 0.05, genotypes density interaction; 0.12						

A-C for each parameters different letters for the same cultivars indicate statically signifacant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars densitty interaction indicate statically signifacant differences ($p \leq 0.05$) between cultivars density interaction, and x-y for each parameters different letters for the same density indicate statically signifacant differences ($p \leq 0.05$) between density

Protein content: The protein content of maize cultivars was significantly influenced by planting densities (Table 7). Bolson cultivar with 9 plant m^{-2} produced the maximum protein content for basal, middel and tip kernels, while it decreased with increasing planting density. These results corrborate with previous reported findings where protein content of grain was signifiantly affected with agronomic managments practices and genotypes (Pixley & Bjarnason, 2002). However, our results are in corroborated with those with Widdicombe & Thelen (2002), who observed that the crude protein contents of forage maize decreased with increased plant density. On the other hand, JiWang *et al*., (2004) reported that crude protein contents increased with increased plant density. In general, there is a tendency of reduction of grain protein percentage due to elevated plant density in most studied genotypes (Al-Naggar *et al*., 2016).

Starch content: Starch content of maize cultivars was generally affected by varying plant populations (Table 8). The differences of plant densities of the cultivars were statistically significant as Pioneer 1921 cultivar under 9 plants m^{-2} density produced the maximum starch contenet, while it was followed by Bolson sown in 9 plants m^{-2}. Contrary to previous trend, all cultivars except Pioneer 1921 recorded higher strach content under increased plant densities. The increase in starch content as a result of increasing plant density was mainly due to the increase of grain yield, as starch content in maize grain changed very slightly and mostly remained non-significantly under varying planting densities (Al-Naggar *et al*., 2015). Similar findings has previously been reported by Awoniyi *et al*., (2020), who inferred that plant poulation was instrumental in determining the nutrional value of maize.

Oil content: The intractive effect of cultivar and planting densities remained significant as far as oil content of maize cultivars was concerned (Table 9). The Bolson cultivar under all planting densities produced the maximum oil content in basal, middle and tip kernels and it was followed by Cadiz and Carella cultivars. It has been established that high plant density intensifies interplant competition (especially for light, water and nutrients), which drastically affects the reproductive growth of maize leading to deterioration of grain quality (Simic *et al*., 2020). However, higher grain production under higher density could potentially overcome such negative impacts of competition, and thus leading to maximize of oil content on per unit basis (Al-Naggar *et al*., 2015b,c).

Table 8. Effects of plant density on starch content (%) of basal, middle and tip kernels of maize cultivars.

Plant densities	Cultivars						Densities Mean
	DKC 6589	Carella	Pioneer 1921	70 May 82	Cadiz	Bolson	
Plant/m^2	Basal kernels						
9	60.17 p	61.57 p	64.03 a	63.37 d	62.83 f	61.43 m	62.23 z
10	59.80 r	62.23 ij	63.47 cd	62.60 g	61.90 k	63.77 b	62.29 y
11	60.73 n	62.33 hi	63.17 e	62.40 h	62.13 j	63.43 d	62.37 x
12	60.03 q	62.23 ij	63.57 c	63.47 cd	62.23 ij	62.83 f	62.39 x
13	60.33 o	61.53 lm	63.57 c	63.87 b	61.47 lm	63.43 d	62.37 x
Genotypes mean	60.21 F	61.98 E	63.56 A	63.14 B	62.11 D	62.98 C	
LSD	genotypes:0.007, density: 0.005, genotypes-densities interaction: 0.13						
	Middle kernels						
9	61.43 q	61.03 r	64.23 bc	63.27 f	62.23 n	61.57 p	62.29 t
10	62.03 o	62.67 j	64.30 b	62.53 k	62.53 k	63.17 fg	62.87 y
11	62.27 mn	62.87 i	64.57 a	62.77 ij	62.43 kl	61.67 p	62.76 z
12	62.00 o	62.73 j	64.13 cd	63.03 h	62.47 kl	63.13 gh	62.92 x
13	61.63 p	62.17 n	64.03 d	63.90 e	62.37 lm	63.13 gh	62.87 x
Mean	61.87 F	62.29 E	64.25 A	63.10 B	62.41 D	62.53 C	
LSD	genotypes; 0.04, density; 0.04, genotypes density interaction; 0.1						
	Tip kernels						
9	62.00 op	61.40r	63.97 bc	62.17 l-n	62.07 no	61.73 q	62.22 y
10	61.93 p	62.47 jk	64.00 b	62.77 h	62.27 l	62.23 lm	62.61 x
11	60.73t	61.47 r	64.27 a	61.93 p	62.67 hi	62.40 k	62.24 y
12	60.57u	63.17 f	63.87 c	63.03 g	62.47 jk	62.57 ij	62.61 x
13	60.97s	62.07 no	63.73 d	63.50 e	62.13 mn	63.03 g	62.57 x
Mean	61.24 F	62.11 E	63.97 A	62.68 B	62.32 D	62.39 C	
LSD	genotypes: 0.02, density: 0.04, genotypes-densities interaction: 0.1						

A-C for each parameters different letters for the same cultivars indicate statically signifacant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars densitty interaction indicate statically signifacant differences ($p \leq 0.05$) between cultivars density interaction, andx-y for each parameters different letters for the same density indicate statically signifacant differences ($p \leq 0.05$) between density

Table 9. Effects of plant density on oil content (%)of basal, middle and tip kernels of maize cultivars

Plant densities	Cultivars						Densities Mean
	DKC 6589	Carella	Pioneer 1921	70 May 82	Cadiz	Bolson	
Plant/m^2	Basal kernels						
9	3.83 c-f	3.87 c-e	3.87 c-e	3.27 ıj	4.10a-c	4.27 ab	3.87 y
10	3.30 h-j	4.13 a-c	3.77 d-f	3.23 j	4.40 a	4.27 ab	3.85 yz
11	3.57 e-ı	3.83 c-f	3.67 e-g	3.67 e-g	4.07 b-d	4.10 b-c	3.82 yz
12	3.67 e-g	4.26 ab	3.67 e-g	3.57 e-ı	4.07 b-d	4.37 ab	3.93 x
13	5.53 f-j	3.87 c-e	3.60 e-h	3.37g-j	4.07 b-d	4.27 ab	3.78 y
Genotypes mean	3.58 E	3.99 C	3.71 D	3.42 F	4.14 B	4.25 A	
LSD	genotypes: 0.05, densities: 0.04, genotypes-densities interaction: 0.3						
	Middle kernels						
9	4.00 e	4.00 e	3.77 fg	3.47 ıj	4.10 c-e	4.03 de	3.89 y
10	3.87 f	3.87 f	3.77 fg	3.67 gh	4.17 bc	4.17 bc	3.92 y
11	3.43 jk	3.67 gh	3.77 fg	3.33 k	4.03 de	4.47 a	3.78 z
12	3.67 gh	3.77 fg	3.77 fg	3.47 jk	4.07 c-e	3.87 f	3.77 z
13	4.17 bc	4.23 b	3.80 f	3.57 hı	4.07 c-e	4.13b-d	3.99 x
Mean	3.83 D	3.91 C	3.77 E	3.50 F	4.09 B	4.13 A	
LSD	genotypes: 0.04, densities: 0.04, genotypes-densities interaction: 0.1						
	Tip kernels						
9	3.07 k	3.17 jk	3.47 fg	3.33 hı	3.77 c	3.63 de	3.40 t
10	3.27 ıj	3.47 fg	3.47 fg	3.33 hı	4.10 a	4.03 ab	3.61 y
11	3.17 jk	3.53 e-g	3.47 fg	3.47 fg	3.70 cd	3.73 cd	3.51 z
12	3.43 gh	3.53 eg	3.43 gh	3.46 fg	4.03 ab	3.77 c	3.61 y
13	3.80 c	3.57 ef	3.47 fg	3.53 eg	3.97 b	3.77 c	3.68 x
Mean	3.35 D	3.45 C	3.46 C	3.43 C	3.91 A	3.79 B	
LSD	genotypes: 0.04, densities: 0.04, genotypes-densitie interaction: 0.1						

A-C for each parameters different letters for the same cultivars indicate statically signifacant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars densitty interaction indicate statically signifacant differences ($p \leq 0.05$) between cultivars density interaction, and x-y for each parameters different letters for the same density indicate statically signifacant differences ($p \leq 0.05$) between density

Conclusion

It might be inferred from the findings that maize cultivars respond differently to planting densities in terms of yield attributes and nutrtional quality of kernels. Overall, yield attributes such as ear length, ear weight and ear diamters were maximized under low planting densities (9 plants m^{-2}) as compared to higher plant densities, which might intensified intra-species competiton leading to reduction in yield attributes. In contradiction, nutrtional quality parameters such as starch and oil contents of maize hybrids were improved under higher planting densities. Thes increments might be attributed to higher grain production under greater planting densities as quality parameters under study exhibited non-significant increment on percentage bases. The genotypes mean values indicated that 70 May 82 and Carella remained superior for ear length, weight and ear dimater respectively. In contrast, Pioneer 1921 and Bolson outformed other cultivars as far as starch and oil contents were concerned so might be recommended for geenral adoption in Mediterrenean regions. However, there is a dire need to conduct further in-depth studies to optimize planting densities for maize cultivars under varying agro-ecological conditions.

Acknowledgments

The authors thank Prof. Dr. Md Shahidul Islam, Dr. Akbar Hossain and Dr. Muhammad aamirbIqbal for their contributions.

References

Ahmad, Z., A.W. Ejaz , Z.R. Muhammad, A.A. Muhammad, U. Muhammad, A. Hesham, B. Atif, B. Celaleddin, A.R. Muhammad, C. Fatih and A. EL Sabagh .2021. Foliar application of phosphorus enhances photosynthesis and biochemical characteristics of maize under drought stress. *Phyton-Inter J. Exp. Bot.*, 90(2): 503-514. https://doi.org /10.32604/phyton.2021.013588

Al-Naggar, A.M.M., M.M.M. Atta, M.A. Ahmed and A.S.M. Younis. 2016. Genotypic differences in grain protein, oil and starch content and yield of maize (*Zea mays* L.) under elevated plant density. *Asian Res. J. Agri.,* 1(1): 1-18.

Al-Naggar, A.M.M., R. Shabana, M.M.M. Atta and T.H. Al-Khalil. 2015b. Matching the optimum plant density and adequate n-rate with highdensity tolerant genotype for maxmizing maize (*Zea mays* L.) crop yield. *J. Agri. Eco. Res*., 2(4): 237-253.

Al-Naggar, A.M.M., R. Shabana, M.M.M. Atta and T.H. Al-Khalil. 2015c. Maize response to elevated plant density combined with lowered Nfertilizer rate is genotype-dependent. *Crop J*., 3: 96-109.

Awoniyi, O., F. Takim, G. Olaoye, P. Olorunmaiye and A.I. Afe. 2020. Assessment of plant population and time of ıntroduction of maize on the performance of garden egg - maize ıntercrop. *Turk. J. Agri. Food Sci. Technol*., 8(7): 1479-1484. https://doi.org/10.24925/turjaf.v8i7.1479-1484.3339.

Bänziger, M. and M. Cooper. 2001. Breeding for low input conditions and consequences for participatory plant breeding: Examples from tropical maize and wheat. *Euphytica*., 122: 503-519. doi:10.1023/A:1017510928038.

Bernhard, B.J. and F.E. Below. 2020. Plant population and row spacing effects on corn: Phenotypic traits of positive yield-responsive hybrids. *Agron. J*., 112: 1589-1600. https://doi.org/10.1002/agj2.20206.

Duvick, D.N. 2005. The contribution of breeding to yield advances in maize (*Zea mays* L.). In: (Ed.): Sparks, D.L. *Advances in Agronomy*. Vol. 86. Elsevier Academic Press, Inc., San Diego, CA. pp. 83-145. doi:10.1016/S0065-2113(05)86002-X.

Duvick, D.N., J.S.C. Smith and M. Cooper. 2004. Long-term selection in a commercial hybrid maize breeding program. *Plant Breed. Rev*., 24: 109-151.

EL Sabagh, A., A. Hossain and C. Barutçular. 2019. Effects of drought stress on the quality of major oilseed crops: implications and possible mitigation strategies- a review. *Appl. Ecol. Environ Res.*, 17: 4019-4043.

EL Sabagh, A., Hossain, A., M.A. Iqbal, C. Barutçular, M.S. Islam, F. Çiğ, M. Erman, O. Sytar, M. Brestic, A. Wasaya and T. Jabeen. 2020. Maize adaptability to heat stress under changing climate. In: *Plant Stress Physiology*. IntechOpen.

Fan, Y., Z. Wang and D. Liao. 2020. Uptake and utilization of nitrogen, phosphorus and potassium as related to yield advantage in maize-soybean intercropping under different row configurations. *Sci. Rep*., 10: 9504.

Ghosh, D., K. Brahmachari, M. Skalicky, A. Hossain, S. Sarkar, N.K. Dinda, A. Das, B. Pramanick, D. Moulick M. Brestic, M.A. Raza, C. Barutcular, S. Fahad, H. Saneoka and A. EL Sabagh. 2020. Nutrients Supplementation through Organic Manures Influence the Growth of Weeds and Maize Productivity. *Molecules*, 25(21): 4924. https://doi.org/10.3390/ molecules25214924.

Gozubenli, H., M. Kılınc, O. Sener and O. Konuskan. 2004. Effect of single and twin row planting on yield and yield components in maize. *Asian J. Plant Sci*., 3(2): 203-206.

Gozubenli, H., O. Sener, O. Konuskan and M. Kilinc. 2003. Effect of hybrid and plant density on grain yield and yield components of maize (*Zea mays*). *Ind. J. Agron*., 48: 203-205.

Haarhoff, S.J. and P.A. Swanepoel. 2020. Narrow rows and high maize plant population improve water use and grain yield under conservation agriculture. *Agron. J*., 112: 921-931.

Iqbal, A., M.A. Iqbal, A. Iqbal, Z. Aslam, M. Maqsood, Z. Ahmad, M.U. Farooq, G. Abbas and M. Faisal. 2017a. Boosting forage yield and quality of maize (*Zea mays* L.) with multi-species bacterial inoculation in Pakistan. *Phyton Int. J. Exp. Bot*., 86: 84-88.

Iqbal, M.A., A. Hamid, I. Hussain, M.H. Siddiqui, T. Ahmad, A. Khaliq and Z. Ahmad. 2019. Competitive indices in cereal and legume mixtures in a South Asian environment. *Agron. J*., 111(1): 242-249.

Iqbal, M.A., A. Hamid, T. Ahmad, I. Hussain, S. Ali, A. Ali and Z. Ahmad. 2019a. Forage sorghum-legumes intercropping: Effect on growth, yields, nutritional quality and economic returns. *Bragantia.,* 78(1): 82-95.

Iqbal, M.A., A. Iqbal and R.N. Abbas. 2018. Spatio-temporal reconciliation to lessen losses in yield and quality of forage soybean (*Glycine max* L.) in soybean-sorghum intercropping systems. *Bragantia*., 77(2): 283-291.

Iqbal, M.A., B.J. Bethune, A. Iqbal, R.N. Abbas, Z. Aslam, H.Z. Khan and B. Ahmad. 2017. Agro–botanical response of forage sorghum–soybean intercropping systems under atypical spatio–temporal pattern. *Pak. J. Bot*., 49: 987-994.

Iqbal, M.A., M.H. Siddiqui, S. Afzal, Z. Ahmad, Q. Maqsood and R.D. Khan. 2018a. Forage productivity of cowpea [*Vigna unguiculata* (L.) Walp] cultivars improves by optimization of spatial arrangements. *Rev. Mex. Cienc. Pec*., 9(2): 203-219.

Jia, Q., L. Sun, S. Ali, Y. Zhang, D. Liu and M. Kamran. 2018. Effect of planting density and pattern on maize yield and rainwater use efficiency in the Loess Plateau in China. *Agric. Water Manage*., 202: 19-32. doi: 10.1016/j. agwat. 2018.02.011.

Konuskan, O. and C. Kilinc. 2019. Effect of plant density on growth and grain yield of some hybrid corn (*Zea mays* L.) varieties under mediterranean environment. *Fres. Environ. Bull*., 28(4): 2795-2801.

Konuskan, O. and H. Gözübenli. 2001. Effect of plant density on grain yield and yield-related traits in some hybrid maize varieties grown as second-crop. *J. Field Crops*, 10(1-2): 50-57.

Lee, E.A. and M. Tollenaar. 2007. Physiological basis of successful breeding strategies for maize grain yield. *Crop Sci*., 47: S202-S215. doi: 10.2135/ cropsci2007.04.0010IPBS.

Liu, W., M. Tollenaar and G. Smith. 2004. Within row plant spacing variability does not affect corn yield. *Agron. J*., 96: 275-280.

Maqsood, Q., R.N. Abbas, M.A. Iqbal, S.K. Aydemir, A. İqbal and A. El Sabagh. 2020. Overviewing weed management practices to reduce weed seed bank and to increase maize yield. *Plant. Daninha*., 38: e20199716.

Mastrodomenico, A.T., J.W. Haegele, J.R. Seebauer and F.E. Below. 2018. Yield stability differs in commercial maize hybrids in response to changes in plant density, nitrogen fertility, and environment. *Crop Sci*., 58: 230-241.

Molla, M.S.H., S. Nakasathien, M.A. Ali, A.S.M.M.R. Khan, M.R. Alam, A. Hossain and A. El Sabagh. 2019. Influence of nitrogen application on dry biomass allocation and translocation in two maize varieties under short pre-anthesis and prolonged bracketing flowering periods of drought. *Archives Agron. & Soil Sci.,* 65(7): 928-944.

Ruffo, M.L., L.F. Gentry, A.S. Henninger, J.R. Seebauer and F.E. Below. 2015. Evaluating management factor contributions to reduce corn yield gaps. *Agron. J*., 107: 495-505. doi:10.2134/ agronj14.0355.

Saboor, A., M.A. Ali, N. Ahmed, M. Skalicky, S. Danish, S.Fahad, F. Hassan, M.M. Hassan, M. Brestic, A. EL Sabagh and R. Datta. 2021. Biofertilizer-based zinc application enhances maize growth, gas exchange attributes, and yield in zinc-deficient soil. *Agriculture*, 11: 310. https://doi.org/10.3390/agriculture11040310

Sangoı, L., M. Ender and A. Merotto Jr. 1998a. Redução do espaçamento entre linhas para cultivares de milho de ciclos contrastantes em duas épocas de semeadura. In: REUNIÃO ANUAL DO MILHO E SORGO, 1997. Erechim, RS. Anais. Erechim: COTREL/EMATER/FEPAGRO. pp. 26-30.

Sariyev, A., C. Barutcular, M. Acar, A. Hossain and A. El Sabagh. 2020. Sub-surface drip irrigation in associated with H 2 O 2 improved the productivity of maize under clay-rich soil of Adana, Turkey. *Phyton*., 89(3): 519.

Sher, A., A. Khan, L.G. Cai, M.I. Ahmad and U. Asharf. 2017. Response of maize grown under high plant density; performance, issues and management - A Critical Review. *Adv. Crop Sci. Tech*., 5: 275. doi: 10.4172/2329-8863.1000275.

Simic, M., V. Dragičevic, M. Babic, M. Brankov and M. Filipovic. 2020. Integrated effects of nitrogen form, row spacing, and herbicide treatment on maize. *Agron. J*., 112: 748-757.

Szymanek, M. 2012. Processing of sweet corn, trends in vital food and control engineering. (Ed.): Ayman Amer Eissa. Intech. Available at http://www.intechopen.com/books/trends-invital- food- and-control engineering/processing-of-sweet-corn., 2012.

Thapa, S., Q. Xue and B.A. Stewart. 2020. Alternative planting geometries reduce production risk in corn and sorghum in water-limited environments. *Agron. J.*, 112: 3322-3334.

Tollenaar, M. and E.A. Lee. 2002. Yield potential, yield stability and stress tolerance in maize. *Field Crops Res.*, 75: 161-169. doi:10.1016/S0378-4290(02)00024-2.

USDA-NASS (USDA-National Agricultural Statistical Service). (2017b). Corn. Plant Population. United States, 1960 to date. USDA-NASS, Washington, DC. Retrieved from https://quickstats.nass.usda.gov/results/8AA5AC5F-BE64-3483-A132-28849DB1DF0F

Wasaya, A., M. Affan, T. Ahmad Yasir, Atique-ur-Rehman, K. Mubeen, H.U. Rehman, M. Ali, F. Nawaz, A. Galal, M.A. Iqbal, M.S. Islam, El-Sharnouby, M.H.U. Rahman and A. EL Sabagh. 2021. Foliar potassium sulfate application improved photosynthetic characteristics, water relations and seedling growth of drought-stressed maize. Aitmosphere, 12, 663. https://doi.org/10.3390/atmos12060663.

Wei, S., X. Wang, G. Li, D. Jiang and S. Dong. 2019. Maize Canopy Apparent Photosynthesis and 13C-Photosynthate reallocation in response to different density and N rate combinations. *Front. Plant Sci.*, 10:1113. doi: 10.3389/fpls.2019.01113.

Wei, S., X. Wang, Q. Zhu, D. Jiang and S. Dong. 2017. Optimising yield and resource utilisation of summer maize under the conditions of increasing density and reducing nitrogen fertilization. *Sci. Nat.*, 104: 86. doi: 10.1007/s00114-017-1509.

(Received for publication 8 October 2020)