

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

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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 m²). The experiment was laid out in split plot arrangement with three replications. Maize hybrids and planting densities were placed in main plots and sub plots, respectively. Growth characteristics like ear length, weight and diameter, and quality traits like protein, starch and oil content in grains were determined as response variables. The results revealed that increasing plant densities gradually reduced the growth parameters including ear length, weight and diameter. 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 diameter respectively. In contrast, Pioneer 1921 and Bolson outperformed 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 reinvigorating production technology packages of cereal crops to ensure nutritional security of rising population (EL Sabagh *et al.*, 2019; Saboor *et al.*, 2021). Global food insecurity has emerged 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 economic 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 nutritional value of maize which have compromised the economic security of growers and nutritional security of populace (Iqbal *et al.*, 2018; Molla, *et al.*, 2019; Ghosh *et al.*, 2020). Therefore, best agronomic practices need to be investigated 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 density 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 & Kılınç, 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 interaction 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 Mediterranean 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 particular 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 pertaining to maize hybrids response to different planting densities (Duvick *et al.*, 2004; Bernhard & Below, 2020), especially under Mediterranean conditions. It was hypothesized that maize hybrids vary in their potential for growth and nutritional quality, and thus may respond differently to varying planting densities. Therefore, the study was conducted to optimize planting density for maize hybrids leading to sort out the superior hybrid for boosting maize productivity and nutritional quality.

Materials 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 cm³ of water holding capacity, and low in available phosphorus (7.41 kg/ha¹).

Fertilizer N was applied as urea (240 kg N ha⁻¹) along with K₂O and P₂O₅ (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 traits 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, middle and bottom) 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 Discussion

The statistical analysis of yield attributes including ear length, ear weight 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 under the planting density of 13 plants m⁻². Overall, lower plant density promoted higher ear length for all maize cultivars in this study. Previous research finding also reported significant variations among maize genotypes in terms of yield attributes depending on their genetic potential and crop management 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 inferred 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 (Sangoi & Salvador, 1998).

Ear weight (g): Ear weight was significantly differed by the interaction effect of plant density and cultivars (Table 4). The results revealed 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 (°C)		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 parameters of maize hybrids sown under 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 variations, DF: Degrees of freedom, ns: not significant, CV: Coefficient of variation, EL: Ear length, EW: Ear weight, ED: Ear diameter; *: Significant 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 diameter was concerned. It might be correlated to previous findings whereby planting density remained more effective compared 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).

Nutritional quality : The statistical analysis of recorded 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-1	18.1 x
10	18.8b-d	18.8 b-d	18.4 d-f	19.3 bc	15.7 mn	17.0 i-k	18.0 x
11	17.7 f-1	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 significant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars density interaction indicate statically significant differences ($p \leq 0.05$) between cultivars density interaction, and x-y for each parameters different letters for the same density indicate statically significant differences ($p \leq 0.05$) 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-1	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 ij	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 significant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars density interaction indicate statically significant differences ($p \leq 0.05$) between cultivars density interaction x-y for each parameters different letters for the same density indicate statically significant differences ($p \leq 0.05$) 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 i-k	45.47 b-f	44.25 f-1	44.38 y
12	41.36 l	46.67 b	45.21 d-g	42.06 kl	45.53b-e	43.47 ij	44.05 y
13	39.49 m	44.81 e-h	41.97 kl	42.07 kl	42.48 j-l	44.18 g-1	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 signfacant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars density interaction indicate statically signfacant differences ($p \leq 0.05$) between cultivars density interaction, andx-y for each parameters different letters for the same density indicate statically signfacant 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 plant/m ²	Cultivars						Densities
	DKC 6589	Carella	Pioneer 1921	70 May 82	Cadiz	Bolson	
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 i	8.10 g	8.22 x
12	8.70 e	7.37 m	7.77 i	8.47 f	7.73 ij	7.73 ij	7.96 t
13	8.83 cd	7.63 jk	7.77 i	8.03gh	8.03 gh	7.77 i	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 i	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 i	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 hi	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 hi	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 ij	8.13 ij	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 signfacant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars density interaction indicate statically signfacant differences ($p \leq 0.05$) between cultivars density interaction, and x-y for each parameters different letters for the same density indicate statically signfacant 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, middle and tip kernels, while it decreased with increasing planting density. These results corroborate with previous reported findings where protein content of grain was significantly affected with agronomic managements 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 content, while it was followed by Bolson sown in 9 plants m⁻². Contrary to previous trend, all cultivars

except Pioneer 1921 recorded higher starch 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 population was instrumental in determining the nutritional value of maize.

Oil content: The interactive 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/m²	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 significant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars density interaction indicate statically significant differences ($p \leq 0.05$) between cultivars density interaction, andx-y for each parameters different letters for the same density indicate statically significant 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/m²	Basal kernels						
9	3.83 c-f	3.87 c-e	3.87 c-e	3.27 ij	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-1	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-1	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 ij	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 hi	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 hi	3.77 c	3.63 de	3.40 t
10	3.27 ij	3.47 fg	3.47 fg	3.33 hi	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-densities interaction: 0.1						

A-C for each parameters different letters for the same cultivars indicate statically significant differences ($p \leq 0.05$) between cultivars, a-c for each parameters different letters for the cultivars density interaction indicate statically significant differences ($p \leq 0.05$) between cultivars density interaction, and x-y for each parameters different letters for the same density indicate statically significant 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 nutritional quality of kernels. Overall, yield attributes such as ear length, ear weight and ear diameters were maximized under low planting densities (9 plants m⁻²) as compared to higher plant densities, which might intensified intra-species competition leading to reduction in yield attributes. In contradiction, nutritional quality parameters such as starch and oil contents of maize hybrids were improved under higher planting densities. These 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 diameter respectively. In contrast, Pioneer 1921 and Bolson outperformed other cultivars as far as starch and oil contents were concerned so might be recommended for general adoption in Mediterranean 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.

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