Plant Production Science

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ESTIMATION OF HETEROSIS FOR GRAIN YIELD AND YIELD ATTRIBUTING TRAITS IN MAIZE UNDER THREE PLANTING DENSITIES AND TWO SOWING DATES

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Received: 29/11/2022 ; Accepted: 19/12/2022

ABSTRACT: Maize (*Zea mays* L.) is an important cereal crop due to its high forage and grain yield potential. The objective of this study was to assess mean performance and heterotic effects of 36 F_1 hybrids with 4 checks under three planting densities, 24,000, 32,000, and 40,000 plants fed^{-1} at optimal sowing date (April 10th) and late one (May 28th) in the middle Egypt. Significant differences were recorded for all studied traits among maize hybrids in the six environments. The 2nd sowing date (SD) had negatively affected on all maize hybrids for all traits. The high plant density (HPD) and medium (MPD) one caused an increase in days to 50% tasseling (later in maturity), plant height (taller plants), and grain yield per feddan (increased by 17.77% and 1.01% in the 1st SD, and 14.8% and 8.65% in the 2nd SD under HPD and MPD, respectively). While, ear length, ear diameter, number of rows per ear, number of kernels per plant, 100- kernel weight, and grain yield per plant were reduced under MPD and HPD. Grain yield varied from 16.6 to 44.89 ardab fed^{-1} in the 1st SD and varied from 11.55 to 35.40 ardab fed^{-1}. in the 2nd SD. The hybrid L8×L9 had the highest average grain yield overall environments (35.13 ardab fed^{-1}) followed by L1×L3, L1×L8, L3×L8, L3×L4, and L3×L5 (32.65, 32.65, 32.5, 32.49 and 32.34 ardab fed^{-1}, respectively). Negative and significant desirable standard heterosis over check variety Pioneer 32D99 were recorded in crosses (L1×L4), (L1×L8), (L6×L7) and (L4×L8) for days to 50% tasseling and crosses (L3×L8), (L3×L9), (L5×L8) (L6×L7), (L6×L8), (L6× L9), (L7×L9) and (L8×L9) for plant height under most environments. Positive and significant heterosis estimates were recorded in crosses (L4 × L7) and (L4 × L9) for ear length in 2nd SD; cross (L1×L6) for ear diameter; crosses (L3×L8) and (L4 × L8) for number of rows per ear under most environments; crosses (L2×L6), (L2 × L9), (L4 × L7), (L6 × L9) and (L8 × L9) for number of kernels per row under all environments; cross (L8 × L9) for 100- kernel under all environments in the 1st SD and NPD in the 2nd SD as well as grain yield under HPD, it showed positive values. The percent heterosis for grain yield varied from -65.02 to 7.28%. Grain yield had positive and significant associations with plant height (0.672**), ear length (0.341*), ear diameter (0.375*), number of rows per ear (0.596**), and number of kernels per row (0.486**).The aforementioned promising hybrids are recommended for further inclusion in the breeding program.

Key words: Heterosis, planting density, sowing dates, maize.

INTRODUCTION

Crops are is the main source of human food supply, and among them, grains are more important. In order to feed the growing world population, increasing crop yields is one of the main goals. Among cereals, maize (*Zea mays* L.) is an important crop in the world after wheat and rice because of its high grain and feed yield potential and it is produced countrywide in numerous environments. Maize is a staple food for many millions people in worldwide, it is the main energy source for animal feed, and also is used in industrially processed foods, and bioenergy-producing crop (**Katsenios *et al*., 2021**). In 2020, the global maize production was

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1162, 352, 997 tonnes (**FAOSTAT, 2021**), in Egypt, the total grain production was about 8 million tons from 1.5 million ha of land and it occupies a prominent position in the agricultural sector of Egypt, each part of maize plant is used and nothing of them goes to waste. The maize grain yield in average is the highest and rather than wheat and rice.

Correct sowing date can take full advantage of climatic factors such as temperature, humidity, day length, and adaptation of flowering time to the corresponding temperature (**Sawan, 2018**). The reduced grain yield in late-sown maize was due to the coincidence of the grain-filling period with autumn cold and was also related to insufficient heat input during the growing season (**Golla *et al*., 2018; Rabbani and Safdary, 2021**). Due to the limitation of arable land area, most researchers in recent years have focused on increasing the yield per unit area. Yield per unit area can usually be increased through breeding and agricultural management. The most important agricultural management practices are the selection of suitable hybrids, optimal planting density, optimal fertilizer application rate, correct sowing date, and irrigation time; therefore, improving maize yield requires sufficient information to understand the impact of these factors on yield and other plant traits. Management methods to increase maize yield, including the use of hybrids and proper planting dates, have been studied a lot (**Rabbani and Safdary, 2021**).

Determining optimal maize planting density (number of plants per unit area) is a critical management decision for crop production (**Assefa *et al.*, 2016**). Planting density (PD) is among the 4 grain yield (GY) of maize components (ear number/ plant, grain number / ear, and grain weight), it is exerting a large influence on attainable maize yield (**Assefa *et al*., 2016**). Modern maize hybrids are more cost-effective in using water and nutrients, therefore are tolerant to improved planting populations. Thus, the improved grain yield/ unit area of new maize hybrids was due to the increased ideal maize planting density rather than the increased grain yield/ plant. Consequently, **Madić *et al.* (2017**) reported that the increase in maize grain yield of most new hybrids comes from increased planting densities. Accordingly, a high planting population has been usually used to increase GY in maize (**Sher *et al*., 2017**). Contrariwise, extra higher planting density decreases the GY of maize because it may lead to the increased pollen to the silking interval, the higher risk lodging, and the following barrenness. Thus, the future visions are morphological and physiological basis controlling barren and stalk lodging resistance (**Sher *et al*., 2017**).

Heterosis is a prerequisite for developing a good economically viable maize variety. Information on the heterotic patterns among maize germplasm is essential in maximizing the effectiveness of hybrid development (**Beck *et al*., 1990**). The phenomenon of heterosis has been exploited extensively in crop breeding, leading to significant increase in yield. Heterosis is used to describe this phenomenon when the parents are taken from different populations of the same species; hybrid vigor is used when the parents are taken from different species (**Charlesworth and Willis, 2009**).

The relationship between any two traits plays an important role in breeding programs. Several investigators showed close association between maize grain yield and its relevant traits (**Nzuve *et al*., 2014; Ali, 2016; Sardar *et a*l., 2019**).

The purpose of this experiment was to evaluate the effects of two planting dates and three different planting densities on grain yield and yield components of 36 F_1 hybrids and 4 control cultivars. Several objectives of this study are as follows: 1) determine the optimal planting date for high GY in the tested area; 2) determine the optimal density for optimal GY; 3) evaluate the planting date, planting density, and interactions of maize genotypes for yield and yield components; 4) determine the magnitude of standard heterosis for grain yield and yield related traits for cultivar development and/or further breeding and 5) identify the interrelationship among various metric traits.

MATERIALS AND METHODS

Plant Material

In the first summer season (2017), nine inbred lines (S_7) (Table 1) were sown at the Experimental Stations of Fine seeds international, Beba district, Beni Suef Governorate (28°54'06.5"N, 30°56'21.2"E), Egypt. The planting date was on 21 May and on 6 June to made all possible cross combinations excluding the reciprocals (half-diallel) and obtained on 36 F_1 hybrids with enough quantities of hybrid seeds for the next season. Each yellow maize inbred line was sown in 20 rows, 5 m long and 0.70 m wide. Two maize seeds were sown per hill, it spaced 20 cm apart along the row, before the first irrigation plants were thinned to one plant per hill.

Table 1. Name, Origin and place bred of 9 parental inbred lines (L)

No.	Name	Origin	Country
L1	CML 114	Pop-45	Mexico
L2	L249	FSI	Egypt
L3	4883	Ajeeb	Egypt
L4	4893	Shams	Egypt
L5	5166	72013	Egypt
L6	YL13-M 0325	155/30N11	USA
L7	YL14-A 0407	S.C. 164	Egypt
L8	YL14-A 0444	Pop. 1	Thailand
L9	YL15-M 0534	Mon. C599	Thailand

Field Trail

The field experiment was carried out at Al Fant, Al Fashn district, Beni Suef Governorate, 28°45'02.4"N, 30°52'25.9"E, Egypt in season 2018 to evaluate 36 diallel crosses and 4 high yielding commercial hybrids (SC 176, Fine 276, Fine 354 and SC Pioneer 32D99) under six environments. Three planting densities were used 24,000, 32,000 and 40,000 plant fed^{-1} as normal (NPD), medium (MPD), and high (HPD), under two sowing dates on 10 April and 28 May as optimal and late, respectively. A split-plot design was used in alpha lattice (5×8) arrangement in three replications. The main plots assigned to planting densities, but the sub-plots were to maize hybrids. The area of sub-plot was 7 m^2 (2 rows, 5 m long and 0.70 m wide), the distance between hills was 25 cm, 18.75 cm, and 15 cm, for normal, medium, and high planting densities, respectively. The hand planted was used in six environments with 2 seeds per hill and after three weeks from planting, the maize plants were thinning to one plant/hill before the first irrigation.

The rates of phosphor, potassium, and nitrogen fertilized were 31.5 kg P_2O_5, 50 kg K_2O and 120 kg N fed^{-1}, respectively. The other practices for maize cultivation were applied as a recommended. The dates of harvest were on 5 August in the 1st SD and 12 September in the 2nd SD. The experimental soil was clay in texture (clay 56.26%, sand 20.18%, and silt 23.56%), and it was slightly alkaline in reaction (pH values various between 7.62 - 7.96). The monthly average temperature is close to the long-term high, the highest temperature in June of the first season and July of the second season was 40°C, and rainfall was absent in two seasons. Therefore, the Neil River is the main source of water for irrigation. The test site is sunny from April to October, with an annual average of more than 4,000 hours of sunshine.

Statistical Procedures

The combined analysis of variance was performed according to **Sharma (1998)**. Economic heterosis or standard heterosis was calculated for the traits that showed significant differences for genotypes. This was computed as a percentage increase or decrease of the cross performances over the best standard check (**Falconer and Mackay, 1996**). Pioneer 32D99 was used as the best standard check. S.H (%) $= \frac{(F_1 - S.CH)}{S.CH} \times 100$ Where, S.H is standard heterosis, F_1 is mean value of a cross, and S.CH is mean value of standard check. Variety test of significance for heterosis (%) was made using the t-test as follows (**Singh and Chaudhary, 1985**). t (standard cross) = $\frac{(F_1 - S.CH)}{SE\ (d)}$ where, SE (d) = $\sqrt{2MSe/r}$ where SE (d) is standard error of the difference, MSe is the error mean square, and r is the number of replications. The computed t value was tested against the t tabular value at the error degree of freedom. Correlation coefficients were computed according to **Snedecor and Cochran (1981).** A PC Microsoft Excel program and SAS 9.2 (**SAS Institute Inc., 2013)** ® Computer programs for Windows were used for the statistical analysis.

Data Collection

Data were composed in the six environments for days to 50% tasseling (days), plant height (cm), ear length (cm), ear diameter (cm), number of rows per ear, and number of kernels per row, hundred-kernel weight (g) and grain yield per feddan (adjusted at 15.5% grain moisture).

RESULTS AND DISCUSSION

Mean Performance

Generally, the analyses of variance revealed significant differences for all studied traits among the 40 maize hybrids in three different planting densities (HPD, MPD, and NPD) under both 1st and 2nd sowing dates. The 2nd SD had negative effects on all maize hybrids for all traits, indicating the role of environmental effects on the growth stages and grain developing in maize. Similar findings have been reported by **Al-Naggar *et al*. (2015), Turkey *et al.* (2018) and Omar *et al*. (2022)**.

Days to Tasseling and Plant Height

The results in Table 2 indicated that, the high (HPD) and medium (MPD) planting densities caused an increase (later) in days to 50% tasseling for most hybrids in the 1st SD by an average of 0.54% under HPD and 0.56% under MPD, and in the 2nd SD by an average of 1.58% under MPD compared with the NPD level.

The maize hybrids G7 (L1 × L8), G27 (L5 × L6), G32 (L6 × L8), G3 (L1 × L4), G4 (L1 × L5), G5 (L1 × L6) exhibited the earliest values for days to 50% tasseling under all plant densities across two sowing dates. Conversely, the hybrids G13 (L2 × L7), G15 (L2 × L9), G21 (L3 × L9), G35 (L7 × L9), and G40 (Fine 354) had the latest ones under six environments. The average of days to 50% tasseling over all environments varied from 57.6 of G27 (L5 × L6) to 63.8 day of G35 (L7 × L9), with an average of 59.5 days.

The general mean of days to 50% tasseling tended to increase from 59.5 under NPD to 60.9 under MPD and 60.8 days under HPD in the 1st SD and from 58.0 (NPD) to 58.9 (MPD) and 57.9 days (HPD) in the 2nd SD. All maize hybrids showed low values in the 2nd SD compared with corresponding crosses in the 1st SD for this trait. These results are in harmony with those of **Ali (2016), Sedhom *et al*. (2016), Sultan *et al*. (2018), Turkey *et al*. (2018), Kamara *et al*. (2020) and Ajayo *et al*. (2021).**

For plant height, the results in Table 2 showed that high (HPD) and medium (MPD) planting densities caused an increase in plant height for the most hybrids, in the 1st SD by an average of 4.67% under HPD and 1.43% under MPD, and in the 2nd SD by an average of 5.37% under HPD and 3.57% under MPD compared with the NPD level. Mean plant height of F_1 crosses ranged in the 1st SD from 222.7 to 305.0 cm under NPD, 231.7 to 296.3 cm under MPD, and 222.0 to 314.7 cm under HPD for (L7 × L9) and (L8 × L9), respectively. Whereas, it was varied in the 2nd SD from 208.2 to 288.8 cm under NPD, 224.7 to 287.1 cm under MPD, and 228.0 to 305.4 cm under HPD for (L7 × L9) and (L8 × L9), respectively.

Across two sowing dates and under all planting densities, the maize hybrids G1 (L1 × L2), G10 (L2 × L4), G36 (L8 × L9), G37 (SC 176), and G40 (Fine 354) had the highest plant height. On the other hand, G35 (L7 × L9) and G21 (L3 × L9) hybrids had the lowest values in all environments. The general means of plant height were 269.2 cm under NPD, 273.0 cm under MPD and 281.7 cm under HPD in the first sowing date; 257.3 cm under NPD, 266.5 cm under MPD, and 271.1 cm under HPD in the second sowing date. This result is consistent with others maize researchers (**Ali, 2009; Al-Naggar *et al*., 2015; Abakemal *et al*., 2016; Assefa *et al*., 2018; Sultan *et al*., 2018; Abdel-Moneam *et al*., 2020**).

Ear Length and Ear Diameter

In the first sowing date, as compared to the NPD level, there is a small increase in ear length (EL) for the majority of hybrids under high planting densities (HPD) by 0.03%. Whereas, under MPD there was a -0.3% reduction. Also,

Table 2. Mean performance of 36 single hybrids and 4 checks for days to 50% tasseling and plant height under three different planting densities in two sowing dates

Trait	Days to 50% tasseling (days)							Plant height (cm)						
Environments	1st Sowing date (April 10)			2nd Sowing date (May 28)			Comb.	1st Sowing date (April 10)			2nd Sowing date (May 28)			Comb.
	HPD	MPD	NPD	HPD	MPD	NPD		HPD	MPD	NPD	HPD	MPD	NPD	
Genotypes	E1	E2	E3	E4	E5	E6		E1	E2	E3	E4	E5	E6	
L1 × L2	61.7	60.7	59.2	58.0	58.0	57.0	59.2	297.0	286.0	278.3	285.3	278.5	274.3	283.3
L1 × L3	60.7	60.0	59.2	57.7	58.0	58.0	59.2	281.3	281.0	278.7	283.7	272.7	264.6	276.9
L1 × L4	59.3	59.0	57.9	55.7	57.0	56.7	57.9	281.0	272.3	271.3	286.3	265.7	262.0	273.1
L1 × L5	59.3	60.3	58.4	56.3	58.0	57.0	58.4	283.7	273.3	272.3	271.3	268.7	261.4	271.8
L1 × L6	59.3	60.3	58.3	56.0	57.7	56.7	58.3	273.3	281.7	273.0	282.0	269.7	258.5	273.0
L1 × L7	60.0	60.3	59.0	56.7	58.7	58.0	59.0	274.0	272.7	277.0	276.0	251.7	254.2	267.6
L1 × L8	58.0	60.0	57.7	55.0	57.7	56.3	57.7	285.7	282.0	275.7	280.0	267.0	262.1	275.4
L1 × L9	60.0	61.7	59.7	57.0	60.0	59.0	59.7	284.0	273.0	263.7	275.0	263.3	255.1	269.0
L2 × L3	61.7	60.7	59.7	58.3	58.3	58.3	59.7	272.3	251.7	264.3	256.0	254.3	246.9	257.4
L2 × L4	63.0	61.0	60.6	59.7	60.0	59.0	60.6	303.3	285.0	288.3	290.0	280.0	275.4	286.9
L2 × L5	61.3	61.7	60.1	58.3	60.0	58.3	60.1	298.0	280.7	274.3	276.3	281.7	267.4	279.7
L2 × L6	60.3	62.0	59.8	58.3	60.0	57.7	59.8	279.7	279.7	281.7	282.0	280.3	265.6	278.2
L2 × L7	62.3	62.3	61.2	59.3	60.7	60.0	61.2	288.7	279.7	281.0	281.0	279.7	265.6	279.3
L2 × L8	61.3	61.0	59.9	59.0	59.3	58.0	59.9	276.3	274.0	276.3	279.0	272.7	260.1	273.1
L2 × L9	62.7	63.3	61.7	59.7	61.3	61.0	61.7	292.3	279.0	268.1	280.0	276.0	266.7	277.0
L3 × L4	59.7	59.7	58.7	57.0	57.3	58.0	58.7	295.7	274.0	264.3	272.7	263.0	259.3	271.5
L3 × L5	60.3	60.3	59.3	57.7	59.3	57.7	59.3	284.3	275.3	268.0	266.3	280.3	259.1	272.2
L3 × L6	60.7	61.0	59.7	58.3	59.3	58.0	59.7	282.0	273.7	276.7	270.7	259.7	258.9	270.2
L3 × L7	61.0	62.7	60.3	58.3	61.0	58.0	60.3	276.0	257.0	247.7	254.0	262.0	241.5	256.3
L3 × L8	60.7	60.3	59.1	58.0	58.3	57.0	59.1	262.3	262.3	271.0	251.3	259.0	245.4	258.6
L3 × L9	63.7	61.3	61.2	61.0	60.3	59.3	61.2	252.3	254.7	229.0	236.7	245.7	228.4	241.1
L4 × L5	59.7	60.0	58.4	57.0	58.0	56.7	58.4	293.7	275.7	256.0	270.3	274.3	259.6	271.6
L4 × L6	61.3	60.0	59.0	57.0	57.3	57.7	59.0	284.3	282.3	277.7	275.0	260.7	261.1	273.4
L4 × L7	61.3	59.7	59.1	57.7	57.7	57.7	59.1	296.0	276.0	276.0	267.0	264.7	261.4	273.5
L4 × L8	60.0	59.7	58.3	56.7	57.7	56.7	58.3	274.7	270.0	263.0	259.3	249.3	248.5	260.8
L4 × L9	60.3	61.0	59.7	58.0	59.7	58.3	59.7	279.0	272.3	261.0	268.7	274.3	254.3	268.3
L5 × L6	58.3	60.0	57.6	55.0	58.0	55.7	57.6	283.0	261.7	269.0	265.0	267.0	252.1	266.0
L5 × L7	60.0	60.3	58.7	57.0	58.3	57.0	58.7	278.0	264.3	258.3	248.0	263.3	247.9	259.9
L5 × L8	60.3	59.3	58.2	57.0	57.3	56.7	58.2	269.3	265.3	250.0	262.0	262.0	248.9	259.6
L5 × L9	60.3	60.3	59.1	57.0	58.3	58.3	59.1	281.7	269.3	258.0	261.7	272.0	253.8	266.0
L6 × L7	59.3	60.3	57.9	56.0	57.3	55.7	57.9	266.0	257.3	250.7	252.3	253.3	241.7	253.6
L6 × L8	58.7	60.0	58.0	55.7	57.0	57.0	58.0	260.0	261.7	259.0	256.3	255.7	241.8	255.7
L6 × L9	61.3	60.3	59.7	58.3	59.0	58.3	59.7	268.0	253.0	257.3	255.0	255.7	242.4	255.2
L7 × L8	60.3	60.3	59.3	57.7	59.0	58.3	59.3	265.7	265.7	259.0	257.7	234.7	239.1	253.6
L7 × L9	63.3	61.7	62.3	61.7	62.3	61.7	62.3	222.0	231.7	222.7	228.0	224.7	208.2	222.9
L8 × L9	60.3	60.3	59.6	58.7	58.3	59.0	59.6	314.7	296.3	305.0	305.4	287.1	288.8	299.7
Checks														
SC 176	62.3	62.7	60.3	59.0	60.3	58.0	60.3	306.3	283.3	281.7	291.0	283.3	274.9	286.4
SC Pioneer 32 D99	60.3	60.3	58.7	57.3	57.7	56.7	58.7	288.0	285.0	284.7	291.7	274.0	269.1	281.9
Fine 276	63.3	63.0	61.9	60.3	61.0	60.3	61.9	303.7	300.7	303.0	294.8	290.4	286.7	296.4
Fine 354	65.3	65.0	63.8	62.3	63.0	62.3	63.8	312.3	301.0	301.0	300.7	281.7	283.7	296.6
Means	**60.8**	**60.9**	**59.5**	**57.9**	**58.9**	**58.0**	**59.5**	**281.7**	**273.0**	**269.3**	**271.1**	**266.5**	**257.4**	**269.8**
Increase%	**0.54**	**0.56**		**-0.27**	**1.58**			**4.67**	**1.43**		**5.37**	**3.57**		
L.S.D. $_{0.05}$ (G)	**1.05**	**1.13**	**0.57**	**1.34**	**1.63**	**1.85**	**0.57**	**2.64**	**11.38**	**2.45**	**1.82**	**1.06**	**2.06**	**2.06**

Days to 50% tasseling:
L.S.D. $_{0.05}$ Sowing (S) = 0.13 L.S.D. $_{0.05}$ G x S = 0.8
L.S.D. $_{0.05}$ S x D = 0.22 L.S.D. $_{0.05}$ G x D = 0.98
L.S.D. $_{0.05}$ Den. (D) = 0.16 L.S.D. $_{0.05}$ G x S x D = 1.39

Plant height:
L.S.D. $_{0.05}$ Sowing (S) = 0.14 L.S.D. $_{0.05}$ G x S = 2.91
L.S.D. $_{0.05}$ S x D = 0.23 L.S.D. $_{0.05}$ G x D = 3.56
L.S.D. $_{0.05}$ Den. (D) = 0.17 L.S.D. $_{0.05}$ G x S x D = 5.03

HPD: high planting density (40,000 plant/fed.); MPD: medium planting density (32,000 plant/fed.); NPD: normal planting density (24,000 plant/fed.).

on the second sowing date, a -0.75% reduction under HPD, and -1.85% under MPD. Mean ear length of F_1 crosses ranged in the 1st SD from 17.0 to 21.1 cm under HPD, from 17.0 to 21.8 cm under MPD and from 17.3 to 21.8 cm under NPD. While it was ranged in the 2nd SD from 16.3 to 20.9 cm under HPD, from 15.8 to 21.3 cm under MPD and from 16.3 to 21.3 cm under NPD (Table 3).

Maize hybrids G39 (Fine 276), G33 (L6 × L9), and G36 (L8 × L9) had the longest ears. Conversely, the hybrids G1 (L1 × L2) and G5 (L1 × L6) had the shortest ears. For the first sowing date, the general mean of EL was 19.3 under NPD, 19.2 under MPD and 19.3 cm under HPD, but it was 19.2 under NPD, 18.8 MPD, and 19 cm under HPD in the late sowing date. This result is consistent with others maize scientists **(Ali, 2009; Al-Naggar *et al.*, 2015; Sedhom *et al*., 2016; Abdel-Moneam *et al*., 2020; Ajayo *et al*., 2021; Rabbani and Safdary, 2021).**

The results in Table 3 showed that three planting densities had non-significant differences on ear diameter in the 1st and 2nd sowing dates. Also, interaction between genotypes × plant density was insignificant. While the late sowing date produced less ear diameter of most crosses. The mean for ear diameter of F_1 crosses ranged in the 1st SD from 4.1 to 5.3 cm under HPD, from 4.0 to 5.2 cm under MPD, and from 4.1 to 5.2 cm under NPD for (L7 × L9) and (L1 × L6), respectively. While it was ranged in the 2nd SD from 3.9 to 5.1 cm under HPD, from 4.1 to 5.1 cm under MPD, and from 4.1 to 5.2 cm under NPD for (L7 × L9) and (L1 × L6), respectively.

The maize hybrids G5 (L1 × L6), G12 (L2 × L6), and G18 (L3 × L6) had the maximum ear diameter values across three plant densities and two sowing dates. Nevertheless, the hybrids G35 (L7 × L9), G34 (L7 × L8), and G28 (L5 × L7) had the lowest diameter under six different conditions. This result is in the line with others academics **(Ali, 2009; Ali, 2016; El-Refaey *et al.*, 2017; Assefa *et al*., 2018).**

Number of Rows Per Ear and Number of Kernels Per Plant

As showen in Table (4), number of rows per ear (NRPE) showed that HPD and MPD caused a reduction by 4.63% and 2.86% in the 1st SD and 0.0% and 2.83% in the 2nd SD, respectively, indicating plant density and sowing dates showed significant differences for this trait, while GxPD and G x SD x PD interactions were insignificant. The maize hybrids G25 (L4 × L8) and G20 (L3 × L8), and checks G39 (Fine 276) and G38 (SC Pioneer 32D99) had the highest number of rows per ear across two sowing dates. In contrast, the hybrids G35 (L7 × L9), G31 (L6 × L7), and G11 (L2 × L5) had the minimum numbers across six environments. Mean NRPE of F_1 crosses ranged in the 1st SD from 12.5 to 16.0 under HPD, from 13.2 to 16.3 under MPD, and from 13.3 to 16.7 under NPD for (L7 × L9) and (L3 × L8), respectively. While it was ranged in the 2nd SD from 12.2 to 15.3 under HPD, from 13.3 to 15.5 under MPD, and from 12.3 to 16.3 under NPD.

For the first SD, the general mean of NRPE was 14.9 under NPD to 14.5 under MPD and 14.2 under HPD, and it was 14.5 (NPD), 14.4 (MPD) and 14.1 (HPD) in the second SD. This result is consistent with others maize researchers **(Al-Naggar *et al*., 2015; Ali, 2016; Sedhom *et al*., 2016; Abdel-Moneam *et al*., 2020; Rabbani and Safdary, 2021).**

In terms of number of kernels per row (NKPR), the maize hybrids G39 (Fine 276), G36 (L8 × L9), G12 (L2 × L6), and G33 (L6 × L9) had the highest number of KPR across two sowing dates. In contrast, the hybrids G21 (L3 × L9), G35 (L7 × L9), and G5 (L1 × L6) had the least numbers across six environments (Table 4). The mean number of kernels per row of F_1 crosses ranged in the 1st SD from 33.5 to 42.1 under HPD, from 36.6 to 44.7 under MPD, and from 37.7 to 45.9 under NPD for G35 (L7 × L9) and G36 (L8×L9), respectively. Although it was ranged in the 2nd SD from 31.7 to 39.8 under HPD, from 36.7 to 41.1 under MPD and from 36.3 to 42.5 under NPD for G35 (L7 × L9) and G36 (L8 × L9), respectively.

Similarly to NRPE, the number of kernels per row (NKPR) was decreased by 8.96% under HPD, and 4.26% under MPD in the 1st SD, and 10.44% under HPD and 4.26% under MPD in the 2nd SD. Similar results were stated by maize scientists **(Ali, 2009; Sedhom *et a*l., 2016; El-Refaey *et al*., 2017; Abdel-Moneam *et al*., 2020; Efendi *et al*., 2020; Ajayo *et al*., 2021).**

Table 3. Mean performance of 36 single hybrids and 4 checks for ear length and ear diameter under three different planting densities in two sowing dates

Trait	Ear length (cm)							Ear diameter (cm)						
Environments	1st Sowing date (April 10)			2nd Sowing date (May 28)			Comb.	1st Sowing date (April 10)			2nd Sowing date (May 28)			Comb.
	HPD	MPD	NPD	HPD	MPD	NPD		HPD	MPD	NPD	HPD	MPD	NPD	
Genotypes	E1	E2	E3	E4	E5	E6		E1	E2	E3	E4	E5	E6	
L1 × L2	17.0	17.1	17.3	16.7	17.1	16.5	17.0	4.9	4.7	4.7	4.9	4.8	4.8	4.8
L1 × L3	18.7	19.0	19.0	18.7	18.0	18.2	18.6	4.9	4.8	4.8	4.7	4.8	4.8	4.8
L1 × L4	19.5	19.7	20.0	19.2	18.5	19.0	19.3	4.8	4.9	4.7	4.7	4.6	4.8	4.7
L1 × L5	17.7	18.3	18.0	17.1	17.2	17.5	17.6	4.7	4.8	4.7	4.7	4.7	4.6	4.7
L1 × L6	18.5	17.0	18.0	17.3	15.8	16.3	17.2	5.3	5.2	5.2	5.1	5.1	5.2	5.2
L1 × L7	18.7	19.7	19.0	19.0	18.9	19.7	19.1	4.7	4.7	4.6	4.5	4.5	4.6	4.6
L1 × L8	20.0	19.7	19.8	20.2	19.2	20.0	19.8	4.7	4.7	4.7	4.8	4.7	4.8	4.7
L1 × L9	20.3	19.0	19.7	19.7	18.5	19.3	19.4	5.0	4.8	4.8	4.9	4.8	5.0	4.9
L2 × L3	18.3	18.7	17.7	18.2	18.2	17.7	18.1	4.9	4.7	4.7	4.8	4.8	4.8	4.8
L2 × L4	19.4	19.0	19.0	19.7	18.6	19.0	19.1	5.1	4.8	4.7	4.8	4.7	4.8	4.8
L2 × L5	17.9	18.0	17.3	18.3	17.8	18.1	17.9	4.7	4.5	4.5	4.5	4.6	4.4	4.5
L2 × L6	18.1	18.5	17.9	17.2	16.9	16.8	17.6	5.1	5.1	5.0	5.0	4.9	5.0	5.0
L2 × L7	19.8	19.3	20.0	19.0	19.0	19.0	19.4	4.7	4.5	4.7	4.4	4.5	4.2	4.5
L2 × L8	18.4	18.5	18.0	18.3	18.3	18.3	18.3	4.7	4.5	4.7	4.3	4.5	4.2	4.5
L2 × L9	20.7	19.4	20.0	19.3	20.0	19.5	19.8	4.9	4.6	4.7	4.9	4.9	5.0	4.8
L3 × L4	20.5	20.9	18.8	20.0	19.3	19.5	19.8	4.7	4.6	4.5	4.5	4.4	4.8	4.6
L3 × L5	17.7	18.4	18.0	18.1	18.5	18.2	18.2	4.8	4.7	4.6	4.6	4.7	4.8	4.7
L3 × L6	19.9	19.3	20.5	19.3	19.3	18.7	19.5	4.9	4.8	4.9	4.9	5.1	5.2	5.0
L3 × L7	19.0	19.1	18.3	19.0	18.3	19.0	18.8	4.5	4.5	4.4	4.4	4.4	4.6	4.5
L3 × L8	18.3	18.9	18.0	18.7	17.7	18.5	18.4	4.7	5.0	4.7	4.5	4.5	4.8	4.7
L3 × L9	19.0	18.7	18.3	18.5	17.9	18.2	18.4	4.4	4.5	4.5	4.5	4.5	4.8	4.5
L4 × L5	19.5	20.2	20.3	20.0	18.9	19.0	19.7	4.4	4.5	4.3	4.5	4.3	4.4	4.4
L4 × L6	19.7	20.5	20.3	19.3	18.5	19.5	19.6	4.9	4.9	4.8	4.9	4.7	5.0	4.9
L4 × L7	19.9	20.2	20.0	20.7	20.5	21.3	20.4	4.6	4.5	4.7	4.5	4.5	4.4	4.5
L4 × L8	18.7	19.5	20.0	20.3	19.0	18.7	19.4	4.3	4.6	4.7	4.5	4.4	4.6	4.5
L4 × L9	20.1	20.7	20.3	20.9	20.7	21.1	20.6	4.7	4.5	4.5	4.6	4.5	4.4	4.5
L5 × L6	19.7	18.7	19.3	18.2	19.0	18.9	19.0	4.7	4.7	4.8	4.5	4.6	4.4	4.6
L5 × L7	19.7	19.0	19.7	20.3	20.3	19.8	19.8	4.5	4.4	4.4	4.4	4.2	4.2	4.3
L5 × L8	18.6	18.5	18.7	18.7	18.3	18.3	18.5	4.5	4.5	4.5	4.3	4.3	4.2	4.4
L5 × L9	19.4	19.3	20.0	20.2	19.5	20.5	19.8	4.3	4.4	4.5	4.5	4.4	4.6	4.5
L6 × L7	19.5	20.0	21.0	20.0	19.7	20.8	20.2	4.5	4.5	4.7	4.6	4.5	4.6	4.6
L6 × L8	19.1	20.3	19.7	18.8	18.5	19.7	19.4	4.9	4.9	4.8	4.6	4.8	4.6	4.8
L6 × L9	20.9	21.8	21.8	19.0	20.2	20.7	20.7	5.0	4.9	4.9	4.6	4.9	4.6	4.8
L7 × L8	19.7	19.1	20.0	19.1	19.3	20.2	19.6	4.5	4.4	4.3	4.3	4.1	4.4	4.3
L7 × L9	18.3	17.3	18.0	16.3	19.7	19.2	18.1	4.1	4.0	4.1	3.9	4.4	3.8	4.1
L8 × L9	21.1	20.2	21.0	19.9	21.3	20.8	20.7	4.8	4.5	4.6	4.5	4.5	4.4	4.5
SC 176														
SC Pioneer 32D99	20.7	19.2	20.3	18.7	18.9	20.0	19.6	4.7	4.8	4.7	4.5	4.6	4.4	4.6
Fine 276	19.8	19.7	20.0	19.1	19.1	20.3	19.7	5.0	4.9	4.8	4.9	4.9	5.0	4.9
Fine 354	21.5	20.7	20.7	21.0	20.0	22.0	21.0	4.9	4.9	4.9	4.9	4.9	4.8	4.9
SC 176	18.1	17.7	17.3	18.5	17.7	18.5	18.0	4.5	4.5	4.2	4.5	4.5	4.8	4.5
Means	19.3	19.2	19.3	19.0	18.8	19.2	19.1	4.7	4.7	4.7	4.6	4.6	4.6	4.7
Increase%	0.03	-0.3		-0.75	-1.85			1.43	0.14		-0.65	-0.65		
L.S.D. 0.05 (G)	**1.29**	**1.26**	**1.02**	**1.27**	**1.47**	**1.42**	**0.55**	**0.29**	**0.2**	**0.24**	**0.26**	**0.28**	**0**	**0.1**

L.S.D. 0.05 Sowing (S) = 0.12 **L.S.D. 0.05 G x S = 0.77** **L.S.D. 0.05 Sowing (S) = 0.02** **L.S.D. 0.05 G x S = 0.14**

L.S.D. 0.05 S x D = 0.21 **L.S.D. 0.05 G x D = 0.95** **L.S.D. 0.05 S x D = 0.04** **L.S.D. 0.05 G x D = 0.17**

L.S.D. 0.05 Den. (D) = 0.15 **L.S.D. 0.05 G x S x D = 1.34** **L.S.D. 0.05 Den. (D) = 0.03** **L.S.D. 0.05 G x S x D = 0.25**

HPD: high planting density (40,000 plant/fed.); MPD: medium planting density (32,000 plant/fed.); NPD: normal planting density (24,000 plant/fed.).

Table 4. Mean performance of 36 single hybrids and 4 checks for Number of rows per ear and Number of kernels per row under three different planting densities in two sowing dates

Trait	Number of rows per ear							Number of kernels per row						
Environments	1st Sowing date (April 10)			2nd Sowing date (May 28)			Comb.	1st Sowing date (April 10)			2nd Sowing date (May 28)			Comb.
	HPD	MPD	NPD	HPD	MPD	NPD		HPD	MPD	NPD	HPD	MPD	NPD	
	E1	E2	E3	E4	E5	E6		E1	E2	E3	E4	E5	E6	
L1 × L2	13.1	13.3	13.9	12.9	13.5	13.7	13.4	38.1	40.5	42.5	36.5	38.1	39.9	39.3
L1 × L3	14.3	14.9	15.3	13.7	14.5	15.2	14.7	41.3	41.1	44.5	34.0	36.0	39.9	38.7
L1 × L4	14.3	15.3	15.3	14.4	15.5	14.9	15.0	41.0	42.3	43.9	36.5	36.8	39.7	40.0
L1 × L5	13.3	12.9	14.4	13.1	12.9	13.7	13.4	39.8	42.8	40.2	34.8	37.1	37.7	38.7
L1 × L6	14.4	14.7	14.1	14.1	14.9	14.5	14.5	34.7	36.7	38.4	33.2	33.1	36.6	35.5
L1 × L7	13.6	13.5	14.3	13.7	13.1	13.5	13.6	38.9	43.0	43.6	32.2	35.9	39.1	38.8
L1 × L8	15.5	14.9	15.5	14.4	14.8	14.8	15.0	39.8	41.3	40.6	33.7	36.5	41.7	38.9
L1 × L9	14.3	14.8	14.3	14.5	14.8	14.8	14.6	39.2	42.3	44.2	32.1	36.5	39.9	39.0
L2 × L3	14.4	15.2	15.1	15.1	14.9	14.3	14.8	39.1	40.4	41.1	35.5	37.9	40.8	39.1
L2 × L4	14.0	14.8	15.3	14.7	15.2	14.9	14.8	40.1	42.3	43.1	36.6	41.1	41.9	40.8
L2 × L5	13.6	13.6	13.5	13.1	13.3	12.3	13.2	40.7	42.0	44.7	37.6	40.2	42.3	41.3
L2 × L6	14.0	13.5	14.7	13.6	14.4	13.6	14.0	40.1	42.2	45.1	38.5	41.5	41.1	41.4
L2 × L7	13.3	13.6	14.8	12.5	12.9	13.1	13.4	36.7	38.1	41.3	37.6	39.7	41.3	39.1
L2 × L8	14.0	15.1	15.7	14.0	14.0	14.5	14.6	40.4	40.6	41.5	37.8	39.3	42.1	40.3
L2 × L9	14.4	13.9	14.9	14.0	14.1	14.1	14.3	40.7	44.1	45.8	36.5	39.9	41.3	41.3
L3 × L4	14.9	15.3	14.5	15.3	16.0	15.1	15.2	37.1	40.2	42.3	29.7	33.2	43.1	37.6
L3 × L5	14.7	14.8	14.9	14.9	14.4	15.3	14.8	34.1	36.6	41.3	36.4	36.4	38.4	37.2
L3 × L6	14.4	14.5	15.5	15.6	15.2	16.1	15.2	37.3	40.4	42.6	33.2	36.3	40.5	38.4
L3 × L7	13.6	14.0	14.8	13.7	14.1	14.7	14.2	36.7	38.0	40.9	37.1	34.7	35.7	37.2
L3 × L8	16.0	16.3	16.7	14.7	15.2	16.3	15.9	38.3	37.6	40.7	37.0	35.8	35.5	37.5
L3 × L9	13.9	15.5	15.2	14.0	14.4	14.5	14.6	32.8	35.1	38.8	31.8	33.1	32.6	34.1
L4 × L5	14.0	14.4	14.7	14.8	14.0	14.7	14.4	39.4	41.0	41.6	37.7	37.9	39.5	39.5
L4 × L6	13.9	12.8	14.1	14.7	14.3	14.8	14.1	37.7	41.0	40.8	36.0	36.7	38.7	38.5
L4 × L7	13.7	14.9	15.3	13.7	14.3	14.5	14.4	39.9	42.6	44.4	36.7	39.5	41.6	40.8
L4 × L8	14.8	15.5	16.1	15.5	16.1	15.6	15.6	37.7	41.3	42.9	33.8	37.5	41.5	39.1
L4 × L9	14.8	15.1	14.9	15.2	14.4	15.3	15.0	38.9	44.0	44.7	34.5	39.2	42.1	40.6
L5 × L6	13.9	14.0	14.4	13.3	14.1	13.9	13.9	39.7	39.9	41.5	36.4	37.3	39.7	39.1
L5 × L7	14.4	13.7	14.7	14.1	13.6	13.3	14.0	39.5	40.4	43.2	35.4	39.7	41.9	40.0
L5 × L8	14.9	13.9	14.7	13.3	14.9	14.0	14.3	39.5	41.2	44.9	36.8	37.4	37.7	39.6
L5 × L9	13.2	14.0	14.5	13.6	13.6	13.7	13.8	38.7	41.0	43.5	35.5	37.8	40.4	39.5
L6 × L7	13.1	12.9	14.0	13.2	13.5	12.9	13.3	41.2	40.0	43.0	38.1	42.7	42.5	41.3
L6 × L8	14.0	14.9	16.4	14.0	15.3	14.5	14.9	39.2	41.4	44.8	35.9	38.2	39.5	39.8
L6 × L9	14.1	14.4	14.9	13.7	13.9	14.0	14.2	40.9	43.4	44.4	36.8	42.1	42.4	41.7
L7 × L8	14.3	14.9	14.5	13.9	13.3	14.1	14.2	40.3	40.7	41.6	39.3	39.9	39.6	40.3
L7 × L9	12.5	13.2	13.3	12.2	14.1	14.0	13.2	33.5	36.6	37.7	31.7	36.7	36.3	35.4
L8 × L9	14.1	14.9	14.7	13.3	13.3	14.4	14.2	42.1	44.7	45.9	39.8	41.1	42.5	42.7
Checks														
SC 176	14.5	14.9	15.3	14.1	15.1	15.6	14.9	39.7	41.3	44.9	36.4	39.9	40.2	40.4
SC Pioneer 32D99	15.3	15.7	15.9	15.6	16.1	16.3	15.8	41.3	42.8	45.3	34.7	40.5	39.9	40.7
Fine 276	15.3	16.0	16.2	14.9	16.3	15.9	15.8	41.1	43.6	44.2	37.7	42.5	43.2	42.1
Fine 354	14.8	14.9	14.0	14.0	14.4	14.0	14.4	39.4	43.3	44.0	38.9	40.4	42.3	41.4
Means	14.2	14.5	14.9	14.1	14.4	14.5	14.4	38.9	40.9	42.8	35.8	38.2	40.1	39.4
Increase%	**-4.63**	**-2.68**		**0**	**-2.86**			**-8.96**	**-4.26**		**-10.44**	**-4.46**		
L.S.D. $_{0.05}$ (G)	**0.31**	**1.23**	**1.12**	**0.33**	**1.26**	**1.03**	**0.39**	**1.03**	**2.2**	**3.07**	**2.41**	**3.71**	**2.6**	**1.07**

Number of rows per ear: **L.S.D. $_{0.05}$ Sowing (S) = 0.11**; **L.S.D. $_{0.05}$ G x S = 0.72**; **L.S.D. $_{0.05}$ S x D = 0.2**; **L.S.D. $_{0.05}$ G x D = 0.89**; **L.S.D. $_{0.05}$ Den. (D) = 0.14**; **L.S.D. $_{0.05}$ G x S x D = 1.25**

Number of kernels per row: **L.S.D. $_{0.05}$ Sowing (S) = 0.24**; **L.S.D. $_{0.05}$ G x S = 1.51**; **L.S.D. $_{0.05}$ S x D = 0.41**; **L.S.D. $_{0.05}$ G x D = 1.85**; **L.S.D. $_{0.05}$ Den. (D) = 0.29**; **L.S.D. $_{0.05}$ G x S x D = 2.62**

HPD: high planting density (40,000 plant/fed.); MPD: medium planting density (32,000 plant/fed.); NPD: normal planting density (24,000 plant/fed.).

The general mean of NKPR was 42.8 under NPD, 40.9 under MPD and 38.9 under HPD in the 1st SD, and it was 40.1 (NPD), 38.2 (MPD) and 35.8 (HPD) in the second sowing date.

100- Kernel Weight and Grain Yield

As for the 100-kernel weight across two sowing dates, it showed that HPD and MPD caused the reduction of 7.9%, and 5.2% in the 1st SD and 14.0 and 7.6% in the 2nd SD, respectively (Table 5). The maize hybrids G16 (L3 × L4), G5 (L1 × L6), G32 (L6 × L8), and G29 (L5 × L8) had the heaviest values for 100-kernel weight under three plant densities across two sowing dates. On the other hand, the hybrids G24 (L4 × L7), G25 (L4 × L8), and G1 (L1×L2) had the lightest grains in each of the six environments. The mean for 100-kernel weight of F_1 crosses ranged in the 1st SD from 26.5 to 32.7 g under HPD, from 28.7 to 33.7 g under MPD and from 30.7 to 35.3 g under NPD. While it was ranged in the 2nd SD from 24.0 to 29.7 g under HPD, from 26.0 to 31.0 g under MPD and from 28.7 to 33.2 g under NPD.

The general mean of 100-kernel weight was 30.2, 31.0, and 32.7 g in 1st SD and 26.8, 28.8 and 31.2 g in 2nd SD under HPD, MPD and NPD, respectively. The HPD and late sowing date were reduced 100- kernel weight than NPD and optimal sowing date of all maize hybrids. Similarly, a higher reduction in kernel weight in maize genotypes under higher plant density and late in sowing date as compared to optimal conditions ones was also observed earlier **(Ali, 2009; Umar *et al*., 2014; Al-Naggar *et al*., 2015; Ali, 2016; Sultan *et al*., 2018; Turkey *et al*., 2018).**

Grain yield per feddan in ardab (Table 5) was ranged under normal planting density (NPD) from 16.6 (G35) to 35.89 ardab fed^{-1} (G36) with an average of 30.78 ardab fed^{-1} in the first sowing date, and from 12.31 (G38) to 30.45 ardab fed^{-1} with an average of 24.77 ardab fed^{-1} in the second sowing date. Under medium planting density (MPD), it was ranged from 16.66 (G35) to 35.7 ardab fed^{-1} (G36) with an average of 31.09 ardab fed^{-1} in the first sowing date, and from 11.55 (G35) to 32.16 ardab fed^{-1} (G38) with an average of 26.91 ardab fed^{-1} in the second sowing date. Under high plant density (HPD), it was ranged from 23.9 (G35) to 44.89 ardab fed^{-1} (G36) with an average of 36.25 ardab fed^{-1} in the first sowing date, and from 13.41 (G35) to 35.40 ardab fed^{-1} (G36) with an average of 28.44 ardab fed^{-1} in the second sowing date, which indicates the large variability and divergence among hybrids in tolerance to high plant density. Such wide ranges of changes indicate that plant breeders are able to select some maize crosses with high tolerance to high plant density stress. Interestingly, genotype G36 (L8×L9) performed better for three plant densities during both sowing dates for this trait. The higher plant density was increased grain yield of most crosses under presented study, while the late sowing date (SD) produced less grain yield than early sowing date. This result is consistent with others maize scientists **(Ali, 2009; Al-Naggar *et al*., 2015; Ali, 2016; Golla *et al*., 2018; Sultan *et al*., 2018; Abdel-Moneam *et al*., 2020; Efendi *et al*., 2020).**

Maize crosses showing higher yield per feddan under high planting density than their grain yield under normal planting density, such as G36 (L8 × L9) and most F1 crosses in two sowing dates may be recommended for commercial use under HPD and/or for abiotic stress environments such as low-nitrogen and drought stress, as well as for breeding programs to improve characters related to tolerance to such stresses **(Al-Naggar *et al*., 2015)**. HPD is particularly useful in augmenting selection for low N and drought stress tolerance **(Al-Naggar *et al*., 2020; Ali, 2009)**. Thus several commercial breeders of maize in North America improved drought resistance by screening genotypes under high plant density **(Gözübenl, 2010).** Simultaneous to yield, the plant density of maize has significantly improved over the years in Canada, United States, Brazil, China, Germany, and other maize-producing countries (**Assefa *et al.*, 2018)**. The agronomic optimum planting density (AOPD) ranged from 75,000 plants/ha for the initial lustrum (1987–1991) and 93, 000 plants/ ha for the final period (2012–2016), with grain yields moving from 9.3 to 12.7 ton/ha, respectively **(Assefa *et al*., 2018).**

Table 5. Mean performance for 36 single hybrids and 4 checks for 100-kernel weight and grain yield under three different planting densities in two sowing dates

Trait	100-kernel weight							Grain yield (ardab fed^{-1})						
Environments	1st Sowing date (April 10)			2nd Sowing date (May 28)			Comb.	1st Sowing date (April 10)			2nd Sowing date (May 28)			Comb.
	HPD	MPD	NPD	HPD	MPD	NPD		HPD	MPD	NPD	HPD	MPD	NPD	
Genotypes	E1	E2	E3	E4	E5	E6		E1	E2	E3	E4	E5	E6	
L1 × L2	26.5	29.0	30.7	26.0	30.3	31.4	29.0	32.14	29.75	26.77	25.77	26.96	24.58	27.66
L1 × L3	29.4	33.7	33.9	28.0	28.0	32.0	30.8	42.08	35.39	31.84	32.39	29.72	24.46	32.65
L1 × L4	28.0	31.0	33.0	25.7	30.7	32.0	30.1	35.14	30.81	30.55	27.66	25.38	26.39	29.32
L1 × L5	30.4	31.7	32.3	27.7	30.3	31.7	30.5	34.35	29.76	29.46	29.50	27.06	25.92	29.34
L1 × L6	32.1	32.3	33.7	27.7	29.0	32.3	31.2	36.73	29.24	29.71	25.55	23.83	23.48	28.09
L1 × L7	32.0	31.7	32.3	25.7	28.0	30.7	30.1	35.60	31.36	32.43	26.17	28.38	24.19	29.69
L1 × L8	30.3	30.0	31.7	29.3	28.4	31.1	30.2	38.37	34.05	31.39	33.03	30.08	28.98	32.65
L1 × L9	32.7	29.0	32.3	26.0	28.3	33.0	30.2	36.80	27.91	30.74	30.11	23.85	23.40	28.80
L2 × L3	31.0	30.7	32.5	28.7	30.0	32.4	30.9	38.25	32.50	30.56	30.74	29.16	27.13	31.39
L2 × L4	29.7	30.0	32.3	24.0	30.0	30.3	29.4	36.20	34.60	34.94	31.31	25.36	25.85	31.38
L2 × L5	30.3	31.5	34.2	25.0	28.7	31.3	30.7	35.79	25.90	28.34	25.71	24.48	23.75	27.33
L2 × L6	30.7	32.0	31.7	25.0	29.0	29.3	29.6	34.84	31.31	31.42	24.04	25.67	24.05	28.56
L2 × L7	29.0	31.0	34.7	26.3	27.4	33.1	30.2	34.77	28.70	28.15	24.63	26.07	21.88	27.37
L2 × L8	29.4	31.7	31.7	25.0	27.3	30.3	29.2	36.76	31.81	34.48	29.13	25.43	23.93	30.26
L2 × L9	28.4	32.7	31.5	26.7	29.1	33.2	30.3	37.57	31.20	33.58	28.58	26.32	22.05	29.88
L3 × L4	32.3	34.0	34.7	29.7	28.3	32.3	31.9	42.29	32.39	29.07	35.17	31.32	24.69	32.49
L3 × L5	30.2	30.0	31.7	27.3	29.3	31.3	29.9	36.90	33.73	33.90	33.16	30.89	25.48	32.34
L3 × L6	32.0	28.3	32.3	25.3	26.0	30.7	29.1	36.12	30.67	32.52	29.92	29.22	24.91	30.56
L3 × L7	27.1	29.3	33.1	26.7	29.3	31.3	29.5	32.46	27.36	25.66	28.38	24.52	23.38	26.96
L3 × L8	29.7	31.0	32.0	28.0	28.3	31.4	29.9	40.50	34.27	30.79	32.30	29.41	27.75	32.50
L3 × L9	31.0	33.0	33.4	26.7	28.0	29.3	30.2	29.06	27.92	24.49	24.86	21.51	20.63	24.75
L4 × L5	31.0	32.3	33.3	25.3	28.7	29.3	30.0	32.13	29.41	28.49	28.20	26.00	24.98	28.20
L4 × L6	32.3	31.7	33.3	27.0	26.0	32.7	30.5	36.19	32.19	31.10	25.97	25.83	26.40	29.61
L4 × L7	29.0	29.3	33.3	26.0	25.3	29.3	28.7	35.26	31.51	30.41	32.13	29.64	27.26	31.03
L4 × L8	28.3	28.7	32.0	25.3	28.3	30.0	28.8	36.77	32.58	34.40	29.45	26.32	22.49	30.33
L4 × L9	29.3	30.7	32.0	26.3	30.0	28.7	29.5	37.16	30.88	31.59	27.90	26.77	27.68	30.33
L5 × L6	30.3	31.3	32.0	26.7	28.7	31.7	30.1	32.61	26.77	26.94	22.41	24.49	22.76	26.00
L5 × L7	29.7	31.0	31.0	25.3	29.7	29.3	29.4	31.87	30.03	28.16	28.93	27.58	24.73	28.55
L5 × L8	32.0	30.7	32.7	29.7	30.0	30.7	30.8	37.88	33.65	31.50	33.20	29.77	26.21	32.03
L5 × L9	31.3	31.0	33.0	27.7	27.7	30.7	30.2	31.63	28.80	28.43	27.83	26.11	25.90	28.12
L6 × L7	28.3	30.0	32.7	26.3	28.7	30.3	29.4	38.70	31.09	30.63	25.27	29.12	23.51	29.72
L6 × L8	29.3	31.3	35.3	27.7	31.0	32.4	31.2	36.06	30.78	30.89	22.51	25.37	25.26	28.48
L6 × L9	29.3	30.0	32.0	25.3	31.0	31.3	29.8	34.37	35.11	31.78	21.73	27.24	21.16	28.57
L7 × L8	30.3	32.3	34.3	26.3	27.4	30.0	30.1	35.65	31.84	31.94	27.72	25.01	22.94	29.18
L7 × L9	29.3	30.0	33.0	27.3	27.0	29.7	29.4	23.90	16.66	16.60	13.41	11.55	12.31	15.74
L8 × L9	32.7	33.0	33.0	26.7	29.3	31.1	30.9	44.89	35.70	35.89	35.40	32.14	26.77	35.13
Checks														
SC 176	32.3	30.3	31.0	28.0	30.3	33.2	30.9	40.58	32.69	34.21	30.94	29.16	26.73	32.38
SC Pioneer 32D99	30.0	29.7	34.1	28.7	30.0	33.0	30.9	43.49	35.18	36.82	33.00	32.16	30.45	35.18
Fine 276	30.3	31.4	33.2	28.7	28.3	31.7	30.6	40.91	34.93	35.88	33.35	31.27	29.87	34.37
Fine 354	29.3	31.3	33.0	26.0	31.0	31.7	30.4	37.07	33.15	34.67	30.02	26.41	26.53	31.31
Means	30.2	31.0	32.7	26.8	28.8	31.2	30.1	36.25	31.09	30.78	28.44	26.91	24.77	29.71
Increase%	-7.9	-5.2		-14	-7.6			17.77	1.01		14.8	8.65		
L.S.D. 0.05 (G)	**2.9**	**2.5**	**3.2**	**1.9**	**1.7**	**1.4**	**1**	**5.59**	**3.24**	**2.41**	**2.89**	**3.1**	**3.53**	**1.57**

L.S.D. 0.05 Sowing (S) = 0.21	**L.S.D. 0.05 G x S = 1.34**	**L.S.D. 0.05 Sowing (S) = 0.35**	**L.S.D. 0.05 G x S = 2.22**
L.S.D. 0.05 S x D = 0.37	**L.S.D. 0.05 G x D = 1.65**	**L.S.D. 0.05 S x D = 0.61**	**L.S.D. 0.05 G x D = 2.72**
L.S.D. 0.05 Den. (D) = 0.26	**L.S.D. 0.05 G x S x D = 2.33**	**L.S.D. 0.05 Den. (D) = 0.43**	**L.S.D. 0.05 G x S x D = 3.84**

HPD: high planting density (40,000 plant/fed.); MPD: medium planting density (32,000 plant/fed.); NPD: normal planting density (24,000 plant/fed.).

Heterosis

Tables 5, 6, 7 and 8 shows standard heterosis values over check variety Pioneer 32D99 for earliness character and yield attributes of diallel fashion (8×8) in yellow maize genotypes across six environments. The percent of heterosis in F_1 hybrids varied from cross to cross or from character to character.

Days to 50% Tasseling and Plant Height

The earliness of flowering of the maize hybrid is determined by days to tasseling and silking, negative heterosis is desired for these characters and plant height. Results in **Table 6** showed that cross (L5 × L6) had negative and significant standard heterosis for days to 50% tasseling under HPD and NPD in both sowing dates. Furthermore, crosses (L1 × L4), (L1 × L8), (L6 × L7) and (L4 × L8) gave negative values and significant heterosis under some environments for this trait. Only 3, 1 and 4 hybrids in the 1st SD and 4, 0, and 2 out of 36 hybrids showed negative and significant heterosis under HPD, MPD, and NPD, respectively for days to 50% tasseling. These results are in a good agreement with those obtained by **Beck *et al*. (1990), Ali (2009), Abakemal *et al*. (2016), Ali (2016) and Abdel-Moneam *et al*. (2020)**.

For plant height, the results showed crosses (L3×L8), (L3×L9), (L5×L8), (L6×L7), (L6×L8), (L6 × L9), (L7 × L9) and (L8×L9) had negative and significant desirable standard heterosis under all environments in both sowing dates, also crosses (L1×L7), (L1×L9), (L3× L4), (L3× L6), (L4×L6), (L4×L8), (L5×L7) and (L7×L8) showed negative and significant heterosis under all environments except HPD in the 2nd SD, Furthermore, in some environments, the majority of crosses resulted in negative values and significant heterosis for this trait, 29, 34 and 34 out of 36 crosses in the 1st SD and 35, 36 and 36 out of 36 crosses in the 2nd SD exhibited negative and significant heterosis. These results are in a good agreement with those obtained by **Ali (2009); Ali (2016); Sedhom *et al.* (2016)**

Ear Length and Ear Diameter

For ear length (Table **7**), heterosis values over check variety Pioneer 32D99 were positive and significant only in crosses (L3 × L4) under HPD in the 1st SD; (L6 × L9) under MPD in the 1st SD and NPD in two SD; (L4 × L7) and (L4 × L9) under three planting densities in the 2nd SD; and (L8 × L9) under HPD in the 1st SD and under MPD and NPD in the 2nd SD. Similarly, cross (L1 × L6) showed positive and significant standard heterosis for ear diameter under HPD in two SDs and NPD in 2nd SD, as well as cross (L4 × L6) under NPD in 2nd SD. These results are in a good agreement with those obtained by **Ali (2009) and Ali, (2016).**

Number of Rows Per Ear and Number of Rows Per Ear

Heterosis values over check variety Pioneer 32D99 for number of rows per ear (Table 8) exhibited positive and significant estimates in cross (L3 × L8) under HPD and MPD in the 1st SD and NPD in two sowing dates; (L4 × L8) under NPD in two sowing date and MPD in the 2nd SD; (L3 × L6) and (L6 × L8) under NPD in the 2nd and 1St SD, respectively; and (L3 × L4) under MPD in the 2nd SD.

For number of kernels per row, 0, 11, and 21 crosses in 1st SD and 15, 23, and 32 out of 36 F1 crosses had positive and significant heterosis (**Table 8**) for this trait under HPD, MPD and NPD, respectively. Crosses L2 × L6, L2 × L9, L4 × L7, L6 × L9, and L8 × L9 had positive and significant heterosis under all environments. These results are in a good agreement with those obtained by **Ali (2003,2009), Alamerew and Warsi (2015), Ali (2016) and Sedhom *et al*. 2016).**

100- Kernel weight and grain yield

No positive and significant heterosis values were recorded under HPD in both sowing dates for 100- kernel weight except cross (L8 × L9) in 1st SD, while under MPD and NPD 5 and 17 crosses in the 1st SD and 5 and 27 crosses in the 2nd SD showed positive and significant heterosis (Table 9). Cross (L8 × L9) showed positive and significant heterosis under all environments in the 1st SD and NPD in the 2nd SD.

Standard heterosis values ranged from -65.02** to 7.28 for grain yield (ardab fed^{-1}) over check variety Pioneer 32D99 (Table 9), all studied hybrids had negative values and significant heterosis under six environments except cross (L8 × L9) exhibited positive values under HPD for this trait. Similar findings were

Table 6. Heterosis effects for days to 50% tasseling and plant height under planting densities in two sowing dates over check variety Pioneer 32D99

Trait	Days to 50% tasseling (days)						Plant height (cm)					
	1st Sowing date (the 10th of April)			2nd Sowing date (the 28th of May)			1st Sowing date (the 10th of April)			2nd Sowing date (the 28th of May)		
Crosses	HPD	MPD	NPD	HPD	MPD	NPD	HPD	MPD	NPD	HPD	MPD	NPD
L1 × L2	2.21*	0.55	-1.10	1.16	1.16	-0.58	3.13**	-0.69	-3.36**	-2.17**	-4.46**	-5.94**
L1 × L3	0.55	-0.55	0.55	0.58	1.16	1.16	-2.31**	-2.43**	-3.24**	-2.74**	-6.51**	-9.37**
L1 × L4	-1.66	-2.21*	-1.10	-2.91*	-0.58	-1.16	-2.43**	-5.44**	-5.79**	-1.83**	-8.91**	-10.17**
L1 × L5	-1.66	0.00	-1.10	-1.74	1.16	-0.58	-1.50**	-5.09**	-5.44**	-6.97**	-7.89**	-10.40**
L1 × L6	-1.66	0.00	-1.10	-2.33	0.58	-1.16	-5.09**	-2.20**	-5.21**	-3.31**	-7.54**	-11.43**
L1 × L7	-0.55	0.00	0.00	-1.16	2.33	1.16	-4.86**	-5.32**	-3.82**	-5.37**	-13.71**	-12.80**
L1 × L8	-3.87**	-0.55	-1.66	-4.07**	0.58	-1.74	-0.81	-2.08**	-4.28**	-4.00**	-8.46**	-10.17**
L1 × L9	-0.55	2.21*	0.55	-0.58	4.65**	2.91*	-1.39**	-5.21**	-8.45**	-5.71**	-9.71**	-12.57**
L2 × L3	2.21*	0.55	0.55	1.74	1.74	1.74	-5.44**	-12.62**	-8.22**	-12.46**	-12.80**	-15.54**
L2 × L4	4.42**	1.10	1.10	4.07**	4.65**	2.91*	5.32**	-1.04*	0.12	-0.57*	-4.00**	-5.71**
L2 × L5	1.66	2.21*	1.10	1.74	4.65**	1.74	3.47**	-2.55**	-4.86**	-5.26**	-3.43**	-8.34**
L2 × L6	0.00	2.76**	0.55	1.74	4.65**	0.58	-2.89**	-2.89**	-2.20**	-3.31**	-3.89**	-8.91**
L2 × L7	3.31**	3.31**	3.31**	3.49**	5.81**	4.65**	0.23	-2.89**	-2.43**	-3.66**	-4.11**	-8.91**
L2 × L8	1.66	1.10	0.55	2.91*	3.49**	1.16	-4.05**	-4.86**	-4.05**	-4.46**	-6.51**	-10.74**
L2 × L9	3.87**	4.97**	2.76**	4.07**	6.98**	6.40**	1.50**	-3.13**	-6.94**	-4.00**	-5.37**	-8.57**
L3 × L4	-1.10	-1.10	0.00	-0.58	0.00	1.16	2.66**	-4.86**	-8.22**	-6.51**	-9.83**	-11.09**
L3 × L5	0.00	0.00	0.00	0.58	3.49**	0.58	-1.27**	-4.40**	-7.18**	-8.69**	-3.89**	-11.09**
L3 × L6	0.55	1.10	1.10	1.74	3.49**	1.16	-2.08**	-4.98**	-4.17**	-7.20**	-10.97**	-11.09**
L3 × L7	1.10	3.87**	1.10	1.74	6.40**	1.16	-4.17**	-10.76**	-14.00**	-12.91**	-10.17**	-17.26**
L3 × L8	0.55	0.00	-0.55	1.16	1.74	-0.58	-8.91**	-8.91**	-5.90**	-13.83**	-11.20**	-15.89**
L3 × L9	5.52**	1.66	2.21*	6.40**	5.23**	3.49**	-12.38**	-11.57**	-20.37**	-18.86**	-15.77**	-21.83**
L4 × L5	-1.10	-0.55	-2.21*	-0.58	1.16	-1.16	1.97**	-4.28**	-11.11**	-7.31**	-5.94**	-11.09**
L4 × L6	1.66	-0.55	0.55	-0.58	0.00	0.58	-1.27**	-1.97**	-3.82**	-5.71**	-10.63**	-10.51**
L4 × L7	1.66	-1.10	0.00	0.58	0.58	0.58	2.78**	-4.17**	-4.17**	-8.46**	-9.26**	-10.40**
L4 × L8	-0.55	-1.10	-1.66	-1.16	0.58	-1.16	-4.63**	-6.25**	-8.68**	-11.09**	-14.51**	-14.86***
L4 × L9	0.00	1.10	1.10	1.16	4.07**	1.74	-3.13**	-5.44**	-9.38**	-7.89**	-5.94**	-12.80**
L5 × L6	-3.31**	-0.55	-2.76**	-4.07**	1.16	-2.91*	-1.74**	-9.14**	-7.29**	-9.14**	-8.46**	-13.49**
L5 × L7	-0.55	0.00	-1.10	-0.58	1.74	-0.58	-3.47**	-8.22**	-10.30**	-14.97**	-9.71**	-15.09**
L5 × L8	0.00	-1.66	-2.76**	-0.58	0.00	-1.16	-6.48**	-7.87**	-13.19**	-10.17**	-10.17**	-14.74**
L5 × L9	0.00	0.00	-0.55	-0.58	1.74	1.74	-2.20**	-6.48**	-10.42**	-10.29**	-6.74**	-13.14**
L6 × L7	-1.66	0.00	-2.76**	-2.33	0.00	-2.91*	-7.64**	-10.65**	-12.96**	-13.49**	-13.14**	-17.14**
L6 × L8	-2.76**	-0.55	-1.10	-2.91*	-0.58	-0.58	-9.72**	-9.14**	-10.19**	-12.11**	-12.34**	-17.14**
L6 × L9	1.66	0.00	1.10	1.74	2.91*	1.74	-6.94**	-12.15**	-10.76**	-12.23**	-12.34**	-17.14**
L7 × L8	0.00	0.00	-0.55	0.58	2.91*	1.74	-7.75**	-7.75**	-10.07**	-11.66**	-19.54**	-18.06**
L7 × L9	4.97**	2.21*	4.42**	7.56**	8.72**	7.56**	-22.92**	-19.56**	-22.69**	-21.83**	-22.97**	-28.57**
L8 × L9	0.00	0.00	0.55	2.33	1.74	2.91*	9.26**	3.01**	5.90**	4.80**	-1.49**	-1.03**

HPD: high planting density (40,000 plant/fed); MPD: medium planting density (32,000 plant/fed); NPD: normal planting density (24,000 plant/fed).

Table 7. Heterosis effects for ear length and ear diameter under three planting densities in two sowing dates over check variety Pioneer 32D99

Trait	Ear length (cm)						Ear diameter (cm)					
	1st Sowing date (the 10th of April)			2nd Sowing date (the 28th of May)			1st Sowing date (the 10th of April)			2nd Sowing date (the 28th of May)		
Crosses	**HPD**	**MPD**	**NPD**	**HPD**	**MPD**	**NPD**	**HPD**	**MPD**	**NPD**	**HPD**	**MPD**	**NPD**
L1 × L2	-14.14**	-13.47**	-12.46**	-12.89**	-10.80**	-13.59**	-2.67	-5.33	-5.33	0.00	-1.37	-1.37
L1 × L3	-5.72	-4.04	-4.04	-2.44	-5.92	-4.88	-2.67	-4.00	-4.00	-2.74	-1.37	-1.37
L1 × L4	-1.35	-0.67	1.01	0.35	-3.14	-0.70	-4.00	-2.67	-6.67*	-2.74	-5.48*	-1.37
L1 × L5	-10.77**	-7.41*	-9.09**	-10.45**	-10.10**	-8.71*	-5.33	-4.00	-5.33	-4.11	-4.11	-5.48*
L1 × L6	-6.73*	-14.14**	-9.09**	-9.41**	-17.42**	-14.63**	6.67*	4.00	4.00	5.48*	4.11	6.85*
L1 × L7	-5.72	-0.67	-4.04	-0.70	-1.39	2.79	-5.33	-6.67*	-8.00**	-6.85*	-6.85*	-5.48*
L1 × L8	1.01	-0.67	0.00	5.57	0.35	4.53	-5.33	-5.33	-5.33	-1.37	-4.11	-1.37
L1 × L9	2.69	-4.04	-0.67	2.79	-3.14	1.05	0.00	-4.00	-4.00	0.00	-1.37	2.74
L2 × L3	-7.41*	-5.72	-10.77**	-4.88	-4.88	-7.67*	-2.67	-5.33	-5.33	-1.37	-1.37	-1.37
L2 × L4	-2.02	-4.04	-4.04	2.79	-2.79	-0.70	1.33	-4.00	-5.33	-1.37	-4.11	-1.37
L2 × L5	-9.76**	-9.09**	-12.46**	-4.18	-6.97*	-5.23	-6.67*	-10.67**	-9.33**	-8.22**	-5.48*	-9.59**
L2 × L6	-8.42*	-6.73*	-9.76**	-10.10**	-11.50**	-12.20**	1.33	2.67	0.00	2.74	1.37	2.74
L2 × L7	0.00	-2.36	1.01	-0.70	-0.70	-0.70	-5.33	-9.33**	-5.33	-9.59**	-8.22**	-13.70**
L2 × L8	-7.07	-6.73*	-9.09**	-4.18	-4.18	-4.18	-6.67*	-10.67**	-5.33	-12.33**	-6.85*	-13.70**
L2 × L9	4.38	-2.02	1.01	1.05	4.53	2.09	-2.67	-8.00**	-5.33	0.00	0.00	2.74
L3 × L4	3.70**	5.39	-5.05	4.53	1.05	1.74	-5.33	-8.00**	-9.33**	-6.85*	-9.59**	-1.37
L3 × L5	-10.77	-7.07*	-9.09**	-5.23	-3.14	-4.88	-4.00	-6.67*	-8.00**	-5.48*	-2.74	-1.37
L3 × L6	0.34	-2.36	3.37	0.70	1.05	-2.44	-1.33	-4.00	-1.33	1.37	4.11	6.85*
L3 × L7	-4.04*	-3.37	-7.41*	-0.70	-4.18	-0.70	-10.67**	-9.33**	-12.00**	-9.59**	-9.59**	-5.48*
L3 × L8	-7.41	-4.38	-9.09**	-2.44	-7.67*	-3.14	-5.33	0.00	-5.33	-8.22**	-8.22**	-1.37
L3 × L9	-4.04	-5.72	-7.41*	-3.14	-6.62	-4.88	-12.00**	-9.33**	-9.33**	-6.85*	-8.22**	-1.37
L4 × L5	-1.35	2.02	2.69	4.53	-1.39	-0.70	-12.00**	-10.67**	-14.67**	-8.22**	-12.33**	-9.59
L4 × L6	-0.67	3.37	2.69	0.70	-3.14	2.09	-2.67	-2.67	-4.00	0.00	-2.74	2.74**
L4 × L7	0.34	2.02	1.01	8.01*	6.97*	11.50**	-8.00**	-9.33**	-6.67*	-8.22**	-6.85*	-9.59**
L4 × L8	-5.72	-1.35	1.01	6.27	-0.70	-2.44	-13.33**	-8.00**	-6.67*	-6.85*	-9.59**	-5.48*
L4 × L9	1.68	4.38	2.69	9.06**	8.36*	10.10**	-6.67*	-9.33**	-10.67**	-5.48*	-6.85*	-9.59**
L5 × L6	-0.67	-5.72	-2.36	-4.88	-0.70	-1.39	-5.33	-6.67*	-4.00	-6.85*	-5.48*	-9.59**
L5 × L7	-0.67	-4.04	-0.67	6.27	5.92	3.48	-10.67**	-12.00**	-12.00**	-9.59**	-13.70**	-13.70**
L5 × L8	-6.06	-6.40	-5.72	-2.44	-4.18	-4.18	-9.33**	-9.33**	-10.67**	-10.96**	-10.96**	-13.70**
L5 × L9	-2.02	-2.36	1.01	5.57	2.09	6.97*	-14.67**	-12.00**	-9.33**	-6.85*	-9.59**	-5.48*
L6 × L7	-1.35	1.01	6.06	4.53	2.79	8.71*	-9.33**	-10.67**	-5.33	-5.48*	-6.85*	-5.48*
L6 × L8	-3.37	2.69	-0.67	-1.74	-3.48	3.14	-2.67	-2.67	-4.00	-5.48*	-1.37	-5.48*
L6 × L9	5.72	10.10**	10.10**	-0.70	5.57	8.01*	0.00	-2.67	-1.33	-5.48*	0.00	-5.48*
L7 × L8	-0.67	-3.37	1.01	0.00	1.05	5.57	-9.33**	-12.00**	-13.33**	-12.33**	-15.07**	-9.59**
L7 × L9	-7.41*	-12.46**	-9.09**	-14.63**	2.79	0.35	-17.33**	-20.00**	-17.33**	-20.55**	-9.59**	-21.92**
L8 × L9	6.73*	2.02	6.06	4.18	11.50**	8.71*	-4.00	-10.67**	-8.00**	-8.22**	-6.85*	-9.59**

HPD: high planting density (40,000 plant/fad); MPD: medium planting density (32,000 plant/fad); NPD: normal planting density (24,000 plant/fad).

Table 8. Heterosis effects for number of rows per ear and number of kernels per row under three planting densities in two sowing dates over check variety Pioneer 32D99

Trait	Number of rows per ear						Number of kernels per row					
	1st Sowing date (the 10th of April)			2nd Sowing date (the 28th of May)			1st Sowing date (the 10th of April)			2nd Sowing date (the 28th of May)		
Crosses	**HPD**	**MPD**	**NPD**	**HPD**	**MPD**	**NPD**	**HPD**	**MPD**	**NPD**	**HPD**	**MPD**	**NPD**
L1 × L2	-14.16**	-12.85**	-9.15**	-15.50**	-12.01**	-10.04**	-7.84**	-1.86	3.07*	5.19	10.00**	15.00**
L1 × L3	-6.32**	-2.40*	0.22	-10.48**	-4.80**	-0.44	0.16	-0.40	7.84**	-1.92	3.85	1.73
L1 × L4	-6.75**	0.22	0.22	-3.06**	1.31	-2.18*	-0.57	2.50*	6.30**	5.29	6.15*	14.42**
L1 × L5	-12.85**	-15.47**	-5.88**	-13.97**	-15.28**	-10.04**	-3.47**	3.55**	-2.58*	0.48	6.92*	8.85**
L1 × L6	-5.88**	-4.14**	-7.63**	-7.64**	-2.18*	-4.80**	-15.99**	-11.07**	-6.87**	-4.13	-4.62	5.58*
L1 × L7	-11.11**	-11.98**	-6.75**	-10.26**	-14.41**	-11.79**	-5.65**	4.20**	5.65**	-7.12*	3.46	12.88**
L1 × L8	1.53	-2.61**	1.31	-5.46**	-3.06**	-3.06**	-3.47**	0.16	-1.62	-2.79	5.38	20.19**
L1 × L9	-6.54**	-3.27**	-6.75**	-5.02**	-3.06**	-3.06**	-5.01**	2.50*	7.19**	-7.40*	5.19	15.00**
L2 × L3	-6.10**	-0.65	-1.09	-0.87	-2.62*	-6.33**	-5.17**	-2.02	-0.48	2.40	9.23*	17.79**
L2 × L4	-8.50**	-3.27**	0.22	-3.93**	-0.44	-2.18*	-2.83*	2.58*	4.52**	4.62	18.65**	20.77**
L2 × L5	-11.11**	-11.11**	-11.98**	-13.97**	-12.66**	-19.65**	-1.37	1.78	8.24**	8.85**	15.87**	21.92**
L2 × L6	-8.71**	-11.55**	-4.14**	-10.92**	-5.68**	-10.92**	-2.91*	2.34*	9.29**	11.35**	19.81**	18.65**
L2 × L7	-13.51**	-11.11**	-3.27**	-18.12**	-15.28**	-14.41**	-11.07**	-7.67**	0.32	8.56*	14.23**	19.23**
L2 × L8	-8.28**	-1.53	2.83**	-8.30**	-8.30**	-4.80**	-2.10*	-1.70	0.65	8.17*	13.65**	21.63**
L2 × L9	-5.66**	-9.37**	-2.40*	-8.30**	-7.42**	-7.42**	-1.37	6.87**	10.90**	5.29*	15.00**	18.65**
L3 × L4	-2.61*	0.22	-5.01**	0.22	4.80**	-1.31	-10.02**	-2.75*	2.58*	-14.42**	-4.23	24.04**
L3 × L5	-3.92**	-3.27**	-2.40*	-2.40*	-5.68**	0.44	-17.45**	-11.31**	0.16	5.58*	5.00	10.77**
L3 × L6	-5.88**	-5.01**	1.09	1.31	-0.44	5.68**	-9.53**	-2.02	3.23**	-4.23	4.62	16.92**
L3 × L7	-11.11**	-8.50**	-3.27**	-10.26**	-7.42**	-3.93**	-11.07**	-7.92**	-0.81	7.60*	0.19	2.88
L3 × L8	4.58**	6.32**	8.93**	-3.71**	-0.44	6.55**	-7.19**	-8.89**	-1.29	6.73*	3.27	2.50
L3 × L9	-8.93**	1.09	-0.65	-8.30**	-5.68**	-4.80**	-20.52**	-14.94**	-5.98**	-7.98*	-4.42*	-5.96
L4 × L5	-8.50**	-5.88**	-4.14**	-3.06**	-8.30**	-3.93**	-4.52**	-0.57	0.81	8.65*	9.23**	13.85**
L4 × L6	-9.15**	-16.34**	-7.63**	-3.93**	-6.55**	-3.06**	-8.64**	-0.65	-1.13	3.85	5.96	11.54**
L4 × L7	-10.46**	-2.40*	0.22	-10.26**	-6.55**	-4.80**	-2.42*	3.15*	7.59**	5.77*	13.85**	20.00**
L4 × L8	-3.27**	1.09	5.45**	1.53	5.68**	2.18*	-8.80**	0.16	4.04**	-2.88	8.27*	19.71**
L4 × L9	-3.27**	-1.53	-2.40*	-0.44	-5.68**	0.44	-5.65**	6.62**	8.32**	-0.48	13.08**	22.12**
L5 × L6	-9.15**	-8.50**	-5.88**	-12.88**	-7.42**	-9.17**	-3.80**	-3.23**	0.65	5.19	7.69*	14.42**
L5 × L7	-5.88**	-10.24**	-4.14**	-7.64**	-10.92**	-12.66**	-4.28**	-2.10*	4.68**	2.40	14.62**	20.48**
L5 × L8	-2.83**	-9.37**	-4.14**	-12.66**	-2.18*	-8.30**	-4.28**	-0.08	8.72**	6.35*	7.88*	8.65**
L5 × L9	-13.73**	-8.50**	-5.01**	-10.92**	-10.92**	-10.04**	-6.14**	-0.65	5.49**	2.40	9.04**	16.15**
L6 × L7	-14.38**	-15.47**	-8.50**	-13.54**	-11.79**	-15.28**	-0.15	-3.07*	4.28**	9.81**	23.27**	22.50**
L6 × L8	-8.50**	-2.40*	7.19**	-8.08**	0.44	-4.80**	-5.09**	0.32	8.56**	3.46	10.19**	14.04**
L6 × L9	-7.84**	-5.88**	-2.40*	-10.26**	-9.17**	-8.30**	-1.05	5.17**	7.59**	6.15*	21.54**	22.31**
L7 × L8	-6.54**	-2.40*	-5.01**	-9.83**	-12.66**	-7.42**	-2.02	-1.29	0.81	13.27**	15.19**	14.23**
L7 × L9	-18.08**	-13.73**	-12.85**	-20.09**	-7.42**	-8.30**	-18.82**	-11.31**	-8.72**	-8.46*	5.96*	4.81*
L8 × L9	-6.10**	-2.40*	-3.70**	-13.10**	-12.88**	-5.46**	2.02	8.32**	11.31**	14.71**	18.65**	22.21**

HPD: high planting density (40,000 plant/fad); MPD: medium planting density (32,000 plant/fad); NPD: normal planting density (24,000 plant/fad).

Table 9. Heterosis effects for 100-kernel weight and grain yield (ardab fed^{-1}) under three planting densities in two sowing dates over check variety Pioneer 32D99

Trait	100-kernel weight						Grain yield (ardab fed^{-1})					
	1st Sowing date (the 10th of April)			2nd Sowing date (the 28th of May)			1st Sowing date (the 10th of April)			2nd Sowing date (the 28th of May)		
Crosses	HPD	MPD	NPD	HPD	MPD	NPD	HPD	MPD	NPD	HPD	MPD	NPD
L1 × L2	-11.67*	-3.33	2.22	-9.30**	5.81*	9.30**	-26.10**	-31.60**	-38.45**	-21.93**	-18.30**	-25.53**
L1 × L3	-2.22	12.22**	12.22**	-2.33	-2.33	11.63**	-3.25	-18.62**	-26.78**	-1.87	-9.94*	-25.89**
L1 × L4	-6.67	3.33	10.00*	-10.47**	6.98*	11.63**	-19.20**	-29.15**	-29.75**	-16.20**	-23.10**	-20.04**
L1 × L5	1.11	2.22	7.78	-3.49	5.81*	10.47**	-21.01**	-31.56**	-32.27**	-10.61*	-18.00**	-21.46**
L1 × L6	6.67	7.78	12.22**	-3.49	1.16	12.79**	-15.53*	-32.76**	-31.69**	-22.59**	-27.80**	-28.85**
L1 × L7	6.67	5.56	7.78	-9.30**	-2.33	6.98*	-18.14**	-27.88**	-25.42**	-20.72**	-14.02**	-26.72**
L1 × L8	1.11	0.00	5.56	2.33	-1.16	9.30**	-11.77	-21.71**	-27.83**	0.09	-8.87*	-12.19**
L1 × L9	8.89	-3.33	7.78	-9.30**	-1.16	15.12**	-15.38*	-35.82**	-29.32**	-8.76*	-27.74**	-29.10**
L2 × L3	3.33	2.22	8.89*	0.00	4.65	12.79**	-12.04	-25.27**	-29.73**	-6.85	-11.66**	-17.79**
L2 × L4	-1.11	0.00	7.78	-16.28**	4.65	5.81*	-16.77*	-20.44**	-19.66**	-5.14	-23.17**	-21.68**
L2 × L5	1.11	14.44**	14.44**	-12.79**	0.00	9.30**	-17.70**	-40.45**	-34.85**	-22.09**	-25.81**	-28.05**
L2 × L6	2.22	6.67	5.56	-12.79**	1.16	2.33	-19.88**	-28.01**	-27.75**	-27.16**	-22.21**	-27.12**
L2 × L7	-3.33	3.33	15.56**	-8.14*	-4.65	15.12**	-20.04*	-34.02**	-35.27**	-25.38**	-21.01**	-33.71**
L2 × L8	-2.22	5.56	5.56	-12.79**	-4.65	5.81*	-15.46*	-26.85**	-20.71**	-11.73*	-22.94**	-27.50**
L2 × L9	-5.56	8.89	5.56	-6.98*	1.16	16.28**	-13.62*	-28.26**	-22.78**	-13.40**	-20.24**	-33.20**
L3 × L4	7.78	13.33**	15.56**	3.49	-1.16	12.79**	-2.76	-25.53**	-33.16**	6.58	-5.10	-25.18**
L3 × L5	0.00	0.00	5.56	-4.65	2.33	9.30**	-15.16*	-22.44**	-22.06**	0.46	-6.41	-22.80**
L3 × L6	6.67	-5.56	7.78	-11.63**	-9.30**	6.98*	-16.94*	-29.47**	-25.23**	-9.35*	-11.47*	-24.51**
L3 × L7	-10.00*	-2.22	11.11**	-6.98*	2.33	9.30**	-25.37**	-37.10**	-41.00**	-14.02**	-25.70**	-29.15**
L3 × L8	-1.11	3.33	6.67	-2.33	-1.16	5.81*	-6.88	-21.19**	-29.21**	-2.13	-10.89*	-15.93**
L3 × L9	3.33	10.00*	11.11*	-6.98*	-2.33	2.33	-33.18**	-35.80**	-43.68**	-24.66**	-34.82**	-37.50**
L4 × L5	3.33	7.78	11.11*	-11.63**	0.00	2.33	-26.12**	-32.38**	-34.50**	-14.54**	-21.23**	-24.30**
L4 × L6	7.78	5.56	11.11*	-5.81*	-9.30**	13.95**	-16.77*	-25.98**	-28.50**	-21.30**	-21.75**	-20.01**
L4 × L7	-3.33	-2.22	11.11*	-9.30**	-11.63**	2.33	-18.93**	-27.55**	-30.07**	-2.65	-10.20*	-17.41**
L4 × L8	-5.56	-4.44	6.67	-11.63**	-1.16	4.65	-15.46*	-25.08**	-20.90**	-10.76*	-20.26**	-31.85**
L4 × L9	-2.22	2.22	6.67	-8.14*	4.65	0.00	-14.55*	-28.99**	-27.36**	-15.46**	-18.88**	-16.12**
L5 × L6	1.11	4.44	6.67	-6.98*	0.00	10.47**	-25.02**	-38.44**	-38.06**	-32.10**	-25.81**	-31.04**
L5 × L7	-1.11	3.33	3.33	-9.30**	3.49	2.33	-26.73**	-30.94**	-35.26**	-12.35**	-16.44**	-25.07**
L5 × L8	6.67	2.22	6.67	3.49	4.65	6.98*	-12.89*	-22.63**	-27.57**	0.59	-9.81*	-20.60**
L5 × L9	4.44	3.33	10.00*	-3.49	-3.49	6.98*	-27.28**	-33.77**	-34.63**	-15.67**	-20.88**	-21.52**
L6 × L7	-5.56	0.00	8.89*	-8.14*	0.00	5.81*	-11.01	-28.51**	-29.56**	-23.44**	-11.76**	-28.76**
L6 × L8	-2.22	4.44	17.78**	-3.49	8.14*	12.79**	-17.09*	-29.23**	-28.97**	-31.79**	-23.12**	-23.47**
L6 × L9	-2.22	0.00	6.67	-11.63**	8.14*	9.30**	-20.97**	-19.27**	-26.92**	-34.16**	-17.46**	-35.88**
L7 × L8	1.11	7.78	14.44**	-8.14*	-4.65	4.65	-18.02**	-26.78**	-26.57**	-16.00**	-24.23**	-30.48**
L7 × L9	-2.22	0.00	10.00*	-4.65	-5.81*	3.49	-45.03**	-61.70**	-61.83**	-59.37**	-65.02**	-62.71**
L8 × L9	8.89*	10.00*	10.00*	-6.98*	2.33	8.14*	3.21	-17.92**	-17.48**	7.28	-2.61	-18.89**

HPD: high planting density (40,000 plant/fad); MPD: medium planting density (32,000 plant/fad); NPD: normal planting density (24,000 plant/fad).

detected by **Beck *et al.* (1990), Ali (2003, 2009), Ali (2016), Sedhom *et al*. (2016) and Talukder *et al*. (2016)**.

From the previous results, the yellow maize cross (L8 × L9) was surpassing the check cultivars SC 176, SC Pioneer 32D99, Fine 276, and Fine 354 for ear length, number of kernels per row, 100-kernel weight, and grain yield under most environments. Also, it could be recommended the following F_1 crosses for using in maize improvement program under planting density, (L1 × L3), (L1 × L8), (L3 × L8), (L3 × L4), and (L3×L5). Similar results were reported by several investigators (**Ali, 2016; Sedhom *et al*., 2016; Murtadha *et al*., 2018; Turkey *et al*., 2018; Abdel-Moneam *et al*., 2020; Rabbani and Safdary, 2021; Omar *et al*., 2022).**

Simple Correlation

Simple correlation based on the combined data over environments was calculated among all possible combinations of the studied characters and listed in Table 10.

Days to 50% tasseling had negative correlations with ear length, ear diameter, number of rows per ear, 100-kernels, and grain yield. Plant height had positive and significant correlations with ear diameter, number of kernels/ear, and grain yield. Positive and highly significant correlations were registered between ear length with both number of kernels per row and grain yield. Ear diameter showed positive and significant correlations with number of rows per ear and grain yield. 100-kernels weight had negative correlations with days to 50% tasseling, ear length, and number of kernels per row. Grain yield had positive and significant associations with plant height (0.672**), ear length (0.341*), ear diameter (0.375*), number of rows per ear (0.596**), and number of kernels per row (0.486**). Similar results were reported by several investigators **(Nzuve *et al*., 2014; Ali, 2016; Sardar *et al*., 2019)**. In this connection, **Ali (2016)** showed that maize grain yield was significantly and positively associated with number of kernels per row, ear length, ear diameter and plant height.

Conclusions

Breeding for increase number of plants per unit area is an important factor to improve maize yield. In some environments, the cross L8 x L9 showed desirable standard heterosis for grain yield, number of grains per row, and plant height. The percent of heterosis for grain yield varied from -65.02 to 7.28%. Hybrids (L4 × L7), (L6×L7), and (L8×L9) can be used as commercial cultivars under similar environmental conditions.

Declarationo of Competing Interest

The authors declare no conflict of interest.

Funding

This work was supported by the Zagazig University and Fine Seeds International Company, Egypt.

Acknowledgments

The authors would like to thank the Zagazig University and Fine Seeds International Company, Egypt for financial support to this research.

Table 10. Simple correlation coefficients as calculated from the combined across six environments for various metric traits in maize genotypes

	Days to 50% tasseling (days)	Plant height (cm)	Ear length (cm)	Ear diameter (cm)	Number of rows per ear	Number of kernels per row	100-kernel weight	Grain yield (ardab fed^{-1})
Days to 50% tasseling (days)	1							
Plant height (cm)	0.145^{ns}	1						
Ear length (cm)	-0.080^{ns}	0.114^{ns}	1					
Ear diameter (cm)	-0.150^{ns}	0.388*	-0.126^{ns}	1				
Number of rows per ear	-0.075^{ns}	0.194^{ns}	0.287^{ns}	0.344*	1			
Number of kernels per row	0.057^{ns}	0.574**	0.469**	0.036^{ns}	-0.003^{ns}	1		
100-kernel weight	-0.060^{ns}	0.227^{ns}	-0.017^{ns}	0.234^{ns}	0.154^{ns}	-0.048^{ns}	1	
Grain yield (ardab fed^{-1})	-0.204^{ns}	0.672**	0.341*	0.375*	0.596**	0.486**	0.298^{ns}	1

ns, * and ** no significant, significant at 0.05 and significant at 0.01, probability levels respectively.

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تقدير قوة الهجين لمحصول الحبوب ومساهماته في الذرة الشامية تحت ثلاث كثافات نباتية وميعادين للزراعة

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تعتبر الذرة الشامية من محاصيل الحبوب الهامة نظرًا لارتفاع إنتاجيتها من العلف والحبوب. تم اجراء هذه الدراسة بهدف تقييم متوسط سلوك وقوة الهجين لـ 36 هجينًا من الذرة الشامية الصفراء فى الجيل الاول F_1 مع 4 أصناف تجارية تحت ثلاث كثافات نباتية (24000، 32000 و 40.000 نبات/فدان تمثل الكثافة العادية، المتوسطة والمرتفعة، علي الترتيب) تحت ميعادين للزراعة، الميعاد الأمثل (10 أبريل) والمتأخر (28 مايو) في وسط مصر (مركز الفشن - محافظة بني سويف). أظهرت النتائج وجود فروق معنوية بين هجن الذرة الشامية لجميع الصفات المدروسة في جميع البيئات. أثر ميعاد الزراعة المتأخر سلبياً على متوسط سلوك جميع هجن الذرة لجميع الصفات تحت الدراسة. تسببت كثافة الزراعة العالية (HPD) والمتوسطة (MPD) في زيادة عدد الأيام حتي طرد 50% من النورة المذكرة (التأخير في النضج)، وزيادة ارتفاع النباتات وزيادة محصول الحبوب للفدان بنسبة 17.77% و 1.01% في ميعاد الزراعة الأمثل، و 14.8% و 8.65% في ميعاد الزراعة المتأخر، علي التوالي. بينما انخفض طول الكوز، قطر الكوز، عدد الصفوف/كوز، عدد حبوب الصف، وزن 100 حبة ، محصول الحبوب/نبات تحت كثافة الزراعة العالية (HPD) والمتوسطة (MPD) مقارنة بالكثافة العادية (NPD). تراوح متوسط محصول الحبوب من 16.6 إلى 44.89 أردب / فدان في ميعاد الزراعة الأمثل وتراوح بين 11.55 إلى 35.40 أردب/فدان في ميعاد الزراعة المتأخر. أعطي الهجين L9 × L8 أعلى متوسط لمحصول الحبوب في جميع البيئات (35.13 أرداب/فدان) يليه الهجن L1 × L3، L1 × L8، L3 × L8، L3 × L4، و L3 × L5 (32.65 ، 32.65 ، 32.5 ، 32.49 و 32.34 أردب/فدان، على التوالي). تم استخدام الصنف التجاري Pioneer 32D99 لحساب قوة الهجين القياسية، وسجلت قوة هجين سالبة ومعنوية في الهجن (L1 × L4) و (L1 × L8) و (L6 × L7) و(L4 × L8) لصفة عدد الأيام حتى طرد 50% من النورة المذكرة وفي الهجن (L3 × L8)، (L3 × L9)، (L5 × L8)، (L6 × L7)، (L6 × L8)، (L6 × L9)، L7 × L9) و (L8 × L9) لصفة ارتفاع النبات تحت معظم البيئات المدروسة. وعلي العكس ، تم الحصول علي قيم موجبة ومعنوية لقوة الهجين القياسية في الهجن (L4 × L7) و(L4 × L9) لطول الكوز في ميعاد الزراعة المتأخر؛ الهجين (L1 × L6) لقطر الكوز؛ الهجن (L3 × L8) و (L4 × L8) لعدد الصفوف للكوز في معظم البيئات؛ الهجن (L2 × L6)، (L2 × L9)، (L4 × L7)، (L6 × L9) و (L8 × L9) لعدد الحبوب/الصف في جميع البيئات. أعطي الهجين (L9 × L8) قيم موجبة لقوة الهجين لصفة وزن 100 حبة تحت جميع البيئات في ميعاد الزراعة الأمثل وتحت كثافة الزراعة العادية في ميعاد الزراعة المتأخر وكذلك محصول الحبوب تحت الكثافة النباتية المرتفعة. وتراوحت قوة الهجين في محصول الحبوب للفدان تحت جميع البيئات من -65.02 إلى 7.28%. وسُجل ارتباط موجب ومعنوي بين محصول الحبوب وكل من، ارتفاع النبات (0.672 **) ، طول الكوز (0.341 *) ، قطر الكوز (0.375 *)، عدد الصفوف للكوز (0.596 **) ، وعدد الحبوب في الصف (0.486 * *). وتوصي الدراسة بإدراج الهجن المبشرة في برامج التربية والإنتاج التجاري للذرة الشامية الصفراء.

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