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SELECTION OF NEW POPCORN HYBRIDS UNDER TWO PLANT DENSITIES

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ABSTRACT

Popcorn (Zea mays L. everta) is an important snack food worldwide with significant nutritional benefits and its market has been continuously growing in Egypt. Therefore the breeding for new hybrids have high grain yield and popping volume should be started. Thirteen new popcorn inbred lines were crossed with three inbred lines as testers in 2017 season. The 39 hybrids were evaluated in two individual experiments, the first under a density of 21000 plant/feddan and the second under a density of 31500 plant/feddan in 2018 season. Combined analysis showed that the higher plant density produced taller plants, higher grain yield and high grain moisture content at popping than these under low plant density. While, days to 50% silking, No. of kernels/10g, popping volume, unpopped kernels% and quality score were not affected by plant density. Significant variability among popcorn hybrids were detected for all traits. While the interaction between hybrid × plant density was not significant for most studied traits. Two new popcorn hybrids (Sk210×Hp6208 and Sk213×Hp6208) had high grain yield and popping volume. The additive gene effects were more important than non-additive ones for the inheritance of days to 50% silking, plant height, number of kernels/10g, popping volume and quality score. While, the non additive gene effects were more important than additive ones in the inheritance of grain yield, grain moisture content at popping and unpopped kernels%. The best new inbred lines for general combing ability effects were Sk204 and Sk206 for grain yield and Sk201 and Sk211 for popping volume. While, the inbred lines Hp6215 and Hp6208 were the best testers for general combing ability effects for grain yield and popping volume, respectively. Two hybrids (Sk207×Hp6252 and Sk213×Hp6208) exhibited desirable specific combing ability effects for grain yield and popping volume.

Key words: ***Line × tester, Additive gene effects, Non additive gene effects, Popcorn, Popping volume.***

INTRODUCTION

Popcorn (*Zea mays* L. *everta*) is essentially a flint type of maize grown by native Indians in south, central and north America. The spread and distribution of maize in other parts of the world resulted in increased production, consumption and popularity of popcorn. In Egypt as a result of increasing the demand for consumption of popcorn, hence it is imported from foreign countries. So the price of popcorn in Egypt is higher four times than that of common corn grain (personal observation). Therefore it is necessary for the national program for corn research in Egypt to produce popcorn hybrids of high grain yield and quality. Popping volume is one of the most important task in popcorn breeding programs, it depends on many factors such as grain moisture content, genotype, physical properties of the kernel, popping method, popping temperature, harvesting and handling practices and grain physical damages. Grain moisture content is one of the most critical factors because it affects the rate and extent of pressure built up in starch granules (Hoseney *et al* 1983). The optimum grain moisture content at popping varies among genotypes, but usually ranges from 10 to 15%, if this content is low (below 10%) the amount of water in the kernel is not sufficient to transform into steam that would provide the pressure necessary for completion of popping. on the other hand, it is assumed that high grain moisture (over 17%) weakens the pericarp causing popping before the adequate pressure is provided (Hoseney *et al* 1983). Industry standard has not been developed for kernel size determination. A common measure is based on the number of kernels in 10 grams, which is classified into large size (52-67), medium size (68-75) and small size (76-105) kernels (Song *et al* 1991, Singh *et al* 1997 and Allred-Coyle *et al* 2000). Factors such as kernel size (No. of kernels/10g) and shape have an impact on popping volume (Karababa 2006 and Ertas *et al* 2009). Large sized kernels mostly produce a lower popping volume due to high percentage of soft endosperm (Gökmen 2004 and Pajic and Babić 1991), while Lin and Anantheswaran (1988) found that the large sized kernels had a significantly higher popping volume than the small sized kernels. Meanwhile, Jele *et al* (2014) stated that the medium sized kernels are appealing to both consumers and processors. Singh *et al* (1997) found that unpopped kernels are not desirable because these do not contribute to popping volume and its considered defective. Sakin *et al* (2005) found that popping volume was significantly higher in hybrid genotypes than open-pollinated cultivars, whereas the percentage of unpopped kernels was 50% lower in hybrids. Babić and Pajic (1992) and Halluer (1994) found that not only genetic potential of hybrid but also cultural practices such plant density have important effects on popcorn yield. Ülger (1998) reported that highest popcorn yield obtained with planting 15cm intra-row and 70cm inter-row spacing. Sezer and Yanbeyi (1997) demonstrated that ear traits were negatively affected by increases in plant densities, although plant height, ear height and grain yield increased with increasing plant density. Junior *et al* (2013) found that the increase in plant population causes a reduction in the number of grains per ear, while the popping volume index is not affected by row spacing or plant population. Miranda *et al* (2008) and Pajic *et al* (2008) concluded that additive gene effects were more important than non additive effects for popping volume. Jele *et al* (2014) found that the additive gene effects were more prominent than non additive effects for unpopped kernels, moisture content, quality score and kernels/10g. Oliveira *et al* (2019) found that the non additive effects were the most important in the genetic control of grain yield and popping volume.

The objectives of this study were to determine combining ability for thirteen new popcorn inbred lines and identify the superior hybrids for grain yield and quality.

MATERIALS AND METHODS

Thirteen new yellow popcorn inbred lines in the selfing generation S_6 developed from the three popcorn populations at Sakha Research Station were crossed with the three inbred lines testers, Hp6208, Hp6215 and Hp6252 in 2017 season. The resulting 39 single crosses were evaluated at Sakha Research Station, Egypt in two experiments, i.e. the first under a plant density of 21000 plant per feddan (feddan= 4200 m^2) and the second under a plant density of 31500 plant per feddan in 2018 season. The experiments were performed using a randomized complete block design with three replications. The experimental plot was one row of 4 m length with 0.8 m width and 25 cm between hills in first experiment and 16.6 cm between hills in second experiment. The hybrids were managed using standard production practices recommended for maize in Egypt. The data were recorded on days to 50% silking, plant height (cm), grain yield expressed in ardab/feddan (ard/fed) (ardab= 140 kg) adjusted at 15.5% grain moisture. Popping traits taken on a grain sample from each plot were grain moisture at popping%, kernel size determined by number of kernels per 10g, for each classification of kernels, i.e. for large size (52-67), medium size (68-75) and small size (76-105), popping volume measured by placing 30g of grain in hot air popping machine (Volt: 220v, Hz:50Hz, power: 1200w) for 2 minutes, then the popcorn volume was measured in a 2000ml graduated cylinder and finally the popping volume was determined as the ratio between the expanded popcorn volume and the weight of 30g of grains (ml/g), percentage of unpopped kernels measured by dividing number of unpopped kernels on the original number of kernels in 30g and the quality score of popcorn flakes after popping measured visually using a scale of 1-5 in terms of whiteness and uniformity of flake colour, flake size, uniformity of flake shape (mushroom or butterfly), tenderness and amount of hulls, the score of 1 was the best quality and 5 was the worst.

The combined analysis of variance for the eight studied traits across the two experiments was done after a test of homogeneity of mean squares of error for the two experiments according to Snedecor and Cochran (1967).

The line × tester procedure according to Kempthorne (1957) was used to estimate general and specific combining ability variance and effects.

RESULTS AND DISCUSSION

Analysis of variance for eight traits across two plant densities is shown in Table (1). The effects of plant density (D) on plant height, grain yield and grain moisture content at popping were significant. While traits, days to 50% silking, No. of kernels/ 10g, popping volume, unpopped kernels% and quality score were not affected by plant density. The results in Table (2), exhibited that the higher plant density (31500 plant/fed) produced taller plants, higher grain yield and higher grain moisture content at popping than those under low plant density (21000 plant/fed). Gözübenli and Konuskan (2010) found that plant height and grain yield increased with increases in plant density. Junior *et al* (2013) reported that the popping expansion index is not affected by plant density.

Table 1. Mean squares from analysis of variance for eight traits across two plant densities.

SOV	df	Days to 50% silking	Plant height (cm)	Grain yield (ard/fed)	Grain moisture content (%)	No. of kernels/ 10g	Popping volume (ml/g)	Unpopped kernels (%)	Quality score
Density (D)	1	0.517	4350.77*	225.48*	3.90*	83.16	251.10	49.20	0.48
Rep/D	4	1.278	207.39	14.01	0.38	180.33	73.62	45.48	1.20
Hybrid (H)	38	20.636**	2162.33**	17.83**	0.66**	77.66**	117.85**	13.04*	0.39**
H×D	38	0.938	70.32	6.42	0.53**	16.70*	7.72	7.64	0.06
Error	152	0.87	67.46	4.58	0.16	9.90	8.40	8.36	0.07

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

Table 2. Effects of plant density on plant height, grain yield and moisture content.

Density	Plant height (cm)	Grain yield (ard/fed)	Grain moisture content (%)
21000 plant/fed	227.23	13.72	12.21
31500 plant/fed	235.85	15.68	12.46
LSD 0.05	5.21	1.35	0.22
0.01	8.9	2.25	0.37

Regarding to Table (1), there were highly significant differences among popcorn hybrids (H) for all traits. While the interaction between hybrid × plant density was not significant for all traits, except for grain moisture content at popping and number of kernels/ 10g. Significant variability among popcorn hybrids for plant height, grain yield and quality traits were reported in previous studies (Sakin *et al* 2005, Moterle *et al* 2012 and Jele *et al* 2014).

Mean performance of 39 popcorn hybrid for eight traits across the two densities is presented in Table (3). Means of days to 50% silking ranged from 55.83 days for Sk208×Hp6215 to 62.33 days for Sk210×Hp6208 with a grand mean of 58.8 days, the best hybrids for earliness were Sk202×Hp6215, Sk203×Hp6215, Sk203×Hp6252, Sk204×Hp6215, Sk204×Hp6252, Sk205×Hp6215, Sk205×Hp6252, Sk207×Hp6252, Sk208×Hp6215 and Sk208×Hp6252. These hybrids can be harvested at 100 days from planting.

For plant height (cm), the means ranged from 202.3 to 269.7cm for Sk202×Hp6252 and Sk212×Hp6208, respectively, with a grand mean of 231.5 cm. The tallest hybrids were Sk204×Hp6208, Sk211×Hp6208 and Sk212×Hp6208, while the shortest hybrids were Sk202×Hp6252, Sk209×Hp6215 and Sk209×Hp6252.

In general, a popcorn ear is significantly smaller than ear of other types of maize; this leads to a decrease in the production of popcorn grain yield. The mean of 39 popcorn hybrids for grain yield ranged from 11.08 ard/fed for Sk208×Hp6252 to 17.85 ard/fed for Sk206×Hp6215 with a grand mean of 14.70 ard/fed (4898.04 kg/ha). The higher hybrids for grain yield were Sk204×Hp6252 (17.40 ard/fed), Sk205×Hp6215 (16.43 ard/fed), Sk205×Hp6252 (16.48 ard/fed), Sk206×Hp6215 (17.85 ard/fed), Sk207×Hp6252 (17.32 ard/fed), Sk210×Hp6208 (16.42 ard/fed) and Sk213×Hp6208 (16.52 ard/fed). Öz and Kapar (2011) found that the grain yield of popcorn genotypes ranged from 3535 to 5399 kg/ha. Oliveira (2019) found that the average grain yield of popcorn hybrids ranged from 321.26 to 4496.31 kg/ha. For grain moisture content at popping, the means ranged from 11.63% for Sk206×Hp6208 to 13% for Sk213×Hp6252 with a grand mean of 12.33%, meaning that all hybrids contained appropriate grain moisture at popping. Eldredge and Lyerly (1943) and Bemis (1959) found that popcorn popped best at an optimum moisture content ranging from 12 to 13%; if moisture is below 11% or above 14% popping volume will be unsatisfactory.

Table 3. Mean performance of 39 popcorn hybrids for eight traits across two plant densities.

Hybrid	Days to 50% silking	Plant height (cm)	Grain yield (ard/fed)	Grain moisture content (%)	No. of kernels/ 10g	Popping volume (ml/g)	Unpopped kernels (%)	Quality score
Sk201×Hp6208	62.00	259.7	12.25	11.83	62.67	33.32	4.83	2.40
Sk201×Hp6215	58.17	222.3	12.45	12.37	58.27	28.17	4.50	1.80
Sk201×Hp6252	58.83	214.7	12.32	11.73	54.83	25.93	4.85	1.73
Sk202×Hp6208	59.67	251.5	13.02	12.43	57.18	34.18	5.80	1.97
Sk202×Hp6215	56.50	218.3	14.65	12.60	60.33	23.98	6.63	1.90
Sk202×Hp6252	57.50	202.3	11.78	12.30	55.62	26.88	2.72	1.70
Sk203×Hp6208	59.83	266.8	12.65	11.83	59.52	32.07	6.25	2.27
Sk203×Hp6215	56.50	224.8	15.93	12.40	58.17	26.28	4.77	1.67
Sk203×Hp6252	56.67	221.5	15.65	12.30	57.57	24.22	6.72	1.87
Sk204×Hp6208	59.83	264.3	15.63	12.03	59.88	32.62	5.73	2.13
Sk204×Hp6215	56.50	222.8	15.98	12.57	61.38	24.55	2.53	1.70
Sk204×Hp6252	56.67	220.5	17.40	12.20	58.28	22.05	4.28	1.77
Sk205×Hp6208	59.00	248.2	13.27	12.83	52.28	29.83	6.08	1.97
Sk205×Hp6215	56.67	228.0	16.43	11.73	51.95	23.38	3.87	1.83
Sk205×Hp6252	56.67	222.7	16.48	12.47	49.35	20.70	5.00	1.90
Sk206×Hp6208	59.33	251.7	15.32	11.63	52.65	33.35	4.52	2.20
Sk206×Hp6215	57.00	227.3	17.85	12.07	55.12	23.67	2.92	1.63
Sk206×Hp6252	57.67	227.8	15.52	12.43	53.02	22.57	5.08	1.97
Sk207×Hp6208	60.17	249.8	13.73	12.13	58.18	30.50	3.60	1.97
Sk207×Hp6215	57.33	222.5	15.40	12.83	59.12	24.57	4.08	1.90
Sk207×Hp6252	56.67	222.3	17.32	12.40	56.22	26.62	3.82	1.77
Sk208×Hp6208	59.67	250.8	14.68	12.30	53.40	30.23	2.82	1.77
Sk208×Hp6215	55.83	217.3	16.37	12.37	61.98	22.62	7.02	1.87
Sk208×Hp6252	56.67	214.0	11.08	12.30	58.22	21.33	3.57	1.87
Sk209×Hp6208	61.67	254.0	13.97	12.23	60.15	34.18	6.87	2.27
Sk209×Hp6215	58.83	213.2	14.17	12.77	59.50	25.28	3.70	1.73
Sk209×Hp6252	59.17	211.5	12.50	12.40	53.10	25.12	2.77	1.63
Sk210×Hp6208	62.33	250.7	16.42	12.17	57.53	35.55	6.48	2.40
Sk210×Hp6215	58.50	214.7	15.22	12.07	60.27	26.37	2.97	1.50
Sk210×Hp6252	59.00	214.2	15.33	12.20	55.50	23.10	3.97	1.80
Sk211×Hp6208	62.17	260.3	12.83	12.40	63.02	34.63	6.00	2.33
Sk211×Hp6215	59.67	221.3	16.20	12.27	62.70	28.72	3.95	1.70
Sk211×Hp6252	60.00	218.3	13.33	12.53	56.07	26.22	2.87	1.67
Sk212×Hp6208	62.00	269.7	13.57	12.93	64.43	33.67	8.13	2.47
Sk212×Hp6215	59.67	221.0	14.63	12.10	63.50	25.40	4.37	2.03
Sk212×Hp6252	59.83	219.0	16.37	12.87	60.70	23.45	3.77	1.70
Sk213×Hp6208	61.50	258.5	16.52	12.50	58.17	33.90	7.23	2.43
Sk213×Hp6215	58.83	218.2	13.95	12.50	57.43	25.13	5.75	1.93
Sk213×Hp6252	59.00	213.5	15.18	13.00	54.37	22.43	3.95	1.77
Grand mean	58.80	231.5	14.70	12.33	57.73	27.35	4.73	1.92
LSD 0.05	1.05	9.29	2.42	0.45	3.56	3.27	3.27	0.29
0.01	1.38	12.23	3.18	0.59	4.68	4.30	4.30	0.39

Ertas *et al* (2009) reported that the optimum grain moisture content for the highest popping volume changed between 12 and 14% for different hybrids. Song and Echhoff (1994) found that the optimum grain moisture content was different for different sized kernels; smaller kernels required slightly higher moisture to achieve the maximum popping volume.

Number of kernels per 10g indicates the size of kernel. The means ranged from 49.35 for Sk205×Hp6252 to 46.43 for Sk212×Hp6208 with an average of 57.73 kernels/10g, meaning that all hybrids had a large size. Lin and Anantheswaran (1988) found that the large-sized kernels had a significantly higher popping volume than the small sized kernels. While, Song *et al* (1991) and Allred-Coyle *et al* (2000) found that the middle sized kernels had the highest popping volume.

Popping volume ranged from 20.70 to 35.55 ml/g for Sk205×Hp6252 and Sk210×Hp6208, respectively, with a grand mean of 27.35ml/g. The highest popcorn hybrids for popping volume were Sk201×Hp6208, Sk202×Hp6208, Sk203×Hp6208, Sk204×Hp6208, Sk206×Hp6208, Sk209×Hp6208, Sk210×Hp6208, Sk211×Hp6208, Sk212×Hp6208 and Sk213×Hp6208. Matz (1984) and Song *et al* (1991) found that popping volume is one of the primary measures of popability, since commercial buyers purchase popcorn by weight and sell by bulk volume. Oliveira (2019) found that the popping expansion ranged from 11.8 to 56 ml/g, while Junior *et al* (2013) observed popping volume of an average of 31 ml/g.

Percentage of unpopped kernels is one of the most important quality traits. The means ranged from 2.53 to 8.13 % for Sk204×Hp6215 and Sk212×Hp6208, respectively, with an average of 3.27%. The desirable hybrids which had lowest unpopped kernels % were Sk202×Hp6252, Sk204×Hp6215, Sk206×Hp6215, Sk208×Hp6208, Sk209×Hp6252, Sk210×Hp6215 and Sk211×Hp6252. Song *et al* (1991) found that popcorn hybrids and kernels size were significantly affected the percentage of unpopped kernels. Öz and Kapar (2011) found that the unpopped kernels ranged from 2.8 to 10.1%.

Quality scores ranged from 1.5 for Sk210×Hp6215 to 2.47 for Sk212×Hp6208 with an average of 1.92. The desirable hybrids for quality scores were Sk202×Hp6252, Sk203×Hp6215, Sk204×Hp6215, Sk206×Hp6215, Sk209×Hp6252, Sk210×Hp6215, Sk211×Hp6215, Sk211×Hp6252 and Sk212×Hp6252. Jele *et al* (2014) found that the quality score of 120 popcorn hybrids ranged from 1.2 to 3.1.

In general, from previous results the two popcorn hybrids Sk210×Hp6208 and Sk213×Hp6208 had high grain yield and popping volume. Six popcorn hybrids (Sk202×Hp6252, Sk204×Hp6215, Sk206×Hp6215, Sk209×Hp6252, Sk210×Hp6215 and Sk211×Hp6252) had the best values for both unpopped kernels % and quality score. Six hybrids (Sk204×Hp6252, Sk205×Hp6215, Sk205×Hp6252, Sk206×Hp6215, Sk207×Hp6252 and Sk208×Hp6215) gave high grain yield and earliness.

Line × tester analysis for eight traits are presented in Table (4). Mean squares due to lines (L) and testers (T) were highly significant for all traits, except lines (L) for unpopped kernels% and quality score and testers for grain moisture content at popping, meaning that great diversity existed among inbred lines and among testers. Mean squares due to L×T interaction were significant or highly significant for all traits, except for days to 50% silking and popping volume, meaning that the inbred lines performed differently in their respective hybrids depending on the type of testers used. Mean squares due to the interactions between L, T and L×T with plant densities (D) were not significant for all traits, except L×D interaction for grain moisture content and number of kernels/ 10g, T×D interaction for days to 50% silking, unpopped kernels% and quality score and L×T×D interaction for grain moisture content at popping.

Table 4. Mean squares from line × tester analysis for eight traits across two plant densities.

SOV	df	Days to 50% silking	Plant height (cm)	Grain yield (ard/fed)	Grain moisture content(%)	No. of kernels/ 10g	Popping volume (ml/g)	Unpopped kernels (%)	Quality score
Lines (L)	12	28.19**	350.47**	26.09**	0.788**	152.15**	42.10**	7.07	0.09
Testers (T)	2	212.78**	37058.03**	27.55**	0.431	278.79**	1852.02**	57.99**	4.48**
L×T	24	0.847	160.28**	12.88**	0.614**	23.66**	11.21	12.27*	0.19**
L×D	12	0.537	97.71	6.04	0.816**	18.92*	5.92	8.51	0.05
T×D	2	3.596*	142.72	1.74	0.124	24.84	1.26	29.32*	0.34**
L×T×D	24	0.918	50.59	7.00	0.415**	14.91	9.15	5.4	0.05
Error	152	0.87	67.46	4.58	0.16	9.90	8.40	8.36	0.07
K^2GCA		0.49	388.26	0.46	0.009	4.28	19.55	0.50	0.04
K^2SCA		0.001	15.47	1.38	0.04	2.29	0.46	0.65	0.02

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

Regarding to Table (4), the additive gene effects (K^2GCA) were higher than the non additive gene effects (K^2SCA) for days to 50% silking, plant height, number of kernels/10g, popping volume and quality score, indicating that the greater importance of additive gene effects for inheritance of these traits. While the non additive gene effects were the most important in the inheritance of grain yield, grain moisture content at popping and unpopped kernels. Similar results were obtained by Larish and Brewbaker (1999), Pereira and Amaral Junjor (2001) and Jele *et al* (2014), who indicated the predominance of additive effects for popping volume. Cabral *et al* (2015) indicated that only genes with additive effects are involved in the genetic control of plant height. Pajic *et al* (2008) suggested that greater contribution of non additive gene effects relative to additive gene effects for grain yield. Jele *et al* (2014) found that the additive gene effects were more prominent than non-additive gene effects for number of kernels/10g and quality score.

The results in Table (5), exhibited that the desirable general combining ability (GCA) effects were obtained by the inbred lines, Sk202, Sk203, Sk204, Sk205, Sk206, Sk207 and Sk208 for earliness, Sk202, Sk208, Sk209 and Sk210 for short plant, Sk204 and Sk206 for grain yield, Sk201, Sk206 and Sk210 for low grain moisture content, Sk204, Sk211 and Sk212 for high number of kernels/10g and Sk201 and Sk211 for popping volume. While, the GCA effects for testers in Table (6), showed that the tester inbred line Hp6215 exhibited desirable general combing ability effects for earliness, short plant height, grain yield, number of kernels/ 10g and quality score. Also the tester inbred line Hp6252 exhibited desirable general combing ability effects for earliness, short plant height, unpopped kernels and quality score. While, the tester inbred line Hp6208 had desirable general combing ability effects for popping volume.

The best hybrids for specific combing ability effects for eight traits are shown in Table (7). The most desirable hybrid was Sk206×Hp6208 for earliness, plant height, moisture content at popping and popping volume, Sk207×Hp6208 for plant height, grain moisture content, unpopped kernels% and quality score, Sk202×Hp6252 for plant height, popping volume and unpopped kernels%, Sk205×Hp6208 for earliness, plant height and quality score, Sk208×Hp6215 for earliness, grain yield and number of kernels/ 10g, Sk207×Hp6252 and Sk213×Hp6208 for grain yield and popping volume, Sk208×Hp6208 and Sk210×Hp6215 for unpopped kernels% and quality score, Sk212×Hp6215 for plant height and moisture content at popping and Sk212×Hp6252 for grain yield and quality score. These popcorn hybrids will be tested in advanced trails for further evaluation.

Table 5. Estimates of general combing ability effects for thirteen inbred lines across two plant densities.

Line	Days to 50% silking	Plant height (cm)	Grain yield (ard/fed)	Grain moisture content (%)	No. of kernels/ 10g	Popping volume (ml/g)	Unpopped kernels (%)	Quality score
Sk201	0.86**	0.68	-2.36**	-0.36**	0.86	1.79**	-0.01	0.06
Sk202	-0.92**	-7.49**	-1.55**	0.11	-0.02	1.00	0.31	-0.07
Sk203	-1.14**	6.18**	0.04	-0.16	0.68	0.17	1.17	0.01
Sk204	-1.14**	4.35*	1.64**	-0.07	2.12**	-0.95	-0.55	-0.05
Sk205	-1.36**	1.40	0.69	0.01	-6.54**	-2.71**	0.25	-0.02
Sk206	-0.81**	4.07*	1.53**	-0.29**	-4.14**	-0.83	-0.57	0.01
Sk207	-0.75**	0.01	0.78	0.12	0.11	-0.13	-0.90	-0.04
Sk208	-1.42**	-4.15*	-0.66	-0.01	0.13	-2.63**	-0.27	-0.09
Sk209	1.08**	-5.32**	-1.16*	0.13	-0.15	0.84	-0.29	-0.04
Sk210	1.14**	-5.04**	0.95	-0.19*	0.03	0.99	-0.27	-0.02
Sk211	1.80**	1.79	-0.58	0.07	2.86**	2.50**	-0.47	-0.02
Sk212	1.69**	5.01**	0.15	0.30**	5.14**	0.15	0.69	0.15
Sk213	0.97**	-1.49	0.52	0.33**	-1.08	-0.20	0.91	0.12
LSD g_{ij} 0.05	0.43	3.79	0.98	0.18	1.45	1.33	1.33	0.13
0.01	0.56	4.99	1.30	0.24	1.91	1.76	1.75	0.16
LSD g_i-g_j 0.05	0.60	5.36	1.39	0.26	2.05	1.89	1.88	0.17
0.01	0.80	7.06	1.84	0.34	2.70	2.49	2.48	0.22

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

Table 6. Estimates of general combing ability effects for three testers across two plant densities.

Tester	Days to 50% silking	Plant height (cm)	Grain yield (ard/fed)	Grain moisture content (%)	No. of kernels/ 10g	Popping volume (ml/g)	Unpopped kernels (%)	Quality score
Hp6208	1.90**	25.07**	-0.56*	-0.08	0.65	5.57**	0.98**	0.28**
Hp6215	-1.12**	-10.63**	0.62**	0.02	1.48**	-2.11**	-0.35	-0.14**
Hp6252	-0.78**	-14.44**	-0.06	0.06	-2.13**	-3.46**	-0.63*	-0.14**
LSD g_{ij} 0.05	0.20	1.82	0.47	0.09	0.69	0.64	0.63	0.05
0.01	0.27	2.39	0.62	0.11	0.91	0.84	0.84	0.07
LSD g_i-g_j 0.05	0.29	2.57	0.67	0.12	0.98	0.90	0.90	0.08
0.01	0.38	3.39	0.88	0.16	1.29	1.19	1.19	0.10

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

Table 7. Best hybrids in specific combing ability effects for eight traits across two plant densities.

Days to 50% silking	Plant height	Grain yield	Grain moisture content %
Sk201×Hp6215	Sk202×Hp6252	Sk207×Hp6252	Sk201×Hp6252
Sk205×Hp6208	Sk205×Hp6208	Sk208×Hp6215	Sk205×Hp6215
Sk206×Hp6208	Sk206×Hp6208	Sk211×Hp6215	Sk206×Hp6208
Sk208×Hp6215	Sk207×Hp6208	Sk212×Hp6252	Sk207×Hp6208
Sk212×Hp6208	Sk212×Hp6215	Sk213×Hp6208	Sk212×Hp6215
No. of kernels/10g	**Popping volume**	**Unpopped kernels%**	**Quality score**
Sk201×Hp6208	Sk202×Hp6252	Sk202×Hp6252	Sk205×Hp6208
Sk208×Hp6215	Sk206×Hp6208	Sk204×Hp6215	Sk207×Hp6208
Sk208×Hp6252	Sk207×Hp6252	Sk207×Hp6208	Sk208×Hp6208
Sk209×Hp6208	Sk210×Hp6208	Sk208×Hp6208	Sk210×Hp6215
Sk211×Hp6208	Sk213×Hp6208	Sk210×Hp6215	Sk212×Hp6252

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انتخاب هجن ذرة فشار جديدة تحت كثافتين نباتيتين

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الذرة الفشار من أهم الوجبات الخفيفة فى العالم لما يحتويه من عناصر غذائية مفيدة نتيجة لزيادة الطلب علي استهلاكه فى مصر كان من الضروري التربية لإنتاج هجن فشار عالية فى الإنتاجية المحصولية وحجم الفشار. تم تهجين ١٣ سلالة جديدة من سلالات الذرة الفشار مع ثلاث كشافات من سلالات ذرة الفشار موسم ٢٠١٧ . قيمت الهجن الناتجة (٣٩) فى تجربتين منفصلتين. التجربة الاولى تحت كثافة ٢١٠٠٠ نبات للفدان والتجربة الثانية تحت كثافة ٣١٥٠٠ نبات للفدان موسم ٢٠١٨ . التحليل المشترك اظهر ان الكثافة النباتية العالية زادت من ارتفاع النبات ومحصول الحبوب ورطوبة الحبوب عند التفشير بالمقارنة بالكثافة المنخفضة. بينما صفات عدد الايام حتى ظهور ٥٠% من حرائر النورات المؤنثة وعدد الحبوب فى ١٠جم وحجم التفشير ونسبة الحبوب الغير مفشرة ودرجة الجودة لم تتأثر بالكثافة النباتية. اظهر التباين بين هجن الفشار المقيمة معنوية لجميع الصفات تحت الدراسة بينما تباين التفاعل بين الهجن والكثافة النباتية لم يكن معنويا فى معظم الصفات تحت الدراسة. هجينى الفشار Sk210×Hp6208 و Sk20813×Hp6208 جمعا بين محصول الحبوب العالى وحجم التفشير العالى. تأثيرات الفعل الوراثى المضيف كانت الأكثر اهمية فى وراثة صفات عدد الأيام حتى ظهور ٥٠% من حرائر النورات المؤنثة وارتفاع النبات وعدد الحبوب فى ١٠جم وحجم التفشير ودرجة الجودة، بينما تأثيرات الفعل الوراثي غير المضيف كانت الاكثر اهمية فى وراثة صفات محصول الحبوب ورطوبة الحبوب عند التفشير ونسبة الحبوب الغير مفشرة. كانت أفضل السلالات الجديدة فى القدرة العامة على الائتلاف : Sk204, Sk206 لمحصول الحبوب و Sk201 وSk211 لصفة حجم التفشير. كذلك اظهر الهجينين Sk207×Hp6252 و Sk213×Hp6208 قدرة خاصة على الائتلاف لصفتى محصول الحبوب و حجم التفشير.

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