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Combining Ability for some New Popcorn Inbred Lines under Two Plant Densities Conditions

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Cross Mark

ABSTRACT

Popcorn is a globally consumed snack that has substantial nutritional advantages. The successful development of hybrids depends on the reliability estimating combining ability of new popcorn inbred lines. This study was conducted to estimate the combining ability of nine popcorn inbred lines through line × tester analysis. Nine inbred lines were crossed with two testers in 2022 season. The 18 resulting popcorn hybrids were assessed under two plant densities arranged as split plot in a randomized complete block design with three replications in the 2023 season. All traits under study were not affected by plant densities except for grain yield. The plant density of 83333 plant/ha gave the highest grain yield compared to 69444 plant/ha. The mean squares of lines, testers and lines × testers were significant for all traits, except for plant height of testers. For the inheritance of days to 50% silking, plant and ear heights, grain yield, and unpopped kernels percentage, non-additive gene effects were more important than additive gene effects; the opposite was true for popping expansion. The best general combiners of inbred lines were Sk8 and Sk9 for earliness, grain yield, popping expansion and unpopped kernels. The two hybrids, Sk8×Sk52 and Sk9×Sk52, exhibited favorable SCA effects regarding quality characteristics, grain yield, and earliness. So, this study recommends using these two hybrids for evaluation in advanced stage in preparation for their use in commercial production.

Keywords: Zea mays everta, Hybrids, GCA, SCA, Additive, Nonadditive, Gene effects, correlation, popping expansion, unpopped kernels.

INTRODUCTION

Zea mays everta L., or popcorn, is a widely consumed snack due to its high fiber, energy, and carbohydrate content. It is a pleasant and healthful dish that provides the body with the necessary fiber to aid in digestion. (Rodovalho *et al*., 2008). Among the various types of corn, popcorn has specialty of puffing up when heated and it has high profitability and great popular recognition (Sweley *et al*., 2011). It differs greatly from flint corn in that it has a low percentage of soft starch and a highly hard endosperm and characterized by its popping ability on heat the kernel, which is a unique quality of the endosperm (Acquaah, 2006). In Egypt, popcorn is not produced commercially yet, but is imported from abroad. In the coming period the first officially registered Egyptian hybrids developed by maize breeding program at Agriculture Research Center will be commercially produced to replace imported ones, because popcorn is becoming more and more popular overtime. Developing popcorn hybrids for both high grain yield and better popping quality is one of the most important goals of popcorn breeders. Many researchers found that the two above traits appeared negative correlation (Viana and Matta, 2003 and Rangel *et al*., 2008). Breeders of popcorn must take into account other distinctive quality attributes, such as popping expansion, hull-freeness, and flakes' general smoothness (Ziegler, 2001). Popcorn quality is measured primarily by the expansion volume and number of unpopped kernels (Song *et al*., 1991). Expansion volume is a quality trait of great importance to consumers, as unpopped kernels are sold by weight and popcorn flakes are sold by volume (Shimoni *et al*., 2002 and Borras *et al*., 2006). Numerous variables, including moisture content, genotype, kernel physical characteristics, popping technique, popping temperature, and harvesting and handling procedures, affect the expansion volume (Hoseney *et al*., 1983). Physical kernel properties such as size, shape and density also affect expansion volume, large kernels generally give lower popping volume than small kernels because they contain a high percentage of soft endosperm (Pajic and Babic, 1991). Additionally, the expansion volume and flake size values were higher in the hybrids with medium-sized kernels (Sabri, 2004). Combining ability study is a potent tool for identifying the good combiners for hybridization especially when a large number of parental lines are available and promising ones are to be selected basis on their ability to give superior cross combination, also offers details on the makeup of genetic variation. Among the accessible ordinary methods, line × tester meting design is an efficient tool giving details on the effects and variances of special combining ability (SCA) and general combining ability (GCA). Popping traits are quantitatively inherited, controlled by multiple genes (Ashman, 1983 and Ziegler, 2001), also influenced by environmental effects (Hüseyin and Konuşkan, 2010 and Mosa *et al*., 2019). Both additive and non-additive gene effects play important roles in the inheritance of popping characteristics (Jele *et al*., 2014; Mosa *et al*., 2019; El-Gazzar, 2021; Rana *et al*., 2020 and Kumar *et al*., 2023). Among the various agronomic practices, plant density is the most

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important factors which greatly influence the potential yield realization from any crop (Hüseyin and Konuşkan, 2010). The recommended plant density for the normal maize hybrids may not be applicable to the popcorn hybrids (Ziegler, 2001; Lakshmi *et al*., 2017 and Mosa *et al*., 2019). Many studies differed in determining the optimal density for planting popcorn hybrids (Ülger, 1998; Hüseyin and Konuşkan, 2010; Lakshmi *et al.*, 2020 and El-Gazzar, 2021). This study aimed to identify the degree of diversity in grain yield production and popping quality traits among hybrids, identify the effects of plant densities on studies traits and estimate the combining ability of nine new popcorn inbred lines and crosses.

MATERIALS AND METHODS

Genetic materials:

The basic materials for the present investigation comprised of nine diverse new yellow popcorn inbred lines *i.e.* Sk1, Sk2, Sk3, Sk4, Sk5, Sk6, Sk7, Sk8 and Sk9 developed at Sakha Agriculture Research Station (Sk). Also two testers *i.e.* inbred line Sk52 and single cross Extra pop101. In 2022 summer growing season eighteen crosses were obtained from crossed between the nine inbred lines and the two testers utilizing the line x tester mating design process as recommended by Kempthorne (1957).

Experimental design:

The field trial consisted of 18 popcorn hybrids and two plant densities. The trial was laid out as split plot with each treatment arranged in a randomized complete block design (RCBD) with three replications. The main plot included two plant densities, 69444 and 83333 plant/ha, while the sub plot included 18 hybrids in 2023 summer growing season. Each plot consisted of one row, 4 m length with 0.8 m width and 18 cm between hills in the first density (D1=69444 plant/ha) and 15 cm between hills in second density (D2= 83333 plant/ha). All suggested standard agricultural practices were followed to raise a good crop.

Traits evaluated:

The following traits were evaluated: number of days to 50% silking, plant height (cm), ear height (cm), grain yield (t/ha) adjusted in 15.5% grain moisture, percentage of unpopped kernels (%) and popping expansion (ml/g).

Statistical and genetic analysis:

Statistical analysis for all traits was done according to Gomez and Gomez (1984), using the Statistical Analysis System (SAS, 2008). When the differences between crosses were significant, hence line × tester analysis was done according by Kempthorne (1957) by AGD-R Software (Analysis of Genetic Designs in R for windows) version 5.0 Statistical Software (Rodríguez *et al.,* 2015).

RESULTS AND DISCUSSION

Statistical analysis:

Mean squares of hybrids, plant densities and their interaction for six traits are shown in Table 1, the results showed that grain yield was influenced significantly by plant densities (D). Also, the mean squares due to hybrids (H) were highly significant, indicating that the popcorn hybrids were diverse for all the studied traits. Meanwhile the interaction between hybrids and plant densities (H × D) was highly significant for grain yield and popping expansion, meaning that both traits were affected by plant densities. Similar results were observed by (El-Gazzar, 2021 and Krishna *et al*., 2021).

Table 1. Mean squares due to hybrids, plant densities and their interaction of six traits.

SOV	df	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (t/ha)	Popping expansion (ml/g)	Unpopped kernels (%)
Replications	2	4.7	855.1	361.1	0.04	2.9	11.7
Plant Density (D)	1	9.5	45.4	0.2	25.61*	1.5	4.3
Error (a)	2	3.4	249.1	139.1	0.91	1.7	19.7
Hybrid (H)	17	62.4**	1277.8**	512.9**	7.09**	41.9**	91.5**
H×D	17	2.7	151.2	44.9	0.67**	10.1**	9.9
Error(b)	68	3.1	147.1	70.2	0.31	3.8	6.6

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

Mean performace:

As shown in (Table 2), the significant increase in grain yield was obtained at D2 plant density 83333 plant/ha (6.3 t/ha) compared to D1 plant density 69444 plant/ha (5.3 t/ha). Hüseyin and Konuşkan (2010) discovered that plant density had a substantial impact on popcorn grain yield, with 88,000 plants/ha being an appropriate plant density. El-Gazzar (2021) reported that plant density 73780 plant/ha was significantly increased than 59500 plant/ha for popcorn grain yield. Ülger (1998) inducted that highest popcorn grain yield was obtained at 95000 plant/ha.

Table 2. Means of two plant densities for six traits as combined across 18 popcorn hybrids.

Plant density	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (t/ha)	Popping expansion (ml/g)	Unpopped kernels (%)
69444 plant/fed (D1)	65.4	191.6	107.5	5.3	21.0	9.9
83333 plant/fed (D2)	66.0	190.3	107.6	6.3	21.2	9.5
LSD 0.05	1.50	13.06	9.76	0.78	1.07	1.71

The average performance of 18 popcorn hybrids across two plant densities for six traits are displayed in (Table 3). Mean of hybrids ranged from, 60.0 days for (Sk9×Sk52) to 71.7 days for (Sk2×Sk52) for days to 50% silking, 167.3 cm for (Sk4×Sk52) to 219.8 cm for (Sk8×Sk52) for plant height, 89.3 cm for (Sk4×Sk52) to 124.5 cm for (Sk8×Sk52) for ear height, 3.4 t/ha for (Sk4×Sk52) to 8.2 t/ha for (Sk9×Sk52) for grain yield, 15.3 ml/g for (Sk2×Sk52) to 24.3 ml/g for (Sk8×SC Extra pop101) for popping expansion and 4.8% for (Sk9×Sk52) to 20.2% for (Sk2×Sk52) for unpopped kernels%.

Table 3. Mean performance of 18 popcorn hybrids for six traits as combined across two plant densities.

Hybrid		Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (t/ha)	Popping expansion (ml/g)	Unpopped kernels (%)
Sk1×Sk52	(1)	69.2	183.3	97.5	6.1	20.8	13.6
Sk2×Sk52	(2)	71.7	187.2	104.5	5.4	15.3	20.2
Sk3×Sk52	(3)	71.0	182.8	97.2	5.1	19.7	14.8
Sk4×Sk52	(4)	70.7	167.3	89.3	3.4	21.9	11.2
Sk5×Sk52	(5)	63.2	176.8	107.3	6.1	18.3	8.3
Sk6×Sk52	(6)	65.3	199.2	99.7	5.9	17.0	7.5
Sk7×Sk52	(7)	66.2	190.0	108.0	5.5	17.3	7.7
Sk8×Sk52	(8)	61.5	219.8	124.5	7.6	22.8	5.2
Sk9×Sk52	(9)	60.0	213.7	116.3	8.2	21.1	4.8
Sk1×SC Extra pop101	(10)	65.7	191.2	112.8	5.8	24.2	11.7
Sk2×SC Extra pop101	(11)	66.7	215.7	121.8	4.5	22.8	9.9
Sk3×SC Extra pop101	(12)	63.8	202.2	116.2	5.6	23.6	11.1
Sk4×SC Extra pop101	(13)	63.8	197.2	110.7	5.8	22.5	8.7
Sk5×SC Extra pop101	(14)	63.0	191.3	116.3	7.1	21.1	5.6
Sk6×SC Extra pop101	(15)	65.5	183.2	103.8	5.8	21.4	12.7
Sk7×SC Extra pop101	(16)	67.0	176.3	102.0	5.5	22.0	7.5
Sk8×SC Extra pop101	(17)	64.5	182.5	105.5	6.1	24.3	8.1
Sk9×SC Extra pop101	(18)	64.7	177.3	101.7	5.3	24.2	6.5
LSD 0.05		1.90	13.30	9.19	0.61	2.13	2.9

Mean of grain yield (t/ha) against mean of popping expansion (ml/g) for 18 hybrids are shown in Figure 1, The ideal hybrids to achieve high popping expansion and high grain yield were (Sk8×Sk52), (Sk9×Sk52), (Sk1×SC Extra pop101), (Sk4×SC Extra pop101), (Sk5×SC Extra pop101), (Sk6×SC Extra pop101) and (Sk8×SC Extra pop101). Also, the hybrids which revealed high grain yield and low unpopped kernels were (Sk5×Sk52), (Sk6×Sk52), (Sk8×Sk52), (Sk9×Sk52), (Sk4×SC Extra pop101), (Sk5×SC Extra pop101) and (Sk8×SC Extra pop101) Figure 2. From above results five hybrids (Sk8×Sk52), (Sk9×Sk52), (Sk4×SC Extra pop101), (Sk5×SC Extra pop101) and (Sk8×SC Extra pop101) were the best hybrids for grain yield and traits of quality. These hybrids could be employed in maize breeding programs.

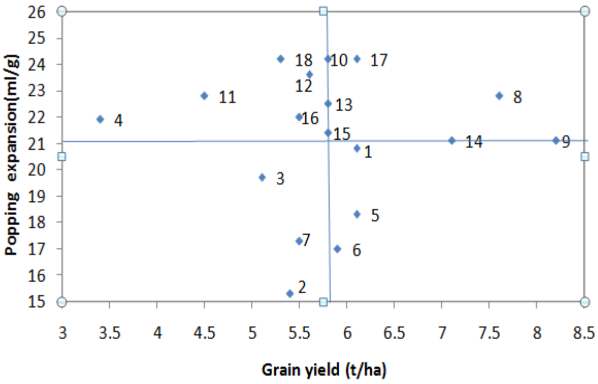

Figure 1. Means of grain yield (t/ha) against means of popping expansion (Ml/g) for 18 hybrids

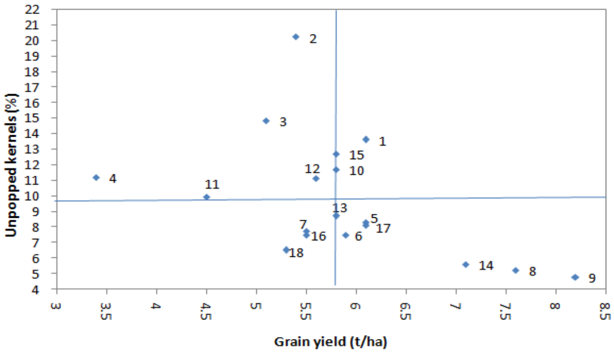

Figure 2. Means of grain yield (t/ha) vs. means of unpopped kernels% for 18 hybrids

Relationships among traits:

Relationships between traits under study are presented in Table 4. The results indicated that a significant and positive correlation showed for (grain yield with plant height), (grain yield with ear height), (days to 50% silking with unpopped kernels%) and (plant height with ear height), indicating that an increase in the first trait is matched by an increase in the other trait and vice versa a decrease is in one trait is offset by a decrease in other trait. So the direct selection in one trait is useful for improving the other trait. Meanwhile, a significant and negative correlation was found between (grain yield and days to 50% silking), (grain yield and unpopped kernels%), (days to 50% silking and plant height) and (days to 50% silking and ear height), indicating that an increase in the first trait is meet by a decrease in the other trait. Therefore, selection must be made for both traits. Similar results were reported in previous studies (Walter *et al.*, 1991; Mosa, 2003 and Mosa *et al.*, 2019).

Table 4. Correlations coefficient between traits under study.

Trait	Grain yield	Days to 50% silking	Plant height	Ear height	Popping expansion
Days to 50% silking	-0.746**				
Plant height	0.525*	-0.539*			
Ear height	0.564*	-0.682**	0.833**		
Popping expansion	0.013	-0.351	0.108	0.280	
Unpopped kernels%	-0.481*	0.808**	-0.314	-0.398	-0.355

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

Line ×Tester analysis:

Table 5, mean squares resulting from, lines (L), testers (T) and their interactions (L×T) were significant or highly significant for all studied traits except for plant height of (T), indicated that these materials selected were diverse for all studied traits. The interactions between L×D, T×D and L×T×D were not significant for all studied traits except for grain yield and popping expansion of L×D and popping expansion of L×T×D. This was in confirmation with results as stated by Jele *et al.*, (2014); Dar *et al.*, (2015) and Dar *et* *al*., (2018). The estimates of K^2GCA and K^2SCA ratio revealed greater importance of K^2SCA or non-additive gene effects for all studied traits except for popping expansion which K^2GCA or additive gene effects was greater importance. Similar results of important non-additive gene effects in the inheritance traits stated by many investigators such as Subramanian and Subbaraman (2006) and Dar *et al*., (2018) for plant height, Dar *et al*., (2007) and El-Gazzar (2021) for days to 50% silking, Mosa *et al*., (2019) and El-Gazzar (2021) for grain yield and El-Gazzar (2021) for unpopped kernels%. In the meanwhile, important additive gene action data have been published by Mosa *et al*., (2019) and Rana *et al*., (2020) for popping expansion.

Table 5. Mean squares resulting from lines, testers, lines × testers and their interactions with plant densities for six studied traits.

SOV	df	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (t/ha)	Popping expansion (ml/g)	Unpopped kernels (%)
Lines (L)	8	69.9**	651.3**	316.6**	7.97**	35.6**	128.4**
Testers (T)	1	65.3**	3.7	720.7**	1.31*	334.3**	44.7*
L×T	8	54.4**	2063.7**	683.2**	6.93**	12.2**	60.2**
L×D	8	4.6	192.5	34.7	1.05**	11.7**	12.7
T×D	1	1.3	1.3	12.7	0.49	12.4	12.2
L×T×D	8	1.0	128.6	59.1	0.30	8.1*	6.9
Error	68	3.1	147.1	70.2	0.31	3.9	6.6
K^2GCA/K^2SCA		0.23	0.10	0.13	0.12	3.97	0.27

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

Combining ability effects:

For each of the six traits under study, estimates of the general combining ability effects for nine inbred lines and two testers are shown in Table 6. Examining the data, it was found that among nine inbred lines, Sk5, Sk8 and Sk9 were best combiner for earliness, Sk4, Sk5 and Sk7 were the most effective combiner for short plant height, Sk4 and Sk6 for short ear height, Sk5, Sk8 and Sk9 showed desirable combiner for grain yield, Sk1, Sk8 and Sk9 revealed desirable GCA effects for popping expansion and Sk5, Sk7, Sk8 and Sk9 were the best combiner for unpopped kernels%. Among two testers, Sk52 was the best combiner for ear height and grain yield while tester SC Extra pop101 showed favorable GCA effects for earliness, popping expansion and unpopped kernels%.

Table 6. General combing ability effects of nine inbred lines and two testers for six traits.

Line	Days to 50% silking	Plant height	Ear height	Grain yield	Popping expansion	Unpopped kernels%
Sk1	1.68**	-3.69	-2.34	0.11	1.39*	2.93**
Sk2	3.43**	10.47**	5.66**	-0.88**	-2.08**	5.34**
Sk3	1.68**	1.56	-0.84	-0.49**	0.56	3.18**
Sk4	1.51**	-8.69*	-7.51**	-1.26**	1.11	0.22
Sk5	-2.66**	-6.86*	4.32	0.82**	-1.39*	-2.74**
Sk6	-0.32	0.22	-5.76*	0.05	-1.94**	0.37
Sk7	0.84	-7.78*	-2.51	-0.32*	-1.53*	-2.09**
Sk8	-2.74**	10.22**	7.49**	1.02**	2.36**	-3.11**
Sk9	-3.41**	4.56	1.49	0.94**	1.53*	-4.09**
LSD L g_{ij} 0.05	0.99	6.86	4.79	0.31	1.19	1.45
0.01	1.31	9.03	6.24	0.41	1.57	1.91
Tester Sk 52	0.78**	0.19	-2.58*	0.11*	-1.76**	0.64*
Tester SC Extra pop101	-0.78**	-0.19	2.58*	-0.11*	1.76**	-0.64*
LSD T g_{ij} 0.05	0.46	3.27	2.23	0.11	0.52	0.64
0.01	0.61	4.25	2.94	0.19	0.69	0.84

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

Estimates of general combining ability (GCA) effects for popping expansion vs. GCA effects for grain yield in (Figure3), showed that the inbred lines Sk1, Sk8 and Sk9 had desirable GCA effects for both grain yield and popping expansion. Meanwhile Sk4 and Sk3 were desirable GCA effects for popping expansion and not desirable GCA effects for grain yield while, the reverse obtained by inbred lines Sk5 and sk6 which had desirable GCA effects for grain yield and not desirable GCA effects for popping expansion. Whereas, the inbred line Sk7 and Sk2 were not desirable GCA effects for both traits. On the other side, the desirable inbred lines of GCA effects for both grain yield and unpopped kernels% were Sk5, Sk8 and Sk9 (Figure4). From above results the inbred lines Sk8 and Sk9 had desirable GCA effects for grain yield and quality traits *i.e.* popping expansion and unpopped kernels%.

Table 7, displays the estimated specific combining ability (SCA) effects of 18 popcorn hybrids for the different traits that have been evaluated. The SCA effects are an important criterion to determine the potential and effectiveness of hybrids. Hence crosses which exhibited significant or desirable SCA effects were (Sk8×Sk52), (Sk9×Sk52), (Sk2×SC Extra pop101), (Sk3×SC Extra pop101) and (Sk4×SC Extra pop101) for earliness, (Sk2×Sk52), (Sk4×Sk52), (Sk8×SC Extra pop101) and (Sk9×SC Extra pop101) for short plant height, (Sk3×Sk52), (Sk4×Sk52), (Sk8×SC Extra pop101) and (Sk9×SC Extra pop101) for ear height, (Sk8×Sk52), (Sk9×Sk52), (Sk4×SC Extra pop101) and (Sk5×SC Extra pop101) for grain yield, (Sk2×SC Extra pop101) for popping expansion and (Sk6×Sk52), (Sk8×Sk52) and (Sk2×SC Extra pop101) for unpopped kernels%. From previous results the crosses (Sk4×Sk52), (Sk8×SC Extra pop101) and (Sk9×SC Extra pop101) exhibited favorable SCA effects for short both plant and ear heights. Meanwhile the crosses (Sk8×Sk52) and (Sk9×Sk52) shown the best SCA effects for both earliness and grain yield, also these two hybrids having the desirable *per se* performance for earliness, high grain yield, popping expansion and unpopped kernels%. So this study recommends using these two hybrids for evaluation in advanced stages in preparation for their use in commercial production.

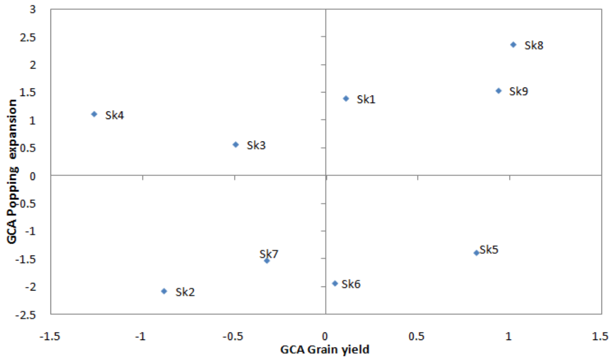

Figure 3. The GCA effects of popping expansion against GCA effects of grain yield

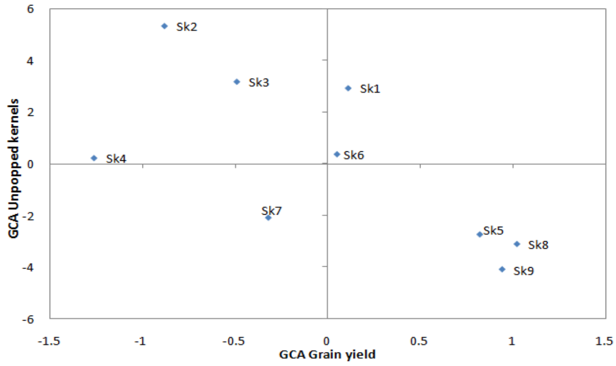

Figure 4. The GCA effects of unpopped kernels% opposite GCA effects of grain yield

Table 7. Specific combing ability effects of 18 popcorn hybrids for six traits.

Hybrid	Days to 50% silking	Plant height	Ear height	Grain yield	Popping expansion	Unpopped kernels
Sk1×Sk52	0.97	-4.10	-5.08	0.01	0.09	0.30
Sk2×Sk52	1.72*	-14.44**	-6.08	0.37	-1.99*	4.53**
Sk3×Sk52	2.81**	-9.85	-6.92*	-0.37	-0.19	1.20
Sk4×Sk52	2.64**	-15.10**	-8.08*	-1.30**	1.48	0.60
Sk5×Sk52	-0.69	-7.44	-1.92	-0.60**	0.37	0.70
Sk6×Sk52	-0.86	7.81	0.50	-0.04	-0.46	-3.24**
Sk7×Sk52	-1.19	6.65	5.58	-0.10	-0.60	-0.55
Sk8×Sk52	-2.28**	18.48**	12.08**	0.68**	1.06	-2.08*
Sk9×Sk52	-3.11**	17.98**	9.92**	1.35**	0.23	-1.46
Sk1×SC Extra pop101	-0.97	4.10	5.08	-0.01	-0.09	-0.30
Sk2×SC Extra pop101	-1.72*	14.44**	6.08	-0.37	1.99*	-4.53**
Sk3×SC Extra pop101	-2.81**	9.85*	6.92*	0.37	0.19	-1.20
Sk4×SC Extra pop101	-2.64**	15.10**	8.08*	1.30**	-1.48	-0.60
Sk5×SC Extra pop101	0.69	7.44	1.92	0.60**	-0.37	-0.70
Sk6×SC Extra pop101	0.86	-7.81	-0.50	0.04	0.46	3.24**
Sk7×SC Extra pop101	1.19	-6.65	-5.58	0.10	0.60	0.55
Sk8×SC Extra pop101	2.28**	-18.48**	-12.08**	-0.68**	-1.06	2.08*
Sk9×SC Extra pop101	3.11**	-17.98**	-9.92**	-1.35**	-0.23	1.46
LSD S_{ij} 0.05	1.40	9.70	6.71	0.44	1.58	2.05
0.01	1.85	12.77	8.82	0.58	2.08	2.70

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

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القدرة على الإئتلاف لبعض سلالات من الذرة الفشار الجديدة تحت ظروف كثافتين نباتيتين

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الملخص

الذرة الفشار وجبة خفيفة شعبية يتم إستهلاكها فى جميع أنحاء العالم لما لها من فوائد غذائية كبيرة. يعتمد نجاح إنتاج الهجن على تقدير القدرة على الإئتلاف لسلالات الفشار الجديدة. تم عمل هذه الدراسة لتقدير القدرة على الإئتلاف لتسع سلالات جديدة من الذرة الفشار من خلال تحليل السلالة × الكشاف. تم تهجين تسعة سلالات جديدة من الذرة الفيشار وإثنين من الكشافات موسم 2022. تم تقييم التهجينات وعددها 18 هجين تحت إثنين من الكثافة النباتية وضعت فى قطع منشقة لتصميم قطاعات كاملة العشوائية فى ثلاث مكررات موسم 2023. أظهرت النتائج أن جميع الصفات تحت الدراسة لم تتأثر بالكثافة النباتية ماعدا صفة محصول الحبوب حيث أعطت الكثافة النباتية 83333 نبات/هكتار أعلى محصول حبوب مقارنةً بالكثافة النباتية 69444 نبات/هكتار. كان التباين الراجع للهجن ومجزأتها (السلالات ، الكشافات ، السلالات × الكشافات) معنوياً لجميع الصفات المدروسة ماعدا تباين الكشافات لصفة إرتفاع النبات. أظهر الفعل الوراثى غير المضيف دوراً أكثر أهمية من الفعل الوراثى المضيف فى وراثة عدد الأيام حتى ظهور حرائر 50% من النباتات ، إرتفاع النبات ، إرتفاع الكوز ، محصول الحبوب ، ونسبة الحبوب غير المفشرة بينما ظهر العكس لصفة حجم التفشير. كانت أفضل السلالات فى القدرة العامة على الإئتلاف هى السلالات Sk8 ، Sk9 لصفات عدد الأيام حتى ظهور حرائر 50% من النباتات، محصول الحبوب ، حجم التفشير ، نسبة الحبوب غير المفشرة. أظهر الهجينين (Sk8×Sk52)، (Sk9×Sk52) قدرة خاصة على الإئتلاف مرغوبة للمحصول والتبكير وصفات الجودة ولذلك توصى الدراسة بتقييم هذه الهجن فى مراحل التقييم المتقدمة لإستخدامها فى الإنتاج التجارى.