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Enhancing Maize Yield: Analyzing Combining Ability and Superiority of Newly Developed Inbreds for High Yield through Diallel Analysis

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ABSTRACT

Developing new corn hybrids is a key factor for increasing maize productivity. Identifying the general and specific combining abilities for inbreds is crucial for developing hybrids and leveraging heterosis. Therefore, the current study was conducted to assess the combining ability for new promising inbreds and also the mean performance and superiority % of 21 hybrids. Twenty-one hybrids were formed by crossing seven elite inbreds using diallel cross scheme. During 2023 season, the formed hybrids were assessed alongside a two commercial check hybrids at Gemmiza, Sakha and Ismailia locations. The assessed traits were days to 50% silking, plant and ear heights and grain yield (ard/fed). Locations, crosses, GCA, SCA mean squares were high significance for all the measured traits. Both additive and non-additive effects played paramount role in the inheritance of the assessed traits. The inbreds P_1, P_2 and P_4 possessed desirable GCA effects for yield. Remarkably, The two hybrids H-10 and H-18 obtained positive SCA effects for yield, significantly out-yielded the best check for yield, and demonstrated superiority percentage over both checks for grain yield. As a result, the study advise forwarding those two hybrids for further evaluation before registration and releasing for commercial production by Maize Research Department, Field Crops Research Institute, Agricultural Research Center to sustain food security in Egypt.

Keywords: *Maize, corn, additive; non-additive; GCA; gene action; mean performance*

INTRODUCTION

Corn is known for being the most widely grown and productive crop in the world. Cultivated area of corn is approximately 200 million hectares worldwide. Over 20% of the dietary calories consumed by populations in certain nations, notably in sub-Saharan Africa, Latin America, and parts of Asia come from maize, which is a staple crop (Erenstein *et al*., 2022). Maize is an indispensable and vital crop in Egypt, contributing to the livestock sector and serving as a major food source as well as animal feeding. Despite, the cultivated area of corn reached 2.4 million feddan in 2022 with a total production of 7.7 million metric tons, Egypt imports corn to narrow the discrepancy between production and consumption (Economic Sector, 2022). Recently, the Egyptian government has implemented various policies and initiatives to promote maize production, for instance, providing subsidies for inputs like seeds and fertilizers, improving irrigation infrastructure, and supporting research and extension services to enhance productivity. Developing of high yielding corn hybrids play a pivotal role in enhancing productivity, sustainability, and meeting the demands of a growing global population. Kage *et al*., (2013) stated that assessing combining abilities of parents and crosses is crucial for developing desirable hybrids. Diallel analysis allows breeder to assess both general and specific combining abilities, which are vital in understanding the gene of action controlling the studied traits (Ferreira Coelho *et al*., 2021). Diallel analysis is being widely employed by plant breeders to assess the combing ability (Chinthiya *et al*., 2019; Rana *et al*. 2020; Seledes *et al*., 2022; Shaaban *et al*., 2022; Kamal *et al*.; 2023; Ismail *et al*., 2023; Abd-Elaziz *et al*., 2024 and Ismail *et al*., 2024). By leveraging heterosis, breeders can create hybrids with improved agronomic performance, disease resistance, and other beneficial traits, ultimately benefiting farmers and consumers alike.

As a result, the current investigation was carried out with the following aims: (i) assess the combining ability effects of 7 white inbreds for grain yield and other agronomic traits across three locations; (ii) assess the mean performance of yield and studied traits for 21 hybrids in order to pick up promising hybrids which may be forwarded to commercialization and (iii) assess the superiority % for 21 hybrids over the best commercial hybrids available in the market .

MATERIALS AND METHODS

The experiment study was carried out at three different locations in Egypt, representing diversity in soil and weather. The hybrids formation were made at Gemmiza Agricultural Research Station, Agricultural Research Center (ARC) in 2022. The plant genotypes comprised of seven parental white maize inbred lines. These lines were developed by Maize Research Department, ARC at different research station, representing high diversity and flowering synchronization (Table 1). A half-diallel scheme was employed to form the crosses among the seven inbreds without reciprocals. During 2023 season, the formed 21 hybrids plus two commercial hybrids *viz*., SC-10 (released by Maize Research Department, ARC) and SC-2031 (released by the private seed company *i.e.* Misr Hytech Seed Int S.A.E) were assessed at Gemmiza, Sakha and Ismailia locations. Each experiment was laid out in a Randomized Complete Block Design with three replications. The plot size was a single row measuring 6.0 m long, with inter-and intra-row

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spacing of 0.80 m and 0.25 m, respectively. Initial seeding was two kernels per hill to ensure perfect germination and later was thinned to one plant per hill. The agronomic practices were adopted as the recommendations of the locations to attain a final plant density of 24,000 plants per feddan. The collected data were days to 50% silking (day), plant and ear heights (cm) and grain yield (kg) per plot adjusted at 15.5% grain moisture and converted later to (ardab /fed), (one ardab = 140 kg and one feddan= 4200 m^2). The collected data was subjected to combined analysis using PROC GLM procedure in SAS software (SAS-Institute Inc. 2008) according to Snedecor and Cochran (1989). The combining abilities were assessed according to the method of Griffing (1956) Method 2, model I.

Table. 1. Identification, names and origin of the inbreds used in the present study.

SN	Identification	Inbred Line	Origin
1	P1	GM-52	Gemmiza
2	P2	SK-2008-28-2-1-1	Sakha
3	P3	SK-2006-3-2-2-1	Sakha
4	P4	SD- L3	Sids
5	P5	SD-41/2013	Sids
6	P6	NUB-CIM-517	Nubaria
7	P7	ISM-L-14	Ismailia

Superiority percentage was calculated using formula:

$$\text{Superiority \%} = \frac{F1 - CH}{CH} \times 100$$

Where:

F_1 and CH represented the mean performance of the hybrids and check hybrids, respectively. The significance test for superiority was done using standard error of the value of the check hybrid.

RESULTS AND DISCUSSION

Analysis of variance for DST, PHT, EHT and Yield traits over three locations:

The combined ANOVA of the hybrids over the three used locations is displayed in Table (2). Results showed highly significant mean squares (MS) for locations, indicating that locations are diverse and encouraging the need of multi-location yield trails for hybrids evaluation. These findings consisted with those reported by (Ismail *et al*., 2023; Abd-Elaziz *et al*., 2024).

Table 2. Combined ANOVA of DTS, PHT, EHT and Yield traits across the three locations evaluated in 2023.

Traits SOV	d.f.	Mean Squares			
		DTS	PHT	EHT	Yield
Loc. (Loc)	2	734.29**	937.91**	12174.82**	432.24**
Rep/L	6	0.38	120.32	105.87	17.78
Genotypes (Gen)	22	49.94**	2231.02**	995.04**	91.59**
Crosses (Cr)	20	49.22**	1969.63**	954.23**	93.41**
Checks (Ch)	1	14.22**	1200.50**	355.55*	17.43 ns
Cr Vs. Ch	1	99.91**	8489.22**	2450.82**	129.20**
Gen x Loc	44	6.71**	255.30**	148.43**	28.09**
Cr x Loc	40	6.07**	247.70**	136.33**	29.45**
Ch x Loc	2	1.05 ns	235.50 ns	156.22 ns	1.45 ns
Cr Vs. Ch x Loc	2	25.29**	426.95*	382.76**	27.57*
Error term	132	0.88	102.31	63.08	6.17

*** Significant at p < 0.05, ** significant at p < 0.01**
DTS= Days to 50% silking (day), PHT= Plant height (cm), EHT= Ear height (cm), Yield= Grain yield (ard/fed).

Genotypes and crosses MS expressed high significance for all the measured traits, reflecting that the parental inbred used in this study are from different background. This findings are in line with those obtained by Kamal *et al*., 2023 and Ismail *et al*., 2024. The MS due to checks and crosses vs checks displayed significance or high significance for all measured traits except, yield for checks. Highly significant MS were obtained by Gen x Loc and Cr x Loc for all the studied traits, suggesting that the expression of these traits are impacted by locations or environments. Thus, selection of high yielding and stable hybrids should be done across different environments. Ismail *et al*., 2024 found that the interaction of crosses with location were highly significant for the same studied traits. Insignificant MS for all the studied traits were obtained by Ch x Loc, suggesting that the performance of checks was similar from one location to another. Contrastively, Cr Vs. Ch x Loc MS were significant or highly significant for all the measured traits.

Performance in terms of means:

The mean performance of twenty-one white single hybrids along with the checks viz., SC-10 and SC-2031 are displayed in Table (3).

Table 3. Mean performance of 21 white single hybrids over three locations for DTS, PHT, EHT and Yield traits.

Code	Hybrid	DTS	PHT	EHT	Yield
H-1	P_1 x P_2	61	261.44	134.67	27.72
H-2	P_1 x P_3	60	264.22	145.33	24.23
H-3	P_1 x P_4	60	263.66	135.89	24.05
H-4	P_1 x P_5	61	294.22	159.56	26.83
H-5	P_1 x P_6	58	272.88	141.67	21.29
H-6	P_1 x P_7	60	276.11	152.89	25.57
H-7	P_2 x P_3	61	245.44	124.11	21.87
H-8	P_2 x P_4	61	251.88	124.67	26.43
H-9	P_2 x P_5	61	263.44	137.89	24.38
H-10	P_2 x P_6	62	256.44	132.33	30.47
H-11	P_2 x P_7	60	243.66	124.11	20.71
H-12	P_3 x P_4	61	244.88	128.78	25.00
H-13	P_3 x P_5	65	271.55	137.67	22.85
H-14	P_3 x P_6	61	250.33	127.89	21.43
H-15	P_3 x P_7	63	250.11	133.11	24.32
H-16	P_4 x P_5	61	253.88	127.56	24.71
H-17	P_4 x P_6	63	270.55	142.00	19.80
H-18	P_4 x P_7	65	298.22	153.67	30.69
H-19	P_5 x P_6	67	259.88	144.89	19.67
H-20	P_5 x P_7	67	253.88	142.00	19.67
H-21	P_6 x P_7	62	252.77	126.56	25.97
Checks	SC-10	63	292.77	153.67	25.99
	SC-2031	65	276.44	144.78	27.96
LSD 0.05		0.88	9.49	7.45	2.33
LSD 0.01		1.14	12.30	9.66	3.02

With regard to days to silking, fifteen hybrids out of the twenty one assessed hybrids were significantly earlier as compared to the earliest check hybrid SC-10 (63 day). The hybrid H-5 (58 day) displayed lowest value for this trait. These early maturity hybrids could be exploited in developing early maturing hybrids which are preferred to escape drought stress, cut one or save irrigation and also enable to sow more than two crops in the same year. Most of assessed hybrids showed significant values for plant and ear heights. Ismail *et al*., (2024) suggested that short stature hybrids could be beneficial in diminishing lodging, increasing plant density and ultimately increased yield. Whilst, the tallest hybrids could be beneficial in silage production purpose. Hence, the hybrids H-1, 3, 7, 8, 10, 11, 12, 14, 15 and H-16 were identified as good hybrids for improving plant and ear height. Albeit, the two hybrids H-4 and H-18 would be forwarded for silage purpose.

The two hybrids H-10 and H-18 significantly out-yielded the best check (SC-2031) for grain yield. Thus, this two hybrids would be forwarded for further evaluation in multi-location yield trails before promoted for releasing as commercial hybrids. H-1, H-4 and H-8 insignificantly out-performed the check hybrid SC-10 for yield. These two hybrids are suggested to be used in yield improvement breeding program (Habiba *et al*., 2022; Ismail *et al*., 2023).

Analysis of combining ability:

The general and specific combining abilities MS were highly significant for all the assessed traits, implied that both additive and non-additive gene effects played paramount role in the inheritance of the studied traits (Table 4). These findings corroborated the results of Kage *et al*., (2013), Aboyousef *et al*., (2022), Karim *et al*., (2022), and Ismail *et al*., (2023). Similarly, the interaction between GCA and SCA with location expressed high significance for all the traits, proving that both additive and non-additive gene action were influenced by location. The ratio of GCA/SCA was found higher than the unity for all the traits except yield, implied that additive gene action played a paramount role than non-additive gene action for studied traits. In the same vein, Abd-Elaziz *et al*., 2024 found that additive gene action was more important in the inheritance of DTS and EHT. The non-additive gene action displayed the key role in the inheritance of yield since the GCA/SCA ratio was less than the unity. The paramount of non-additive gene effect in maize inheritance has been reported earlier by various workers for different traits (Chinthiya *et al*., 2019; Abd-Elaziz *et al*., 2020 and Revilla *et al*., 2021). The ratio of GCA x Loc / SCA x Loc also exceeded the unity for all studied traits except yield, implied that additive gene effects were influenced more by location rather than non-additive. The Contrastively with yield trait.

General combining ability:

Significant negative GCA effects are targeted in DTS, PHT and EHT traits. Whilst, the significant positive are preferred in yield traits.

Table 4. Analysis of general and Specific combining abilities effects over three locations for DTS, PHT, EHT and Yield traits.

SOV	d.f.	DTS	PHT	EHT	Yield
GCA	6	10.57**	300.97**	196.32**	7.23**
SCA	14	3.28**	183.65**	67.32**	11.72**
GCA x Loc	12	12.35**	457.37**	282.82**	16.60**
SCA x Loc	28	5.41**	234.57**	95.17**	21.73**
error	120	0.101	11.603	6.760	0.675
GCA / SCA		3.224	1.639	2.916	0.617
GCA x Loc / SCA x Loc		2.281	1.950	2.972	0.764

*** Significant at $p < 0.05$, ** significant at $p < 0.01$**

DTS= Days to 50% silking (day), PHT= Plant height (cm), EHT= Ear height (cm), Yield= Grain yield (ard/fed).

Inbreds with favorable GCA effects could be exploited in breeding programs to improve the respective traits as they can transmit the favourable alleles to their offspring. As the result, the inbreds P_1 and P_2 could be identified as good combiners for earliness (Table 5). With regard to plant and ear heights, the inbreds P_2 and P_3 displayed the desirable GCA effects for both traits. Thus, They could be served as donner for improving these traits. The inbreds P_1, P_2 and P_4 were identified a good combiners for yield trait since they showed significant positive GCA effects for yield trait.

Table 5. General combining ability effects of seven inbreds over three locations for DTS, PHT, EHT and Yield traits.

Characters / Inbred lines	DTS	PHT	EHT	Yield
P1	-2.44**	12.25**	9.58**	0.92**
P2	-1.08**	-9.79**	-8.85**	1.30**
P3	0.07	-8.94**	-5.03**	-1.06**
P4	0.07	2.36	-1.90	1.12**
P5	2.15**	5.11**	5.49**	-1.38**
P6	0.35**	-1.68	-1.34	-1.28**
P7	0.87**	0.69	2.05	0.37
LSD gi 0.05	0.26	2.80	2.14	0.67
LSD gi 0.01	0.34	3.63	2.77	0.87
LSD (gi-gj) 0.05	0.40	4.28	3.27	1.03
LSD (gi-gj) 0.01	0.51	5.55	4.24	1.34

*** Significant at $p < 0.05$, ** significant at $p < 0.01$**

DTS= Days to 50% silking (day), PHT= Plant height (cm), EHT= Ear height (cm), Yield= Grain yield (ard/fed).

Specific combining ability:

The hybrids displayed significant negative SCA effects are targeted for DTS, PHT and EHT traits. Controversially, the hybrids expressed significant and positive SCA effects are desired for yield traits. Nine hybrids viz., H-4, 5, 6, 9, 11, 12, 14, 16 and H-21 were identified for desirable SCA effects for DTS trait (Table 6).

Table 6. Specific combining ability effects of 21 white single hybrids over three locations for DTS, PHT, EHT and Yield traits.

Code	Hybrid	DTS	PHT	EHT	Yield
H-1	$P_1 \times P_2$	2.43**	-2.89	-3.07	1.30
H-2	$P_1 \times P_3$	0.72**	-0.96	3.77	0.19
H-3	$P_1 \times P_4$	0.05	-12.83**	-8.80**	-2.18**
H-4	$P_1 \times P_5$	-0.58*	14.97**	7.45**	3.11**
H-5	$P_1 \times P_6$	-2.00**	0.43	-3.58	-2.53**
H-6	$P_1 \times P_7$	-0.63*	1.28	4.23*	0.09
H-7	$P_2 \times P_3$	-0.07	2.30	0.99	-2.54**
H-8	$P_2 \times P_4$	0.03	-2.56	-1.58	-0.17
H-9	$P_2 \times P_5$	-1.71**	6.23*	4.23*	0.28
H-10	$P_2 \times P_6$	1.30**	6.03**	5.52**	6.27**
H-11	$P_2 \times P_7$	-1.98**	-9.11**	-6.09**	-5.15**
H-12	$P_3 \times P_4$	-0.67**	-10.40**	-1.29	0.76
H-13	$P_3 \times P_5$	0.90**	13.50**	0.19	1.13
H-14	$P_3 \times P_6$	-1.07**	-0.91	-2.74	-0.39
H-15	$P_3 \times P_7$	0.19	-3.51	-0.91	0.84
H-16	$P_4 \times P_5$	-2.65**	-15.47**	-13.05**	0.79
H-17	$P_4 \times P_6$	1.03**	7.99**	8.23**	-4.21**
H-18	$P_4 \times P_7$	2.19**	33.28**	16.50**	5.01**
H-19	$P_5 \times P_6$	2.28**	-5.43	3.72	-1.83**
H-20	$P_5 \times P_7$	1.77**	-13.80**	-2.56	-3.49**
H-21	$P_6 \times P_7$	-1.54**	-8.11**	-11.16**	2.69**
LSD S_{ij} 0.05		0.51	5.53	4.22	1.33
LSD S_{ij} 0.01		0.67	7.17	5.47	1.73
LSD S_{ij}- S_{ik} 0.05		0.80	8.57	6.54	2.06
LSD S_{ij}- S_{ik} 0.01		1.03	11.11	8.48	2.68

*** Significant at $p < 0.05$, ** significant at $p < 0.01$**

DTS= Days to 50% silking (day), PHT= Plant height (cm), EHT= Ear height (cm), Yield= Grain yield (ard/fed).

Similarly, the hybrids H-3, 11, 16 and H-21 possessed favourable SCA effects for PHT and EHT traits. For yield trait, the hybrids H-4, 10, 18 and H-21 exhibited significant positive SCA effects. Notably, the two hybrids H-10 and H-

18 significantly out-yielded the best check hybrid for yield trait. Generally, the identified hybrids for desirable SCA effects would be deployed in the breeding program for enhancement of the respective traits.

Superiority

Table (7) displays the superiority of the assessed 21 hybrids related to the checks SC-10 and SC-2031. As for DTS trait, fifteen hybrids showed significant negative superiority over the check SC-10. Whereas, eighteen hybrids displayed desirable superiority over the check hybrid SC-2031 for the same trait. Most of the hybrids exhibited desirable superiority compared to SC-10 for PHT. Likewise, fifteen hybrids possessed significant negative superiority over the check SC-2031 for the same trait. With regard to EHT trait, eighteen and elven hybrids obtained favourable superiority over the check hybrids SC-10 and SC-2031, respectively. The two hybrids H-10 and H-18 demonstrated superiority percentage over the both checks for yield trait. Notably, these two hybrids included one good combiner for yield. Vasal (1998) recommended using a good combiner (particularly a female parent) during crossing to increase heterosis. Several investigators reported useful superiority for yield in maize (Ismail *et al*., 2018; Patel *et al*., 2019; Aboyousef *et al*., 2022; Karim *et al*., 2022; Ismail *et al*., 2023).

Table 7. Superiority % of 21 white single hybrids over the two checks for studied traits across three locations.

Code	Crosses	DTS		PHT		EHT		Yield	
		SC.10	SC.2031	SC.10	SC.2031	SC.10	SC.2031	SC.10	SC.2031
H-1	$P_1 \times P_2$	-4.20**	-6.81**	-10.70**	-5.43**	-12.36**	-6.98**	6.62	-0.88
H-2	$P_1 \times P_3$	-5.08**	-7.67**	-9.75**	-4.42*	-5.42*	0.38	-6.80	-13.36**
H-3	$P_1 \times P_4$	-6.13**	-8.69**	-9.94**	-4.62**	-11.57**	-6.14*	-7.49	-14.00**
H-4	$P_1 \times P_5$	-3.85**	-6.47**	0.49	6.43**	3.83	10.21**	3.22	-4.04
H-5	$P_1 \times P_6$	-8.93**	-11.41**	-6.79**	-1.29	-7.81**	-2.15	-18.09**	-23.86**
H-6	$P_1 \times P_7$	-5.95**	-8.52**	-5.69**	-0.12	-0.51	5.60**	-1.63	-8.55*
H-7	$P_2 \times P_3$	-4.20**	-6.81**	-16.17**	-11.21**	-19.23**	-14.27**	-15.87**	-21.79**
H-8	$P_2 \times P_4$	-4.03**	-6.64**	-13.97**	-8.88**	-18.87**	-13.89**	1.68	-5.47
H-9	$P_2 \times P_5$	-3.50**	-6.13**	-10.02**	-4.70**	-10.27**	-4.76	-6.19	-12.80**
H-10	$P_2 \times P_6$	-1.58*	-4.26**	-12.41**	-7.23**	-13.88**	-8.60**	17.23**	8.98*
H-11	$P_2 \times P_7$	-5.95**	-8.52**	-16.77**	-11.86**	-19.23**	-14.27**	-20.34**	-25.94**
H-12	$P_3 \times P_4$	-3.33**	-5.96**	-16.36**	-11.41**	-16.20**	-11.05**	-3.83	-10.60*
H-13	$P_3 \times P_5$	2.45**	-0.34**	-7.25**	-1.77	-10.41**	-4.91	-12.09**	-18.27**
H-14	$P_3 \times P_6$	-3.50**	-6.13**	-14.50**	-9.45**	-16.78**	-11.67**	-17.54**	-23.35**
H-15	$P_3 \times P_7$	-0.70	-3.41**	-14.57**	-9.53**	-13.38**	-8.06**	-6.43	-13.01**
H-16	$P_4 \times P_5$	-3.15**	-5.79**	-13.28**	-8.16**	-16.99**	-11.90**	-4.95	-11.64**
H-17	$P_4 \times P_6$	-0.18	-2.90**	-7.59**	-2.13	-7.59**	-1.92	-23.81**	-29.17**
H-18	$P_4 \times P_7$	2.45**	-0.34	1.86	7.88**	0.00	6.14*	18.05**	9.74*
H-19	$P_5 \times P_6$	5.08**	2.21**	-11.23**	-5.99**	-5.71*	0.08	-24.32**	-29.64**
H-20	$P_5 \times P_7$	5.08**	2.21**	-13.28**	-8.16**	-7.59**	-1.92	-24.32**	-29.64
H-21	$P_6 \times P_7$	-2.98**	-5.62**	-13.66**	-8.56**	-17.64**	-12.59**	-0.10	-7.13

*** Significant at $p < 0.05$, ** significant at $p < 0.01$**

DTS= Days to 50% silking (day), PHT= Plant height (cm), EHT= Ear height (cm), Yield= Grain yield (ard/fed).

CONCLUSION

This study concluded that locations has a paramount impact on the hybrids performance. Therefore, multi-location yield trials are suggested for further evaluation before commercialization. The inbreds P_2 was identified as a good combiner for all the studied traits. Thus, it could serve as a good tester in improving the studied trait. Additionally, the inbreds P_1, P_2 and P_4 possessed desirable GCA effects for yield, proving that at least one parental good combiner is required to get high positive heterosis for yield. Remarkably, The two hybrids H-10 and H-18 obtained positive SCA effects for yield, significantly out-yielded the best check hybrid for yield and demonstrated superiority percentage over both checks for yield trait. As a result, the study suggests forwarding those two hybrids for further evaluation before commercializing by Maize Research Department, Field Crops Research Institute, Agricultural Research Center to sustain the food security in Egypt.

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تحسين إنتاجية الذرة الشامية: تحليل القدرة على الائتلاف والتفوق لسلالات مستنبطة حديثا من الذرة الشامية للمحصول العالي من خلال التهجين التبادل

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الملخص

استنباط هجن الذرة الشامية الجديدة من أهم العوامل الرئيسية لزيادة إنتاجية الذرة الشامية. تقييم القدرة على الائتلاف للسلالات يعد أمرًا بالغ الأهمية لتطوير واستنباط الهجن والإستفادة من قوة الهجين. لذلك أجريت هذه الدراسة لتقييم القدرة على الائتلاف لسلالات جديدة ومبشرة من الذرة الشامية، وتقييم متوسط الأداء ونسبة التفوق لـ ٢١ هجيناً. تم تكوين هذه الهجن عن طريق تهجين سبع سلالات مبشرة باستخدام نظام التهجين التبادلي في اتجاه واحد خلال موسم ٢٠٢٣، تم تقييم هذه الهجن الناتجة مع هجينين تجاريين للمقارنة في ثلاثة مواقع هي الجميزة، سخا، والإسماعيلية. وكانت الصفات المدروسة هي؛ عدد الأيام حتى خروج ٥٠ بالمائة من حرائر النورة المؤنثة، ارتفاع النبات، ارتفاع الكوز ومحصول الحبوب (أردب/فدان). أظهرت النتائج ان تباين المواقع، الهجن، والقدرة العامة والخاصة على الائتلاف عالية المعنوية لجميع الصفات المدروسة. كما أكدت النتائج ان كلا من الفعل الجيني المضيف والغير مضيف لهما دورا مهما في توارث الصفات تحت الدراسة. وقد أظهرت السلالات (١، ٢، ٤) قدرة عامة على الائتلاف موجبة ومرغوبة لصفة المحصول. ومن الجدير بالذكر ان الهجينين (١٠، ١٨) اظهرا قدرة خاصة على الائتلاف مرغوبة لصفة المحصول، وتفوقا معنويا على افضل هجن المقارنة لصفة المحصول في متوسط الأداء والنسبة المئوية للتفوق. ونتيجة لذلك توصى الدراسة بتصعيد هذين الهجينين لمزيد من التجارب التأكيدية قبل اطلاقهما تجاريا من قبل قسم بحوث الذرة الشامية، معهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية للحفاظ على الأمن الغذائي في مصر.