Genetic analysis of nine yellow maize inbred lines for yield and resistance to northern leaf blight disease

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ABSTRACT:

Nine maize inbred lines were crossed at the Sakha Agricultural Research Station in a half-diallel mating scheme in the season of 2021. The resulting 36 crosses were screened in two trials in the summer season of 2022. To obtain superior hybrids for grain production and resistance to northern leaf blight. In the first experiment, thirty-six hybrids and two commercial hybrids (SC168 and SC3444) were tested at the Agricultural Research Stations in Sakha, Sides and Mallawi, to investigate, days to 50% silking, plant and ear heights, number of ears/plant, ear length, ear diameter, and grain yield. In the second experiment, thirty-six hybrids were evaluated under three levels of nitrogen in a nursery under conditions of artificial infection conditions with northern leaf blight at the Sakha Agricultural Research Station to estimate the percentage of resistance to northern leaf blight disease. Highly significant differences were observed among the three sites in the first experiment for all traits evaluated and among the three nitrogen levels in the second experiment regarding the percentage of resistance to northern leaf blight. GCA and SCA variances were significant for all traits examined, except for mean squares resulting from SCA for number of ears/plant and ear length in the first trial and northern leaf blight in the second trial. The best general combiners for earliness, shorter plants, and lower ear placement were inbred lines Gm636 and Sd9. Meanwhile, desirable GCA effects for both grain yield and resistance to northern leaf blight were inbred lines Sk28/31 and Sd15. Three yellow crosses (Sk5010×Sd9), (Sk28/31×Sk5025) and (Sk5025×Sd15) recorded high values for both grain yield and resistance to northern leaf blight. These hybrids will be further evaluated at the advanced test level in the maize breeding program.

Keywords: Zea mays; GCA; SCA; Artificial infection; Nitrogen levels.

INTRODUCTION

Maize or corn (*Zea mays* L.), is a crucial source of food for humans, animal feed, and industrial materials and it is also widely regarded as the most significant cereal crop worldwide. This necessitates looking for ways to boost productivity to satisfy these demands, where production has the propensity to rise due to the introduction of new crosses with high-yielding capacities in various environmental conditions. However, to meet the needs of maize producers, new hybrids of the crop must be created with high-yielding capacities. Therefore, many inbred lines must be crossed or interbred to determine the better cross combinations. Before performing crosses between these inbred lines, it would be very useful to evaluate the combining ability of inbred lines, genetic actions, and the effects of heterosis (Xu and Crouch 2008).

The diallel-mating designs are frequently used by plant breeders and geneticists to extract genetic data from a randomly or fixed selected group of inbred lines on a trait of interest (Murray et al 2003). The most important factor in hybrid breeding is the selection of germplasm as the basic population that will determine the availability of superior parents. Good parents derived from superior genetic material are tied with ideal agronomic characters that will have high GCA and SCA (Takdir *et al* 2007).

The cross-breeding models proposed by Griffing (1956) and Gardner and Eberhart (1966) are the standards used in combining ability analysis widely used in maize breeding programs to identify combining ability and superiority related to check hybrid and their interaction across environments (Turkey *et al*. 2018). Many researchers have found that the inheritance of grain yield, ear length, ear diameter, plant height, and ear height are affected by the effects of non-additive genes (Nawar *et al* 1980, El-Shamarka 1995 and El-Shenawy *et al* 2002). Meanwhile, additive genetic type played an important role in the inheritance of silking date, grain yield, number of ears/plant, ear length, ear diameter, plant height and ear heights (Al-Naggar 1991, Mosa 2003 and Mosa *et al* 2023).

GCA and SCA are two categories of combining abilities.GCA is a size of additive gene effects and is defined as the average genotype performance across a set of hybrid populations. While SCA is a measure of non-additive gene effects, it also indicates the genotype performance in a particular cross compared to the official (Yingzhong 1999 and Sharief *et al* 2009). The disease known as northern leaf blight (NLB) sporadically appears where maize is grown in temperate, humid climates (Scrivener *et al* 2001). The symptoms of NLB disease are mostly seen on the leaves, and plants can become infected at any stage of growth, but typically right after anthesis (Scrivener *et al* 2001 and Sharma *et al* 2015). Due to the favorable weather circumstances, the *Helminthosporium turcicum* of maize-caused NLB disease is the main issue in the late summer in the northern and northwestern portions of the Delta in Egypt. The inheritance of northern leaf blight involved both additive and non-additive gene actions (El-Shenawy and Tolba 2004). However additive gene actions were found to be of major importance in the inheritance of NLB (Vivck *et al* 2010 and Mosa *et al* 2023), wiliest the non-additive gene effects were more important as reported by Schechert *et al*. (1997). It is clear from the information presented above that the main aims of this study were to determine the effects of GCA and SCA as well as to identify the best crosses for grain yield and NLB disease resistance.

MATERIALS AND METHODS

Nine different elite yellow maize inbred lines (Sk5010, Sk28/31, Sk5025, Gm6038, Gm636, Sd9, Sd15, Mall5048, and Ism1) were used in this study. They were acquired from various sources at five Agricultural Research Stations: Sakha (Sk), Gemmiza (Gm), Sids (Sd), Mallawi (Mall), and Ismailia (Ism). At Sakha Research Station, these inbred lines were mated during the 2021 season using a half-diallel mating design (Griffing, 1956). The resulting 36 crosses were investigated in two experimental trials in 2022 growing season. In the first experiment, the 36 crosses as well as the two check hybrids SC168 and SC3444 were assessed at Sakha, Sids, and Mallawi Agricultural Research Stations using a randomized complete block design (RCBD) with three replications. The plot size was one row, 6 m long, 0.80 m apart and 0.25 m between hills. Every suggested agricultural practice was implemented at the appropriate time. The obtained data included the number of days to 50% silking, plant height (cm), ear height (cm), number of ears/plant, ear length (cm), ear diameter (cm), and grain yield ardab per feddan (ard/fed), which was adjusted to 15.5% grain moisture (ardab=140Kg and feddan=4200 m^2).

In the second trial, the 36 crosses were evaluated in a disease nursery under artificial infection conditions by northern leaf disease at Sakha Agricultural Research Station under three levels of nitrogen (60, 120 and 180 kg N/fed). In this trail, split plot design using RCBD with two replications was used. The main plot included three nitrogen levels, while sub plot included 36 crosses. The plot was one row, 2 m long, 0.8 m apart and 0.2 m between hills. Each row consisted of 11 hills with three kernels were seeded per hill. Before the first irrigation, the plants were later reduced to one plant per hill. The obtained disease infection was identified by a staff member (maize pathologist) from Institute of Plant Pathology, ARC, Giza, Egypt. The spores suspension of the fungus of northern leaf blight was sprayed to cover all leaves of the plant; this technique was adopted according to Badr *et al* (1999). Data were recorded at 75-90 days after planting date using the modified scale of Elliott and Jenkins (1946) to estimate *Helminthosporium turcicum* infection on maize plants and transformed to percentage of resistance to northern leaf blight disease.

Combined analysis was done across the three locations in the first trial after performing homogeneity test according to Snedecor and Cochran (1989). Combining ability analysis was performed for all traits and displayed statistical differences among crosses. Griffing's Method-4 Model-1 (Griffing 1956) was applied to determine GCA and SCA as well as their interaction effects with locations for the first trial and the nitrogen levels for the second trial used AGD-R (2018). Relative superiority% of 36 crosses for grain yield across the three locations was estimated according to Singh *et al* (2004), expressed as the % deviation of the mean performance of F_1 than the two check hybrids. Calculations of analysis of variances were carried out by using computer application of Statistical Analysis System (SAS 2008).

RESULTS AND DISCUSSION

First trial

Table 1, displays crosses, locations, and their interactions mean squares for seven traits assessed. The results showed that all the measured traits differed highly significant across the various locations (L). This indicates that there are noticeable differences between the locations tested. The mean squares of the crosses (C) were highly significant for all the studied traits, which indicate the variances of the tested crosses from each other. The mean squares of the C×L interaction were highly significant for all examined traits, exhibiting that the hybrids were affected by the change in their locations. The same results are achieved by Aboyousef *et al* (2022), Aly *et al* (2022) and Mosa *et al* (2023).

Table 2, shows GCA and SCA variances and their interactions with locations for each of the seven traits examined, the variances resulting from GCA and SCA were highly significant except for number of ears/plant and ear diameter for SCA, demonstrating the role of additive and non-additive genetic influences in the heritability of these traits. Moreover, GCA/SCA revealed that for all traits examined, the effects of additive genes were more critical in inheritance than the effects of non-additive genes.

The variances resulting from the GCA×L interaction were highly significant for all evaluated traits, exhibiting that the GCA of the inbred lines was altered by environmental conditions. On the other hand, the SCA×L interaction was significant or highly significant for number of ears/plant and grain yield, allowing us to conclude that the identified hybrid combinations were not stable across locations for these traits.

Thus, GCA×L/SCA×L showed that the additive gene effects were more interactive with location than the non-additive gene effects for all traits studied. The predominance of additive genetic effects over non-additive was reported by El-Shenawy and Mosa (2005), for days to 50% silking, Malik *et al* (2004), for number of ears/plant, Sibiya *et al* (2013), for ear length and ear diameter Mosa *et al* (2023), for plant and ear heights and grain yield. Additionally, Mosa (2003) found that the effects of additive genes were more interacted with locations than the effects of non-additive genes for plant and ear heights, ear diameter, and grain yield.

Thirty-six of single crosses and two check hybrids mean performance for days to 50% silking, plant and ear heights, number of ears/plant, ear length and ear diameter across various locations are shown in Table 3. The results indicated that, the crosses ranged from 58.67 for the cross (Sd9×Ism1) to 65.67 days for the cross (Sk5010×Sk5025) with respect to the number of days to 50% silking. Twenty-five crosses out of 36 were significantly earlier than the check hybrid SC168. The best of them were (Sd9×Ism1), (Gm6038×Sd9), (Sd9×Mall5048) and (Mall5048×Ism1). The crosses ranged from 185.22 cm for (Gm636×Sd9) to 276.22 cm for (Sk5010×Sk5025) for plant height. Results showed that, eleven crosses were shorter plant and significantly than the shortest check hybrid SC168. The desirable hybrids for short plant height were Gm636×Sd9, Sd9×Ism1, Gm636×Ism1 and Sd9×Mall5048 (to resistance lodging). The crosses ranged from 76.67 cm for (Gm636×Sd9) to 146.22 cm for (Sk5010×Sk5025) for ear height. Only ten among 36 crosses toward significantly lower ear placement than the best check hybrid SC3444. The best crosses form them (Gm636×Sd9), (Gm636×Ism1) and (Sd9×Ism1).

Crosses ranged from 0.97 for (Sk5025×Gm636) to 1.11 for (Sk5010×Gm636) and (Sd9×Sd15) for number of ears/plant. Five crosses (Sk5010×Sk28/31), (Sk5010×Sd9), (Sk28/31×Sd15), (Sk28/31×Mall5048) and (Sd9×Sd15) were not increased significantly compared with the check hybrid SC168. For ear length, the hybrids ranged from 15.36 cm for (Gm636×Ism1) to 21.36 cm for (Sk5010×Sk28/31). The best hybrids in ear length were (Sk5001×Sk5004), (Sk5001×Sd41), (Sk5001×Sd7), (Sk5005×Sd41), (Sk5004×Sd41), (Sk5004×Sk13), and (Sd41×Sk13). As for ear length, the lengths of the hybrids ranged from 15.36 cm for (Gm636×Ism1) to 21.36 cm for (Sk5010×Sk28/31). Ten hybrids did not significantly various in comparison with the check hybrid SC168. For ear diameter, the cross (Sk5010×Sk28/31) compared remarkably well the best check hybrid SC168.

Mean performance of 36 crosses and the percentage of superiority compared to the two checks across the various locations are shown in Table 4. The crosses ranged from 21.47 ard/fed for (Mall5048×Ism1) to 33.07 ard/fed for (Sk5010×Sd9). Three crosses, (Sk5010×Sd9), (Sk28/31×Sk5025) and (Sk5025×Sd15) were not significant superiority relative to check SC168 (32.14 ard/fed) but its significant superiority relative to check SC3444 (29.53 ard/fed). Also seven crosses, (Sk5010×Sk5025), (Sk5010×Gm6038), (Sk5010×Sd15), (Sk5010×Mall5048), (Sk5025×Sd9), (Sk5025×Mall5048), and (Sd9×Sd15) were not significant superiority relative to check SC3444. These crosses will be stepped up for evaluation on a large scale in the hybrids registration program in Egypt.

Table 5, presents GCA effects for nine inbred lines of the seven traits examined across various locations. Positive GCA influenced are desirable for improving yield and its component traits, while negative GCA influences are desirable when selecting for earliness, shortness and lower ear positions. Our results indicated that the lines Gm636, Sd9, and Ism1 showed negative and highly significant estimates effects of GCA for days to 50% silking, indicating that these lines have an allele frequency suitable for early maturation. Regarding plant and ear heights, four inbred lines (Gm6038, Gm636, Sd9 and Ism1) showed negative and highly significant estimates of GCA effects toward shortness.

Regarding no. of ears/plant, positive and significant or highly significant GCA effects were recorded for the lines Sk5010, Sk28/31, Sd9 and Sd15. Moreover, lines (Sk5010, Sk28/31, Sk5025 and Mall5048) showed positive and significant GCA effects for ear length. Positive and highly significant GCA effects for ear diameter, were recorded for Sk5010 and Sk5025 lines.

In the case of grain yield, four yellow inbred lines (Sk5010, Sk28/31, Sk5025 and Sd15) exhibited positive and significant or highly significant estimates of GCA effects. Previous results indicated that the two lines (Sk5010 and Sk5025) were the best general combiners for grain yield and its component traits. While, the three lines (Gm636, Sd9 and Ism1) were the best combiners for earliness, shortness and lower ear position. These lines can be used to create hybrids with excellent yield potential, earliness, and suitability of plant and ear heights.

Table 6 shows SCA effects of 36 hybrids for seven traits at three sites. Positive SCA effects are desired to improve grain yield and its component traits, while negative SCA effects are desired when selecting earliness, shortens and lower ear placement. Our results indicated that the four crosses (Sk5010×Gm6038), (Sk28/31×Sk5025), (Sk5025×Gm636) and (Sd15×Ism1) had significant or highly significant and negative SCA effects for days to 50% silking toward earliness. Four hybrids (Sk28/31×Ism1), (Sk5025×Ism1), (Gm636×Sd15) and (Sd9×Mall5048) had significant and negative SCA effects for shortens toward tolerant to lodging. The crosses (Sk28/31×Ism1), (Sk5025×Ism1) and (Gm636×Sd15) exhibited negative and significant or highly significant SCA effects toward lower ear position.

For number of ears/plant, two crosses (Sk28/31×Mall5048) and (Sd9×Sd15) had positive and significant SCA effects. With regard to ear length, six crosses (Sk5010×Sk28/31), (Sk5010×Gm636), (Sk5025×Sd9), (Gm6036×Mall5048), (Sd15×Ism1) and (Mall5048×Ism1) exhibited positive and significant or highly significant SCA effects for ear length. Positive and significant SCA effects were obtained for ear diameter, two crosses (Sk5010×Ism1) and (Gm636×Mall5048).

In respect of grain yield, three yellow crosses (Sk5010×Sd9), (Gm6038×Mall5048) and (Sd15×Ism1) demonstrated positive and highly significant estimates of SCA effects toward high yielding. The cross (Sk5010×Sd9) showed a desired SCA effect and had high grain yield values. The above hybrids can be used for maize breeding efforts.

Second trial:

Variances due to nitrogen levels (N), GCA, SCA and their interaction for resistance to NLB disease % are given in Table 7. The mean squares resulting in nitrogen levels were highly significant, indicating that the resistance to northern leaf blight disease was affected by nitrogen levels.

The GCA mean square was highly significant, while the SCA mean square was not significant, showing that the inheritance of northern leaf blight disease is controlled by the effects of additive genes. The resulting variances of GCA×N and SCA×N interactions were highly significant and significant, respectively, exhibiting that the effects of additive and non-additive genes were affected by nitrogen levels. According to Vivek *et al*. (2010) and Mosa *et al*. (2023), additive gene effects were found to be of major importance in the inheritance of resistance to NLB.

Table 8, illustrates how nitrogen levels affect resistance to the NLB disease. Our results exhibited that the highest resistance to northern leaf blight disease% recorded at lowest nitrogen level (60 kg N/fed) meanwhile, the lowest resistance to NLB disease% recorded at highest nitrogen level (180 kg N/fed). The same result was obtained by Mosa *et al* (2023).

The results in Table 9, indicated that, the mean of crosses ranged from 84% for (Gm636×Ism1) to 98.33% for (Gm6038×Sd9) and (Sk28/31×Sd9) with twenty crosses had resistance over 90%. The best from them were (Sk5025×Gm6038), (Sk5010×Sd9), (Sk28/31×Sd15), (Sk28/31×Mall5048) and (Sd9×Sd15). The desirable inbred lines for GCA effects were (Sk28/31, Sd9 and Sd15). Meanwhile, two crosses (Sk5010×Sd9) and (Gm6038×Ism1) had significant and positive SCA effects for tolerance to northern leaf blight disease.

From above results in first and second trials, two inbred lines Sk28/31 and Sd15 showed the desirable GCA effects for both yield and northern leaf blight disease resistance. Also three crosses, (Sk5010×Sd9), (Sk28/31×Sk5025) and (Sk5025×Sd15) showed the highest grain yield and northern leaf blight disease resistance (over 90%). These hybrids and inbred lines will be applied to the breeding program of maize in Egypt.

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Table 1. Analysis of varainces for seven studied traits across three locations.

SOV	df	Mean squares						
		Days to 50% silking	Plant height	Ear height	No. of ears/plant	Ear length	Ear diameter	Grain yield
Locations (L)	2	1098.00**	170229.20**	66073.34**	0.577**	726.56**	26.34**	4277.48**
Rep/L	6	40.39	2814.05	1247.09	0.005	5.08	0.18	82.55
Crosses (C)	37	40.75**	4471.63**	2858.17**	0.012**	22.69**	0.37**	99.86**
C×L	74	6.52**	272.86**	179.20**	0.011**	5.85**	0.08**	32.21**
Error	222	2.55	138.62	87.96	0.005	1.53	0.05	8.08

** Indicate significant at 0.01 level of probability.

Table 2: Mean squares of GCA, SCA and their interactions with locations for seven studied traits.

SOV	df	Mean squares						
		Days to 50% silking	Plant height	Ear height	No. of ears/plant	Ear length	Ear diameter	Grain yield
GCA	8	136.50**	19458.65**	12438.74**	0.039**	80.74**	1.44**	355.31**
SCA	27	4.89**	350.28**	212.22**	0.005	4.09**	0.06	23.31**
GCA×L	16	23.13**	845.41**	502.84**	0.022**	19.45**	0.16**	82.94**
SCA×L	54	1.61	113.02	79.90	0.008*	1.87	0.05	16.84**
Error	210	2.57	135.89	87.86	0.005	1.43	0.04	7.97
GCA/SCA		27.93	55.55	58.61	8.11	19.76	25.06	15.24
GCA×L/SCA×L		14.34	7.48	6.29	2.76	10.39	3.39	4.93

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

Table 3: Mean performance of 36 crosses and two check hybrids for number of days to 50% silking, Plant height, ear height, number of ears/plant, ear length and ear diameter across three locations.

Crosses	Days to 50% silking	Plant height (cm)	Ear Height (cm)	No. of ears per plant	Ear length (cm)	Ear diameter (cm)
Sk5010×Sk28/31	65.56	261.56	136.22	1.09	21.36	4.76
Sk5010×Sk5025	65.67	276.22	146.22	1.01	21.29	5.18
Sk5010×Gm6038	62.67	239.67	114.44	1.03	17.98	4.78
Sk5010×Gm636	63.56	241.22	118.11	1.07	20.56	4.67
Sk5010×Sd9	61.56	227.89	111.44	1.11	19.22	4.78
Sk5010×Sd15	64.78	258.67	139.22	1.07	19.04	4.84
Sk5010×Mall5048	63.00	253.00	126.78	1.05	19.78	4.76
Sk5010×Ism1	62.00	237.22	115.56	1.03	17.67	4.93
Sk28/31×Sk5025	62.56	268.67	141.22	1.01	20.20	5.13
Sk28/31×Gm6038	62.22	231.00	116.89	1.04	18.00	4.78
Sk28/31×Gm636	61.00	220.00	112.11	1.01	19.76	4.58
Sk28/31×Sd9	60.00	214.22	111.22	1.07	18.18	4.51
Sk28/31×Sd15	63.11	243.44	134.44	1.08	18.93	4.62
Sk28/31×Mall5048	61.78	243.89	125.56	1.10	19.76	4.51
Sk28/31×Ism1	59.56	212.00	101.00	0.99	16.42	4.71
Sk5025×Gm6038	63.89	239.00	118.67	1.00	18.87	5.04
Sk5025×Gm636	61.33	240.56	121.67	0.97	20.02	4.93
Sk5025×Sd9	63.11	232.67	114.89	0.99	20.44	4.96
Sk5025×Sd15	63.56	256.78	140.44	1.00	19.58	5.04
Sk5025×Mall5048	63.44	256.89	135.44	0.99	19.80	5.09
Sk5025×Ism1	60.11	221.00	101.78	0.99	16.84	4.96
Gm6038×Gm636	60.22	203.89	89.56	1.01	16.76	4.62
Gm6038×Sd9	59.00	200.67	85.56	1.02	17.80	4.62
Gm6038×Sd15	62.22	227.56	114.00	1.03	16.56	4.80
Gm6038×Mall5048	60.89	229.33	112.78	1.00	18.91	4.64
Gm6038×Ism1	59.22	205.11	86.78	0.98	15.49	4.60
Gm636×Sd9	59.11	185.22	76.67	1.03	18.98	4.36
Gm636×Sd15	61.56	211.44	107.78	1.01	18.44	4.48
Gm636×Mall5048	60.56	220.33	106.56	1.00	18.22	4.69
Gm636×Ism1	59.22	192.22	78.22	1.00	15.36	4.60
Sd9×Sd15	60.22	212.00	106.22	1.11	17.33	4.52
Sd9×Mall5048	59.00	193.33	96.44	1.00	18.78	4.62
Sd9×Ism1	58.67	191.44	84.00	1.03	16.29	4.43
Sd15×Mall5048	62.44	233.78	123.44	1.02	17.73	4.76
Sd15×Ism1	59.11	231.78	120.11	1.02	16.56	4.67
Mall5048×Ism1	59.00	216.44	100.56	1.01	17.93	4.64
Check SC168	64.11	223.11	120.56	1.07	20.76	4.98
Check SC3444	66.67	225.89	111.56	1.01	20.60	4.87
LSD 0.05	1.49	10.94	8.71	0.07	1.15	0.20

Table 4: Mean performance of 36 crosses along with two check hybrids and superiority percentage relative to the two checks for grain yield across the three locations.

Hybrid	Mean (ard/fed)	Superiority % relative to check hybrids	
		SC168	SC3444
Sk5010×Sk28/31	28.54	-11.19**	-3.36
Sk5010×Sk5025	31.63	-1.58	7.10
Sk5010×Gm6038	29.70	-7.57	0.58
Sk5010×Gm636	28.87	-10.16*	-2.24
Sk5010×Sd9	33.07	2.92	11.99*
Sk5010×Sd15	32.00	-0.42	8.36
Sk5010×Mall5048	31.19	-2.95	5.61
Sk5010×Ism1	28.97	-9.87*	-1.92
Sk28/31×Sk5025	32.17	0.09	8.94*
Sk28/31×Gm6038	28.34	-11.83**	-4.05
Sk28/31×Gm636	25.40	-20.95**	-13.98**
Sk28/31×Sd9	27.00	-15.99**	-8.58
Sk28/31×Sd15	28.90	-10.08*	-2.15
Sk28/31×Mall5048	29.25	-8.99*	-0.96
Sk28/31×Ism1	25.05	-22.04**	-15.16**
Sk5025×Gm6038	28.45	-11.48**	-3.68
Sk5025×Gm636	26.85	-16.45**	-9.08*
Sk5025×Sd9	31.16	-3.03	5.52
Sk5025×Sd15	32.52	1.20	10.13*
Sk5025×Mall5048	30.87	-3.95	4.52
Sk5025×Ism1	26.67	-17.00**	-9.68*
Gm6038×Gm636	23.86	-25.76**	-19.22**
Gm6038×Sd9	26.00	-19.08**	-11.95**
Gm6038×Sd15	26.76	-16.73**	-9.38*
Gm6038×Mall5048	28.35	-11.78**	-4.00
Gm6038×Ism1	21.55	-32.95**	-27.04**
Gm636×Sd9	21.53	-33.01**	-27.10**
Gm636×Sd15	24.81	-22.80**	-16.00**
Gm636×Mall5048	23.68	-26.32**	-19.82**
Gm636×Ism1	22.20	-30.92**	-24.82**
Sd9×Sd15	29.67	-7.67	0.47
Sd9×Mall5048	25.87	-19.49**	-12.39**
Sd9×Ism1	23.00	-28.42**	-22.11**
Sd15×Mall5048	26.04	-18.97**	-11.83**
Sd15×Ism1	27.74	-13.68**	-6.07
Mall5048×Ism1	21.47	-33.20**	-27.31**
Check SC168	32.14	-	-
Check SC3444	29.53	-	-
LSD 0.05		2.64	
LSD 0.01		3.48	

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

Table 5: Estimates of GCA effects of nine inbred lines for seven studied traits across three locations.

Inbred line	Days to 50% silking	Plant height	Ear Height	No. of ears/plant	Ear length	Ear diameter	Grain yield
Sk5010	2.37**	23.79**	14.73**	0.034**	1.31**	0.11**	3.45**
Sk28/31	0.51**	9.41**	10.54**	0.024**	0.69**	-0.04	0.69*
Sk5025	1.64**	23.27**	16.49**	-0.037**	1.33**	0.35**	2.93**
Gm6038	-0.27	-7.53**	-9.46**	-0.018*	-1.05**	0.01	-0.97**
Gm636	-0.81**	-16.29**	-13.46**	-0.016	0.05	-0.14**	-3.23**
Sd9	-1.65**	-24.50**	-16.92**	0.022*	-0.10	-0.16**	-0.35
Sd15	0.69**	6.65**	11.54**	0.017*	-0.51**	-0.03	1.23**
Mall5048	-0.30	2.58	3.24**	-0.005	0.45**	-0.03	-0.44
Ism1	-2.19**	-17.38**	-16.70**	-0.022*	-2.17**	-0.05*	-3.31**
LSD g_i 0.05	0.38	2.73	2.19	0.017	0.28	0.05	0.66
LSD g_i 0.01	0.49	3.60	2.89	0.023	0.37	0.06	0.87
LSD g_i-g_i 0.05	0.56	4.09	3.29	0.026	0.42	0.07	0.99
LSD g_i-g_i 0.01	0.74	5.40	4.34	0.034	0.55	0.10	1.31

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

Table 6: Estimates of SCA effects of 36 crosses for seven studied traits across three locations.

Cross	Days to 50% silking	Plant Height	Ear Height	No. of ears/plant	Ear length	Ear diameter	Grain yield
Sk5010×Sk28/31	1.15**	-0.26	-2.16	0.002	0.89*	-0.05	-3.08**
Sk5010×Sk5025	0.13	0.55	1.89	-0.017	0.18	-0.02	-2.23**
Sk5010×Gm6038	-0.96*	-5.21	-3.94	-0.017	-0.74*	-0.07	-0.25
Sk5010×Gm636	0.47	5.11	3.73	0.029	0.73*	-0.04	1.17
Sk5010×Sd9	-0.69	-0.02	0.52	0.029	-0.45	0.09	2.50**
Sk5010×Sd15	0.20	-0.38	-0.16	-0.011	-0.22	0.02	-0.16
Sk5010×Mall5048	-0.60	-1.99	-4.30	-0.003	-0.45	-0.07	0.70
Sk5010×Ism1	0.29	2.20	4.41	-0.013	0.06	0.14*	1.34
Sk28/31×Sk5025	-1.12**	7.38*	1.08	-0.005	-0.29	0.09	1.06
Sk28/31×Gm6038	0.45	0.50	2.70	0.003	-0.11	0.09	1.14
Sk28/31×Gm636	-0.23	-1.73	1.92	-0.029	0.54	0.03	0.47
Sk28/31×Sd9	-0.39	0.69	4.49	0.001	-0.88*	-0.02	-0.81
Sk28/31×Sd15	0.39	-1.23	-0.75	0.009	0.28	-0.05	-0.50
Sk28/31×Mall5048	0.04	3.28	-1.33	0.054*	0.14	-0.15*	1.53
Sk28/31×Ism1	-0.29	-8.64**	-5.95*	-0.036	-0.57	0.07	0.20
Sk5025×Gm6038	0.99*	-5.35	-1.48	0.026	0.12	-0.04	-0.99
Sk5025×Gm636	-1.02*	4.96	5.52*	-0.002	0.18	-0.01	-0.32
Sk5025×Sd9	1.60**	5.28	2.21	-0.019	0.75*	0.03	1.11
Sk5025×Sd15	-0.29	-1.75	-0.70	-0.010	0.29	-0.01	0.89
Sk5025×Mall5048	0.58	2.42	2.60	0.003	-0.45	0.03	0.90
Sk5025×Ism1	-0.87	-13.50**	-11.13**	0.024	-0.78*	-0.08	-0.42
Gm6038×Gm636	-0.23	-0.91	-0.63	0.012	-0.71*	0.03	0.58
Gm6038×Sd9	-0.61	4.08	-1.17	-0.013	0.49	0.05	-0.14
Gm6038×Sd15	0.28	-0.18	-1.19	0.000	-0.35	0.09	-0.98
Gm6038×Mall5048	-0.07	5.66	5.89*	-0.004	1.05**	-0.06	2.29**
Gm6038×Ism1	0.15	1.41	-0.17	-0.007	0.25	-0.08	-1.65*
Gm636×Sd9	0.04	-2.61	-6.06*	-0.005	0.56	-0.08	-2.36**
Gm636×Sd15	0.15	-7.53*	-3.41	-0.014	0.44	-0.09	-0.67
Gm636×Mall5048	0.13	5.42	3.67	-0.007	-0.75*	0.12*	-0.13
Gm636×Ism1	0.69	-2.72	-4.73	0.015	-0.99**	0.06	1.26
Sd9×Sd15	-0.34	1.23	-1.51	0.045*	-0.52	-0.03	1.32

Sd9×Mall5048	-0.58	-13.37**	-2.98	-0.039	-0.04	0.07	-0.80
Sd9×Ism1	0.98*	4.71	4.51	0.001	0.09	-0.09	-0.81
Sd15×Mall5048	0.53	-4.07	-4.44	-0.019	-0.68*	0.07	-2.23**
Sd15×Ism1	-0.91*	13.90**	12.16**	0.001	0.77*	0.01	2.34**
Mall5048×Ism1	-0.04	2.63	0.90	0.015	1.18**	-0.01	-2.26**
LSD S_{ij} 0.05	0.91	6.63	5.33	0.042	0.68	0.12	1.61
LSD S_{ij} 0.01	1.11	8.75	7.03	0.055	0.90	0.16	2.12
LSD S_{ij}-S_{ik} 0.05	1.38	10.03	8.06	0.063	1.03	0.18	2.43
LSD S_{ij}-S_{ik} 0.01	1.82	13.22	10.63	0.083	1.36	0.24	3.20
LSD S_{ij}-S_{kl} 0.05	1.26	9.16	7.36	0.057	0.94	0.16	2.22
LSD S_{ij}-S_{kl} 0.01	1.66	12.07	9.71	0.076	1.24	0.22	2.92

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

Table 7: Mean squares of nitrogen levels, GCA, SCA and their interaction for resistance to northern leaf blight disease%.

SOV	df	Resistance to northern leaf blight disease%	
		S.S.	M.S.
Replication	1	296.34	296.34
Nitrogen (N)	2	15058.45	7529.23**
$Error_{(a)}$	2	259.79	129.89
Crosses (C)	35	4087.72	116.79**
GCA	8	2845.78	355.72**
SCA	27	1241.93	46.00
C×N	70	5545.88	79.23**
GCA×N	16	2507.58	156.72**
SCA×N	54	3038.30	56.26*
$Error_{(b)}$	105	4084.38	38.90

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

Table 8: Effects of nitrogen levels on resistance to northern leaf blight disease%.

Nitrogen level	Resistance to leaf blight disease%
60 kg N/fed (N_1)	97.71
120 kg N/fed (N_2)	96.36
180 kg N/fed (N_3)	79.36
LSD 0.05	8.17
LSD 0.01	18.85

Table 9: Estimates of GCA effects for nine inbred lines (diagonal), mean performance (below diagonal) and SCA effects (above diagonal) for 36 crosses for resistance to northern leaf blight disease % across three nitrogen levels.

Inbred lines	Sk5010	Sk28/31	Sk5025	Gm6038	Gm636	Sd9	Sd15	Mall5048	Ism1
Sk5010	-1.09	1.90	-1.51	-5.60*	0.64	4.61*	1.11	-0.05	-1.10
Sk28/31	96.00	4.05**	-2.32	-0.08	1.83	-3.20	0.80	2.97	-1.91
Sk5025	88.83	93.17	0.29	4.35	2.59	-2.10	0.90	-1.43	-0.48
Gm6038	85.67	96.33	97.00	1.22	-2.84	3.30	-3.36	-0.53	4.76*
Gm636	86.83	93.17	90.17	85.67	-3.85**	-3.79	1.87	-1.46	1.16
Sd9	97.33	94.67	92.00	98.33	86.17	2.67**	0.85	0.52	-0.20
Sd15	93.50	98.33	94.67	91.33	91.50	97.00	2.34*	0.02	-2.20
Mall5048	88.83	97.00	88.83	90.67	84.67	93.17	92.33	-1.16	-0.03
Ism1	84.50	88.83	86.50	92.67	84.00	89.17	86.83	85.50	-4.45**

LSD $\bar{X}$ 0.05=7.14 and 0.01=9.45

LSD g_i 0.05=1.80 and 0.01=2.38; LSD g_i-g_j 0.05=2.70 and 0.01=3.57

LSD S_{ij} 0.05=4.37 and 0.01=5.78; LSD S_{ij}-S_{kl} 0.05=6.03 and 0.01=7.98

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

التحليل الوراثى لتسعة سلالات من الذرة الشامية صفراء الحبوب للمحصول ومقاومة مرض لفحة الأوراق الشمالية

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الملخص العربي:

تم تهجين تسعة سلالات من الذرة الصفراء في نظام التزاوج النصف دائرى بمحطة بحوث سخا موسم 2021. تم تقييم التهجينات الناتجة وعددها 36 في تجربتين موسم 2022. وذلك للحصول على هجن متفوقة فى محصول الحبوب ومقاومة لمرض لفحة الأوراق الشمالية. التجربة الأولى تم تقييم 36 هجين مع إثنين من الهجن التجارية فى ثلاث محطات بحثية (سخا وسدس وملوى) لصفات عدد الأيام حتى ظهور 50% من حرائر النورات المؤنثة ، إرتفاع النبات، إرتفاع الكوز وعدد الكيزان لكل نبات وطول الكوز وقطر الكوز ومحصول الحبوب. بينما التجربة الثانية تم تقييم الـ 36 هجين تحت ثلاث مستويات من التسميد النيتروجينى فى حقل العدوى الصناعية بمرض لفحة الأوراق الشمالية بمحطة بحوث سخا لتقدير نسبة المقاومة لمرض لفحة الأوراق الشمالية. أظهرت النتائج اختلافات عالية المعنوية بين المواقع فى التجربة الأولى لجميع الصفات المدروسة وبين معدلات التسميد للتجربة الثانية لنسبة المقاومة لمرض لفحة الأوراق الشمالية. كان التباين الراجع لكلا من القدرة العامة والخاصة على الائتلاف عالى المعنوية لجميع الصفات ماعدا التباين الراجع للقدرة الخاصة على الائتلاف لصفة عدد الكيزان لكل نبات وصفة طول الكوز فى التجربة الأولى ونسبة المقاومة لفحة الأوراق الشمالية فى التجربة الثانية. أظهرت السلالتان Gm636 ، Sd9 أعلى قدرة عامة على التآلف لصفات التبكير وقصر النباتات وإنخفاض موقع الكوز. بينما أظهرت السلالتان Sk28/31 ، Sd15 قدرة عامة على الإئتلاف مرغوبة لكلاً من محصول الحبوب ومقاومة مرض لفحة الأوراق الشمالية. تفوقت الهجن (Sk5010×Sd9) ، (Sk28/31×Sk5025) ، (Sk5025×Sd15) فى محصول الحبوب وفى مقاومة مرض لفحة الأوراق الشمالية. ولذلك سوف يتم تقييم هذه الهجن فى الإختبارات المتقدمة ببرنامج تربية الذرة الشامية.

الكلمات الاسترشادية: الذرة الشامية، القدرة العامة على الإئتلاف، القدرة الخاصة على الإئتلاف، العدوى الصناعية بالمرض، مستويات النتروجين.