Egypt. J. Plant Breed. 27(2):269– 287(2023)

COMBINING ABILITY OF ELITE MAIZE INBRED LINES FOR GRAIN YIELD, RESISTANCE TO BOTH LATE WILT AND NORTHERN LEAF BLIGHT DISEASES UNDER DIFFERENT ENVIRONMENTS

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ABSTRACT

Late wilt and northern leaf blight of maize are the most important diseases in Egypt. Inbred lines combining ability and its interaction with environment are required information to get superior hybrids for grain yield and resistance to late wilt and northern leaf blight diseases. Nine white maize inbred lines were crossed in a half diallel mating design at Sakha Research Station in 2021 season. The 36 resulted crosses were evaluated in two trials in 2022 season. In the first trial, 36 F_1 hybrids plus two checks were evaluated at Sakha, Sids and Mallawi Agricultural Research Stations for traits, days to 50% silking, plant height, ear height, number of ears/plant, grain yield, ear length and ear diameter, while in the second trials, 36 F_1 were evaluated under three nitrogen levels in a diseases nursery under artificial infection conditions by late wilt and northern leaf blight diseases at Sakha Research Station to estimate percentage of resistance to both diseases. Highly significant differences were detected among three locations in the first trial and between three nitrogen levels in the second trial. The mean squares due to general and specific combining ability were significant or highly significant for all traits, except mean squares due to specific combining ability for plant height, ear height and ear length in the first trial and northern leaf blight in the second trial. The desirable inbred lines for general combining ability effects were Sd41 and Ism77 for earliness, short plant and low ear height, Sd4, Sd7 and Sk13 for increased number of ears/plant, Sk5001, Sk5004, Sd41 and Sk13 for increased grain yield and ear length, Sk5001 and Sk5004 for increased ear diameter and Sk5005, Sd41, Sd7 and Ism77 for resistance to late wilt disease and Sk5001 and Sd41 for resistance to northern leaf blight disease. The desirable hybrid for specific combining ability effects was (Sd4×Ism77) for earliness, short both plant height and ear height, (Sd1121×Sd7) for number of ears/plant, (Sk5001×Sd7) for grain yield, (Sd4× Sd1121) for ear length, (Sk5004×Sd7) for ear diameter, (Sk5001×Sd1121) for resistance to late wilt disease and (Sk5001 ×Sd13) for resistance to northern leaf blight disease. The hybrids which had high grain yield and resistance to late wilt and northern leaf blight diseases were (Sk5001×Sk5004), (Sk5001×Sd41), (Sk5004×Sd7), (Sk5004×Sd41), (Sd41×Sk13) and (Sd7×Sk13). These hybrids will be evaluated in the advanced level of testing in maize breeding program.

Key words: ***General combining ability, Specific combining ability, Artificial infection, Nitrogen levels.***

INTRODUCTION

Maize (*Zea mays* L.) is the world's most widely grown cereal. The identification of parental inbred lines that perform superior hybrids, is the most costly and time consuming phase in maize hybrid development (Morris *et al* 1999, Keskin *et al* 2005 and Mohammed *et al* 2014). The most important factor in hybrid breeding is the selection of germplasm as the basic population that will determine the availability of superior parents. The good parents derived from superior genetic material is ties with an ideal agronomic character will have high general combining ability (GCA) and high specific combining ability (SCA) (Takdir *et al* 2007). Diallel crosses had been widely used in genetic research to investigate the inheritance of important traits among a set of genotypes, especially to investigate the general (GCA) and specific (SCA) combining ability of the parental lines for the purpose of identification of superior parents to be used in hybrid development programs (Malik *et al* 2004). Analysis of diallel data is usually conducted according to the methods of Griffing (1956) which partition the total variation of diallel data into GCA of the parents and SCA of the crosses (Yan and Hunt 2002). GCA is the average appearance of an inbred line that is crossed with several other inbred lines (Santoso *et al* 2014). SCA is the contribution of an inbred line to hybrid performance in a cross with a specified inbred line, in relation to its contributions in crosses with an array of specified inbred lines (Poehlman and Sleper 1995). Hence the combining ability analysis was an important method to know gene action and it was frequently used by crop breeders to choose the parents with high GCA effects and hybrid with high SCA effects (Yingzhong 1999). Also GCA is attributed to additive type of gene effects, while SCA is attributed to non additive gene effects. The late wilt disease caused by *Cephalosporium maydis* is one of the major diseases affecting maize grain yield in Egypt; the best way of controlling this disease is through developing genetically resistant maize hybrids. Mosa and Motawei (2005) found that both additive and non additive gene effects were important in the inheritance of late wilt disease. However, Mosa *et al* (2010) found that the additive gene effects had the main influence in the inheritance of this disease, while El-Itriby *et al* (1984) and Amer *et al* (2002) reported that non additive gene effects were the major contributors to the inheritance of resistance to late wilt disease. Northern leaf blight (NLB) caused by *Helminthosporium turcicum* of maize is the major problem in late summer in the northern and north-western regions of the Delta in Egypt, because the weather conditions are suitable for this disease. NLB disease occurs sporadically in most temperate, humid areas where maize is grown (Scrivener *et al* 2001). The NLB disease symptoms primarily appear on the leaves and plant might be infected at any growth stage, but usually at after anthesis (Scrivener *et al* 2001 and Sharma *et al* 2015). Both additive and non additive gene effects were important in the inheritance of northern leaf blight (El-Shenawy and Tolba 2004). However additive gene effects were found to be of major importance in the inheritance of LBN (Vivck *et al* 2010), while the non-additive effects were more important as reported by Schechert *et al* (1997). The objectives of this study were to estimate GCA and SCA effects and identify superior hybrids for grain yield and resistance to each of late wilt and northern leaf blight diseases.

MATERIALS AND METHODS

Nine diverse elite white maize inbred lines i.e. Sk5001, Sk5005, Sk5004, Sd41, Sd4, Sd1121, Sd7, Sk13 and Ism77 were obtained from maize research program. These maize inbred lines were crossed in a half diallel mating scheme (Griffing 1956) in 2021 season at Sakha Research Station. The resulting 36 F_1 hybrids were evaluated in two trials in 2022 season. In the first trial, the 36 F_1 hybrids plus two check hybrids (SC10 and Hytech SC2031) were evaluated at Sakha, Sids and Mallawi Agricultural Research Stations using a randomized complete block design (RCBD) with three replications. The plot was one row, 6m long, 80cm apart and 25cm between hills. All agricultural recommended practices were applied in the proper time. The data were recorded on number of days to 50% silking, plant height (cm), ear height (cm), number of ears/plant, grain yield adjusted at 15.5% grain moisture (ard/fed) (one ardab = 140kg and one feddan = 4200m^2), ear length (cm) and ear diameter (cm). In the second trial, the 36 F_1 hybrids were evaluated in a disease nursery under artificial infection conditions by late wilt and northern leaf diseases at Sakha Research Station under three levels of nitrogen (60, 120 and 180 kg N/fed) .Split plot design using RCBD with two replications was used. The main plot included three nitrogen levels, while sub plot included 36 F_1 hybrids. The plot was one row, 2m long, 80cm apart and 20cm between hills. Each row consisted of 11 hills with three kernels were seeded per hill. The plants were thinned later to one plant per hill before the first irrigation. The obtained fungi for two diseases were identified by Stafe Number of Fungal Taxonomy Institute of

Plant Pathology ARC, Giza, Egypt. Different isolates of *Cephalosporium maydis* were used annually to re-infect disease nursery to increase the efficiency of selection. The data were recorded after 35 days from flowering and then the percentage of resistance to late wilt disease was estimated. The spores suspension of fungus of northern leaf blight was sprayed to cover the leaves of all plants; 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 computed by procedure of Griffing (1956), method-4 model-1. Calculations of analyses of variances were carried out by using computer application of Statistical Analysis System (SAS, 2008),

RESULTS AND DISCUSSION

First trial

The locations (L) mean squares were highly significant for all studied traits (Table 1), revealing that the responses of the genotypes across all the environments were different.

Table 1. Mean squares of locations, hybrids and their interaction for seven studied traits.

SOV	df	Days to 50% silking	Plant height	Ear height	No of ears/plant	Grain yield	Ear length	Ear diameter
Locations (L)	2	686.14**	233153.9**	67814.3**	0.32**	5763.75**	980.04**	41.77**
Rep/L	6	39.71	1771.9	669.4	0.01	21.15	1.63	0.06
Hybrids (H)	37	30.75**	2218.4**	1254.1**	0.02**	76.60**	7.46**	0.09**
H×L	74	3.25**	298.8**	259.1**	0.02**	45.43**	3.88**	0.05**
Error	222	2.06	168.5	91.7	0.01	7.99	1.72	0.03

**** Indicate significant at 0.01 level of probability.**

Similar significant differences following combined analysis were previously reported (Abera *et al* 2016 and Mosa (2003). Mean squares of hybrids (H) were highly significant for studied traits, indicating that the hybrids varied in these traits. Also, mean squares due to H×L interaction was highly significant for all studied traits, indicating that differences among hybrids were not the same at all locations. Similar results were reported by Fan *et al* (2008) and Mosa *et al* (2010).

Means of 36 single crosses and two checks for seven traits across three locations are presented in Table 2. For number of days to 50 % silking, the hybrids ranged from 60.8 day for (Sd4×Ism77) to 66.9 day for (Sk5004×Sd7) with nineteen hybrids were earlier than the best check SC10; the best hybrids from them were (Sk5001×Ism77), (Sk5005×Ism77), (Sk5004×Ism77), (Sd4×Ism77), (Sd1121×Ism77) and (Sk13×Ism77), indicating that the inbred line Ism77 was common in all early hybrids. For plant height, the hybrids ranged from 214.3 cm for (Sd4×Ism77) to 285.6 cm for (Sk5004×Sd41). The desirable hybrids for tall plant height were (Sk5001×Sk5004), (Sk5005×Sd41), (Sk5004×Sd41), (Sk5004×Sd7) and (Sd41×Sd7) (to make the silage), while the desirable hybrids for short plant height were (Sd4×Sd1121), (Sd4×Sk13), (Sd4×Ism77), (Sd1121×SK13), (Sd1121×Ism77) and (Sk13×Ism77) (to resistance lodging). For ear height, the hybrids ranged from 99.8 cm for (Sd4×Ism77) to 152.7 cm for (Sk5004×Sd41; the desirable hybrids for low ear height were (Sk5001×Sd4), (Sk5005×Sd4), (Sk5005×Ism77), (Sd4×Sd1121), (Sd4×Sk13), (Sd4×Ism77), (Sd1121×Sk13), (Sd1121×Ism77) and (Sk13×Ism77). For number of ears/plant, the hybrids ranged from 0.96 for (Sk5005×Sk5004) to 1.13 for each of (Sd1121×Sd7) and (Sd7×Sk13), the best hybrids bearing more than one ear/plant were (Sk5001×Sd41), (Sk5004×Sd41), (Sk5004×Sk13), (Sd41×Sd7), (Sd41×Sk13), (Sd1121×Sd7), (Sd1121×Sk13) and (Sd7×Sk13). For grain yield, the hybrids ranged from 23.9 ard/fed for (Sd1121×Ism77) to 35.6 ard/fed for (Sd41×Sk13). The hybrids, (Sk5001×Sk5004), (Sk5001×Sd41), (Sk5001×Sd7), (Sk5004×Sd41), (Sk5004×Sk13), (Sd41×Sk13) and (Sd7×Sk13) were significantly outyielded the two checks, SC10 and SC2031.

Table 2. Mean performance of 36 hybrids and two checks for seven studied traits across three locations.

Hybrid	Days to 50% silking	Plant height (cm)	Ear height (cm)	No of ears/plant	Grain yield (ard/fed)	Ear length (cm)	Ear diameter (cm)
Sk5001×Sk5005	62.9	253.9	126.3	0.99	28.1	20.0	4.6
Sk5001×Sk5004	64.2	272.6	136.9	1.03	34.6	21.5	5.0
Sk5001×Sd41	66.3	268.7	140.2	1.09	34.0	21.1	5.0
Sk5001×Sd4	62.0	243.1	115.0	1.04	24.8	18.7	4.8
Sk5001×Sd1121	63.9	261.8	132.8	1.01	29.1	20.3	4.8
Sk5001×Sd7	66.7	267.8	137.2	1.02	32.8	21.1	4.8
Sk5001×Sk13	64.3	248.1	125.0	1.00	30.1	21.0	4.8
Sk5001×Ism77	61.4	251.8	128.6	1.03	28.8	20.0	4.7
Sk5005×Sk5004	64.1	263.9	137.7	0.96	30.3	20.2	4.8
Sk5005×Sd41	64.4	274.0	144.7	1.03	30.9	21.2	4.7
Sk5005×Sd4	62.0	247.8	118.2	1.00	25.8	19.3	4.7
Sk5005×Sd1121	63.7	248.0	121.4	1.04	27.3	19.6	4.7
Sk5005×Sd7	66.6	267.3	135.8	0.99	24.8	19.3	4.6
Sk5005×Sk13	64.4	246.9	122.6	1.01	29.6	20.8	4.8
Sk5005×Ism77	61.2	246.7	116.0	1.00	27.5	19.4	4.6
Sk5004×Sd41	66.8	285.6	152.7	1.08	34.3	21.4	4.8
Sk5004×Sd4	62.7	258.3	126.6	1.04	28.2	18.9	4.7
Sk5004×Sd1121	63.3	266.4	136.0	0.98	27.0	20.6	4.7
Sk5004×Sd7	66.9	274.8	142.0	1.01	28.2	19.5	4.9
Sk5004×Sk13	64.9	251.1	127.9	1.09	33.9	21.2	4.8
Sk5004×Ism77	61.8	258.6	131.4	1.02	30.0	19.8	4.7
Sd41×Sd4	63.1	255.2	131.8	1.02	31.4	20.0	4.7
Sd41×Sd1121	64.8	259.8	135.9	1.01	27.5	20.1	4.8
Sd41×Sd7	66.2	283.3	151.9	1.10	31.0	20.9	4.6
Sd41×Sk13	66.3	258.2	138.9	1.06	35.6	21.2	4.7
Sd41×Ism77	62.2	249.4	129.6	1.02	31.2	20.1	4.8
Sd4×Sd1121	62.4	236.4	116.4	1.01	27.0	19.4	4.6
Sd4×Sd7	64.7	248.2	124.3	1.03	26.3	18.6	4.6
Sd4×Sk13	62.4	223.8	106.4	1.00	29.7	19.4	4.7
Sd4×Ism77	60.8	214.3	99.8	1.01	25.9	18.2	4.5
Sd1121×Sd7	66.3	259.1	136.3	1.13	27.2	20.2	4.6
Sd1121×Sk13	63.9	233.3	113.7	1.09	29.5	20.8	4.6
Sd1121×Ism77	61.4	230.6	118.3	1.00	23.9	18.0	4.6
Sd7×Sk13	64.9	246.7	127.2	1.13	33.4	20.8	4.7
Sd7×Ism77	62.7	246.0	126.1	1.04	29.0	20.1	4.6
Sk13×Ism77	61.7	232.7	117.1	1.00	30.4	20.3	4.6
Check SC10	65.4	272.1	147.3	1.00	30.1	20.4	4.7
Check SC2031	66.6	252.4	132.9	0.98	30.0	21.0	4.9
LSD 0.05	1.33	11.99	8.85	0.09	2.61	1.21	0.16
0.01	1.75	15.79	11.65	0.12	3.44	1.60	0.21

The better hybrids in ear length were (Sk5001×Sk5004), (Sk5001×Sd41), (Sk5001×Sd7), (Sk5005×Sd41), (Sk5004×Sd41), (Sk5004×Sk13), and (Sd41×Sk13). For ear diameter the hybrids ranged from 4.5 cm for (Sd4×Ism77) to 5 cm for (Sk5001×Sk5004) and (Sk5001×Sd41). The desirable hybrids for ear diameter, were (Sk5001×Sk5004), (Sk5001×Sd41) and (Sk5004×Sd7). From above results the hybrids (Sk5001×Sk5004), (Sk5001×Sd41) (Sk5004×Sd41), (Sk5004×Sk13) and (Sd41×Sk13) were superior to checks for grain yield, ear length, ear diameter and number of ears/plant, these hybrids will be stepped up for evaluation on a large scale in the hybrids registration program in Egypt.

The mean squares due to GCA, SCA and their interactions with location are presented in Table 3. The general combining ability (GCA) was highly significant for all seven studied traits, indicating that the inbred lines contributed differently in the hybrids, where they were involved.

Table 3. Mean squares of GCA and SCA and their interactions with locations for seven studied traits.

SOV	df	Days to 50% silking	Plant height	Ear height	No of ears/plant	Grain yield	Ear length	Ear diameter
Hybrids (H)	**35**	**30.09****	**2259.8****	**1234.1****	**0.016****	**80.79****	**7.7****	**0.09****
GCA	**8**	**117.96****	**9093.5****	**4977.2****	**0.030****	**262.03****	**25.8****	**0.22****
SCA	**27**	**4.06****	**235.0**	**125.0**	**0.012****	**27.09****	**2.34**	**0.05****
Hybrids× L	**70**	**3.38****	**287.4****	**243.4****	**0.019****	**47.47****	**3.9****	**0.05***
GCA× L	**16**	**7.95****	**637.2****	**677.5****	**0.040****	**160.60****	**12.5****	**0.09****
SCA× L	**54**	**2.03**	**183.8**	**114.8**	**0.012****	**13.95****	**1.4**	**0.04**
Error	**210**	**2.06**	**168.2**	**89.2**	**0.006**	**7.78**	**1.7**	**0.03**
GCA/SCA		**29.05**	**38.69**	**39.81**	**2.50**	**9.67**	**11.02**	**4.40**

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

The specific combining ability (SCA) was significant or highly significant for all studied traits, except for plant and ear heights and ear length, which allow us to infer that there were hybrid combinations that had a performance different from that excepted only on the GCA effects. Also these results indicated that the additive gene effects (GCA) and non additive gene effects (SCA) were important in the inheritance of all studied traits, except for plant height and ear height and ear length, where the non-additive gene effects were not significant. Considering the interactions, the highly significant GCA× location (Loc) interaction was detected for all traits, indicating that the GCA of inbred lines were altered by the environmental conditions. On the other hand, the interaction SCA×location was significant or highly significant for grain yield and number of ears/plant, which allows us to infer that the specific hybrid combinations were not stable across locations for grain yield and number of ears/plant and stable across locations for days to 50% silking, plant and ear heights, ear length and ear diameter. Thus the additive gene effects were more interacted with location than non-additive ones for most studied traits. The ratio between mean squares due to GCA and mean squares due to SCA showed that the additive gene effects (GCA) were more important than non additive gene effects (SCA) for all studied traits. Predominance of additive over non additive gene effects reported by Aguiar *et al* (2003), Sibiya *et al* (2013) and Abera *et al* (2016) for plant height, ear height and grain yield, 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.

Estimates of general combining ability effects for nine inbred lines for seven traits across three locations are presented in Table 4. For days to 50% silking, the inbred lines ranged from -2.51 for Ism77 to 2.02 for Sd7. When breeding for early maturity, negative values for GCA effects would be desirable; hence the best inbred lines for earliness were Sd4 and Ism77. For plant height and ear height, the highest inbred line for GCA effects was Sd41, while the lowest inbred line for GCA effects was Sd4, the desirable inbred lines for short plant and ear height were Sd4, Ism77, Sk13 and Sd1121, respectively. For number of ears/plant, it ranged from -0.036 for Sk5005 to 0.03 for Sd7, the best inbred lines were Sd41, Sd7 and Sk13. For grain yield GCA effects of the inbred lines ranged from -2.42 for Sd1121 to 2.93 for Sd41, the desirable inbred lines were Sk5001, Sk5004, Sd41 and Sk13. For ear length, GCA effects of the inbred lines ranged from -1.17 for Sd4 to 0.77 for Sd41, the desirable inbred lines were Sk5001, Sk5004, Sd41 and Sk13. For ear diameter, GCA effects of the inbred lines ranged from -0.064 for Ism77 to 0.108 for Sk5001, the best inbred lines were Sk5001 and Sk5004. These inbred lines could be utilized in making hybrids that had high yielding ability, earliness, suitable for plant and ear height and prolificacy trait.

Table 4. 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	Grain yield	Ear length	Ear diameter
Sk5001	0.14	5.41**	1.92	-0.005	0.99**	0.44**	0.108**
Sk5005	-0.20	2.66	-0.85	-0.036**	-1.57**	-0.13	-0.008
Sk5004	0.56**	14.49**	8.93**	-0.010	1.61**	0.32*	0.073**
Sd41	1.35**	14.92**	13.85**	0.019*	2.93**	0.77**	0.031
Sd4	-1.52**	-14.65**	-12.86**	-0.013	-2.31**	-1.17**	-0.035
Sd1121	-0.14	-4.91**	-2.53*	0.009	-2.42**	-0.23	-0.048*
Sd7	2.02**	9.06**	7.47**	0.030**	-0.40	-0.03	-0.050*
Sk13	0.30	-12.72**	-7.12**	0.021*	2.40**	0.70**	-0.007
Ism77	-2.51**	-14.26**	-8.81**	-0.016	-1.23**	-0.67**	-0.064**
LSD g_i 0.05	0.34	3.04	2.21	0.018	0.65	0.31	0.041
0.01	0.44	4.00	2.92	0.024	0.86	0.40	0.053
LSD g_i-g_J 0.05	0.50	4.56	3.32	0.027	0.98	0.46	0.061
0.01	0.66	6.01	4.73	0.036	1.29	0.60	0.080

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

Estimates of specific combining ability effects of 36 hybrids for seven traits across three locations are presented in Table 5. The desirable hybrids for SCA effects were (Sk5001×Sk5005), (Sk5004×Sd1121), (Sd41×Sd7) and (Sd7×Sk13) for early maturity, (Sk5001×Sk5005) and (Sd4×Ism77) for short plant height, (Sd4×Ism77) for short ear height, (Sk5005×Sd1121), (Sk5004×Sd41), (Sd1121×Sk13) and (Sd7×Sk13) for prolificacy, (Sk5001×Sk5004), (Sk5001×Sd7), (Sk5005×Sd1121), (Sd4×Sd1121) and (Sd7×Sk13) for grain yield, (Sd4×Sd1121) for ear length and (Sk5001×Sd41), (Sk5005×Sk13), (Sk5004×Sd7) and (Sd41×Ism77) for ear diameter. The above hybrids might be utilized in maize breeding programs for different purposes.

Table 5. Estimates of SCA effects of 36 hybrids for seven studied traits across three locations.

Hybrid	Days to 50% silking	Plant height	Ear height	No of ears/plant	Grain yield	Ear length	Ear diameter
Sk5001×Sk5005	-0.90*	-7.91*	-3.31	0.007	-0.78	-0.38	-0.194**
Sk5001×Sk5004	-0.33	-1.07	-2.53	0.009	2.62**	0.68	0.058
Sk5001×Sd41	0.99*	-5.38	-4.12	0.026	0.66	-0.19	0.100*
Sk5001×Sd4	-0.47	-1.37	-2.63	0.026	-3.25**	-0.69	0.011
Sk5001×Sd1121	0.04	7.55*	4.82	-0.018	1.10	0.04	0.001
Sk5001×Sd7	0.66	-0.42	-0.74	-0.032	2.76**	0.61	0.047
Sk5001×Sk13	0.04	1.69	1.63	-0.045*	-2.75**	-0.23	0.004
Sk5001×Ism77	-0.04	6.90	6.88*	0.026	-0.35	0.16	-0.027
Sk5005×Sk5004	-0.09	-6.99	1.01	-0.032	0.88	-0.10	0.041
Sk5005×Sd41	-0.55	2.69	3.09	0.001	0.09	0.51	-0.007
Sk5005×Sd4	-0.12	6.04	3.36	0.008	0.31	0.48	0.060
Sk5005×Sd1121	0.17	-3.48	-3.75	0.040*	1.87*	-0.14	0.073
Sk5005×Sd7	0.90*	1.88	0.58	-0.044*	-2.67**	-0.66	-0.070
Sk5005×Sk13	0.50	3.22	1.94	-0.002	-0.62	0.13	0.120*
Sk5005×Ism77	0.09	4.54	-2.91	0.023	0.92	0.16	-0.023
Sk5004×Sd41	1.02*	2.42	1.31	0.043*	0.39	0.17	-0.043
Sk5004×Sd4	-0.21	4.77	1.91	0.036	-0.52	-0.37	-0.065
Sk5004×Sd1121	-0.93*	3.14	1.02	-0.055*	-1.58*	0.38	-0.053
Sk5004×Sd7	0.47	-2.50	-2.98	-0.041*	-2.44**	-0.89*	0.127*
Sk5004×Sk13	0.18	-4.38	-2.50	0.034	0.48	0.07	-0.027
Sk5004×Ism77	-0.12	4.60	2.75	0.007	0.16	0.06	-0.037

Table 5. Cont.

Hybrid	Days to 50% silking	Plant height	Ear height	No of ears/plant	Grain yield	Ear length	Ear diameter
Sd41×Sd4	-0.56	1.23	2.21	-0.015	1.32	0.31	-0.024
Sd41×Sd1121	-0.28	-3.96	-4.01	-0.045*	-2.44**	-0.49	0.055
Sd41×Sd7	-0.99*	5.63	1.99	0.001	-0.96	0.06	-0.121*
Sd41×Sk13	0.83*	2.30	3.58	-0.002	0.83	-0.31	-0.053
Sd41×Ism77	-0.47	-4.94	-4.06	-0.007	0.12	-0.06	0.093*
Sd4×Sd1121	0.26	2.28	3.26	-0.001	2.33**	0.74*	-0.012
Sd4×Sd7	0.33	0.09	1.15	-0.018	-0.45	-0.26	-0.010
Sd4×Sk13	-0.18	-2.58	-2.15	-0.040*	0.20	-0.17	0.036
Sd4×Ism77	0.96*	-10.48**	-7.12**	0.004	0.06	-0.03	0.004
Sd1121×Sd7	0.61	1.23	2.82	0.074**	0.56	0.38	-0.042
Sd1121×Sk13	-0.12	-2.77	-5.26	0.029	0.06	0.26	-0.062
Sd1121×Ism77	0.25	-4.00	1.10	-0.024	-1.89*	-1.16**	0.039
Sd7×Sk13	-1.28**	-3.40	-1.71	0.058**	2.01*	0.07	0.050
Sd7×Ism77	-0.69	-2.53	-1.12	0.002	1.19	0.68	0.019
Sk13×Ism77	0.02	5.92	4.47	-0.031	-0.22	0.18	-0.069
LSD S_{ij} 0.05	0.82	7.38	5.37	0.040	1.59	0.74	0.090
0.01	1.08	9.73	7.09	0.058	2.09	0.98	0.129
LSD S_{ij}-S_{ik} 0.05	1.23	11.16	8.13	0.067	2.40	1.12	0.149
0.01	1.63	14.71	10.71	0.088	3.16	1.48	0.196
LSD S_{ij} S_{kl} 0.05	1.13	10.19	7.41	0.061	2.19	1.02	0.136
0.01	1.49	13.43	9.78	0.080	2.89	1.35	0.179

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

Second trial:

Mean squares of GCA, SCA, nitrogen levels and their interactions for resistance to both late wilt and northern leaf blight diseases are presented in Table 6. The mean squares due to nitrogen levels were highly significant for the two traits, indicating that the resistance to late wilt and northern leaf blight diseases were affected by nitrogen levels. The high nitrogen level (180 kg N/fed) recorded high infection followed by 120 kg N/fed and 60 kg N /fed for both traits (Table 7). Similar results were reported by Mosa *et al* (2010) for resistance to late wilt disease.

Regarding to Table 6, the mean squares due to GCA and SCA were highly significant for both resistance late wilt and northern leaf blight diseases, except for SCA for northern leaf blight, indicating that both additive and non additive gene effects were important for the resistance to late wilt diseases, while, only the additive gene effects were important for controlling northern leaf blight disease.

Table 6. Mean squares of GCA, SCA, Nitrogen levels and their interactions for resistance to both late wilt and northern leaf blight diseases.

SOV	df	Resistance to late wilt disease (%)	Resistance to leaf blight disease (%)
Replication	1	17.56	60.17**
Nitrogen (N)	2	331.3*	16352.9**
Error$_a$	2	17.19	3.01
Hybrids (H)	35	362.3**	182.0**
GCA	8	615.6**	427.0**
SCA	27	287.3**	109.4
H × N	70	28.3	177.3**
GCA× N	16	13.4	333.1**
SCA× N	54	32.7	131.2
Error$_b$	105	30.2	98.9
GCA/SCA		2.14	3.90

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

Table 7. Effects of nitrogen levels on resistance to both late wilt and northern leaf blight diseases.

Nitrogen level	Resistance to late wilt disease (%)	Resistance to leaf blight disease (%)
60 kg N/fed (N1)	95.52	98.02
120 kg N/fed (N2)	92.16	96.34
180 kg N/fed (N3)	91.53	71.12
LSD 0.05	2.97	1.24
0.01	6.84	2.86

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

The ratio between mean squares due to GCA and mean squares due to SCA showed that additive gene effects were more predominance than non-additive gene effects for resistance to late wilt and northern leaf blight diseases. Mosa *et al* (2010) found that additive gene effects were more important than non-additive gene effects in the inheritance of late wilt disease. While, El-Itriby *et al* (1984) and Amer *et al* (2002) reported that non-additive gene effects were the major contributors to the inheritance of resistance to late wilt disease. Also Sigulas *et al* (1988), Carson (1995) and Vivek *et al* (2010) reported that additive gene effects were found to be of major importance in the inheritance of resistance to northern leaf blight disease. While, Schechert *et al* (1997) found that non-additive gene effects had the main influence on the inheritance of northern leaf blight disease.

Estimates of GCA effects of nine inbred lines, mean performance and SCA effects of 36 hybrids for resistance to late wilt disease across three nitrogen levels are presented in Table 8. The desirable inbred lines of GCA effects for resistance to late wilt were Sk5005, Sd41, Sd7 and Ism77. The best mean hybrids for resistance to late wilt disease were (Sk5001×Sd41), (Sk5001×Sd1121), (Sk5001×Ism77), (Sk5005×Sk5004), (Sk5005×Sd1121), (Sk5005×Sk13), (Sk5004×Sd41), (Sd41×Ism77), (Sd4×Ism77) and (Sd7×Ism77) (resistance over 97%). The desirable hybrids for SCA effects were (Sk5001×Sk5004), (Sk5001×Sd1121), (Sk5001×Sk13), (Sk5005×Sk5004), (k5005×Sd1121), (Sk5004×Sd4), (Sd41×Sd4), (Sd4×Sd7), (Sd4×Ism77) and (Sd1121×SK13).

Table 8. Estimates of GCA effects of nine inbred lines (diagonal), mean performance (above diagonal) and SCA effects (below diagonal) of 36 hybrids for resistance to late wilt disease across three nitrogen levels.

Inbred line	Sk5001	Sk5005	Sk5004	Sd41	Sd4	Sd1121	Sd7	Sk13	Ism77
Sk5001	-0.33	88.4	96.8	98.3	68.7	97.9	96.8	97.0	98.3
Sk5005	-6.06**	1.74*	98.3	96.1	85.0	98.5	95.1	98.3	97.0
Sk5004	7.35**	6.79**	-3.28**	97.1	88.4	71.7	95.3	78.7	95.5
Sd41	1.43	-2.87	3.01	4.16**	95.3	96.1	97.0	95.5	98.5
Sd4	-17.23**	-2.95	5.44**	4.90*	-6.83**	76.2	97.0	87.9	98.3
Sd1121	8.20**	6.69**	-15.06**	1.89	-7.01**	-3.02**	90.6	97.0	95.5
Sd7	1.35	-2.43	2.77	-2.99	7.99**	-2.18	2.73**	93.8	98.2
Sk13	4.17*	3.46	-11.18**	-1.84	1.57	6.86**	-2.08	0.06	97.0
Ism77	0.80	-2.63	0.86	-3.54	7.29**	0.61	-2.44	-0.96	4.79**
Means LSD 0.05		6.1	LSD g_i 0.05		1.59		LSD S_{ij} 0.05		3.85
0.01		8.1	0.01		2.10		0.01		5.10
			LSD g_i-g_J 0.05		2.38		LSD S_{ij}-S_{ik} 0.05		5.82
			0.01		3.15		0.01		7.71
							LSD S_{ij} S_{kl} 0.05		5.32
							0.01		7.03

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

Table 9, showed that the best inbred line for GCA effects of resistance to northern leaf blight disease was Sd41 followed by Sk5001. The desirable hybrids for resistance to northern leaf blight disease were (Sk5001×Sk5005), (Sk5001×Sd41), (Sk5001×Sd1121), (Sk5001×Sd7), (Sk5001×Sk13), (Sk5005×Sd41), (SK5005×Sd4), (Sk5005×Sd1121), (Sk5004×Sd1121), (Sk5004×Sd7), (Sd41×Sd4), (Sd41×Sd1121), (Sd41×Sd7), (Sd1121×Sd7) and (Sd7×Ism77) (resistance over 90%). Meanwhile, the best hybrid for SCA effects was (Sk5001×Sk13).

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

Inbred line	Sk5001	Sk5005	Sk5004	Sd41	Sd4	Sd1121	Sd7	Sk13	Ism77
Sk5001	**2.81***	**93.3**	**89.8**	**97.3**	**78.8**	**96.0**	**91.8**	**92.8**	**87.7**
Sk5005	**0.07**	**1.95**	**88.5**	**96.7**	**92.2**	**94.2**	**89.3**	**81.5**	**86.0**
Sk5004	**-1.10**	**-1.57**	**-0.38**	**88.7**	**82.2**	**94.7**	**91.2**	**82.0**	**88.3**
Sd41	**3.07**	**3.26**	**-2.40**	**2.95***	**91.5**	**94.0**	**97.8**	**85.3**	**77.3**
Sd4	**-9.76****	**4.43**	**-3.24**	**2.76**	**-2.71***	**86.5**	**86.3**	**87.2**	**84.3**
Sd1121	**2.55**	**1.57**	**4.40**	**0.40**	**-1.43**	**2.14**	**91.8**	**82.0**	**83.8**
Sd7	**-1.95**	**-3.60**	**0.57**	**3.90**	**-1.93**	**-1.29**	**2.48**	**86.5**	**90.5**
Sk13	**6.89***	**-4.29**	**-1.45**	**-1.45**	**6.05**	**-3.98**	**0.19**	**-4.67****	**78.0**
Ism77	**0.93**	**0.12**	**4.79**	**-9.55****	**3.12**	**-2.24**	**4.10**	**-1.26**	**-4.57****
Means LSD 0.05		**11.1**	**LSD g_i 0.05**		**2.70**		**LSD S_{ij} 0.05**		**6.89**
0.01		**14.6**	**0.01**		**3.73**		**0.01**		**9.07**
			LSD g_i-g_J 0.05		**4.30**		**LSD S_{ij}-S_{ik} 0.05**		**10.54**
			0.01		**5.69**		**0.01**		**13.95**
							LSD S_{ij} S_{kl} 0.05		**9.62**
							0.01		**12.73**

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

From above results in the first and second trials, the hybrids which had high grain yield and resistance to late wilt and northern leaf blight disease (over 85%) were (Sk5001×Sk5004) (34.6 ard/fed, 96.8% and 89.8%), (Sk5001×Sd41) (34 ard/fed,98.3% and 97.3%), (Sk5001×Sd7) (32.8 ard/fed, 96.8% and 91.8%), (Sk5004×Sd41) (34.3 ard/fed, 97.1% and 88.7%), (Sd41×Sk13) (35.6 ard/fed, 95.5% and 85.3%) and (Sd7×Sk13) (33.4 ard/fed, 93.8% and 86.5%), respectively. Therefore they will be evaluated in the advanced level of testing in the maize breeding program.

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القدرة على الائتلاف لسلالات منتخبة من الذرة الشامية للمحصول والمقاومة لكلا من مرض الذبول المتأخر وتبقع الأوراق الشمالي تحت بيئات مختلفة

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مركز البحوث الزراعية – معهد بحوث المحاصيل الحقلية – قسم بحوث الذرة الشامية

يعتبر الذبول المتأخر وتبقع الأوراق الشمالي من اهم الأمراض التي تصيب محصول الذرة الشامية فى مصر.ان تقدير القدرة على الائتلاف للسلالات وتفاعلها مع البيئة مهم للحصول على هجن متفوقة فى المحصول والمقاومة لمرضى الذبول المتأخر وتبقع الأوراق الشمالي. تم عمل التلقيح النصف دائري لتسعة سلالات بيضاء من الذرة الشامية بمحطة بحوث سخا موسم ٢٠٢١. الهجن ٣٦ الناتجة تم تقييمها فى تجربتين موسم ٢٠٢٢. التجربة الأولى تم تقييم ٣٦ هجين بالإضافة إلى اثنين من هجن المقارنة فى ثلاث محطات بحثية (سخا وسدس وملوى) لصفات عدد الأيام حتى ظهور ٥٠% من حرائر النورات المؤنثة وارتفاع النبات وارتفاع الكوز وعدد الكيزان لكل نبات ومحصول الحبوب وطول الكوز وقطر الكوز. بينما التجربة الثانية تم تقييم الــ ٣٦ هجين تحت ثلاث مستويات من التسميد النيتروجينى فى حقل العدوى الصناعية بمرض الذبول المتأخر ومرض تبقع الأوراق الشمالي بمحطة بحوث سخا لتقدير نسبة المقاومة لكلا من مرض الذبول المتأخر ومرض تبقع الأوراق الشمالي. أظهرت النتائج اختلافات عالية المعنوية بين الثلاث مواقع فى التجربة الأولى وبين الثلاث معدلات تسميد للتجربة الثانية. كان التباين الراجع لكلا من القدرة العامة والخاصة على الائتلاف معنوي أو عالي المعنوية لجميع الصفات ماعدا التباين الراجع للقدرة الخاصة على الائتلاف لصفات ارتفاع النبات وارتفاع الكوز وطول الكوز فى التجربة الأولى وتبقع الأوراق الشمالي فى التجربة الثانية. السلالات المرغوبة فى تأثيرات القدرة العامة على الائتلاف هى

سلالات سدس ٤١, اسماعلية٧٧ للتبكير وقصر كلا من ارتفاع النبات وارتفاع الكوز وسلالات سدس ٤، سدس ٧، وسخا ١٣ فى زيادة عدد الكيزان لكل نبات وسلالات سخا ٥٠٠١، وسخا ٥٠٠٤ وسدس ٤١ وسخا ١٣ فى زيادة كلا من محصول الحبوب وطول الكوز وسلالات سخا ٥٠٠١ وسخا ٥٠٠٤ فى زيادة قطر الكوز وسلالات سخا ٥٠٠٥ , وسدس ٤١ وسدس ٧ واسماعلية ٧٧ فى المقاومة لمرض الذبول المتأخر والسلالات سخا ٥٠٠١ وسدس ٤١ فى المقاومة لمرض تبقع الأوراق الشمالي. أفضل هجين فى القدرة الخاصة على الائتلاف هو الهجين(سدس ٤ × اسماعلية ٧٧) للتبكير وقصر ارتفاع النبات والكوز والهجين (سدس ١١٢١ × سدس ٧) فى عدد الكيزان لكل نبات والهجين (سخا ٥٠٠١ × سدس٧) للمحصول والهجين (سدس ٤ × سدس ١١٢١) لطول الكوز والهجين (سخا ٥٠٠٤ × سدس٧) لقطر الكوز والهجين (سخا ٥٠٠١ × سدس ١١٢١) فى المقاومة لمرض الذبول المتأخر والهجين (سخا٥٠٠١ × سدس١٣) لمقاومة مرض تبقع الأوراق الشمالي. أظهرت الهجن (سخا٥٠٠١ × سخا٥٠٠٤) و (سخا ٥٠٠١ × سدس٤١) و (سخا ٥٠٠٤ × سدس٧) و (سخا ٥٠٠٤ × سدس٤١) و (سدس ٤١ × سخا١٣) و (سدس ٧ × سخا١٣) محصول عالى ومقاومة لمرض الذبول المتأخر ومرض تبقع الأوراق الشمالي ولذلك سوف تصعد لمراحل التقييم المتقدمة فى برنامج تربية الذرة الشامية بمصر.

المجلة المصرية لتربية النبات ٢٧(٢): ٢٦٩- ٢٨٧ (٢٠٢٣)