Combining Ability and Classification of New Thirteen Yellow Maize Inbred Lines (*Zea mays* L.) Using Line X Tester Mating Design Across Three Locations

Aly, R.S.H. *; Abd El-Azeem, M.E. and El-Sayed, W.M.
Maize Research Department, Field Crops Research Institute, ARC, Egypt.

Received: *27/8/2023*

Abstract: Thirteen new promising yellow maize inbred lines were top crossed with three inbred lines as testers, *i.e.,* Sd.3, Sd.42 and Mallawy.5035 at Sids Agricultural Research Station during 2020 growing season. In the growing season 2021, the 39 top crosses and two yellow commercial check hybrids; SC.168 and SC.3444 were evaluated in a yield trail at three locations, *i.e*., Sids, Sakha and Nubaria Agricultural Research Stations. Data were recorded on days to 50% silking emergence (DTS day), plant height (PHT cm), ear height (EHT cm), ear position% (Epos%), percentage of plants to late wilt resistant (LWR%), grain yield plant^{-1} (GYP^{-1}) and grain yield (GY ard fed^{-1}). Results showed significant differences between the three locations for all studied traits. Mean squares due to genotypes, crosses and their interaction with locations were significant for all studied traits except PHT, EHT and LWR% were not significant for C x Loc. Mean squares of lines, testers, line x tester and their interaction with locations were significant or highly significant for all studied traits except LWR% for T, L x Loc and T x Loc; DTS for T x Loc and PHT and EHT for L x T x Loc. Results showed that, L7 and L10 had good general combiner for DTS, PHT, EHT and Epos% toward earliness, shorter plants, shorter ear heights and lower ear placement also L13 had the best combiner for highest GYP^{-1}, GY ard fed^{-1} and resistant plants to late wilt disease. Eight crosses; L4 x T2, L5 x T2, L7 x T1, L8 x T1, L10 x T3, L12 x T3, L13 x T1 and L13 x T2 had positive and significant SCA effects for these traits. These crosses could be chosen for development of hybrids to be used by National Maize Breeding Program (NMBP). The results were showed that the thirteen inbred lines were placed into three heterotic groups; group1 and 2 consisted of four inbred lines in each group, while group 3 included three inbred lines. The method was not able to classify the three inbred lines; L3, L11 and L12 in any group. These results could be recommended for NMBP in selecting good parents for making hybrids and give breeder the chances for developing high yielding crosses through crossing of this inbred lines belonging to other inbred lines from different heterotic groups.

***Key words*:** Maize, line x tester, late wilt resistant, GCA, SCA, Heterotic groups.

INTRODUCTION

Maize (*Zea mays* L.) crop is gaining a great importance in terms of area and total production in Egypt, notably in the poultry and livestock feeding either as green fodder or silage as main component (grain) of dry feed. It's also having a variety of uses as a raw material for several industries such as starch, fructose, and corn oil. Acreage and production of maize have an increasing tendency with the introduction of hybrids due to its high yield potential. Therefore, efforts required to be made for developing hybrids with high yield potential to increase the production of maize. Most efficient use of such materials would be possible only when adequate information on the amount and type of genetic variation and combining ability effects in the materials is available. The combining ability analysis is a powerful tool for identifying the best combiners that can be used in crosses to exploit heterosis or accumulate productive genes. It also aids in understanding the genetic architecture of various characters, allowing a breeder to create an effective breeding plant for further improvement of existing breeding material. The combining ability analyses are widely used in maize breeding programs to determine general combining ability (GCA) and specific combining ability (SCA) information of maize populations for genetic diversity evaluation, inbred line selection, heterotic pattern classification, heterosis estimation, and hybrid development (Sughroue and Hallauer, 1997; Barata and Carena, 2006 and Fan *et al*., 2008). Information was generated using line x tester mating design (Kempthorne's 1957), which offers trustworthy information on the general and specific combining ability impacts of parents and their hybrid combinations. Several researchers have utilized the design of maize, and it is still being used in quantitative genetic studies in maize (Joshi *et al*., 2002 and Sharma *et al*., 2004). The recent trend even in the developing and underdeveloped countries is to go for single crosses, as these are the high yielders under most favorable environments (Atanaw *et al*., 2003). On the other hand, wherever maize is growing, it is liable to attach by various and fungi pathogens, which cause considerable losses in the yield (Awad and EL-Ghonemy 2015). Among these fungous or diseases, vascular wilt pathogen *Cephalosporium maydis* as a soil borne fungi is the most

*Corresponding author e-mail: rizkeg2004@gmail.com

economical disease of maize in Egypt. This disease was the first identified in the early sixties by Samra *et al.* (1962 and 1963). It was recorded as single or infected plants in a restricted area (Sabet *et al.* 1962). Later on, it has been spread out over all growing areas with variable percentage depending on maize genotype and pathogen. The best technique to control this disease is through developing genetically resistance genotypes. The late wilt disease causes severe losses in yield of susceptible maize cultivars (Awad and EL-Ghonemy, 2015). So, resistance to late wilt disease is one of the most important evaluation tests to restriction hybrids in National Maize Breeding Program (NMBP) in Egypt. On the other hand, heterotic groups are important in hybrid breeding programs, and it has been defined as a set of related or unrelated genotypes from the same or different sources (Melchinger and Gumber, 1998). Heterotic groups using specific and general combining abilities (HSGCA) were identified according to Fan *et al*., (2009). This method has proven to be more effective than other methods (Legesse *et al*., 2014). The current investigation was undertaken to estimate the general and specific combining abilities effects for days to 50% silking (DTS day), plant height (PHT cm), ear height EHT cm), ear position% (Epos%), resistance to late wilt disease (LWR%), grain yield plant^{-1} (GYP^{-1}) and grain yield (GY ard fed^{-1}). In addition, identifying a superior hybrid in grain yield and resistance to late wilt disease was considering. Also, the classification of the inbred lines into heterotic groups using HSGCA method was involved in this investigation.

MATERIALS AND METHODS

Materials and its sources: Thirteen yellow maize (*Zea mays* L.) inbred lines derived from different sources at different Agricultural Research Stations, National Maize Research Program. Code, name, and pedigree of these materials (lines and testers) are presented in Table (1).

Table (1): Code, name, and pedigree of the plant materials, which used in this investigation

	Parent code	Name	pedigree
Inbred lines	L_1	Inbred Sd.2	From National Maize Research Program, Field Crops Research Institute, Agricultural Research Center, Egypt
	L_2	Inbred Sd.3	
	L_3	Inbred Sd.4	
	L_4	Inbred Sd.6	
	L_5	Inbred Sd.8	
	L_6	Inbred Sd.9	
	L_7	Inbred Sd.11	
	L_8	Inbred Sd.12	
	L_9	Inbred Sd.14	
	L_{10}	Inbred Sd.18	
	L_{11}	Inbred Sd.21	
	L_{12}	Inbred Sd.22	
	L_{13}	Inbred Sd.23	
Testers	T_1	Sd.3/2015	
	T_2	Sd.42/2015	
	T_3	Mallawy.5035	

Experimental sites and growing seasons: In 2020 season, the thirteen yellow maize inbred lines were top crossed with three testers in a line x tester mating design at Sids Agric. Res. Sta., National Maize Research Program, Benisuief, Egypt. In growing season 2021, the resulted 39 crosses along with two yellow check hybrids; SC.168 and SC.3444 were evaluated in a yield trail at three locations; Sids, Sakha and Nubaria Agric. Res. Stations.

Experimental design and its management: Randomized Complete Block Design (RCBD) with three replications was used at each location. Plot size was one row, 0.6 m long and 0.8 m apart. Seeds were planted in hills evenly at 25 cm along the row at the rate of two kernels hill^{-1}, thinned to one plant hill^{-1} after 21 days from planting date. All other agricultural practices were carried out according to standard commercial recommendation for maize production in each location at the proper time.

Data recorded: The collected data were days to 50% silking date (DTS day), plant height (PHT cm), ear height (EHT cm), ear position% (Epos %), late wilt resistant % (LWR %), grain yield plant^{-1} (GYP^{-1} g) and grain yield (GY ard fed^{-1})

adjusted to 15.5% moisture content, one ardab = 140 Kg and one feddan = 4200 m^2. Late wilt assessments were recorded after 40 days of DTS according to El-Shafey *et al.,* (1988), as percentage of diseased plants to the total

Number of plants/replicates as follows: Disease incidence (%) = (No. of infected plants/No. of total plants) X 100, and the resulting will subtract from one hundred to get the percentage of late wilt resistance.

Statistical analysis: Data were analyzed using general linear model (GLM) procedures in SAS (SAS, v 9.3, 2014). Means for all maize combinations adjusted for block effects through sites were analyzed according to Snedecor and Cochran (1980). Combining ability analysis was performed for traits that showed statistical differences among crosses. Kempthorne (1957) was employed to determine general and specific combining abilities (GCA and SCA) effects and their interaction with locations.

Heterotic groups: Heterotic groups using specific and general combining abilities (HSGCA) method were estimated according to Fan *et al*., (2009) as follows:

HSGCA = Cross mean Xij – Tester means Xi = GCA + SCA

Where, Xij = mean yield of the cross between i^{th} tester and j^{th} line and Xi = mean yield of the i^{th} tester.

RESULTS AND DISCUSSION

Analysis of variances: Analysis of variances for seven studied traits; *viz* DTS days, PHT cm, EHT cm, Epos%, LWR%, GYP^{-1} and GY ard fed^{-1} of 41 crosses combined a cross through three locations; Sids, Sakha and Nubaria Agric. Res. Stations are presented in Table 2. Results showed that highly significant differences among the three locations for all studied traits, indicating that the three locations different from each other in their environmental conditions under this study. Mean squared due to Genotypes (G), Crosses (C) and their interaction with locations were significant or highly significant for all studied traits except PHT, EHT and LWR% were not significant for C x Loc. These results indicating that, the presence of genetic variation among the plant materials for these studied traits. Several researchers were in agreement with these results; Mohamed *et al*., (2020), Ibrahim *et al*., (2021), Raihan *et al*., (2021), Indu *et al*., (2022), and Abd El-Azeem *et al*., (2022), Aly (2013) and Badu Apraku *et al*., (2023). Line x testers analysis for the seven studied traits of 39 maize crosses combined through three locations are shown in Table 3. Results revealed that, lines (L), testers (T), (L x T) and their interaction with locations were significant or highly significant for all studied traits except LWR% for T, L x Loc and T x Loc; DTS for T x Loc and PHT and EHT for L x T x Loc. These findings results were in harmony with the results detected by Mohamed *et al*., (2020), Mousa *et al*. (2021), Raihan *et al*., (2021), Subba *et al*., (2021), Abd El-Azeem *et al*., (2022) and El-Shenawy *et al*., (2022).

Table (2): Combined analysis of variances for all studied traits of 41 maize crosses through three locations

sov	df	DTS (days)	PHT (cm)	EHT (cm)	Epos%	LWR%	GYP (g)	GY (ard fed^{-1})
Locations (Loc.)	2	55.46**	24235.79**	12208.00**	299.77**	263.43**	308658.52**	3763.75**
Reps/Loc.	6	5.21	1647.45	772.21	21.67	9.71	536.39	8.23
Genotypes (G)	40	21.13**	1614.43**	969.65**	45.97**	6.21**	11429.30**	142.12**
Crosses (C)	38	18.61**	1694.36**	1003.80**	45.75**	6.16**	9908.99**	137.89**
G x Loc	80	2.75**	250.38*	185.65*	19.39**	5.72**	1875.00**	23.28**
C x Loc.	114	1.86**	171.49	122.53	12.95*	3.77	1112.56**	14.47**
Pooled error	244	1.183	165.017	130.777	10.173	3.351	572.188	5.468

*,** significant at 0.05 and 0.01 level of probability, respectively

DTS = days to 50% silking (days) PHT = plant height, cm EHT = ear height, cm Epos% = ear position %

LWR% = late wilt resistant % GYP (g) = yield $plant^{-1}$ (gram) GY = grain yield ard. fed^{-1}

Mean performances of 39 crosses and two check hybrids (SC.168 and SC.3444) for all studied traits combined across three locations are presented in Table 4. For DTS days, the crosses ranged from 56.89 for L6 x T2 to 64.00 days for L2 x T3. The 36 crosses out 39 crosses were significant earlier than the earliest check hybrid SC.168 (62.00 day), indicating that these crosses may be used in developing crosses toward earliness in National Maize Breeding Program (NMBP). Regarding, PHT cm, the maize crosses ranged from 212.33 for L13 x T3 to 263.89 cm for L9 x T1 and 7 crosses. Also, out 39 crosses were shorter than the shortest check cross SC.168 (229.78 cm). For EHT cm, the crosses ranged from 109.44 for L7 x T3 to 167.67 cm for cross L3 x T2. The results were showed that, the crosses ranged from 52.94% for L1 x T1 to 62.01% for L11 x T3 for Epos% trait. The 3 out 39 crosses were not differed significantly than the lowest ear heights SC.3444 (53.75%). Whereas one cross (L7 x T3) significant differed from the same check. For percentage of resistant plants to late wilt disease (LWR %), 21 out 39 crosses were 100% resistance to late wilt disease. Regarding GYP^{-1} g, the crosses ranged from 167.74 for L5 x T3 to 305.39 g for L13 x T1. For GY ard fed^{-1}, the crosses ranged from 17.18 for L4 x T1 to 31.83 ard fed^{-1} for L12 x T3. Results showed that the 5 crosses; L3 x T1, L3 x T2, L12 x T3, L13 x T1 and L13 x T2 (30.20, 31.67, 31.83, 31.45 and 31.04 ard fed^{-1}, respectively) did not differ significantly than the highest check hybrid SC.3444 (31.02 ard fed^{-1}). These new crosses may be used in developing new crosses of maize toward high yielding potential in NMBP in Egypt.

Table (3): Line x tester analysis for all studied traits of 39 maize crosses across three locations

sov	df	DTS (days)	PHT (cm)	EHT (cm)	Epos%	LWR%	GYP (g)	GY (ard fed^{-1})
Lines (L)	12	26.68**	3486.49**	1778.55**	70.63**	6.48*	12448.74**	187.79**
Testers (T)	2	78.54**	3693.10**	3696.65**	161.50**	1.41	10383.83**	50.82**
Lines x Testers	24	9.58**	631.73**	392.02**	23.67**	6.40**	8599.55**	120.20**
Lines x Loc.	24	3.07**	313.59**	295.63**	23.67**	3.97	1744.19**	22.54**
Testers x Loc.	4	1.28	549.06**	367.55*	27.20*	1.96	1347.47*	25.49**
L x T x Loc	48	2.78**	204.73	112.57	16.65**	6.80**	1657.95**	20.98**
Pooled error	228	1.079	142.403	118.693	10.148	3.253	537.481	5.359

*,** significant at 0.05 and 0.01 level of probability, respectively

Combining abilities effects:

General combining ability (GCA) effects for thirteen inbred lines and three testers for all studied traits combined across three locations are shown in Table 5. The GCA effects allow identification of superior plants that could be used to make and select better crosses for direct use or insert these materials in breeding programs (Simmonds, 1979). The GCA effect of an inbred is important for the improvement of a target trait in a population and for the development of hybrids (Akinwale *et al*., 2014). The Results were revealed that four lines; L5, L6, L7 and L10 had negative (desirable) and significant GCA effects for DTS, PHT and EHT toward earliness, shorter plants, and lowest ear heights. These lines possessed (-1.838**, --12.160** and -6.439**), (-1.467**, -8.789** and -5.031**), (-0.467*, -13.900** and -14.031**) and (-0.838**, -5.567* and -7.328**) values, in respectively. In addition, L8 was showed negative and significant GCA effect for PHT cm. Three lines; L7, L10 and L12 were showed negative (desirable) and significant GCA effects for Epos% toward lower ear placement with scored -2.838**, -1.838** and -2.134** values. L13 appeared the good combiner GCA effect for LWR% by 0.821 as value. Four lines; L3, L9, L12 and L13 had the best GCA effects for GYP^{-1} and GY ard fed^{-1}. In addition, that, three lines; L1, L2 and L11 had the best GCA effects for GY ard fed^{-1}. From the previous results, L7 and L10 had the good general combiner for DTS, PHT, EHT and Epos% toward earliness, shorter plant, lower ear heights and lower ear placement toward plants to loading resistance and the L13 has the best combiner for highest GYP^{-1}, GY ard fed^{-1} and resistant plant to late wilt disease. On the other hand, the best tester for GCA effects was T2 for earliness (-0.641**), shorter plant (-4.111**), lower ear heights (-1.829*) and high grain yield (0.565**). Whereas, T3 for shorter plant (-2.291*), shorter ear heights (-4.479**) and lower ear placement (-1.268**).

Specific combining ability (SCA) effects of 39 crosses for all studied traits combined across three locations are presented in Table 6. Results revealed that, seven crosses; L2 x T1, L2 x T2, L6 x T2, L7 x T3, L9 x T3, L12 x T3 and L13 x T3 were negative (desirable) and significant SCA effects for DTS toward earliness. These crosses possessed -1.348**, -1.100**, -0.840*, -0.738*, -0.849*, -0.701* and -2.219**, respectively. In the same respect, three crosses; *viz* L1 x T1, L4 x T1 and L13 x T3 showed negative (desirable) and significant SCA effects for PHT and EHT toward shorter plant and lower ear heights with recorded (-7.698* and -8.271*), (-18.698** and -13.011**) and (-16.821** and -8.595*), respectively. Cross L8 x T2 was showed negative and significant SCA effects for EHT (-10.652**) and Epos% (-3.561**) traits toward lower ear placement. For LWR%, cross L2 x T3 have positive and significant SCA effects toward resistant plant of late wilt disease (1.140*). However, 13 crosses out 39 crosses were scored a positive and significant SCA effects value for GYP^{-1}. In addition, results revealed that, 11 crosses out 39 crosses were positive and significant or highly significant SCA effects for GY ard fed^{-1}. Between 13 and 11 crosses, which had SCA effects for both of GYP^{-1} and GY ard fed^{-1}, respectively,

Table (4): Mean performances of 39 maize crosses and two yellow check hybrids for all studied traits combined across three locations.

cross	DTS (days)	PHT (cm)	EHT (cm)	Epos%	LWR %	GYP (g)	GY (ard fed^{-1})
L_1 x T_1	60.78	230.67	117.22	52.94	95.56	243.73	29.07
L_1 x T_2	60.33	226.22	139.00	56.89	99.56	221.71	25.65
L_1 x T_3	62.67	239.00	136.67	59.37	100.00	239.51	27.79
L_2 x T_1	59.00	242.22	128.33	56.14	96.44	235.09	25.38
L_2 x T_2	58.89	230.11	139.67	55.38	100.00	239.37	28.73
L_2 x T_3	64.00	239.44	132.22	57.21	100.00	239.87	28.35
L_3x T_1	61.00	261.11	132.22	55.70	98.67	267.36	30.20
L_3x T_2	60.11	250.22	167.67	60.17	100.00	288.39	31.67
L_3x T_3	62.22	252.33	145.56	58.89	100.00	232.85	28.26
L4x T_1	58.89	221.67	127.78	54.94	98.22	168.30	17.48
L4x T_2	58.67	241.00	141.33	56.54	100.00	260.33	28.31
L4x T_3	61.33	239.22	128.33	58.36	100.00	229.66	23.67
L_5 x T_1	57.44	231.78	117.78	53.64	96.89	217.62	24.27
L_5 x T_2	57.11	218.22	142.22	59.24	99.56	228.55	25.17
L_5 x T_3	59.44	216.11	120.56	58.59	99.56	167.74	18.59
L_6 x T_1	58.67	235.22	121.67	54.09	97.78	229.00	25.04
L_6 x T_2	56.89	223.89	141.44	58.94	100.00	223.68	25.53
L_6 x T_3	59.56	217.11	121.67	57.33	100.00	186.01	19.62
L_7 x T_1	59.89	225.44	118.33	53.87	96.44	249.97	27.54
L_7 x T_2	58.67	217.89	130.00	54.99	100.00	187.76	19.59
L_7 x T_3	59.56	217.56	109.44	53.16	100.00	211.63	24.67
L_8 x T_1	60.22	237.44	122.78	55.22	96.44	231.88	25.04
L_8 x T_2	59.78	214.44	143.44	60.17	100.00	168.28	17.18
L_8 x T_3	61.78	217.78	124.89	59.14	100.00	213.62	21.55
L_9 x T_1	60.22	263.89	132.22	56.09	97.78	262.50	24.98
L_9 x T_2	60.00	238.67	163.67	59.74	100.00	259.72	28.32
L_9 x T_3	60.22	246.44	142.22	59.34	100.00	252.17	27.68
L_{10} x T_1	58.56	225.00	125.00	55.39	96.00	191.42	21.50
L_{10} x T_2	58.44	224.67	131.78	54.98	99.11	240.78	26.07
L_{10} x T_3	60.00	236.22	121.11	54.64	99.56	230.08	25.54
L_{11} x T_1	60.00	245.56	127.22	55.83	96.44	225.23	25.87
L_{11} x T_2	59.00	224.78	158.00	61.20	100.00	237.26	26.86
L_{11} x T_3	60.11	233.11	135.00	62.01	100.00	233.57	27.60
L_{12} x T_1	60.11	260.33	137.22	55.86	98.67	283.66	27.41
L_{12} x T_2	60.56	246.44	144.67	54.66	100.00	237.37	26.40
L_{12} x T_3	60.67	248.11	131.11	53.61	100.00	267.82	31.83
L_{13} x T_1	59.44	247.44	125.00	55.20	99.56	305.39	31.45
L_{13} x T_2	61.11	234.56	140.56	57.47	100.00	279.99	31.04
L_{13} x T_3	58.33	212.33	133.33	59.88	100.00	178.05	18.59
SC 168	62.00	229.78	133.89	58.17	98.22	295.07	30.41
SC. 3444	63.22	232.56	124.78	53.75	100.00	306.64	31.02
LSD 0.05	1.00	11.87	10.57	2.95	1.69	22.10	2.16
0.01	1.32	15.60	13.89	3.87	2.22	29.05	2.84

*,** significant at 0.05 and 0.01 level of probability, respectively
DTS = days to 50% silking (days) PHT = plant height, cm EHT = ear height, cm Epos% = ear position %
LWR% = late wilt resistant % GYP (g) = yield plant^{-1} (gram) GY = grain yield ard. fed^{-1}

eight crosses; L4 x T2, L5 x T2, L7 x T1, L8 x T1, L10 x T3, L12 x T3, L13 x T1 and L13 x T2 were positive and significant SCA effects for both these traits. These crosses could be chosen for development of maize hybrids to be used in NMBP.

Table (5): General combining ability (GCA) effects of 13 maize inbred lines and three testers for all studied traits combined across three locations

Crosses	DTS (days)	PHT (cm)	EHT (cm)	Epos%	LWR %	GYP (g)	GY (ard fed^{-1})
L1	1.422**	-2.234	-2.328	-0.442	-0.661*	2.497	1.878**
L2	0.792**	3.063	0.117	-0.597	-0.217	5.626	1.861**
L3	1.274**	20.359**	15.191**	1.410*	0.524	30.382**	4.414**
L4	-0.208	-0.234	-0.809	-0.227	0.376	-13.056**	-2.473**
L5	-1.838**	-12.160**	-6.439**	0.318	-0.365	-27.848**	-2.950**
L6	-1.467**	-8.789**	-5.031*	-0.053	0.228	-19.588**	-2.231**
L7	-0.467*	-13.900**	-14.031**	-2.838**	-0.217	-16.032**	-1.695**
L8	0.755**	-10.974**	-2.920	1.336*	-0.217	-27.893**	-4.370**
L9	0.311	15.470**	12.746**	1.551**	0.228	25.645**	1.362**
L10	-0.838**	-5.567*	-7.328**	-1.838**	-0.809*	-11.725**	-1.258**
L11	-0.134	0.285	6.783**	2.840**	-0.217	-0.465	1.145**
L12	0.607**	17.433**	4.376*	-2.134**	0.524	30.465**	2.918**
L13	-0.208	-2.752	-0.328	0.673	0.821*	21.993**	1.400**
SE gi (L)	0.200	2.297	2.097	0.613	0.347	4.462	0.446
T1	-0.282**	6.402**	6.308**	1.052**	-0.125	6.833**	0.158
T2	-0.641**	-4.111**	-1.829*	0.217	0.080	3.914	0.565**
T3	0.923**	-2.291*	-4.479**	-1.268**	0.046	-10.747**	-0.724**
S.E. gi (T)	0.096	1.103	1.007	0.295	0.167	2.143	0.214

*,** significant at 0.05 and 0.01 level of probability, respectively

DTS = days to 50% silking (days) PHT = plant height, cm EHT = ear height, cm Epos% = ear position %

LWR% = late wilt resistant % GYP (g) = yield plant^{-1} (gram) GY = grain yield ard. fed^{-1}

The results are in agreement with those obtained with by Vasal *et al*., (1992), Kanagarasu *et al*., (2010), Aly (2013), Yadav *et al*., (2020) and Ibrahim *et al*., (2021).

Genetic parameters and contribution of L,T and L x T

Genetic parameters and their interactions with locations, proportional contribution of lines, testers and their interactions to total variance in maize combined across three locations are illustrated in Table 7. Results showed that, the K^2GCA was larger than that obtained for K^2SCA for EHT, Epos% and LWR%, indicating that the additive type of gene actions played an important role in the inheritance of these traits. These results are harmony with those reported by Tessema *et al*., (2014) and Mousa *et al*., (2021). In contrast, the non-additive gene actions played an important role in the inheritance of DTS, PHT, GYP^{-1} and GY ard fed^{-1}. Similar results were revealed by Mousa and Aly (2012), Aly (2013), Zeyad *et al*., (2020), Abd El-Azeem *et al*., (2022) and El-Shenawy *et al*., (2022). The interactions of SCA x location were higher than GCA x location for all studied traits, except for EHT trait, indicating that the non-additive type of gene action was more effected by environmental changes than additive type of gene action. These results were supported the findings of Mosa (2017), Aly (2013), El-Gazzer *et al*., (2013), Ibrahim *et al*., (2021), and Mousa *et al*., (2021). The contributions of lines were higher than those of the testers for all studied traits, indicating that the line played an important role toward the improving of these traits. On the other hand, the contribution of line x tester was low for most of these traits. These results are in agreement with those obtained by Aly and Hassan (2011) and Mousa and Aly (2012).

Heterotic groups

Heterotic groups estimate based on specific and general combining ability effects (HSGCA) for grain yield are presented in Table 8. Results showed that the thirteen inbred lines of maize were placed into three heterotic groups. Group1 (T1 Sd.3) consisted of L2, L4, L9 and L10. While group2 (T2 Sd.42) included three inbred lines; L1, L7 and L8. Group3 (T3 Mallawy.5035) included L5, L6 and L13. According to this results, it can be said that this method was not able to classify the three inbred lines; L3, L11 and L12 in any group. These results could be recommended for NMBP in selecting good parents for making hybrids and give the breeder chances for developing a high yielding crosses through crossing of this inbred lines belonging to other inbred lines from different heterotic groups (Legesse *et al*., 2014 and Fan *et al*., 2009).

Table (6): Specific combining ability (SCA) effects of maize 39 crosses for all studied traits combined across three locations

Crosses	DTS (days)	PHT (cm)	EHT (cm)	Epos%	LWR %	GYP (g)	GY (ard fed^{-1})
L_1 x T_1	-0.199	-7.698*	-8.271*	-1.574	0.866	1.910	1.405
L_1 x T_2	-0.285	-1.630	1.311	0.950	-1.561**	-17.186*	-2.417**
L_1 x T_3	0.484	9.328*	6.960	0.624	0.695	15.275*	1.012
L_2 x T_1	-1.348**	-1.439	-2.493	-0.629	-0.467	-9.849	-2.264**
L_2 x T_2	-1.100**	-3.037	-2.356	-0.217	-0.672	-2.660	0.675
L_2 x T_3	2.447**	4.476	4.849	0.846	1.140*	12.509	1.589*
L_3x T_1	0.171	0.154	-2.456	-1.003	-0.764	-2.342	0.000
L_3x T_2	-0.359	-0.222	2.348	1.032	0.365	21.610**	1.062
L_3x T_3	0.188	0.068	0.108	-0.028	0.399	-19.268**	-1.062
L4x T_1	-0.459	-18.698**	-13.011**	-1.033	-0.171	-57.967**	-5.829**
L4x T_2	-0.322	11.148**	9.903**	1.558	0.513	36.989**	4.585**
L4x T_3	0.781*	7.550	3.108	-0.525	-0.342	20.977**	1.243
L_5 x T_1	-0.274	3.339	-2.382	-1.922	1.014	6.146	1.431
L_5 x T_2	-0.248	0.296	-2.689	-1.331	0.365	20.000**	1.931*
L_5 x T_3	0.521	-3.635	5.071	3.253**	-1.379*	-26.146**	-3.362**
L_6 x T_1	0.578	3.413	2.100	0.193	0.422	9.275	1.488
L_6 x T_2	-0.840*	2.593	3.348	0.850	0.661	6.869	1.569*
L_6 x T_3	0.262	-6.006	-5.447	-1.043	-1.083	-16.144*	-3.057**
L_7 x T_1	0.801*	-1.254	0.877	0.889	-0.023	26.680**	3.446**
L_7 x T_2	-0.063	1.704	2.792	0.758	-0.672	-32.608**	-4.909**
L_7 x T_3	-0.738*	-0.450	-3.670	-1.647	0.695	5.928	1.463
L_8 x T_1	-0.088	7.821*	10.877**	2.826**	-0.912	20.450**	3.623**
L_8 x T_2	-0.174	-4.667	-10.652**	-3.561**	0.661	-40.227**	-4.641**
L_8 x T_3	0.262	-3.154	-0.225	0.735	0.251	19.777**	1.018
L_9 x T_1	0.356	7.821*	5.766	0.423	-0.467	-2.462	-2.173**
L_9 x T_2	0.493	-6.889	-2.097	0.824	0.661	-2.329	0.761
L_9 x T_3	-0.849*	-0.932	-3.670	-1.247	-0.194	4.791	1.412
L_{10} x T_1	-0.162	-10.031*	-4.493	0.334	0.125	-36.174**	-3.031**
L_{10} x T_2	0.085	0.148	-0.245	-0.076	0.365	16.110*	1.132
L_{10} x T_3	0.077	9.883*	4.738	-0.258	-0.490	20.064**	1.899*
L_{11} x T_1	0.578	4.672	2.729	-0.100	-0.467	-13.622	-1.065
L_{11} x T_2	-0.063	-5.593	-1.578	0.791	0.217	1.322	-0.483
L_{11} x T_3	-0.516	0.920	-1.151	-0.691	0.251	12.301	1.548*
L_{12} x T_1	-0.051	2.302	1.915	0.363	0.570	13.873	-1.297
L_{12} x T_2	0.752*	-1.074	0.162	0.198	-0.969	-29.493**	-2.715**
L_{12} x T_3	-0.701*	-1.228	-2.077	-0.562	0.399	15.620*	4.013**
L_{13} x T_1	0.097	9.598*	8.840*	1.234	0.274	44.082**	4.264**
L_{13} x T_2	2.123**	7.222	-0.245	-1.776	0.068	21.602**	3.450**
L_{13} x T_3	-2.219**	-16.821**	-8.595*	0.542	-0.342	-65.683**	-7.714**
SE Sij	0.35	3.98	3.63	1.06	0.601	7.73	0.77
LSD 0.05	0.68	7.80	7.12	2.08	1.178	15.15	1.51
0.01	0.89	10.25	9.35	2.74	1.549	19.91	1.99

*,** significant at 0.05 and 0.01 level of probability, respectively

DTS = days to 50% silking (days) PHT = plant height, cm EHT = ear height, cm Epos% = ear position %

LWR% = late wilt resistant % GYP (g) = yield plant^{-1} (gram) GY = grain yield ard. fed^{1}

Table (7): Genetic parameters and their interactions with locations, proportional contribution of lines, testers, and their interaction to total variance in maize combined across three locations for all studied traits

Genetic parameters	DTS (days)	PHT (cm)	EHT (cm)	Epos%	LWR %	GYP (g)	GY (ard fed^{-1})
K^2 GCA	0.700	43.868	33.417	1.259	0.014	137.089	1.323
K^2SCA	0.755	47.445	31.050	0.780	-0.044	771.290	11.024
σ^2 GCA x Loc	0.041	11.096	8.367	0.636	-0.016	40.568	0.773
σ^2 SCA x Loc	0.533	13.238	-6.069	2.159	1.150	361.920	5.171
Contribution of Lines	45.283	64.980	55.952	48.750	33.204	39.673	43.005
Contribution of Tester	22.215	11.472	19.382	18.579	1.207	5.515	1.940
Contribution of L x T	32.502	23.548	24.665	32.672	65.590	54.812	55.055

DTS = days to 50% silking (days) PHT = plant height, cm EHT = ear height, cm Epos% = ear position %
LWR% = late wilt resistant % GYP (g) = yield plant^{-1} (gram) GY = grain yield ard. fed^{-1}

Table (8): Heterotic groups using specific and general combining ability (HSGCA) for grain yield combined across three locations.

Lines	T_1 (Sd.3)	T_2 (Sd.42)	T_3 (Mall.5035)
L_1	3.28	-0.54#	2.89
L_2	-0.40#	2.54	3.45
L_3	4.41	5.48	3.35
L_4	-8.30#	2.11	-1.23
L_5	-1.52	-1.02	-6.31#
L_6	-0.74	-0.66	-5.29#
L_7	1.75	-6.60#	-0.23
L_8	-0.75	-9.01#	-3.35
L_9	-0.81#	2.12	2.77
L_{10}	-4.29#	-0.13	0.64
L_{11}	0.08	0.66	2.69
L_{12}	1.62	0.20	6.93
L_{13}	5.66	4.85	-6.31#

means that this inbred line belongs to tester group.

CONCLUSION

Results revealed that, most of the studied traits were significantly or highly significant combined across three locations, indicating that the presence of genetic variation among of this plant material. The inbred lines L7, L10 and L13 had the good general combiner toward the desirable traits, then these lines could be chosen for development of maize hybrids to be used in NMBR. Eight crosses were positive and significant SCA effects toward high yielding ability GYP^{-1} and GY ard fed^{-1}). Classification of the new yellow maize inbred lines and put them in different groups it useful and give the breeding chance for selecting and making the good hybrids based on the different heterotic groups.

REFERENCES

Abd El-Azeem, M.E.M.; Abd El-Mottalb, A.A.; Aly, R.S.H.; Elsayed, W.M. and E. I. M. Mohamed (2022). Combining Ability of Some New Yellow Maize Inbred Lines by Using Line X Tester Analysis. Journal of the Advances in Agricultural Research (JAAR) Volume: 27 (2):442-448.

Akinwale, R.O.; Badu-Apraku, B.; Fakorede, M.A.B. and I. Vroh-Bi (2014). Heterotic grouping of tropical early-maturing maize inbred lines based on combining ability in Striga-infested and Striga-free environments and the use of SSR markers for genotyping. Field Crops Res., 156: 48-62.

Aly, R.S.H. (2013). Relationship between combining ability of grain yield and yield components for some newly yellow maize inbred lines via line x tester analysis. Alex. J. Agric. Res., (58): 2, 115-124.

Aly, R.S.H. and M.M.M. Hassan (2011). Combining ability of grain yield and yield components in maize. Egypt. J. Plant Breed., 15(5): 149-161.

Atanaw, A.; Nayakar, N.Y.; and M.C. Wali (2003). Combining ability, heterosis and per se performance of height characters in maize. Karnataka J. Agril. Sci. 16(1): 131-133.

Awad , H.M.F. and M.A.M. El-Ghonemy (2015). Effect of Genetic Variability of Maize Genotypes on Late Wilt Disease (*Cephalosporium maydis*) and Losses of Yield Components. Egypt. J. Phytopathol., 43: (1-2), pp. 1-10.

Badu-Apraku. B.; Adewale, S.; Paterne, A.; Offornedo Q. and M. Gedil (2023). Mapping quantitative trait loci and predicting candidate genes for Striga resistance in maize using resistance donor line derived from Zea diploperennis. Frontiers in Genetics.

Barata, C. and M. Carena (2006). Classification of North Dakota maize inbred lines into heterotic groups based on molecular and testcross data. Euphytica 151: 339-349.

EL- Gazzar, I.A.I.; EL-Ghonemy, M. A. and S.Th. Mousa (2013). Evaluation of new inbred lines of white maize via line x tester analysis over three locations. J. Plant Production, Mansoura Univ. 4(6): 897-906.

El-Shafey, H.A.; El-Shorbagy, F.A.; Khalil, I.I. and E.M. El-Assiuty (1988). Additional sources of resistance to the late-wilt disease of maize caused by *Cephalosporium maydis.* Agric. Res. Rev. (Egypt), 66: 221-230.

El-Shenawy, A.A.; Hassan, M.A.A.; Abo El-Haress, S.M. and M.A.A. Abd-Elaziz (2022). Assessment of combining ability in some newly maize inbred lines for grain yield and late wilt resistance. J. of Plant Production, Mansoura Univ., 13 (2):45 – 48.

Fan, X.M.; Chen, H.M.; Tan, J.C.; Xu, X.; Zhang, Y.D.; Luo, L.M.; Huang, Y.X. and M.S. Kang (2008). Combining abilities for yield and yield components in maize. Maydica 53 (2008): 39-46.

Fan, X.M.; Zhang, Y.M.; Yao, W.H.; Chen, H.M.; Tan, J.; Xu, C.X.; Han, X.L.; Luo, L.M. and M.S. Kang (2009). Classifying maize inbred lines into heterotic groups using a factorial mating design. Agron J., 101: 106-112.

Ibrahim, Kh. A.M.; Said, A.A. and M.M. Kamara (2021). Evaluation and classification of yellow maize inbred lines using line x tester analysis across two locations. J. of Plant Production, Mansoura Univ., 12: (6):605 – 611.

Indu, A.D.; Dubey, R.B.; Jain, H.K.; Jain D. and M.K. Kaushik (2022). Combining ability analysis of maize (*Zea mays* L.) single cross hybrids evaluated in three environments. The Pharma Innovation Journal; 11(5): 2070-2074.

Joshi V.N.; Dubey, R.B. and S. Marker (2002). Combining ability for polygenic traits in early maturity hybrids of maize (*Zea mays* L.). Ind. J of Gen. and Plant Breed. 62:312- 315.

Kanagarasu, S.; Nallathambi, G. and K.N. Ganesan (2010). Combining ability analysis for yield and its components traits in maize (*Zea mays* L.). Electronic Journal of Plant Breeding. 1(4): 915-920.

Kempthorne, O. (1957). An introduction to Genetic Statistics. John Wiley and Sons Inc., New York. , 323-331.

Legesse, W.; Mosisa,, W., Berhanu, T.; Girum, A.; Wande, A.; Solomon, A.; Tolera, K.; Andualem, W. and A. Belay (2014). Genetic improvement of maize for mid-altitude and lowland sudhumid agroecologies of Ethiopia. In Worku, M., S. Twumasi-AfriyieB. M. Prasanna, (Eds.), 57: 24-34, 18-20 April 2012. Proceedings of the third National Maize Workshop of Ethiopia, Addis Ababa, Ethiopia.

Melchinger, A.E. and R.K. Gumber (1998). Overview of heterotic groups in agronomic crops. 29-44. In: K.R. Lamkey and J.E: Staub (Eds.), concepts and breeding of heterosis in crop plants. CSSA, Madison, W.I., USA.

Mohamed M. Kamara, Medhat Rehan , Khaled M. Ibrahim , Abdullah S. Alsohim , Mohsen M. Elsharkawy , Ahmed M. S. Kheir , Emad M. Hafez and Mohamed A. El-Esawi (2020). Genetic Diversity and Combining Ability of White Maize Inbred Lines under Different Plant Densities. Plants, 9, 1140

Mosa, H. E.; Abo El-Hares S.M. and M.A.A. Hassan (2017). Evaluation and classification of maize inbred lines by line x tester analysis for grain yield, late wilt and downy mildew resistance. J. of Plant Production, Mansoura Univ. 8(1): 97:102.

Mousa, S.Th.M. and R.S.H. Aly (2012). Estimation of combining ability effects of new white maize inbred lines (*Zea mays* L.) via line x tester analysis. Fourth Field Crops Conference "Field Crops Facing Future Challenges". Egy. J. Agric. Res., 90(4): 77-90.

Mousa, S.Th.M.; Mohamed, H.A.A.; Aly, R.S.H. and H.A. Darwish (2021). Combining ability of white maize inbred lines via line x tester analysis. J. of Plant Production, Mansoura Univ., 12(2):109 – 113.

Raihan, H.U.Z.; Mithila, N.J.; Akhter S.; Khan, A.A. and M. Hoque (2021). Heterosis and combining ability analysis in maize using line x tester model. Bangladesh j. Argil. Res. 46(3): 161-274.

Sabet, K.A.; . Samra, A.S; Hingorani, M.K. and F.A. Fadle (1962). Further studies on stalk and root rots of maize in U.A.R., F.A.O. Plant Prot. Bull. 10:132-133.

Samra, A.S.; Sabet, K.A. and M.K. Hingorani (1962). A new wilt disease of maize in Egypt. Plant Dis. Rept. 46:481-483.

Samra, A.S.; Sabet, K.A. and M.K. Hingorani (1963). Late wilt disease of maize caused by *Cephalosporium maydis*. Phyto-pathology, 53:402-406.

SAS Institute (2014). Statistical Analysis System Version 9.3, SAS Institute, Inc., Cary, NC, USA.

Sharma, S.; Narwal. R.; Kumar, M.S. and S. Dass (2004). Line x tester analysis in maize (*Zea mays* L.), Forage Res. 30:28- 30.

Simmonds, N. W. (1979). Principles of Crop Improvement. Longman, London.

Snedecor, G. W. and W. G. Cochran (1980) Statistical Methods. 7th Iowa State Univ. Press. Ames, Iowa, USA.Subba, V.; Nath, A.; Kundagrami, S. and A. Ghosh (2021). Study of Combining Ability and Heterosis in Quality Protein Maize using Line × Tester Mating Design. A Research Journal of Agriculture, Animal and Veterinary Sciences. 1-7.

Sughroue, J.R. and A.R. Hallauer (1997). Analysis of the diallel mating design for maize inbred line. Crop Sci. 37: 400-405.

Tessema T.; Sentayehu, A.; Temesgen, M. and W. Dagne (2014). Test cross mean performance and combining ability study of elite lowland maize (*Zea mays* L.) inbred lines at Melkassa, Ethiopia. Advances in Crop Science and Technology 2:140.

Vassal, S.K.; Srinivasan, F.; Beck, D.L.; Crossa, J.; Pandey, S. and C.De. Leon (1992). Heterosis and combining ability of CIMMYT، s tropical late white maize germplasm. Maydica, 37(2): 217 – 223.

Yadav, N.K.; Sinha, S.K.; Tiwari, J.K. and D.K. Thakur (2020). Line x tester model for evaluation the combining ability of some new white maize inbred lines. Int. J. Curr. Microbiol. App. Sci., Special Issue, 10: 483-499.

Zeyad A.A.; Sinan A.A. and A.A. Aayd (2020). Studying some genetic in maize by line × tester analysis. Int. J. Agricult. Stat. Sci. Vol. 16, Supplement 1, pp. 1421-1426.

قدرة الإئتلاف وتقسيم ثلاثة عشر سلالة صفراء جديدة من الذرة الشامية بإستخدام نظام التزاوج السلالة فى الكشاف عبر ثلاثة مواقع

رزق صلاح حسانين على، محمد المهدي محمد عبد العظيم، وائل محمد النبوي السيد موسي

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

أجرى التهجين القمى لثلاثة عشر سلالة صفراء جديدة من الذرة الشامية مع ثلاثة سلالات كشافة (سدس-3، سدس-42 وملوى-5035) بالمزرعة البحثية بمحطة البحوث الزراعية بسدس فى الموسم 2020. فى الموسم الزراعى 2021 تم تقييم الـ 39 هجيناً قمياً مع إثنين من الهجن التجارية الصفراء كهجن مقارنة (هجين فردى-168 وهجين فردى – 3444) في تجارب محصولية في ثلاثة مواقع وهي محطات البحوث الزراعية بسدس، سخا والنوبارية خلال موسم 2021. تم تسجيل البيانات على صفات: عدد الأيام حتى ظهور50% من الحراير، إرتفاع النبات، إرتفاع الكوز، النسبة المئوية لموقع الكوز على النبات، النسبة المئوية لمقاومة النبات لمرض الذبول المتأخر، محصول النبات بالجرام ومحصول الحبوب بالأردب للفدان. أشارت النتائج إلى وجود اختلافات معنوية بين المواقع الثلاثة لجميع الصفات المدروسة، حيث كانت مربعات القيم لكل من الطرز الجينية والهجن وتفاعلهما مع المواقع معنوياً لكل الصفات المدروسة عدا صفات إرتفاع النبات، إرتفاع الكوز والنسبة المئوية لمقاومة النبات لمرض الذبول المتأخر بالنسبة لتفاعل الهجن مع المواقع. أوضحت النتائج أن قيم التباينات للسلالات، الكشافات، السلالة في الكشاف وتفاعلهم مع المواقع كانت معنوية أو عالية المعنوية لكافة الصفات المدروسة، فيما عدا صفة المقاومة لمرض الذبول المتأخر بالنسبة للكشاف، السلالة والكشاف فى المواقع وصفة عدد الأيام حتى ظهور 50% من ظهور الحراير بالنسبة للكشاف فى المواقع وصفات إرتفاع النبات وإرتفاع الكوز بالنسبة لتفاعل السلالة والكشاف والمواقع. أظهرت السلالاتين سلالة – 7 والسلالة – 10 أفضل قدرة إئتلاف عامة لصفات التزهير، إرتفاع النبات، إرتفاع الكوز والنسبة المئوية لموقع الكوز على النبات تجاه التبكير وقصر النبات وأفضلية موقع الكوز على النبات، فى حين أظهرت السلالة – 13 أفضلية لإمتلاكها قدرة عامة على الإئتلاف لصفات محصول النبات ومحصول الفدان بالأردب إلى جانب المقاومة لمرض الذبول المتأخر. أيضا إمتكلت ثمانى هجن (سلالة – 4 x سلالة – 2) ، (سلالة – 5 x سلالة – 2) ، (سلالة – 7 x سلالة – 1) ، (سلالة – 8 x سلالة – 1) ، (سلالة – 10 x سلالة – 3) ، (سلالة – 12 x سلالة – 3) ، (سلالة – 13 x سلالة – 1) ، (سلالة – 13 x سلالة – 2) ، قدرة خاصة على التألف لصفات محصول النبات ومحصول الفدان بالأردب ، لذا يمكن إستخدام تلك الهجن في البرنامج القومي لبحوث الذرة الشامية لتحسين هذه الصفات. أوضحت النتائج إلى أنه تم تقسيم الثلاثة عشر سلالة إلى ثلاثة مجموعات، شملت المجموعة-1 والمجموعة-2 أربعة سلالات لكل مجموعة، في حين شملت المجموعة الثالثة ثلاثة سلالات، وهذا يوضح إلى أن هذه الطريقة كانت غير قادرة على تقسيم الثلاثة عشر سلالة إلى ثلاث مجموعات، وبناءاً عليه يمكن التوصية بإمكانية استخدام تلك السلالات فى برنامج تربية الذرة الشامية لإنتخاب أباء جيدة ومن ثم إعطاء المربى الفرصة لتحسين الهجن لتصبح ذات قدرة إنتاجية عالية من خلال تهجين السلالات التابعة لتلك المجموعات الهجينية مع سلالات اخرى تابعة لمجموعات هجينية مختلفة.

الكلمات المفتاحية: الذرة، السلالة، السلالةُ x الكشاف، القدرة الائتلافية العامة والخاصة، المقاومة لمرض الذبول المتأخر، المجموعات الهجينية