Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(5): 112-118
Received: 23-07-2017
Accepted: 25-08-2017

Combining ability analysis for yield contributing and quality traits in yellow seeded late maturing maize (*Zea mays* L.) hybrids using Line x Tester

Mohan Singh, RB Dubey, KD Ameta, Santra Haritwal and Bhagchand Ola

Mohan Singh
Department of Plant Breeding and Genetics, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

RB Dubey
Department of Plant Breeding and Genetics, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

KD Ameta
Department of Plant Breeding and Genetics, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Santra Haritwal
Department of Plant Breeding and Genetics, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Bhagchand Ola
Department of Plant Breeding and Genetics, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Correspondence
Mohan Singh
Department of Plant Breeding and Genetics, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Abstract
Thirty six hybrids of maize were developed through Line x Tester design using three male tester lines and twelve female inbred lines as parental material along with four standard checks Vivek-H-43, Pratap Hybrid Maize-3, Pratap Makka-9 and HM-11, to study combining ability in maize (*Zea mays* L.). The parents, hybrids and four standard checks were evaluated during *kharif* season 2016 for 15 characters. The mean square due to genotypes, parents, crosses and parents v/s crosses were significant for all the traits, except, days to 50 % tasseling, days to 50 % silking, days to 75 % brown husk, number of leaves per plant, shelling percentage and starch content. The ratio of σ^2_{sca} / σ^2_{gca} was greater than one for all the traits except days to 50 per cent silking, anthesis - silking interval and days to 75 per cent brown husk, number of leaves per plant, grain yield (per plant), starch content. This indicated that the preponderance of non-additive gene effects in the inheritance of these traits Among female inbred lines, EI-2438 had significant GCA effects for grain yield per plant (30.71) and yield component traits like number of grain rows per ear (0.82), shelling percentage (4.27), harvest index (2.14), maturity traits like, days to 50 per cent tasseling (-1.62), days to 50 per cent silking (-1.19) and quality traits like oil content (0.34), protein content(0.39) and starch content (2.75), indicated that best general combiner for these traits, while in male parent BML-6 was the best general combiner for yield contributing traits viz., grain yield per plant (6.38), harvest index (1.53), number of grain rows per ear (0.55), and quality traits viz., oil content (0.05), protein content (0.18). Maximum positive significant sca effects for yield per plant was showed by hybrid EI-2614 x EI-586-2 (42.91) followed by hybrid EI-2306x EI-586-2 (37.98), EI-2312x BML-6 (36.33), EI-2525xEI-670-2 (26.65) and EI-2430 x EI-670-2 (18.70). Hybrid EI-2430 x EI-670-2 showed positive significant effects for most of the traits like grain yield per plant(18.70), harvest index (4.69), number of grain rows per ear (1.14), 100 – grain weight (1.75), protein content(0.69).They produced significant and desirable SCA effects for most of the traits studied indicating potential for exploiting hybrid vigour in breeding programme.

Keywords: Combining ability, yield contributing, yellow seeded, *Zea mays*

1. Introduction

Combining ability analysis is one of the most powerful tool in identifying the best combiners that may be used in crosses either to exploit heterosis or to accumulate productive genes. It also helps to understand the genetic architecture of various characters that enable to breeder to design effective breeding plan for other improvement of the existing breeding material. Maize (*Zea mays* L.) is the world's feading crop and is widely cultivated as cereal grain that was domesticated in Central America. It is one of the most versatile emerging crop having wider adoptability. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Maize is the only food cereals crop that can be grown in diverse seasons, ecologies and uses. Beside this maize have many types like normal yellow / white grain, sweet corn, baby corn, pop corn, waxy corn, high amylase corn, high oil corn, quality protein maize etc. Apart from this, maize is an important industrial raw material and provides large opportunity for value addition.

Heterosis and combining ability is prerequisite for developing good economically viable hybrids of maize. Information on the heterotic patterns and combining ability among maize germplasm is essential in maximizing the effectiveness of hybrid development. In succesful hybridization programme, the ability of a parent to combine well and produce segregations in succeeding generations is an important criterian in selecting parents.

The concept of general and specific combining ability was proposed by Sprague and Tatum (1942) [13]. They defined general combining ability as "an average of a line in hybrid combination" and used specific combining ability to designate "deviation of certain crosses from expectation on the basis of the average performance of the line involved". Their studies in a set of F_1 crosses of maize revealed that general combining ability is the function of additive gene effect whereas, specific combining ability results from intra – allelic interaction (dominance) and inter – allelic interaction (epistasis). Comstock *et al*. (1949) [3] designated breeding procedure to make maximum use of both general and specific combining ability. The present study was, therefore, undertaken with a view to estimate general and specific combining ability variances and effects to identify superior maize hybrids for good yield potential and quality traits.

Materials and Methods

The present investigation was carried out in analysis of combining ability in yellow seeded late maturing maize (Zea mays L.)" Hbrids at Instructional farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, India during Kharif, 2016. The experimental material consisting of 12 female parents (Lines) and 3 male parents (Tester) presented in Table 1. In this experiment, 12 inbred lines were crossed with three testers viz., EI-670-2, EI-586-2 and BML-6 during Rabi -2015-16 to develop a total of 36 hybrids. These 36 F1 hybrids along with 15 parents and 4 checks *viz*., Vivek-H-43, Pratap Hybrid Maize-3, Pratap Makka-9, HM-11 were evaluated in randomized block design with three replications during *Kharif* 2016. The experimental material consisting of a total of 55 entries (36 F1 hybrids, 15 parents and 4 checks) were sown in randomized block design with three replications with a single row plot of four meter length, maintaining crop geometry of 60 x 25 cm. Observations for all traits were recorded on five randomly selected competitive plants of each entry in each replication except for days to 50 per cent tasseling, days to 50 per cent silking and days to 75 per cent brown husk where observations were recorded on plot basis. Data recorded were subjected to analysis of variance according to Panse and Sukhatme (1985) [9] to determine significant differences among genotypes. Combining ability analysis for line x tester mating design was performed as per method suggested by Kempthorne (1957) [6]. Estimation of oil content, starch content and protein content were done as per method suggested by Soxhlet's Ether Extraction method developed by A.O.A.C. (1965) [1], Anthrone Reagent method and Micro kjeldahl's method given by Lindner (1944), respectively.

Results and Discussion

The mean square values for fifteen traits are presented in Table 2.

The mean square due to genotypes, parents, crosses and parents v/s crosses were significant for all the traits, except for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, number of leaves per plant and shelling percentage due to genotype, days to 75 per cent brown husk due to parents, days to 75 per cent brown husk and number of leaves per plant due to crosses and starch content due to parent v/s crosses. This revealed presence of appreciable amount of genetic variability in the experimental material of the present investigation

Estimates of combining ability variance:

Combining ability variance of grain yield and its component of quality protein maize are presented in Table 3.The analysis of variance for combining ability revealed that variance due to lines was of higher magnitude than that of testers for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, 100- grain weight, shelling percentage, grain yield per plant, oil content, protein content and starch content. This indicated that the contribution of lines for these traits, towards σ^2_{gca} was greater. Variance due to testers was of higher magnitude than that of lines for anthesis – silking interval, plant height, ear height, number of leaves per plant, number of grain rows per ear and harvest index. This indicated that the contribution of testers for these traits, towards σ^2_{gca} was greater. The estimates of sca variance were of higher magnitude than gca variance for all the traits except days to 75 per cent brown husk and starch content. Besides this the ratio of σ^2_{sca} / σ^2_{gca} was greater than one for all the traits except days to 50 per cent silking, anthesis - silking interval and days to 75 per cent brown husk, number of leaves per plant, grain yield (per plant), starch content. This indicated that the preponderance of non-additive gene effects in the inheritance of these traits These results are in accordance with the findings of Amiruzzaman *et al.* (2013) [2], Verma *et al*. (2014) [14] and Sharma *et al.* (2015) [12].

Estimates of combining ability effects:

The combining ability analysis was performed to obtain information on selection of better parents and crosses for their further use in breeding programme. The estimates of gca effects of the parents and sca effects of the hybrids for different traits are presented in Table 4 and Table 5, respectively. Among the lines, the estimates of gca effects revealed that inbred lines viz., EI-2430, EI-2438, EI-2526 and EI-2527 are found good general combiner for grain yield per plant. Inbreed line EI-2438 was found good general combiner for grain yield per plant and yield component traits like number of grain rows per ear, shelling percentage, harvest index and maturity traits like days to 50 % tasseling, days to 50 % silking and quality traits like oil content and protein content. As regard quality traits, six inbred lines viz., EI-2306, EI-2405, EI-2430, EI-2438, EI-2614, and EI-2525 were found good general combiners for oil content, while five inbred lines viz., EI-2312, EI-2405, EI-2421, EI-2430 and EI-2525 were found good general combiners for starch content. Similarly five inbred lines EI-2421, EI-2430, EI-2438, EI-2614 and EI-2525 were good general combiners for protein content, while two inbred lines EI-2438 and EI-2526 were good general combiner for harvest index. Similarly three inbred lines like EI-2306, EI-2421, EI-2438 and EI-2526 were good general combiner for number of grain rows per ear. Among the testers, BML-6 was considered good general combiner for grain yield per plant, harvest index, number of grain rows per ear, oil content, protein content and starch content. High general combining ability effects (gca) observed were due to additive and additive x additive gene effects (Griffing, 1956 and Sprague, 1942) [13]. Among the hybrids, positive significant sca effects for grain yield per plant was recorded in seven hybrids *viz*., EI-2430 x EI-670-2, EI-2637 x EI-670-2, EI-2525 x EI-670-2, EI-2306 x EI-586-2, EI-2614 x EI-586-2, EI-2312 x BML-6 and EI-2514 x BML-6, L. Hybrid EI-2614 x EI-586-2 showed highest significant SCA effects in positive direction for grain yield per plant. This hybrid also exhibited positive significant sca effects for ear harvest index and oil content. This was a cross between average x average gca effect parents for grain yield per plant. Another hybrid L_5 x T_1 showed positive significant effects for most of the traits like grain yield per plant, harvest index, number of grain rows per ear, 100 – grain weight, protein content and negative significant sca effects for maturity traits like days to 50 per cent silking and anthsis- silking interval. This was also cross between good x poor gca effect parents for grain yield per plant. Out of total 36 hybrids, five best hybrids which exhibited highest significant positive sca effects for grain yield per plant are *viz*., EI-2614 x EI-586-2, EI-2306 x EI-586-2, EI-2312 x BML-3, EI-2525 x EI-670-2 and EI-2430 x EI-670-2. Similar finding for identification of superior inbred lines and hybrids based on gca and sca effects for grain yield and its components in maize were also reported by Miranda *et al*. (2008) [8] and Jamptong *et al*. (2010) and Rastgari *et al*. (2014) [10]. Among the 36 hybrids, five best hybrids exhibiting highest magnitude of positive significant sca effects for oil content are *viz*., EI-2430 x BML-6 followed by EI-2438 x EI-586-2, EI-2306 x BML-6, EI-2405 x EI-586-2 and EI-2438 x EI-670-2. The maximum positive significant sca effect for this trait was expressed by hybrid EI-2430 x BML-6. This was a cross between good x good gca effect parents for oil content. None of the hybrid showed highest significant sca effects for starch content. Hybrid EI-2430 x EI-586-2 expressed highest *per se* performance for starch content. Among the 36 hybrids, five best hybrids exhibiting highest magnitude of positive significant sca effects for protein content are *viz*., EI-2312 x EI-586-2 followed by EI-2438 x EI-586-2, EI-2637x BML-6, EI-2405 x BML-6 and EI-2526 x BML-6. The maximum positive significant sca effect for this trait was expressed by hybrid EI-2312 x EI-586-2 (1.36) and per se performance for grain yield per plant (91.07g/ plant). This hybrid also showed significant positive sca effects 100-grain weight. This was a cross between poor x poor gca effect parents for protein content. Similar finding for identification of superior inbred lines and hybrids based on gca and sca effects for grain yield and its components in maize were also reported by Jain and Bhardwaj (2014) and Rovaris *et al.* (2014) [11]. The five best hybrids exhibiting highest magnitude of sca effects for number of grain rows per ear are *viz*., EI-2614 x EI-670-2, EI-2312 x BML-6, EI-2526 x EI-586-2, EI-2412 x BML-6 and EI-2527 x BML-6 and five best hybrids for harvest percent are *viz*., EI-2430 x EI-670-2, EI-2637 x EI-670-2, EI-2614 x EI-586-2, EI-2312 x BML-6 and EI-2306 x EI-586-2.

Table 1: Details of Inbred lines used as Parents and Checks

S.no	Inbred line	Symbol (Code)	Stage of level of inbred line	Source (Origin)
1.	EI-2306	L_1	S_5	AICRP on maize, Udaipur
2.	EI-2312	L_2	S_5	AICRP on maize, Udaipur
3.	EI-2405	L_3	S_5	AICRP on maize, Udaipur
4.	EI-2421	L_4	S_5	AICRP on maize, Udaipur
5.	EI-2430	L_5	S_5	AICRP on maize, Udaipur
6.	EI-2438	L_6	S_5	AICRP on maize, Udaipur
7.	EI-2614	L_7	S_5	AICRP on maize, Udaipur
8.	EI-2637	L_8	S_5	AICRP on maize, Udaipur
9.	EI-2514	L_9	S_5	AICRP on maize, Udaipur
10.	EI-2525	L_{10}	S_5	AICRP on maize, Udaipur
11.	EI-2526	L_{11}	S_5	AICRP on maize, Udaipur
12.	EI-2527	L_{12}	S_5	AICRP on maize, Udaipur
13.	EI-670-2	T_1	S_6	AICRP on maize, Udaipur
14.	EI-586-2	T_2	S_6	AICRP on maize, Udaipur
15.	BML-6	T_3	S_6	AICRP on maize, Udaipur
16.	Vivek-Hybrid-43		Hybrid variety	VPKAS, Almora
17.	Pratap Hybrid Maize-3		Hybrid	AICRP on maize, Udaipur
18.	Pratap Makka-9		Composite	AICRP on maize, Udaipur
19.	HM-11		Hybrid	CCSHAU, Karnal

Where,
AICRP – All India Coordinated Research Project.
CCS HAU - Chaudhary Charan Singh Haryana Agriculture University, Hisar
VPKAS - Vivekand Parvatiya Krishi Anusandhan Shala, Almora

Table 2: Analysis of variance for combining ability for different characters in maize

				Mean square			
SN	Characters Source	Rep	Genotype	Parents	P Vs C	Crosses	Error
	d.f	[2]	[54]	[14]	[1]	[35]	[108]
1	Days to 50% tasseling	8.46*	13.40	11.91**	113.56**	11.72**	2.01
2	Days to 50 % silking	7.17*	14.65	9.23**	139.34**	13.26**	1.98
3	Anthesis-silking interval	0.08	1.44**	1.37**	1.37**	1.47**	0.11
4	Days to 75% brown husk	25.48*	6.02	5.63	47.59**	5.23	6.68
5	Plant height (cm)	120.34	2539.57**	1863.78**	88177.65**	454.03**	53.94
6	Ear height (cm)	38.88	538.84**	462.78**	17562.52**	107.70**	15.45
7	No of leaves per plant	3.35	3.27	2.58*	76.72**	1.69	1.15
8	100 -Grain wt (g)	3.64	98.06**	187.27**	693.80**	50.16**	1.58
9	No of grain rows/ear	0.68	5.95**	6.27**	15.75**	4.86**	0.40
10	Shelling percentage	111.18	106.43	145.18**	290.17**	96.53**	38.02
11	Harvest index (%)	10.60	41.04**	31.16**	62.48**	43.51**	3.89
12	Grain yield (g/plant)	457.64*	3639.91**	817.95**	98567.70**	2098.99**	113.98
13	Oil content (%)	0.04*	1.68**	1.82**	0.61**	1.56**	0.01
14	Protein content (%)	0.16	2.46**	2.83**	0.60**	2.40**	0.06
15	Starch content (%)	9.58*	12.11*	9.26**	1.02	13.44**	2.46

*, ** Significant at 5 % and 1 % level of significance, respectively.

Table 3: Analysis of variance for combining ability for different characters in maize

Source of Variation	Days to 50% tasseling	Days to 50 % silking	Anthesis-Silking interval	Days to 75 % brown husk	Plant height	Ear height	No of leaves per plant	100-grain weight	No of Grain rows per ear	Shelling percentag e	Harvest index	Grain yield (g/plant)	Oil content	Protein content	Starch content
σ^2_L	0.66	-0.25	-0.05	0.34	2.93	2.12	-0.05	4.26	0.32	6.39	-1.78	-13.43	0.30	0.31	4.19
σ^2_t	-0.12	-0.30	-0.03	-0.04	33.18	13.82	0.06	-0.26	0.35	-0.74	6.73	-19.66	-0.01	-0.02	0.01
σ^2_{GCA}	0.10	-0.08	-0.01	0.05	4.82	2.17	-0.00	0.73	0.10	1.04	0.56	-4.94	0.05	0.05	0.75
σ^2_{SCA}	2.69	4.21	0.52	-0.77	107.84	19.28	0.19	12.35	0.94	13.98	10.27	687.81	0.24	0.50	-0.30
$\sigma^2_{SCA/GCA}$	26.90	-52.625	-52.00	-15.40	22.37344	8.8848	-	16.917808	9.4	13.442307	18.33928	-139.2328	4.8	10	-0.4

*,** Significant at 5 % and 1 % level of significance respectivel

Table No. 4: Estimates of gca and sca effects for days to 50 per cent tasseling, days to 50 per cent silking, anthesis-silking interval, days to 75 per cent brown husk, plant height, ear height, number of leaves per plant and 100 -grain weight

SN	Genotype	Days to 50% tasseling	Days to 50 % silking	Anthesis-silking interval	Days to 75% brown husk	Plant height (cm)	Ear height (cm)	No of leaves per plant	100 -Grain wt (g)
1	EI-670-2	0.32	0.25	-0.12	0.24	-1.97	-2.20**	-0.08	0.97**
2	EI586-2	-0.45	-0.36	0.13*	-0.31	-5.40**	-2.40**	-0.28	-0.15
3	BML-6	0.13	0.11	-0.01	0.07	7.37**	4.60**	0.36	-0.82**
4	EI-3206	1.05*	0.47	-0.37**	0.60	1.37	0.98	0.10	-1.47**
5	EI-2312	1.27*	0.58	-0.70**	0.16	-0.34	0.29	0.15	-0.43
6	EI-2405	1.71**	1.69**	-0.04	1.05	0.44	-0.95	-0.01	3.07**
7	EI-2421	0.60	0.25	-0.48**	-0.06	4.06	-0.71	-0.34	-0.47
8	EI-2430	-1.95**	-1.53**	0.41**	-1.29	-2.47	-1.38	-0.79*	7.36**
9	EI-2438	-1.62**	-1.19*	0.41**	-0.62	-10.21**	-5.00**	-0.43	-1.10*
10	EI-2614	1.27*	1.36**	0.19	1.49	7.13**	2.49	0.39	-1.95**
11	EI-2637	0.71	0.81	0.07	-0.29	-5.74*	-1.00	0.26	-0.93*
12	EI-2514	-0.40	-0.42	-0.04	0.94	-12.30**	-5.73**	0.01	-1.53**
13	EI-2525	-0.40	-0.31	0.07	0.16	7.41**	3.27*	0.21	-2.46**
14	EI-2526	-2.18**	-2.19**	-0.04	-0.95	2.33	2.67	0.55	-2.66**
15	E I-2527	-0.06	0.47	0.52**	-1.18	8.33**	5.07**	-0.12	2.56**
16	EI-2306xEI-670-2	0.79	1.19	0.23	1.98	-11.67*	-1.18	-1.25	-2.91**
17	EI-2312x EI-670-2	1.90	1.75	-0.10	0.09	-7.89	-5.36	-0.63	-1.96*
18	EI-2405x EI-670-2	-0.55	0.31	0.90**	-0.13	3.33	-2.78	0.19	-0.29
19	EI-2421x EI-670-2	-0.44	-0.92	-0.66**	-0.35	15.57**	3.84	0.39	3.59**
20	EI-2430x EI-670-2	-1.55	-2.14*	-0.55*	-0.46	16.91**	7.78**	-0.30	1.75*
21	EI-2438x EI-670-2	1.79	1.53	-0.21	0.54	4.91	1.40	0.08	-1.35
22	EI-2614x EI-670-2	1.23	1.97*	0.68**	-0.91	2.51	5.18	0.92	2.63**
23	EI-2637x EI-670-2	-2.88**	-3.14**	-0.21	-1.46	-4.36	-1.54	0.59	0.34
24	EI-2514x EI-670-2	1.23	1.08	-0.10	0.65	-0.87	-0.34	0.24	-2.02*
25	EI-2525x EI-670-2	0.56	1.31	0.79**	0.09	-5.31	-0.27	0.57	3.18**
26	EI-2526x EI-670-2	0.01	-0.14	-0.10	1.20	-16.29**	-6.34*	-0.83	-3.29**
27	E I-2527x EI-670-2	-2.10*	-2.81**	-0.66**	-1.24	3.17	-0.40	0.04	0.32
28	EI-3206xEI-586-2	-2.44*	-3.19**	-0.35	-2.80	9.42	-1.18	0.41	3.87**
29	EI-2312 xEI-586-2	-1.99*	-1.64	0.31	-0.02	-6.94	-4.49	0.10	4.00**

30	EI-2405 xEI-586-2	-0.77	-2.08*	-1.35**	-0.24	-6.98	-1.45	-0.01	0.83
31	EI-2421 xEI-586-2	1.01	1.36	0.43	1.54	3.80	1.11	0.39	2.37**
32	EI-2430 xEI-586-2	0.56	1.81	1.20**	0.09	-4.20	-1.82	0.10	-2.79**
33	EI-2438 xEI-586-2	0.90	1.14	0.20	0.76	3.40	4.53	0.21	-0.49
34	EI-2614 xEI-586-2	-0.99	-1.08	-0.24	0.65	-8.34	-3.36	-0.28	-0.48
35	EI-2637 xEI-586-2	2.90**	2.47*	-0.46*	0.43	-5.40	-0.07	-0.61	-2.67**
36	EI-2514 xEI-586-2	1.01	1.69	0.65**	0.20	-6.45	-2.67	-0.63	-1.57
37	EI-2525 xEI-586-2	-1.66	-2.08*	-0.46*	-1.02	5.71	2.66	-1.30	-7.64**
38	EI-2526 xEI-586-2	0.45	1.14	0.65**	-0.57	10.60*	3.20	1.37	4.23**
39	E I-2527 xEI 586-2	1.01	0.47	-0.57*	0.98	5.40	3.53	0.24	0.34
40	EI-3206xBML-6	1.65	2.00*	0.12	0.81	2.25	2.36	0.84	-0.96
41	EI-2312 xBML-6	0.09	-0.11	-0.21	-0.07	14.83**	9.85**	0.53	-2.04*
42	EI-2405 xBML-6	1.31	1.78	0.45	0.37	3.65	4.23	-0.18	-0.54
43	EI-2421 xBML-6	-0.57	-0.44	0.23	-1.19	-19.37**	-4.95	-0.78	-5.96**
44	EI-2430 xBML-6	0.98	0.33	-0.66**	0.37	-12.70*	-5.95*	0.20	1.04
45	EI-2438 xBML-6	-2.69**	-2.67**	0.01	-1.30	-8.30	-5.93*	-0.29	1.84*
46	EI-2614 xBML-6	-0.24	-0.89	-0.44	0.26	5.83	-1.82	-0.65	-2.15*
47	EI-2637 xBML-6	-0.02	0.67	0.68**	1.04	9.76	1.60	0.02	2.33**
48	EI-2514 xBML-6	-2.24*	-2.78**	-0.55*	-0.85	7.32	3.00	0.40	3.59**
49	EI-2525 xBML-6	1.09	0.78	-0.32	0.93	-0.39	-2.40	0.73	4.46**
50	EI-2526 xBML-6	-0.46	-1.00	-0.55*	-0.63	5.70	3.14	-0.54	-0.94
51	EI-2527 xBML-6	1.09	2.33*	1.23**	0.26	-8.57	-3.13	-0.27	-0.66
	Standard error								
	Ti	0.27	0.27	0.06	0.50	1.41	0.76	0.21	0.24
	Lj	0.4s9	0.49	0.11	0.90	2.55	1.36	0.37	0.44
	Sij	0.98	0.98	0.23	1.79	5.10	2.73	0.74	0.87
	Ti-j	0.33	0.33	0.08	0.61	1.73	0.93	0.25	0.30
	Li-j	0.67	0.66	0.16	1.22	3.46	1.85	0.50	0.59
	Ti-Lj	0.53	0.52	0.12	0.96	2.74	1.46	0.40	0.47
	STi-Tj	1.20	1.20	0.28	2.20	6.24	3.34	0.91	1.07
	SiL-jL	1.34	1.33	0.31	2.44	6.92	3.71	1.01	1.19
	Sij-kl	1.38	1.37	0.32	2.51	7.14	3.82	1.04	1.22

*, ** Significant at 5 % and 1 % level of significance respectively

Table. 5: Estimate of gca and sca effects for number of grain rows/ear, shelling percentage, harvest index, grain yield per plant, oil content, protein content and starch content

SN	Genotype	No of grain rows/ear	Shelling percentage	Harvest index (%)	Grain yield (g/plant)	Oil content (%)	Protein content (%)	Starch content (%)
1	EI-670-2	-0.74**	0.99	-3.20**	-6.40**	0.05*	-0.04	0.04
2	EI586-2	0.19	-1.36	1.67**	0.02	-0.10**	-0.14**	0.21
3	BML-6	0.55**	0.36	1.53**	6.38**	0.05*	0.18**	-0.26
4	EI-2306	1.44**	0.84	-0.55	-12.93**	0.33**	-0.96**	-1.41*
5	EI-2312	-0.16	-9.86**	-1.12	-22.64**	-0.29**	-0.21*	1.71**
6	EI-2405	-0.71**	0.29	-0.53	7.17	0.62**	-0.25**	1.75**
7	EI-2421	0.91**	2.31	0.76	0.85	-0.41**	0.27**	2.62**
8	EI-2430	-1.49**	2.70	1.27	8.10*	0.12**	0.69**	2.20**
9	EI-2438	0.82**	4.27*	2.14**	30.71**	0.34**	0.39**	-2.75**
10	EI-2614	-0.42	-5.63**	0.61	2.20	0.80**	0.58**	-2.34**
11	EI-2637	-0.02	1.42	-2.62**	-14.35**	-0.14**	0.14	-1.41*
12	EI-2514	0.11	1.69	-0.87	-5.15	-0.90**	-0.76**	-0.65
13	EI-2525	-0.25	-0.24	-1.16	-16.64**	0.93**	1.18**	2.73**
14	EI-2526	0.55*	1.35	2.20**	10.76**	-0.83**	0.04	-0.11
15	E I-2527	-0.78**	0.85	-0.14	11.93**	-0.57**	-1.11**	-2.33**
16	EI-2306xEI-670-2	0.47	-3.82	-1.61	-41.00**	0.10	0.69**	1.12
17	EI-2312x EI-670-2	-1.19**	5.20	-1.38	-29.62**	0.27**	-0.80**	0.57
18	EI-2405x EI-670-2	0.56	-0.34	0.28	3.33	-0.45**	-0.35*	0.25
19	EI-2421x EI-670-2	-1.46**	-0.17	0.74	7.69	0.22**	0.16	0.22
20	EI-2430x EI-670-2	1.14*	2.55	4.69**	18.70*	-0.23**	0.69**	-1.01
21	EI-2438x EI-670-2	-0.70	4.80	-4.27**	1.36	0.49**	-0.45*	0.29
22	EI-2614x EI-670-2	1.41**	-5.28	2.24	10.00	-0.49**	0.32	-1.11
23	EI-2637x EI-670-2	0.47	-1.05	4.29**	25.89**	0.33**	-0.06	-0.06
24	EI-2514x EI-670-2	0.34	-1.07	-1.26	-15.84*	-0.06	0.25	0.06
25	EI-2525x EI-670-2	-0.50	1.86	-0.85	26.65**	0.10	0.21	0.07
26	EI-2526x EI-670-2	-0.97*	0.33	-1.64	-15.29*	-0.12	-0.66**	0.78
27	E I-2527x EI-670-2	0.43	-2.99	-1.22	8.13	-0.16*	0.01	-1.20
28	EI-3206xEI-586-2	-0.06	3.01	3.17*	37.98**	-0.71**	0.05	-1.16
29	EI-2312 xEI-586-2	-0.13	-15.71**	-2.89*	-6.71	-0.35**	1.36**	-0.54
30	EI-2405 xEI-586-2	-0.57	0.31	-1.35	-17.12*	0.49**	-0.49**	-0.11
31	EI-2421 xEI-586-2	0.34	0.15	0.74	-0.93	0.04	-0.23	-0.19
32	EI-2430 xEI-586-2	-1.13*	0.26	-4.38**	-25.46**	-0.60**	-0.16	0.63
33	EI-2438 xEI-586-2	0.63	-2.78	2.43	0.40	0.64**	1.14**	0.36
34	EI-2614 xEI-586-2	-0.19	7.15	4.27**	42.91**	0.36**	0.03	0.85
35	EI-2637 xEI-586-2	-0.26	2.31	-0.62	-7.20	-0.04	-0.88**	0.04
36	EI-2514 xEI-586-2	0.54	2.90	-2.07	-8.53	-0.05	-0.57**	0.42
37	EI-2525 xEI-586-2	0.96*	-1.35	-1.45	-29.05**	0.01	0.12	-0.26
38	EI-2526 xEI-586-2	1.30**	0.90	-0.06	7.69	0.07	-0.15	-0.68
39	E I-2527 xEI-586-2	-1.44**	2.85	2.19	6.04	0.12	-0.22	0.64
40	EI-3206xBML-6	-0.41	0.81	-1.56	3.02	0.61**	-0.74**	0.04
41	EI-2312 xBML-6	1.32**	10.51*	4.27**	36.33**	0.08	-0.56**	-0.04
42	EI-2405 xBML-6	0.01	0.03	1.07	13.79	-0.05	0.84**	-0.14
43	EI-2421 xBML-6	1.12*	0.03	-1.48	-6.76	-0.26**	0.08	-0.03
44	EI-2430 xBML-6	-0.01	-2.81	-0.31	6.76	0.83**	-0.52**	0.37
45	EI-2438 xBML-6	0.07	-2.02	1.84	-1.76	-1.13**	-0.69**	-0.65
46	EI-2614 xBML-6	-1.21**	-1.87	-6.51**	-52.91**	0.13	-0.35*	0.26
47	EI-2637 xBML-6	-0.21	-1.26	-3.67**	-18.69*	-0.29**	0.94**	0.01
48	EI-2514 xBML-6	-0.88*	-1.83	3.34*	24.38**	0.11	0.31	-0.49
49	EI-2525 xBML-6	-0.46	-0.50	2.30	2.40	-0.11	-0.33	0.20
50	EI-2526 xBML-6	-0.33	-1.23	1.70	7.60	0.05	0.81**	-0.10
51	EI-2527 xBML-6	1.01*	0.14	-0.98	-14.18	0.03	0.22	0.56
	Standard error							
	Ti	0.12	1.19	0.38	2.05	0.02	0.05	0.30
	Lj	0.22	2.14	0.68	3.70	0.04	0.09	0.54
	Sij	0.44	4.28	1.37	7.41	0.07	0.17	1.09
	Ti-j	0.15	1.45	0.46	2.52	0.03	0.06	0.37
	Li-j	0.30	2.91	0.93	5.03	0.05	0.12	0.74
	Ti-Lj	0.23	2.30	0.73	3.98	0.04	0.09	0.58
	STi-Tj	0.53	5.24	1.68	9.07	0.09	0.21	1.33
	SiL-Jl	0.59	5.81	1.86	10.07	0.10	0.23	1.48
	Sij-kl	0.61	5.99	1.92	10.38	0.10	0.24	1.53

*, * * Significant at 5 % and 1 % level of significance respectively

References

1. AOAC. Official methods for oil analysis for association of Official Agricultural Chemists 10th Ed. Washington., DC, 1965.
2. Amiruzzaman M, Islam MA, Hasan L, Kadir M, Rohman MM. Heterosis and combining ability in a diallel among elite inbred lines of maize (Zea mays L.). Emirates Journal of Food and Agriculture, 2013; 25:132-137.
3. Comstock RE, Robinson HF, Harvey PH. A breeding procedure designed to make maximum use of both general and specific combining ability. Journal of American Society Agronomy, 1949; 41:360- 367.
4. Jain, Rashmi, Bharadwaj, Dinesh Narayan. Heterosis and inbreeding depression for grain yield and yield contributing characters in quality protein maize. Agricultural communications. 2014; 2:8-16.
5. Jampatong S, Ngean MT, Balla C, Boonrumpun P, Mekarun A, Jompuk C, Kaveeta R. Evaluation of improved maize populations and their diallel crosses for yield. Kasetsart J. (Natural. Science.). 2010; 44:523–528.
6. Kempthorne O. An introduction to genetical statistics. John Willey and Sons Inc., New York, 1957, 323-331.
7. Linder RC. Rapid analytical method for some of the more common inorganic constituents of plant tissues. Plant Physiology, 1944; 19:76-89.
8. Miranda GV, Souza LV, Galvao JCC, Guimarães LJM, Melo AV, Santos IC. Genetic variability and heterotic groups of Brazilian popcorn populations. Euphytica. 2008; 162:431-440.
9. Panse VG, Sukhatme PV. Statistical methods for agricultural workers, ICAR Publication, New Delhi, 1985, 145.
10. Rastgari M, Ahmadi H, Zebarjadi AR. Combining ability analysis and gene effects in maize (*Zea mays* L.) using line × tester crosses. Research on Crops. 2014; 15:621-625.
11. Rovaris Sara RS, Paterniani Maria EAG Zagatto, Sawazaki E. Combining ability of white corn genotypes with two commercial hybrids. Maydica Electronic Publication, 2014; 59:96-103.
12. Sharma PP, Vyas M, Sharma SP. Analysis of combining ability in white seeded genotypes of maize (*Zea mays* L.). International Journal of Plant Science. 2015; 10:80-84.
13. Sprague GH, Tatum LA. General v/s specific combining ability in single crosses in corn. Journal American Society of Agronomy. 1942; 30:923-932.
14. Verma R, Kumar SS, Reddy VN, Sankar AS. Heterosis studies for grain yield and its component traits in single cross hybrids of maize (*Zea mays* L.). International Journal of Plant and Animal Environment Science. 2014; 4:304-306.