

Original Research Article

<https://doi.org/10.20546/ijcmas.2017.610.025>

Diallel Analysis of Combining Ability for Yield and Yield Contributing Traits over the Environments in Maize (*Zea mays* L.)

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ABSTRACT

Present study was conducted with 10 parents, their 45 hybrids along with 4 checks viz., Pratap QPM Hybrid-1, Vivek QPM-9, HQPM-1 and HQPM-5 to estimate GCA and SCA of parents and crosses respectively in diallel mating design (excluding reciprocal crosses) in two environments (*Kharif 2014* and *Rabi 2014-15*) at the Instructional farm, Rajasthan College of Agriculture, MPUAT, Udaipur. Two characters viz., grain yield per plant and harvest index exhibited high mean sum of squares due to GCA than SCA in E₁ environment while, in E₂ environment they exhibited high mean sum of squares due to SCA than GCA. The estimates of SCA variance were of higher magnitude than GCA variance for all the traits in both the environments. In pooled analysis mean squares due to environment, GCA, SCA, GCA x E and SCA x E were significant for all the three characters except GCA x E and SCA x E for number of grain rows per ear. The estimates of GCA effects for grain yield per plant revealed that only three inbred lines viz., EIQ-106, EIQ-109 and EIQ-112 in E₁ and only two inbreds; EIQ-112 and EIQ-109 in E₂ showed positive significant GCA effects. The estimates of positive significant SCA effects for grain yield per plant were depicted by 20 and 17 hybrids in E₁ and E₂ environments respectively. The estimates of GCA effects revealed that good general combiner inbred lines for grain yield per plant were EIQ-112, EIQ-109 and EIQ-106 in E₁ environment while, EIQ-109 and EIQ-112 in E₂ environment. On the basis of mean and SCA effects out of total 45 hybrids, five hybrids which exhibited higher mean and significant positive SCA effects for grain yield per plant were EIQ-110 x EIQ-112, EIQ-107 x EIQ-109, EIQ-109 x EIQ-111, EIQ-105 x EIQ-112 and EIQ-105 x EIQ-114 in E₁ environment while hybrids EIQ-110 x EIQ-112, EIQ-105 x EIQ-112, EIQ-109 x EIQ-111, EIQ-107 x EIQ-109, EIQ-105 x EIQ-113 in E₂ environment. Among these the crosses EIQ-110 x EIQ-112, EIQ-107 x EIQ-109, EIQ-109 x EIQ-111, EIQ-105 x EIQ-112 were better performer in both the environment.

Keywords

Maize, Diallel analysis, Combining ability effects, GCA variance, SCA variance, Over environments.

Article Info

Accepted:
04 September 2017
Available Online:
10 October 2017

Introduction

Maize is the third most widely distributed crop of the world after Rice and Wheat (Poehlman, 2006), being grown in diverse seasons and ecologies with highest production

and productivity among food cereals. It is an important food, feed and industrial crop in India as well as other countries of the world which is believed to be originated in Southern

Mexico or Northern Guatemala (Weatherwax, 1955). It has great yield potential and attained the leading position among the cereals based on production as well as productivity (Keskin *et al.*, 2005). Every part of the plant has economic value; the grain, leaves, stalk, tassel are used to produce hundreds of food and non-food products (Haddadi *et al.*, 2012). Maize ranks first in global cereal production of approximately 967 million tonnes in 2014 from 177 million hectare area with an average yield of 5.50 tonnes/hectare (Foreign Agriculture Services/USDA, Office of Global Analysis, 2014). In India, maize is cultivated on an area of 9.23 million ha with a production of 23.67 million tonnes and productivity of 2564 kg/ha (Annual progress report, AICRP on Maize 2015: Indian Institute of Maize Research, New Delhi). To establish a sound basis for any breeding programme, breeders must have information on the nature of combining ability of parents, their behaviour and performance in hybrid combinations (Chawla and Gupta, 1984). Such knowledge of combining ability is essential for selection of suitable parents for hybridization and identification of promising hybrids for the development of improved varieties for a diverse agro-ecology (Alabi *et al.*, 1987). One of the most informative methodology in this concern is diallel analysis system which is widely and extensively used for estimating the types of gene action. The two main genetic parameters of diallel analysis are GCA and SCA which are essential in developing breeding strategies. Combining ability is a powerful tool in identifying the best combiners for hybridization especially, when a large number of advance inbred lines are available and most promising ones are to be selected on the basis of their ability to give superior quality protein maize hybrids. General and specific combining ability are due to genes which are largely additive and dominance or epistatic effects respectively (Sprague and Tatum,

1942). Therefore, the present investigation was undertaken to study the general and specific combining ability of parents and crosses respectively over the environments for grain yield and yield contributing traits.

Materials and Methods

The materials of present investigation consisted of 10 inbred lines crossed in diallel design (Griffing, Model-I, Method-II) during *Rabi* 2013-14 to develop 45 half-diallel crosses (reciprocals excluded). These 45 F₁ hybrids along with 10 parents (EIQ-105, EIQ-106, EIQ-107, EIQ-108, EIQ-109, EIQ-110, EIQ-111, EIQ-112, EIQ-113 and EIQ-114) and 4 checks *viz.*, Pratap QPM Hybrid-1, Vivek QPM-9, HQPM-1 and HQPM-5 were evaluated for GCA and SCA of parents and crosses respectively in randomized block design (RBD) with three replications during *Kharif* 2014 and *Rabi* 2014-15. The materials were grown in a single row plot of four meter length, maintaining crop geometry of 60 x 25 cm. The observations were taken for yield and yield contributing traits *viz.*, ear length (cm), ear girth (cm), no. of grain rows per ear, 100 grain weight (g) harvest index (%) and grain yield per plant (g). The combining ability analysis for individual environment as well as over environments was performed to determine the general and specific combining ability effects. The combining ability analysis of data for individual environment was carried out for both environments separately, using Griffing's method II, model I (1956). The combining ability analysis for over environments was carried out using the method suggested by Singh (1973 and 1979), which is an extension of Griffing's method II, model I (1956) to estimate the interactions of general and specific combining ability effects with environments, besides determining the significance of general and specific combining ability variance.

Results and Discussion

Analysis of variance in individual environment revealed that mean sum of squares due to genotypes was significant for all the characters in both the environments (Table 2). Similar results were observed by Dar *et al.*, (2015), Kumar *et al.*, (2013) and Krupakar *et al.*, (2013). By further partitioning of genotypic variance the mean square due to parents were significant for all the characters except for grain yield per plant which was non-significant in E2 environment. Mean squares due to crosses and mean sum of square due to parents v/s crosses were significant for all the characters in both the environments. This result is in accordance with Lal and Kumar (2012). The Bartlett test revealed that error variance was homogenous for ear girth, number of grain rows per ear and harvest index. Therefore, pooled analysis was carried out for these characters only. The results of Bartlett test are comparable with the findings of Bacha *et al.*, 2001. The pooled analysis revealed significant differences between the environments for the three characters. The mean sum of squares due to genotypes, parents, crosses, parents vs. crosses and parents x environments were also significant for all the three characters. Mean sum of squares due to genotypes x environment interactions were significant for ear girth and harvest index, whereas for number of grain rows per ear it was non-significant, indicating influence of environments on the expression of this character. The mean sum of squares due to crosses x environments interaction were significant for ear girth and harvest index while non-significant for number of grain rows per ear (Table 3). The mean sum of squares for combining ability and estimated components of genetic variance for various characters are presented in (Table 4). The analysis of variance for combining ability revealed significant mean sum of squares due

to GCA and SCA for all the traits, excepted mean sum of squares due to SCA for number of grain rows per year in E1 environment. These results suggested the existence of additive and non-additive gene actions for various traits in the material under study. The magnitude of mean sum of squares due to GCA was higher than SCA for ear length, ear girth and 100 grain weight in both the environments. In case of number of grain rows per ear the mean sum of squares due to SCA was higher than that of GCA in E1 environment while, mean sum of squares due to GCA was higher than SCA in E2 environment. Two characters viz., grain yield per plant and harvest index exhibited high mean sum of squares due to GCA than SCA in E1 environment (same result for grain yield per plant was observed by Moneam *et al.*, 2009) while, in E2 environment they exhibited high mean sum of squares due to SCA than GCA. The estimates of SCA variance were of higher magnitude than GCA variance for all the traits in both the environments. In pooled analysis mean squares due to environment, GCA, SCA, GCA x E and SCA x E were significant for all the three characters except GCA x E and SCA x E interactions for number of grain rows per ear (Table 5). Similar results for pooled mean squares due to GCA and SCA were observed by Nass *et al.*, 2000; Aguiar *et al.*, 2003; Qi *et al.*, 2010; Alamerew and Warsi, 2015. The σ^2 SCA was higher than their corresponding σ^2 GCA for all the three characters. These results were also supported by the earlier findings of Vasal *et al.*, (1992), Joshi *et al.*, (1998) and Izhar and Chakraborty (2013). Similarly, σ^2 GCA x E were higher than the σ^2 SCA x E for all the three characters.

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 (Tables 6 and 7). In case of ear length, out of ten inbred lines, three inbred lines in E1 viz., EIQ-109 (0.34) and EIQ-112 (0.75) and four inbred lines in E2 viz., EIQ-108 (0.35), EIQ-109 (0.48), EIQ-112 (0.81) and EIQ-105 (0.88) exhibited positive significant GCA effects. Estimates of SCA effects revealed that out of forty- five hybrids, seventeen hybrids in E1 with the magnitude ranged from 0.85 (EIQ-109 x EIQ-111) to 3.51 (EIQ-106 x EIQ-114) and ten hybrids in E2 with the range from 1.14 (EIQ-106 x EIQ-109 and EIQ -106 x EIQ-112) to 2.65 (EIQ-106 x EIQ-110) exhibited significant SCA effects in positive direction. For ear girth, two inbred lines viz., EIQ-109 (0.34) and EIQ-112 (0.75) in E1 and EIQ-105 (0.30) and EIQ-109 (0.50) in E2 exhibited positive significant GCA effects. Estimates of SCA effects revealed that out of forty- five hybrids, eleven hybrids in E1 with the magnitude ranged from 0.96 (EIQ-108 x EIQ-113 and EIQ-113 x EIQ-114) to 2.25 (EIQ-105 x EIQ-112) and only four hybrids in E2 with the range from 0.71 (EIQ-111 x EIQ-114) to 0.99 (EIQ-106 x EIQ-107) exhibited significant SCA effects in positive direction. Analysis of pool data for ear girth revealed that two inbreds viz., EIQ-

112 (0.24) and EIQ-109 (0.42) showed positive significant gca effects while, out of forty five, fifteen hybrids with the range 0.54 (EIQ-108 x EIQ-110 and EIQ-109 x EIQ-113) to 1.26 (EIQ-110 x EIQ-112) expressed positive significant SCA effects. The estimates of positive significant GCA effects for number of grain rows per ear revealed that only one inbred line in both the environments with the magnitude 0.43 and 0.77 (EIQ-114) expressed positive significant GCA effects. The positive significant SCA effects for number of grain rows per ear was exhibited by six hybrids in E1 with the magnitude ranged from 1.13 (EIQ-105 x EIQ-110 and EIQ-106 x EIQ-114) to 1.52 (EIQ-108 x EIQ-109). In E2, only four hybrids viz., EIQ-109 x EIQ-112 (1.16), EIQ-110 x EIQ-111 (1.32), EIQ-110 x EIQ-112 (1.49) and EIQ-106 x EIQ-114 (2.21) exhibited positive significant SCA effects for number of grain rows per ear. Analysis of pooled data for number of grain rows per ear revealed that only one hybrid; EIQ-114 (0.60) depicted positive significant GCA effects. Among the hybrids, five hybrids with the magnitude ranged from 0.84 (EIQ-107 x EIQ-113) to 1.67 (EIQ-106 x EIQ-114) exhibited positive significant SCA effects.

Table.1 Estimates of GCA effects for yield and yield contributing traits in individual environment and over the environments

S. No.	Characters/Traits	Good General Combiners		
		E ₁	E ₂	Pool
1	Ear Length	EIQ-112, EIQ-110 and EIQ-107	EIQ-105, EIQ-112, EIQ-109 and EIQ-108	--
2	Ear Girth	EIQ-112 and EIQ-109	EIQ-105 and EIQ-109	EIQ-112 and EIQ-109
3	No. of Grain Rows per Ear	EIQ-114	EIQ-114	EIQ-114
4	100 Grain Weight	EIQ-112, EIQ-111, and EIQ-106	EIQ-106, EIQ-113, EIQ-105 and EIQ-110	--
5	Harvest Index	EIQ-106, EIQ-109 and EIQ-112	EIQ-106, EIQ-113, EIQ-110 and EIQ-109	EIQ-106, EIQ-109 and EIQ-113
6	Grain Yield per Plant	EIQ-112, EIQ-109 and EIQ-106	EIQ-109 and EIQ-112	--

Table.2 Mean squares for different characters in Maize (*Zea mays* L.) environment wise

SN	Characters	Env	Source						Bartlett
			Rep	Genotype	Parent	Crosses	Parents vs crosses	Error	
			[2]	[54]	[9]	[44]	[1]	[108]	
1	Ear length (cm)	1	1.38788	11.9556**	11.7185**	10.0526**	97.8185**	0.536027	14.87**
		2	4.22769*	8.46996**	7.18967**	5.75756**	139.338**	1.13552	
2	Ear girth (cm)	1	1.16515	4.16818**	3.7787**	2.9766**	60.1031**	0.55867	2.37689
		2	0.878571	1.68896**	2.97052**	0.675731*	34.7372**	0.415013	
3	Number of grain rows per ear	1	0.169697	2.70438**	3.68889**	2.23973**	14.2882**	1.13266	0.0252574
		2	0.678788	3.03659**	4.74074**	2.04983**	31.1165**	1.09854	
4	100-Grain weight (g)	1	1.57276	27.5754**	8.11111**	28.0809**	180.511**	0.82675	16.8673**
		2	6.65486*	17.2658**	11.2576**	17.2588**	71.6491**	1.84128	
5	Grain yield per plant (g)	1	15.8061	982.046**	127.482**	853.212**	14341.8**	10.411	65.9651**
		2	69.1869	665.872**	56.3824	447.078**	15778.2**	53.8692	
6	Harvest index (%)	1	1.3373	30.8761**	18.3143**	27.902**	274.792**	2.55375	0.484708
		2	7.05377*	31.5175**	19.7769**	23.4901**	490.392**	2.23341	

*, ** Significant at 5 and 1 per cent respectively (Model I)

Table.3 Pooled mean squares for Ear girth, Number of grain rows per ear and Harvest index in Maize (*Zea mays* L.)

SN	Characters	Source											Bartlett
		Env	Rep/Env	Genotype	Parents	Crosses	Parents vs crosses	GxE	Parent x Env	Crosses x E	Parents vs Crosses x E	Pool Error	
		[1]	[4]	[54]	[9]	[44]	[1]	[54]	[9]	[44]	[1]	[216]	
1	Ear girth (cm)	22.5688**	1.02186	4.17592**	4.67498**	2.05255**	93.1128**	1.68123**	2.07424**	1.59979**	1.72755	0.486842	2.37689
2	Number of grain rows per ear	87.5758**	0.424242	4.23928**	5.25185**	3.13333**	43.7879**	1.50168	3.17778**	1.15623	1.61684	1.1156	0.0252574
3	Harvest index (%)	178.118**	4.19554	52.7503**	28.8107**	41.8076**	749.683**	9.64332**	9.28043**	9.58442**	15.501*	2.39358	0.484708

*, ** Significant at 5 and 1 per cent respectively (Model I)

Table.4 Combining ability mean squares and EMS for different characters in maize (*Zea mays* L.) environment wise

SN	Characters	Env	Source			Var Model I	
			GCA	SCA	Error	GCA	SCA
			[9]	[45]	[108]		
6	Ear length (cm)	1	4.70535**	3.84115**	0.178676	1.6975	82.4057
		2	5.46514**	2.29494**	0.378507	1.90749	43.1198
7	Ear girth (cm)	1	1.58426**	1.35042**	0.186223	0.524263	26.1944
		2	0.760446**	0.523487**	0.138338	0.233291	8.66586
8	Number of grain rows per ear	1	0.46749	0.988253**	0.377553	0.0337262	13.7407
		2	1.65267**	0.8841**	0.36618	0.482435	11.6532
9	100-grain weight (g)	1	10.7448**	8.88116**	0.275583	3.92597	193.626
		2	6.03394**	5.69953**	0.613761	2.03257	114.43
10	Grain yield per plant (g)	1	441.615**	304.495**	3.47033	164.304	6773.06
		2	204.363**	225.476**	17.9564	69.9024	4669.19
11	Harvest index (%)	1	10.7325**	10.204**	0.851251	3.70548	210.437
		2	4.70446**	11.666**	0.744469	1.485	245.735

*, ** Significant at 5 and 1 per cent respectively (Model I)

Table.5 Combining ability mean square and EMS over the environments for Ear girth, Number of grain rows per ear and Harvest index

S N	Characte rs	Source						Bartlett	Variance Model I			
		Env	GCA	SCA	GCA x E	SCA x E	Pool Error		GCA	SCA	GCA x E	SCA x E
		[1]	[9]	[45]	[9]	[45]	[216]		[1]			
1	Ear girth (cm)	2.50764**	1.11008* *	1.44834* *	1.23463**	0.425565**	0.162281	2.37689	0.0426429	0.35542 4	28.936 4	0.80426
2	Number of grain rows per ear	9.73064**	1.53992* *	1.38773* *	0.580247	0.484624	0.371867	0.025257 4	0.17016	0.43801 9	22.856 9	0.156285
3	Harvest Index (%)	19.7909**	11.7619* *	18.7474* *	3.67505**	3.12262**	0.79786	0.484708	0.345329	4.11153	403.86 5	2.15789

*, ** Significant at 5 and 1 per cent respectively (Model I)

Table.6 GCA and SCA effects for Ear length (cm), 100-grain weight (g) and Grain yield per plant (g)

SN	Genotype	Ear length (cm)		100-grain weight (g)		Grain yield per plant (g)	
		E1	E2	E1	E2	E1	E2
1	EIQ-105	-0.04	0.88**	-0.98**	0.61**	-2.41**	-1.40
2	EIQ-106	-0.09	-0.35*	0.45**	0.83**	3.05**	2.23
3	EIQ-107	0.38**	-0.09	0.05	-0.95**	-4.11**	-2.54*
4	EIQ-108	-0.24*	0.35*	-1.80**	-0.89**	-9.97**	-6.32**
5	EIQ-109	0.19	0.48**	0.16	0.12	8.89**	6.79**
6	EIQ-110	0.51**	0.01	-0.09	0.50*	-1.38**	1.23
7	EIQ-111	-0.30*	-0.47**	1.47**	0.21	-2.61**	-3.65**
8	EIQ-112	1.17**	0.81**	1.17**	-0.04	10.46**	6.01**
9	EIQ-113	-0.38**	-1.37**	-0.26	0.64**	-0.36	-1.15
10	EIQ-114	-1.19**	-0.25	-0.19	-1.03**	-1.58**	-1.19
11	EIQ-106 x EIQ-105	0.69	-0.46	-1.36**	-0.10	-2.63	0.37
12	EIQ-107 x EIQ-105	0.39	0.21	2.37**	-0.65	-7.48**	-4.19
13	EIQ-108 x EIQ-105	1.01*	0.74	-0.94	-1.13	-0.28	-3.08
14	EIQ-109 x EIQ-105	-2.58**	1.81**	-1.40**	-1.39	-12.81**	-10.52**
15	EIQ-110 x EIQ-105	-1.07**	0.31	-5.99**	0.73	4.80**	6.37
16	EIQ-111 x EIQ-105	0.90*	-0.07	-0.71	0.52	-7.31**	-2.41
17	EIQ-112 x EIQ-105	1.76**	-0.59	2.59**	1.11	25.95**	26.59**
18	EIQ-113 x EIQ-105	1.15**	1.60**	4.18**	0.59	21.77**	21.75**
19	EIQ-114 x EIQ-105	0.12	-0.43	3.11**	2.09**	25.66**	17.12**
20	EIQ-107 x EIQ-106	0.61	1.51**	2.78**	2.80**	6.40**	8.17*
21	EIQ-108 x EIQ-106	-0.26	0.68	-0.54	2.74**	0.59	10.28**
22	EIQ-109 x EIQ-106	0.47	1.14*	3.17**	2.40**	15.06**	7.17
23	EIQ-110 x EIQ-106	1.99**	2.65**	2.42**	3.60**	11.01**	14.06**
24	EIQ-111 x EIQ-106	0.46	0.19	0.70	-0.28	-8.44**	-0.72
25	EIQ - 112 x EIQ - 106	2.65**	1.14*	1.15*	2.89**	18.99**	7.95*
26	EIQ-113 x EIQ-106	-0.29	0.80	-0.25	-1.96**	8.31**	5.78
27	EIQ-114 x EIQ-106	3.51**	1.07	-1.82**	-0.13	-6.46**	-2.51
28	EIQ - 108 x EIQ - 107	0.60	-0.18	0.19	-1.32	2.74	-4.61
29	EIQ-109 x EIQ-107	3.50**	0.48	4.07**	-1.99**	31.22**	21.95**
30	EIQ-110 x EIQ-107	-1.49**	-1.24*	1.35**	0.29	-6.51**	-0.83

SN	Genotype	Ear length (cm)		100-grain weight (g)		Grain yield per plant (g)	
		E1	E2	E1	E2	E1	E2
31	EIQ-111 x EIQ-107	-0.85*	0.87	0.60	-1.92**	-1.95	-0.61
32	EIQ-112 x EIQ-107	-0.49	0.65	1.89**	-2.00**	6.31**	1.73
33	EIQ-113 x EIQ-107	-1.10**	0.61	-2.35**	2.82**	9.13**	9.23*
34	EIQ-114 x EIQ-107	1.21**	0.92	-2.25**	-0.85	2.36	9.93*
35	EIQ-109 x EIQ-108	1.46**	0.11	2.92**	-2.06**	-0.59	10.73**
36	EIQ-110 x EIQ-108	1.14**	2.02**	0.67	-2.77**	7.02**	7.28
37	EIQ-111 x EIQ - 108	-3.39**	-1.10	-1.55**	-0.31	0.58	3.84
38	EIQ-112 x EIQ-108	-0.53	-0.42	-0.10	2.61**	-8.16**	-0.83
39	EIQ-113 x EIQ-108	2.69**	1.37*	1.84**	3.17**	-1.01	-4.00
40	EIQ-114 x EIQ-108	-2.50**	1.35*	-1.23*	-1.16	-4.12*	2.04
41	EIQ-110 x EIQ-109	-0.46	0.51	-2.96**	6.06**	-23.51**	-17.16**
42	EIQ-111 x EIQ-109	0.85*	-0.41	-1.01*	-0.99	28.72**	23.73**
43	EIQ-112 x EIQ-109	2.54**	1.01	-1.22*	0.60	20.65**	9.39*
44	EIQ-113 x EIQ-109	1.43**	0.33	0.38	1.08	15.47**	14.56**
45	EIQ-114 x EIQ-109	0.74	0.21	1.81**	0.08	0.02	-4.40
46	EIQ-111 x EIQ-110	-0.81*	1.50**	-1.10*	-1.87*	-2.01	-2.38
47	EIQ-112 x EIQ-110	2.56**	0.45	7.86**	-0.28	34.59**	27.95**
48	EIQ-113 x EIQ-110	-0.22	-0.29	-0.38	-2.80**	4.41*	7.78*
49	EIQ-114 x EIQ-110	0.92*	0.85	-3.45**	-0.97	-7.70**	-1.18
50	EIQ-112 x EIQ-111	-0.97*	1.07	0.47	1.34	-15.85**	-8.16*
51	EIQ-113 x EIQ-111	-0.25	-1.98**	-0.10	2.49**	3.30	-6.33
52	EIQ-114 x EIQ-111	0.06	-0.44	8.00**	0.16	21.86**	12.71**
53	EIQ-113 x EIQ-112	-0.89*	-0.43	-2.80**	1.08	-12.44**	-6.66
54	EIQ-114 x EIQ-112	0.58	1.01	-0.04	2.58**	-4.88**	2.04
55	EIQ-114 x EIQ-113	-1.53**	-1.63**	1.22*	-2.94**	4.94**	-2.46
Standard error							
	Gi	0.12	0.17	0.14	0.21	0.51	1.16
	Gi-Gj	0.17	0.25	0.21	0.32	0.76	1.73
	Sii	0.35	0.51	0.43	0.65	1.54	3.50
	Sij	0.39	0.57	0.48	0.72	1.72	3.90
	Sij-ik	0.57	0.83	0.71	1.06	2.52	5.74
	Sij-Skl	0.55	0.79	0.68	1.01	2.40	5.47

Table.7 GCA and SCA effects for Ear girth (cm), No. of grain rows per ear and Harvest Index

SN	Genotype	Ear girth (cm)			Number of grain rows per ear			Harvest index (%)		
		E1	E2	Pool	E1	E2	Pool	E1	E2	Pool
1	EIQ-105	-0.56**	0.30**	-0.13	-0.18	0.32	0.07	-0.45	0.06	-0.20
2	EIQ-106	-0.04	-0.16	-0.10	-0.12	-0.57**	-0.34*	1.13**	0.72**	0.93**
3	EIQ-107	-0.03	-0.05	-0.04	0.04	0.16	0.10	-1.42**	-0.93**	-1.18*
4	EIQ-108	-0.24*	-0.10	-0.17*	-0.07	-0.29	-0.18	-1.62**	-0.56*	-1.09*
5	EIQ-109	0.34**	0.50**	0.42**	-0.01	0.16	0.07	0.93**	0.52*	0.72**
6	EIQ-110	-0.34**	-0.33**	-0.33*	-0.18	-0.18	-0.18	-0.20	0.65**	0.22
7	EIQ-111	0.14	-0.05	0.04	-0.18	-0.07	-0.12	0.19	-0.55*	-0.18
8	EIQ-112	0.75**	-0.26*	0.24**	0.21	-0.23	-0.01	0.87**	-0.61*	0.13
9	EIQ-113	0.05	0.09	0.07	0.04	-0.07	-0.01	0.46	0.67**	0.57**
10	EIQ-114	-0.07	0.06	-0.01	0.43*	0.77**	0.60**	0.11	0.02	0.07
11	EIQ-106 x EIQ-105	0.71	0.28	0.49	1.08	0.66	0.87*	0.42	-0.33	0.04
12	EIQ-107 x EIQ-105	0.53	0.87*	0.70**	-0.42	0.60	0.09	-0.01	2.61**	1.30*
13	EIQ - 108 x EIQ - 105	0.57	-0.29	0.14	0.35	0.38	0.37	-2.69**	-3.49**	-3.09**
14	EIQ-109 x EIQ-105	-0.85*	-0.25	-0.55*	0.30	-0.07	0.12	-3.90**	-2.07*	-2.99**
15	EIQ-110 x EIQ-105	-0.84*	0.15	-0.34	1.13*	0.27	0.70	0.90	1.08	0.99
16	EIQ-111 x EIQ-105	-0.97*	-0.36	-0.67*	-0.20	-0.51	-0.36	-1.04	0.80	-0.12
17	EIQ-112 x EIQ-105	2.25**	-0.43	0.91**	0.74	-0.34	0.20	3.39**	1.14	2.26**
18	EIQ-113 x EIQ-105	0.44	0.03	0.23	-0.42	0.16	-0.13	9.11**	9.81**	9.46**
19	EIQ-114 x EIQ-105	0.73	0.36	0.55*	0.52	-0.68	-0.08	3.24**	1.86*	2.55**
20	EIQ-107 x EIQ-106	-0.16	0.99**	0.42	-0.48	0.82	0.17	4.68**	6.26**	5.47**
21	EIQ-108 x EIQ-106	-0.78	0.34	-0.22	0.30	-0.07	0.12	-1.12	2.01*	0.45
22	EIQ-109 x EIQ-106	1.47**	-0.06	0.70**	0.24	0.16	0.20	1.16	-1.44	-0.14
23	EIQ-110 x EIQ-106	0.65	0.97**	0.81**	-0.26	0.49	0.12	1.78*	4.18**	2.98**
24	EIQ-111 x EIQ-106	-0.16	0.23	0.03	1.08	0.38	0.73	-3.56**	-2.54**	-3.05**
25	EIQ-112 x EIQ-106	1.07**	0.43	0.75**	-0.65	-0.12	-0.38	2.20*	1.03	1.61**
26	EIQ-113 x EIQ-106	0.09	0.18	0.14	0.85	0.38	0.62	2.29**	2.02*	2.15**
27	EIQ-114 x EIQ-106	1.39**	0.65	1.02**	1.13*	2.21**	1.67**	-1.48	-0.12	-0.80
28	EIQ-108 x EIQ-107	0.21	0.26	0.23	-1.20*	0.55	-0.33	-1.11	-2.50**	-1.80**
29	EIQ-109 x EIQ-107	2.12**	0.26	1.19**	1.41*	-0.57	0.42	4.14**	-0.69	1.72**
30	EIQ-110 x EIQ-107	0.47	0.40	0.43	0.24	-0.23	0.01	-2.55**	-1.47	-2.01**

SN	Genotype	Ear girth (cm)			Number of grain rows per ear			Harvest index (%)		
		E1	E2	Pool	E1	E2	Pool	E1	E2	Pool
31	EIQ-111 x EIQ-107	-0.00	-0.28	-0.14	-0.42	-0.34	-0.38	0.22	1.09	0.65
32	EIQ-112 x EIQ-107	-0.95*	-0.37	-0.66*	-0.15	-0.18	-0.16	2.43**	0.72	1.57**
33	EIQ-113 x EIQ-107	-0.59	0.34	-0.12	0.69	0.99	0.84*	-0.35	0.16	-0.09
34	EIQ-114 x EIQ-107	0.71	-0.26	0.22	0.30	-0.51	-0.11	-0.44	1.53	0.54
35	EIQ-109 x EIQ-108	-0.34	0.44	0.05	1.52**	0.55	1.03*	2.25**	3.29**	2.77**
36	EIQ-110 x EIQ-108	0.51	0.58	0.54*	-0.98	-0.45	-0.72	-0.89	-1.79*	-1.34*
37	EIQ-111 x EIQ-108	-0.13	-0.81*	-0.47	-0.31	-1.23*	-0.77	0.38	2.67**	1.52*
38	EIQ-112 x EIQ-108	-0.07	-0.13	-0.10	0.63	-0.40	0.12	-0.85	3.56**	1.36*
39	EIQ-113 x EIQ-108	0.96*	0.65	0.80**	-0.54	0.10	-0.22	0.65	-0.79	-0.07
40	EIQ-114 x EIQ-108	-0.42	0.22	-0.10	-0.26	-0.07	-0.16	1.79*	4.55**	3.17**
41	EIQ-110 x EIQ-109	0.09	0.51	0.30	-0.37	0.43	0.03	-3.63**	-0.08	-1.85**
42	EIQ-111 x EIQ-109	1.12**	0.03	0.58*	-0.37	0.32	-0.02	3.62**	1.70*	2.66**
43	EIQ-112 x EIQ-109	1.01*	0.53	0.77**	1.24*	1.16*	1.20**	2.98**	-0.71	1.13
44	EIQ-113 x EIQ-109	0.54	0.55	0.54*	-0.59	-0.34	-0.47	1.64	2.62**	2.13**
45	EIQ-114 x EIQ-109	-0.34	0.45	0.06	0.35	0.82	0.59	1.69*	-0.66	0.52
46	EIQ-111 x EIQ-110	0.47	0.46	0.47	-0.20	1.32*	0.56	-0.23	1.57	0.67
47	EIQ-112 x EIQ-110	2.03**	0.50	1.26**	-0.59	1.49**	0.45	4.54**	3.65**	4.10**
48	EIQ-113 x EIQ-110	0.22	0.45	0.34	0.91	0.66	0.78	-2.50**	-2.76**	-2.63**
49	EIQ-114 x EIQ-110	0.18	0.22	0.20	0.52	-0.18	0.17	-2.01*	0.05	-0.98
50	EIQ-112 x EIQ-111	-1.45**	-0.21	-0.83**	-2.59**	-1.29*	-1.94**	-0.39	2.51**	1.06
51	EIQ-113 x EIQ-111	-0.42	-0.19	-0.31	0.91	-0.12	0.39	-1.78*	-5.56**	-3.67**
52	EIQ-114 x EIQ-111	1.54**	0.71*	1.12**	1.19*	0.38	0.78	4.32**	2.79**	3.55**
53	EIQ-113 x EIQ-112	-1.20**	0.14	-0.53*	-0.81	0.05	-0.38	-0.95	1.42	0.23
54	EIQ-114 x EIQ-112	-0.57	0.28	-0.15	0.13	0.55	0.34	-0.94	0.13	-0.41
55	EIQ-114 x EIQ-113	0.96*	-0.07	0.44	0.30	1.05	0.67	0.00	-3.23**	-1.61**
Standard error										
	Gi	0.12	0.10	0.08	0.17	0.17	0.12	0.25	0.24	0.17
	Gi-Gj	0.18	0.15	0.12	0.25	0.25	0.18	0.38	0.35	0.26
	Sii	0.36	0.31	0.24	0.51	0.50	0.36	0.76	0.71	0.52
	Sij	0.40	0.34	0.26	0.57	0.56	0.40	0.85	0.79	0.58
	Sij-ik	0.58	0.50	0.39	0.83	0.82	0.58	1.25	1.17	0.86
	Sij-Skl	0.56	0.48	0.37	0.79	0.78	0.56	1.19	1.11	0.82

The estimates of positive significant GCA effects for 100-grain weight revealed that among the ten inbred lines, only three inbred lines viz., EIQ-106 (0.45), EIQ-112 (1.17) and EIQ-111 (1.47) in E1 and only four inbred lines viz., EIQ-110 (0.50), EIQ-105 (0.61), EIQ-113 (0.64) and EIQ-106 (0.83) in E2 exhibited positive significant GCA effects. Specific combining ability effects revealed that out of forty- five hybrids, seventeen hybrids in E1 with the magnitude ranged from 1.35 (EIQ-107 x EIQ-110) to 8.00 (EIQ-111 x EIQ-114) and twelve hybrids in E2 with the magnitude ranged from 2.09 (EIQ-105 x EIQ-114) to 6.06 (EIQ-109 x EIQ-110) exhibited positive significant SCA effects.

The estimates of GCA effects for grain yield per plant revealed that only three inbred lines in E1 with the magnitude of 3.05 (EIQ-106), 8.89 (EIQ-109) and 10.46 (EIQ-112) and only two inbreds in E2 with the magnitude of 6.01 (EIQ-112) and 6.79 (EIQ-109) showed positive significant GCA effects. The estimates of positive significant SCA effects for grain yield per plant were depicted by twenty and seventeen hybrids in E1 and E2 environments respectively. The range in E1 was 4.41 (EIQ-110 x EIQ-113) to 34.59 g (EIQ-110 x EIQ-112) while, the range in E2 varied from 7.78 (EIQ-110 x EIQ-113) to 27.95 (EIQ-110 x EIQ-112). For Harvest Index three inbred lines in E1 viz., EIQ-112 (0.87), EIQ-109 (0.93) and EIQ-106 (1.13) and four inbred lines in E2 environment viz., EIQ-109 (0.52), EIQ-110 (0.65), EIQ-113 (0.67) and EIQ-106 (0.72) expressed significant GCA effects for harvest index.

The estimates of SCA effects revealed that sixteen hybrids in E1 exhibited positive significant SCA effects with the magnitude varied from 1.69 (EIQ-109 x EIQ-114) to 9.11 (EIQ-105 x EIQ-113) and in E2 also sixteen hybrids exhibited positive significant SCA effects with the magnitude varied from

1.70 (EIQ-109 x EIQ-111) to 9.81 (EIQ-105 x EIQ-113). Over the environment analysis revealed that only three inbred lines viz., EIQ-113 (0.57), EIQ-109 (0.72) and EIQ-106 (0.93) expressed significant GCA effects. By the estimates of SCA effects eighteen hybrids with the magnitude ranged from 1.30 (EIQ-105 x EIQ-107) to 9.46 (EIQ-105 x EIQ-113) exhibited positive significant SCA effects.

The GCA effects represent the additive nature of gene action. A good general combiner parent is characterized by its better breeding value when crossed with other parents. Depending upon the character concerned the nature (direction/sign) and per se (mean) performance of the parent is also considered in association with GCA since the former offers reliability and authenticity to GCA as a guide to selection of the parent. On the basis of per se performance and GCA effects good general combiner lines were identified and presented in (Table 1).

On the basis of mean and SCA effects out of total 45 hybrids, five hybrids which exhibited higher mean and significant positive SCA effects for grain yield per plant were EIQ-110 x EIQ-112, EIQ-107 x EIQ-109, EIQ-109 x EIQ-111, EIQ-105 x EIQ-112 and EIQ-105 x EIQ-114 in E₁ environment while hybrids EIQ-110 x EIQ-112, EIQ-105 x EIQ-112, EIQ-109 x EIQ-111, EIQ-107 x EIQ-109, EIQ-105 x EIQ-113 in E₂ environment.

Among these the crosses EIQ-110 x EIQ-112, EIQ-107 x EIQ-109, EIQ-109 x EIQ-111, EIQ-105 x EIQ-112 were better performer in both the environment, so these lines can be recommended for multi-location trials. By the study, it can be concluded that the crosses having best specific combination for grain yield per plant would obtained either through poor x good, average x good or poor x poor parental combinations.

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How to cite this article:

Avinash Kumar, Amit Dadheech, N. Kiran, Prashant Bisen and Santosh Kumar. 2017. Diallel Analysis of Combining Ability for Yield and Yield Contributing Traits over the Environments in Maize (*Zea mays* L.). *Int.J.Curr.Microbiol.App.Sci*. 6(10): 196-208.
doi: <https://doi.org/10.20546/ijcmas.2017.610.025>