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GENERAL AND SPECIFIC COMBINING ABILITY ANALYSES IN MAIZE UNDER NORMAL AND MOISTURE STRESS CONDITIONS

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ABSTRACT

Combining ability analyses are important biometrical tools for evaluation of high yielding maize hybrids to appreciate yield. Present study was conducted to screen out inbred lines for the synthesis of drought tolerant corn hybrids by manipulating the combining ability analyses techniques in present scenario of diminishing water resources Combining ability estimates were studied by using 6×6 diallel technique in maize crop under normal and moisture stress conditions in the department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during 2008 and 2009.Mean squares due to genotypes, specific and general combining abilities along with reciprocals were found highly significant for all the traits in both conditions. Additive type of gene action was inferred from the values of general and specific combining ability variances. Inbred line **"**F-206" was found the best general combiner for days to tasseling, silking, maturity and grain yield per plant in both conditions. Maximum GCA effects for plant height were observed in inbred line S-42. Maximum SCA effects for grain yield per plant were expressed in F1 hybrid F-110×F-206 followed by F-192 × F-189 and F-110 × S-42. F-192 × F-206 recombinant was most efficient hybrid for days to maturity. The best F1 hybrid was F-206 × F-110 followed by F-206 × F-189 ,and S-42× F-206 These F1 hybrids displayed good SCA along with better mean performance for grain yield per plant and most of the traits studied in moisture stress condition. Inbred lines F-206, F-189 and S-42 were the good general combiners for most of the traits. These parents can be involved to produce high yielding and moisture stress tolerant corn hybrids to enhance production in drought prone environment.

Key words: *Zea mays;* genotypes; morphological characters; combining ability, moisture stress, Pakistan.

INTRODUCTION

Maize (Zea mays L.), is an important short duration high yielding and widely grown crop for food, feed and fuel. Pakistan is located in 23.37 to 36.45 North latitude in subtropical region and corn is grown successfully in this agro climate. Its mainly cultivated in Punjab and KPK provinces in Pakistan during spring and summer seasons Drought is basic yield limiting abiotic factor and depress biomass production up to 50% depending upon stress severity. Moisture stress and low humidity damage exposed silk and pollen grains. The extent of damage depends upon the intensity and duration of dry spell. High temperature condition may aggravate this condition. Therefore Plant Breeders are required to develop high yielding and drought tolerant corn hybrids to fulfil the diversified demand. Identification of promising inbred lines is a crucial step to develop drought tolerant corn hybrids. Genetic variation is primary play ground for genetic improvement for any trait. Hybridization of diverse inbred lines provides substantial variation for effective selection of requisite traits. Elite inbred lines and their specific recombinant are selected on the basis of combining ability effects with better mean performance. Combinining ability analyses give a real picture about the anticipated performance of inbred lines in hybrid combination. Pswarayi and Bindiganavile (2008) reported positive general combing ability effects in complete diallel experiment for grain yield. Various workers viz Wegary *et al*., (2009) Karaya *et al*. (2009), Barros, *et al*. (2011), Beyene *et al.* (2011) studied maize genotypes under optimum and water stressed conditions and reported identification of drought tolerant maize inbred line based on combining ability analyses. This technique elucidates sources of gene contributing the trait. Machikowa *et al*. (2011) worked out general and specific combining ability for quantitative characters in sunflower and explained that the GCA variance was higher than the SCA variance for yield, head diameter and oil content and thus additive gene action was more important than non-additive gene action for these traits. Therefore profound knowledge of genetic mechanism for moisture stress tolerance is pre requisite for development of tolerant corn hybrid and synthetics for sustainable agriculture. The present study involving a 6 × 6 diallel analysis aimed to obtain information on genetic makeup of drought tolerance by estimating combining ability effects for some metric traits.

MATERIALS AND METHODS

The studies were conducted in the Department of Plant Breeding and Genetics, University of

Agriculture, Faisalabad, during 2008 and 2009. The breeding material was comprised of six maize inbred lines i.e. F-192, F-110, S-42, F-189, Y-330 and F-206. For crossing in a complete diallel fashion, each inbred line was sown in the field in rows of five meter long. Two seeds were sown per hole. The plant spacing was kept 25 cm and row spacing 75 cm. Thinning was done and only one seedling per hole was maintained. Uniform agronomic and cultural practices were applied. To avoid contamination, the shoots of plants to be used as female were covered with butter paper bags (8" × 4") before silk emergence. The tassels of the male plants were covered with kraft paper bags (14" × 11") before anthesis. On emergence, silks were pollinated accordingly. Pollens were collected in petri dish and then were applied on to silks with the help of camel hair brush. Shoots were pollinated twice on consecutive days to ensure required seed setting. After pollination, the shoots were again covered with their respective bags. After each pollination, the instruments were sterilized. Each female plant was tagged carefully for proper identification. Ten plants from each parent were selfed also. At maturity the ears from all the 36 genotypes were harvested and dried up to 15% moisture contents and then were shelled. During next crop season, seeds of crosses, reciprocals and parental lines were sown in two sets in RCBD with three replications. All agronomic practices were kept uniform except irrigation. To the normal set, usual irrigations were applied and to other set, 50% of the total irrigations were applied. At maturity ten plants were selected from three central rows of each entry and data for plant height, days to tasseling, days to silking, anthesis-silking interval, days to maturity and grain yield per plant were recorded and were analyzed statistically as per method given by Steel *et al.* (1997). ombining ability analysis were conducted following Griffing, (1956), method I Model II as under

Source of variation	Degree of freedom	Sum of squares	Mean squares	F-value	Expected(mean squares)
GCA	(p-1)	Sg	Mg	Ng/Ms	$\sigma^2 e + 2(n-1)2/n)\sigma^2 s + n\sigma^2 g$
SCA	P(p-1)/2	Ss	Ms	Ms/Me'	$\sigma^2 e + 2(n^2 - n + 1)/n^2)\sigma^2 s$
Reciprocal	P(p-1)/2	Sr	Mr	Mr/Me'	$\sigma^2 e + 2\sigma^2 r$
Error	(r-1)(p2-1)	Se	Me'		$\sigma^2 e$

RESULTS AND DISCUSSION

Plant height (cm): Components of variation (Table 2) depicted a greater GCA variance (δ^2g) as compared to SCA (δ^2s). It indicated the involvement of additive genetic effect for plant height under normal and moisture stress conditions. Table 3 (A) showed that four parental genotypes had negative and two had positive general combining ability effects. Maximum value of GCA effects (19.665) was observed for S-42 and considered to be the best general combiner for plant height. Parental inbred line Y-330 with value of -15.115 was the poorest general combiner. Among crosses, the most useful combinations was S-42 × F-189 (16.903) followed by Y-330 × F-206 (11.403) and F-192 × S-42 (6.620). Cross F-189 × F-206 had maximum negative value of specific combining ability (-18.513) followed by F-110 × S-42 (-17.780). Under water stress condition F-189x Y-330 gave maximum SCA effects (17.019). S-42 × F-189 was useful cross having good mean performance. Wegary *et al.* (2009) also found that GCA and SCA effects were significant for plant height. Vicente *et al*. (2001), Yuan *et al* (2003), Malik *et al.* (2004) and Rezaei *et al*. (2005) also found plant height under control of additive type of gene action. Prakash and Ganguli (2004) found that plant height was under control of non- additive type of gene action. Tabassum *et al.* (2007) observed plant height was under control of additive and non- additive type of gene action. Akbar *et al*. (2008) observed that SCA variances were greater than GCA. The conclusion was varied due to difference in breeding material as well as environment under which these were conducted. Inbred line Y-330 can be utilized as donor for developing dwarf genotypes.

Table 1. Mean squares attributed to GCA, SCA and reciprocal effects under normal (N) & moisture stress (S) condition.

Traits	GCA (df=5)		SCA (df=15)		Reciprocal (df=15)		Error (df=70)	
	N	S	N	S	N	S	N	S
Plant height	1584.21**	1351.88**	194.64**	155.83**	19.52**	53.75**	107.97	57.68
Days to tasseling	59.37**	59.10**	5.14**	2.79**	2.63**	4.318**	10.33	3.79
Days to silking	53.24**	25.54**	3.04**	2.75**	2.65**	3.41**	6.38	8.44
Anthesis-silking interval	0.0531**	4.86**	0.2945**	0.0632**	0.200**	0.3506**	0.0026	0.0245
Days to maturity	254.43**	185.71**	5.41**	5.68**	2.72**	7.53**	36.85	28.07
Grains yield per plant	976.36**	644.34**	97.36**	73.12**	94.24**	67.23**	9.63	10,29

** = significant P < 0.01

Table 2. Estimates of genotypic variance and its components relative to GCA, SCA and reciprocal effects under normal (N) & moisture deficit (S) condition.

Traits	O^2g		O^2s		$O^2 r$		O^2e	
	N	S	N	S	N	S	N	S
Plant height	116.03	99.93	50.32	56.98	-44.22	-1.96	107.97	57.68
Days to tasseling	4.5	4.68	-3.01	-0.5782	-3.85	0.2593	10.33	3.79
Days to silking	4.17	4.13	-1.93	-3.3	-1.86	-2.52	6.38	8.44
Anthesis silking interval	-1.93	0.4003	0.1695	0.0224	9.87	0.163	0.00258	0.0245
Days to maturity	20.66	14.94	-18.25	-13	-17.06	-10.27	36.85	28.07
Grains yield per plant	73.48	47.77	50.94	36.48	42.3	28.47	9.63	10,29

Table 3. Estimates of general & specific combining ability and reciprocal effects under normal (N) and stress (S) conditions.

A-Plant height

Parents	F-192		F-110		S-42		F-189		Y-330		F-206	
	N	S	N	S	N	S	N	S	N	S	N	S
F-192	-3.416	-4.997	1.491	0.742	6.62	4.487	-0.017	-2.878	-5.6	-4.054	2.204	0.1
F-110	-2.31	6.552	-4.516	-0.731	-17.78	-8.006	6.583	-5.323	2.5	0.181	5.304	11.431
S-42	1	-2.5	-0.5	-10.572	19.665	17.522	16.903	5.757	-11.18	-15.073	-3.106	2.366
F-189	-3.5	0.347	-1	1.167	-1.5	3.5	-0.198	2.734	2.778	17.019	-18.513	-16.131
Y-330	-1	-0.5	1	-6	-2.5	-2	-4.398	1.81	-15.115	-14.937	11.403	4.54
F-206	0.5	11	-0.5	-3.917	9.257	-0.882	-1	6.5	-3	-2.5	3.581	0.409

B-Days to Tasseling

Parents	F-192		F-110		S-42		F-189		Y-330		F-206	
	N	S	N	S	N	S	N	S	N	S	N	S
F-192	-0.837	-1.925	-0.163	-1.925	0.087	-1.047	-1.413	-0.88	1.062	-0.503	2.92	3.551
F-110	-0.5	2.167	-1.665	2.167	-1.585	0.806	1.415	-0.361	-2.5	0.065	0.748	-0.429
S-42	0.667	1.5	-0.5	1.5	-1.415	-1.782	1.165	0.976	0.67	0.047	-1.002	-1.092
F-189	0.5	1	0.5	1	-0.5	-1	0.585	0.551	0.17	0.381	-2.002	-0.759
Y-330	1.017	2.9	0.001	2.9	-1.5	-1	-1	-1.667	-0.92	-0.52	-0.997	0.776
F-206	2.5	2	-1.5	2	-1	-0.5	2	-0.167	-0.5	-2.078	4.252	4.12

C-Days to Silking

Parents	F-192		F-110		S-42		F-189		Y-330		F-206	
	N	S	N	S	N	S	N	S	N	S	N	S
F-192	-1.146	-1.409	0.029	0.017	-0.066	-0.326	-0.687	-0.84	-0.262	-0.35	2.639	2.742
F-110	-0.5	-1	-1.327	-0.668	-2.131	-0.484	0.493	10.086	0.039	0.603	-0.139	-0.498
S-42	0.158	0.02	-1	0.001	-1.487	-1.575	1.153	1.655	0.535	0.156	-0.52	-1.091
F-189	0.5	0.5	0.5	1.167	-1	0.172	0.389	-0.311	0.16	-0.107	-1.396	-1.355
Y-330	-0.043	1.077	1.163	-0.52	-1.5	-1.5	-1	-1.5	-0.493	-0.142	-1.514	-1.525
F-206	2,500	2.5	-0.542	-1.5	-1	-1.5	2	1.5	-1	-1.5	4.063	4.106

D-Anthesis-silking interval

Parents	F-192		F-110		S-42		F-189		Y-330		F-206	
	N	S	N	S	N	S	N	S	N	S	N	S
F-192	0.049	0.42	0.267	-0.157	0.203	-0.094	0.368	-0.152	-0.299	0.0123	-0.712	0.274
F-110	0.001	0.013	-0.012	-0.429	-0.238	-0.041	-0.571	0.217	-0.238	-0.041	0.349	-0.174
S-42	0.002	-0.428	-0.5	-0.445	0.054	0.153	-0.138	0.274	0.196	-0.151	-0.218	-0.115
F-189	0.001	-0.5	0.001	1.02	-0.5	0.183	-0,113	-0.946	0.363	-0.025	0.449	-0.047
Y-330	0.5	0.333	-0.5	0.001	0.001	0.1	0.001	-0.5	0.054	0.292	-0.217	-0.144
F-206	0.001	0.353	0.001	-0.517	-0.5	-0.355	-0.001	0.001	-0.5	-0.102	-0.033	0.815

E-Days to maturity

Parents	F-192		F-110		S-42		F-189		Y-330		F-206	
	N	S	N	S	N	S	N	S	N	S	N	S
F-192	-1.645	-3.157	0.006	0.244	-1.668	-0.91	1.258	-3.171	-2.16	2.402	3.135	1.467
F-110	0.5	0.598	-2.723	-0.91	0.409	0.255	-0.831	1.455	0.784	0.655	0.046	-1.753
S-42	0.5	-0.505	0.5	-0.25	3.952	3.227	-0.35	0.265	2.609	-1.254	0.765	2.776
F-189	0.5	-2.54	0.333	0.667	-0.662	1.72	2.025	0.11	-0.464	-0.732	-0.702	1.082
Y-330	-2.867	-3	0.001	0.5	0.5	-0.595	-0.5	1.467	-6.923	-4.923	-2.754	-1.907
F-206	2.667	2.36	0.5	2.333	1.527	3.667	0.5	3.088	0.5	0.5	5.315	5.652

F-Grain yield per plant												
Parents	**F-192**		**F-110**		**S-42**		**F-189**		**Y-330**		**F-206**	
	N	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**
F-192	-3.327	-8.209	-6.89	5.303	0.511	-3.34	12.738	-1.22	0.446	0.732	1.739	-5.753
F-110	-1.567	-1.382	-8.549	-5.392	6.4	2.581	-4.373	0.343	0.835	-3.085	14.128	12.214
S-42	-1.5	-2.745	-0.5	-1.15	2.116	5.154	-0.755	-1.64	1.419	5.569	-8.144	-1.72
F-189	2	1	2.667	1.947	2.383	-3.843	-2.61	-1.711	-3.771	-0.604	3.139	4.841
Y-330	0.667	-1	-1.5	2	0.73	-0.8	0.5	-0.495	-4.652	-1.663	-1.034	2.201
F-206	0.367	-1	-25.2	-20.217	4.573	3.27	0.417	-4.575	-5.032	-5.167	17.022	11.822

Days to tasseling: Mean squares for GCA, SCA and reciprocal were significant for days to tasseling under both the conditions. Estimates of variance were greater for GCA ($ð^2g$) as compared to SCA ($ð^2s$). Thus additive genetic effects were more important as compared to non-additive. Prakash and Ganguli (2004), reported similar results and found additive gene action for days to tasseling. Barati *et al*. (2004) concluded that both additive and non-additive genetic effects were important for this trait. Table 3 (B) showed the combining abilities effects for days to tasseling. Under normal conditions, F-206 showed maximum value of GCA effects (4.252) and hence it was good general combiner. F-110 showed -1.665 value of GCA being poorest general combiner. Among crosses 8 combinations showed positive SCA effects. F-192 × F-206 showed maximum positive value (2.920) of SCA being most useful combination. F-110 × Y-330 showed maximum negative value (-2.5 00) of SCA being poorest combiner. Maximum reciprocal effects were shown by F-206 × F-192 (2.500) followed by F-206 × F-189 (2.000). Eight combinations showed negative reciprocal effects. Among them Y-330 × S-42 showed maximum negative value of reciprocal effects (-1.500).

Days to silking: GCA variance ($ð^2g$) was greater than SCA ($ð^2s$) for days to silking indicating preponderance of additive gene effects. Reddy (2004) reported that additive effects were important in genetic control of days to silking. Vicente (2001), Saleem *et al*. (2002) and Barati *et al*. (2004) concluded that both additive and non-additive gene effects were important for days to silking. Under normal condition (Table 3-C), inbred line F-206 was good general combiner with GCA effect of 4.063 followed by F-189 having GCA value 0.389. Inbred line S-42 was poorest general combiner with GCA value of -1.487. Combination F-192 × F-206 observed SCA value of 2.639 followed by combination S-42 × F-189 (1.153). Combination F-110 × S-42 was poorest with most negative value of SCA effects (-2.131), followed by Y-330 × F-206 (-1.514). Under moisture stress conditions, again F-206 was good general combiner with GCA effect (4.106). Inbred line S-42 showed negative value of GCA effect (-1.575). Combination F-192 × F-206 had maximum value (2.742) of SCA followed by S-42 × F-189 (1.655). F-206 × F-192 showed highest positive value (2.500) of reciprocal effects followed by F-206 × F-189 (1.500). Negative value of reciprocal effect was shown by five combinations i.e. Y-330 × S-42, Y-330 × F-189, F-206 × F-110, F-206 × S42 and F-206 × Y-330. Comparison of combining ability effects under two conditions depicted that four inbred lines maintained their negative GCA effects under both the conditions. F-206 showed positive GCA effects under both conditions. F-189 showed positive value of GCA effects under normal where as under moisture stress conditions it showed negative value of GCA effects. It has been concluded that inbred line S-42 may be useful for developing genotypes with lesser days to silking.

Anthesis silking interval (ASI): Mean squares for GCA, SCA and reciprocal effects were significant for anthesis silking interval under normal and moisture stress conditions (Table 1). Table 2 revealed a greater value of GCA variance ($ð^2g$) than SCA ($ð^2s$) under normal conditions. Nigussie and Zellke (2001) found additive genetic effects for anthesis-silking interval. Table 3 (D) revealed the GCA, SCA and reciprocal effects for anthesis-silking interval. Under normal conditions three inbred lines had positive GCA effects. F-110, F-189 and F-206 showed negative GCA effects. Seven crosses showed positive SCA effects. Combination F-189 × F-206 showed highest positive value of SCA effects (0.449). Eight combinations showed negative value of SCA effects. F-192 × F-206 showed maximum negative value of SCA effects (-0.712). Nine combinations expressed positive value of reciprocal effects. Maximum value of reciprocal effects was shown by combination Y-330 × F-192 followed by S-42 × F-192. Six crosses showed negative value of reciprocal effects. Parent F-192 and Y-330 maintained their positive GCA effects under both conditions. Parental lines F-110, S-42 and F-189 showed negative GCA effects. F206 gave maximum value of GCA effects (0.815) and stood first as general combiner. Among crosses, four combinations showed positive value of SCA effects. Nine combinations showed negative value of SCA effects. F-192 × F-110 was poor combiner with a negative value (-0.157) of SCA effects. Reciprocal effects under moisture stress conditions were positive for eight combinations. Maximum value of reciprocal effects (0.353) was shown by cross F-206 × F-192. Seven combinations showed negative value of reciprocal effects an maximum negative value was shown by F-206 × F-110 (-0.517). Minimizing the ASI interval is key for improving the performance of maize genotypes. Inbred lines F-110, F-189 and F-206 may be used as donor for reducing ASI.

Table: 4- Mean performance of genotypes under normal (N) and stress (S) conditions

Gen	PH_N	PH_S	Tass_N	Tass_S	Silk_N	Silk_S	AS_N	AS_S	Mat_N	Mat_S	GYP_N	GYP_S
1× **2**	158.38	137.00	67.00	69.33	69.00	71.00	2.00	5.02	120.00	106.45	59.87	53.46
1× **3**	191.00	150.00	68.67	66.00	69.40	70.77	2.00	4.92	125.00	108.33	78.00	54.00
1× **4**	160.00	130.69	69.00	68.00	71.00	72.00	2.00	4.00	126.00	100.92	85.00	51.00
1× **5**	142.00	111.00	70.49	69.21	70.00	73.24	2.00	6.35	110.27	101.00	73.33	53.00
1× **6**	170.00	142.00	79.00	77.00	80.00	82.00	1.00	7.04	133.33	116.00	96.00	60.00
2× **3**	164.00	133.70	65.00	67.33	66.00	71.33	1.00	4.11	126.00	112.00	79.67	64.33
2× **4**	168.00	133.33	71.00	69.00	72.00	74.33	1.00	5.04	122.67	111.00	67.33	58.33
2× **5**	151.00	114.00	65.00	68.71	71.33	73.33	1.00	5.00	115.00	105.00	66.33	55.00
2× **6**	171.00	142.68	72.00	71.00	74.00	75.00	2.00	4.87	127.00	115.00	77.60	61.57
3× **4**	202.00	165.00	70.00	68.00	71.00	74.00	1.00	4.54	128.83	115.00	81.33	61.10
3× **5**	158.00	121.00	67.00	66.00	69.00	71.00	2.00	5.27	124.00	106.13	79.81	71.40
3× **6**	196.56	154.90	71.00	70.00	73.00	74.00	1.00	5.34	135.42	125.00	95.77	81.67
4× **5**	150.20	142.11	69.00	68.00	71.00	72.00	2.00	4.00	118.00	105.60	69.67	58.67
4× **6**	151.00	129.00	75.00	73.00	77.00	78.00	2.00	5.00	131.00	119.61	98.17	73.52
5× **6**	164.00	123.00	72.00	70.00	73.00	75.00	1.00	6.04	120.00	109.00	86.50	70.33
2× **1**	163.00	124.00	68.00	65.00	70.00	73.00	2.00	5.00	119.00	105.26	63.00	56.22
3× **1**	189.00	155.00	67.33	63.00	69.09	70.73	2.00	5.78	124.00	109.34	81.00	59.49
4× **1**	167.00	130.00	68.00	66.00	70.00	71.00	2.00	5.00	125.00	106.00	89.00	53.00
5× **1**	144.00	112.00	68.45	63.41	70.09	71.08	1.00	5.68	116.00	107.00	72.00	55.00
6× **1**	169.00	120.00	74.00	73.00	75.00	77.00	1.00	6.33	128.00	111.28	95.27	62.00
3× **2**	165.00	154.84	66.00	68.33	68.00	71.33	2.00	5.00	125.00	112.50	80.67	66.63
4× **2**	170.00	131.00	70.00	69.00	71.00	72.00	1.00	3.00	122.00	109.67	62.00	54.43
5× **2**	149.00	126.00	65.00	68.00	69.00	74.37	2.00	5.00	115.00	104.00	69.33	51.00
6× **2**	172.00	150.51	75.00	74.00	75.08	79.00	2.00	5.91	126.00	110.33	128.00	102.00
4× **3**	205.00	158.00	71.00	70.00	73.00	73.66	2.00	4.17	130.15	111.56	76.57	68.79
5× **3**	163.00	125.00	70.00	68.00	72.00	74.00	2.00	5.07	123.00	107.32	78.35	73.00
6× **3**	177.98	156.67	73.00	71.00	75.00	77.00	2.00	6.11	132.37	117.67	86.62	75.13
5× **4**	158.99	138.49	71.00	71.33	73.00	75.00	2.00	5.00	119.00	102.67	68.67	59.66
6× **4**	153.00	116.00	71.00	73.33	73.00	75.00	2.00	5.00	130.00	113.43	97.33	82.67
6× **5**	170.00	128.00	73.00	74.16	75.00	78.00	2.00	6.24	119.00	108.00	96.57	80.67
1× **1**	155.60	127.10	66.00	64.00	68.00	70.00	1.97	6.02	120.00	103.33	65.00	51.00
2× **2**	160.00	135.00	69.00	68.00	71.00	73.00	2.10	4.52	118.00	107.00	53.00	35.00
3× **3**	215.00	181.00	68.00	66.00	70.00	71.00	2.00	5.00	130.00	115.00	85.00	72.00
4× **4**	159.00	142.51	72.00	71.00	73.00	74.00	1.00	3.02	129.00	111.00	68.00	58.00
5× **5**	137.00	103.00	70.00	69.00	72.00	75.00	2.00	6.00	112.00	100.67	73.00	55.00
6× **6**	177.00	134.00	79.00	77.00	81.00	84.00	1.98	7.01	134.00	119.32	104.41	75.00

Gen= Genotype, 1= F-192, 2= F-110, 3= S-42, 4= F-189, 5= Y-330 and 6= F-206 PH= Plant height (cms), Tass= Days to tasseling, Silk= Days to silking, AS= Anthesis-silking interval, Mat= Days to maturity, Gyp= Grain yield per plant (gms), N=Normal,S=Stress.

Days to maturity: Mean squares of GCA, SCA and reciprocal effects regarding days to maturity were significant under both the conditions. Table 2 depicted that GCA variance ($ð^2g$) was greater than SCA variance ($ð^2s$). Additive gene effects were important under both the conditions. Wegary *et al.* (2009) reported similar results GCA and SCA effects were significant for days to maturity. Table 3 (E) depicted GCA, SCA and reciprocal effects under normal conditions. Three parental lines (S-42, F-189, F-206) showed positive value of GCA effects. Inbred line Y-330 showed maximum negative value of GCA effects (-6.923). F-192 × F-206 was most efficient combination with a SCA value of 3.135 followed by S-42 × Y-330 (2.609) and F-192 × F-189 (1.258). Seven crosses showed maximum negative value of SCA effects. F-206 × F192 showed maximum positive value of reciprocal effects followed by F-206 × S-42 (1.527). Three crosses showed negative reciprocal effects. Under moisture stress conditions F-206 had maximum value of GCA effects (5.652) followed by S-42 (3.227). Inbred line Y-330 showed maximum negative value of GCA effects (-4.923) followed by F-192 (-3.157). Combination S-42 × F-206 showed maximum positive values of SCA effects (2.776) followed by F-192 x Y-330 (2.402) and F-110 × F-189 (1.455). F-192 × F-189 showed maximum negative value (-3.171) followed by Y-330 × F-026 (-1.907). Ten crosses showed positive reciprocal effects. F-206 × S-42 showed maximum value of reciprocal effects (3.667) followed by F-206 × F-189 (3.088). F-206 was most promising inbred line under both the conditions with positive value of 5.315 and 5.652 respectively. Among crosses, F-192 × F-189 showed positive value of SCA effects (1.258) under normal conditions while under moisture deficit conditions its value changed to negative (-3.171). Maximum value of reciprocal effects (2.667) was shown by F-206 × F-192 under normal conditions, while under moisture deficit conditions cross F-206 × S-42 showed maximum value of reciprocal effects (3.667).

Grain yield per plant (g): Mean squares for GCA, SCA and reciprocal effects were significant regarding grain yield per plant under normal and moisture stress conditions (Table 1). GCA sum of squares component was greater than SCA, suggesting that selection would be effective in improving grain yield. Table 2 showed that GCA variance ($ð^2$g) was greater than SCA ($ð^2$s), but difference was negligible. So it was concluded that both additive and non-additive gene effects were important. However, additive gene action was more important than non-additive. Yuan *et al*. (2003) and Rezaei *et al*. (2005) reported that grain yield was controlled by additive gene action. Chen *et al*. (2002), and Barati *et al*. (2004) found that grain yield per plant was under control of additive and non- additive gene action. Beyene *et al*. (2011) also reported that in maize GCA sum of squares component for grain yield was five times greater than SCA, suggesting that variation among crosses was mainly due to additive rather than non-additive gene effects. Table 3 (F) revealed that two inbred lines were good general combiner. F-206 showed greatest GCA effects (17.012) followed by S-42 (2.116). Five inbred lines showed negative value of GCA effects. Maximum negative value of GCA effects were shown by F-110 (-8.549) followed by Y-330 (-4.652). Under normal conditions, nine crosses showed positive value of SCA effects. F-110 × F-206 showed greatest value of SCA effects (14.128) followed by F-192 × F-189 (12.738). Six crosses showed negative value of SCA effects. Cross S-42 × F-206 showed maximum negative value of SCA effects (-8.144). Eight crosses showed positive value of reciprocal effects. F-206 × S-42 showed maximum value of reciprocal effects (4.573) followed by F-189 × S-42 (2.383). Under moisture stress conditions again two inbred lines showed positive values of GCA effects. Maximum positive value of GCA effects (11.822) was shown by F-206 followed by S-42 (5.154). F-192 showed maximum negative value of GCA effects (-8.209) followed by F-110 (-5.392). Eight crosses observed positive SCA effects. Maximum value of SCA effects (12.214) was shown by F-110 × F-206 followed by S-42 × Y-330 (5.569). Only three crosses showed positive value of reciprocal effects. Maximum value of reciprocal effects (3.270) was shown by F-206 × F-110 followed by Y-330 × F-110 (2.000). Maximum negative value of reciprocal effects (3.270) was observed by cross F-206 × Y-330 (-5.167) followed by F-206 × F-189 (-4.575).

Regarding general combining ability (gca) effects, performance of the parents revealed that none of these were found to be a good general combiner for all the characters studied. A wide range of variability of gca effects was observed among the parents. For grain yield, parents F-206, showed significant positive gca effect and high mean value indicating that the performance of the parent could prove as an useful index for combining ability. Roy *et al*. (1998) and Hussain *et al.* (2003) also observed similar phenomenon. So, this parent could be used in breeding program with a view to increase the yield level. Parent S-42, F-189 and F-206 showed positive gca for yield/plant, days to tasseling, days to silking, plant height and days to maturity So, these may be good combiner for said traits. Parents F-110 and F-189 showed negative gca for anthesis silking interval and might be useful in developing genotype with minimum ASI.

Conclusion: Significant mean squares for general and specific combining abilities along with reciprocal effects were found. A greater GCA variance than SCA indicated the preponderance of additive type of gene action. Inbred lines F-206, F-189 and S-42 were the good general combiners for most of the traits. These parents can be involved to produce high yielding and moisture stress tolerant corn hybrids to enhance production in drought prone environment. Parents with good positive gca for yield (F-206 and S-42), negative gca for days to silking and days to maturity (S-42 and Y-330) and dwarf plant height and may be extensively used in hybridization program as a donor. The crosses F-110 × F-206 and F-192 × F-189 exhibited good SCA effects with outstanding mean performance for grain yield in moisture stress condition. The better performing crosses can be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigour.

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