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The Agriculture-nutrition-health Nexus at the Cost of Water Availability in Maize Diverse Genotypes to Ensure Food Security

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Abstract: The study is based on the health conservation of most important crop plant biodiversity under limited water supply to combat water stress condition prevailing speedily throughout the world creating food shortage. The main idea is to find suitable plant material which can be grown in arid environment by making sufficient crosses and checking the combining abilities to bear water stress in their life cycles. The most versatile plant i.e. Maize is used by line × tester mating fashion to estimate general and specific combing ability in self and cross combinations of diverse maize genotypes under different water stress environment. Twelve parents genotypes comprising of eight lines and four testers were crossed to produce 32 F_1 hybrids. In next crop season the parents along with their hybrids were evaluated with three water treatments in two seasons. Results showed the nature and magnitude of general and specific combining ability for grain yield and yield related traits like plant height, leaf area, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index. The significant estimates of GCA and SCA suggested the importance of both additive and non-additive gene actions for the expression of the traits which can help for the selection of parents to be used for the development of useful synthetics and hybrids resilient to contrasting water regimes.

Key words: Maize · Water stress · Line × Tester · General combining ability · Specific combining ability

INTRODUCTION

Globally maize is the third most important cereal crop after wheat and rice and Pakistan occupies 31st position in term of acreage, 28th in production and 67th in yield per hectare in maize in the world. Average yield of maize is low in Pakistan as compared to world average yield [1]. It is true that the use of uncertified and low-quality seed in addition to repeated use of hybrid seed is one of the main causes of low maize yield [2, 3]. On the backdrop of water shortage and existing genetic potential a strong endeavor is required to exploit the genetic potential of various cultivars to provide the ample quantity of food having enough nutritional and viable capability. Such research will surely be valuable in planning a useful breeding program for the development of a new array of maize genomes to ensure sustainable food production in water scarce areas.

Considering the shortage of irrigation water at global and national it is need of time and farmer demand to develop an efficient package for development of new genotypes that are better adapted to adverse climatic conditions [4-6].

Combing ability concept of breeding was given by Sprague and Tatum in 1942 and many plant breeders have developed heterosis among several maize genotypes to maximize yield [7-9]. Estimation of genetic diversity among maize plants can be useful for determining the high performing crosses [10, 11]. Combining ability is very useful tool for the development of plants exhibited heterosis as described by [12, 13]. By adopting this procedure the identification of parental lines for better GCA and SCA can be exploited for the development of sustainable yield producing lines [14] described the Line x Tester mating fashion to check reliable information on the ability of male and female parents in the process of

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hybridization and in selecting useful breeding program. Genetic studies proved that water stress tolerance in crop plants is an important trait used for the yield stability on global bases [15-17].

In conventional breeding, genetic variability against water stress tolerance can be identified by genetic variation which is introduced through different mating/crossing techniques to develop cultivars with good agronomic traits [18, 19, 20]. The present study was initiated with a view to improve maize germplasm for grain yield under water stress conditions with a hope to get scientific information on maize under water stress conditions.

MATERIALS AND METHODS

The experiment was initiated with diverse maize genotypes collected from Maize and Millet Research Institute, Yousafwala, Sahiwal, Fodder Research Institute, Sargodha and Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. The best adopted and diverse 12 genotypes were screened out and were crossed by using 8 lines 4 testers to produce 32 hybrids totaling 44 genotypes.

All 44 genotypes were sown in the polythene bags (45 30cm) filled with mixture of soil (Soil, Silt and organic matter, in equal amount) having (pH 8.2 and ECe 0.28 dS/m-1), following Completely Randomized Design (CRD).The experiment was splitted into three sub units and a diverse water treatment was applied as follows.

Water treatment 1(T1 80% of field capacity),
Water treatment 2(T2 60% of field capacity),
Water treatment 3 (T3 40% of field capacity)

in a wire-house, Department of Plant Breeding and Genetics, University College of Agriculture, University of Sargodha, Pakistan. Recommended agronomic and plant protection measures were kept uniform in all the three sets of experiment, except irrigation water.

Two factor factorial triplicate randomized complete designs were followed in two seasons during spring season, March, 2011 and autumn season, August, 2011. Three water treatments were applied by [21]. The data were recorded for the traits like plant height, leaf area, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index of maize genotypes at maturity.

The data were recorded for the following traits on appropriate time.

1	Plant height	was measured of five randomly selected mature plants from each entry with meter rod in centimeters from the ground level to the base of the tassel
2	Leaf area	Fully expanded mature 2nd leaf from the top of the plant was measured on five randomly selected plants of each accession per replication. Leaf area was measured in cm^2 using leaf area meter (ΔT-MK2, England).
3	Number of kernels per row	were obtained by counting the kernels in each row of five randomly selected plants and then average were determined.
4	Ear length	Each ear in the five randomly selected plants was measured in centimeters with the help of measuring tape and then averaged.
5	Ear diameter	Each ear of five randomly selected plants was measured with the help of vernier caliper in centimeters at the base, center and top of the ear and then average was obtained.
6	Grain yield per plant	Five randomly selected plant grains were separately weighed in grams with and then average was counted.
7	Harvest index (%)	for each entry was calculated in percentage by using the following formula: Harvest index (%) = $\frac{Grainyieldperplant}{Biological\ yield} \times 100$

Statistical Analysis: The recorded data on genetic materials were statistically analyzed according to [22]. subjected to line tester analysis of variance (ANOVA) for general and specific combining abilities effects as outlined by [14]. General and specific combining abilities effects were calculated according to the following formulae;

1. Estimation of GCA Effects

Lines: $gi=\{(x._{j}./tr)\}-(x.../ltr)\}$

Testers: $gi=\{(x._{j}./lr)\}-(x.../ltr)\}$

2. Estimation of SCA Effects

$$si=\{(xij.)/r)-(xi../tr)-(x.j./lr)+x.../l\,tr$$

RESULTS

Analysis of variance for plant height, leaf area, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index in line × tester analysis under three water regimes in controlled conditions in season-I and II (Table 1), showed highly significant differences (P ≤ 0.01) among genotypes, parents, crosses and parent's vs crosses. General combining ability effects were revealed for plant height, leaf area, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index (Table 2), in different water regimes under controlled conditions in seasons-I and II Under water treatment 1 in season-I, the lines DR-198, DR-189 and DR-159 showed positive and significant GCA effects for the trait plant height and lines DR-177, DR-198 and DR-94 for leaf area. Similarly the lines DR-187, DR-185 and DR-159 revealed positive and significant GCA effects for number of kernels per row, lines DR-177 and DR-159 for ear diameter and lines DR-177, DR-198 and DR-185 for grain yield per plant. The genotypes used as lines DR-158, DR-189 and DR-159 showed positive and significant GCA effects for the trait harvest index. The contrasting results of negative and significant GCA effects were depicted by the lines DR-187, DR-194 and DR-185for plant height, lines DR-187, DR-185, DR-189, DR-159, DR-158 for leaf area, lines DR-177, DR-194, DR-158, DR-189 for number of kernels per row, lines DR-194, DR-158, DR-189 and DR-159 ear diameter, lines DR-187, DR-198, DR-158, DR-185 for grain yield per plant, lines DR-187, DR-177, DR-198, DR-194 and DR-185for harvest index. Among testers the genotype Pak Afgoee showed positive and significant GCA effects for plant height and leaf area, Sadaaf for number of kernels per row, Pak Afgoee for ear diameter, Pak Afgoee and Ev-6098 for grain yield per plant, Pak Afgoee, Ev-1098 and Ev-6098 for harvest index. However the testers Sadaaf and Ev-1098 revealed negative and significant GCA effects for the trait plant height, Sadaaf for leaf area, Ev-6098 for number of kernels, Sadaaf and Ev-1098 for ear length, Pak Afgoee, Ev-1098 and Ev-6098.

Table 1: Mean squares values for plant height, leaf area, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index of maize genotypes in 8 lines × 4 testers cross grown under contrasting water regimes

			1st Season							2nd Season						
S.O.V	d.f		Pl.ht.	L.A	Kernels	E.L	E.D	G.Y	H.I	Pl.ht.	L.A	Kernels	E.L	E.D	G.Y	H.I
Genotype	43	T1	1618.35**	5520.75**	31.14**	9.27**	0.31**	6575.17**	1064.40**	1618.23**	3134.44**	38.99**	30.09**	0.26**	6524.96**	740.55**
		T2	606.63**	7707.32**	29.50**	6.05**	1.29**	5304.82**	716.40**	894.41**	5996.85**	32.01**	34.81**	0.56**	5154.92**	256.64**
		T3	699.11**	5010.03**	29.27**	17.40**	0.09**	9623.50**	115.69**	702.08**	4732.31**	31.27**	23.74**	0.57**	9249.81**	137.15**
Parents	11	T1	991.77**	4253.80**	25.05**	15.43**	0.29**	2740.41**	13.46**	949.12**	4132.54**	21.84**	35.00**	0.36**	2920.46**	43.03**
		T2	927.23**	10856.68**	22.10**	1.48**	1.29**	4028.86**	52.84**	1477.42**	12127.23**	21.26**	46.50**	0.91**	4166.92**	30.94
		T3	11198.37**	3178.41**	20.21**	18.57**	0.07*	5802.27**	56.43**	1178.33**	6684.51**	20.49**	25.18**	0.90**	5943.17**	60.31**
Crosses	31	T1	1593.88**	6139.06**	33.87**	4.71	0.31**	8094.72**	1405.04**	1583.67**	2742.39**	44.40**	16.44**	0.20**	7896.28**	995.77**
		T2	466.79**	6594.18**	32.46**	7.40**	1.33**	5858.18**	918.90**	716.20**	3896.00**	36.11**	15.56**	0.45**	5571.98**	337.07**
		T3	544.25**	5766.64**	32.58**	14.94**	0.10**	11203.40**	136.79**	548.69**	3803.56**	35.34**	13.51**	0.47**	10620.81**	165.28**
Parents vs crosses	1	T1	9269.43**	289.53	13.27**	82.94**	0.73**	1651.37**	2065.06**	10049.81**	4308.94**	60.01**	399.15**	0.83**	3663.34**	501.41**
		T2	1414.94**	7571.65**	19.26**	14.38**	0.01	2186.11**	1738.20**	5.67	3689.24	23.35**	503.13**	0.06	3094.19**	245.96
		T3	7.68**	1702.96	26.36**	80.50**	0.01	2680.36**	113.41**	218.19**	12049.48**	23.53**	324.81**	0.01	3121.75**	110.44**
Lines	7	T1	2726.42	12084.68**	81.53**	6.70	0.57*	10225.73	1724.35	2680.78	3154.00	96.40**	21.14**	0.27	10328.48	1078.32
		T2	333.07**	5013.81	76.34**	17.18**	3.18**	7304.63	1368.77	1209.47*	5645.77	82.31**	21.98	0.98**	8105.66	494.81
		T3	269.14**	8536.16	72.83**	28.31*	0.14	11096.33	153.12	1078.47	4911.29	80.33**	16.77	0.95**	11805.92	210.47
Testers	3	T1	763.00	8363.03**	3.40	3.25	0.17	2711.15	1648.58	787.25	3188.86	5.64	1.16	0.16	2236.64	402.90
		T2	295.47**	5706.06	5.12	1.66**	1.01	6079.13	469.83	793.46	1251.37	13.81	0.49	0.47	5583.12	12.02
		T3	545.86**	5326.68	7.90	12.84	0.07	17191.40	158.61	336.15	1086.89	12.90**	0.84o	0.43	15010.80	125.55
Line × Tester	21	T1	1335.07**	3839.47**	22.34**	4.26	0.24**	8153.47**	1263.81**	1331.74**	2541.41**	32.61**	17.06**	0.19**	7894.07**	1052.94**
		T2	535.84**	7247.84**	21.74**	4.97**	0.76**	5344.47**	833.10**	540.74**	3690.54**	23.89**	15.57**	0.27**	4725.83**	330.92**
		T3	635.73**	4906.32**	22.69**	10.79**	0.10**	10383.66**	128.23**	402.46**	3822.41**	23.55**	14.24**	0.30**	9598.63**	155.90**
Error	86	T1	41.04**	709.74	0.59	4.06	0.03	2.34	1.10	22.09	906.20	6.77	0.31	0.03	11.14	2.12
		T2	22.22	859.81	0.35	0.28	0.12	28.88	10.35	46.72	1015.15	0.24	0.98	0.04	46.27	157.81
		T3	30.51	553.75	1.00	1.93	0.04	113.71	8.12	30.10	1109.66	0.32	0.56	0.04	97.52	9.79

S.O.V: Source of variance: Df: Degree of freedom, T1: Treatment T2: Treatment-2, T3: Treatment 3,Dominance á: Dominance Variance, Additive á: Additive variance, Pl.ht: plant height, L.A: leaf area, NK; number of kernels, E.L: ear length, E.D: ear diameter, GYPP: grain yield per plant and H.I: harvest index.

Table 2: General combining ability (GCA) effects of Parents for plant height, leaf area, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index of maize genotypes under contrasting water regime

		1st season							2nd season						
Lines		Pl.ht	L.A	N.K.	E.L	E.D	G.Y	H.I	Pl.ht	L.A	N.K.	E.L	E.D	G.Y	H.I
DR-187	T1	-11.82	-17.18	3.82	1.1	-0.18	-36.83	-8.96	-11.71	-33.35	4.38	0.43	0.1	-40.22	-4.2
	T2	-14.54	-22.25	4.05	-0.73	0.57	-38.9	-8.56	-8.48	-9.81	4.08	0.83	0.54	-41.08	-2.96
	T3	-14.13	24.93	4.28	2.74	-0.1	-41.19	-2.96	-13	-25.07	4.11	0.63	0.49	-40.93	-2.04
DR-177	T1	3.09	30.55	-1.84	-0.94	0.46	25.83	-6.17	2.95	8.13	-2.04	-1.82	0.15	23.23	12.64
	T2	-5.71	35.14	-1.95	-1.01	-0.05	14.89	-4.79	-13.4	-22.77	-2.25	-1.51	-0.03	12.78	11.19
	T3	-9.38	-27.67	-2.05	-0.47	0.09	3.73	8.5	-10.5	-2.81	-2.22	-1.37	0.01	3.34	9.24
DR-198	T1	26.3	33.74	-0.18	0.25	-0.11	48.22	-6.58	26.12	7.06	-2.21	0.06	0.05	47.87	5.09
	T2	18.94	-8.91	0.05	-0.4	0.33	34.87	-4.63	11.6	-7.1	0.08	-0.67	-0.2	38.43	3.89
	T3	14.88	25	0.28	0.95	0.13	21.31	-0.33	15.63	35.1	0.11	0.05	-0.2	29.98	2.22
DR-194	T1	-20.41	48.7	-1.18	0.65	-0.09	-15.61	-4.74	-20.38	19.58	-1.21	-0.23	0.01	-13.28	-17.22
	T2	5.64	26.55	-1.2	1.66	-0.87	20.75	1.63	9.6	6.13	-1.42	0.08	-0.24	20.36	-9.01
	T3	10.13	-9.58	-1.22	0.36	-0.04	56.9	-0.09	8.67	13.81	-1.39	-0.28	-0.27	55.02	-0.97
DR-158	T1	-0.32	-25.62	-2.68	-0.63	-0.12	-16.89	7.29	-0.8	3.52	-2.29	-0.57	-0.24	-15.89	5.27
	T2	0.75	1.24	-2.49	0.26	-0.43	-24.5	-0.19	-6.15	27.73	-2.5	-0.8	-0.32	-25.46	1.56
	T3	1.29	7.72	-2.3	-1.01	-0.05	-31.94	-1.64	2.04	11.55	-2.47	-1.03	-0.33	-34.03	-2.47
DR-185	T1	-12.95	-26.21	2.49	-0.68	-0.13	25.03	-9.68	-12.51	-13	2.71	-1.32	-0.19	26.76	7.58
	T2	-8.72	-13.48	1.97	1.96	-0.23	10.32	-11.6	-8.15	-22	2.25	-1.26	-0.09	13.05	4.13
	T3	-4.46	35.03	1.45	-2.18	-0.18	-4.6	-0.63	-4.59	-4.18	2.2	-1.02	-0.07	0.35	0.38
DR-189	T1	3.84	-21.75	-2.93	0.6	-0.01	-11.89	3.04	4.29	1.35	-2.29	2.35	-0.03	-10.7	-5.54
	T2	0.84	-14.63	-2.74	-1.15	0.03	-5.51	5.48	9.85	-7.89	-2.67	2.58	0.08	-7.62	-4.09
	T3	2.54	-22.62	-2.55	0.78	0.09	1.15	-2.13	2.22	-2.98	-2.64	2.13	0.11	-3.53	-3.86
DR-159	T1	12.26	-22.23	2.49	-0.36	0.19	-17.86	25.8	12.04	6.71	2.96	1.1	0.16	-17.77	-3.61
	T2	2.8	-3.67	2.3	-0.59	0.66	-11.92	22.66	5.1	35.72	2.42	0.74	0.25	-10.47	-4.71
	T3	-0.88	-32.82	2.11	-1.18	0.05	-5.35	-0.72	-0.47	-25.41	2.28	0.88	0.27	-10.2	-2.5
S.E	T1	1.85	7.69	0.22	0.58	0.05	0.44	0.3	1.36	8.69	0.75	0.16	0.05	0.96	0.42
	T2	1.36	8.46	0.17	0.15	0.1	1.55	0.93	1.97	9.2	0.14	0.28	0.06	1.96	3.63
	T3	0.03	6.79	0.29	0.4	0.06	3.08	0.82	1.58	9.62	0.16	0.22	0.06	2.85	0.9
Testers	T1	7.37	16.49	0.07	-0.13	0.12	13.04	-4.87	7.52	1.49	0.58	-0.15	0.06	11.65	3.03
Pak Afgoee	T2	1.93	-9.45	0.2	-0.39	-0.07	3.26	-5.06	0.94	9.92	0.29	-0.03	0.05	0.81	0.3
	T3	-2.42	16.23	0.32	-0.01	0.03	-6.44	-1.41	-2.02	-2.91	0.24	0.22	0.07	-9.03	-2.32
Sadaaf	T1	-5.62	-26.83	0.49	-0.4	-0.06	-7.31	12.17	-5.38	-8.38	-0.21	-0.19	0.04	-5.93	3.84
	T2	-0.12	3.43	0.49	0.11	0.27	-18.16	5.67	-0.4	-6.95	0.83	-0.05	0.1	-16.56	0.74
	T3	2.92	8.5	0.49	-0.89	0.00	-28.98	-1.01	2.21	8.76	0.82	-0.23	0.07	-26.18	-0.47
Ev-1098	T1	-2.89	5.47	-0.18	0.06	-0.06	-9.9	-1.7	-3.38	-8.85	0.17	0.06	-0.12	-9.66	-2.27
	T2	1.2	-14.23	-0.09	0.09	-0.22	-4.97	-0.96	6.73	-3.12	-0.17	0.2	-0.21	-4.35	-0.92
	T3	3.54	-8.9	-0.01	-0.01	-0.07	-0.19	-1.43	3.97	1.18	-0.14	0.05	-0.2	1.96	-0.37
Ev-6098	T1	1.14	4.87	-0.39	0.47	0.00	4.17	-5.6	1.25	15.74	-0.54	0.29	0.02	3.94	-4.61
	T2	-3.02	20.25	-0.59	0.19	0.03	19.87	0.34	-7.27	0.15	-0.96	-0.13	0.06	20.1	-0.12
	T3	-4.04	-15.84	-0.8	0.91	0.05	35.6	3.85	-4.16	-7.02	-0.93	-0.03	0.05	33.25	3.15
S.E	T1	1.31	5.44	0.16	0.41	0.04	0.31	0.21	0.96	6.14	0.53	0.11	0.03	0.68	0.3
	T2	0.96	5.99	0.12	0.11	0.07	1.1	0.66	1.4	6.5	0.1	0.2	0.04	1.39	2.56
	T3	0.02	4.8	0.2	0.28	0.04	2.18	0.58	1.12	6.8	0.12	0.15	0.04	2.02	0.64

S.E: standard error, T1: Treatment-1, T2: Treatment-2, T3: Treatment-3, Pl.ht: plant height, L.A: leaf area, N.K; number of kernels, E.L: ear length, E.D: ear diameter, GYPP: grain yield per plant and H.I: harvest index.

Under water treatment 1 in season-II, the lines revealed positive and significant general combining effects for different traits like genotypes DR-177, DR-198, DR-189 and DR-159 for the trait plant height, line DR-194 for leaf area, lines DR-187, DR-185 and DR-159 for number of kernels per row, lines DR-187, DR-189 and DR-159 for ear length, lines DR-187, DR-177 and DR-159 for ear diameter, lines DR-177, DR-198 and DR-185 for grain yield per plant, lines DR-177, DR-198, DR-158 and DR-185for harvest index whereas the genotypes showed negative and significant GCA effects for DR-187, DR-194 and DR-185 for the trait plant height, line DR-187 for leaf area, lines DR-177, DR-198, DR-158 and DR-189 for number of kernels per row, lines DR-177, DR-158 and DR-185 for ear length, lines DR-158, DR-185 for ear diameter, lines DR-187, DR-194, DR-158, DR-189 and DR-159 for grain yield per plant, lines DR-187, DR-194, DR-189 and DR-159 for harvest index. Similarly among testers the genotype Pak Afgoee for the trait plant height, Ev-6098 for leaf area per plant, Ev-6098 for ear length, Pak Afgoee for ear diameter, Pak Afgoee and Ev-6098 for grain yield per plant, Pak Afgoee and Sadaaf for harvest while testers Sadaaf and Ev-1098 for ear length, Ev-1098 for ear diameter, Sadaaf and Ev-1098 for grain yield per plant, Ev-6098 and Ev-1098 for harvest index had negative and significant GCA effects.

Under water treatment 2 in the 1st season, the genotypes behaved positive with significant GCA effects DR-198, DR-194, DR-158 and DR-159 for the trait plant

Table 3: Specific combining ability effects of cross combinations for plant height, leaf area, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index under contrasting water regime

		1st season							2nd season						
Crosses		Pl.ht	L.A	N.K.	E.L	E.D	G.Y	H.I	Pl.ht	L.A	N.K.	E.L	E.D	G.Y	H.I
DR-187 × Pak Afgoee	T1	31.72	-5.32	1.59	2.12	-0.17	-6.43	3.43	30.98	-4.03	1	5.48	-0.03	-9.6	-7.06
	T2	16.4	-2.2	1.43	0.94	0.13	-0.04	0.03	6.98	3.88	1.29	5.11	0.11	0.07	-4.58
	T3	0.33	90.69	1.26	0.55	0.01	6.27	-2.54	-0.56	-1.35	1.34	5.03	0.06	8.74	-2.23
DR-187 × Sadaaf	T1	0.03	14	-0.16	-1.13	0.14	3.36	-7.09	0.21	15.5	1.13	-0.47	0.28	7.34	1.16
	T2	-6.22	-17.84	0.3	-0.49	0.08	14.77	-0.21	-5.02	-1.28	0.42	-0.54	-0.47	15.81	2.98
	T3	-9	-46.22	0.76	-2.74	-0.15	26.15	4.18	-8.46	-16.38	0.43	-0.18	-0.47	23.27	2.9
DR-187 × Ev-1098	T1	-20.03	24.32	-0.49	-1.88	0.08	16.07	-0.68	-19.79	-2.36	-0.58	-3.06	0.05	14.77	2.3
	T2	-9.2	60.74	-0.45	0.09	0.17	11.97	-1.11	2.52	14.98	-0.25	-3.12	0.1	10.63	2.53
	T3	3.38	-26.33	-0.41	-2.78	0.15	8.02	2.35	4.11	-10.67	-0.28	-2.13	0.13	5.49	3.53
DR-187 × EV-6098	T1	-11.72	-32.99	-0.95	0.89	-0.05	-13	4.34	-11.41	-9.12	-1.54	-1.95	-0.3	-12.51	3.6
	T2	-0.98	-40.7	-1.28	-0.54	-0.38	-26.7	1.29	-4.48	-17.58	-1.46	-1.45	0.26	-26.51	-0.92
	T3	5.29	-18.13	-1.62	4.97	-0.01	-40.44	-4	4.91	28.4	-1.49	-2.72	0.28	-37.5	-4.2
DR-177 × Pak Afgoee	T1	17.8	2.91	1.93	0.06	-0.38	-75.43	3.8	17.32	11.46	1.75	-1.93	0.25	-72.53	-23.53
	T2	7.24	-20.6	2.09	0.52	1.08	-45.67	4.2	-9.77	21.14	2.29	-1.89	0.29	-42.69	-15.86
	T3	-7.42	-7.28	2.26	1.43	-0.14	-15.98	-8.13	-7.39	9.08	2.34	-0.63	0.51	-13.86	-8.05
DR-177 × Sadaaf	T1	-7.55	-38.77	-0.82	-0.27	0.03	65.8	-8.48	-8.12	-5.91	0.54	1.44	-0.13	61.52	16.88
	T2	-13.04	39.2	-0.37	-0.04	0.33	23.37	-12.07	-22.1	-46.52	-0.25	1.13	0.01	20.13	6.35
	T3	-16.75	10.99	0.09	-1.37	0.03	-19.1	-7.7	-15.96	13.85	-0.24	1.15	-0.06	-22.26	-6.82
DR-177 × Ev-1098	T1	6.39	-36.01	-0.82	0.27	0.1	-40.71	2.85	6.55	-25.04	-2.17	-0.81	-0.01	-36	-16.03
	T2	2.61	-62.65	-1.45	-0.19	-0.41	-27.04	1.2	8.77	13.48	-1.92	-0.79	-0.26	-25	-13.3
	T3	5.96	-20.97	-2.07	1.43	0.1	-13.23	-7.33	4.94	-13.1	-1.95	-1.13	-0.35	-15.01	-9.52
DR-177 × EV-6098	T1	-16.64	71.86	-0.28	-0.06	0.24	50.33	1.83	-15.75	19.49	-0.13	1.3	-0.11	47.02	22.68
	T2	3.19	44.05	-0.28	-0.29	-1	49.34	6.67	23.1	11.91	-0.13	1.55	-0.03	47.57	22.81
	T3	18.21	17.26	-0.28	-1.49	0.01	48.31	23.16	18.41	-9.83	-0.16	0.62	-0.1	51.13	24.39
DR-198 × Pak Afgoee	T1	-24.74	55.72	-5.41	-1.23	0.16	24.18	1.53	-25.85	-15.31	-3.42	-2.81	-0.05	23.53	26.22
	T2	-6.24	-4.38	-5.57	0.12	-0.57	-20.99	2.87	1.9	-36.53	-5.71	-2.39	0.02	-23.74	13.19
	T3	6.33	-45.74	-5.74	-0.32	-0.12	-66.23	-0.5	4.81	-51.69	-5.66	-3.05	-0.05	-72.01	-0.63
DR-198 × Sadaaf	T1	24.91	-28.36	0.51	-0.44	0.1	-55.69	-10.92	25.38	21.72	-6.29	-1.27	-0.07	-57.62	-7.72
	T2	11.8	9.92	0.64	-1.05	-0.08	-38.01	-5.32	5.9	-0.02	0.42	-0.37	-0.4	-26.98	0.37
	T3	2.66	53.08	0.76	0.72	-0.05	-20.35	1.13	1.91	32.74	0.43	-1.27	-0.35	2.65	6.79
DR-198 × EV-1098	T1	21.68	9.79	2.84	0.32	0.2	26.12	-0.57	21.71	37.93	4.67	1.82	0.36	26.4	-10.76
	T2	4.57	43.3	2.55	0.37	0.68	47.08	-0.64	-9.23	65.11	2.42	2.38	0.47	42.71	-6.17
	T3	-7.63	1.76	2.26	-1.16	0.19	68.19	2.8	-9.52	8.92	2.39	1.78	0.49	58.01	-0.54
DR-198 × EV-6098	T1	-21.84	-37.14	2.05	1.35	-0.46	5.39	9.96	-21.25	-44.33	5.04	2.26	-0.25	7.7	-7.73
	T2	-10.13	-48.84	2.39	0.57	-0.04	11.91	3.08	1.44	-28.56	2.88	0.38	-0.1	8.02	-7.39
	T3	-1.38	-9.1	2.72	0.76	-0.03	18.4	-3.44	2.81	10.02	2.84	2.53	-0.1	11.35	-5.62
DR-194 × Pak Afgoee	T1	-11.03	-69.4	4.93	-0.6	-0.16	77.9	1.8	-11.68	-7.93	4.25	0.65	-0.14	78.21	6.38
	T2	-9.27	-19.94	4.68	-1.14	-0.18	60.75	-1.42	-5.77	15.58	4.46	0.53	0.13	63.3	4.41
	T3	0.08	59.94	4.43	-1.74	-0.08	43.52	1.49	0.44	22.97	4.51	-0.38	0.12	47.39	2.25
DR-194 × Sadaaf	T1	-21.39	7.66	-1.49	1.15	0.18	-20.86	-11.18	-21.45	-9.46	0.38	-0.14	0.07	-21.33	4.17
	T2	7.74	-44.21	-0.95	2.29	0.25	-33.88	-10.64	18.9	-19.29	-0.75	-0.45	0.01	-32.49	3.12
	T3	14.08	-56.23	-0.41	1.47	0.12	-46.94	-0.63	12.88	34.5	-0.74	-0.27	0.02	-44.65	0.11
DR-194 × EV-1098	T1	-14.45	33.45	-2.49	0.85	0.19	-25.71	4.21	-13.79	-47.35	-2	-0.06	0.14	-26.12	-7.64
	T2	0.69	-64.92	-2.2	0.97	-0.33	-2.63	10.12	1.77	-32.65	-1.75	0.3	-0.15	-5.19	-4.04
	T3	1.13	-20.16	-1.91	1.59	0.06	20.6	1.89	1.44	-38.85	-1.78	0.45	-0.14	14.74	0.47
DR-194 × Ev-6098	T1	46.87	28.28	-0.95	-1.4	-0.21	-31.33	5.17	46.92	64.74	-2.63	-0.45	-0.07	-30.75	-2.9
	T2	0.84	129.07	-1.53	-2.12	0.25	-24.24	1.94	-14.9	36.36	-1.96	-0.37	0.01	-25.63	-3.48
	T3	-15.29	16.45	-2.12	-1.32	-0.1	-17.19	-2.75	-14.76	-18.62	-1.99	0.2	0.01	-17.48	-2.84
DR-158 × Pak Afgoee	T1	12.22	1.56	-3.57	0.48	0.21	9.07	-10.36	12.4	17.47	-4	2.32	0.17	10.26	-25.73
	T2	3.44	14.7	-3.53	-2.15	-0.38	65.44	3.7	-5.02	-1.14	-3.46	2.57	-0.26	65.72	-10.87
	T3	-2.08	-43.53	-3.49	0.97	0.02	121.35	4.07	1.9	-23.18	-3.41	2.37	-0.28	120.17	3.99
DR-158 × Sadaaf	T1	-7.47	9.22	-2.99	0.09	-0.05	0.42	9.81	-8.37	-0.28	-2.21	0.36	0.08	-0.28	-3.76
	T2	-3.64	29.03	-2.99	-1.32	-0.22	3.87	-2.85	5.98	52.48	-3.33	0.09	0.05	4.09	-0.99
	T3	2.92	45.39	-2.99	1.51	0.06	7.9	0.25	2.84	2.26	-3.32	0.15	0.02	7.46	-0.1
DR-158 × Ev-1098	T1	-21.2	-3.47	3.01	-0.79	-0.22	5.57	11.73	-20.37	-32.42	2.42	-1.56	-0.39	3.78	24.35
	T2	-2.03	-40.75	2.76	0.87	0.4	-30.99	7.07	3.85	-56.99	2.67	-1.83	0.02	-31.03	11.76
	T3	6.99	11.19	2.51	-0.37	-0.01	-67.23	0.69	6.4	32.61	2.64	-1.8	0.06	-66.85	0
DR-158 × Ev-6098	T1	16.45	-7.31	3.55	0.22	0.06	-15.05	-11.18	16.34	15.23	3.79	-1.12	0.14	-13.76	5.14
	T2	2.23	-2.98	3.76	2.6	0.19	-38.33	-7.92	-4.81	5.64	4.13	-0.83	0.19	-38.78	0.1
	T3	-7.79	-13.06	3.97	-2.12	-0.08	-62.02	-5.01	-11.14	-11.69	4.09	-0.72	0.21	-60.77	-3.89

Table 3: Continued

		1st season							2nd season						
Crosses		Pl.ht	L.A	N.K.	E.L	E.D	G.Y	H.I	Pl.ht	L.A	N.K.	E.L	E.D	G.Y	H.I
DR-185 × Pak Afgoee	T1	-1.32	13.35	1.59	-0.3	-0.15	47.26	5.5	-1.06	14.9	2	-1.93	0.06	46.71	29.71
	T2	0.33	10.34	2.34	1.49	0.06	1.35	-3.31	3.31	44.71	2.13	-1.81	0.05	-1.24	15.1
	T3	5.33	-29.52	3.09	-1.2	0.23	-44.65	1.53	4.69	37.02	2.26	-1.98	0.02	-50.21	0.13
DR-185 × Sadaaf	T1	9.49	-4.6	2.18	-0.86	0.12	-55.39	-13.37	10.34	-14.68	3.13	-1.06	0.04	-53.8	-24.59
	T2	1.66	20	0.89	-0.17	-0.08	-6.4	1.31	5.31	10.51	2.25	-1.45	0.23	-12.32	-13.05
	T3	1.66	7.86	-0.41	-0.32	0.26	42.56	0.82	2.13	-4.01	2.01	-0.8	0.25	28.15	-3.35
DR-185 × Ev-1098	T1	2.43	-13.49	-0.82	0.93	-0.31	-45.35	0.86	2.34	22.22	-1.25	2.03	-0.26	-47.12	3.78
	T2	-12.02	12.1	-0.37	-1.49	-0.1	-53.19	-1.72	-22.15	-50.02	-0.75	1.63	-0.13	-41.34	5.11
	T3	-20.29	33.97	0.09	1.14	-0.5	-60.9	0.49	-20.97	-70.99	-0.7	1.52	-0.14	-36.56	7.37
DR-185 × Ev-6098	T1	-10.59	4.75	-2.95	0.23	0.34	53.47	7	-11.62	-22.44	-3.88	0.96	0.16	54.2	-8.91
	T2	10.03	-42.44	-2.87	0.18	0.12	58.24	3.73	13.52	-5.19	-3.63	1.63	-0.14	54.9	-7.16
	T3	13.29	-12.3	-2.78	0.39	0.01	62.98	-2.84	14.16	37.97	-3.57	1.27	-0.13	58.62	-4.15
DR189×Pak Afgoee	T1	-12.62	33.02	-1.99	-0.13	-0.04	-34.6	-6.84	-11.35	-14.4	-2.33	-0.6	-0.01	-35.02	-6.88
	T2	-11.81	-3.46	-1.95	-0.17	-0.01	-17.04	-5.77	8.31	-23.93	-1.96	-0.64	-0.13	-15.82	-1.83
	T3	-12	10.04	-1.91	-0.16	-0.08	-0.06	3.43	-12.12	11.82	-1.91	-0.13	-0.16	2.37	4.08
DR189×Sadaaf	T1	3.03	9.45	1.26	0.7	-0.09	-21.7	-23.95	2.21	15.67	1.46	0.61	-0.46	-17.42	-2.97
	T2	6.41	3.87	1.09	0.27	-0.25	-11.51	-20.63	7.98	2.73	0.5	1.05	0.12	-10.51	-1.1
	T3	11.66	3.42	0.93	0.05	-0.18	-1.85	1.39	11.99	-26.27	0.51	0.65	0.14	-4.61	-0.11
DR189×Ev-1098	T1	18.3	-23.94	0.26	1.4	-0.16	84.35	16.24	19.55	14.14	0.75	3.19	0.04	84.19	25.92
	T2	13.59	19.52	0.68	-0.02	-0.6	19.53	-0.31	2.19	18.5	1.17	2.8	-0.31	18.82	10.53
	T3	9.71	-6.93	1.09	1.18	0.06	-45.65	-3.41	11.22	51.94	1.14	2.37	-0.32	-47.55	-3.54
DR189×Ev-6098	T1	-8.72	-18.53	0.47	-1.98	0.29	-28.05	14.54	-10.41	-15.42	0.13	-3.2	0.43	-31.75	-16.07
	T2	-8.19	-19.92	0.18	-0.08	0.85	9.02	26.71	-18.48	2.7	0.29	-3.2	0.32	7.51	-7.59
	T3	-9.38	-6.53	-0.12	-1.07	0.21	47.56	-1.41	-11.09	-37.49	0.26	-2.88	0.33	49.79	-0.43
DR159×Pak Afgoee	T1	-12.03	-31.84	0.93	-0.4	0.53	-41.96	1.14	-10.77	-2.16	0.75	-1.18	-0.26	-41.55	0.89
	T2	-0.1	25.55	0.51	0.4	-0.13	-43.81	-0.3	0.06	-23.71	0.96	-1.47	-0.2	-45.59	0.45
	T3	9.42	-34.59	0.09	0.47	0.16	-44.23	0.64	8.24	-4.68	0.51	-1.22	-0.22	-42.59	0.46
DR159×Sadaaf	T1	-1.05	31.41	1.51	0.76	-0.43	84.06	65.18	-0.2	-22.56	1.88	0.53	0.18	81.6	16.83
	T2	-4.72	-39.96	1.39	0.5	-0.04	47.78	50.41	-16.94	1.39	0.75	0.55	0.45	42.28	2.32
	T3	-7.25	-18.29	1.26	0.68	-0.1	11.65	0.56	-7.32	-36.69	0.93	0.57	0.45	10	0.57
DR159×Ev-1098	T1	6.89	9.35	-1.49	-1.1	0.11	-20.35	-34.65	3.8	32.88	-1.83	-1.56	0.08	-19.89	-21.9
	T2	1.8	32.66	-1.53	-0.59	0.18	35.26	-14.61	12.27	27.59	-1.58	-1.37	0.26	30.4	-6.41
	T3	0.79	27.47	-1.57	-1.03	-0.04	90.19	2.51	2.38	40.14	-1.45	-1.05	0.26	87.73	2.23
DR159×Ev-6098	T1	6.2	-8.92	-0.95	0.75	-0.22	-21.75	-31.67	7.17	-8.15	-0.79	2.21	0.01	-20.16	4.19
	T2	3.16	-18.25	-0.37	-0.32	-0.01	-39.24	-35.51	4.6	-5.28	-0.13	2.3	-0.51	-27.08	3.64
	T3	-2.96	25.41	0.22	-0.12	-0.02	-57.6	-3.71	-3.29	1.24	0.01	1.7	-0.5	-55.13	-3.26
S.E	T1	3.7	15.38	0.44	1.16	0.11	0.88	0.61	2.71	17.38	1.5	0.32	0.1	1.93	0.84
	T2	2.72	16.93	0.34	0.3	0.2	3.1	1.86	3.95	18.4	0.29	0.57	0.11	3.93	7.25
	T3	0.06	13.59	0.58	0.8	0.11	6.16	1.65	3.17	19.23	0.33	0.43	0.12	5.7	1.81

S.E: Standard error, T1: Treatment-1, T2: Treatment-2, T3: Treatment-3, Pl.ht: plant height, L.A: leaf area, NK; number of kernels, E.L: ear length, E.D: ear diameter, GYPP: grain yield per plant and H.I: harvest index.

height, DR-177 and DR-194 for leaf area, DR-187, DR-185 and DR-159 for number of kernels per row, DR-194 and DR-185 for ear length, DR-187, DR-198 and DR-159 for ear diameter, DR-177, DR-198, DR-194 and DR-185 for grain yield per plant, DR-189 and DR-159 for harvest index similarly the genotypes revealed negative with significant GCA effectsas DR-187, DR-177 and DR-185 for plant height, DR-187 for leaf area, DR-177, DR-194 and DR-158 for number of kernels per row, DR-187, DR-177, DR-198, DR-189 and DR-159 for ear length, DR-194, DR-158 and DR-185 for ear diameter,, DR-187, DR-158, DR-189 and DR-159 for grain yield per plant DR-187, DR-177, DR-198 and DR-185for harvest index. Among parents the (Testers) the genotypes showed positive and significant GCA effects Pak Afgoee for plant height, Ev-6098 for leaf area, Sadaaf for kernels per row, Sadaaf for ear diameter, Pak Afgoee and Ev-6098 for grain yield per plant, Sadaaf for harvest index while the genotypes Ev-6098 showed negative and significant GCA effects for the traits plant height, Ev-1098 for leaf area, Ev-6098 for number of kernels per row, Pak Afgoee for ear length, Ev-1098 for ear diameter, Sadaaf and Ev-1098 for grain yield per plant, Pak Afgoee for harvest index.

In the same experiment the next water treatment was 2 in the 2nd season, where results showed that the genotypes DR-198, DR-194, DR-189 and DR-159 showed positive and significant GCA effects for the traits like plant height, DR-158 and DR-159 for leaf area, DR-187, DR-185 and DR-159 for number of kernels per row, DR-187 and DR-198 for ear length, DR-187 and DR-159 for ear diameter, DR-177, DR-198, DR-194 and DR-185 for grain yield per plant and DR-177 for harvest index. Negative but significant GCA effects were noted among the genotypes DR-187, DR-177, DR-158 and DR-185 for plant height, DR-185 and DR-177 for leaf area, DR-177, DR-194, DR-158 and DR-189 for number of kernels, DR-158, DR-185 and DR-159 for ear length, DR-198 and DR-194 for ear diameter, DR-187, DR-158, DR-189 and DR-159 for grain yield per plant. The parent genotypes also showed contrasting results for the genotypes (Testers) Ev-1098 for the trait plant height, Pak Afgoee and Sadaaf for number of kernels per row, Ev-6098 for ear length, Sadaaf, Ev-1098 for ear diameter, Ev-6098for grain yield per plant as positive and significant GCA effects while negative and significant GCA effects were shown by the genotype Ev-6098 for the trait plant height, Ev-6098 for number of kernels per row, Sadaaf for ear length, Ev-1098 for ear diameter, Sadaaf and Ev-1098 for grain yield per plant. Under water treatment 3, in season-I, positive and significant GCA effects were depicted by the parent genotypes(Lines) DR-198, DR-194, DR-158 and DR-189 for the trait plant height, DR-187, DR-185 and DR-198 for leaf area, DR-187, DR-185 and DR-159 for number of kernels per row, DR-187, DR-189 and DR-159 for ear length, DR-198 for ear diameter, DR-198 and DR-194 for grain yield per plant, DR-177 for harvest index. However the genotypes DR-187, DR-177, DR-185 and DR-159 for plant height, DR-159, DR-177 and DR-189 for leaf area, lines DR-177, DR-194, DR-158 and DR-189 for number of kernels per row, DR-177, DR-158 and DR-185 for ear length, DR-185 for ear diameter, DR-187, DR-158 and DR-159 for grain yield per plant, DR-187, DR-158 and DR-189 for harvest index, showed negative and significant GCA effects. Among other parent (Testers) the genotypes Sadaaf and Ev-1098 showed positive and significant GCA effects for the trait plant height, Pak Afgoee for leaf area, Sadaaf for number of kernels per row, Ev-6098 for grain yield per plant, Ev-6098 for harvest index, while the genotypes Pak Afgoee and Ev-6098 behaved negative with significant GCA effects for the traits like plant height, Ev-6098 for leaf area, Ev-6098 for number of kernels per row, Pak Afgoee and Sadaaf for grain yield per plant, whereas Pak Afgoee and Ev-1098for harvest index. Specific combining ability effects of maize hybrids under water treatment T1, T2 and T3 in the 1st and 2nd seasons were shown in (Table 3).

DISCUSSION

It is true that the genetic diversity among different genotypes field crops pave the path for yield and yield related traits improvements [23, 24] under normal and water stress environments. Plant height a trait of interest in crop plant was considered a point of variation to combat water stress situation in maize crop as reported by [25]. A significant genotype x environment interaction also played an important role under normal and water stress environment [26] the presence of significant genetic diversity enhances the chance for better selection of accession and crosses. Hybrids produced from more diverse parents give better yield than developed from similar parents which support the present study findings [27, 28].

Leaf is the first organ which shows visible signs when subjected to water stress, therefore the selection for water stress tolerance on the basis of leave traits are effective selection criteria. With increasing water stress, the leaf area was reduced and this is the first attempt of any plant to save loss of moisture from its body. By reducing leaf area, water lose can be reduced during water stress condition [29, 30]. There was much genetic diversity present among different maize genotypes for different traits reported by [23]. Under water stress, significant variability was reported by [31,24]. The accumulation of biomass and drought avoidance results in reduction of transpiration rates because assimilation of photosynthesis is totally depend on leaf area and stomatal size which increase the water use efficiency. Water stress at flowering stage reduced the number of kernels and number of kernel rows per ear and even kernel size [32, 33]. Number of kernels is the products of photosynthesis and under low water treatment, the photosynthesis was decreased which results in poor production of number of kernels and in distribution of biomass to different plant organs [34, 13] which supports our findings. The biomass production can be enhanced by increasing the soil moisture uptake required for evaporation that results decrease in moisture content through evaporation. Ear length and ear diameter is directly related to yield. In maize with increasing low water treatment intensity the grain yield was reduced. Similar results were reported and supported by [35]. Under low water treatment, a significant relation has been reported between low root mass and increase ear growth. The main component of yield is the grain yield per plant and harvest index that are directly related to the amount of water use efficiency [36]. Under low water treatment, photosynthesis can decrease [37] and results in poor production of biomass and distribution of biomass to different plant organs.

The important breeding program in maize is estimation of GCA and SCA of lines in first generation [38]. Combining abilities and gene effects played a vital role in plant breeding to get promising genotypes for water stress environment, [39]. For evaluation of developed hybrids, the evaluation and selection of parents was the main objective of the study. General and specific combining abilities effects give important genetic information in parent selection on the basses of their hybrids performance. [40]. General combing ability is the average performance of a line in hybrid combinations and it gives the estimates of GCA effects of parents for its potential utilization for generating superior genotypes, while SCA is used to designate deviation of certain crosses from expectation on the basses of average performance of the parents involved [41, 42]. High GCA value including positive and negative indicate that the parental mean is superior or inferior to the general mean and gave information about the concentration of dominant gene with additive effects whereas SCA gives non-additive interactions. The selection of the parents was made on the combination of SCA, GCA and hybrid mean. The frequency of favorable genes increases with best combination was hybrid mean, favorable SCA and high GCA effects [43]. Low GCA and SCA can be improved through intra and inter population selection. In present study GCA effects of lines and testers had variable direction and magnitude.

It is obviously evident that SCA effects vary both in direction and magnitude. The cross DR-194 × Ev-6098 had the highest significant SCA effects for plant height, cross DR-177× EV-6098 and cross DR-194 × Ev-6098 for leaf area in the first and second seasons, cross DR-194 × Pak Afgoee in the 1st season and cross DR-198 × EV-6098 in the 2nd season for number of kernels per row, cross DR-158 × Ev-6098 in the 1st and cross DR-187 × Pak Afgoee in the 2nd season for ear length, cross DR-159 × Pak Afgoee in the 1st season and cross DR-189 × Ev-6098 in the 2 nd season for ear diameter, cross DR-189 × Ev-1098 for grain yield per plant in both seasons, cross DR-159 × Sadaaf in season-I and cross DR-159 × Pak Afgoee in season-II for harvest index, for SCA effects under water treatment1. Under water treatment 2 and 3, cross DR-189 × Ev-1098 in the 1st season and cross DR-177 × EV-6098 in the 2nd season had the highest positive and significant SCA effects for plant height.

Some crosses with significant SCA effects involved in which both the parents with significant GCA effects and in some crosses at least one parent had significant GCA effects indicating the predominance of additive genetic effects for the trait. Crosses in which one of the parents had significant GCA indicated the presence of non-additive genetic effects controlling that character. Cross DR-177 × EV- 6098; cross DR-158 × EV-1098, cross DR-185 × Ev-6098 and cross DR-177 × Sadaaf showed high SCA effects for grain yield and its components. For selection of lines as parents, only SCA effects had limited value. Therefore, SCA effects are used in combination with parameters like hybrid means and GCA of the respective parent. The cross combination with good mean, favorable SCA and at least one parent with GCA effects, tend to increase favorable alleles. Hybrids were evolved through, high × high, high × low and low × low general combiners, such as DR-159 × Pak Afgoee, DR-177 × Pak Afgoee, DR-198 × Sadaaf and DR-158 × 6098 for plant height and DR-177 × EV-6098, DR-198 × Pak Afgoee, DR-185 × Pak Afgoee, DR-177 × EV-1098, DR-198 × EV-1098, DR-194 × Pak Afgoee, DR-189 × Ev-1098, DR-187 × Sadaaf and DR-187 × Ev-1098 for grain yield per plant.

It is observed that high positive SCA effects were observed in which both the parents involved had positive GCA effects for grain yield per plant crosses DR-177 × EV-6098, DR-198 × Pak Afgoee and DR-185 × Pak Afgoee have positive high SCA effects and hybrid DR-177 × Ev-1098, DR-198 × EV-1098 and DR-194 × Pak Afgoee for grain yield per plant in which at least one parent had positive high GCA value. None of the parents have high GCA effects for grain yield per plant in crosses DR-189 × Ev-1098, DR-187 × Sadaaf and DR-187×EV-1098 which indicate that any combination of parents with high or low GCA effects can results in high SCA effects. It is clear that hybrid combination are not always due to best general combining ability effects, but hybrid means and GCA effects of parents both are considered together. High means of hybrids with favorable SCA effects along with parents with high GCA effects is actually due to high concentration of favorable alleles, which is good for plant breeders. For grain yield per plant, significant and highest GCA effect was recorded in parental line DR-198 and it showed significant GCA effects for plant height. Tester revealed significant positive GCA effects for 100-grain weight.

CONCLUSIONS

It can be concluded that discrimination of genetic material under three water regimes in two seasons for the conservation of plant biodiversity to bear water stress on the basis of general combining ability effects indicates lines DR-177, DR-198, DR-194, Pak Afgoee and EV-6098 can be successfully used in hybridization program in future progress and specific combining ability indicates that crosses DR-177 × EV-6098, DR-198 × EV-1098 and DR-198 × EV-6098 are the hybrids with outstanding heterotic values.

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