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HETEROSIS AND PROPORTIONAL CONTRIBUTION OF LINE × TESTER INTERACTION AND GENE ACTION IN DIFFERENT MAIZE HYBRIDS UNDER WATER REGIMES

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ABSTRACT

The project is based on line × tester analysis to study the heterosis, proportional contribution of line, testers and line × tester interaction and gene action in cross combinations of diverse maize genotypes under normal irrigation and water stress conditions. Twelve parents comprised of eight inbred lines as females and four as male; were crossed to produce 32 F_1 hybrids. Parents along with their hybrids were evaluated in Completely Randomized Design (CRD) with three replications in two seasons. The heterotic value**,** proportional contribution of Lines, Testers and Line × Tester interaction and gene action was studied for the characters i.e. plant height, leaf area per plant, kernels per row, ear length, ear diameter, grain yield per plant and harvest index. Variable heterosis both in magnitude and direction was evident. Non-additive gene effects were observed for plant height, kernels per rows, ear length, ear diameter, grain yield per plant and harvest index for successful breeding programme.

Key words: Maize, Water stress, Line × tester, Heterosis, Gene Action, Additive, Susceptible.

INTRODUCTION

Maize is a versatile plant and can be grown on a wide range of climatic conditions from temperate to mountainous areas of warm plans in tropical regions. Maize is one of the major components of human food and animal feed thus grown for both grain and forage purposes. The demand for maize has also increased significantly due to rapid development of poultry and animal feed industries. Almost the whole plant is utilized in different forms either directly or indirectly to produce different byproducts (Taufiqullah and Noorka, 2014). Due to rapid increase in population of developing countries, the demand for food is increasing with every passing day, and this pressure for high food demand will continue for next three decades to come (USDA, 2011). Maize is a C4 plant and is generally showing good yields potential in the areas with sufficient amount of irrigated water. It is an efficient user of water in terms of biomass production among cereals. Maize is highly responsive to water shortages (Cakir, 2004). Despite of the strenuous efforts, the water availability is continuously decreasing in Pakistan. Chowdhry *et al.,* (1999); Noorka and Heslop-Harrison (2015). The main reason for the low availability of water is due to changes in climatic condition in the world level. For the maize crop, there are many constraints in maize production including different kinds of biotic and abiotic stresses. Biotic stresses include pathogens, diseases and bacteria (Salasya *et al*., 1998; Mohamed *et al*., 2010).Among many abiotic stresses salinity, fluctuating heat pattern, temperature variations, high pH, metal toxicity and water stress have detrimental effects on plant growth and yield particularly when they occur simultaneously in different combinations (Borlaug and Dowswell, 2005). The use of uncertified, low-quality seed with repeated use of hybrid seed is also restraining the maize productivity mainly due to high prices of the seeds (Salasya *et al.,* 1998). Due to lack of timely availability of capital to farmers, they are unable to purchase good quality seed and continue recycling the hybrid seeds (Pixley and Banziger, 2001).

Maize is a highly cross pollinated crop and can be successfully used for exploitation of hybrids. Properly selection of parental lines is very important step in the development of hybrids in breeding program (Lippman and Zamir, 2007). Krivanek *et al.* (2007) declared that heterosis and combining ability is pre-requisite for developing a desirable maize hybrid that are economically viable, used as a commercial maize hybrid variety. Information on heterosis and combining ability among germplasm is essential in maximizing the success of hybrid development. In heterosis responses of newly developed hybrids largely depend on genetic diversity present among parental lines and environmental conditions and heterosis response increases with increased genetic diversity (Rauf *et al*., 2012).Due to the future threats of water shortage; there is a dire need to estimates the genetic potential of various cultivars to have good yield potential along with nutritional and commercial abilities, which can escape the plant through hazard of water stress. Such investigation will be used to formulate a breeding program for development of new hybrids to ensure sustainable quality maize production in water deficit areas. It started with the development of short stature and high yielding varieties with more tolerance for lodging. With the introduction of semi dwarf gene especially in wheat and maize, are giving much response to irrigation and nitrogen fertilizer. This challenge has much importance for plant breeder to develop an effective package for development of new genotypes that are better adapted to adverse climatic conditions (Ashraf, 2010; Noorka *et al*., 2013a).

The objective of the present study was to investigate the parents and crosses under different water regimes in Line × tester analysis, its direction and magnitude of gene action and heterotic effects to obtain reliable genetic information of desirable traits in maize breeding program. This information helps the breeder to optimize the breeding strategy under drought stress conditions (Stubler, 1994; Amiruzzaman *et al.,* 2010) and the project is expected to give scientific information on maize yield components under water stress environment and generate plant material useful for breeding maize under water stress conditions.

MATERIALS AND METHODS

Total forty-four genotypes (32 crosses and 12 parents) were sown in the polythene bags (45 × 30 cm) filled with mixture of soil (Soil, Silt and organic matter, in equal amount) having (pH. 8.2 and EC.0.4) under three water treatments i.e. T1, T2 and T3 in wire-house of Department of Plant Breeding and Genetics, University College of Agriculture, University of Sargodha, Sargodha, Pakistan. Recommended agronomic, cultural and plant protection measures were kept uniform to all the three sets of experiment except irrigation water. Insecticide was applied to control shoofly and borer attack. Two factor factorial triplicate randomized complete designs were followed. Each genotype was sown in three lines per replication per treatment in two seasons during spring season, in March, 2011 and autumn season, in August, 2011. Three water treatments were applied following Kirda *et al.,* 2005; Noorka and Tabasum, 2015)
Water treatment 1= T1 Eighty percent of field capacity, Water treatment 2 = T2 Sixty percent of field capacity, Water treatment 3 = T3 Forty percent of field capacity.

The data were recorded for the following traits on appropriate time e.g plant height, leaf area per plant. number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index

Biometrical Approaches: Rerecorded data on maize germplasm were statistically analyzed (Steel *et al.,* 1997) and data from genetic materials (crosses and parents) were subjected to line × tester analysis of variance (ANOVA) as outlined by Kempthorne (1957).

Heterosis: Heterosis over better parent was estimated as followed by Falconer and Mackay, (1996).

T-test was calculated to compare significance of heterosis (Wynne *et al.,* 1970).

Proportional Contribution of lines, Testers, and their interaction to total variance:

Contribution of lines = $\{ss(l) / ss(crosses)\} \times 100$

Contribution of testers = $\{ss(t) / ss(crosses)\} \times 100$

Contribution of (lxt) = {ss ((lxt)/ ss (crosses)} ×100

RESULTS

Analysis of variance for the different traits in line × tester analysis is presented in Table 1 under contrasting water regimes in controlled conditions for season-I and II. The results revealed highly significant differences (P ≤ 0.01) among diverse genotypes. Parents, crosses and parents vs. crosses and line × tester were also significant (P ≤ 0.01) for most of the traits under three water conditions and two seasons which showed significant differences among genotypes, parents, crosses, parents vs. crosses, lines, testers and line × tester interaction for the trait plant height, leaf area per plant, number of kernel rows per ear, ear length, ear diameter, biological yield, grain yield per plant and harvest index. Line × tester interaction had significant differences for all the traits under study.

Heterosis manifestation in 32 maize genotypes for plant height, leaf area per plant, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index under T1: water treatment180% of field capacity, T2: water treatment 2, 60% of field capacity and T3: water treatment 40% of field capacity in season-I and II (Table-2), was observed in variable magnitude and direction. Under water treatment1 in season-I, the cross DR-198 × EV-1098 showed best performance for plant height, Cross DR-177 × EV-6098 for leaf area per plant, hybrid DR-187 × Pak Afgoee for number of kernels per row, none of the cross for ear length, Cross DR-198 × EV-1098 for ear diameter, hybrid DR-198 × Pak Afgoee for grain yield per plant and cross DR-159 × Sadaaf had maximum positive and significant heterotic value while cross DR-198 × Sadaaf for plant height, cross DR-177 × Ev-1098 leaf area per plant, cross DR-177 × EV-6098 for number of kernels per row ,cross DR-189 x Ev-6098 for ear diameter, cross DR-159 × Sadaaf for grain yield per plant and cross DR-198 × Sadaaf had minimum heterotic value. In season-II, the cross combination DR-198 × Sadaaf showed maximum positive and significant heterosis for the trait plant height, the cross combination DR-177 × EV-6098 for leaf area per plant, cross DR-187 × Sadaaf for number of kernels per row, cross DR-198 × EV-1098 for ear diameter, cross DR-198 × Pak Afgoee for grain yield per plant and cross DR-185 × Pak Afgoee for the trait harvest index. The zero heterosis was showed by the cross combination DR-198 × EV-1098 for the traits like plant height, cross DR-159 x Ev-6098 for leaf area per plant, cross DR-185 × Pak

Afgoee for number of kernels per row, crosses DR-198 × Sadaaf and DR-189 x Ev-6098 for ear diameter, cross DR-159 × Sadaaf for grain yield per plant and cross DR-159 × Pak Afgoee for harvest index.

Similarly under water treatment 2, in season-I, the cross combinations DR-198 ×EV-1098 revealed maximum positive and significant heterotic effect for the traits like plant height, Cross DR-177 × EV-6098 for leaf area per plant, cross DR-187 × Sadaaf for number of kernels per row, cross DR-194 × Sadaaf for ear length, Cross DR-198 × EV-1098 for ear diameter, cross DR-198 × EV-1098 for grain yield per plant and cross DR-159 × Sadaaf for harvest index. In season-II, the cross combination DR-159 × Ev-1098 showed maximum positive and significant heterosis, for the traits plant height, cross DR-159 × Ev-6098 for leaf area per plant, cross DR-187 × Sadaaf for number of kernels per row, none of the cross for ear length, cross DR-187 × Ev-6098 for ear diameter, cross DR-185 × Ev-6098 for grain yield per plant and cross DR-177 × EV-6098 for the trait harvest index. Similarly the cross combinations DR-194 × EV-1098 had minimum and significant heterosis for the traits like plant height, cross DR-177 × EV-6098 for leaf area per plant, cross DR-185 × Sadaaf and cross DR-185 × Pak Afgoee, and cross DR-189 × Sadaaf had zero heterosis for number of kernels per row. Under water treatment 3 in season-I, the hybrids DR-189 × Ev-1098 had maximum positive and significant heterosis for the trait plant height, cross DR-185 × Ev-1098 for leaf area per plant, hybrid DR-187 × Sadaaf for number of kernels per plant, cross DR-187 × Ev-6098 for ear length, hybrid DR-185 × Ev-6098 for grain yield per plant and cross DR-177× Ev-608 for harvest index. Minimum positive and significant heterotic effects were shown by the cross combinations DR-194 × Sadaaf for the traits like plant height, cross DR-198 × EV-6098 for leaf area per plant, cross DR-187 × Pak Afgoee for number of kernels per plant, cross DR-177 × Sadaaf and cross DR-194 × Pak Afgoee had zero heterosis for ear diameter. In season-II, the cross combinations DR-189 × Ev-1098 depicted maximum positive and significant heterosis for the trait plant height, cross DR-185 × Ev-6098 for leaf area per plant, cross DR-187 × Sadaaf for number of kernels per row none of the cross for ear length, cross DR-187 × Ev-6098 for ear diameter, cross DR-185 × Ev-6098 for grain yield per plant and cross DR-177 × EV-6098 for harvest index. while the minimum and significant heterosis was shown by the cross combination DR-194 × EV-1098 for the trait plant height, cross DR-159 × Ev-6098 for leaf area per plant, cross DR-189 × Sadaaf had zero heterosis for number of kernels per row, cross DR-198 × EV-1098 and cross DR-189 × Sadaaf had heterosis (zero) for ear diameter, cross DR-194 × Ev-6098 for grain yield per plant.

Proportional Contribution: Under three water treatment T1: water treatment180% of field capacity, T2: water treatment 2, 60% of field capacity and T3: water treatment 40% of field capacity in season-I and II, Proportional contribution of Lines, Testers and Line × Tester and Gene Action for plant height, leaf area per plant, number of kernels per row, Line × tester interaction for ear length, grain yield per plant and harvest index presented in Table-1 and 3.Under water treatment 1 in season-I, Lines × testers interaction for plant height, line for leaf area per plant, Lines for number of kernels per row, lines for ear length ,Line × tester interaction ear diameter, Line × tester interaction for grain yield per plant and Line × tester interaction for harvest index contribute maximum in the total phenotypic variance. In season-II, lines × tester's interaction for plant height, Line × tester interaction for leaf area per plant, Line × tester interaction for the number of kernels per row, Line × tester interaction for ear length ,Line × tester interaction for ear diameter, Line × tester interaction for grain yield per plant and Line × tester interaction for harvest index shared maximum in the phenotypic variance. Under water treatment2 in season-I, Line × tester interaction for plant height, Line × tester interaction for leaf area per plant, Lines for number of kernels per plant, Lines for ear length, lines for ear diameter, Line × tester interaction for grain yield per plant and Line × tester interaction for harvest index was shared maximum contribution in the total phenotypic variance. In season–II, Line × tester interaction for plant height, Line × tester interaction for leaf area per plant, Lines for number of kernels per row, Lines for ear length, Lines for ear diameter, Line × tester interaction for grain yield per plant and Line × tester interaction for harvest index had maximum contribution in phenotypic variance. Under water treatment 3 in season-I, proportional contribution of lines × testers' interaction for plant height Line × tester interaction for leaf area per plant, Lines for number of kernels per row, Line × tester interaction for ear length, Line × tester interaction for ear diameter, lines × tester interaction for grain yield per plant and lines × tester interaction for harvest index had more contribution in total phenotypic variance. In season-II, lines × testers' interaction for plant height, lines × testers' interaction for leaf area per plant, Lines for number of kernels per row, Line × tester interaction for ear length, Line × tester interaction for ear diameter, lines × tester interaction for grain yield per plant and lines × tester interaction for harvest index had more contribution in the total phenotypic variance.

Gene Action: Under water treatment T1, T2 and T3 in season-I and II, the gene action was based on additive and non-additive effects that played an important role in the heritance of plant traits. Non-additive effects ware observed for plant height, leaf area per plant, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index (Table-3).

Table-1 ANOVA for 32 maize genotypes for plant height, leaf area per plant, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index under controlled conditions in season-I and II

		Season-I								Season-II						
SOV	**df**	**T**	**Pl.ht**	**L.A**	**N.K**	**E.L**	**E.D**	**GYPP**	**H.I**	**Pl.ht**	**L.A**	**N.K**	**E.L**	**E.D**	**GYPP**	**H.I**
		T1	1618**	7373.4**	7.29**	9.27**	0.3**	6575.2**	1064**	1618.3**	7932.7**	5.88**	30.09**	0.26**	6524.9**	740.5**
GEN	43	T2	606.6**	5976.4**	4.06**	6.05**	1.3**	5304.8**	716**	894.4**	5932**	5.29**	34.8**	0.56**	5194.9**	256.7**
		T3	699.1**	5241.7**	3.84**	17.4**	0.09**	9623.5**	115.7**	702.1**	5294.5**	4.59**	23.7**	0.57**	9249.8**	137**
		T1	991.8**	2068.1**	6.26**	15.43**	0.3**	2740.4**	1346**	949.2**	3246.6**	6.82**	35.0**	0.4**	2920.5**	43.03**
PAR	11	T2	927.2**	1367.9**	4.67**	1.48**	1.3**	4028.9**	52.8**	1477.4**	2085**	5.69**	46.5**	0.9**	4166.92**	30.9
		T3	11198**	1004.3**	4.20**	18.57**	0.07*	5802.3**	56.4**	1178.3**	1563.7**	5.44**	25.2**	0.9**	5943.2**	60.3
		T1	1593.9**	5393.5**	4.97**	4.7	0.3**	8094.7**	1405**	1583.7**	5864.7**	4.19**	16.4**	0.2**	7896.3**	995.8**
CRO	31	T2	466.8**	4597.2**	2.82**	7.40**	1.3**	5858.2**	919**	716.2**	3528**	3.65**	15.6**	0.45**	5572**	337.1**
		T3	544.3**	4490.6**	2.26**	14.94**	0.1**	11203**	137**	548.7**	3182.2**	3.01**	13.5**	0.47**	10621**	165.3**
		T1	9269**	127110**	90.7**	82.9**	0.7**	1651.4**	2065**	10049.8**	123586.3**	48.01**	399.1**	0.8**	3663.3**	501.4**
P vs C	1	T2	1414.9**	99426**	35.6**	14.4**	0.01	2186.1**	1738**	5.67	122786**	51.52**	503.1**	0.1	3094.2**	246
		T3	7.7**	75137.5**	49.0**	90.5**	0,01	2680.4**	113.4**	218.2**	111816.4**	44.15**	324.8**	0,1	3121.7**	110.4**
		T1	2726	14988**	7.62	6.7	0.6*	10226	1724.4	2680.8	16040.4**	5.95**	21.1**	0.3	10328.5	1078.3
Lines	7	T2	333.0**	12866**	5.76**	17.18**	3.2**	7304.6	1369	1209.5*	2488**	5.79	21.98	0.98**	8105.7	495
		T3	269.4**	11433.**	3.47	28.3*	0.14	11096	153.1	1078.5	7744.4**	4.33	16.70	0.95**	11806	210.5
		T1	763.0	5829.3**	1.44	3,3	0.2	2711.1	1648.6	787.3	7478.6*	1.15	1.2	0.2	2237	403
Testers	3	T2	295.5**	5223.1**	2.67*	1.7**	1.01	6079.1	470	793.5	124	0.72	0.49	0.5	5583.2	12.02
		T3	545.9**	5428.6	0,15	12.8	0.07	17191	159	336.2	3854.7	1.15	0.84	0.43	15011	125.5
Lines x	21	T1	1335**	2132.9**	4.59**	4.3	0.24**	8153.5**	1264**	1331.7**	2242.3**	4.04**	17.1**	0.19**	7894.1	1052.9**
Testers		T2	535.8**	1751.5**	1.86*	4.97**	0.76**	5344.5**	833**	540.7**	4361**	3.36**	15.57**	0.27**	4726**	330.9**
		T3	635.7**	2042.3**	2.15**	10.79**	0.1**	10383.7**	128.2**	402.5**	1565.3**	2.84**	14.24**	0.3**	9599**	156**
		T1	41.04	28.63	0.55	4.06	0.03	2.34	1.10	22.09	134.0	0.83	0.31	0.03	11.14	2.12
Error	86	T2	22.22	36.58	0.95	0.28	0.12	28.88	10.4	46.72	143	0.89	0.98	0.04	46.3	158
		T3	30.51	113.8	0.66	1.93	0.04	113.7	8.12	30.10	179.6	0.60	0.56	0.04	97.52	9.79

df: Degree of freedom, SOV. Source of variance: GEN. Genotypes, PAR: Parents. CRO: Crosses, P vs C : Parents vs crosses, T1: water treatment1, T2: water treatment 2, T3: water treatment 3, pl.ht: plant height, L.A: leaf area per plant, N.K: number of kernels per row, E.L: ear length, E.D: ear diameter, GYPP: grain yield per plant and H.I: harvest index

Table-2 Heterotic effects in 32 maize genotypes for plant height, leaf area per plant, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index under controlled conditions in season-I and II.

		Season-I							Season-II						
Crosses		**Pl.ht**	**L.A**	**N.K**	**E.L**	**E.D**	**GYPP**	**H.I**	**Pl.ht**	**L.A**	**N.K**	**E.L**	**E.D**	**GYPP**	**H.I**
DR-187 ×	T1	-12.5	-34.51	17.78	-12.16	-4.12	-18.77	-29.17	-13.28	-41.37	1.98	-12.5	-2.04	-21.38	-48.99
Pak Afgoee	T2	-25.34	-54.1	4.06	-7.64	-2.04	-23.51	-32.11	-30.7	-41.16	3.06	-18.18	-3.37	-24.93	-55.28
	T3	-40.25	57.9	4.21	-12.96	-2.09	-28.59	-35.22	-40.53	-44.66	3.09	-9.43	-3.61	-28.65	-55.1
DR-187 ×	T1	-36.45	-41.19	13.33	-26.46	-11.82	-21.89	-29.49	-35.98	-31.85	16.09	-36.67	12.9	-21.56	-31.52
Sadaaf	T2	-35.76	-35.71	19.05	-4.82	12.9	-25.54	-22.4	-28.21	-32.63	23.46	-39.34	22.81	-25.42	-44.37
	T3	-36.11	-16.22	25.65	-32.35	-11.7	-29.43	-15.13	-35.95	-43.52	23.75	-35.42	-9.86	-29.47	-51.77

DR-187 × Ev-1098	T1	-48.6	-17.54	10	-33.54	-2.06	-18.9	8.46	-48.6	21.34	5.43	-54.41	9.41	-20.47	-27.59
	T2	-32.37	36.83	5.49	-2.6	10.71	-22.36	-6.04	-4.64	-2	5.56	-57.14	36.84	-23.28	-44.22
	T3	-12.66	-0.83	5.68	-30.19	-7.22	-26.05	-20	-12.5	-4.69	5.62	-52.73	15.63	-26.24	-53.68
DR-187 × EV-6098	T1	-39.95	-49.67	7.78	-6.07	-7.92	-23.34	-15.08	-39.49	-6.73	5.75	-41.67	-17.14	-24.53	-15.89
	T2	-33.55	10.1	9.52	-2.22	-20	-26.59	-9.13	-34.8	-5.97	8.54	-44.26	59.65	-27.14	-40.74
	T3	-32.62	0.26	8.75	31.25	-3.26	-30.06	-5.65	-32.11	26.58	8.64	-52.94	40.98	-29.89	-40.98
DR-177 × Pak Afgoee	T1	-11.85	-6.31	-11.76	-34.17	13.98	-18.97	-5.36	-12.63	-14.7	-14.85	-57.81	8.16	-20.57	2.53
	T2	-25.57	-41.59	-12.18	-12.23	8.16	-18.31	7.65	-44.56	-39.58	-13.27	-60.61	-16.85	-19.32	-39.75
	T3	-42.47	-40.71	-13.69	-25.93	-0.99	-17.59	21.38	-43.65	-30.2	-13.4	-52.83	-4.82	-17.96	-45.58
DR-177 × Sadaaf	T1	-30.5	-20.63	-2.35	-33.14	2.73	17.56	-19.23	-30.73	-21.71	-3.61	-38.33	1.08	14.32	-20.65
	T2	-34.23	16.68	-1.84	-3.61	1.08	-3.25	-11.69	-44.84	-60.97	-1.25	-42.62	-14.1	-5.1	-37.09
	T3	-38.61	-34.85	-1.27	-43.14	0	-26.11	-3.95	-40	-19.18	-1.27	-39.58	-16.22	-26.33	-39.01
DR-177 × Ev-1098	T1	-18.1	12.92	-13.83	-32.92	21.05	-15.41	-2.31	-18.33	1.12	-20.65	-54.41	3.33	-16.01	-6.9
	T2	-15.39	-8.02	-17.58	-6.62	-33.72	-15.02	-0.75	-3.48	-10.95	-21.11	-57.14	-35.9	-15.4	-44.9
	T3	-5.52	-62.33	-21.59	-24.53	-2.78	-14.6	0.74	-9.38	11.07	-21.35	-58.18	-39.19	-14.74	-50.74
DR-177 × EV-6098	T1	-28.96	101.97	0	-23.88	19.8	16.35	24.08	-28.04	78.77	-7.23	-36.67	-10.48	12.93	-30.46
	T2	-23.52	126.54	-4.94	-1.74	-32.86	16.99	6.69	-18.14	8.68	-9.76	-40.98	-16.67	14.95	-45.19
	T3	-18.45	-44.91	-10	-29.17	4.51	17.7	-10.48	-19.47	20.2	-9.88	-45.1	-18.92	17.16	-43.44
DR-198 × Pak Afgoee	T1	-24.35	21.89	-28.43	-34.7	12.9	25.74	-10.12	-25.48	-27.73	-30.69	-53.13	-4.08	23.69	-33.84
	T2	-17.89	-50.52	-29.44	-10.92	-30.61	0.04	-11.62	-21.11	-54.99	-30.61	-59.09	-31.46	-1.33	-53.42
	T3	-14.32	-25.87	-30.53	-27.78	4.55	-26.98	-13.21	-16.07	-40.31	-30.93	-58.49	-32.53	-27.27	-53.74
DR-198 × Sadaaf	T1	8.98	-20.15	-9.8	-27.32	-10.91	-6.55	-4.49	9.46	-8.29	-9.69	-42.5	0	-7.95	-47.83
	T2	3.7	-16.89	-8.25	-6.51	0	-12.66	-19.48	-4.79	-30.7	-7.37	-45.9	-33.33	-8.06	-35.76
	T3	-2.22	57.86	-6.52	-22.55	-1.06	-19.07	-34.87	-4.32	7.15	-7.45	-45.83	-33.8	-8.17	-41.84
DR-198 × EV-1098	T1	9.41	28.95	-4.9	-26.39	24.69	18.98	-21.54	9.05	47.36	-5.1	-34.56	20.24	17.79	-41.38
	T2	6.52	34.04	-4.12	1.65	20.24	19.8	-23.4	2.61	30.68	-4.21	-40	-4.29	18.66	-44.22
	T3	4.87	21.29	-3.26	-31.13	1.03	20.65	-25.19	1.56	36.21	-4.26	-34.55	0	19.56	-50.74
DR-198 × EV-6098	T1	-15.59	-4.18	-7.84	-8.36	-17.82	16.83	-14.29	-14.89	19.35	-6.12	-22.5	-17.14	16.15	-49.01
	T2	-14.78	14.36	-6.19	9.2	-17.14	16.38	-24.95	-15.69	10.82	-5.26	-42.62	-10.77	15.32	-20
	T3	-14.71	6.19	-4.37	-6.25	3.26	15.91	-35.48	-11.16	31.37	-5.32	-25.49	-11.48	14.46	-27.87
DR-194 × Pak Afgoee	T1	-45.69	-33.6	-0.98	-29.16	3.23	9.02	-43.45	-46.25	-18.41	-4.95	-38.28	-8.16	5.5	-37.37
	T2	-29.13	-44.14	-2.03	-5.68	-32.65	10.95	-33.64	-27.29	-31.02	-4.08	-42.42	-30	8.62	-46.58
	T3	-22.47	17.81	-3.15	-38.89	0	13.05	-23.27	-24.22	-16.72	-4.12	-45.28	-30.59	12.08	-51.02
DR-194 × Sadaaf	T1	-56.97	30.13	-12.63	-15.95	-8.18	-25.14	-29.49	-56.74	-17.92	-12.77	-38.33	2.13	-27.06	-41.3
	T2	-9.6	-25.44	-12.5	32.53	-28.72	-23.8	-30.19	3.53	-33.64	-12.09	-42.62	-32.22	-24.47	-42.38
	T3	3.33	-49.41	-12.36	-21.57	-1.06	-22.34	-32.69	-1.08	-1.9	-12.22	-41.67	-34.12	-21.6	-43.97
DR-194 × EV-1098	T1	-49.76	89.17	-17.89	-21.45	10.99	-27.28	-43.85	-49.52	-37.26	-19.15	-44.12	-1.06	-29.43	-41.44
	T2	-7.63	-40.38	-18.48	26.55	-44.15	-10.5	-35.04	10.44	-29.96	-18.68	-45.71	-47.78	-12.92	-23.81
	T3	8.77	-25.33	-19.1	-18.87	-8.25	7.83	-32.69	5.31	-6.95	-18.89	-43.64	-49.41	5.4	-30.15
DR-194 × Ev-6098	T1	0.74	95.59	-13.68	-22.39	-9.9	-24.86	-55.92	1.24	31.63	-23.4	-37.5	-13.33	-26.94	-50.83
	T2	-16.58	69.02	-17.93	4.22	-42.86	-9.53	-47.45	-29.17	9.99	-21.98	-42.62	-33.33	-11.74	-28.89
	T3	-29.68	0.28	-22.47	-22.92	-4.35	7.2	-42.31	-30.53	1.61	-22.22	-41.18	-35.29	5.11	-35.25

DR-158 × Pak Afgoee	T1	-17.67	-35.29	-33.02	-30.23	13.98	-7.06	-22.62	-18.2	-14.04	-33.98	-32.03	-6.12	-7.3	-50.51
	T2	-23.74	-41.14	-33	-21.4	-47.96	2.61	-29.66	-36.89	-29.23	-33	-37.12	-44.94	1.51	-44.1
	T3	-30.62	-35.13	-32.98	-31.48	1.11	13.02	-37.11	-27.94	-38.12	-32.65	-33.96	-54.22	10.88	-46.26
DR-158 × Sadaaf	T1	-32.86	-27.06	-30.19	-29.32	-15.45	-16.05	-22.44	-33.57	-21.19	-31.07	-37.5	-4.3	-15.74	-21.2
	T2	-22.07	-3.49	-30.54	-3.61	-29.03	-23.2	-14.94	-18.14	11.83	-31	-44.26	-20	-22.94	-43.38
	T3	-13.33	39.25	-30.94	-29.41	-3.19	-30.89	-7.24	-14.6	-17.9	-30.61	-43.75	-23.94	-30.6	-44.68
DR-158 × Ev-1098	T1	-40.24	-4.92	-15.09	-36.89	-4.35	-15.16	-5.54	-40.24	-7.84	-16.5	-52.21	-16.67	-15.64	-39.66
	T2	-13.88	-16.17	-15.27	9.93	-16.67	-29.94	-14.04	-1.45	-32.54	-16	-58.57	-30.56	-30.03	-36.73
	T3	5.84	7.37	-15.47	-37.74	-10.31	-45.86	-22.22	3.75	58.79	-15.31	-60	-28.79	-45.34	-36.03
DR-158 × Ev-6098	T1	-6.93	39.97	-14.15	-20.4	-2.97	-16.95	-0.81	-6.95	54.19	-14.56	-42.5	-14.29	-16.82	-49.01
	T2	-19.28	54.19	-13.79	23.52	-32.38	-24.49	-18.55	-33.33	3.32	-14	-49.18	-12.5	-24.86	-42.22
	T3	-30.75	-17.4	-13.4	-36.46	-4.02	-32.62	-36	-32.9	23.42	-13.27	-50.98	-10.61	-33.41	-41.8
DR-185 × Pak Afgoee	T1	-34.59	-29.65	0	-34.7	2.15	21.03	-14.29	-34.37	-22.98	0	-55.47	-8.16	19.63	-59.09
	T2	-32.4	-47.26	0.51	13.54	-28.57	-2.26	-31.19	-32.84	-30.65	0	-59.09	-26.97	-3.52	-54.66
	T3	-29.38	-9.74	1.05	-50	-0.96	-27.87	-49.06	-30.7	-18.46	0	-58.49	-25.3	-28.83	-54.42
DR-185 × Sadaaf	T1	-29.79	-39.35	15.38	-35.05	-3.92	-17.13	-25.64	-28.61	-36.81	15.91	-48.33	-4.3	-16.78	-45.11
	T2	-25.26	-14.37	9.77	16.87	-18.28	-11.74	-29.22	-20.15	-32.82	17.65	-54.1	-4	-12.68	-25.83
	T3	-19.17	31.63	3.61	-47.06	-1.06	-5.8	-32.89	-20.54	-28.09	16.67	-49.58	-2.82	-8.2	-28.37
DR-185 × Ev-1098	T1	-32.38	-21.24	0	-28.07	-22.73	-14.82	-15.38	-32.38	20.64	-2.17	-39.71	-10.71	-15.87	-5.75
	T2	-29.9	9.74	-1.1	5.2	-27.38	-22.66	-12.45	-25.8	-49.75	-2.22	-45.71	-25.71	-18.09	-30.61
	T3	-26.3	108.23	-2.26	-35.85	-29.9	-31.29	-9.63	-28.13	-36.02	-2.25	-41.82	-23.44	-20.53	-35.29
DR-185 × Ev-6098	T1	-36.39	-7.6	-4.4	-20.6	3.92	20.2	-8.98	-36.48	18.09	-9.09	-35.83	-12.38	19.56	-15.89
	T2	-20.57	15.87	-6.9	23.88	-28.57	21.63	-13.39	-21.32	18.58	-9.41	-39.34	-7.69	20.77	-31.11
	T3	-18.45	67.21	-9.65	-28.13	-7.35	23.21	-17.74	-18.16	61.59	-9.52	-39.22	-6.56	22.1	-31.15
DR-189 × Pak Afgoee	T1	-31.03	-17.5	-26.47	-26.92	3.03	-17.47	-38.69	-30.19	-29.98	-27.72	-32.03	-5.1	-18.9	-26.26
	T2	-34.17	-52.05	-26.9	-17.69	-22.45	-14.55	-39.45	-18.12	-50.66	-27.55	-36.36	-26.97	-16.25	-45.96
	T3	-37.04	-20.86	-27.37	-27.78	-3.26	-11.3	-40.25	-37.89	-29.07	-27.84	-30.19	-25.3	-13.32	-51.02
DR-189 × Sadaaf	T1	-22.46	-45.38	1.18	-18.82	-13.64	-19.74	-30.13	-22.46	-14.23	-1.2	-21.67	-15.05	-18.89	-17.39
	T2	-14.3	-22.28	0.61	-2.41	-15.05	-19.65	-27.27	-4.53	-29.74	0	-22.95	-1.33	-20.07	-31.13
	T3	-5	-14.66	0	-27.45	-7.47	-19.55	-24.34	-7.03	-37.86	0	-20.83	0	-21.37	-37.59
DR-189 × Ev-1098	T1	-9.05	-45.99	-13.83	-18.8	-6.06	11.73	-15.81	-8.1	3.97	-11.96	-18.38	5.95	10.64	-45.4
	T2	-0.96	3.97	-13.19	-6.38	-35.71	-5.47	-20.04	11.01	1.36	-12.22	-24.29	-25.71	-6.91	-26.53
	T3	9.74	-31.95	-12.49	-18.87	-4.12	-24.63	-26.67	8.44	45.7	-12.36	-20	-23.44	-26.31	-36.03
DR-189 × Ev-6098	T1	-22.53	-43.28	-1.22	-26.17	6.93	-18.79	-11.03	-23.08	0.89	-7.23	-38.33	0	-20.24	-19.87
	T2	-27.25	0.89	-6.17	-1.24	0	-0.87	-9.74	-31.62	-2.16	-9.76	-44.26	21.54	-2.74	14.07
	T3	-31.02	-37.08	-11.24	-18.75	6.2	19.1	-8.4	-32.71	-23.8	-9.88	-45.1	24.59	16.6	-18.85
DR-159 × Pak Afgoee	T1	-25.22	-50.41	-1.96	-33.54	22.55	-25.17	-26.19	-24.84	-21.74	-2.97	-40.63	-7.14	-25.38	-46.97
	T2	-24.77	-39.24	-4.06	-10.26	-7.14	-28.2	-28.75	-26.44	-34.58	-3.06	-48.48	-23.6	-29.05	-32.3
	T3	-23.7	-54.54	-6.31	-35.19	3.05	-31.57	-31.45	-25.18	-46.28	-5.15	-43.4	-21.69	-33.09	-34.69
DR-159 × Sadaaf	T1	-19.39	-9.38	11.96	-23.97	-17.27	6.15	-21.15	-18.68	-30.84	12.5	-28.33	11.83	5.49	-34.78
	T2	-21.33	-37.33	11.36	3.37	11.83	-6.61	-20.45	-26.95	-9.16	11.63	-34.43	18.67	-7.46	-8.61

	T3	-23.61	-38.45	10.71	-35.29	-6.1	-20.76	-19.74	-24.87	-53.09	11.76	-29.17	19.72	-21.7	-21.28
DR-159 × Ev-1098	T1	-11.19	-1.55	-2.13	-33.8	4.9	-24.88	-2.29	-13.81	28	-3.26	-44.85	7.87	-25.28	-32.18
	T2	-9.05	28	-3.85	-6.38	14.29	-6.41	-6.42	15.65	33.96	-4.44	-50	5.71	-7.36	-8.16
	T3	-2.27	24.67	-5.67	-42.45	-8.25	14.05	-11.11	-2.38	35.41	-4.49	-45.45	10.94	12.32	-28.68
DR-159 × Ev-6098	T1	-5.2	-15.99	1.09	-1.49	-2.94	-21.17	-8.4	-4.22	17.03	2.27	-17.5	-6.67	-21.38	-0.64
	T2	-17.1	17.03	1.7	1.24	-6.67	-21.69	-7.66	-18.14	71.42	2.33	-26.23	-9.23	-17.48	17.78
	T3	-28.61	23.31	2.39	-25	-2.21	-22.27	-6.92	-28.68	9.92	2.35	-25.49	-8.2	-23.53	-26.23

T1: water treatment1, T2: water treatment 2, T3: water treatment 3, pl.ht: plant height, L.A: leaf area per plant, N.K: number of kernels per row, E.L: ear length, E.D: ear diameter, GYPP: grain yield per plant and H.I: harvest index

Table-3 per cent contribution of lines, testers and lines × testers interaction sand gene action for plant height, leaf area per plant, number of kernels per row, ear length, ear diameter, grain yield per plant and harvest index of maize genotypes in 8 line × 4 tester cross under control conditions in season–I and season-II.

Per cent contribution		Season-I							Season-II						
		Pl.ht.	L.A	N.K	E.L	E.D	GYPP	H.I	Pl.ht.	L.A	N.K	E.L	E.D	GYPP	H.I
Lines	T1	38.63	44.45	54.36	32.11	41.94	28.53	27.71	38.22	25.97	49.03	29.04	29.46	29.54	24.45
	T2	16.11	17.17	53.1	52.4	54.07	28.16	33.64	38.13	32.72	51.47	31.9	49.12	32.85	33.15
	T3	11.17	33.43	50.48	42.78	30.87	22.37	25.28	44.38	29.16	51.33	28.03	45.85	25.1	28.75
Testers	T1	4.63	13.18	0.97	6.68	5.3	3.24	11.36	4.81	11.25	1.23	0.68	7.51	2.74	3.92
	T2	6.13	8.37	1.53	2.17	7.36	10.04	4.95	10.72	3.11	3.7	0.3	10.08	9.7	0.35
	T3	9.71	8.94	2.35	8.32	6.17	14.85	11.22	5.93	2.77	3.53	0.6	9.01	13.68	7.35
Line × tester	T1	56.74	42.37	44.67	61.21	52.76	68.23	60.93	56.97	62.78	49.75	70.28	63.04	67.72	71.63
	T2	77.76	74.46	45.37	45.43	38.57	61.8	61.42	51.15	64.17	44.83	67.8	40.8	57.46	66.51
	T3	79.13	57.64	47.17	48.91	62.96	62.79	63.5	49.69	68.08	45.14	71.37	45.14	61.22	63.9
Dominance б	T1	431.34	1043.24	7.25	1.56	0.07	2717.04	420.9	436.55	545.07	8.61	5.58	0.05	2627.64	350.28
	T2	171.21	2129.34	7.13	1.56	0.21	1771.86	274.25	164.68	891.8	7.88	4.87	0.08	1559.86	57.71
	T3	201.74	1450.86	7.23	2.96	0.02	3423.32	40.04	124.12	904.25	7.74	4.56	0.09	3167.04	48.7
Additive б	T1	1.56	13.82	0.07	0.02	0	-0.35	0.85	1.51	1.21	0.07	-0.01	0	0.01	-0.34
	T2	-2.74	-3.93	0.06	0.02	0.01	3.09	0.52	1.05	1.23	0.07	0	0.01	5.08	0.04
	T3	-3.64	5.17	0.06	0.03	0	4.93	0.05	0.88	-0.11	0.07	-0.01	0.01	6.14	0.06
Potence ratio (Degree of dominance)	T1	277.41	75.51	104.59	106.67	167.65	-7698.66	496.07	288.43	451.42	121.55	-1510.9	632.86	197700.6	-1019.71
	T2	-62.39	-542.23	110.75	106.66	61.37	574.11	532.02	156.22	722.51	107.42	-62336.2	72.34	306.85	1562.65
	T3	-55.5	280.71	121.65	118.36	446.28	695.12	778.61	141.29	-7985.04	109.32	-1048.41	29.46	515.72	863.64

T1: water treatment1, T2: water treatment 2, T3: water treatment 3, Dominance б: Dominance Variance, Additive б: Additive variance, pl.ht: plant height, L.A: leaf area per plant, N.K: number of kernels per row, E.L: ear length, E.D: ear diameter, GYPP: grain yield per plant and H.I: harvest index

DISCUSSION

The grain yield per plant and harvest index are the main component of yield in any crop plants and it is also the main aim of any breeding programme. The grain yield directly depends upon the amount of water used and nitrogen availability to the crop (Tambussi *et al*., 2007; Blum, 2011).. In present limited irrigation water scenario the need for better crop variety to bear the water stress was a dire need of any society. The results obtained by this study revealed that under water treatment 2 and 3, the photosynthesis was decreased which ultimately decreased the grain yield and harvest index (Carmo-Silva *et al*., 2008). It is true the poor biomass production and change in the distribution of biomass to different plant organs decreased due to low water supply (Kenga *et al*., 2004, Noorka *et al*., 2013a, 2013b; Noorka and Tabasum, 2015)..

Maize is a highly allogamous crop and can be successfully used for the exploitation of hybrids. The choice of the parent is always a founding stone in the process of hybridization. Heterosis is a phenomenon in which the cross of two parental (inbred) lines are used to produce hybrid that is superior in growth, size ,yield and vigour of the F_1 hybrid plant over the better parent Ahmad *et al.*, (1988); (Lippman and Zamir, 2007, Krivanek *et al.*, 2007, Batool, *et al*., 2013)

In season I and II, ten crosses depicted positive and significant heterosis for grain yield per plant under T1 irrigation regime. The cross combination DR-198 × PakAfgoee showed the highest value. Whereas under water stress conditions of T2 and T3, five crosses showed positive and significant heterosis, while the cross combination DR-198 × EV-1098 in season-I and hybrid DR-185 × EV-6098 in season-II showing the highest value. Under water stress conditions of T3 ten crosses revealed positive significant heterosis while the hybrid DR-185 × EV-6098 had the highest value in both the seasons. The results showed that under water stress condition the promising genotypes have good genetic architecture with non-additive type of gene action to combat the severity of the water availability. These results are in line with the earlier studies of Kumar *et al*. (1998); Joshi *et al*. (1998) and Perez-Velasquez *et al*. (1996), who reported that maize grain yield and flowering traits were under the control of non-additive type of gene action.

Our results are also in agreement with the reports of konak *et al.*, (1999); Lee and Shung (1995); Soengas, *et al.*, (2003). It is concluded that positive and highest significant heterosis having non-additive type of gene action is favorable to devise a breeding programme by which hybrids can be successfully utilized for commercial cultivation.

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