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HETEROSIS STUDIES FOR VARIOUS MORPHOLOGICAL TRAITS OF BASMATI RICE GERMPLASM UNDER WATER STRESS CONDITIONS

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ABSTRACT

Experiment was conducted to study heterosis for different morphological traits i.e. productive tillers per plant, primary branches per panicle, seeds per panicle, seed weight per panicle, 1000 seed weight, yield per plant and seed length width ratio under different irrigated conditions with Randomized Complete Block Design (RCBD) at University of Agriculture Faisalabad in 2010Our results indicates that the maximum heterosis under water stress condition i.e. 80.53% was recorded in (Basmati-2000 x CB-40) for seeds per panicle followed by 44.58% in (Basmati-198 x CB-17) for productive tillers per plant, 16.12% in (Basmati-198 x CB-32) for 1000 seed weight, 12.06% in (CB-32 x CB-14) for yield per plant, 11.10% in (Basmati-198 x CB-42) for primary branches per panicle, 10.14% in (Basmati-2000 x Super Basmati) for seed weight per panicle and 8.64% in (Super Basmati x CB-14) for length width ratio. From Griffing analysis genotypes CB-17, CB-42, Basmati-198 and Basmati-2000 were found good general combiners for various traits especially under water stress condition. Maximum specific combining ability was found in Basmati-198 × CB-17 for primary branches per panicle, Basmati-198 x CB-17 for productive tillers per plant and CB-32 x CB-14 for yield per plant. Some hybrids had good heterosis for specific traits such as productive tillers per plant, 1000 grain weight and yield per plant that can be used for the development of new hybrid rice varieties. it can be concluded that our recent germplasm has great potential that can be used for development of new varieties.

Key words: Heterosis, *Oryza sativa L*, Yield traits, Water stress, combining ability and Genotypes.

INTRODUCTION

Rice (*Oryza sativa* L.) is a principal staple food for more than 50% of the world's population. Rice is grown under diverse eco-geographical conditions in various tropical and subtropical countries, including India and Pakistan. To meet the future food demand, anticipated from the projected world population increase, there is an urgent need to take necessary steps for enhancing the productivity of this crop (Ram *et al.*, 2007). Heterosis breeding is a fundamental tool for the expression of various cross combinations and its potential for commercial exploitation of heterosis under different environmental conditions.

Overall positive heterosis desired for yield and yield relating traits and negative heterosis for plant height and early maturity (Nuruzzaman *et al*., 2002). Generally heterosis is expressed in three ways according to the performance of the hybrids over its parents (mid parent and better parent heterosis) and commercially growing rice varieties (standard heterosis) in comparison with different morphological traits (Gupta, 2000). Heterosis breeding is very important genetic tool in conventional breeding for the enhancement of yield and many other yield related traits both qualitative and quantitative in all crops under stress conditions (Srivstava, 2000).

Conventional breeding strategy play a very important role for the screening, production of high yielding hybrids and exploitation of heterosis as well as the specific combining ability of crosses. The most important point for the plant breeders is to produce high yielding hybrids is the selection of the parents and their hybrids. Diallel analysis is the most powerful tool for estimating the general combining ability (GCA), specific combining ability (SCA) and the exploitation of the heterosis. Positive heterosis for grain yield per plant and other parameters were reported by many researchers (Li *et al*., 2002). On the other hand, positive significant heterosis was reported by (Hong *et al*. (2002) and Alam *et al*., (2004) for yield and various yield contributing traits. Hybrid rice varieties have been released from different countries with greater yield potential 15 to 20% than the commercial growing rice varieties under different environments (Yuan *et al*., 2000).

Manickavelu *et al.*, (2006) conducted an experiment to develop and evaluate biparental progenies for drought tolerance in rice. Genetic analysis of biparental progenies resulted that, the traits viz; days to 70% RWC, leaf rolling, leaf drying and plant height were governed by additive gene action for improvement of these traits while recovery rate, days to flowering, productive tillers per plant, hundred grain weight, root length, root dry weight, root shoot ratio and grain yield can be improved by heterosis breeding.

Main objective of the study was to evaluate rice germplasm collected from different sources for yield and yield related traits for heterosis to develop new breeding lines that can perform better in water stress conditions.

MATERIALS AND METHODS

Plant Material: The study includes the 8 genotypes of rice (*Oryza sativa* L.) namely (CB-14, CB-17, CB-32, CB-40, CB-42, Super Basmati, Basmati-198 and Basmati-2000) advance breeding lines and approved rice varieties. The seeds of these genotypes were collected from Rice Research Institute Kala Shah Kaku Punjab (RRI-KSK). These genotypes were used as a parental material for diallel crosses.

Nursery Preparation: Before sowing, seeds of all genotypes were treated with fungicides i.e. 2 g Benlate for 1 Kg of Rice seed. All the seeds were soaked in water at 30^{o}C for 24 hours. The soils were also well prepared by adding organic matter for the growing of rice nursery. The seeds of each genotype were sown separately in different blocks through broadcasting method. Rice nursery was prepared for transplanting within 30 to 40 days after the date of sowing.

Transplanting: The prepared nursery of all the rice genotypes and their specific crosses were transplanted in to separate field using Randomized Complete Block Design (RCBD) with three replications. The rice plants were transplanted according to the row to row and plant to plant distance separately into earthen pots. The row to row and plant to plant distance between rice plants were maintained in to 9 inch. Five plants data of each genotype was recorded separately in each replication.

Recording Observations: Some of the morphological traits were recorded at the physiological maturity stage of each genotype. The data of 5 plants of each genotype was taken. Productive tillers of each plant were counted to determine the total number of panicles in each plant, Many other traits were also taken at the physiological maturity and after the harvesting of each genotype i.e. primary branches per Panicle, seeds per panicle, seed weight per panicle, 1000 grain weight, plant yield and seed length width ratio. Genotypes were used for making the crosses to develop the F_1 seed for the future studies. The genotypes and the F_1 generation were tested under water stress condition to check the heterosis.

Seed Traits Measurements: To determine the seed length width ratio the seeds of these genotypes i.e. CB-14, CB-17, CB32, CB-40, CB-42, Super basmati, Basmati-198 and Basmati-2000 were studied by using Vernier calipers. The 10 seeds of each genotype were randomly selected for the seed size and shape measurement. First we measured the seeds of each genotype with husk, and then after removing the husk manually measured the seeds of all genotypes without husk. Seed shape was defined by the length: width (L/W) ratio and ranges from slender (3.0 or > 3.0), medium (2.1-3.0), bold (2) and round (1 or < 1). Length and width ratio can be calculated by the following formula.

$$\text{Seed length width ratio} = \frac{\text{Seed Length (mm)}}{\text{Seed Width (mm)}}$$

Diallel Cross: The eight genotypes were crossed in diallel fashion to produce F_1 seed in all possible combination excluding the reciprocal crosses during the year 2009. The seeds of F_1 and their parents were grown in the green house in pots with RCBD replicated trial under normal and water stress condition. The parents and F_1 seeds were grown direct seeded in each pot for the further genetic studies in Randomized Complete Block Design with three replications in both experiments to determine mid parent heterosis and better parent heterosis.

A replication comprised of 36 entries (28 F_1s+ parents). One seed of each cross and parent was planted in each pot. Five seeds of each parent and their respective crosses were planted separately in pots. Data was recorded of each parent plant and their respective cross on the basis of following observations productive tillers/plant, primary branches per panicle, 1000-grain weight (g), seeds per panicle, seed weight/panicle (g), yield/plant (g) and seed length width ratio.

Statistical Analysis: The data recorded on the 28 F_1 hybrids and 8 parents were subjected to statistical analysis SAS version 9.2. Combining ability was also calculated by Grifing,s approach (1956) Mid parent heterosis and better parent heterosis were calculated by using different formulas.

RESULTS

Combining ability estimates: The goal of a plant breeder in a self-pollinated crop like rice is to develop a true breeding (homozygous) population among various desirable characteristics contributing to the yield of rice crop with great genetic potential.

According to (Griffing, 1956) the combining ability analysis partitions the genotypic variability in to variances due to general combining ability (GCA) and specific combining ability (SCA), which represent the additive type of gene action, over dominance and dominance type of gene action for the controlling of various traits of parents and their hybrids under normal and water stress conditions. The data were initially subjected to the analysis of variance that showed the significant variation among the eight parents and their 28

F_1 hybrids. The results of mean square values of all the traits were presented in the (table 1).

General combining ability (GCA) effects: All drought tolerant parents viz., CB-17, CB-40, Basmati-198 and susceptible parents CB-14, CB-32, CB-42, Super basmati and Basmati 2000, showed themselves as good general combiners for some of the traits both under normal and water stress conditions. Some parents (CB-42, Basmati-198) showed highly significant positive GCA effects for some traits and some (CB -14, Super Basmati) showed negative significant GCA effects for some traits (Table 2).

Specific combining ability (SCA) effects: The specific combining ability effects were summarized in table 3. Some crosses showed highest positive significant effects under both normal and water stress condition for specific traits. Maximum specific combining ability was found in Basmati-198 × CB-17 for primary branches per panicle, Basmati-198 x CB-17 for productive tillers per plant and CB-32 x CB-14 for yield per plant especially under water stress condition.

Heterosis for yield and yield related traits under normal condition: The data of various morphological traits mentioned in the table 4.

Productive tillers per plant: The heterotic effects of 18 crosses out of 28 crosses showed increase over mid parental values and these 18 crosses were found to be positive significant, and the heterosis ranged from 1.17% (Basmati-198 × Super Basmati) to 32.8% (Basmati-198 × CB-17). The range of negative heterosis was found to –2.12% (CB-42 × CB-14) to –93.43% (CB-42 × CB-40). The overall range of heterobeltiosis was found to be from –4.269% (CB-32 × CB-14) to -50.45% (CB-42 × CB-40), 10 crosses out of 28 crosses showed negative heterobeltiosis and these 10 values out of 28 were found to be significant.

Primary branches per panicle: The study of heterosis over mid parent indicates that 14 out of 28 crosses showed increase over their respective mid parents and 14 crosses of these were found to be having significant heterosis. Positive heterosis over the mid parent was manifested by 14 crosses and the range of positive heterosis was from 0.55% (Basmati-198 × CB-40) to 13.00% (Basmati-198 × Super Basmati). Whereas, the heterobeltiosis ranged from -1.24% (Basmati-198 × CB-14) to -42.44% (Basmati-2000 × Super Basmati). The hybrid Basmati-2000 × Basmat-198 showed highest values for both heterosis and heterobeltiosis.

Seeds per panicle: The study of heterosis over mid parent indicates that 9 out of 28 crosses showed increase over their respective mid parents and these were found to be having significant positive heterosis. The positive heterosis ranged from 2.55% (Basmati-198 × CB-40) to 31.67% (Basmati-198 × CB-42). Whereas, the heterobeltiosis ranged from –17.05% (Bas-2000 × Bas-198) to - 79.06% (Super Basmati × CB-14). The hybrid Super Basmati × CB-14 showed highest values for both heterosis and heterobeltiosis.

Seed Weight per panicle: While for heterosis over the mid parent almost all the 28 crosses exceeded their respective mid parent. The overall negative heterosis was from –3.85% (Basmati-198 × Super Basmati) to –48.29% (CB-42 × CB-40). Significant negative heterosis and heterobeltiosis was manifested by 28 crosses. The range of negative heterobeltiosis was from -7.41% (Basmati-198 × Super Basmati) to -65.13% (CB-42 × CB-40). 28 crosses showed a decrease from their respective better parents.

1000-seed weight: The study of heterosis over better parent indicates that 5 crosses out of 28 crosses showed increase over their respective mid parents and these were found to be having significant positive heterosis. The range of overall positive heterosis was from 1.97% (Basmati-2000 × CB-17) to 12.20% (Basmati-198 × CB-32). Whereas, the negative heterobeltiosis ranged from –5.56% (CB-40 × CB-32) to –46.15% (Super Basmati × CB-14). The hybrid Bas-198 × CB-32 showed highest values for heterosis.

Yield per plant: All the crosses showed significant negative heterosis. The negative heterosis ranged from -0.39% (CB-32 × CB-14) to -56.80% (CB-42 × CB-40). 28 crosses showed negative heterobeltiosis and the range of negative heterobeltiosis was from -0.78% (CB-32 × CB-14) to –72.46% (CB-42 × CB-40).

Length-width ratio: The heterotic effects showed that 10 out of 28 crosses showed increase over mid parent values and these were found to be significant, and the heterosis ranged from 0.21% (CB-40 × CB-32) to 9.45% (CB-40 × CB-17). The range of negative heterosis was found to –0.62% (Basmati-2000 × CB-32) to -13.80% (Basmati-2000 × CB-40). On the other hand for heterobeltiosis 17 crosses showed significant negative heterobeltiosis out of 28 hybrids. The range of negative heterobeltiosis ranged from -1.23% (Basmati-2000 × CB-32) to -24.30% (Basmati-2000 × CB-40).

Heterosis for yield and yield related traits under water stress condition: The data of various morphological traits mentioned in the table 5.

Productive tillers per plant: The study of heterosis over mid parent indicates that 15 out of 28 crosses showed increase over their respective mid parent. 15 of these were found to be having significant positive heterosis. The positive heterosis was ranged 0.44% (Basmati-198 × CB-42) to 44.58% (Basmati-198 × CB-17). 11 out of 28 showed negative heterosis and the range of negative heterosis was found to be from -1.30 (CB-42 × CB-14) to

Table 1. General and specific combining ability analysis under normal and water stress conditions.

Source of variation	D.F	T/P		PB/P		S/P		SW/P		1000SW		Y/P		LWR	
		N	S	N	S	N	S	N	S	N	S	N	S	N	S
Rep.	2	0.12	0.149	0.32	0.054	6.33	1.13	0.0021	0.0036	0.36	0.258	0.529	0.0005	0.091	0.235
GCA	7	12.74**	6.76**	1.65**	1.10**	1391.60**	457.93**	0.170**	0.0925**	25.84**	25.16**	14.57**	11.78**	0.151**	0.099**
SCA	28	5.15**	3.85**	1.95**	1.47**	894.73**	671.26**	0.449**	0.223**	10.59**	12.07**	54.21**	12.84**	0.233**	0.116**
Error	70	0.14	0.018	0.041	0.020	1.30	0.771	0.0039	0.0011	0.11	0.038	0.157	0.091	0.012	0.037

Level of significance at 1% and 5 %

T/P; Tillers per plant, PB/P; Primary branches per panicle, S/P; Seed per panicle, SW/P; Seed weight per panicle, 1000SW; 1000 seed weight, Y/P; Yield per plant, LWR; Seed length width ratio, While 'N, represent the normal irrigated condition and 'S, represent the water stress condition.

Table 2. General combining ability effects of the parents

Parents	T/P		PB/P		S/P		SW/P		1000SW		Y/P		LWR	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S
CB-14	-11.91**	-27.00**	-9.50**	-6.50**	-25.21**	-12.04**	7.00**	-5.56**	11.78**	32.00**	-5.27**	1.40	2.00**	-1.20
CB-17	-5.36**	-11.50**	-5.00**	2.75**	63.33**	20.88***	19.00**	5.56**	14.00**	21.40**	18.18**	11.50**	-5.00**	0.60
CB-32	-5.73**	1.25**	9.00**	9.00**	2.73**	5.76***	5.00**	7.78**	-15.78**	-26.40***	4.73**	3.80**	0.67	-1.80**
CB-40	5.45**	18.00**	4.83**	1.00	39.97**	37.96**	1.00	-2.22**	7.33**	4.00**	-5.82**	-3.30**	6.00**	0.80
CB-42	-9.00**	-21.00**	-4.67**	-10.50**	-18.79**	-7.36**	4.00**	20.00**	23.67**	40.00**	13.73**	16.60**	4.00**	3.40**
Super Basmati	13.45**	23.00**	-1.83**	-5.00**	-38.76**	-42.52**	-21.00**	-12.22**	-30.33**	-53.80**	-11.91**	-14.30**	-0.67	1.60*
Basmati-198	15.18**	26.25**	8.17**	13.75**	-28.39**	-25.88**	-2.00**	-4.44**	-10.22**	-17.80**	-7.09**	-13.10**	-4.67**	-1.20
Basmati-2000	-1.91**	-9.00**	-0.83	-4.50**	5.12**	23.16**	-15.00**	-7.78**	-0.33	0.16	-6.55**	-2.50**	-2.67**	-2.00**
S.E (gi)	0.11	0.04	0.06	0.04	0.33	0.25	0.01	0.009	0.09	0.05	0.11	0.1	0.03	0.05

Level of significance at 1% and 5 %

Table 3. Specific Combining ability effects of hybrids

Crosses	T/P		PB/P		S/P		SW/P		1000SW		PY		LWR	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S
CB-17 × CB-14	-5.32**	-1.42*	7.78**	2.23**	-23.06**	-15.99**	-7.02**	-4.00**	-10.47**	-23.53**	-10.20**	-3.30**	3.54**	0.29
CB- 32 × CB-14	-2.85**	3.08**	1.17	1.85**	-28.05**	-32.72**	15.44**	27.33**	-4.83**	8.18**	16.06**	16.33**	2.53**	0.47
CB-40 × CB-14	-5.56**	-4.25**	-6.22**	-4.08**	27.32**	48.99**	-10.00**	-6.33**	7.80**	15.24**	-9.74**	-0.85	0.30	-2.82**
CB-42 × CB-14	-0.24	1.92**	-5.50**	-5.38**	-9.62**	-10.27**	-4.74**	-7.00**	-1.80**	-6.71**	-8.40**	-7.12**	-0.91	3.00**
Super Bas× CB-14	-4.91**	-21.00**	-2.94**	-1.15	-17.48**	-5.24**	-0.53	0.33	-12.47**	-21.18**	5.77**	7.88**	5.25**	-1.29*
Bas-198 × CB-14	-9.50**	-19.75**	5.22**	9.23**	34.93**	39.19**	-1.40*	-7.67**	-10.17**	-18.82**	-1.80**	0.42	-1.01	-3.47**
Bas-2000 × CB-14	-1.79**	0.60	-2.28**	0.15	7.01**	1.22	-8.77**	-16.33**	-3.37**	-11.41**	-15.06**	-13.85**	6.97**	2.00**
CB-32 × CB-17	8.21**	-11.75**	0.22	4.46**	-2.07**	14.76**	-5.61**	-11.33**	2.60**	3.47**	-14.37**	-5.61**	-0.71	2.06**
CB-40 × CB-17	1.26*	-5.00**	-0.05	3.08**	-11.66**	-17.08**	-20.53**	-25.67**	1.57**	5.82**	-21.14**	-14.24**	-4.44**	-1.12
CB-42× CB-17	-6.47**	-16.17**	2.83**	2.92**	-25.85**	-26.59**	-20.18**	-21.67**	-2.03**	-3.18**	-24.80**	-17.33**	-0.10	0.24
Super Bas × CB-17	2.65**	-6.83**	0.44	1.54*	-15.51**	-16.77**	-11.75**	-10.00**	-17.13**	-36.71**	-16.71**	-7.73**	-4.34**	3.24**
Bas-198 × CB-17	4.06**	22.33**	12.28**	13.54**	-16.57**	-0.19	-0.70	-6.67**	8.83**	13.47**	-1.17	2.30**	-6.57**	-1.18
Bas-2000 × CB-17	5.15**	10.75**	-5.00**	-0.08	-17.23**	-17.00**	-11.75**	-15.00**	-2.17**	-7.65**	-15.57**	-8.45**	3.54**	-1.41*

CB-40 × CB-32	1.50*	25.17**	3.00**	4.31**	-3.66**	-0.70	-7.54**	-8.67**	-12.47**	-22.59**	-13.80**	-5.82**	6.97**	0.59
CB-42 × CB-32	3.47**	8.83**	3.28**	1.69**	12.25**	11.70**	5.61**	18.33**	5.93**	13.82**	-4.40**	3.12**	1.62*	1.06
Super Bas × CB-32	4.24**	4.75**	-4.39**	-4.15**	17.91**	17.29**	3.86**	6.33**	10.13**	11.47**	7.94**	10.94**	-1.31*	-4.06**
Bas-198 × CB-32	12.50**	35.08**	-12.94**	-5.00**	-17.18**	-1.99**	-4.04**	-9.67**	-20.50**	-38.24**	-3.77**	-1.76**	2.73**	0.29
Bas-2000 × CB-32	5.24**	3.00**	-11.00**	-16.69**	-9.04**	-11.29**	-2.98**	-8.67**	15.43**	22.88**	-10.77**	-2.33**	-3.33**	1.65*
CB-42 × CB-40	-6.91**	-15.83**	2.17**	1.54*	-10.42**	-8.82**	-2.63**	-11.00**	14.80**	25.59**	-13.54**	-6.33**	-5.25**	1.06
Super Bas × CB-40	-4.32**	-3.83**	0.94	4.62**	31.46**	35.30**	1.75**	12.00**	3.23**	9.12**	-7.74**	-0.88	-1.52**	-0.47
Bas-198 × CB-40	-4.18**	-0.83	5.22**	2.46**	21.42**	25.75**	3.16**	6.33**	-7.17**	1.47*	-9.89**	1.12	-4.04**	-0.88
Bas-2000 × CB-40	3.12**	-9.50**	-1.72**	5.54**	-12.50**	-23.89**	-13.68**	-9.00**	7.17**	6.18**	-13.66**	-8.42**	-8.28**	-3.29**
Super Bas × CB-42	-2.29**	8.58**	9.28**	3.69**	-28.25**	-17.86**	-2.98**	-10.67**	13.17**	32.88**	-10.03**	-4.94**	-4.34**	2.24**
Bas-198 × CB-42	10.91**	33.75**	5.28**	5.38**	-11.17**	-15.18**	-3.86**	-11.33**	-7.83**	-17.65**	-10.94**	-8.91**	1.01	0.94
Bas-2000 × CB-42	2.74**	-0.17	-6.22**	-6.00**	101.03**	116.63**	-2.28**	-5.00**	-8.13**	-14.94**	-9.77**	-3.73**	-8.18**	0.06
Bas-198× Super Bas	-1.12	2.33**	-1.50*	-4.46**	-2.65**	-10.52**	4.04**	9.67**	3.60**	9.71**	-9.94**	-6.70**	-2.53**	-1.94**
Bas-2000×Super Bas	-3.91**	-22.33**	-3.17**	-6.15**	2.71**	0.68	3.68**	11.33**	-6.80**	-9.65**	-6.29**	0.09	-3.84**	0.04
Bas-2000×Bas-198	10.00**	-8.42**	-16.94**	-26.31**	-21.51**	-24.82**	-3.51**	5.67**	-9.50**	-14.35**	-12.77**	-4.88**	6.57**	0.08
S.E. (sii)	0.34	0.12	0.18	0.13	1.03	0.79	0.057	0.03	0.3	0.17	0.35	0.33	0.099	0.17

Level of significance at 1% and 5 %

Table 4. Heterosis studies over mid-parent and better parent for yield and yield related traits under normal conditions

	Productive tillers/plant		Primary branches/panicle		Seeds/panicle		Seed weight/panicle		1000 seed weight		Yield/plant		Length-width ratio	
Crosses	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %
CB-17 × CB-14	-7.82*	-14.62*	5.29*	-	-29.70*	-40.61*	-19.63*	-32.82*	-13.04*	-23.08*	-24.25*	-39.03*	-	-
CB- 32 × CB-14	-2.12*	-4.269*	4.01*	-	-63.76*	-77.87*	-3.87*	-7.74*	-15.56*	-26.92*	-0.39*	-0.78*	0.79*	-
CB-40 × CB-14	10.43*	-	-2.45*	-4.79*	-18.71*	-31.53*	-20.60*	-34.37*	-8.33*	-15.38*	-32.29*	-48.81*	-2.03*	-3.98*
CB-42 × CB-14	-2.12*	-4.269*	-2.45*	-4.20*	-21.13*	-34.89*	-25.29*	-40.56*	-6.12*	-11.54*	-33.05*	-49.69*	5.99*	-
Super Bas× CB-14	19.25*	-	0.88*	-	-65.37*	-79.06*	-36.86*	-53.87*	-30.00*	-46.15*	-48.45*	-65.28*	-7.02*	-13.10*
Bas-198 × CB-14	22.16*	-	-0.62*	-1.24*	-12.94*	-22.93*	-11.03*	-20.12*	-4.00*	-7.69*	-12.17*	-21.74*	-4.80*	-9.34*
Bas-2000 × CB-14	12.16*	-	-0.90*	-1.78*	-36.03*	-52.97*	-38.03*	-55.11*	-4.00*	-7.69*	-40.09*	-57.24*	-12.30*	-21.90*
CB-32 × CB-17	-5.26*	-10*	1.83*	-	-13.53	-23.84	-29.14*	-45.13*	-4.17*	-8.00*	-30.16*	-46.36*	2.86*	-
CB-40 × CB-17	4.458*	-	3.33*	-	-32.74	-49.33	-18.15*	-30.92*	-13.64*	-24.00*	-18.52*	-31.27*	9.45*	-
CB-42× CB-17	18.14*	-	3.33*	-	-35.12	-51.98	-23.45*	-38.16*	-	-	-33.23*	-49.89*	2.64*	-
Super Bas × CB-17	22.33*	-	12.60*	-	-51.73	-68.19	-23.10*	-37.88*	-6.38*	-12.00*	-27.45*	-43.1*	-5.76*	-11.10*
Bas-198 × CB-17	32.8*	-	-4.17*	-8.02*	-49.34	-66.08	-23.10*	-37.88*	-25.00*	-40.00*	-28.62*	-44.5*	3.50*	-
Bas-2000 × CB-17	4.426*	-	10.80*	-	-49.63	-66.34	-24.65*	-39.55*	1.97*	-	-34.82*	-51.67*	-3.76*	-7.47*
CB-40 × CB-32	-7.82*	-14.51*	-0.93*	-1.92*	25.052*	-	-19.65*	-32.84*	-2.86*	-5.56*	-28.75*	-44.68*	0.21*	-
CB-42 × CB-32	4.943*	-	-6.83*	-12.79*	-28.31*	-44.13*	-46.98*	-63.93*	10.00*	-	-46.18*	-63.2*	-4.29*	-8.23*
Super Bas × CB-32	21.98*	-	-9.92*	-18.05*	-47.52*	-64.43*	-39.75*	-56.89*	-5.88*	-11.11*	-49.64*	-66.36*	2.61*	-
Bas-198 × CB-32	22.99*	-	-11.90*	-21.32*	-28.94*	-44.89*	-22.66*	-36.95*	12..20*	-	-40.49*	-57.66*	-5.90*	-11.30*
Bas-2000 × CB-32	23.02*	-	-2.18*	-4.26*	-17.86*	-30.30*	-26.39*	-41.94*	-2.86*	-5.56*	-40.47*	-57.62*	-0.62*	-1.23*
CB-42 × CB-40	-93.4*	-50.45*	-0.79*	-1.57*	-14.27*	-24.99*	-48.29*	-65.13*	-8.00*	-14.81*	-56.80*	-72.46*	-2.69*	-5.42*
Super Bas × CB-40	-9.33*	-17.12*	-	-	6.38*	-	-35.02*	-51.87*	-28.57*	-44.44*	-51.96*	-68.36*	2.55*	-
Bas-198 × CB-40	-20.6*	-34.17*	0.55*	-	2.55*	-	-23.57*	-38.33*	-3.85*	-7.41*	-49.17*	-65.94*	-11.00*	-20.00*
Bas-2000 × CB-40	-14.4*	-25.19*	-5.21*	-9.99*	13.04*	-	-26.18*	-41.5*	-17.39*	-29.63*	-42.81*	-59.97*	-13.80*	-24.30*

Super Bas × CB-42	17.65*	-	4.63*	-	13.12*	-	-19.34*	-32.42*	-2.22*	-4.35*	-44.78*	-61.86*	-0.20*	-0.40*
Bas-198 × CB-42	5.889*	-	5.44*	-	31.67*	-	-19.00*	-33.24*	-	-	-46.69*	-63.71*	-4.56*	-8.91*
Bas-2000 × CB-42	1.512*	-	1.24*	-	12.16*	-	-19.00*	-33.24*	2.13*	-	-47.60*	-64.51*	-5.21*	-9.90*
Bas-198×Super Bas	1.174*	-	13.00*	-	19.85*	-	-3.85*	-7.41*	-14.29*	-25.00*	-44.63*	-61.73*	-9.11*	-16.70*
Bas-2000×Super Bas	-6.89*	-12.97*	4.35*	-	11.33*	-	-6.11*	-11.52*	-11.11*	-20.00*	-39.10*	-56.23*	-8.19*	-15.30*
Bas-2000×Bas-198	16.65*	-	-26.90*	-42.44*	-9.32*	-17.05*	-11.74*	-21.01*	-2.86*	-5.56*	-43.08*	-60.24*	4.00*	-

Level of significance at 1% and 5%

Table 5. Heterosis studies over mid-parent and better parent for yield and yield related traits under water stress conditions

	Productive tillers/plant		Primary branches/panicle		Seeds/panicle		Seed weight/panicle		1000 seed weight		Yield/plant		Length-width ratio	
Crosses	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %
CB-17 × CB-14	-	-	3.64*	-	-39.95*	-57.09*	-7.48*	-13.92*	-23.08*	-37.50*	-9.84*	-17.99*	3.40*	-
CB- 32 × CB-14	8.83*	-	4.50*	-	-71.99*	-83.71*	19.49*	-	-14.29*	-25.00*	12.06*	-	2.15*	-
CB-40 × CB-14	12.76*	-	-5.75*	-2.55*	-27.64*	-43.31*	-13.80*	-24.68*	-17.07*	-29.17*	-24.80*	-39.78*	7.88*	-
CB-42 × CB-14	-1.30*	-2.56*	-4.50*	-	-30.60*	-46.87*	-17.20*	-29.75*	-14.29*	-25.00*	-26.10*	-41.44*	7.32*	-
Super Bas× CB-14	6.35*	-	1.85*	-	-70.84*	-82.93*	-21.70*	-36.08*	-45.45*	-62.50*	-33.30*	-50.00*	8.64*	-
Bas-198 × CB-14	17.12*	-	1.85*	-	-20.65*	-34.23*	-	-	-11.63*	-20.83*	-0.08*	-0.238*	-6.29*	-11.84*
Bas-2000 × CB-14	-8.55*	-15.90*	4.25*	-	-49.10*	-65.86*	-18.80*	-31.65*	-11.63*	-20.83*	-27.00*	-42.47*	-5.32*	-10.31*
CB-32 × CB-17	15.47*	-	2.75*	-	35.70*	-	-24.10*	-39.06*	-5.263*	-10.00*	-8.35*	-15.48*	-6.94*	-13.16*
CB-40 × CB-17	3.57*	-	3.11*	-	10.23*	-	-20.70*	-34.33*	-17.65*	-30.00*	0.295*	-	-2.49*	-4.86*
CB-42× CB-17	-1.32*	-2.83*	4.25*	-	14.51*	-	-25.40*	-40.77*	-	-	-9.67*	-17.63*	4.45*	-
Super Bas × CB-17	38.47*	-	9.95*	-	-10.08*	-18.32*	-31.10*	-47.64*	-8.108*	-15.00*	-11.80*	-21.19*	-1.86*	-3.64*
Bas-198 × CB-17	44.58*	-	3.11*	-	-5.94*	-11.21*	-31.60*	-48.07*	-33.33*	-50.00*	-17.90*	-30.37*	-0.61*	-1.42*
Bas-2000 × CB-17	23.33*	-	4.85*	-	-6.37*	-11.97*	-33.90*	-50.64*	6.9767*	-	-17.80*	-30.22*	2.18*	-
CB-40 × CB-32	-3.45*	-6.67*	3.21*	-	30.33*	-	-29.10*	-45.11*	-4*	-7.69*	-14.70*	-25.61*	-10.10*	-18.32*
CB-42 × CB-32	-1.69*	-3.33*	-1.94*	-3.89*	-28.20*	-44.00*	-41.60*	-58.72*	16.129*	-	-29.90*	-46.04*	-4.27*	-8.19*
Super Bas × CB-32	22.51*	-	-2.81*	-5.55*	-47.51*	-64.43*	-27.90*	-43.83*	-8.333*	-15.38*	-37.50*	-54.60*	-17.90*	-30.41*
Bas-198 × CB-32	18.28*	-	-9.34*	-17.10*	-28.44*	-44.30*	-30.60*	-46.81*	16.129*	-	-24.40*	-39.28*	-1.79*	-3.51*
Bas-2000 × CB-32	29.2*	-	0.25*	-	-12.75*	-22.63*	-35.10*	-51.91*	-4*	-7.69*	-30.90*	-47.19*	-3.23*	-6.43*
CB-42 × CB-40	-37.9*	-55.00*	1.26*	-	21.82*	-	-40.70*	-58.05*	-10*	-18.18*	-43.70*	-60.82*	6.24*	-
Super Bas × CB-40	2.06*	-	4.35*	-	39.44*	-	-36.60*	-53.81*	-37.5*	-54.55*	-38.90*	-56.05*	1.80*	-
Bas-198 × CB-40	-23.40*	-38.00*	4.68*	-	36.68*	-	-36.60*	-53.81*	-4.762*	-9.09*	-39.20*	-56.33*	0.81*	-
Bas-2000 × CB-40	-20.40*	-33.90*	-2.55*	-6.09*	80.53*	-	-31.30*	-47.88*	-22.22*	-36.36*	-27.70*	-43.40*	-1.45*	-2.85*
Super Bas × CB-42	9.61*	-	6.26*	-	6.19*	-	-5.80*	-10.97*	-	-	-36.80*	-53.85*	2.33*	-
Bas-198 × CB-42	0.44*	-	11.10*	-	30.45*	-	-7.24*	-13.50*	2.7027*	-	-37.70*	-54.82*	-1.82*	-3.58*
Bas-2000 × CB-42	-4.57*	-8.73*	2.44*	-	4.46*	-	-11.30*	-20.25*	5.2632*	-	-41.50*	-58.63*	-4.80*	-9.34*
Bas-198 × Super Bas	13.38*	-	10.20*	-	46.07*	-	6.99*	-39.53*	-7.143*	-13.33*	-11.50*	-20.77*	-1.67*	-3.49*
Bas-2000×Super Bas	-15.50*	-26.80*	1.72*	-	37.64*	-	10.14*	-38.02*	-11.11*	-20.00*	-7.10*	-13.44*	-0.41*	-1.02*
Bas-2000×Bas-198	-10.40*	-18.90*	-29.9*	-46.10*	16.95*	-55.62*	5.48*	-	-	-	-8.18*	-15.12*	-2.30*	-4.49*

Level of significance at 1% and 5%

-37.9 (CB-42 × CB-40). In 11 crosses were found to be negative significant heterobeltiosis. The negative heterobeltiosis ranged from -2.56% (CB-42 × CB-14) to -55.00% (CB-42 × CB-40).

Primary branches per panicle: For heterosis over the mid parent 20 out of 28 crosses showed an increase over their respective mid parent value with significant positive heterosis and 8 crosses out of 28 hybrids showed negative heterosis. The positive heterosis ranged from 0.25% (Basmati-2000 × CB-32) to 11.10% (Basmati-198 × CB-42). The negative heterosis ranged from -2.81% (Super Basmati × CB-32) to -29.9% (Basmati-2000 × Basmati-198). On the other hand 6 crosses showed significant negative heterobeltiosis. The negative heterobeltiosis ranged from -2.55% (CB-40 × CB-14) to -46.10% (Basmati-2000 × Basmati-198).

Seeds per panicle: The heterotic effects showed that 13 out of 28 crosses showed increase over mid parental values, 13 crosses were found to significant and the heterosis ranged from 6.19% (Super Basmati × CB-42) to 46.07% (Basmati-198 × Super Basmati). The 15 crosses showed significant negative heterobeltiosis. The overall range of heterobeltiosis was found to be from -11.21% (Basmati-198 × CB-17) to -82.93% (Super Basmati × CB-14).

Seed weight per panicle: For heterosis over the mid parent four out of 28 crosses showed an increase over their respective mid parents and these four crosses showed significant positive heterosis. The positive heterosis ranged from 5.48% (Basmati-2000 × Basmati-198) to 19.49% (CB-32 × CB-14). 25 crosses found to be significant negative heterobeltiosis. The range of negative heterobeltiosis ranged from -10.97% (Super Basmati × CB-42) to -58.72% (CB-42 × CB-32).

1000-seed weight: While for heterosis over the mid parent 8 crosses out of 28 exceeded their respective mid parent. The positive heterosis ranged from 2.707% (Basmati-198 × CB-42) to 16.129% (CB-42 × CB-32). The overall range of negative heterosis was -4.00% (CB-40 × CB-32) to -33.33 (Basmati-198 × CB-17). On the other hand, negative heterobeltiosis ranged from -7.69% (CB-40 × CB-32) to -62.50% (Super Basmati × CB-14).

Yield per plant: The study of heterosis over mid parent showed that 2 crosses out of 28 crosses showed an increase over their respective mid parent and these two showed significant positive heterosis. The positive heterosis ranged from 0.295% (CB-40 × CB-17) to 12.06% (CB-32 × CB-14). On the other hand, over all 26 showed significant negative heterosis. The negative heterosis ranged from -0.08 (Basmati-198 × CB-14) to -43.40% (Basmati-2000 × CB-40). In the hetrobeltiosis 28 crosses found to be significant negative. All the crosses ranged from -0.78 (CB-32 × CB-14) to -66.36% (Super Bas × CB-32).

Length width ratio: The study of heterosis over mid parent indicates that 11 out of 28 crosses showed increase over their respective mid parent values and these were found to be having significant positive heterosis. The positive heterosis ranged from 0.81% (Basmati-198 × CB-40) to 8.64% (Super Basmati × CB-14) and 17 crosses showed significant negative heterobeltiosis. The overall ranged of these crosses -1.42% (Bas-198 × CB-17) to -30.41% (Super Basmati × CB-32).

DISCUSSION

The nature and magnitude of gene action involved in phenotypic expression of plant traits is crucial for successful development of crop cultivars. The right selection of parents for hybridization is very important for development of varieties as well. Most of the traits show constant gene action in both environments but gene action of some traits was affected by the environment. Morphological traits like productive tillers per plant, primary branches per panicle, seeds per panicle, seed weight per panicle, 1000 seed weight, yield per plant and seed length width ratio showed over dominance type of gene action in both environments i.e. normal and drought environments. Panicle length showed over dominance only in normal irrigation condition. These results are supported by the findings of Akram *et al.*, (2007).

The analyses of variance (mean square values) showed that the variances due to GCA effects were higher than that due to SCA effects suggesting predominance of additive type of gene action. The finding of the present study showed that the additive gene effects generally plays a more important role than the dominance gene effects for the traits studied. These findings are confirm with several of earlier findings of Vanaja *et al.*, (2003); Pradhan *et al.*, (2006); Ramkrishan *et al.*, (2006). Non-additive type of gene action was also important for the appropriate breeding studies. Some researchers have reported the results related to yield and yield related traits of non-additive type of gene action (Allahgholipour and Ali, 2006).

The parents (CB-40, Super Basmati and Basmati-198) showed positive significant GCA effects in productive tillers per plant and the parents CB-32, Basmati-198 showed positive GCA effects in primary branches per panicle with respect to other parents under both conditions. While the parents (CB-17, CB-32, CB-40 and Basmati-2000) showed positive GCA effects in seeds per panicle. In seed weight per panicle, it was found that the parents (CB-17, CB-32 and CB-42) showed positive significant GCA effects under both conditions. The parents (CB-17, CB-40, CB-42), (CB-17, CB-32, CB-42) and CB-42 showed positive significant

GCA effects for 1000 seed weight, yield per plant and seed length width ratio under normal and water stress condition. An overall analysis indicated that the parents (CB-17, CB-32, CB-42, and Basmati-198) were good general combiners for most of the traits in present study for the improvement of yield and development of the new rice varieties. Ahangar *et al*., (2008) studied the various morphological traits in rice. Genetic variability and diversity is based on the basmati rice germplasm and various phenotypic/genotypic traits that are used for the germplasm enhancement and development of new rice varieties under normal and water stress condition (Ashfaq *et al.,* 2012; Ashfaq and Khan, 2012).

Regarding specific combining ability the trait for productive tillers per plant, the highest positive SCA effects were recorded for the cross combinations (Basmati-198 x CB-32, Basmati-198 x CB-42, and Basmati-198 x CB-17) under normal and water stress conditions. The cross combinations of (Basmati-198 x CB-42, Basmati-198 x CB-14, Basmati-198 x CB-17) and (Basmati-2000 x CB-42, Basmati-198 x CB-40, Super Basmati x CB-40, CB-42 x CB-32) showed highest positive significant SCA effects for primary branches per panicle and seeds per panicle.

For seed weight per panicle, the cross combinations which showed positive significant SCA effects were CB-32 x CB-14, CB-42 x CB-32, Basmati-198 x Super Basmati, Super Basmati x CB-32, Basmati 2000 x Super Basmati and Basmati-198 x CB-40. The traits 1000 seed weight, yield per plant and seed length width ratio showed highest positive significant SCA effects for following cross combinations (Super Basmati x CB-32, Basmati-2000 x CB-32, CB-42 x CB-40, Super Basmati x CB-42, CB-42 x CB-32) (CB-32 x CB-14, Super Basmati x CB-14, Super Basmati x CB-32) and Basmati-2000 x CB-14.

Heterosis over mid parent and better parent under normal and water stress conditions were tested. Some hybrids showed positive and significant heterosis and some showed negative significant heterosis for the yield and yield related traits. Under normal condition some crosses showed maximum heterosis for the concerned traits under study. The maximum heterosis 32.2% was recorded in the cross combinations (Basmati-198 x CB-17) for productive tillers per plant followed by 31.67% in (Basmati-198 x CB-42) for seeds per panicle, 13% in (Basmati-198 x Super Basmati) for primary branches per panicle and 9.45% in (CB-40 x CB-17) for seed length width ratio (Lippman *et al.,* 2007.

On the other hand, under water stress conditions the same situation was observed as observed in normal condition for specific yield trait studies. The maximum heterosis 80.53% was recorded in the following cross combinations (Basmati-2000 x CB-40) for seeds per panicle, 44.58% in (Basmati-198 x CB-17) productive tillers per plant, 16.12% in (Basmati-198 x CB-32) for 1000 seed weight, 12.06% in (CB-32 x CB-14) for yield per plant, 11.10% in (Basmati-198 x CB-42) for primary branches per panicle, 10.14% in (Basmati-2000 x Super Basmati) for seed weight per panicle and 8.64% in (Super Basmati x CB-14) length width ratio. Many researchers also reported the heterosis for yield and yield related traits under both normal and stress condition (Melchinger *et al.*, 2007; Li *et al.*, 2008 and Muthuramu *et al.*, 2010). On the other hand, Barth *et al.*, (2003) reported the heterosis for yield and yield related traits in Arabidaposis.

Over all analysis indicated that, the best parents were selected on the basis of genetic parameter studies, general and specific combining ability analysis and heterosis studies of the crosses showed that the greatest contribution of the following parents in present studies were CB-17, CB-32, CB-42 and Basmati-198.

Conclusion: It is concluded that these parents could be used for the development of new rice varieties and for future breeding research program. On the basis of specific combining ability analysis and heterosis studies following best crosses were selected for water stress condition that have a great potential for the specific traits contributing to increase the yield potential of the rice crop and beneficial for researchers to develop hybrids with high yield. The crosses which identified in water stress condition from specific combing ability and heterosis studies were:

Productive tillers per plant	Basmati-198 x CB-17
Primary branches per panicle	Basmati-198 x CB-42
Yield per plant	CB-32 x CB-14

These hybrids could be used as such or further selection could make to develop high yielding rice genotypes suitable for cultivation under water stress condition.

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