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Research Article

Combining ability studies for yield and quality parameters in basmati rice (*Oryza sativa* L.) genotypes using diallel approach

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Abstract
General and specific combining ability of six basmati rice varieties and their fifteen hybrids made through diallel mating without reciprocals for different yield and quality parameters were studied to select the general combiners for future domestic breeding programs. The Analysis of Variance showed that the mean squares due to general and specific combining ability were highly significant for all the traits indicating that both additive and non-additive gene actions were involved in the inheritance of fourteen yield and quality traits. Significant SCA effects for different characters indicated preponderance of non-additive gene actions in the inheritance of the characters under study. Different lines and hybrids were found as best general and specific combiners for different yield and quality traits, respectively. Thus, important specific cross-combiners can be used effectively in crop improvement programs to develop varieties, and further validation of specific genes to develop gene-based perfect markers in rice breeding.

Keywords
Rice, combining ability, diallel analysis, heterosis.

Introduction

Rice (*Oryza sativa* L; 2n=24; estimated genome size = 430Mb) is a major cultivated crop in the World (Verma and Srivastav, 2017). More than 90% of the World's rice is grown and consumed in Asia, where 60% of the World's population lives (www.worldatlas.com). Rice accounts for 35-60% of the calorie intake of 3 billion Asians (Guyer *et al*., 1998). According to the USDA, in 2008, more than 430 million metric tons of rice were consumed worldwide. India ranks second with rice production of approximately 165.3 million metric tons after China (210.1 million metric tons) (www.world atlas.com).

Basmati rice holds a special rank among all aromatic rice cultivars on account of the appropriate combination of the preferable traits such as minimum kernel dimension, aroma intensity, fluffiness, cooked rice texture, palatability, high volume expansion during cooking, linear kernel elongation with minimum breadth wise swelling, easy digestibility and longer shelf life (Singh *et al*., 2000). During 1970s, Type-3 and Basmati 370 were the most popular basmati varieties exported from India (Jaiswal *et al.*, 2015). Later on during 1996, Taraori Basmati, was released for commercial cultivation in India. HUBR-16 is as comparable as derived from Basmati and Pusa Basmati 1121 for major grain quality traits and yielding potential (Jaiswal *et al.*, 2015).

According to a comprehensive study conducted by Food and Agricultural Policy Research Institute (FAPRI), the World's demand for milled rice can be expected to rise to 496 million tons in 2020 and to 746 million tons by 2030 (Roy and Mistra, 2002). To feed this ever increasing population, it is necessary to have rice genotype having good yielding capacity along with preferable superior grain quality traits. Grain yield and quality traits are economically important for the traders as well as consumers of aromatic rice (Talukdar *et al*., 2017). Traditional Basmati Varieties are generally low yielder and do not match the yield pace of recently developed Basmati varieties (Chandi and Sogi, 2008). Therefore, there is an immediate need to improve traditional indigenous varieties like Basmati 370, Taraori Basmati and Type 3 using recent technological advances. Selection of parents for breeding programe should be based on the sound knowledge on combining ability of parents for various traits which could be used to obtain information on designing efficient breeding strategies in rice (Xiang *et al.*, 2016). The diallel analysis is used to get information about the genetic structure of populations and controlling genetic mechanism of various traits (Hayman, 1954 and

Griffing, 1956). This study reveals the effect of general and specific combining ability of some basmati rice varieties for different yield and quality parameters with diallel analysis with a broader perspective of facilitating useful information to the future rice hybridization programmes. Diallel analysis in rice would lead to a fruitful result for identification of genetic parameters regarding combining ability as well as dominance relationship of the parents and improvement inbreeding program. However, very little information is available on combining ability and heritability of basmati rice genotypes selected in the present study. Hence this study was initiated to estimate the general combining ability (GCA) and specific combining ability (SCA) effects and variances for yield and quality traits and to identify high heterotic parental combination in order to develop hybrid with improved quality traits, particularly kernel characteristics similar to Basmati rice along with high yield.

Materials and Methods

The present study was conducted at the Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar pradesh during Kharif 2014 and Kharif 2015. The experimental material comprised of six parents and 15 crosses. Six parental lines selected for the experiments were HUBR10-9, HUBR16, TYPE-3, B 370, Taraori basmati, and Sanowal Basmati. The hybrids used in the experiments were obtained by crossing the parents in diallel fashion without reciprocals during Kharif 2014.

21 days old seedlings of the 15 hybrids and six parents were planted in Randomised Block Design (RBD) with three replications during Kharif 2015. Single seedling per hill was planted with a spacing of 20 x 20 cm and recommended agronomic package of practices were followed to raise a healthy crop. In this design (Method 2, Model I), all possible mating of selected set of fixed genotypes i.e. six parents were made, excluding reciprocals, and this yielded a total of 15 hybrids.

Data generated from the Method 2, Model I (as described above) of diallel mating design were subjected to the statistical analysis in order to estimate the GCA and SCA variances and effects. The following mathematical model was used for the combining ability analysis (Griffing, 1956)

$$X_{ij} = \mu + g_i + g_j + S_{ij} + \frac{1}{bc}\Sigma_k e_{i\,jkl} \quad \begin{cases} i, j = 1, \ldots\ldots\ldots p \\ k = 1, \ldots\ldots\ldots b \\ l = 1, \ldots\ldots\ldots c \end{cases}$$

Where, μ is the population mean, g_i and g_j are the GCA effect for the i^{th} and j^{th} parents respectively, S^{ij} is the SCA effect for the cross between the i^{th} and j^{th} parents such that $S_{ij} = S_{ji}$, e_{ijkl} is the environmental effect associated with the $ijkl^{th}$ individual observation. The following restrictions are imposed on the combining ability elements:

$$\sum_i g_i = 0; \qquad \sum_j^i S_{ij} + S_{ii} = 0 \text{ (for each i).}$$

Results and Discussion

The Analysis of Variance revealed highly significant difference among the parents and their hybrids for the yield, yield contributing and quality traits under study indicating the existence of significant differences among the parents and crosses of basmati rice genotypes. The GCA and SCA variances were significant for the yield and quality traits studied (Table 1). The results indicated that both additive and non-additive gene actions were involved in the inheritances of fourteen yield and quality traits (Table 1).

The *gca* effect represents the additive nature of gene action. Depending on a character apparent with higher positive or negative significant effect is considered as good general combiner. The per se performance of parents and general combining ability effects of the selected parents for yield and yield contributing traits are mentioned character-wise in Table 2 and Table 3 respectively.

The genotype HUBR 16 found best with minimum mean value for days to 50% flowering and days to maturity, Sanowal Basmati and Taraori basmati exhibited the highest mean value for effective tillers per plant. HUBR 16 showed the highest mean value for grain yield and yield contributing trait like panicle length and seeds per panicle followed by Basmati 370. On analyzing different quality traits like kernel length before and after cooking, HUBR 16 showed maximum kernel length expansion. Similarly, for kernel breadth before and after cooking, HUBR 10-9 showed least per se value. Type 3 showed a desirable value within the intermediate range for amylose content.

Further, *gca* effects were analysed for given parents for different yield and quality traits (Fig.3). The parent, HUBR 16 showed earliness in days to maturity and thus can be a preferable parent for developing early maturing varieties. A high positive and significant *gca* effect was obtained for the trait effective tillers per plant Sanowal Basmati (2.904). The parent HUBR16, found to be the best general combiner for panicle length with a significant value of 1.96 and it had also exhibited

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high positive and significant *gca* effect for seeds per panicle (23.657) followed by Type 3 (6.379). The parents HUBR10-9 (9.262) and HUBR16 (3.822) were adjudged as good general combiners for grain yield. Among the six parents studied, the parents *viz.*, Sanowal Basmati, HUBR 16, HUBR 10-9 and Type 3 were found as general combiners for the breeding programs for improving yield and yield contributing traits. Similar results were reported earlier by Salgotra *et al.*, (2009) . The genotypes *viz*., Pusa 2517-2-51-1, Sanowal Basmati, Super Basmati, Ranbir Basmati and Basmati 370 were found as good general combiners for plant height, effective tillers plant per plant, panicle length, number of grains per panicle, 1000-grain weight and grain yield per plant in line X tester analysis. Pradhan *et al.* (2006) while using L X T analysis, reported that the parents *viz.,* Taraori Basmati, Pusa 2503-693-1, Pusa 1235-95-73-1 and Pusa 2512-97-83-98-4 as best general combiners for grain yield and yield component traits.

A correlated study of mean performance and *gca* effects are needed for different yield and yield contributing traits, since it directly implies about the general combining ability of the parents for that particular trait. Significant and positive mean performance and *gca* effects are preferable for all the traits.

With respect to the quality characters, it was observed that the parent HU BR16, had the highest positive and significant *gca* effect for the trait kernel length before and after cooking and kernel width followed by Basmati 370. The highest positive and significant *gca* effect was obtained with the parent HUBR10-9 (0.351) for the trait Alkali Spread Value, whereas Basmati 370 showed the highest negative *gca* effect (-0.499). The parent Type 3 exhibited the mean value (23.45%) for Amylose content was found to be the best general combiner for this trait. This was in accordance with the earlier eports that the *gca* effects of basmati rice varieties *viz.*, CB-17, CB-42, Basmati 2000 and Basmati-198 (Ashfaq *et al.*, 2012) ; Biser-2, Ranka, and S-136 (Ilieva *et al.*, 2013). and HUBR16 and Pusa 1121(Jaiswal *et al.* 2015) were high and significant positive for major grain quality traits *viz*., kernel length, kernel breadth and kernel length after cooking.

In the present study, among the six parents studied, HUBR16 was identified as the best general combiner for days to 50% flowering, panicle length, 100 grain weight, grain yield, and kernel length before and after cooking. The parents *viz.*, HUBR10-9 and Sanowal Basmati were found to be the potential donors for yield contributing traits like seeds per panicle and effective tillers per plant respectively, owing to their highly positive *gca* effect. Taraori basmati was found to be a good general combiner for least breadth wise kernel expansion after cooking with desirable *gca* effects.

The performance of a parent in specific cross in relation to general combining ability is termed as specific combining ability. The results of mean performance and *SCA* effects of 15 crosses among the six parental lines were given in Table 4 and Table 5 respectively.

Among the 15 hybrids studied, the hybrid HUBR 10-9 X B370 exhibited superior values for days to maturity, seeds per panicle and grain yield. The hybrid, HUBR 10-9 X Sanowal Basmati was identified as best specific combiner for the traits effective tillers per plant and grain yield. The hybrids viz., HUBR 16 X Basmati 370 and HUBR 16 X Type 3 showed desirable mean value for 100 grain weight , panicle length and kernel length and the hybrid s Type 3 X Basmati 370 showed the desirable intermediate range for amylose content.
On the basis of *sca* effects, the hybrid, HUBR10-9 X B370 showed the highest negative *sca* effect (-5.202) for the trait days to 50% flowering and days to maturity and thus can be used in the breeding program for developing short duration varieties. The hybrids *viz*., HUBR10-9 X Sanowal Basmati and HUBR 10-9 X Basmati 370 possessed highest *sca* effects for characters like effective tillers per plant, seeds per panicle and grain yield consisting one of the parents with high *gca*. An appraisal of *sca* effects for kernel length in F_1 indicated that the hybrids HUBR16 X Type 3 and Basmati 370 X Sanowal basmati were the best specific combiners. Type 3 X Basmati 370 exhibited the desirable *sca* effect for amylose content.

This was also in line with the findings of Pradhan *et al.*, (2006) in L X T analysis reported that the hybrid Pusa 3A x Taraori Basmati was found to be a promosing specific combiners for yield and other yield traits. Salgotra *et al.*, (2009) found the hybrid, PAU 29-35-16-3-5-2/Basmati 370 were adjudged as a good specific combiner for yield traits. Koli *et al.* (2013) in L X T design identified the crosses IET 19695 / Pusa Sugandha 4, IET12016 / Pusa Sugandha 4 and IET 19695 / Pusa Sugandha 4 were the best specific combiner for grain yield and panicles per m2. Aditya and Bhartiya,(2015) observed high *sca* effects in the crosses, VL 31632 X P. Sugandh 5, VL 31634 X P. Bas 1 and VL 31638 X P. Bas 1 for grain yield and components traits.

Though different parents had been found to be good general combiners for different characters the results indicated that there was close relationship between mean performance of the parents and their *gca* effects in most of the cases studied. HUBR 16, HUBR 10-9, Sanowal Basmati and Taraori basmati were found to be good general combiners for different yield and yield related traits like seeds per panicle, grain yield, panicle length and effective tillers per plant and hence, these parents might give desirable segregants and for further selection can be exercised. Likewise Type 3 and basmati 370 showed desirable amylose content. Similarly, positive relationship was observed between *sca* effects and mean performances of different crosses. It was observed that crosses with significant *sca* effects were due to different good or poor general combiner parent combinations. Depending upon the nature of gene actions and the combining abilities of parents and crosses, suitable breeding procedure such as heterosis breeding or biparental mating can be advocated and selection can be post poned in later generations for various trait improvement in basmati rice genotypes.

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Table 1. Analysis of Variance for Diallel Model I Method II for yield and quality traits in Basmati rice

	For eight yield characters								
	DF[+]	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Effective tillers / plant**	**Panicle length (cm)**	**Seeds / panicle**	**100 grain weight**	**Grain yield / plant**
GCA	5	15.454**	7.644**	693.389**	26.642**	11.129**	2574.206**	0.124**	290.774**
SCA	15	15.258**	21.321**	102.395**	32.808**	7.848**	866.782**	0.042**	335.143**
Error	40	0.239	0.283	5.110	1.233	0.720	89.848	0.005	13.457

	For six quality characters						
	DF	**Kernel length**	**Kernel breadth**	**Kernel length after cooking**	**Kernel breadth after cooking**	**Alkali spread value**	**Amylose content**
GCA	5	0.935**	0.022**	3.885**	0.018**	1.072**	1.469**
SCA	15	0.232**	0.014**	0.962**	0.015**	0.550**	3.942**
Error	40	0.020	0.003	0.019	0.002	0.055	0.029

Level of significance: *p<0.05 and **P<0.01; [+]Degree of freedom

Table 2. Per se performance of parents for 14 yield and quality characters in Basmati rice

PARENTS	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Effective tillers / plant**	**Panicle length (cm)**	**Seeds / panicle**	**100 grain weight**	**Grain yield / plant**	**Kernel length**
HUBR10-9	106	137.67	97.17	12.447	27.983	155.37	2.323	37.22	7.587
HUBR16	88	121	107.74	13.26	33.683	155.037	2.67	45.93	8.83
TYPE3	97	127.33	142.417	15.33	30.687	145.88	2.003	34.673	6.907
BASMATI 370	97.33	130.67	149.477	14.587	29.377	155.987	2.053	29.427	7.013
TARAORI BASMATI	102.67	133	130.727	17.027	25.213	94.36	2.307	23.983	7.26
SONOWAL BASMATI	94	125	121.81	18.913	31.463	117.093	1.66	35.29	6.92

PARENTS	**Kernel breadth**	**Kernel length after cooking**	**Kernel breadth after cooking**	**Alkali spread value**	**Amylose content**
HUBR 10-9	1.7	13.23	2.277	5.217	22.543
HUBR16	1.827	16.973	2.42	4.95	24.07
TYPE3	1.557	12.937	2.327	3.887	23.457
B370	1.727	12.993	2.277	3.19	26.413
TARAORI BASMATI	1.543	12.237	2.28	4.75	23.623
SONOWAL BASMATI	1.52	12.137	2.417	6.07	25.4

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Table 3. GCA effects of parental lines of basmati rice for 14 characters

For eight yield characters								
Parent	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Effective tillers / plant**	**Panicle length (cm)**	**Seeds / panicle**	**100 grain weight**	**Grain yield / plant**
HUBR10-9	0.931**	1.292**	-14.380**	0.456	-0.953**	23.657**	0.013	9.262**
HUBR16	-2.569**	-1.375**	-5.185**	-2.711**	1.960**	6.224*	0.223**	3.822**
TYPE3	0.514**	0.375*	11.416**	-0.804*	0.408	6.379*	0.021	-3.818**
B370	0.097	0.458*	8.183**	0.076	0.319	5.813	-0.045	1.776
Taraori Basmati	1.347**	0.167	-1.117	0.079	-1.333**	-15.991**	-0.071**	-6.668**
Sanowal Basmati	-0.319*	-0.917**	1.084	2.904**	-0.402	-26.082**	-0.142**	-4.376**
SE^{+}(gi)	0.158	0.172	0.729	0.358	0.274	3.059	0.023	1.184
SE^{++}(gi-gj)	0.245	0.266	1.1302	0.555	0.424	4.739	0.0355	1.834

For six quality characters						
Parent	**Kernel length**	**Kernel breadth**	**Kernel length after cooking**	**Kernel breadth after cooking**	**Alkali spread value**	**Amylose content**
HUBR10-9	-0.175**	0.019	-0.318**	-0.015	0.351**	-0.683**
HUBR16	0.671**	0.078**	1.254**	0.066**	0.342**	0.024
TYPE3	-0.129**	-0.012	-0.110*	0.020	-0.389**	-0.048
B370	0.045	0.020	0.307**	0.024	-0.499**	0.669**
Taraori Basmati	-0.229**	-0.076**	-0.498**	-0.073 **	0.169*	0.014
Sanowal Basmati	-0.182**	-0.029	-0.633**	-0.022	0.026	0.024
SE(gi)	0.046	0.0176	0.044	0.0157	0.076	0.055
SE(gi-gj)	0.0714	0.0273	0.068	0.0244	0.117	0.085

Level of significance: *p<0.05 and **P<0.01, $^{+}$Standard error of GCA effect of *i*th inbred line; $^{++}$Difference between GCA effects of *i*th and *j*th inbred lines.

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Table 4. Per se performance of crosses for 14 yield and quality characters of Basmati rice

CROSSES	Days to 50% flowering	Days to maturity	Plant height (cm)	Effective tillers / plant	Panicle length (cm)	Seeds / panicle	100 grain weight	Grain yield / plant	Kernel length
HUBR10-9 X HUBR16	92.666	127	104.21	16.6767	28.42	189.523	2.37	49.47	7.87
HUBR10-9 X TYPE3	95.667	126.667	143.463	22.37	33.67	213.737	2.43	60.417	7.13
HUBR10-9 X B 370	92	122	107.393	20.5367	30.4833	244.257	2.267	89.887	7.21
HUBR10-9 X TB	95	128	118.0467	23.11333	27.21667	182.1133	2.12	52.92667	7.303333
HUBR10-9 X SB	93.333	123.333	126.617	36.707	30.547	102.923	2.363	81.13	7.053
HUBR16 X TYPE3	92.667	125	136.293	20.373	36.963	184.037	2.82	58.38	8.793
HUBR16 X B 370	97.667	130.333	146.163	21.443	35.29	139.253	2.567	76.87	8.687
HUBR16 X TB	93.667	125	126.51	19.853	32.797	154.4	2.42	59.88	8.023
HUBR16 X SB	100	131.667	138.963	14.097	28.767	126.547	2.357	28.29	7.473
TYPE3 X B 370	97.667	128.333	151.097	18.813	23.873	138.11	2.353	35.72	7.763
TYPE 3 X TB	99.667	128.667	140.897	19.983	30.053	142.25	2.203	45.927	7.047
TYPE 3 X SB	97.667	131.667	143.843	22.013	27.923	135.18	2.443	33.84	7.563
B 370 X TB	95.333	125.667	129.743	21.163	33.483	139.517	2.063	37.927	7.233
B 370 X SB	96.667	128	141.217	30.127	31.26	127.433	2.37	49.123	8.58
TB X SB	95	120	123.513	23.117	29.283	119.11	2.103	36.203	7.18

CROSSES	Kernel breadth	Kernel length after cooking	Kernel breadth after cooking	Alkali spread value	Amylose content
HUBR10-9 X HUBR16	1.9	13.957	2.36	5.257	25.49
HUBR10-9 X TYPE3	1.973	13.673	2.37	4.87	24.603
HUBR10-9 X B 370	1.797	14.103	2.457	5.103	27.783
HUBR10-9 X TB	1.57	14.213	2.003	5.05	24.397
HUBR10-9 X SB	1.847	11.953	2.337	3.833	19.727
HUBR16 X TYPE3	1.827	14.967	2.333	5.147	26.217
HUBR16 X B 370	1.927	16.853	2.423	4.547	21.717
HUBR16 X TB	1.79	13.89	2.473	6	25.49
HUBR16 X SB	1.857	13.323	2.3	3.623	25.69
TYPE3 X B 370	1.793	14.277	2.55	3.36	23.537
TYPE3 X TB	1.77	13.593	2.223	4.083	24.62
TYPE 3 X SB	1.76	13.643	2.23	3.39	26.277
B 370 X TB	1.717	13.123	2.223	3.927	26.353
B 370 X SB	1.807	15.017	2.19	4.43	25.69
TB X SB	1.787	13.63	2.14	4.527	24.56

Table 5. SCA effects for crosses in diallel fashion among 6 parental lines of basmati rice for 14 characters

For eight yield characters

Crosses	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Effective tillers / plant**	**Panicle length (cm)**	**Seeds / panicle**	**100 grain weight**	**Grain yield / plant**
HUBR10-9 X HUBR16	-1.869**	-0.345	-6.097**	-1.161	-3.148**	9.065	-0.165*	-11.353**
HUBR10-9 X TYPE3	-1.952**	-2.429**	16.556**	2.625*	3.654**	33.124**	0.097	7.233*
HUBR10-9 X B370	-5.202**	-7.179**	-16.282**	-0.088	0.556	64.210**	0.000	31.109**
HUBR10-9 X Taraori Basmati	-3.452**	-0.887	3.672	2.486*	-1.058	23.871*	-0.121	2.593
HUBR10-9 X Sanowal Basmati	-3.452**	-4.470**	10.041**	13.254**	1.341	-45.228**	0.193**	28.504**
HUBR16 X TYPE3	-1.452**	-1.429**	0.191	3.795**	4.035**	20.856*	0.278**	10.637**
HUBR16 X B370	3.964**	3.821**	13.294**	3.986**	2.450**	-23.361*	0.090	23.533**
HUBR16 X Taraori Basmati	-1.286**	-1.220*	2.941	2.392*	1.609*	13.590	-0.031	14.987**
HUBR16 X Sanowal Basmati	6.714**	6.530**	13.193**	-6.190**	-3.352**	-4.172	-0.023	-18.896**
TYPE3 X B370	0.881	0.071	1.626	-0.551	-4.081**	-24.659*	0.079	-9.977**
TYPE3 X Taraori Basmati	1.631**	0.696	0.727	0.615	0.417	1.285	-0.045	8.673*
TYPE3 X Sanowal Basmati	1.298**	4.780**	1.472	-0.180	-2.643**	4.306	0.265**	-5.706
B370 X Taraori Basmati	-2.286**	-2.387**	-7.194**	0.916	3.937**	-0.882	-0.119	-4.921
B370 X Sanowal Basmati	0.714	1.030*	2.078	7.054**	0.782	-2.874	0.258**	3.984
Taraori Basmati X Sanowal Basmati	-2.202**	-6.679**	-6.325**	0.040	0.458	10.606	0.017	-0.492
SE^{+}(Sij)	0.4337	0.471	2.0036	0.984	0.752	8.402	0.063	3.252
SE^{++}(Sij-Sik)	0.647	0.703	2.990	1.469	1.122	12.54	0.0941	4.853

For six quality characters

Crosses	**Kernel length**	**Kernel breadth**	**Kernel length after cooking**	**Kernel breadth after cooking**	**Alkali spread value**	**Amylose content**
HUBR10-9 X HUBR16	-0.217	0.041	-0.822**	-0.005	0.030	1.499**
HUBR10-9 X TYPE3	-0.157	0.204**	0.258*	0.051	0.374	0.684**
HUBR10-9 X B370	-0.251	-0.005	0.271*	0.133**	0.717**	3.147**
HUBR10-9 X Taraori Basmati	0.116	-0.135*	1.186**	-0.224**	-0.004	0.415*
HUBR10-9 X Sanowal Basmati	-0.182	0.095	-0.939**	0.059	-1.078**	-4.264**
HUBR16 X TYPE3	0.660**	-0.001	-0.021	-0.067	0.660**	1.591**
HUBR16 X B370	0.380**	0.067	1.449**	0.019	0.170	-3.627**
HUBR16 X Taraori Basmati	-0.010	0.027	-0.710**	0.165**	0.955**	0.801**
HUBR16 X Sanowal Basmati	-0.607**	0.047	-1.141**	-0.059	-1.278**	0.992**
TYPE3 X B370	0.256	0.023	0.236	0.191**	-0.286	-1.735**
TYPE3 X Taraori Basmati	-0.187	0.097	0.358**	-0.039	-0.230	0.004
TYPE3 X Sanowal Basmati	0.282*	0.040	0.543**	-0.083	-0.780**	1.651**
B370 X Taraori Basmati	-0.174	0.011	-0.529**	-0.043	-0.277	1.019**
B370 X Sanowal Basmati	1.125**	0.054	1.500**	-0.127*	0.369	0.346*
Taraori Basmati X Sanowal Basmati	-0.001	0.131	0.918**	-0.081	-0.202	-0.129
SE(Sij)	0.1267	0.0484	0.1207	0.0433	0.2077	0.1511
SE(Sij-Sik)	0.1891	0.0723	0.1801	0.065	0.310	0.2255

Level of significance: *p<0.05 and **P<0.01; $^{+}$Standard error; $^{++}$Difference between SCA effects of *i*th and *j*th inbred lines.

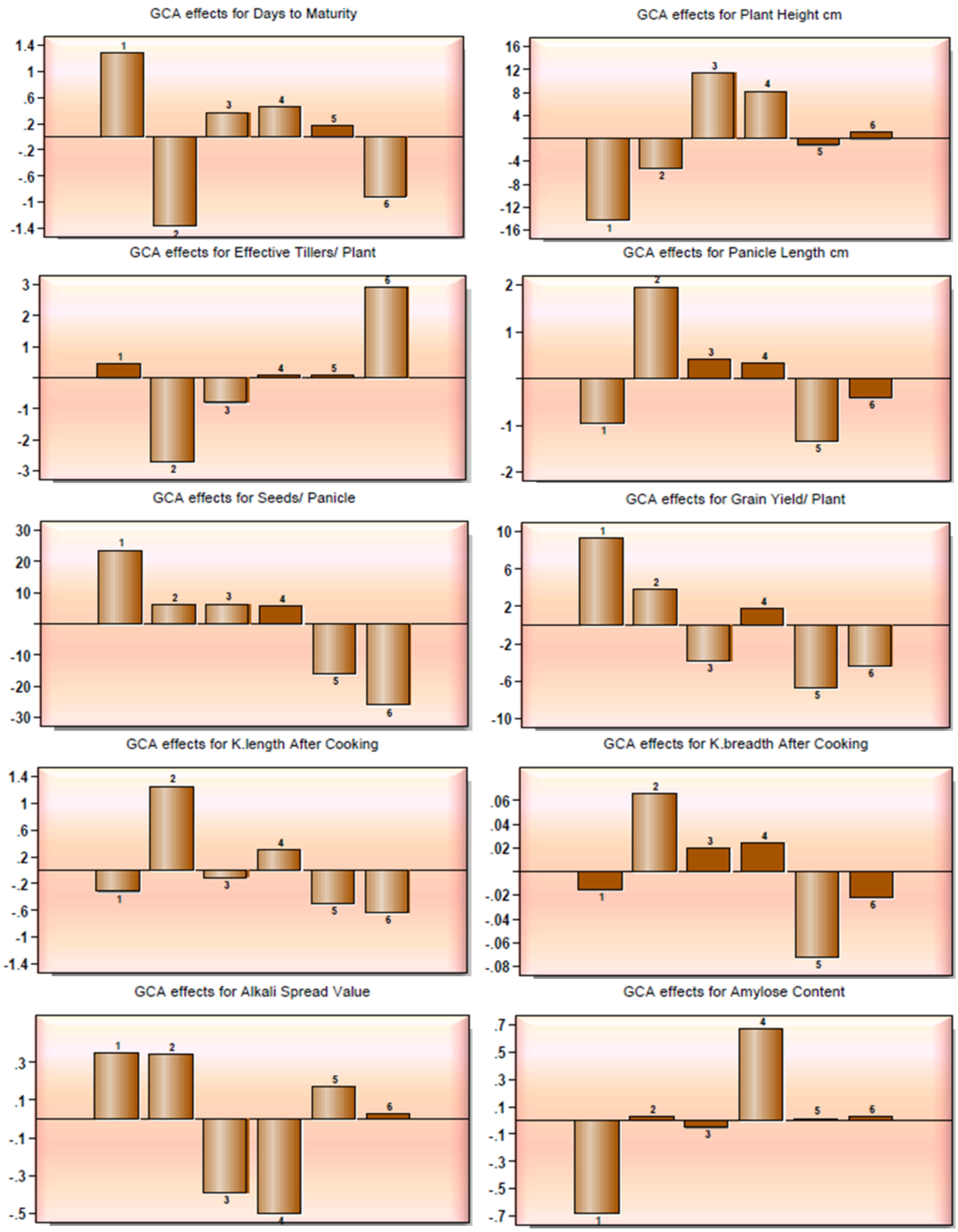

Fig. 1. GCA effects for various traits.
The values on y-axis represent GCA effect values and the values on x-axis represent parent type (1 = HUBR10-9; 2 = HUBR16; 3 = Type 3; 4 = B370; 5 = Taraori Basmati; 6 = Sanowal Basmati).