DOI: 10.5958/0976-4038.2016.00083.X

Full Research Article

Assessment of Combining Ability for Productivity and Quality Traits in Aromatic Rice (*Oryza sativa* L)

Naseer Mohammad[#*], Surendra Singh, Ekhlaque Ahmad[##] and Salil Tewari

Dept. of Genetics and Plant Breeding, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (263 145), India
[#]*Presently* Tropical Forest Research Institute, Jabalpur, Madhya Pradesh (482 021), India
[##]*Presently* Zonal Research Station, Birsa Agricultural University, Chianki, Palamau, Jharkhand (822 101), India

Article History

Manuscript No. ARISE 68
Received in 2nd May, 2016
Received in revised form 29th July, 2016
Accepted in final form 1st August, 2016

Correspondence to

[*]*E-mail*: naseer35518@gmail.com

Keywords

Aromatic rice, GCA, SCA, yield, quality

Abstract

Analysis of combining ability in relation to mean performance, morphometric and quality parameters in aromatic rice holds vital importance for improvement. The present experiment was carried out to study the general combining ability of eight aromatic varieties and specific combining ability of their all possible crosses for grain yield and quality traits. The analysis of variance for combining ability revealed that the GCA and SCA variances were significant for all characters under study except panicle length. It showed that both the additive as well as non-additive genetic variance were important for expression of the characters studied. The variance due to SCA (σ^2s) was higher than GCA (σ^2g) for days to flowering, plant height, flag leaf length, number of effective tillers plant^{-1}, panicle length, number of spikelets panicle^{-1}, seed yield, biological yield plant^{-1}, harvest index, hulling recovery, milling recovery, head rice recovery, dehulled kernel length, dehulled kernel breadth, L/B ratio, cooked kernel length, cooked kernel breadh, cooked kernel L/B ratio, elongation ratio, alkali digestion value, gel consistency and amylose content suggesting significant role of non additive gene actions like dominance, epistasis and other interaction effects in the expression of these characters. The GCA effects of the parents indicated that the parent, Pant sugandh Dhan-17 to be the best general combiner. Crosses, Sugandhmati×Pant Sugandh Dhan-15, Sugandhmati×Pant Sugandh Dhan-17, Pant Sugandh Dhan-15×Taraori basmati and Pant Sugandh Dhan-15×Pant Sugandh Dhan-17 exhibited significant *sca* effect for seed yield and can be exploited by heterosis breeding.

1. Introduction

Rice is one of the most important food crop of India and 2nd of the world. It feeds more than 50% of the world population. It is the staple food of most of the people of South-East Asia. Asia accounts for about 90% and 91% of world's rice area and production, respectively. Among the rice growing countries, India having the largest area under rice in the world and in case of production it is next to China. However, productivity of India is much lower than that of Egypt, Japan, China, and Vietnam, USA & Indonesia and also the average productivity of the world (Anonymous, 2009).

Aromatic/basmati quality rice is a nature's gift to Indian sub-continent. Epicureans acclaimed its delightful fragrance, taste and texture which makes it the best among the aromatic rices of the world. The farmers of Indian sub-continent have been growing the scented rices for centuries and ancient texts and treatises abound such references (Nene, 1998) as well as about the rice diversity available in the country. Although immense aromatic rice diversity is existing in the country, not all aromatic types are recognized as Basmati. Typically the delicately curved, long grained, highly aromatic rices which elongate and cook soft and fluffy were the ones which were categorized as Basmati and enjoy privileged treatment both in domestic and international markets generating three times higher price. Basmati and aromatic recognized to be low yielding and so are grown in small pockets all over the country, patronized by elite, and consumed on festive occasions (Shastry, 2006). The varietal improvement programmes for basmati/aromatic rice were initiated long time back as early as 1920's at Kala Shah kaku (now in Pakistan) and at Nagina in Uttar Pradesh. These efforts were mainly through pure line selections made in the available germplasm.

Attempts to improve yield of Basmati rice through hybridization in dwarf background has been partly successful. Basmati/aromatic rice has narrow genetic base, scarcity of donor parents for grain quality and poor combining ability response. It is therefore necessary to concentrate breeding efforts on exploration of good combiners which can efficiently be hybridized to produce superior genotypes without loss of traditional Basmati quality. In this regard, pace of breeding efforts mainly depends on choice of parents, understanding of genetic phenomenon controlling the inheritance of yield and yield components and adaptation of suitable breeding methods (Saleem et al*.,* 2010).

Keeping in view the above facts the present investigation was to assess the general combining ability of parents and specific combining ability of eight elite basmati/aromatic varieties and their all possible crosses for grain yield and other characters.

2. Materials and Methods

The experimental material comprised of eight basmati varieties (Table 1), 28 F_1 crosses along with 2 checks. 28 F_1 were derived from the crossing of eight basmati parents in diallel fashion excluding reciprocals. The hybridization work was carried out in *kharif* 2009–10. Ten panicles each with 10–15 spikelets were hand emasculated in each female parent and pollinated to get the sufficient quantity of F_1 seeds of a cross. During following off-season those parental lines which produced lesser amount of seed were again grown for crossing them in all possible combinations as well as for their seed multiplication.

Table 1: Details of the parents and checks

Sl. No.	Parents	Pedigree
1.	Pusa Sugandh-4	(Pusa 614-1-2×Pusa 614 2-4-3)
2.	Pusa Sugandh-6	Pusa Basmati-1×Pusa 1121-92-8-7-1
3.	Sugandhmati	Pusa Basmati-1×IET12603
4.	Pusa Sugandh-5	Pusa 3A×Haryana basmati
5.	Pant Sugandh Dhan-15	(Basmati 370/Sadari)×(Bahral/Muskan- 41)
6.	Type-3	Selection from Dehradun Basmati
7.	Taraori Basmati	Pure line selection from HBC 19
8.	Pant Sugandh Dhan-17	(Pusa basmati 1×UPRM 500)
Check-1	Pusa Basmati 1	Pusa 150×Karnal Local
Check-2	Basmati-370	Pureline selection from local basmati land races

In *kharif* 2010–11, the F_1 hybrids along with parents and two popular check varieties were grown in randomized complete block design with three replications. The experiment was conducted with normal package of practices and need based plant protection measures. For recording observations on different characters 5 random and competitive plants in each F_1 and parent were tagged and observations were recorded on various characters. Averages of these plants were used for computation. The characters studied includes days to 50% flowering, plant height (cm), flag leaf length (cm), number of effective tillers plant^{-1}, panicle length (cm), number of spikelets panicle^{-1}, 1000-grain weight (g), seed yield plant^{-1} (g), biological yield plant^{-1} (g), harvest index (HI), hulling percent, milling percent, head rice recovery, dehulled kernel length (mm), dehulled kernel breath (mm), length/breath ratio, cooked kernel length (mm), cooked kernel breadth (mm.), cooked kernel L/B ratio, elongation ratio, alkali digestion value, gel consistency and amylose content.

3. Results and Discussion

Combining ability analysis as an effective tool for identifying superior parents for hybrids has been divided into two categories by Sprague and Tatum (1942), i.e. general combining ability and specific combining ability. General combining ability (GCA) denotes the average performance of the lines in the hybrid combinations and the specific combining ability (SCA) as the deviation from expectation on the basis of GCA. The analysis of variance for combining ability for 23 characters under study is presented in Table 2. A critical perusal of analysis of variance for combining ability revealed that the general combining ability (GCA) and specific combining ability (SCA) variances were significant for all characters under study except panicle length. It showed that both the additive as well as non-additive genetic variance were important for expression of the characters studied. The findings are in general agreements with the findings of Ceng (1977), Singh and Nanda (1977), Cheema and Awan (1985), Geetha (1998), and Kumar et al. (2007) for most of the traits. The estimates of SCA variance (σ^2 SCA) were greater than GCA variance (σ^2 GCA) for all the characters, except for 1000-grain weight suggesting significant role of non additive gene actions like dominance, epistasis and other interaction effects in the expression of these characters.

A predictability ratio greater than 0.5 indicates additive gene action, less than 0.5 indicates non-additive gene action and equal to 0.5 indicates predominance of both additive and non additive gene action for a character. In the present study the predictability ratio was high and exceeded the value of 0.50

Table 2: ANOVA for general combining ability (GCA) and specific combining ability (SCA) for different characters in aromatic rice

Sl. No.	Source of variation	Mean some of squares of different characters								
		d.f.	Days to 50% flowering	Plant height (cm)	Flag leaf length (cm)	No. of effective tillers	Panicle length (cm)	No. of spikelets panicle^{-1}	1000 grain weight (g)	Seed yield plant^{-1} (g)
1.	GCA	7	51.8278**	340.0490**	32.9367**	2.4065**	1.5476	2192.954**	20.7761**	21.4029**
2.	SCA	28	24.3397**	86.3293**	22.3297**	1.6527**	1.3069	676.2877**	2.8672**	15.6488**
3.	Error	70	10.8347	15.6403	5.0030	0.6391	0.8744	33.7706	1.0260	2.2505
GCA/SCA ratio			0.304	0.459	0.161	0.174	0.156	0.336	1.073	0.143
Predictability ratio			0.378	0.479	0.244	0.259	0.237	0.402	0.682	0.222

Sl. No.	Source of variation	Mean some of squares of different characters								
		d.f.	Biological yield plant^{-1} (g)	Harvest index	Hulling recovery %	Milling recovery %	Head rice recovery %	Dehulled kernel length (mm)	Dehulled kernel breadth (mm)	L/B Ratio
1.	GCA	7	107.1230**	85.1713**	15.5580**	12.9556**	21.6289**	0.1002**	0.0074**	0.0363**
2.	SCA	28	74.2584**	49.0450**	9.3648**	11.2671**	43.5029**	0.1057**	0.0068**	0.0931**
3.	Error	70	8.0155	7.8895	0.8856	1.7226	4.1799	0.0220	0.0007	0.0144
GCA/SCA ratio			0.150	0.188	0.173	0.118	0.044	0.093	0.110	0.028
Predictability ratio			0.230	0.273	0.257	0.191	0.082	0.158	0.181	0.053

Sl. No.	Source of variation	Mean some of squares of different characters							
		d.f.	Cooked kernel length (mm)	Cooked kernel breadth (mm)	Cooked kernel L/B ratio	Elongation ratio	Alkali digestion value	Gel consistency	Amylose content %
1.	GCA	2	7.2799**	0.0179**	1.0785**	0.0885**	0.3172**	71.8318**	3.0717**
2.	SCA	28	2.9071**	0.0185**	0.4715**	0.0474**	0.2655**	54.4467**	0.8143**
3.	Error	70	0.0200	0.0012	0.0087	0.0011	0.0945	6.3177	0.2458
GCA/SCA ratio			0.251	0.096	0.231	0.189	0.130	0.136	0.497
Predictability ratio			0.335	0.162	0.316	0.274	0.207	0.214	0.499

*Significant at p=0.05; ** at p=0.01

for 1000-grain weight indicating the predominance of additive gene action for this character. Plant height, amylose content and number of spikelets panicle^{-1} recorded the moderate predictability ratio very nearer to 0.50 indicating both additive and non-additive gene action for these characters. Days to 50% flowering, flag leaf length, no of effective tillers plant^{-1}, panicle length, seed yield plant^{-1}, biological yield plant^{-1}, harvest index, hulling recovery, milling recovery, head rice recovery, dehulled kernel length, dehulled kernel breadth, L/B ratio, cooked kernel length, cooked kernel breadh, cooked kernel L/B ratio, elongation ratio, alkali digestion value and gel consistency recorded low predictability ratios indicating the predominance of non additive gene action for these characters. Roy and Senapati (2012) also reported the similar reports for these characters while assessing combining ability for grain yield and quality characters in 20 F_1 hybrids produced from crosses between five high yielding genotypes.

The estimates of GCA effects of parents and SCA effects of crosses for all the 23 characters under study are summarized in Table 3 and 4, respectively. Critical perusal of Table 3 revealed that none of the parents was excellent general combiner for all the characters studied. This suggested use of multiple parent participation through multiple crossing to effect substantial improvement in yield and yield components. Pant Sugandh Dhan-17 had good general combing ability for maximum number of characters and these includes both yield contributing as well as quality traits viz., seed yield plant^{-1}, biological yield plant^{-1}, panicle length, number of spikelets panicle^{-1}, milling recovery, hulling recovery, dehulled kernel breadth, L/B ratio, cooked kernel length, cooked kernel breadth and cooked kernel

Table 3: Summary of general combining ability effects of parents on the basis of their ratings in 8×8 half diallel of aromatic rice

Sl. No.	Characters	Parent							
		Pusa Sugandh-4	Pusa Sugandh-6	Sugandhmati	Pusa Sugandh-5	Pant Sugandh Dhan-15	Type-3	Toraori Basmati	Pant Sugandh Dhan-17
1.	Days to 50% flowering	A	G	A	G	A	A	P	P
2.	Plant height (cm)	G	G	G	G	A	P	P	P
3.	Flag leaf length (cm)	P	A	G	A	A	A	A	A
4.	No. of effective tillers plant^{-1}	G	A	G	P	P	A	A	A
5.	Panicle length (cm)	A	A	P	A	A	A	A	G
6.	No. of kernels panicle^{-1}	P	A	A	A	G	A	G	G
7.	1000-grain wt (g)	G	A	P	G	A	P	P	P
8.	Seed yield plant^{-1} (g)	P	P	A	A	G	A	A	G
9.	Biological yield plant^{-1} (g)	A	P	A	P	G	P	A	G
10.	Harvest index	P	P	G	G	A	G	A	A
11.	Hulling recovery %	P	A	G	P	G	G	A	A
12.	Milling recovery %	P	A	A	A	A	A	A	G
13.	Head rice recovery %	P	A	A	P	A	G	P	G
14.	Dehulled kernel length (mm)	G	A	A	A	A	P	A	A
15.	Dehulled kernel breadth (mm)	P	A	A	G	A	G	A	G
16.	L/B Ratio	P	A	A	A	A	A	A	G
17.	Cooked kernel length (mm)	G	G	G	P	P	P	P	G
18.	Cooked kernel breadh (mm)	P	P	P	G	A	p	G	G
19.	Cooked kernel L/B ratio	G	A	G	A	P	P	P	G
20.	Elongation ratio	G	A	G	A	P	P	P	A
21.	Alkali digestion value	A	A	G	A	A	P	A	A
22.	Gel consistency	A	P	G	P	A	A	A	A
23.	Amylose content %	A	A	P	G	P	P	G	A

Significant GCA effect towards desirable direction were considered as good general combiner (G), non-significant effect were considered as average general combiner (A) and parents with significant GCA effect in undesirable direction designated as poor general combiner (P)

L/B ratio. These findings are in agreement with the findings of Kumar (2009).

Among the crosses showing high SCA effects for grain yield, Sugandhmati×Pant Sugandh Dhan-15, Sugandhmati×Pant Sugandh Dhan-17, Pant Sugandh Dhan-15×Taraori basmati and Pant Sugandh Dhan-15×PSD-17 involved one parent having good gca effects and can be exploited by heterosis breeding. Among important quality traits, for dehulled kernel, Pusa Sugandh-4×Pant Sugandh Dhan-15, Sugandhmati×Type-3, Sugandhmati×Pant sugandh Dhan-17, Pusa Sugandh-5× Type-3, Pusa Sugandh-5×Taraori basmati, Pant Sugandh Dhan-15×Type-3 and Taraori basmati×Pant sugandh Dhan-17, for L/B ratio, Pusa Sugandh-6×Type-3, Pusa Sugandh-6×Taraori basmati, Sugandhmati×Pant sugandh Dhan-17, Pusa Sugandh-5×Type-3, Pusa Sugandh-5×Taraori basmati, Pant Sugandh Dhan-15×Type-3 and Pant Sugandh Dhan-15×Taraori basmati, for elongation ratio, Pusa Sugandh-4×Pusa Sugandh-6, Pusa Sugandh-4×Pant Sugandh Dhan-15, Pusa Sugandh-4×Taraori basmati, Pusa Sugandh-4 ×Pant sugandh Dhan-17, Sugandhmati×Pusa Sugandh-5, Sugandhmati×Type-3 and Sugandhmati×Taraori basmati, whereas for gel consistency, Pusa Sugandh-6×Sugandhmati, Pusa Sugandh-6×Pant sugandh Dhan-17, Sugandhmati×Pusa Sugandh-5, Sugandhmati×Type-3, Pusa Sugandh-5×Type-3 and Type-3×Pant Sugandh Dhan-17 showed good specific combining ability effects. Among these crosses, which had both or one of the parent having good general combining ability for the concerned trait could likely to produce some

Table 4: Summary of specific combining ability (sca) effects of F1 crosses in aromatic rice

Sl. No.	Crosses	Days to 50% flow-ering	Plant height (cm)	Flag leaf length (cm)	No. of effective tillers	Pan-icle length (cm)	No. of spikelets Panicle^{-1}	1000 grain weight (gm)	Seed yield plant^{-1} (gm)
1.	Pusa Sugandh-4×Pusa Sugandh-6	A	A	A	G	G	A	A	G
2.	Pusa Sugandh-4×Sugandhmati	A	A	A	P	A	A	A	p
3.	Pusa Sugandh-4×Pusa Sugandh-5	A	P	A	A	A	A	A	A
4.	Pusa Sugandh-4×Pant Sugandh Dhan-15	A	A	A	A	A	P	G	A
5.	Pusa Sugandh-4×Type-3	A	A	A	A	A	A	G	A
6.	Pusa Sugandh-4×Taraori basmati	A	G	A	A	A	A	A	A
7.	Pusa Sugandh-4×Pant sugandh Dhan-17	A	A	A	A	A	P	A	A
8.	Pusa Sugandh-6×Sugandhmati	A	P	A	A	A	P	A	A
9.	Pusa Sugandh-6×Pusa Sugandh-5	A	P	G	A	A	A	A	A
10.	Pusa Sugandh-6×Pant Sugandh Dhan-15	A	A	A	A	A	G	A	P
11.	Pusa Sugandh-6×Type-3	G	G	A	A	A	G	A	A
12.	Pusa Sugandh-6×Taraori basmati	A	A	G	A	A	G	A	A
13.	Pusa Sugandh-6×Pant sugandh Dhan-17	A	A	A	A	A	G	A	P
14.	Sugandhmati×Pusa Sugandh-5	A	A	A	A	A	A	A	A
15.	Sugandhmati×Pant Sugandh Dhan-15	A	A	G	G	A	G	A	G
16.	Sugandhmati×Type-3	A	A	G	A	A	G	A	G
17.	Sugandhmati×Taraori basmati	A	A	G	A	A	G	A	P
18.	Sugandhmati×Pant sugandh Dhan-17	P	P	G	G	A	A	G	G
19.	Pusa Sugandh-5 × Pant Sugandh Dhan-15	A	A	A	A	A	A	A	A
20.	Pusa Sugandh-5×Type-3	G	A	A	A	A	G	A	A
21.	Pusa Sugandh-5×Taraori basmati	A	A	A	P	A	G	A	A
22.	Pusa Sugandh-5× Pant sugandh Dhan-17	A	A	G	P	A	A	A	A
23.	Pant Sugandh Dhan-15×Type-3	A	A	G	A	A	G	A	A
24.	Pant Sugandh Dhan-15×Taraori basmati	A	A	A	P	A	G	P	G
25.	Pant Sugandh Dhan-15×PSD-17	A	A	A	G	A	G	A	G
26.	Type-3×Taraori basmati	A	P	A	A	G	A	P	P
27.	Type-3×Pant sugandh Dhan-17	A	P	A	A	A	A	A	A
28.	Taraori basmati×Pant sugandh Dhan-17	G	P	P	A	A	A	A	A

*Significant gca effect towards desirable direction were considered as good general combiner (G), non-significant effect were considered as average general combiner (A) and parents with significant gca effect in undesirable direction designated as poor general combiner (P).

Table 4: Continue...

Sl. No.	Crosses	Biological yield-plant^{-1} (gm)	Harvest index	Hulling recovery %	Milling recovery %	Head rice recovery %	Dehulled kernel length (mm)	Dehulled kernel breadth (mm)	L/B Ratio
1.	Pusa Sugandh-4×Pusa Sugandh-6	G	A	A	G	G	A	A	A
2.	Pusa Sugandh-4×Sugandhmati	A	P	G	G	G	P	A	A
3.	Pusa Sugandh-4×Pusa Sugandh-5	A	A	A	G	A	A	p	A

Continue...

Sl. No.	Crosses	Biological yield plant^{-1} (gm)	Harvest index	Hulling recovery %	Milling recovery %	Head rice recovery %	Dehulled kernel length (mm)	Dehulled kernel breadth (mm)	L/B Ratio
4.	Pusa Sugandh-4×Pant Sugandh Dhan-15	A	A	P	A	A	G	A	A
5.	Pusa Sugandh-4×Type-3	G	P	A	P	P	A	P	A
6.	Pusa Sugandh-4×Taraori basmati	A	A	P	P	A	A	P	P
7.	Pusa Sugandh-4×Pant sugandh Dhan-17	A	A	P	P	A	A	A	A
8.	Pusa Sugandh-6×Sugandhmati	P	G	A	A	A	A	A	A
9.	Pusa Sugandh-6×Pusa Sugandh-5	A	A	P	P	A	A	G	A
10.	Pusa Sugandh-6×Pant Sugandh Dhan-15	P	A	A	G	G	A	P	A
11.	Pusa Sugandh-6×Type-3	A	P	A	A	A	A	G	G
12.	Pusa Sugandh-6×Taraori basmati	P	A	G	A	P	A	G	G
13.	Pusa Sugandh-6×Pant sugandh Dhan-17	P	P	A	G	G	A	P	P
14.	Sugandhmati×Pusa Sugandh-5	A	G	P	P	A	A	A	A
15.	Sugandhmati×Pant Sugandh Dhan-15	A	G	P	A	G	A	A	A
16.	Sugandhmati×Type-3	A	A	A	A	A	G	P	A
17.	Sugandhmati×Taraori basmati	G	P	A	A	A	A	A	A
18.	Sugandhmati×Pant sugandh Dhan-17	G	A	G	G	G	G	G	G
19.	Pusa Sugandh-5 × Pant Sugandh Dhan-15	G	A	A	A	G	A	A	A
20.	Pusa Sugandh-5×Type-3	P	G	G	A	P	G	A	G
21.	Pusa Sugandh-5×Taraori basmati	A	G	A	A	g	G	A	G
22.	Pusa Sugandh-5× Pant sugandh Dhan-17	G	A	G	G	G	A	P	p
23.	Pant Sugandh Dhan-15×Type-3	A	A	A	G	G	G	G	G
24.	Pant Sugandh Dhan-15×Taraori basmati	G	A	P	p	A	A	G	G
25.	Pant Sugandh Dhan-15×PSD-17	A	G	G	G	A	A	A	A
26.	Type-3×Taraori basmati	A	G	A	A	A	P	p	P
27.	Type-3×Pant sugandh Dhan-17	G	a	P	P	A	P	g	A
28.	Taraori basmati×Pant sugandh Dhan-17	P	g	A	A	G	G	a	A

G: Good; A: Average; P: Poor

Table 4: Continue...

Sl. No.	Crosses	Cooked kernel length (mm)	Cooked kernel breadh (mm)	Cooked kernel L/B ratio	Elongation ratio	Alkali digestion value	Gel consistency	Amylose content %
1.	Pusa Sugandh-4×Pusa Sugandh-6	G	G	G	G	A	P	A
2.	Pusa Sugandh-4×Sugandhmati	P	P	P	P	A	A	P
3.	Pusa Sugandh-4×Pusa Sugandh-5	P	G	P	P	A	A	G
4.	Pusa Sugandh-4×Pant Sugandh Dhan-15	G	P	G	G	P	A	A
5.	Pusa Sugandh-4×Type-3	P	P	P	P	A	P	A
6.	Pusa Sugandh-4×Taraori basmati	G	P	G	G	A	A	A
7.	Pusa Sugandh-4×Pant sugandh Dhan-17	G	A	G	G	A	A	G
8.	Pusa Sugandh-6×Sugandhmati	P	P	P	P	P	G	G

Continue...

Sl. No.	Crosses	Cooked kernel length (mm)	Cooked kernel breadh (mm)	Cooked kernel L/B ratio	Elonga-tion ratio	Alkali digestion value	Gel con-sistency	Amylose content %
9.	Pusa Sugandh-6×Pusa Sugandh-5	P	A	P	P	P	P	A
10.	Pusa Sugandh-6×Pant Sugandh Dhan-15	A	P	P	A	A	A	P
11.	Pusa Sugandh-6×Type-3	P	G	A	P	A	A	A
12.	Pusa Sugandh-6×Taraori basmati	P	P	P	P	A	P	A
13.	Pusa Sugandh-6×Pant sugandh Dhan-17	P	P	P	P	A	G	A
14.	Sugandhmati×Pusa Sugandh-5	G	G	G	G	A	G	A
15.	Sugandhmati×Pant Sugandh Dhan-15	P	A	P	P	A	A	A
16.	Sugandhmati×Type-3	G	P	G	G	G	G	A
17.	Sugandhmati×Taraori basmati	A	G	G	G	A	A	A
18.	Sugandhmati×Pant sugandh Dhan-17	P	G	A	P	A	A	P
19.	Pusa Sugandh-5 × Pant Sugandh Dhan-15	P	P	P	A	A	P	A
20.	Pusa Sugandh-5×Type-3	P	P	P	P	A	G	A
21.	Pusa Sugandh-5×Taraori basmati	A	P	A	P	G	A	A
22.	Pusa Sugandh-5× Pant sugandh Dhan-17	P	G	P	P	P	A	A
23.	Pant Sugandh Dhan-15×Type-3	G	G	G	A	P	P	G
24.	Pant Sugandh Dhan-15×Taraori basmati	A	G	G	A	A	A	A
25.	Pant Sugandh Dhan-15×PSD-17	P	G	A	P	A	P	A
26.	Type-3×Taraori basmati	P	G	A	P	A	A	A
27.	Type-3×Pant sugandh Dhan-17	P	A	P	A	A	G	P
28.	Taraori basmati×Pant sugandh Dhan-17	P	A	P	P	A	A	A

good segregants if the additive genetic system present in a good general combiner parent and epistatic effects in the cross act in the same direction. These results are more or less in consistence with the findings of Pradhan et al. (2006), kumar (2009), Selvaraj et al. (2011); Roy and Senapati (2012).

4. Conclusion

Pant sugandh Dhan-17 was found to be the best general combiner with 11 characters followed by Sugandhmati with 10 characters. Crosses, Sugandhmati×Pant Sugandh Dhan-15, Sugandhmati×Pant sugandh Dhan-17, Pant Sugandh Dhan-15×Taraori basmati and Pant Sugandh Dhan-15×PSD-17 can be exploited by heterosis breeding for increasing productivity.

5. Acknowledgement

Authors are thankful to the Head, Department of Genetics and Plant Breeding and Directorate (Research), GBPUA & T, Pantnagar for providing necessary facilities for investigation.

6. References

Anonymous, 2009. Rice in India during Tenth Plan, Directorate of Rice Development, GOI, Ministry of Agriculture, Patna-800 013, Bihar.

Ceng, M.C., 1977. Diallel analysis of grain size, grain shape and other quantitative characters in rice. Memories of the college of Agri. National Taiwanuniv 17, 78−90.

Cheema, A.A., Awan, M.A., 1985. Heterosis, gene action and combining ability study of yield and some of the yield components of four-parent diallel cross in rice. Pakistan Journal of Scientific and Industrial Research 28, 175−178.

Geetha, S., 1998. Combining ability analysis of quality characters of rice grains. Agricultural Science Digest Karnal 18(1), 1−3.

Kumar, A., 2009. Genetic analysis of yield and quality attributes in rice (*Oryza sativa* L.). MSc, G.B. Pant University of Agriculture and Technology, Pantnagar, India.

Kumar, S.T., Narasimman, R., Eswaran, R., Kumar, C.P.S., Thangavel, P., 2007. Studies on the relationship among *per se* performance, combining ability effects and heterosis in rice (*Oryza sativa* L.). International Journal of Plant Sciences 2(1), 195−198.

Nene, Y.L., 1998. Basmati rice: distinct variety (cultivar) of the Indian subcontinent. Asian Agri-history 2(3), 175−188.

Pradhan, S.K., Bose, L.K., Meher, J., 2006. Studies on Gene action and Combining ability analysis in Basmati rice. Journal of Central European Agriculture 7(2), 267–272.

Roy, S.K., Senapati, B.K., 2012. Combining ability analysis for grain yield and quality characters in rice (*Oryza sativa*). Indian Journal of Agricultural Sciences 82(4), 293–303.

Saleem, M.Y., Mirza, J.I., Haq, M.A., 2010. Combining ability analysis for yield and related traits in basmati rice (*Oryza sativa* l.). Pakistan Journal of Botany 42(1), 627–637.

Selvaraj, C.M., Nagarajan, P., Thiyagarajan, K., Bharati, M., Rabindran, R., 2011. Studies on heterosis and combining ability of well known blast resistant rice genotypes with high yielding varieties of rice (*O. sativa*). International Journal of Plant Breeding and Genetics 5(2), 111–129.

Shastry, S.V.S., 2006. Rice breeding in retrospect. Current Science 91(12), 1621–1625.

Singh, D.P., Nanda, J.S., 1977. Inheritance of yield and yield contributing characters in rice. Indian Journal of Agricultural Sciences 37(3), 384–387.

Sprague, G.F., Tatum, L.A., 1942. General and specific combining ability in single crosses of corn. American Society of Agronomy 34, 923–932.