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Combining ability analysis for yield and yield components in basmati rice

Aditya Kumar[1], Surendra Singh[2*] and Santosh Kumar Magadum[2]

[1] Institute of Forest Productivity, Lalgutwa, Ranchi-835303, Jharkhand, India.

[2]Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar- 263145, Uttarakhand, India.

**E-mail: ss_meher@rediffmail.com*

ABSTRACT

Twenty eight F_1's produced from diallel cross excluding reciprocals among eight parents, were studied along with the parents for combining ability for yield and 15 yield components. The study revealed importance of both additive and non-additive gene effects in governing yield and yield components with preponderance of non-additive gene action for most of the yield components. Additive gene action was found important for 1000-grain weight. The parental genotype UPR 2845-6-3-1 and Pant Sugandh Dhan 15 were found good general combiners. The hybrids namely Pant Sugandh Dhan 15/Basmati 370, Pant Sugandh Dhan 15/Type 3, Pant Sugandh Dhan 15/Pant Sugandh Dhan 17, Pant Sugandh Dhan 15/Pusa Basmati 1, Pant Sugandh Dhan 15/Pusa Sugandh 4, Pant Sugandh Dhan 15/UPR 2845-6-3-1, Pant Sugandh Dhan 15/UPR 3003-11-1-1, Basmati 370/Pant Sugandh Dhan 17, Basmati 370/Pusa Basmati 1, Type 3/Pusa Basmati1, Type 3/UPR 2845-6-3-1, Pant Sugandh Dhan 17/ Pusa Sugandh 4, Pant Sugandh Dhan17/UPR 2845-6-3-1, Pant Sugandh Dhan 17/UPR 3003-11-1-1, Pusa Basmati 1/Pusa Sugandh 4, Pusa Sugandh 4/UPR 2845-6-3-1 and UPR 2845-6-3-1/UPR 3003-11-1-1 have shown significant favourable sca *effect for yield and different yield components.*

Key words: *Diallel analysis, combining ability, gca effect, sca effect, basmati rice*

Basmati rice, because of its unique aroma flavour and cooking quality, is the pride of India. The cultivation of basmati rice is very economical for farmers, but the yield potential of present varieties is very poor. In order to formulate efficient breeding strategies for improvement of yield, it is essential to characterise the nature and mode of gene action that determines the yield and its components. A sound breeding methodology rests on a proper understanding of the gene effects involved (Kumar *et al.* 2012).

The combining ability studies of the parents and their crosses provide information for the selection of high order parents for effective breeding. Success of any plant breeding programme depends on the choice of right type of genotypes as parents in the hybridization programme. Combining ability analysis provides information on two components of variance *viz.*, additive and dominance variance. Its role is important to decide parents, crosses and adoption of appropriate breeding procedures to be followed to select desirable segregants (Salgotra *et al.*, 2009). Therefore, the present investigation was undertaken to select right type of Basmati varieties as parents in the hybridization programme and the appropriate breeding procedures to be followed involving indigenous and exotic promising Basmati varieties.

MATERIALS AND METHODS

The material comprised of 8 basmati rice varieties namely Pant Sugandh Dhan 15, Basmati 370, Type 3, Pant Sugandh Dhan 17, Pusa Basmati 1, Pusa Sugandh 4, UPR 2845-6-3-1, UPR 3003-11-1-1 were crossed in half diallel fashion during wet season 2006. Next year during wet season 2007, 36 entries (28 crosses and 8 parents) were grown in a randomised block design with two replications at N.E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). Single seedling hill^{-1} was transplanted at a spacing of 20 cm x 15 cm. The F_1's and parents were planted in a two row plot of 2 meter length. Data were collected from 5 competitive plants, leaving border plant on each side of each genotype (Dhaliwal and Sharma, 1990). Observations were recorded on 16 characters *viz*., days to 50% flowering (DF), plant height (PH), flag leaf length (FL), flag leaf breadth (FB), panicle length (PL), number of panicles plant^{-1} (PN), grain number panicle^{-1} (GP), 1000-grain weight (TW), grain yield plant^{-1} (GY), biological yield plant^{-1} (BY), harvest index (HI), kernel length (KL), kernel breadth (KB), kernel L/B ratio (LBR), amylose content (AC) and alkali spreading value (AS). The combining ability analysis was carried out as per Griffing (1956), Method-2.

Persual of ANOVA for combining ability (Table 1) showed that mean square due to general combining ability (*gca*) was highly significant for all characters except KB. Mean squares due to specific combining ability (*sca*) were also significant for all the characters. This suggests the importance of both additive and non-additive gene effects in the materials under study. The study also showed that the magnitude of *gca* variances were greater than *sca* variances for DF, FB, GP, TW, GY, HI, KL, LBR, AC and AS, while for rest of the characters the magnitude of *sca* variance was greater. Hence any approach that facilitates simultaneous exploitation of additive and non-additive gene effects would be the most desirable for the improvement of these traits.

The estimates of *sca* effect and *gca:sca* ratio **(**Table 2) indicate non additive gene effect controlling all the characters except TW. Although the mean square for *gca* (additive genetic variance) was significant, the dominant component was preponderant for all the characters except for TW.

Occurrence of both additive and non-additive gene effects with preponderance of non-additive gene action for yield and important yield components in rice were reported by several scientists like Peng and Virmani (1990), Manuel and Prasad (1992), Sharma *et al*. (1996), Ganesan *et al*. (1997) and Vanaja *et al*. (2003).

The genotype UPR 2845-6-3-1 was found to be a good general combiner for DF, PH, FL, PL, GP, GY, BY, HI, KL, KB and AC (Table 3). Apart from

Table 1. Analysis of variance for general combining ability (*gca*) and specific combining ability (*sca*) for different characters

Source of Variation	d.f.	Mean sum of squares															
		DF	PH (cm)	FL (cm)	FB (cm)	PL (cm)	PN	GP	TW (g)	GY (g)	BY (g)	HI (%)	KL (mm)	KB (mm)	LBR (mm)	AC	AS
GCA	7	113.364**	1048.91**	23.040**	0.025**	2.622**	12.058**	1357.78**	13.329**	279.689**	892.090**	72.312**	0.354**	0.009	0.197**	1.473**	0.408**
SCA	28	31.307**	282.237**	24.118**	0.020**	3.157**	46.887**	583.450**	3.479*	199.360**	1196.71**	32.084**	0.241**	0.012**	0.137**	0.602**	0.162**
Error	105	5.842	19.972	8.110	0.007	0.807	1.561	30.465	2.242	0.788	6.983	0.986	0.072	0.005	0.064	0.145	0.079
GCA/SCA		3.62	3.72	0.96	1.25	0.83	0.26	2.33	3.83	1.40	0.75	2.25	1.47	0.75	1.44	2.45	2.52

* and ** Significant at 5 and 1 per cent probability levels, respectively

Table 2. Estimates of components of genetic variance from 8 x 8 half diallel analysis using Griffing's Method-2

Components of genetic variance	DF	PH (cm)	FL (cm)	FB (cm)	PL (cm)	PN	GP	TW (g)	GY (g)	BY (g)	HI (%)	KL (mm)	KB (mm)	LBR (mm)	AC	AS
Additive genetic variance	16.41	153.34	0.22	0.001	0.12	6.97	154.86	1.97	16.07	60.92	8.04	0.02	0.0006	0.012	0.17	0.05
Non-additive genetic variance	25.47	262.27	16.00	0.013	2.35	45.33	552.98	1.24	198.57	1189.73	31.09	0.17	0.007	0.073	0.46	0.083
Variance due to error	5.842	19.972	8.110	0.007	0.807	1.561	30.465	2.242	0.788	6.983	0.986	0.072	0.005	0.064	0.145	0.079
Ratio of additive to non-additive genetic variance	0.65	0.58	0.014	0.077	0.05	0.154	0.28	1.59	0.08	0.05	0.26	0.12	0.086	0.16	0.37	0.60

DF- Days to 50 % flowering, PH- Plant height, FL- Flag leaf length, FB- Flag leaf breadth, PL- Panicle length, PN- Number of panicles plant^{-1}, GP- Grain number panicle^{-1}, TW- 1000 grain weight, GY- Grain yield plant^{-1}, BY- Biological yield plant^{-1}, HI- Harvest index, KL- Kernel length, KB- Kernel breadth, LBR- Kernel L/B ratio, AC- Amylose content and AS- Alkali spreading value

UPR 2845-6-3-1, good general combiners for different characters were Pant Sugandh Dhan 15 for PH, FB, GP, GY, BY and HI; Basmati 370 found for PN; Pant Sugandh Dhan 17 for DF, PH, FB, PL, GP, GY, BY, KL, AC and AS; Pusa Basmati 1 for PN, GP, GY, BY and AS; Pusa Sugandh 4 for PH and TW and UPR 3003-11-1-1 for DF, PH, FL, GP, GY, HI, KL, LBR and AS.

Seventeen F_1's out of 28 namely Pant Sugandh Dhan 15/Basmati 370, Pant Sugandh Dhan 15/Type 3, Pant Sugandh Dhan 15/Pant Sugandh Dhan 17, Pant Sugandh Dhan 15/Pusa Basmati 1, Pant Sugandh Dhan 15/Pusa Sugandh 4, Pant Sugandh Dhan 15/UPR 2845-6-3-1, Pant Sugandh Dhan 15/UPR 3003-11-1-1,Basmati 370/Pant Sugandh Dhan 17, Basmati 370/ Pusa Basmati 1, Type 3/Pusa Basmati1, Type 3/UPR 2845-6-3-1, Pant Sugandh Dhan 17/Pusa Sugandh 4, Pant Sugandh Dhan17/UPR 2845-6-3-1, Pant Sugandh Dhan 17/UPR 3003-11-1-1, Pusa Basmati 1/Pusa Sugandh 4, Pusa Sugandh 4/UPR 2845-6-3-1 and UPR 2845-6-3-1/UPR 3003-11-1-1 exhibited significant *sca* effects for GY (Table 4). Among these hybrids all have at least one parent with positive *gca* effect, while 7 hybrids have both parents with positive *gca* effect (Table 3). The hybrid Pusa Basmati 1/ Pusa Sugandh 4 showed significant favourable *sca* effects for eight yield components (Table 4). The hybrids Pant Sugandh Dhan 15/UPR 2845-6-3-1, Pant Sugandh Dhan 17/Pusa Sugandh 4 and Pant Sugandh Dhan 17/UPR 2845-6-3-1 showed significant favourable *sca* effects for seven yield components; Pant Sugandh Dhan 15/Pant Sugandh Dhan 17, Pant Sugandh Dhan 15/Pusa Sugandh 4, Basmati 370/Pusa Basmati 1, Type3/Pusa Basmati1, Type 3/UPR 2845-6-3-1, Pusa Basmati1/ UPR 3003-11-1-1 and UPR 2845-6-3-1/UPR 3003-11-1-1 for six yield components; Basmati 370/UPR 2845-6-3-1, Pant Sugandh Dhan 15/Basmati 370, Pant Sugandh Dhan 15/UPR 3003-11-1-1 and Pant Sugandh Dhan 17/UPR 3003-11-1-1 for five yield components.

The crosses Pant Sugandh Dhan 15/Pant ugandh Dhan 17, Pant Sugandh Dhan 15/Pusa Bamati 1, Pant Sugandh Dhan 15/UPR 2845-6-3-1, Pant Sugandh Dhan 15/UPR 3003-11-1-1, Pant Sugandh Dhan 17/UPR 284-6-3-1, Pant Sugandh Dhan 17/UPR 3003-11-1-1 and UPR 2845-6-3-1/UPR 3003-11-1-1 for GY showing high *sca* effects were in the category of high x high general combiner cross combinations. This

Table 3. Estimate of general combining ability (*gca*) effect of parents for various characters

Components of genetic variance	DF	PH	FL (cm)	FB (cm)	PL (cm)	PN (cm)	GP	TW	GY (g)	BY (g)	HI (g)	KL (%)	KB (mm)	LBR (mm)	AC (mm)	AS
Pant Sugandh Dhan 15	-0.925	-3.873*	1.34	0.076**	-0.099	-0.088	11.684**	0.705	7.151**	10.884**	2.984**	0.05	-0.021	0.073	-0.21	-0.08
Basmati 370	4.575**	18.188**	-1.14	-0.028	-0.394	1.997**	-21.45**	-0.38	-7.874**	-12.511**	-4.235**	-0.12	0.034	-0.144*	0.10	-0.16*
Type 3	5.125**	11.148**	-1.565	-0.026	-0.519	-1.527**	-9.494**	-.947*	-6.619**	-12.011**	-2.519**	-0.37**	0.014	-0.269**	-0.21	-0.26**
Pant Sugandh Dhan 17	-2.725**	-3.233*	-0.908	0.050*	0.531*	-0.961*	6.498**	0.14	1.361**	9.089**	-1.260**	0.185*	0.004	0.099	0.49**	0.26**
Pusa Basmati 1	0.025	2.588*	-0.941	-0.043	0.451	0.903*	4.664*	-1.535**	1.566**	5.984**	0.032	0.01	-0.001	0.017	0.16	0.18*
Pusa Sugandh 4	0.275	-6.312**	-0.831	-0.066*	-0.52*	-0.551	-7.155**	2.317**	-2.504**	-5.061**	-0.474	-0.075	-0.05*	0.057	0.18	-0.05
UPR 2845-6-3-1	-1.825*	-5.013**	1.966*	-0.001	0.771*	0.266	11.626**	-0.127	4.931**	7.039**	2.169**	0.160*	0.044*	0.005	0.25*	-0.14
UPR 3003-11-1-1	-4.525**	-13.492**	2.076*	0.037	-0.224	-0.039	3.630*	-0.175	1.986**	-3.411**	3.304**	0.160*	-0.026	0.163*	-0.76**	0.23*
SE (gi)	0.715	1.32	0.84	0.02	0.27	0.37	1.63	0.44	0.26	0.78	0.29	0.08	0.02	0.07	0.11	0.08
SE (gi-gj)	1.08	2	1.27	0.04	0.4	0.59	2.47	0.67	0.4	1.18	0.44	0.12	0.03	0.11	0.17	0.12

* and ** Significant at 5 and 1 per cent probability levels, respectively

DF- Days to 50 % flowering, PH- Plant height, FL- Flag leaf length, FB- Flag leaf breadth, PL- Panicle length, PN- Number of panicles plant^{-1}, GP- Grain number panicle^{-1}, TW- 1000 grain weight, GY- Grain yield plant^{-1}, BY- Biological yield plant^{-1}, HI- Harvest index, KL- Kernel length, KB- Kernel breadth, LBR- Kernel L/B ratio, AC- Amylose content and AS- Alkali spreading value.

Table 4. Estimate of specific combining ability (*sca*) effect for different characters

Crosses	DF	PH (cm)	FL (cm)	FB (cm)	PL (cm)	PN	GP	TW (g)
Pant Sugandh Dhan 15/Basmati 370	-5.456*	-3.612	0.58	0.097	1.061	7.349**	-0.899	-0.208
Pant Sugandh Dhan 15/ Type 3	-1.006	14.078**	3.204	0.095	2.086**	2.998**	0.006	1.158
Pant Sugandh Dhan 15/Pant Sugandh Dhan 17	-0.156	-0.242	7.447**	0.189**	1.736*	-6.169**	29.254**	1.821
Pant Sugandh Dhan 15/Pusa Basmati 1	0.094	-10.96**	2.381	0.102	1.116	0.168	0.578	2.146
Pant Sugandh Dhan 15/Pusa sugandh 4	5.844**	16.688**	-4.880*	-0.220**	0.986	13.271**	-16.28**	-0.856
Pant Sugandh Dhan 15/UPR 2845-6-3-1	3.944*	-6.912*	-6.091*	-0.116	-0.804	-0.41	30.271**	1.489
Pant Sugandh dhan 15/UPR 3003-11-1-1	5.644**	1.568	1.963	0.027	1.691*	1.509	9.687*	1.636
Basmati 370/Type 3	-6.506**	-22.10**	-0.038	-0.076	-0.219	-2.437*	-1.841	-0.076
Basmati 370/Pant Sugandh Dhan 17	6.844**	13.248**	-5.235*	-0.007	0.781	7.347**	3.698	1.857
Basmati 370/Pusa Basmati 1	6.094**	7.878*	4.863*	-0.105	0.211	4.883**	23.186**	0.682
Basmati 370/Pusa sugandh 4	3.344	6.278	-0.547	-0.071	-0.619	1.737	-9.270*	-1.57
Basmati 370 / UPR 2845-6-3-1	2.444	12.778**	-2.194	-0.007	1.491*	3.620**	-32.17**	-0.901
Basmati 370/UPR 3003-11-1-1	0.144	12.958**	4.246	0.086	1.386*	-1.275	15.090**	-4.728**
Type 3/Pant Sugandh dhan 17	6.294**	16.038**	-3.146	-0.029	0.756	0.971	-26.42**	0.523
Type 3/ Pusa Basmati 1	7.044**	10.618**	2.888	-0.007	1.236	0.107	27.076**	0.298
Type 3/Pusa sugandh 4	8.294**	0.618	1.878	0.157*	1.506*	-1.64	10.085*	-2.254
Type 3/UPR 2845-6-3-1	4.394*	22.818**	1.881	0.122	1.516*	9.694**	-6.006	1.291
Type 3/UPR 3003-11-1-1	-5.406**	-41.80**	-7.089**	-0.236**	-3.289**	-1.966**	5.955	-0.862
Pant Sugandh Dhan 17/Pusa basmati 1	5.394*	31.698**	3.431	0.148*	-0.014	6.691**	-21.79**	-0.889
Pant Sugandh Dhan 17/Pusa Sugandh 4	-8.356**	-9.602*	2.521	0.191**	0.956	-2.356*	39.668**	-1.841
Pant Sugandh Dhan 17/UPR 2845-6-3-1	-6.256**	-10.05**	0.249	-0.225**	0.366	-4.873**	42.327**	-0.196
Pant Sugandh Dhan 17/UPR 3003-11-1-1	0.944	0.678	-6.662**	-0.257**	-0.589	14.383**	-6.317	-0.049
Pusa Basmati 1/Pusa sugandh 4	-6.606**	-21.67**	10.154**	0.124	1.436*	-3.820**	39.212**	-1.216
Pusa Basmati 1/ UPR 2845-6-3-1	-3.006	8.378*	0.107	0.108	0.396	8.299**	-12.289*	-2.671*
Pusa Basmati 1/UPR 3003-11-1-1	-4.306*	13.908**	1.247	0.09	1.491*	2.920**	-9.543*	0.376
Pusa Sugandh 4/UPR 2845-6-3-1	-8.256**	1.278	2.947	0.032	-1.084	-3.233**	7.68	0.877
Pusa sugandh /UPR 3003-11-1-1	-3.556	14.458**	0.837	0.054	1.411*	-0.728	-20.27**	2.024
UPR 2845-6-3-1/UPR 3003 -11-1-1	3.044	4.558	1	0.014	-0.129	-1.765	26.220**	1.069
SE (sij)	2.19	4.05	2.58	0.08	0.81	1.13	5	1.36

DF- Days to 50 % flowering, PH- Plant height, FL- Flag leaf length, FB- Flag leaf breadth, PL- Panicle length, PN- Number of panicles plant^{-1}, GP- Grain number panicle^{-1}, TW- 1000 grain weight.

Crosses	GY (g)	BY (g)	HI (%)	KL (mm)	KB (mm)	LBR (mm)	AC	AS
Pant Sugandh Dhan 15/Basmati 370	7.779**	8.448**	6.577**	0.009	0.047	-0.101	-0.015	-0.098
Pant Sugandh Dhan 15/ Type 3	4.774**	15.448**	0.961	0.269	-0.033	0.244	0.405	-0.249
Pant Sugandh Dhan 15 / Pant Sugandh Dhan 17	0.312	2.544**	-4.152*	4.117**	-0.191	0.027	-0.18	-0.548
Pant Sugandh Dhan 15 /Pusa Basmati 1	4.839**	2.903	3.656**	0.384	-0.018	0.253	-0.607*	0.298
Pant Sugandh Dhan 15 / Pusa sugandh 4	9.909**	25.998**	1.36	0.969**	0.027	0.533*	0.655*	-0.2
Pant Sugandh Dhan 15 / UPR 2845-6-3-1	18.974**	33.898**	4.838**	0.184	-0.063	0.235	0.879**	0.471*
Pant Sugandh dhan 15 / UPR 3003-11-1-1	11.669**	39.348**	-1.842**	-0.016	0.207**	-0.278*	0.516	-0.319
Basmati 370 / Type 3	-3.801**	0.343	-5.780**	0.034	-0.138*	0.361	0.107	-0.167
Basmati 370 /Pant Sugandh Dhan 17	14.519**	60.243**	-524	0.74	0.072	-0.128	-0.386	-0.021
Basmati 370 / Pusa Basmati 1	19.614**	43.348**	5.899**	0.099	0.027	-0.02	0.339	0.38
Basmati 370 / Pusa sugandh 4	-4.866**	-15.61**	-0.636	-0.466*	0.172**	-0.605**	-0.174	0.295
Basmati 370 / UPR 2845-6-3-1	-15.05**	-26.21**	-7.913**	0.649**	-0.118*	0.632**	-0.075	0.468*
Basmati 370 / UPR 3003-11-1-1	-13.81**	-37.26**	-2.373**	0.749**	0.052	0.279	-1.238**	0.342
Type 3 / Pant Sugandh dhan 17	-10.29**	-20.26**	-5.450**	0.684	0.092	0.207	-0.936**	0.243
Type 3 / Pusa Basmati 1	11.059**	10.348**	7.704**	0.259	-0.103	0.390*	-1.610**	0.559*
Type 3 / Pusa sugandh 4	0.429	33.893**	-8.301**	-0.106	0.042	-0.436*	-0.694*	0.394
Type 3 / UPR 2845-6-3-1	12.494**	31.793**	2.726**	-0.291	0.202**	-0.509*	-0.415	0.072
Type 3 / UPR 3003-11-1-1	-2.761**	-16.26**	4.602**	-0.541*	-0.128*	-0.037	0.378	-0.059
Pant Sugandh Dhan 17 / Pusa basmati 1	-3.271**	26.748**	-7.866**	-1.151**	0.057	-0.794**	0.138	-0.549*

Table 4 Contd..

Crosses	GY (g)	BY (g)	HI (%)	KL (mm)	KB (mm)	LBR (mm)	AC	AS
Pant Sugandh Dhan 17 / Pusa Sugandh 4	13.449**	35.293**	2.120*	0.284	-0.048	0.292	0.084	0.035
Pant Sugandh Dhan 17 / UPR 2845-6-3-1	7.664**	10.693**	3.907**	-0.201	-0.138*	0.189	-0.417	0.543*
Pant Sugandh Dhan 17 / UPR 3003-11-1-1	19.209**	26.143**	7.897**	-0.151	0.032	-0.185	0.871**	0.167
Pusa Basmati 1 / Pusa sugandh 4	10.794**	10.898**	6.568**	0.209	0.057	-0.021	-0.151	-0.564*
Pusa Basmati 1 / UPR 2845-6-3-1	-0.691	6.298**	-1.845*	-0.376	0.018	-0.279	-0.157	-0.141
Pusa Basmati 1 /UPR 3003-11-1-1	-0.696	6.748**	-2.689**	-0.076	0.037	-0.147	1.021**	-0.017
Pusa Sugandh 4 /UPR 2845-6-3-1	2.829**	-10.16**	7.795**	0.159	0.012	0.066	-0.38	-0.472*
Pusa sugandh 4 / UPR 3003-11-1-1	-9.176**	-12.21**	-5.44**	0.159	0.032	-0.207	0.358	-0.012
UPR 2845-6-3-1/ UPR 3003 -11-1-1	12.389**	28.193**	1.968**	-0.276	-0.058	-0.04	0.857**	0.496*
SE (sij)	0.8	2.4	0.9	12.24	0.06	0.23	0.35	0.25

GY- Grain yield plant^{-1}, BY- Biological yield plant^{-1}, HI- Harvest index, KL- Kernel length, KB- Kernel breadth, LBR- Kernel L/B ratio, AC- Amylose content and AS- Alkali spreading value.

is attributable to additive and/or additive x additive type of gene effects which are fixable in nature (Singh *et al*., 1971). Therefore, there is high probability of obtaining good transgressive segregants in the progeny of these crosses for improvement of this trait. On the other hand, Pant Sugandh Dhan 15/Basmati 370 and Pant Sugandh Dhan 15/Type 3 both of which displayed high *sca* effects for GY had common female parent with significant *gca* while male parent with non-significant *gca*, respectively. The case of high *sca* between high x poor combiners could produce good segregants only if the additive genetic effects are present in the good general combiners and complimentary epistatic effects in the poor combiners and they act in the same direction to maximise desirable plant attributes (Singh and Chaudhary, 1992).

The non-significant *sca* effect was exhibited by the cross Pant Sugandh Dhan 17/Pusa Basmati 1 for GY. These according to Devraj and Nadarajan (1996) are expected to produce desirable recombinants in advance generation of inbreeding. The cross Basmati 370/Type 3 showed high *sca* effect for DF and PH while parents were poor x poor general combiners. This is belived to be due to epistatic gene action. In other hybrids also, all kinds of parental combinations like high x high, high x low, medium x medium and medium x low were found. These type of interactions, according to Dhaliwal and Sharma (1990), Katre and Jambhale (1996), Ramalingam *et al.* (1997) and Vanaja *et al.* (2003) attributed to either additive x additive and/or additive x dominance genetic interactions. Also they suggested that the superiority of these crosses may be due to complimentary and duplicate type of gene interactions. Therefore, these crosses are expected to produce desirable segregants and could be exploited successfully in varietal improvement programme.

The present study reveals importance of both additive and non-additive gene effects in governing yield and yield attributes with preponderance of non-additive gene action. In this situation, where both non-additive and additive components were important for the expression of characters, especially when the former component is preponderant, simple pedigree method of selection would be ineffective for its improvement. Population improvement programme like reciprocal recurrent selection which may allow to accumulate the fixable gene effects as well as to maintain considerable variability and heterozygosity for exploiting non-fixable gene effects will prove to be the most effective method (Joshi, 1979). However rice is a highly self pollinated crop, forming single seed per pollination, this selection procedure not practicable. Three of the top parents, F_1's, general combiners and specific combiners for various characters based on *per se* performance of parents and F_1's are given in Table 5.

So possible choice is the use of biparental mating among selected crosses or use of selection procedure such as diallel selective mating (Jensen, 1970) to exploit both the additive and non-additive genetic components. The parent UPR 2845-6-3-1 and Pant Sugandh Dhan 17 could be utilised in hybridization programme because of its good general combining ability for yield and its components. Hybrids namely Pant Sugandh Dhan 15/Basmati 370, Pant Sugandh Dhan 15/Type 3, Pant Sugandh Dhan 15/Pant Sugandh Dhan 17, Pant Sugandh Dhan 15/Pusa Basmati 1, Pant Sugandh Dhan 15/Pusa Sugandh 4, Pant Sugandh Dhan 15/UPR 2845-6-3-1, Pant Sugandh Dhan 15/UPR 3003-11-1-1, Basmati 370/Pant Sugandh Dhan 17, Basmati

Table 5. Three of the top parents, F_1's, general combiners and specific combiners for yield, yield contributing and quality characters

Characters	Parent*	F_1's*	General Combiner	Specific Combiner
Days to 50% flowering	Basmati 370 Pusa Sugandh 4 Type 3	Type 3/ Pusa Sugandh 4 Type 3/Pusa Basmati 1 Basmati 37/ Pusa Basmati 1	UPR 3003-11-1-1 Pant Sugandh Dhan 17 UPR 2845-6-3-1	Pant Sugandh Dhan 17/Pusa Sugandh 4 Pusa Sugandh 4/UPR 2845-6-3-1 Pusa Basmati 1/Pusa Sugandh 4
Plant height (cm)	Basmati 370, Type 3, Pant Sugandh Dhan 15	Pant Sugandh Dhan 17/ Pusa Basmati 1, Type 3/ UPR 2845-6-3-1, Basmati 370/Pusa Basmati 1	UPR 3003-11-1-1 Pusa Sugandh 4 UPR 2845-6-3-1	Type 3/UPR 3003-11-1-1 Basmati 370/Type 3 Pusa Basmati 1/Pusa Sugandh 4
Flag leaf length (cm)	UPR 3003-11-1-1, UPR 2845-6-3-1,	Pant Sugandh Dhan 15/ Pant Sugandh Dhan 15 Pant Sugandh Dhan 17, Basmati 370/UPR 3003-11-1-1,UPR 2845-6-3-1/ UPR 3003-11-1-1	UPR 3003-11-1-1 UPR 2845-6-3-1 Pant Sugandh Dhan 15	Pusa Basmati 1/Pusa sugandh 4 Pant Sugandh Dhan 15/Pant Sugandh Dhan 17,Basmati 370/Pusa Basmati 1
Flag leaf breadth (cm)	UPR 3003-11-1-1, Pant Sugandh Dhan 17, Pant Sugandh Dhan 15	Pant Sugandh Dhan 15/ Pant Sugandh Dhan 17, Pant Sugandh Dhan 17/ Pusa Sugandh 4, Pant Sugandh Dhan 17/ Pusa basmati 1	Pant Sugandh Dhan 15 Pant Sugandh Dhan 17 UPR 3003-11-1-1	Pant Sugandh Dhan 17/Pusa Sugandh4 Pant Sugandh Dhan 15/Pant Sugandh Dhan 17Type 3/Pusa Sugandh 4
Panicle length (cm)	UPR 2845-6-3-1, Pant Sugandh Dhan 17, UPR 3003-11-1-1	Pant Sugandh Dhan 15/ Pant Sugandh Dhan 17, Basmati 370/UPR 2845-6-3-1, Type 3/UPR 2845-6-3-1	UPR 2845-6-3-1 Pant Sugandh Dhan 17 Pusa Basmati 1	Pant Sugandh Dhan 15/Type 3,Pant Sugandh Dhan 15/Pant Sugandh Dhan 17, Pant Sugandh Dhan 15/UPR 3003 -11-1-1
Number of panicles plant^{-1}	UPR 3003-11-1-1, Basmati 370,Type 3	Pant Sugandh Dhan 17/ UPR 3003-11-1-1, Pant Sugandh Dhan 15/ Pusa Sugandh 4, Pusa Basmati 1/UPR 2845-6-3-1	Basmati 370 Pusa Basmati 1 UPR 2845-6-3-1	Pant Sugandh Dhan 17/UPR 3003-11-1-1, Pant Sugandh Dhan 15/Pusa Sugandh 4, Pusa Basmati 1/UPR 2845-6-3-1
Grain number panicle^{-1}	UPR 3003-11-1-1, Pant Sugandh Dhan 15, UPR 2845-6-3-1	Pant Sugandh Dhan 17/UPR 2845-6-3-1,Pant Sugandh Dhan 15/UPR 2845-6-3-1, Pant Sugandh Dhan 15/Pant Sugandh Dhan 17	Pant Sugandh Dhan 15 UPR 2845-6-3-1Pant Sugandh Dhan 17	Pant Sugandh Dhan 17/UPR 2845-6-3-1, Pant Sugandh Dhan 17/Pusa Sugandh 4, Pusa Basmati 1/Pusa Sugandh 4
1000-grain weight (g)	Pusa Sugandh 4, Basmati 370, UPR 3003-11-1-1	Pusa Sugandh 4/UPR 3003-11-1-1,Pusa Sugandh 4/ UPR 2845-6-3-1, Pant Sugandh Dhan 15/Pant Sugandh Dhan 17	Pusa Sugandh 4 Pant Sugandh Dhan 15 Pant Sugandh Dhan 17	Pant Sugandh Dhan 15/Pusa Basmati 1,Pusa Sugandh 4/UPR 3003-11-1-1,Basmati 370/Pant Sugandh Dhan 17

* Based on *per se* performance

Characters	Parent*	F_1's*	General Combiner	Specific Combiner
Grain yield plant^{-1} (g)	UPR 3003-11-1-1, UPR 2845-6-3-1, Pant Sugandh Dhan 15	Pant Sugandh Dhan 15/ UPR 2845-6-3-1, Pant Sugandh Dhan 17/ UPR 3003-11-1-1, Pant Sugandh dhan 15/ UPR 3003-11-1-1	Pant Sugandh Dhan 15 UPR 2845-6-3-1 UPR 3003-11-1-1	Basmati 370/Pusa Basmati 1,Pant Sugandh Dhan 17/UPR 3003-11-1-1, Pant Sugandh Dhan 15/UPR 2845-6-3-1
Biological yield plant^{-1} (g)	UPR 2845-6-3-1, UPR 3003-11-1-1, Pant Sugandh Dhan 15	Basmati 370/Pant Sugandh Dhan 17,Pant Sugandh Dhan 15/UPR 2845-6-3-1, Pant Sugandh Dhan 15/UPR 3003-11-1-1	Pant Sugandh Dhan 15 Pant Sugandh Dhan 17 UPR 2845-6-3-1	Basmati 370/Pusa Basmati 1,Pant Sugandh dhan 15/UPR 3003-11-1-1, Pant Sugandh Dhan 17/Pusa Sugandh 4

Table 5 Contd..

Characters	Parent*	F_1's*	General Combiner	Specific Combiner
Harvest index (%)	UPR 3003-11-1-1, UPR 2845-6-3-1, Type 3	Pant Sugandh Dhan 15/ UPR 2845-6-3-1, Pant Sugandh Dhan 17/ UPR 3003-11-1-1, Pusa Sugandh 4/UPR 2845-6-3-1	UPR 3003-11-1-1 Pant Sugandh Dhan 15 UPR 2845-6-3-1	Pant Sugandh Dhan 17/UPR 3003-11-1-1, Pusa Sugandh 4/UPR 2845-6-3-1,Type 3/Pusa Basmati 1
Dehulled kernel length (mm)	Pant Sugandh Dhan 17, UPR 2845-6-3-1, UPR 3003-11-1-1	Pant Sugandh Dhan 15/ Pusa Sugandh 4, Basmati 370/UPR 3003-11-1-1,Basmati 370/ UPR 2845-6-3-1	Pant Sugandh Dhan 17 UPR 3003-11-1-1 UPR 2845-6-3-1	Pant Sugandh Dhan 15/Pusa Sugandh 4, Basmati 370/UPR 3003-11-1-1, Basmati 370/UPR 2845-6-3-1
Dehulled kernel breadth (mm)	UPR 2845-6-3-1, Type 3, Pusa Basmati 1	Type 3/UPR 2845-6-3-1, Type 3/UPR 2845-6-3-1, Pant Sugandh Dhan 15/ UPR 3003-11-1-1	UPR 2845-6-3-1 Basmati 370 Type 3	Pant Sugandh Dhan 15/UPR 3003-11-1-1, Type 3/UPR 2845-6-3-1,Basmati 370/Pusa Sugandh 4
Dehulled kernel L/B ratio (mm)	UPR 3003-11-1-1, Pant Sugandh Dhan 17, Pusa Basmati 1	Pant Sugandh Dhan 15/ Pusa Sugandh 4, Basmati 370/UPR 2845-6-3-1, Pant Sugandh Dhan 17/ Pusa Sugandh 4	UPR 3003-11-1-1 Pant Sugandh Dhan 17 Pant Sugandh Dhan 15	Basmati 370/UPR 2845-6-3-1,Type 3/ Pusa Basmati 1,Pant Sugandh Dhan 15/ Pusa Sugandh 4
Endosperm content of amylase	Pant Sugandh Dhan 17, Type 3, Basmati 370	Pant Sugandh Dhan 15/UPR 2845-6-3-1, Pant Sugandh Dhan 15/Pusa Sugandh 4, Basmati 370/Pusa Basmati 1	Pant Sugandh Dhan 17 UPR 2845-6-3-1 Pusa Sugandh 4	Pusa Basmati 1/UPR 3003-11-1-1,Pant Sugandh Dhan 15/UPR 2845-6-3-1, UPR 2845-6-3-1/UPR 3003 -11-1-1
Gelatinization temperature	Pusa Basmati 1, Pusa sugandh 4, UPR 3003-11-1-1	Pant Sugandh Dhan 17/ UPR 3003-11-1-1, Pant Sugandh Dhan 17/ UPR 2845-6-3-1, UPR 2845-6-3-1/ UPR 3003 -11-1-1	Pant Sugandh Dhan 17 UPR 3003-11-1-1 Pusa Basmati 1	Type 3/Pusa Basmati 1,Sugandh Dhan 17/UPR 2845-6-3-1,Pant Sugandh Dhan 15/UPR 2845-6-3-1

* Based on *per se* performance

370/Pusa Basmati 1, Type 3/Pusa Basmati1, Type 3/ UPR 2845-6-3-1, Pant Sugandh Dhan 17/Pusa Sugandh 4, Pant Sugandh Dhan17/UPR 2845-6-3-1, Pant Sugandh Dhan 17/UPR 3003-11-1-1, Pusa Basmati 1/ Pusa Sugandh 4, Pusa Sugandh 4/UPR 2845-6-3-1 and UPR 2845-6-3-1/UPR 3003-11-1-1 could be utilised for development of high yielding basmati hybrids.

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