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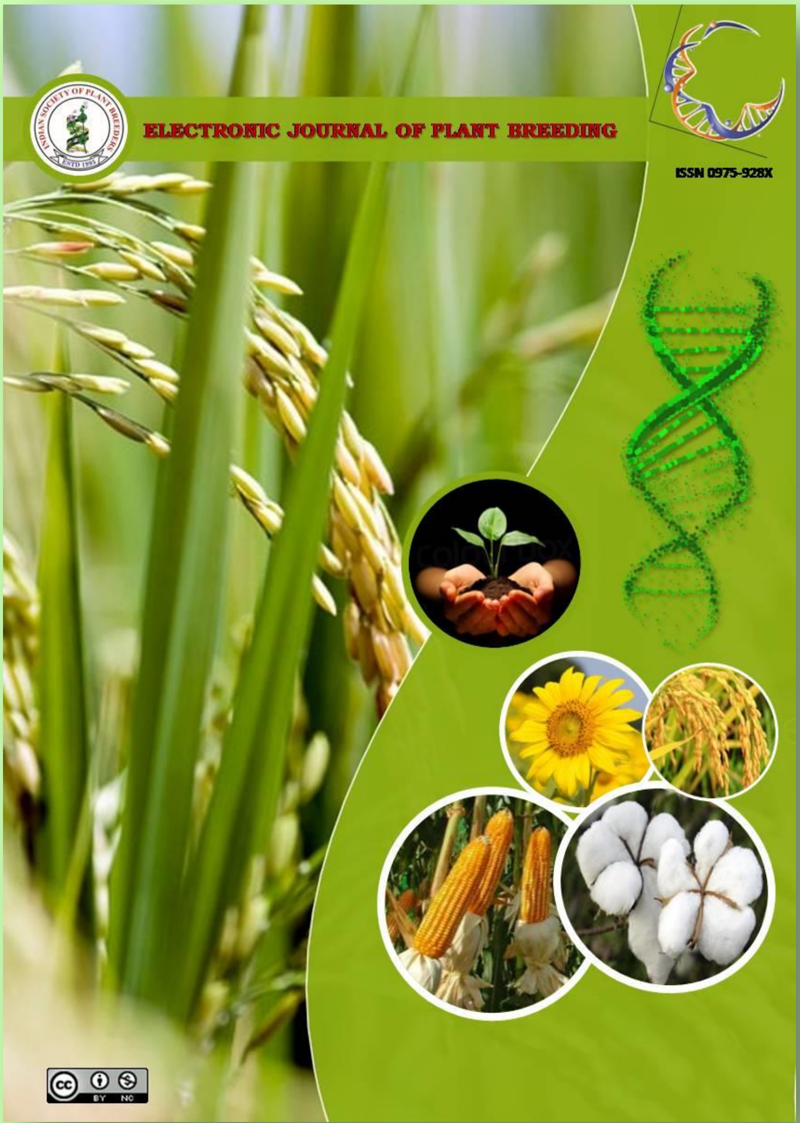

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Research Article

Genetic evaluation of yield and yield attributing traits in rice (*Oryza sativa* L.) using line x tester analysis

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Abstract
In order to study the combining behaviour of quantative traits of rice, line x tester (10x3) progenies were generated involving 10diverse parents viz., Basmati 370, Basmati 564, Saanwal basmati, Pusa basmati 1121, Pusa basmati 1, Pusasugandh, RR-600, Basmati 386, Type 3 and CSR-30 and three well adapted varieties Pusa basmati 1509, Ranbir basmati and Pusa 1460. The preponderance of both additive and dominant gene action was observed for most of the traits. Basmati 370, Basmati 564, Pusa Basmati 1121, Pusa basmati 1, Pusa basmati 1509 and Pusa 1460 were found to be good general combiners which can be utilized to generate desirable segregates for further selection. High sca effects were observed for grain yield and its component in cross combinations Basmati 370/Pusa basmati 1509, Basmati 564/Pusa 1460, Saanwal basmati/ Pusa basmati 1509, Saanwal basmati/Pusa 1460, Pusa basmati 1/Ranbir basmati, RR600/ Pusa 1460, Basmati 386/ Pusa 1460, Type 3/Ranbir basmati and CSR 30/Ranbir basmati which can be used for the exploitation of heterosis for yield.

Keywords
Line x tester, additive, dominance, general combiners

Introduction

Globally rice is cultivated approximately on an area of 158 million hectares, with production of more than 700 million tons annually. Out of the total production nearly 640 million tons of rice is grown in Asia alone, representing 90% of global production. India has highest acreage of 44 million hectares under rice with production and productivity of 108.8 million tonnes and 2.47tonnes per hectare respectively (Anonymous, 2016).Jammu and Kashmir state is rich in rice culture from the ancient times and it plays a pivotal role in the socio-cultural life of the people of the state. In J&K during 2015-16 rice was grown over an area of 3.04 lakh hectare with production and productivity of 64.66 lakh quintals and 21.24 quintals per hectare respectively (Anonymous, 2015).Basmati the premier rice known for quality was also grown over an area of about of 62.25thousand hectare with production of 129.04 metric tons(Anonymous, 2016) thereby, augmenting the income of farmers. In Jammu region rice is cultivated on an area of 1.61 lakh hectares with a production and productivity of 26.04 lakh quintals and 16.18 quintals per hectare, respectively. In addition basmati has a narrow genetic base owing to which it is difficult to get full spectrum of recombinants thus, creating bottlenecks for evolving high yielding cultivars. Simultaneously, basmati is poor combiner and there is dearth of donors for improving the quality and nutritional traits. With growing demand for aromatic rice in the local and international market, high emphasis has been laid on development and improvement of basmati types. In spite of high quality traditional basmati varieties in India, the research is continued for the development of many new basmati and hybrid varieties of rice with better quality and agronomic traits to meet the consumer and farmers demand (Joshi and Behera, 2006). Therefore, concerted breeding efforts are needed to broaden the genetic base and also to explore the best combiners for their effective exploitation in hybridization programme. Combining ability helps in understanding the nature and magnitude of gene action involved in inheritance and also identifies superior parental genotypes as well as good cross combinations (Saleem *et al.*, 2008). Therefore, the present investigation was aimed to assess combining ability of various morpho-physiological, quality and nutritional traits following line × tester technique (Kempthorne, 1957) so as to identify suitable parental genotypes and cross combinations for further genetic improvement.

Materials and Method

10 lines viz., Basmati 370, Basmati 564, Saanwal basmati, Pusa basmati 1121, Pusa basmati 1, Pusasugandh, RR-600, Basmati 386, Type 3 and CSR-30 and three testers Pusa basmati 1509, Ranbir basmati and Pusa 1460 constitute the material for the present study. Parents were evaluated in a Randomized Block Design with three replications at the experimental area of Division of Plant Breeding & Genetics, Sher-e-

Kashmir University Main Campus, Chatha Jammu during Kharif 2014 and three staggered sowings were taken up at 10 days interval to have synchronization in flowering. Seedlings were transplanted in the main field on 25 days of sowing in two row plot of 3m.length with a spacing of 20 cm. between rows and 15cm. between plants within a row. For easiness in crossing work, a wider spacing of 60cm. was maintained on either side of female row plot. Recommended package of practices were followed to raise a good crop. Each line was crossed to all the three testers in Line × Tester fashion (Kempthorne, 1957) and sufficient quantity of F_1 seed of 30 cross combinations so generated was produced. Observations were recorded on five randomly selected plants, per replications for 50 per cent flowering, plant height(cm.), number of effective tillers, panicle length, days to maturity, grain yield(kg/plot), 1000 grain weight, and spikelets per panicle. Observations on days to 50 per cent flowering and days to maturity were recorded on plot basis. The combining ability analysis was carried out by the following method given by Kempthorne (1957). This design (Line × Tester) leads to partitioning of the effects of hybrids into general combining ability effects of lines and testers and their specific combining ability effects in cross combinations. At the same time, it is helpful in estimating various types of gene effects. The mating pattern of this design is that “l” lines are crossed to each of the “t” testers and thus “l × t” full sib families are produced.

Results and discussion

The analysis of variances for present study have been given in table 1. The analysis of combining ability for most of the characters revealed significant differences among genotypes, parents, crosses, parents vs crosses, lines and testers. Singh and Kumar (2004) and Panwar (2005) also reported worth of genetic variability for different traits *viz*, days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, panicle length, spikelets per panicle, 1000-grain weight and grain yield per plant Estimates of genetic components are presented in (Table 1). Estimates of variance of general combining ability (σ^2gca) was lower than those of variance of specific combining ability (σ^2SCA) for the traits *viz* days to 50% flowering, plant height, spikelets per panicle, panicle length, days to maturity, grain yield per plant and 1000 grain weight, whereas no. of effective tillers showed additive gene action. The ratio of variance of general to specific combining ability (σ^2gca/σ^2SCA) was found to be approaching/ nearby one thereby indicating additive gene action ratio of additive to dominance variance (σ^2D/σ^2A) each being less than unity indicating except in few characters as in (Table 4).Similar results were reported by Latha *et al.* (2013),Reddy, 2002). (Honarnejad and Tarang, 2001) Sanghera and Hussain (2012); Fellahi *et al* (2013); and Adilakshmi and Upendra (2014)

For general combining ability effects of the parents are presented in table 2. For plant height, two lines viz., Basmati 564, Saanwal basmati and one tester Pusa basmati 1509 showed significant and negative GCA effects. Latha *et al* (2013), Priyanka *et al* (2014), Savita *et al* (2015) adjudged several parents with desirable GCA effects for plant height in rice. For grain yield per plant four lines viz., Basmati 370, Basmati 564, Pusa 1121 and Pusa basmati 1 and two testers Pusa basmati 1509 and Pusa 1460 showed significant and desirable GCA effects. Kohli *et al* (2013), Dharwal *et al* (2017), Devi *et al* (2017) documented several promising genotypes with significantly high GCA effects in rice. For days to maturity Pusa 1121, Pusa basmati 1, RR-600, Basmati 386 and Type 3 among lines and Pusa basmati 1509 and Pusa 1460 among testers showed significant negative GCA. Consideration of GCA effects led to the identifications that Basmati 564 and Pusa basmati 1 among lines and Pusa basmati 1509 among tester as a good combiners for grain yield per plant. Pusa basmati 1121, Saanwal basmati and Pusa 1460 for short plant height. High GCA effects show presence of favourable genes with additive type of gene action. Therefore; a multiple crossing programme involving good general combiners isolated in current study is recommended to identify superior genotypes as proposed by Nadarajan and Gunasekaran (2005)

Specific combining ability effects are presented in table 3. None of the hybrids exhibited significant and desirable SCA effects for all the parameters. For grain yield per plant, nine cross combinations viz., Basmati 370 x Pusa basmati 1509, Basmati 564 x Pusa 1460, Saanwal basmati x Pusa basmati 1509, Saanwal Basmati x Pusa 1460, Pusa basmati 1 x Ranbir basmati, RR-600 x Pusa 1460, Basmati 386 x Pusa 1460, Type 3 x Ranbir basmati and CSR-30 x Pusa 1460 were found good specific combiners based on SCA effects. These results are in line with those of Panwar (2005) and Petchimmal and Kumar (2007) who reported several promising specific combiners based on high SCA effects for yield per plant. For other traits, sets of good specific combiners were identified based on high SCA effects. In this regards, three cross combinations viz., Basmati 564 x Pusa basmati, Pusasugandh x Pusa 1460 and CSR-30 x Ranbir basmati were good for early flowering; three cross combinations viz., Basmati 370 x Ranbir basmati, Basmati 370 x Pusa 1460 and Pusa basmati 1121 x Pusa 1460 were ideal for short stature;

Dharwal *et al* (2017) and Devi *et al* (2017),on the identification of best specific combiners for short plant height. Two cross combinations *viz*., Pusa basmati 1121 x Pusa basmati 1509 and Pusa basmati 1 x Ranbir basmati were important for 1000 garin weight. Priyanka *et al* (2014) and Dharwal *et al* (2017) also identified good combiners for improving 1000-grain weight in rice.

From the above study, it was concluded that preponderance of both additive and dominant gene action was observed for most of the traits. Basmati 370, Basmati 564, Pusa Basmati 1121, Pusa basmati 1, Pusa basmati 1509 and Pusa 1460 were found to be good general combiners. Cross combinations Basmati 370/Pusa basmati 1509, Basmati 564/Pusa 1460, Saanwal basmati/ Pusa basmati 1509, Saanwal basmati/ Pusa 1460, Pusa basmati 1/Ranbir basmati, RR600/ Pusa 1460, Basmati 386/ Pusa 1460, Type 3/Ranbir basmati and CSR 30/ Ranbir basmati were found to be the superior for grain yield.

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Table 1. Analysis of variance for combining ability of different yield, its attributing traits in basmati rice

Source	Df	Days to 50% flowering	Number of effective tillers per plant	Plant height (cm)	Spikelets per panicle (no.)	Panicle length (cm)	Days to maturity (no.)	Grain yield per plant (g)	1000 grain weight (g)
Replications	2	48.65	1.59	4.58	5.71	0.83	9.90	2.52	15.80**
Genotypes/ Progenies	42	346.95**	56.30**	187.90**	675.30**	9.94**	135.80**	51.40**	44.90**
Parents	12	548.90**	51.30**	149.85**	627.80*	16.04**	98.90**	43.50**	39.30**
Crosses	29	321.90**	58.60**	105.90**	699.00**	6.95**	141.00**	51.30**	47.40**
Parents *vs*crosses	1	1549.10**	50.21**	123.55**	555.60**	23.66**	127.10*	62.85**	41.60*
Lines	9	362.40**	125.70**	167.50**	685.50**	11.60**	240.50*	133.70**	89.20*
Testers	2	179.40*	16.40**	258.30**	215.50**	3.81**	208.02**	18.80**	15.08**
L x T	18	109.75**	9.75**	55.2**	105.3**	1.25**	20.3**	8.3**	8.7**
Error	84	88.3	6.1	28.5	94.7	1.41	37.9	6.8	7.5

*and ** respectively indicate significant at 5 and 1 percent level

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Table 2. General combining ability effects of different yield, its attributing traits in basmati rice genotypes

Parents	Days to 50% flowering	Number of effective tillers per plant	Plant height (cm)	Spikelets per panicle (no.)	Panicle length (cm)	Days to maturity (no.)	Grain yield per plant (g)	1000 grain weight (g)
Basmati 370	2.47**	1.67**	4.64**	11.36**	-0.41	6.11**	2.26**	2.08**
Basmati 564	-6.30**	1.47*	-2.90**	6.01**	-1.11**	1.9**	3.49**	2.22**
SaanwalBasmati	1.82**	2.40**	-3.51**	-1.68*	-0.33	2.00**	-0.66	1.29*
Pusa Basmati 1121	1.09	-3.97**	-3.60**	2.68**	1.90**	-2.95*	3.74**	-4.19**
Pusa Basmati 1	1.03	-3.48**	-1.28	6.95**	1.49**	-2.69**	5.38**	-2.95**
PusaSugandh	2.75**	-1.35	1.63*	-20.6**	-1.43**	-5.15**	-2.04**	1.97**
RR-600	-5.54**	2.30**	1.29	-1.76*	-0.70**	-4.74**	-2.66**	3.51**
Basmati 386	-0.59	0.94	1.65*	-6.72*	-1.50**	-2.59**	-2.05**	2.30*
Type-3	1.89**	1.02	-1.28	2.01*	1.47**	-2.46**	0.85	-5.82**
CSR-30	1.38*	-1.00	3.36**	1.75**	0.62**	-0.47	0.87	1.47*
S.E (gi)	**0.83**	**0.84**	**0.78**	**0.80**	**0.25**	**0.47**	**0.15**	**0.65**
S.E (gli-glj)	**6.83**	**1.19**	**5.35**	**8.21**	**1.07**	**4.91**	**1.61**	**1.34**
Testers								
PusaBasmati 1509	-1.38*	2.79**	-0.65**	1.12**	-1.35**	-1.50*	1.90**	-1.15**
RanbirBasmati	1.44*	-1.12*	3.20**	-2.15**	-1.00*	-1.55*	-3.43**	-1.34**
Pusa-1460	2.82**	-1.67**	-2.55**	1.03**	2.35**	3.05**	1.53**	2.49**
S.E (gi)	**0.65**	**0.46**	**0.07**	**0.18**	**0.41**	**0.90**	**0.63**	**0.52**
S.E (gti-gtj)	**3.74**	**0.65**	**2.93**	**4.50**	**0.58**	**2.70**	**0.89**	**0.74**

*and ** respectively indicate significant at 5 and 1 percent level

Table 3. Specific combining ability effects of different yield, attributingtraits

Cross Combinations	Days to 50% flowering	Number of effective tillers per plant	Plant height (cm)	Spikelets per panicle (no.)	Panicle length (cm)	Days to maturity (no.)	Grain yield per plant (g)	1000 grain weight (g)
Basmati 370 x Pusa Basmati1509	-2.97**	-0.90**	-2.5**	8.60**	1.64*	-6.57**	3.97**	1.64
Basmati 370 x Ranbir.Basmati	-2.01**	1.57**	-7.72**	-4.19**	-1.15	8.95**	-2.13	-1.47
Basmati 370 x Pusa1460	3.98**	-0.67**	-5.15**	-13.62**	1.93**	-2.77*	-3.16**	-2.37**
Basmati 564 x Basmati 1509	-4.90**	-2.41**	-2.70**	1.56**	2.41**	2.00	-3.57**	-4.88**
Basmati 564 x RanbirBasmati	4.77**	1.93**	0.87	1.21	1.94**	-5.41**	-2.24	-1.83*
Basmati 564 x Pusa1460	1.12	0.48	4.00**	-2.78**	1.36*	1.90	4.03**	1.80*
Saanwal Basmati x Pusa Basmati 1509	-1.99**	2.70**	3.90**	-4.72**	2.07**	4.10**	3.92**	1.92**
Saanwal Basmati x RanbirBasmati	-2.99**	-1.54**	-3.24**	3.29**	-2.56**	-3.06**	-2.19	1.46
SaanwalBasmati x Pusa1460	3.82**	-1.16**	-0.86	1.43**	2.17**	-2.64*	3.27**	-2.57**
Pusa Basmati 1121 x Pusa Basmati 1509	1.10	6.60**	-4.51**	1.07	-1.09	-2.57*	-5.64**	7.19**
Pusa Basmati 1121 x Ranbir.Basmati	1.56*	-3.84*	13.03**	5.9**	-1.14	4.49**	-2.23	-5.36**
Pusa Basmati1121 x Pusa1460	-1.67*	-2.76**	-8.52**	-11.67**	2.17**	-2.91*	1.48	-1.52
Pusa Basmati 1 x Pusa Basmati 1509	-1.44*	-3.12*	-1.92**	-16.75**	1.12	1.33	1.51	-1.47
Pusa Basmati 1 x Ranbir.Basmati	-2.86**	-0.31	-2.14**	-12.15**	1.84*	-2.78*	5.78**	4.09**
Pusa Basmati 1 x Pusa1460	4.00**	3.34**	4.06**	12.92**	-2.56**	-2.51*	-2.22	2.79**
PusaSugandh x Pusa Basmati 1509	14.63**	0.39	2.37**	6.14**	-1.14	5.59**	-2.00	-1.43
PusaSugandh x Ranbir Basmati	10.30**	1.97**	-2.40**	-5.44**	-2.23**	-3.31**	1.34	1.61
PusaSugandh x Pusa1460	-24.3**	-1.40**	1.40**	-0.70	1.67*	-3.28**	1.94	-1.48
RR-600 x Pusa Basmati 1509	1.03	0.55	-5.86**	1.12	-1.05*	-5.78**	-5.30**	1.51
RR-600 x Ranbir Basmati	1.52*	0.50	-1.64**	0.52	-1.74*	4.71**	-2.14	2.16**
RR-600 x Pusa1460	-2.73*	-1.05**	7.50**	-3.93**	1.59*	1.17	4.40**	-1.67*
Basmati 386 x Pusa Basmati 1509	-3.97**	-0.94**	-1.71**	-0.71	-2.27**	3.51**	-3.33**	1.45
Basmati 386 x Ranbir Basmati	.89	-1.26**	1.05**	-0.79	1.10	1.57	-2.20	1.44
Basmati 386 x Pusa1460	1.00	2.19**	-0.87	1.51**	2.04**	-2.62**	5.78*	-1.79*
Type-3 x Pusa Basmati 1509	-2.76**	1.78**	7.03**	17.89**	-1.66*	-3.39**	-3.04**	-1.64
Type-3 x Ranbir Basmati	-2.74**	-2.77**	-2.42**	8.83**	1.12	3.93**	3.07**	-2.12**
Type-3 x Pusa1460	5.51**	0.98**	-4.61**	-6.72**	-2.17**	3.46**	-4.27**	-4.77**
CSR-30 x Pusa Basmati 1509	4.56**	-4.66*	-4.85**	-2.47**	-1.10	4.51**	2.16	2.77**
CSR-30 x Ranbir Basmati	-7.94**	4.62**	-1.33**	15.09**	2.03**	-3.62**	3.35**	3.40**
CSR-30 x Pusa1460	5.45**	0.72**	5.18**	20.56**	-1.69*	2.00	-3.71**	1.67*
S.E(Sij)	**0.70**	**0.34**	**0.53**	**0.74**	**0.71**	**1.25**	**1.35**	**1.00**
S.E(Sij-Skl)	**11.84**	**2.06**	**9.27**	**14.22**	**1.85**	**8.51**	**2.82**	**2.33**

*and ** respectively indicate significant at 5 and 1 percent level

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Table 4. Estimates of genetic components of rice genotype

Genetic components	Days to 50% flowering	Number of effective tillers per plant	Plant height (cm)	Spikelets per panicle (no.)	Panicle length (cm)	Days to maturity (no.)	Grain yield per plant (g)	1000 grain weight (g)
$\sigma^2 gca$	8.26	3.14	8.09	17.70	0.33	10.46	3.48	2.23
$\sigma^2 sca$	8.69	3.26	8.90	18.65	0.35	11.25	3.68	2.28
σ^2A	16.53	6.29	16.17	35.41	0.66	20.92	6.97	4.46
σ^2D	8.69	3.26	8.90	18.65	0.35	11.25	3.68	2.28
$\sigma^2 gca/\sigma^2 sca$	0.95	0.96	0.91	0.95	0.95	0.93	0.95	0.98
$[\sigma^2D/\sigma^2A]^{1/2}$	0.73	0.72	0.74	0.73	0.72	0.73	0.73	0.72

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