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Combining ability analysis for yield and quality traits in indigenous aromatic rice

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ABSTRACT

Combining ability analysis for ten yield and three grain quality traits was made among 48 crosses generated in a line x tester (L x T) fashion with 12 indigenous aromatic lines and 4 testers. The LxT interaction was significant for all the traits under study. The magnitude of specific combining ability variances was higher than that of general combining ability variance for all the traits under study indicating a major role of non-additive gene effect in controlling these traits. The lines Juhi Bengal 21, Jeera Battis, Kalanamak 6, Kalanamak 11 and Kalanamak 2 were found to be good general combiners for grain yield and related traits. Among best crosses showing high sca for grain yield plant^{-1}, the cross BPT 5204 x Jeera Battis involves parents with good general combining ability for yield. The crosses BPT 5204 x Adamchini and Jaya x Kalanamak 11 involved parents with high x low general combining ability..

Key words: *combining ability, aromatic rice, yield, grain quality*

India is bestowed with a great treasure of indigenous aromatic short grain cultivars which compare equally with basmati rice as far as aroma and cooking qualities are concerned. However, these possess medium to short grains which makes them a class apart from the long grained basmati varieties. Change in income level and self-sufficiency including rice availability for consumption has brought a shift in the consumer as well as market preferences for better rice grain quality. As good grain quality fetches higher returns to the farmers, it has now become imperative to incorporate quality features in desirable range into the conventionally bred varieties as well as in the hybrids for their adoption. To compete with basmati rice in market, the yield level of the aromatic short grain rice varieties need to be improved keeping the desirable quality traits intact. With focus being on improvement of long grain Basmati rice, few reports on germplasm evaluation, genetics of quality traits are available on indigenous aromatic rice (Singh *et al*., 1996). It is high time that efforts should be focussed on the improvement of indigenous aromatic rice for getting a premium price in domestic as well as global market. The present study was undertaken to study the combining ability and genetics of yield, and grain quality traits in indigenous aromatic rice.

MATERIALS AND METHODS

The material for the present study comprised of 12 indigenous aromatic short grain genotypes accessions viz., Kalanamak 2, Kalanamak 5, Kalanamak 6, Kalanamak 11, Jeera Battis, Juhi Bengal 21, Juhi Bengal 23, Basmati Local 73, Badshahbhog, Katarni, Adamchini and Kanakjeera 28 crossed with four popular varieties viz., Jaya, Sarjoo 52, HUR 105 and BPT 5204 in a line x tester fashion. The 48 line x tester crosses thus made were sown along with their parents in a Compact Family Randomized Block Design with 3 replications for 2 consecutive years (2006 and 2007) following a spacing of 15 x 20 cm within and between rows. Each entry was transplanted in 3 rows, each being 5 m in length. All the recommended agronomic practices were followed. Observations were recorded on ten yield traits viz., days to 50% flowering (DTF), days to maturity (DTM), plant height (PH), flag leaf length (FLL), main panicle length (MPL), number of panicle plant^{-1} (PBT), number of grains panicle^{-1} (G/PAN), spikelet fertility (SF), 100-grain weight (100 GW), yield plant^{-1} (Y/P),

and three grain quality traits viz, brown rice length (BRL), brown rice breadth (BRB) and brown rice L/B ratio (BRL/B). Combining ability analysis was done following the method outlined by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed significant variance due to parents for all the traits under study (Table 1). The variance due to lines was significant for all the traits except panicles plant^{-1} while it was non-significant for all the traits except days to 50% flowering, main panicle length and yield plant^{-1} for testers. This indicated sufficient variability among the genotypes for the traits under study. Further, LxT interaction was significant for all the traits under study. The magnitude of specific combining ability variances was higher than that of general combining ability variance indicating major role of non-additive gene effect in controlling these traits. Importance of non-additive gene action in governing yield and yield components have been reported by earlier workers (Ramalingam *et al*., 1993, Babu *et al*., 2000, Satyanarayana *et.al*., 2000, Kumar and Singh, 2004, Panwar, 2005, Venkatesan *et al*., 2007).

The lines Juhi Bengal 21, Jeera Battis, Kalanamak 6, Kalanamak 11 and Kalanamak 2 were found to be good general combiners for grain yield (Table 2) among all the lines. In general, these lines were also good general combiners for other yield components. Juhi Bengal 21 combined well for flag leaf length, grains panicle^{-1}, spikelet fertility and brown rice breadth while Jeera Battis combined well for days to 50% flowering, days to maturity, grains panicle^{-1} and spikelet fertility. Kalanamak 6 was a good general combiner for days to 50% flowering, days to maturity, main panicle length, flag leaf length, spikelet fertility, 100-grain weight, brown rice length and brown rice L/B while Kalanamak 11 combined well for days to 50% flowering, days to maturity, number of panicles plant^{-1}, plant height, grains panicle^{-1}, 100-grain weight, brown rice length and brown rice L/B. Further, some lines showed better combining ability for some yield components but did not combine well for yield plant^{-1}. e.g. Kalanamak 5 combined well for days to 50% flowering, days to maturity, number of panicles plant^{-1}, plant height, 100-grain weight, brown rice length and brown rice L/B; Juhi Bengal 23 for flag leaf length,

Table 1. Analysis of Variance for Line x Tester analysis in indigenous aromatic rice (pooled over two years)

Source	d.f.	DTF	DTM	PBT	PH	MPL	FLL	G/PAN	SF	100GW	Y/P	BRL	BRB	BRL/B
Replications	2	1.001	2.42	1.01	27.36	0.43	11.36	1145.31**	3.68	0.01*	7.63*	0.01	0.01**	0.01
Treatments	63	117.92**	137.04**	10.14**	1030.49**	20.94**	86.46**	8968.69**	2674.98**	0.59**	141.11**	1.66**	0.14**	0.44**
Parents	15	288.68**	361.15**	11.56**	3070.70**	43.68**	117.57**	20037.34**	46.46**	0.92**	110.33**	2.94**	0.22*	0.69**
Crosses	47	25.74**	31.16**	9.75**	360.71**	12.49**	41.98**	5619.34**	2238.84**	0.38**	153.42**	1.28**	0.11**	0.37**
Parents vs Crosses	1	1888.62**	1751.77**	7.39**	1906.96**	77.02**	1710.68**	358.43*	62601.13**	5.24**	24.39**	0.69**	0.10**	0.01
Lines	11	51.61**	57.11*	9.88	799.91**	19.53*	76.85*	11130.11**	4831.14**	0.75**	396.40**	2.27*	0.23**	0.60*
Testers	3	38.50**	24.81	8.70	325.17	30.54*	38.57	9807.2	1797.65	0.22	220.99*	0.39	0.12	0.34
Lines vs Testers	33	15.96**	23.08**	9.79**	217.54**	8.51**	30.66**	3401.70**	1414.85**	0.27**	66.28**	1.03**	0.08**	0.30**
Error	126	0.66	1.39	0.42	11.44	1.19	5.39	86.96	5.13	0.01	2.25	0.01	0.01	0.01
Var gca		1.21	0.75	-0.02	14.38	0.69	1.13	294.46	79.15	0.01	10.10	0.01	0.01	0.01
Var sca		5.10	7.23	3.12	68.69	2.44	8.43	1104.91	469.91	0.09	21.34	0.34	0.03	0.09

*, ** Significant at P=0.05 and 0.01 respectively.

DTF = days to 50% flowering, DTM = days to maturity, PBT= no. of panicles/plant, PH = plant height, MPL = main panicle length, FLL = flag leaf length, G/PAN = number of grains/ panicle, SF = spikelet fertility (%), 100 GW = 100 - grain weight, Y/P = yield/plant, BRL = brown rice length, BRB = brown rice breadth and BRL/B = brown rice L/B ratio = BRL/B.

Table 2. General Combining Ability (gca) effects of 16 rice varieties (Lines and testers) in indigenous aromatic rice.

Lines	DTF	DTM	PBT	PH	MPL	FLL	G/PAN	SF	100GW	Y/P	BRL	BRB	BRL/B
Kalanamak 5	-2.764**	-0.257	1.069**	-18.171**	-2.428**	-5.298**	-29.043**	-22.539**	0.178**	-5.689**	0.338**	0.066**	0.096**
Juhi Bengal 21	0.653**	0.951**	-0.365	0.121	0.07	3.332**	67.524**	19.724**	-0.220**	11.730**	-0.297**	-0.081**	-0.042**
Juhi Bengal 23	-1.264**	-0.882**	0.481*	-0.688	-0.897**	-1.018	-4.551	5.584**	0.220**	-2.800**	0.107**	0.153**	-0.122**
Kanakjeera 28	-2.972**	-3.840**	0.385*	2.504*	0.165	0.657	9.565**	-11.948**	0.209**	-2.576**	0.161**	0.195**	-0.146**
Jeera Battis	-0.389	-1.924**	-0.385*	6.100**	0.374	-1.393*	44.159**	26.453**	-0.301**	6.288**	-0.382**	0.013	-0.200**
Kalanamak 6	-1.056**	-1.924**	-0.727**	11.833**	2.228**	2.215**	-20.351**	14.337**	0.314**	5.698**	0.473**	0.050**	0.151**
Kalanamak 11	-2.222**	-1.299**	0.831**	-7.900**	0.24	-0.039	12.045**	-14.113**	0.190**	1.596**	0.458**	0.115**	0.069**
Kalanamak 2	2.944**	3.326**	-2.260**	3.858**	-1.164**	-1.827**	-24.576**	35.192**	-0.387**	3.555**	-0.388**	-0.257**	0.110**
Basmati Local 73	2.028**	1.243**	-0.273	-8.033**	-1.039**	1.311	-31.801**	1.136	0.093**	-1.536**	0.475**	-0.225**	0.519**
Badshahbhog	0.944**	-0.59	0.11	-0.037	1.624**	3.098**	1.207	-20.636**	0.048**	-6.237**	-0.105**	0.006	-0.056**
Katarni	2.569**	2.201**	0.252	8.600**	0.957**	1.452*	-0.489	-20.876**	0.018	-4.698**	0.089**	0.018	0.009
Adamchini	1.528**	2.993**	0.881**	1.813	-0.13	-2.489**	-23.689**	-12.315**	-0.360**	-5.331**	-0.929**	-0.052**	-0.388**
SE gca (Lines)	0.234	0.341	0.187	0.976	0.315	0.67	2.692	0.654	0.01	0.433	0.02	0.01	0.015
Testers													
Jaya	-1.028**	-1.215**	-0.055	4.392**	0.792**	0.422	-1.18	-1.145**	0.085**	-1.701**	0.142**	-0.039**	0.112**
Sarjoo 52	-0.694**	0.660**	-0.666**	-2.239**	0.102	0.5	-10.471**	-5.792**	-0.031**	-2.239**	-0.092**	0.053**	-0.105**
HUR 105	1.167**	0.257	0.458**	-1.567**	0.422*	0.626	-12.040**	-3.273**	0.038**	0.798**	0.011	0.047**	-0.050**
BPT 5204	0.556**	0.299	0.263*	-0.586	-1.315**	-1.548**	23.691**	10.210**	-0.092**	3.142**	-0.061**	-0.061**	0.043**
SE gca (Testers)	0.135	0.197	0.108	0.564	0.182	0.387	1.554	0.378	0.006	0.25	0.012	0.006	0.009

*,** Significant at P=0.05 and 0.01 respectively.

spikelet fertility (%), 100-grain weight and brown rice length; Kanakjeera 28 for days to 50% flowering, days to maturity, number of panicles plant^{-1}, grains panicle^{-1}, 100-grain weight and brown rice length; Basmati Local 73 for plant height, 100-grain weight, brown rice length, brown rice breadth and brown rice L/B; Badshahbhog for main panicle length, flag leaf length and 100-grain weight; Katarni for main panicle length, flag leaf length and brown rice length and Adamchini for number of panicles plant^{-1}, 100-grain weight and brown rice breadth. This may be due to the negative correlation between different yield components leading to cancellation of the desirable effects and hence poor combining ability for grain yield.

The specific combining ability effects among 48 crosses (12x4) for 13 yield and quality traits (Table 3). Maximum desirable sca effect for days to flowering was exhibited by cross Sarjoo 52 x Juhi Bengal 21. The cross Jaya x Kalanamak 2 exhibited the highest negative value among 15 crosses that showed desirable negative specific combining ability for days to maturity. The cross HUR 105 x Kalanamak 11 showed maximum significant negative specific combining ability value for plant height. For number of panicles plant^{-1}, the cross Jaya x Kalanamak 11 showed highest positive specific combining ability. The cross Jaya x Jeera Battis showed the maximum positive specific combining ability for main panicle length. For flag leaf length, the cross BPT 5204 x Badshahbhog, showed maximum positive specific combining ability. Maximum positive specific combining ability was exhibited by the cross BPT 5204 x Jeera Battis for number of grains panicle^{-1}. For spikelet fertility, maximum positive specific combining ability was exhibited by the cross BPT 5204 x Adamchini. The cross HUR 105 x Juhi Bengal 23 showed maximum positive specific combining ability for 100-grain weight. 19 crosses exhibited significant positive specific combining ability for yield plant^{-1} with the cross BPT 5204 x Jeera Battis showing the highest value. The cross Jaya x Basmati Local 73 exhibited highest positive specific combining ability for brown rice length. The cross BPT 5204 x Juhi Bengal 23 showed maximum negative specific combining ability for brown rice breadth. The maximum positive specific combining ability for brown rice L/B was shown by the cross Jaya x Basmati Local 73.

The study of sca effects of crosses in relation to gca effects of parents (Table 4) showed that almost all types of sca effects were obtained from any kind of combination of gca effects and hence sca effects of crosses was independent of gca effects of parents involved in the crosses. E.g. the crosses BPT 5204 x Jeera Battis, BPT 5204 x Adamchini and Jaya x Kalanamak 11 showed high sca for grain yield plant^{-1}. Out of these BPT 5204, Jeera Battis and Kalanamak 11 are good general combiners for grain yield while other two lines are poor combiners.

The manifestation of high, low or non-significant sca effects by any sort of combination among the parents might be due to differential expression of component traits in specific residual genetic backgrounds. As the yield components are correlated either positively or negatively, it is usual to find for a particular parent, gca in the desirable direction for some traits and in the undesirable direction for others. Therefore establishing the status of a parent with respect to gca over a number of component characters assumes importance.

The crosses showing high sca involving good general combiners (high x high gca) are expected to throw some useful transgressive segregants in the breeding programme for pedigree method of selection. However, in crosses having high sca with high x low combining parents, the high yield potential is attributed to interaction between positive alleles from good combiners and negative alleles from poor combiners (Dubey *et al.,* 1975). The high yield from such crosses would be unfixable in later generations, while heterosis involved in high x high gca combiners would involve interaction between positive x positive alleles and can be fixed in the subsequent generations if no repulsion phase linkage is involved (Singh *et al.,* 1971). The superiority of crosses involving low x low gca parents can be attributed to overdominance and epistasis (Rahman *et al.,* 1981).

In the present study, the lines Juhi Bengal 21, Jeera Battis, Kalanamak 6, Kalanamak 11 and Kalanamak 2 were found to be good general combiners for grain yield and related traits. These can be utilized in hybridization programmes for obtaining desirable progenies. The cross BPT 5204 x Jeera Battis involves parents with good general combining ability for yield. Pedigree method of selection can be followed in this cross to identify some useful transgressive segregants

Table 3. Specific Combining Ability (sca) effects of 48 crosses in indigenous aromatic rice

Crosses	DTF	DTM	PBT	PH	MPL	FLL	G/PAN	SF	100GW	Y/P	BRL	BRB	BRL/B
Jaya x Kalanamak 5	2.48**	2.13**	-0.22	-13.50**	-2.24**	-4.71**	-48.70**	-11.63**	0.08**	-2.93**	0.18**	-0.01	0.05
Jaya x Juhi Bengal 21	0.73	3.59**	-1.59**	9.36**	2.29**	-4.53**	24.41**	17.64**	0.12**	-1.01	-0.36**	0.18**	-0.38**
Jaya x Juhi Bengal 23	-0.18	3.09**	-1.62**	3.80	0.30	0.45	-1.66	31.93**	-0.62**	4.48**	-0.78**	-0.22**	-0.13**
Jaya x Kanakjeera 28	-0.13	-0.28	-0.19	8.88**	0.42	0.84	-2.82	-18.29**	-0.14**	-1.38	0.21**	0.05**	0.01
Jaya x Jeera Battis	-0.38	-0.20	1.87**	1.88	3.13**	1.12	-50.58**	-6.32**	-0.32**	2.23**	-0.01	0.02	-0.03
Jaya x Kalanamak 6	-1.06*	0.79	2.20**	-2.37	-0.67	-1.08	-3.54	-5.32**	0.16**	-0.69	0.14**	0.01	0.04
Jaya x Kalanamak 11	0.28	-1.16	3.65**	7.95**	0.97	-2.52	9.76	24.45**	0.35**	6.38**	0.20**	0.27**	-0.22**
Jaya x Kalanamak 2	-1.06*	-4.45**	-0.13	-3.60	-1.69**	1.46	20.34**	-3.43**	-0.13**	-2.66**	-0.48**	0.03	-0.28**
Jaya x Basmati Local 73	-0.13	-1.36*	-1.98**	-0.61	-0.48	5.25**	29.40**	14.92**	0.29**	0.39	1.03**	-0.07**	0.69**
Jaya x Badshahbhog	2.11**	1.13	-2.00**	-3.77	-1.41*	-0.99	-9.28	-17.39**	0.11**	-4.73**	-0.16**	-0.25**	0.22**
Jaya x Katarni	-1.51**	-3.66**	-0.19	-4.27*	-0.01	3.98**	24.99**	2.02	0.15**	4.78**	0.46**	-0.02	0.23**
Jaya x Adamchini	-1.13*	0.38	0.22	-3.74	-0.62	0.72	7.69	-28.56**	-0.06**	-4.85**	-0.43**	-0.01	-0.21**
Sarjoo 52 x Kalanamak 5	0.65	-1.24	0.48	-2.51	-0.33	0.98	3.32	8.11**	0.28**	2.86**	0.26**	0.11**	-0.036
Sarjoo 52 x Juhi Bengal 21	-3.76**	-1.95**	-0.75*	2.16	0.39	-0.27	1.72	6.36**	-0.06**	4.57**	-0.08*	0.02	-0.08**
Sarjoo 52 x Juhi Bengal 23	4.98**	2.88**	0.30	1.37	-0.33	0.01	-21.20**	-34.53**	-0.54**	-6.83**	-0.62**	0.09**	-0.32**
Sarjoo 52 x Kanakjeera 28	1.69**	2.34**	-0.46	-1.18	0.40	4.87**	15.82**	24.47**	0.26**	2.64**	0.56**	-0.02	0.27**
Sarjoo 52 x Jeera Battis	1.11*	0.42	-1.13**	-2.21	-0.19	-3.48**	-23.64**	10.84**	0.21**	-6.12**	0.57**	-0.04*	0.31**
Sarjoo 52 x Kalanamak 6	-1.22**	-3.74**	0.98**	3.38	2.84**	4.94**	20.39**	-36.63**	-0.11**	-1.05	-0.57**	0.10**	-0.34**
Sarjoo 52 x Kalanamak 11	0.11	-2.20**	-1.71**	5.93**	-1.40*	-1.57	-5.11	4.07**	0.01	-3.01**	0.10**	-0.08**	0.13**
Sarjoo 52 x Kalanamak 2	0.27	0.34	0.36	3.62	-0.10	-0.75	38.10**	5.07**	-0.11**	2.09*	-0.15**	-0.05*	-0.05
Sarjoo 52 x Basmati Local 73	-1.47**	0.25	-0.17	1.01	-2.09**	-1.72	-50.88**	2.10	-0.08**	-0.01	-0.49**	-0.11**	-0.12**
Sarjoo 52 x Badshahbhog	-0.06	0.25	1.39**	-0.51	1.64**	-2.14	2.63	14.41**	-0.13**	4.43**	-0.12**	0.03	-0.09**
Sarjoo 52 x Katarni	1.31**	4.13**	1.38**	-4.44*	-3.06**	-3.79**	-17.10**	22.01**	0.06**	5.19**	0.60**	-0.03	0.31**
Sarjoo 52 x Adamchini	-3.63**	-1.49*	-0.66	-6.62**	2.23**	2.93*	35.95**	-26.31**	0.21**	-4.78**	0.01	-0.03	0.04

*,** Significant at P=0.05 and 0.01 respectively.

Table 3. Continued……..

Table 3. contd.

Crosses	DTF	DTM	PBT	PH	MPL	FLL	G/PAN	SF	100GW	Y/P	BRL	BRB	BRL/B
HUR 105 x Kalanamak 5	-2.20**	-0.84	-2.40**	12.61**	2.20**	4.89**	63.22**	-0.16	-0.07**	-1.74*	-0.47**	0.19**	-0.41**
HUR 105 xJuhi Bengal 21	2.87**	1.61*	3.25**	3.69	-1.37*	2.93*	-19.99**	-25.73**	0.26**	-4.19**	0.79**	0.12**	0.21**
HUR 105 xJuhi Bengal 23	-3.04**	-1.88**	2.48**	-1.73	0.15	-0.55	14.18**	-23.66**	0.63**	2.69**	0.88**	0.20**	0.15**
HUR 105 xKanakjeera 28	-2.50**	-4.25**	0.54	1.07	-1.28*	-3.72**	12.48*	-11.57**	-0.16**	-5.41**	-0.48**	0.05*	-0.23**
HUR 105 xJeera Battis	2.75**	1.16	0.23	1.79	-1.69**	1.35	-27.44**	-1.64	0.09**	-2.64**	-0.01	-0.08**	0.08**
HUR 105 x Kalanamak 6	-0.91*	-1.84**	-0.58	2.32	-1.19	-0.15	2.68	25.89**	0.06**	6.15**	0.08*	-0.16**	0.23**
HUR 105 x Kalanamak 11	-0.58	2.03**	0.09	-28.68**	0.42	3.25*	-3.48	8.56**	-0.06**	3.58**	0.72**	-0.200*	0.56**
HUR 105 x Kalanamak 2	1.08*	3.24**	-0.35	-0.81	1.21	-1.27	-55.04**	4.49**	-0.09**	0.06	0.01	-0.03	0.04
HUR 105 x Basmati Local 73	-0.67	2.32**	-1.16**	-4.52*	1.98**	-2.23	7.88	-2.60*	-0.26**	3.16**	-0.73**	-0.05**	-0.32**
HUR 105 x Badshahbhog	1.25**	1.16	0.25	-0.30	0.54	-2.28	17.80**	11.18**	-0.17**	-0.02	-0.29**	-0.04	-0.09**
HUR 105 x Katarni	0.12	-2.46**	-0.80*	5.96**	1.15	1.28	8.93	-4.880*	0.03	-4.86**	-0.51**	0.01	-0.22**
HUR 105 x Adamchini	1.83**	-0.25	-1.55**	8.58**	-2.12**	-3.49**	-21.23**	20.13**	-0.25**	3.24**	0.01	0.01	0.01
BPT 5204 x Kalanamak 5	-0.93*	-0.04	2.15**	3.40	0.38	-1.165	-17.84**	3.67**	-0.28**	1.82*	0.03	-0.30**	0.39**
BPT 5204 x Juhi Bengal 21	0.15	-3.25**	-0.91*	-15.22**	-1.31*	1.87	-6.14	1.72	-0.33**	0.62	-0.34**	-0.33**	0.25**
BPT 5204 x Juhi Bengal 23	-1.76**	-4.09**	-1.15**	-3.44	-0.11	0.08	8.68	26.26**	0.54**	-0.34	0.52**	-0.07**	0.29**
BPT 5204 x Kanakjeera 28	0.94*	2.20**	0.12	-8.77**	0.45	-1.98	-25.48**	5.39**	0.04*	4.15**	-0.28**	-0.08**	-0.04
BPT 5204 x Jeera Battis	-3.47**	-1.38*	-0.97**	-1.46	-1.25*	0.99	101.68**	-2.87*	0.01	6.52**	-0.55**	0.10**	-0.36**
BPT 5204 x Kalanamak 6	3.19**	4.78**	-2.60**	-3.33	-0.97	-3.71**	-19.53**	16.06**	-0.11**	-4.41**	0.33**	0.05**	0.07*
BPT 5204 x Kalanamak 11	0.19	1.32	-2.04**	14.79**	0.01	0.84	-1.16	-37.09**	-0.30**	-6.95**	-1.03**	0.01	-0.47**
BPT 5204 x Kalanamak 2	-0.31	0.86	0.11	0.79	0.58	0.56	-3.40	-6.13**	0.34**	0.51	0.67**	0.04*	0.29**
BPT 5204 x Basmati Local73	2.28**	-1.21	3.32**	4.11*	0.59	-1.30	13.60*	-14.41**	0.05**	-3.54**	0.20**	0.24**	-0.24**
BPT 5204 x Badshahbhog	-3.30**	-2.54**	0.36	4.58*	-0.77	5.42**	-11.15*	-8.19**	0.18**	0.32	0.57**	0.24**	-0.02
BPT 5204 x Katarni	0.06	1.99**	-0.38	2.76	1.91**	-1.46	-16.82**	-19.15**	-0.24**	-5.11**	-0.55**	0.05**	-0.32**
BPT 5204 x Adamchini	2.94**	1.36*	1.99**	1.78	0.51	-0.15	-22.41**	34.74**	0.10**	6.39**	0.41**	0.02	0.15**
SE SCA	0.46	0.68	0.37	1.95	0.63	1.34	5.38	1.30	0.02	0.86	0.04	0.02	0.03

*,** Significant at P=0.05 and 0.01 respectively

Table 4. Top three General and specific combiners for different yield and quality characters.

Characters	Best general combiners	Best Specific combiners
Days to 50% Flowering	Kanakjeera 28, Kalanamak 5, Kalanamak 11	Sarjoo 52 X Juhi Bengal 21, Sarjoo 52 X Adamchini, BPT 5204 X Jeera Battis
Days to Maturity	Kanakjeera 28, Jeera Battis, Kalanamak 6	Jaya X Kalanamak 2, HUR 105 X Kanakjeera 28, BPT 5204 X Juhi Bengal 23
No. of Panicles/ Plant	Kalanamak 5, Adamchini, Kalanamak 11	Jaya X Kalanamak 11, BPT 5204 X Basmati Local 73, HUR 105 X Juhi Bengal 21
Plant Height (cm)	Kalanamak 5, Basmati Local 73, Kalanamak 11	HUR-105 X Kalanamak 11, BPT 5204 X Juhi Bengal 21, Jaya X Kalanamak 5
Main Panicle Length (cm)	Kalanamak 6, Badshahbhog, Katarni	Jaya X Jeera Battis, Sarjoo 52 X Kalanamak 6, Jaya X Juhi Bengal 21
Flag Leaf Length (cm)	Juhi Bengal 21, Badshahbhog, Kalanamak 6	BPT 5204 X Badshahbhog, Jaya X Basmati Local 73, Sarjoo 52 X Kalanamak 6
Grains/ Panicle	Juhi Bengal 21, Jeera Battis, Kalanamak 11	BPT 5204 X Jeera Battis, HUR 105 X Kalanamak 5, Sarjoo 52 X Kalanamak 2
Spikelet Fertility (%)	Juhi Bengal 21, Jeera Battis, Kalanamak 2	BPT 5204 X Adamchini, Jaya X Juhi Bengal 23, BPT 5204 X Juhi Bengal 23
100 – Grain Weight (g)	Kalanamak 6, Juhi Bengal 23, Kanakjeera 28	HUR 105 X Juhi Bengal 23, BPT 5204 X Juhi Bengal 23, Jaya X Kalanamak 11
Yield/ Plant (g)	Juhi Bengal 21, Jeera Battis, Kalanamak 6	BPT 5204 X Jeera Battis, BPT 5204 X Adamchini, Jaya X Kalanamak 11
Brown Rice Length (mm)	Basmati Local 73, Kalanamak 6, Kalanamak 11	Jaya X Basmati Local 73, HUR 105 X Juhi Bengal 23, HUR-105 X Juhi Bengal 21
Brown Rice Breadth (mm)	Kalanamak 2, Basmati Local 73, Juhi Bengal 21	BPT 5204 X Juhi Bengal 21, BPT 5204 X Kalanamak – 5, Jaya X Badshahbhog
Brown Rice L/B	Basmati Local 73, Kalanamak 6, Kalanamak 2	Jaya X Basmati Local 73, HUR 105 X Kalanamak 11, BPT 5204 X Kalanamak 5

in later generations. The crosses BPT 5204 x Adamchini and Jaya x Kalanamak 11 involved parents with high x low general combining ability. These crosses can be utilised in heterosis breeding as the improved yield is likely to be unfixable in later generations.

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