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Combining ability of elite hybrids for grain yield and its component in rice (*Oryza sativa* L.)

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Abstract
Twenty one hybrids derived during *kharif* 2015 along with ten parents and three checks namely (*viz.*, Jaya, IR 64 and Anjali) a total 34 genotypes were evaluated for 15 yield and yield attributing characters. The analysis of variance for combining ability showed high significance of crosses for all the traits studied. The variance due to lines and testers were significant for all the characters studied. All the traits were observed significant for line × tester interaction. The SCA variances were higher than GCA variances for all the characters indicating the predominance of non-additive gene action. The lines Sahabhagi dhan (1.03) and MTU 1010 (0.32) and the tester SHIATS Dhan1 (1.43) possessed significant positive GCA effects implying that they are good general combiners and may serve as useful source for improvement hybridization programmes. Three hybrids MTU 1010 x BM 71 (high x low), MTU 1001 x NDR 359 (low x high) and NLR 34449 x SHIATS dhan1 (low x high) were identified as good specific cross combinations based on positive sca effects and per se performance.

Keywords: Combining ability, GCA, SCA, variance

Introduction
Rice (*Oryza sativa*, 2n = 24) is one of the world's most important staple cereal food crop growing in at least 114 countries under diverse conditions (Anon., 2013) [2]. Among the rice producing countries India ranks first in the world in area of rice cultivation with 44.2 mha and second in production with 104.32 million tons (Directorate of Economics and Statistics, 2016-17). In Uttar Pradesh area, production and productivity is 5.98 million hectare, 14.63 million tonnes, and 2447 kg/ha respectively. Thus, it is understood that there is an extreme need to enhance the rice productivity in Uttar Pradesh, which will be achieved only by developing high yielding varieties (Agricultural statistics, 2016) [1].

The rice plant belongs to the genus *Oryza* of *Poaeceae* family. The combining ability of the genotypes provide information which helps in the selection of better parents for effective breeding. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desired parent and crosses for the exploitation of heterosis. Therefore, gathering information on nature of gene effects and their expression in terms of combing ability is necessary. Additive and non-additive gene actions in the parents estimated through combining ability analysis are useful in determining the possibility for commercial exploitation of heterosis. Its role is important to decide parents, crosses and appropriate breeding procedure to be followed to select desirable segregants (Salgotra *et al.* 2009) [9].

Materials and Methods
Twenty one hybrids derived during *kharif* 2015 along with ten parents and three checks namely
(*viz.*, Jaya, IR 64 and Anjali) a total 34 genotypes were evaluated in *Rabi* 2015-16 at NRRI Cuttack. With the objective to collect the magnitude of heterosis and combining ability The data was recorded on 15 quantitative characters *viz.*, days to 50% flowering, plant height, number of tillers / plant, number of panicles/plant, panicle length, flag leaf length, flag leaf width, number of grains/panicle, days to maturity, spikelet fertility %, spikelet sterility %, biological yield, harvest index, test weight and grain yield / plant. The combining ability analysis was made following the method outlined by Kempthorne (1957) [5].

Result and Discussion

The analysis of variance showed higly significant differences among the genotypes for all the yield and yield contributing characters. The mean sum of square due to genotypes, GCA, SCA, lines and testers were significant for all the characters presented in (table no 1) So all the characters were subjected to combining ability analysis of line x tester design proposed by Kempthrone (1957) [5]. The character wise estimates of general combining ability (GCA) effects (seven lines and three testers) and specific combining ability (sca) effects of (21 hybrids) for different characters and analysis are presented in character-wise below. (Table 2 and 3. General combining ability effects for days to 50% flowering showed wide range of variation only five parents *viz.,* Sahabhagi dhan (-8.51**), MTU 1010 (-4.24**), NLR 34449 (-1.16**) SHIATS Dhan1 (-0.93) and MTU 1001 (-0.91*) showed negative GCA effect for days to 50% flowering Among the lines showed significant negative *GCA* effects for days to 50% flowering these parents considered as good combiners for earliness. Promising hybrids which scored significant negative *sca* effects are MTU 1010 x BM 7 (-7.25**) MTU 1001 x BM 71(-6.58**), Sahabhagi dhan x SHIATS Dhan1 (-7.25**), BPT 2411 x SHIATS Dhan1 (-4.96**), BPT 2615 x NDR 359 (-2.57) and NLR 34449 x NDR 359. -5.99**) were recorded as a good specific combiners to days to 50% flowering. Among the lines BPT 5204(1.4**) recorded significant positive *GCA* effects and in testers SHIATS Dhan1 (1.08**) recorded significant positive effects were found to be good general combiners for number of panicles/ plant. Evaluation of the hybrids for *sca* effects for number of number of panicle/plant revealed that 1 cross was good with significant positive *GCA* effects. The cross MTU 1001 x BM 71 (1.94**) was the desirable specific combiner. For the character number of grains / panicle, three linesBPT-5204 (12.41), BPT-2411 (10.88**) andMTU-1010 (7.73**) showed significant positive *GCA* effects. The testers SHIATS Dhan1 (7.47**) exhibited significant positive *GCA* effects and *Sca* effects were identified as a good general combiners for number of grains/panicle. The maximum *sca* effects was recorded in five hybrids *viz.,* NLR 34449 x SHIATS Dhan1 (20.09**), Sahabhagi dhan x BM 71(19.05**), MTU 1010 x BM 71(17.08**), BPT 5204 x SHIATS Dhan 1(14.27**) and MTU 1001 x NDR 359(11.39**) recorded high *sca* effects which were significant and positive high *sca* effects were identified as best specific combiner for number of grains/panicle. The positive significant GCA effect for grain yield/plant were exhibited by Sahabhagi dhan (1.03) and MTU-1010 (0.32) manifested positive *GCA* effects. Among the testers, SHIATS Dhan1 (1.43**) recorded significant positive *GCA* effects which indicated these parents to be good general combiners for grain yield per plant. Promising parental lines identified of rice on the basis of *perse* and GCA effects for important yield related traits are presented in (table 4).For grain yield per plant, 3 crosses recorded significant positive sca effects. Among twenty one hybrids, three hybrids MTU 1010 x BM 71(3.44**), MTU 1001 x NDR 359 (2.34), and NLR 34449 x SHIATS Dhan 1 (2.51**) registered significant positive *sca* effects were identified as good specific combiners for grain yield/plant. In the present investigation, none of the cross combination showed high SCA effect for all the characters. Ghosh (1993) and Dwivedi *et al*. (1999) also observed that none of the cross exhibited significant sca effect for all the traits. The present finding revealed that cross combination MTU 1010 x BM 71, NLR 34449 x SHIATS Dhan 1, MTU 1001 x NDR 359 and BPT 2615 x NDR 359 exhibited high sca effects for grain yield / plant. The desirable sca effect MTU 1010 x BM 71 was found to relate with number of grains / panicle, grain yield / plant was accompanied by desirable sca effects for test weight, days to 50% flowering, days to maturity, biological yield. Desirable sca effect of NLR 34449 x SHIATS Dhan 1 for grain yield/plant and number of grains / panicle. Desirable sca effect of MTU 1001 x NDR 359 for number of grains / panicle, biological yield, test weight and grain yield/plant

However, it was noted that lines (female) MTU 1010 and MTU 1001 proved to be the best general combiners for days to 50% flowering, plant height, total number of grains /panicle and for grain yield/plant. Whereas tester (male) SHIATS Dhan1 was best general combiner for grain yield/plant, biological yield, spikelet fertility %, number of panicles/plant, number of tillers/ plant, and days to 50% flowering. These findings are in agreement with those reported Singh and Kumar (2004), Singh *et al*. (2005), Narasiman *et al*. (2007), Sahu *et al*. (2013) [8] Santha *et al* (2016) [7] and Bhati *et al.*(2017) [3]. The GCA effects together with relative per se performance is useful for selecting desirable parent with favourable genes for different component of yield and quality. Three hybrids MTU 1010 x BM 71 (high x low), MTU 1001 x NDR 359 (low x high) and NLR 34449 x SHIATS Dhan1(high x high) were identified as good specific cross combinations based on positive *sca* effects and *per se* performance. The estimates of SCA variances were much higher for all the characters as compared to their respective GCA variances suggesting the preponderance of non-additive gene action. Based on *per se* performance, significant sca effects and heterosis for yield in the crosses NLR-34449 x SHIATS Dhan1, Sahabhagi dhan x SHIATS Dhan1, BPT-2615 x NDR-359 and MTU 1010 x BM 71 recorded high *per se* performance (37.46, 36.17, 35.60 and 35.30), sca effects (2.51, 0.44, 1.72 and 3.44) and standard heterosis (13.74%, 9.82%, 8.09% and 7.19 %) and recorded high *per se* performance over the best check IR-64 for grain yield/plant were identified as promising heterotic hybrids.

Table 1: Analysis of variance for combining ability for 15 quantitative characters in rice

		Days to 50% Flowering	Plant Height (cm)	Number of Tillers / Plant	Number of panicles /plant	Panicle Length (cm)	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Number of Grains / panicle	Days to Maturity	Spikelet Fertility (%)	Spikelet Sterility (%)	Biological Yield (g)	Harvest Index (%)	Test Weight (g)	Grain Yield/ Plant(g)
Replicates	2	0.45	5.21	1.31	1.83	1.76	0.18	0.01	35.36	0.51	1.96	2.43	10.42	1.24	0.22	3.69
Crosses	20	139.7**	147.97**	4.36**	5.82**	4.44*	5.66**	0.04**	849.59**	92.98**	19.03**	31.27**	61.15**	2.66	13.22**	14.74**
Line Effect	6	288.94*	84.11	5.49	5.59	6.14	2.87	0.04	1029.81	201.02*	13.95	29.27	19.92	0.98	9.13	4.66
Tester Effect	2	23.14	223.8	8.9	24.11**	2.68	6.2	0.01	1414.88	3.4	43.12	105.28*	208.31	2.63	4.16	53.75*
Line * Tester Effect	12	84.51**	167.27**	3.05**	2.89*	3.89	6.96**	0.05**	665.26**	53.88**	17.55**	19.94*	57.24**	3.51*	16.77**	13.28**
Error	40	0.7	7.71	1.06	1.3	1.99	1.9	0.01	83.38	1.55	6.25	8.54	15.19	1.59	0.43	2.14
Total	62	45.53	52.88	2.13	2.78	2.77	3.05	0.02	329	31.01	10.24	15.68	29.86	1.92	4.55	6.25
Var. GCA		10.33	9.82	0.41	0.91	0.09	0.16	0.008	77	6.73	1.5	4	6.47	0.01	0.42	1.79
Var. SCA		27.83	53.56	0.69	0.57	0.28	1.63	0.01	199.29	17.52	3.84	4.24	13.4	0.61	5.46	3.64
GCA/ca		0.37	0.18	0.59	1.60	0.32	0.10	0.70	0.39	0.38	0.39	0.94	0.48	0.02	0.08	0.49

*Significance at 5% level, **significance at 1% level

Table 2: General Combining ability effects of parent for 15 quantitative characters in rice

Character	Days to 50% Flowering	Plant Height (cm)	Number of Tillers/ Plant	Number of panicles/plant	Panicle Length (cm)	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Number of Grains / panicle	Days to Maturity	Spikelet Fertility (%)	Spikelet Sterility (%)	Biological Yield (g)	Harvest Index (%)	Test Weight (g)	Grain Yield/ Plant (g)
MTU-1010	-4.24**	-4.06**	0.24	0.28	0.28	0.72	0.09**	7.73**	-5.08**	1.27	-2.08*	0	0.62	0.95**	0.32
MTU-1001	-0.91*	-2.45**	0.29	0.47	-0.08	0.12	0.03	-7.89**	-1.1**	-2.47**	3.53**	-1.23	0.12	0.45*	-0.48
Shahabagi dhan	-8.51**	5.49**	-0.29	-0.33	-1.21*	-0.7	0	-13.48**	-5.83**	0.9	-1.43	2.21	-0.41	1.56**	1.03
BPT-5204	6.53**	0.83	1.4**	1.32**	1.06	-0.42	-0.11**	12.41**	5.91**	-0.58	0.05	-2.32	-0.15	-1.19**	-1.24*
BPT-2411	7.53**	-0.89	-0.79*	-0.08	0.57	0.37	-0.04	10.88**	6.15**	0.16	0.65	-0.32	-0.25	-0.48*	-0.17
BPT-2615	0.76*	-0.27	-0.92**	-1.14**	-0.98	0.49	0.04	0.83	0.36	0.6	-0.33	0.79	0.09	-0.79***	0.3
NLR-34449	-1.16**	1.36	0.06	-0.53	0.36	-0.58	-0.01	-10.47**	-0.41	0.12	-0.39	0.87	-0.02	-0.5*	0.25
NDR-359	-0.21	-3.77**	-0.41	-1.06**	0.35	0.49	0.01	1.32	-0.33	-0.09	0.45	-0.39	0.23	0.39**	0.3
BM-71	1.14**	1.97**	-0.34	-0.02	-0.36	-0.58	0.01	-8.79**	-0.12	-1.39*	1.98**	-2.94**	-0.41	-0.48**	-1.73**
SHIATS Dhan 1	-0.93**	1.8**	0.75**	1.08**	0.01	0.09	-0.02	7.47**	0.45	1.47**	-2.43**	3.33**	0.18	0.09	1.43**
CD 95% GCA(Line)	0.68	1.73	0.66	0.73	1.17	0.97	0.05	5.53	0.77	1.65	1.81	2.78	0.87	0.42	1.04
CD 95% GCA(Tester)	0.45	1.13	0.44	0.48	0.77	0.64	0.03	3.62	0.51	1.08	1.19	1.82	0.57	0.28	0.68

*Significance at 5% level, **significance at 1% level

Table 3 Specific Combining ability effects of hybrids for 15 quantitative characters in rice

F1 crosses (Hybrids)	Days to 50% Flowering	Plant Height (cm)	Number of Tillers/ Plant	Number of panicles/ plant	Panicle Length (cm)	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Number of Grains / panicle	Days to Maturity	Spikelet Fertility (%)	Spikelet Sterility (%)	Biological Yield (g)	Harvest Index (%)	Test Weight (g)	Grain Yield/ Plant (g)
MTU-1010 X NDR-359	3.43**	7.97**	-0.43	0.01	0.45	0.14	-0.06	-7.23	4.04**	-0.52	0.08	-0.39	-0.93	3.29**	-1.16
MTU-1010 XBM-71	-7.25**	-1.94	0.04	-0.9	0.23	-1.18	0.06	17.08**	-6.73**	1.81	-1.95	6.24*	0.81	-3.34**	3.44**
MTU-1010 X SHIATS Dhan 1	3.82**	-6.03**	0.38	0.9	-0.67	1.04	0.01	-9.85*	2.7**	-1.29	1.86	-5.85*	0.12	0.05	-2.28*
MTU-1001 X NDR-359	3.1**	5.39**	-1.72**	-1.12	0.51	-0.43	-0.11*	11.39*	2.33**	2.85	-2.1	6.55**	-0.73	2.32**	2.34*
MTU-1001X BM-71	-6.58**	-0.71	1.86**	1.94**	0.19	-0.22	-0.06	2.47	-3.71**	-1.48	1.94	-6*	1.24	-3.47**	-1.73
MTU-1001X SHIATS Dhan 1	3.48**	-4.68**	-0.14	-0.83	-0.71	0.64	0.17**	-13.86**	1.38*	-1.37	0.15	-0.55	-0.52	1.15**	-0.62
Sahabagi dhanX NDR-359	1.37*	5.98**	0.6	-0.35	0.67	-0.07	0	-6.45	-3.61**	3.44*	-4.04*	0.19	-0.14	0.14	0.76
Sahabagi dhanX BM-71	5.88**	-0.09	0.07	0.57	-0.12	0.2	0.11**	19.05**	1.69*	-3.12*	2.6	-2.85	0.53	0.38	-1.2
Sahabagi dhan XSHIATS Dhan 1	-7.25**	-5.89**	-0.66	-0.23	-0.55	-0.13	-0.12**	-12.6*	1.92**	-0.32	1.44	2.67	-0.39	-0.53	0.44
BPT-5204X NDR-359	-0.68	4.38**	0.14	1.14	-0.97	-1.82*	0.03	5.59	-1.52*	-1.93	2.75	-0.29	0.61	-1.6**	0
BPT-5204XBM-71	-0.03	-7.96**	0.24	-1	-0.72	0.33	0.11*	-19.87**	0.28	-0.7	0.19	0.84	-1.33	1.91**	-0.44
BPT-5204XSHIATS Dhan 1	0.7	3.58*	-0.38	-0.14	1.68	1.49	-0.14**	14.27**	1.24	2.64	-2.94	-0.55	0.72	-0.3	0.44
BPT-2411XNDR-359	1.32*	-10.08**	0.36	0.24	-1.84	-0.44	0.07	0.15	2.92**	-1.88	1.35	-2.82	0.44	-0.98**	-0.5
BPT-2411XBM-71	3.64**	7.55**	-0.3	0.23	1.64	-0.56	-0.18**	-0.48	4.38**	0.69	0.15	1.71	0.37	2.26**	0.86
BPT-2411XSHIATS Dhan 1	-4.96**	2.52	-0.06	-0.47	0.2	1	0.11*	0.33	-7.29**	1.19	-1.5	1.11	-0.82	-1.28**	-0.36
BPT-2615XNDR-359	-2.57**	-9.85**	0.26	0.43	0.88	0.07	-0.03	-0.06	-2.96**	-1.59	2.33	1.94	1.53*	-1.24**	1.72
BPT-2615XBM-71	1.75**	2.27	-0.27	-0.61	-0.21	1.05	0.06	-1.56	3.17**	3.04*	-3.43*	-1.76	-1.3	0.01	-1.58
BPT-2615XSHIATS Dhan 1	0.82	7.58**	0	0.19	-0.67	-1.12	-0.03	1.62	-0.2	-1.45	1.11	-0.18	-0.23	1.23**	-0.14
NLR-34449XNDR-359	-5.99**	-3.79*	0.78	-0.35	0.3	2.54**	0.09*	-3.4	-1.2	-0.37	-0.37	-5.16*	-0.79	-1.93**	-3.16**
NLR-34449X BM-71	2.59**	0.87	-1.64	-0.23	-1.02	0.38	-0.1*	-16.69**	0.93	-0.23	0.5	1.82	-0.33	2.25**	0.64
NLR-34449X SHIATS Dhan 1	3.39**	2.91	0.86	0.57	0.72	-2.92**	0	20.09**	0.26	0.6	-0.13	3.35	1.12	-0.33	2.51**
CD 95% SCA	1.18	3	1.15	1.27	2.03	1.68	0.08	9.58	1.34	2.87	3.14	4.82	1.51	0.73	1.8

*Significance at 5% level, **significance at 1% level

Table 4: Promising parental lines of rice on the basis of perse and GCA effects for important yield related traits

Characters	Parent	*Perse*	GCA
Grain Yield/ Plant	BPT-5204	33.23	-1.24*
	SHIATS Dhan 1	31.13	1.43**
	BM 71	20.3	-1.73**
	MTU 1010	30.73	0.32
Days to 50% Flowering	BPT-5204	105.33	6.53**
	BPT-2411	102	7.53**
	BM 71	102.33	1.14**
Plant Height (cm)	Sahabhagi dhan	127.6	5.49**
	SHIATS Dhan 1	120.33	1.8**
	BM-71	125	1.97**
Number of panicles/plant	BPT-5204	14.77	1.32**
	SHIATS Dhan 1	14.6	1.08**
Total number of Grains / panicle	BPT-5204	172.67	12.41**
	BPT-2411	185	10.88**
	SHIATS Dhan 1	206.97	7.47**
	MTU 1010	145	7.73**

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