SHORT COMMUNICATION

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Genetic analysis of yield and components traits under drought in rice (*Oryza sativa* L.)

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ABSTRACT

Twenty eight hybrids generated from crossing seven lines with four testers were studied along with their parents and utilized to assess the gene action involved in the expression of characters in rice under drought. The gca and sca effects were significant for all the characters. The magnitude of σ^2_D *was higher than the* σ^2_A *for all the traits studied, showing predominance of non-additive gene action. Among the parents, Danteshwari and Barani Deep of lines IR-36 and Pant Dhan-12 of testers were found to be best general combiners for grain yield and drought tolerant traits. The best cross combinations for sca effects are IR36×Birsa Dhan-105, HUR-105×Birsa Dhan-105, Pant Dhan-12×Danteshwari, Pant Dhan-12×Shushka Samrat and NDR-359×Vandana. Promising hybrids based on per se performance, gca and sca effects are IR36×Birsa Dhan-105, IR36×N-22, HUR-105×Birsa Dhan-105, HUR-105×NDR-97, Pant Dhan-12×Danteshwari, Pant Dhan-12×N22, Pant Dhan-12×Shushka Samrat, NDR-359×Barani Deep and NDR-359×Vandana.*

Key words: *Rice, gene action, yield and drought tolerant traits*

Rice is one of the most important staple food crops of more than three billon people in the world. It has semi-aquatic evolutionary adaptation but grown in wide range of diverse conditions from below sea level to 3000 m above sea level in India. The major constraints in rice production are due to biotic and abiotic stresses faced by rice in these areas. Rice has relatively few adaptations to water-limited conditions and is extremely sensitive to drought stress (Lafitte *et al*. 2004). Rice breeding programmes focusing on drought tolerance have made little progress to date. This may be explained by the fact that drought tolerance is a trait controlled by many genes having different effects, and is affected by drought timing and severity. Another way to explain the complexity of drought is that drought tolerance involves an interaction between the genes involved in yield potential *per se* (which are numerous) and the genes for drought tolerance (Price 2002). Therefore the rice breeding programmes should consider incorporating drought tolerance and recovery of the specific combinations so that both a realistic yield potential and a stable production level may be achieved under a given set of environmental conditions. Hence for a breeder, individual or combinations of traits that are directly or indirectly associated with enhanced plant survival are likely to improve economic yield (with or without stability), which may constitute potential target (s) for study and selection (Kirigwi *et al*. 2007). The genetic improvement for drought tolerance has also been addressed using a conventional approach by selecting for yield and secondary traits (Farooq *et al*. 2009). Thus, the breeding programme for a target environment must have prime emphasis on selection of stable genotypes to be improved and donor parent from whom desired gene (s) to be introgressed.

Combining ability analysis helps in the identification of parents with high general combining ability (gca) effects and cross combinations with high - specific combining ability effects (sca) for commercial exploitation of heterosis and isolation of pure lines among the progenies having high heterotic values.

Therefore, the present investigation has been conducted to assess the combining ability effects and to determine the additive and non-additive components of gene action for traits related to drought tolerance.

The experimental material comprised of 28 hybrids obtained from the 11 parents involving four broad based testers (IR-36, HUR-105, Pant Dhan-12 and NDR-359) and seven lines (Barani Deep, Birsa Dhan-105, Danteshwari, Nagina-22, NDR-97, Shushka Samrat and Vandana) which are collected from various Agricultural Universities/Institutes and rice cultivating areas of eastern Uttar Pradesh. All the lines have various morpho-physiological potential to combat drought environments. A set of twenty eight crosses were attempted in lines × tester fashion for the purpose at Varanasi and grown along with the parents in randomized complete block design with three replications at experimental research farm of CRRI, Cuttack under rainfed conditions during off season of 2012-13. Twenty one days old seedlings of all the crosses and parents were transplanted in the field. A standard spacing of 20 x 20 cm was adopted for planting and 12 plants were maintained in a single row with single seedling per hill. Recommended package of practices were followed. Observations were recorded on ten randomly selected plants in all the three replications for ten traits *viz.*, seedling height, plant height, proline content, stomatal behavior, panicle weight, seeds per panicle, leaf rolling, stay green and yield per plant. Combining ability analysis was carried out by the method suggested by Kempthorne (1957).

The analysis of variance (Table 1) showed highly significant differences for parents and hybrids for all the characters except panicle weight for parents and panicle weight and panicle length for hybrids. Similarly, the significant differences among all the lines and testers for all the characters (except panicle weight for tester only) were observed showing wider genetic variability between them. The significant differences were also recorded for parent's Vs crosses for all the traits except panicle weight and stay green trait indicating presence of heterosis for these characters. The significance of line x tester for all the characters except leaf rolling provided a direct test, indicating that non- additive variances were important for majority of the characters (Jayasudha and Sharma 2009).

Table 1. Analysis of variance for combining ability (Line × Testers) for seed yield and drought tolerant traits in rice under rainfed conditions

Source	D. F.	Seedling	Plant	Proline height	Stomatal height	Panicle content	Seeds/Panicle behavior	Percent filled weight	Leaf grains	Stay green rolling	Yield/Plant
Replication	2	0.02	4.48**	0.12	2.09*	0.01	2.81**	1.32	0	0.24	2.91**
Parents	10	18.62**	1089.88**	419.48**	19.47**	1.34	477.69**	82.2**	18.65**	2.12*	32.87**
Hybrids	27	10.05**	56.23**	64.81**	17.19**	1.55	562.85**	1.04	27**	2.75**	0.35
Parents *Vs* Hybrids	1	14.21**	746.66**	138.93**	15.05**	0.28	55.44**	95.7**	2.00*	0.1	35.77**
Lines	6	70.85**	6250.12**	3166.83**	52.86**	7.05**	2755.69**	244.71**	93.55**	12.39**	113.05**
Testers	3	5.49**	580.67**	46.43**	21.81**	0.71	875.54**	550.25**	2.73**	2.95**	263.23**
Lines × Testers	18	4.60**	119.44**	341.46**	189.62**	12.46**	20988.34**	11613.44**	1.22	43.57**	6511.61**
Error	76	0.05	6.43**	0.12	1.92	0.01	2.53*	0.48	0.02	0.13	3.74**

*= Significance of p=0.05 level, **= Significance of p=0.01 level

The comparative estimates of variance due to gca and sca revealed the importance of sca variance. The sca variance was higher than the gca for all the traits suggesting the significant role of non additive gene action predominance of non additive gene action for grain yield and its component. The presence of non-additive genetic variance offers scope for exploitation of heterosis. This was also reported by Jayasudha and Sharma (2009), Manuel and Palanisamy (1989), Sarawgi et al. (1991), Manomani and Ranganathan (1998), Kalitha and Upadhaya (2000), Shanthi et al. (2003), Rosamma et al. (2005), Kumar *et al.*(2007) and Panwar (2005). The observations were also confirmed by the values observed for σ_A^2 and σ_D^2, where additive genetic variance were less than the non additive genetic variance for all the traits (Table 2).

The estimates of general combining ability effects of lines and testers showed that line Danteshwari and testers IR36 and Pant Dhan-12 were superior general combiners for seed yield per plant (Table 3). Character-wise estimation of gca effects of lines revealed Danteshwari was a good general combiner for seed yield and several other drought tolerant and contributing characters *viz.*, plant height, stomatal behavior, seeds per panicle and percent filled grains. This line was also found to be good general combiner for early duration, semi tall height and moderate combiner for productive tillers per plant. The line Barani Deep was good general combiner for plant height, panicle weight, stay green trait and percent filled grains (Table 3). The line Vandana also found to be good combiner for plant height, stomatal conductance, seeds per panicle, leaf rolling and yield per plant. It was observed that, leaf rolling and stomatal conductance are mutually influences each other in positive way for yield under moisture stress conditions. Among the testers NDR-359 was found to be best general combiner for grain yield, plant height, proline content, seeds per panicle and percent filled grains. Testers, IR-36 and HUR-105 were also found good general combiners for the characters *viz.*, plant height, proline content, stomatal conductance, seeds per panicle, grain yield and percent filled grains.

Table 2. Estimates of genetic components of variance for seed yield and drought tolerant traits in rice under rainfed condition

Sr. No.	Components	Seedling height	Plant height	Proline content	Stomatal behavior	Panicle weight	Seeds/ Panicle	Percent filled grains	Leaf rolling	Stay green	Yield/ Plant
1	σ^2 Female	5.49	580.67	46.43	21.81	0.71	875.54	550.25	2.73	2.95	263.23
2	σ^2 Male	70.85	6250.12	3166.83	52.86	7.05	2755.69	244.71	93.55	12.39	113.05
3	σ^2 gca	64.57	5596.47	3086.76	32.67	6.40	2097.21	170.19	89.7	9.81	74.00
4	σ^2 sca	418.30	36075.8	20414.2	158.84	39.91	10120.6	3389.18	591.48	55.31	1659.28
5	σ^2 A	16.14	1399.12	771.69	8.16	1.60	524.30	42.54	22.43	2.45	18.50
6	σ^2 D	104.57	9018.94	5103.56	39.76	9.99	2530.16	847.25	147.87	13.82	414.82
7	σ (σ^2 D/) σ^2 A	2.57	2.53	2.57	2.20	2.49	2.19	4.46	2.56	2.37	4.73

Table 3. Estimates of general combining ability (sca) effects different drought affected traits in rice

Traits	Seedling height	Plant height	Proline content	Stomatal behavior	Panicle weight	Seeds/ Panicle	Percent filled grains	Leaf rolling	Stay green	Yield/ Plant
Lines										
Barani Deep	-0.48	-3.87**	0.64	1.07	-2.07**	0.18	3.08**	0.25	-3.25**	2.76**
Birsa Dhan-105	-0.39	7.16**	0.04	0.32	-0.18	-1.5	1.27	0.25	0.25	-3.21**
Danteshwari	-0.73	-11.61**	-1.57	3.32**	-0.05	-4.65**	2.18**	-0.75	0.08	2.94**
N-22	0.73	2.29*	0.82	-0.26	0.08	3.04**	-0.93	-0.08	0.25	0.19
NDR-97	0.41	6.26	0.26	-0.18	0.02	-0.71	-1.52	0	-0.17	-1.12
Sushk Samrat	0.12	3.6	0.74	-0.43	0.03	-0.4	-4.79	-0.42	0.08	-2.27
Vandana	0.34	-3.83**	-0.93	-2.85**	0.17	4.04**	1.71	2.75**	-0.25	-3.29**
SE± (Lines)	0.06	0.67	0.08	0.30	0.02	0.40	0.13	0.04	0.08	0.49
Tester										
IR-36	0.20	-2.71*	3.58**	1.40	0.20	20.42**	6.23**	0.07	-0.75	6.57**
HUR-105	-1.05	-7.6**	-3.74**	-2.45*	-0.54	-14.39**	-11.12**	0.50	0.96	-6.23**
Pant Dhan-12	1.05	11.59**	0.71	1.64	0.31	-1.37	10.16**	-0.93	-0.32	4.44**
NDR-359	-0.19	-3.28**	-3.55**	-0.60	0.03	-4.66**	-5.27**	0.36	0.11	-4.78**
SE± (Testers)	0.04	0.48	0.05	0.21	0.02	0.28	0.09	0.03	0.06	0.35

*= Significance of p=0.05 level, **= Significance of p=0.01 level

The usefulness of a particular cross in the exploitation of heterosis is judged by specific combining ability effects. NDR-359×Barani Deep recorded the highest sca estimates for grain yield and several other drought tolerant contributing traits, followed by other cross combinations like IR36×Birsa Dhan-105, HUR-105×Birsa Dhan-105, Pant Dhan-12×Danteshwari, Pant Dhan-12×Shushka Samrat and NDR-359×Vandana (Table 4). It is evident that cross combinations, which expressed high sca effects for grain yield, have invariable positive sca effects for one or more yield related traits as well. Secondly to get best specific combination for enhancing seed yield, it would be desirable to give due weightage to seed yield related traits. Grafius (1954) has already suggested that there may not be separate gene(s) for yield per se and yield being end product of multiple gene interactions among various yield components. Cross combinations, NDR-359×Barani Deep, IR36×Birsa Dhan-105, HUR-105×Birsa Dhan-105 and Pant Dhan-12×Danteshwari recorded high x high parental gca effects, suggesting that additive x additive type gene action. Manual and Palanisamy (1989) also reported interaction between positive alleles in crosses involving high x high combiners which can be fixed in subsequent generations if no repulsion phase linkages are involved. Crosses like IR36×Nagina-22, HUR-105×NDR-97, and Pant Dhan-12 ×Shushka Samrat showed high x low parental gca effects, indicating the involvement of additive x dominance genetic interaction. Peng and Virmani (1990) also reported about the possibility of interaction between positive alleles from good combiners and negative alleles from poor combiners in high x low

Table 4. Estimates of specific combining ability effects (sca) for seed yield and drought tolerant traits in rice.

Traits	SH	PH	PC	SB	PW	SPP	PFG	LR	SG	YPP
IR-36×										
Barani Deep	-1.15	-1.24	2.97**	1.6	0.09	0.13	4.92**	-0.82	0.25	3.37**
Birsa Dhan-105	0.73	15.07**	-0.46	0.35	0.08	0.54	7.73**	-0.82	-0.25	8.16**
Danteshwari	1.56	19.07**	2.66**	0.68	0.04	4.72**	1.09	1.18	-0.08	-3.35**
N-22	-0.89	2.87**	-0.43	2.26*	-0.19	-4.43**	-3**	0.51	-0.25	3.35**
NDR-97	-0.32	-5.84**	-2.28*	-0.82	0.02	0.91	-1.61	0.43	0.17	-1.34
Sushk Samrat	-0.18	-24.87**	-1.42	-1.9	0.05	1.27	-0.61	-1.15	-0.08	-2.56*
Vandana	0.25	-5.05**	-1.05	-2.15*	-0.09	-3.13**	-8.51**	0.68	0.25	-4.63**
HUR-105×										
Barani Deep	-0.42	-6.35**	-0.34	-0.88	0.18	3.58**	7.77**	-0.25	-1.46	5.49**
Birsa Dhan-105	0.03	-1.21	3.66**	-0.46	0.06	0.65	9.12**	0.75	0.04	7.36**
Danteshwari	0.18	-2.24*	2.44*	-1.46	0.25	9.4**	-4.69**	-0.25	0.2	-4.83**
N-22	-0.57	-6.14**	-2.15*	-0.21	-0.16	-3.35**	-4.28**	0.08	0.04	-3.61**
NDR-97	0.78	6.08**	-0.46	1.04	-0.1	0.29	-4.29**	0	0.45	-2.62*
Sushk Samrat	0.04	12.38**	-1.77	1.62	-0.12	0.25	-1.26	0.42	0.2	-2.28*
Vandana	-0.03	-2.53*	-1.37	0.37	-0.12	-10.82**	-2.38*	-0.75	0.54	0.49
Pant Dhan-12×										
Barani Deep	-0.18	-5.67**	-4.49**	-3.98**	-0.56	-18.58**	-24.84**	1.18	1.82	-12.85**
Birsa Dhan-105	-1.39	-14.83**	-4.13**	-2.89**	-0.77	-22.04**	-25.93**	0.18	1.32	-21.05**
Danteshwari	-0.99	-9.26**	-6.08**	4.44**	-0.08	-8.62**	13.27**	-0.82	-0.51	13.69**
N-22	2.9**	14.14**	5.17**	0.02	0.74	22.56**	13**	-0.49	-0.68	7.12**
NDR-97	-0.43	-2*	4.89**	0.27	0.36	8.8**	13.72**	-0.57	-1.26	7.04**
Sushk Samrat	0.91	5.3**	5.32**	0.19	0.44	10.76**	5.98**	0.85	-0.51	9.23**
Vandana	-0.81	12.32**	-0.68	1.94	-0.14	7.13**	4.8**	-0.32	-0.18	-3.17**
NDR-359×										
Barani Deep	1.75	13.26**	1.86	3.26**	0.3	14.88**	12.15**	-0.11	-0.61	16.99**
Birsa Dhan-105	0.63	0.97	0.93	3.01**	0.63	20.85**	9.07**	-0.11	-1.11	5.53**
Danteshwari	-0.74	-7.57**	0.98	-3.65**	-0.21	-5.5**	-9.67**	-0.11	0.39	-5.5**
N-22	-1.45	-10.87**	-2.59*	-2.07*	-0.4	-14.78**	-5.73**	-0.11	0.89	-3.85**
NDR-97	-0.02	1.76	-2.15*	-0.49	-0.29	-10**	-7.81**	0.14	0.64	-3.08**
Sushk Samrat	-0.78	7.19**	-2.13*	0.1	-0.37	-12.28**	-4.11**	-0.11	0.39	-4.39**
Vandana	0.6	-4.75**	3.1**	-0.15	0.35	6.82**	6.09**	0.39	-0.61	7.31**
SE±	0.10	1.17	0.13	0.51	0.04	0.69	0.23	0.06	0.14	0.85

*= Significance of p=0.05 level, **= Significance of p=0.01 level

Table 5. Promising hybrids based on per se performance, SCA and GCA effects

Cross Combinations	Per se Performance (Yield per Plant in g)	SCA effects	GCA Effects (Female)	GCA Effects (Male)
IR-36×Birsa Dhan-105	39.431	8.16**	6.57**	-3.21**
IR-36×N-22	32.01567	3.35**	6.57**	0.19
HUR-105×Birsa Dhan-105	25.82867	7.36**	-6.23**	-3.21**
HUR-105×NDR-97	14.93333	-2.62*	-6.23**	-1.12
Pant Dhan-12×Danteshwari	45.97967	13.69**	4.44**	2.94**
Pant Dhan-12×N-22	36.66233	7.12**	4.44**	0.19
Pant Dhan-12×Shushka Samrat	36.31133	9.23**	4.44**	-2.27
NDR-359×Barani Deep	25.87767	16.99**	-4.78**	2.76**
NDR-359×Vandana	26.148	7.31**	-4.78**	-3.29**

*= Significance of p=0.05 level, **= Significance of p=0.01 level
Note:-SH: Seedling height, PH: Plant height, PC: Proline content, SB: Stomatal behavior, PW: Panicle weight, SPP: Seeds/ Panicle, PFG: Seeds/Panicle, LR: Leaf rolling, SG: Stay green and YPP: Yield per plant

crosses and suggested exploitation of heterosis in F_1 generation. Similar results were also obtained by Dubey (1975). The crosses IR36×Nagina-22, IR36×NDR-97 and HUR-105×Vandana recorded low x low parental gca effects indicating over dominance and epistatic interactions.

Water deficit had a more pronounced effect on leaf expansive growth than any other traits which ultimately affects photosynthesis and results in yield loss. Maintenance of the transpiration rate during mild water stress enabled tolerant cultivars to minimize injury from the stress. Differential response of rice cultivars to water deficit was demonstrated. Among twenty eight cross combinations, majority of crosses were found effective for enhancing seed yield potential under drought conditions. Since, the performance of these crosses showed non-additive gene action and expected to be non-fixable in succeeding generation and therefore, the potential promising cross combinations were identified based on both per se performance and sca effects which may be utilized for heterosis breeding programme.

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