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BREEDING FOR DROUGHT TOLERANCE AND COMBINING ABILITY ANALYSIS FOR YIELD AND YIELD ASSOCIATED TRAITS IN RICE (*ORYZA SATIVA* L.)

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ABSTRACT

Crop yield adversely affected by drought in recent years. In this context to design an efficient breeding programme for variety development virtues of drought tolerant and high yielding ability. It is necessary to identify potential parent that combine well for both yield and drought tolerant. The crosses were designed in Line (3 high yielding genotypes) x Tester (6 drought tolerant genotypes) fashion, resultant eighteen crosses were assessed through combining ability for fourteen yield related traits. Among crosses Karma Mahsuri x IR 42253 (6.654) represented high *sca* effect followed by MTU 1010 x Moroberekan (6.456) and Karma Mahsuri x Chaptigurmatiya (5.299) while Swarna x IR 42253 (5.999) showed high x low *gca* effects and gives best heterotic combination. However, line Karma Mahsuri showed non-significant negative *gca* effects for grain yield per plant. Karma Mahsuri x IR 42253 (6.654) showed highly positive significant *sca* effects for grain yield. Such combinations may be used for exploitation of heterosis for drought tolerance traits. Chaptigurmatiya (3.124) showed positive significant high *gca* effect among testers. This genotype could be considered in breeding programme as a donor parent for development of drought tolerant lines.

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INTRODUCTION

"Global grain (Rice)"is the staple food of more than three billion people in the world, most of who live in Asia.India has the largest area under rice, about 44.6 million hectare area with a production of about 106.19 million tons. Virtually 75% of the comprehensive rice production comes from irrigated environment that covers around 55 % while total cropped rice area under rainfed upland and lowland contributed only 21 % and 34% respectively (MoA, 2014).Crop yieldadversely affected by drought during recent years particularly reproductive stage of drought (Reddy, 2005 and Venuprasad *et al*., 2009a; Lanceras *et al*., 2004)).Gene banks are stewards of the world's crop diversity, and represent large potential for sources of drought tolerance. (Rolando *et al*., 2013).In crop improvement programme, to enlarge the productivity, breeder wants to retain a pool of assorted desirable donor parents (Joshi *et al*., 2013). Breeders can hold the most precious gene and effectively utilized in the breeding programmes to expand high yielding rice varieties with quality, biotic and abiotic stresses and introducing drought resistant varieties as well as exploit this base material as donors for the drought tolerance for higher yield in crop improvement (Kumar, *et al*.2015) and Bhattacharya and Ghosh, 2004). The success of any plant breeding method depends on the choice of appropriate genotypes as parents in the hybridization programme and combining ability studies of the genotypes provide information which helps in the selection of better parent for effective breeding (Bhati *et al*., 2015).Therefore a trait based breeding approach has been proposed to improve rice yields under inadequate water circumstances (Reynolds *et al*., 2008).The concept of combining ability helps the breeder to determine the nature of gene action involved in the expression of quantitative traits of economic importance. The choice of suitable breeding method for the improvement of drought tolerance traits primarily depends on the relative importance of *gca* and *sca* variances. Proper choice of parents on the basis of their combining ability status for putative drought tolerant attributes as well as yield contributing traits and selection in typical target environment will help in combining complex traits such as productivity and drought tolerance (Hanamaratti *et al*., 2004). In this context to design an efficient breeding programme for variety development virtues of drought tolerant and high yielding ability for identification of potential parent that combine well for both yield and drought tolerant. Hence required this study for development of drought tolerant lines along with genetic potentiality and crosses were attempted (Ganapathy *et al*., 2008).The objective of the present investigation was to obtain a genotype having high grain yield along with deployment of drought tolerant lines and also identifying the best combing parent and their crosses on the basis of their general and specific combing ability effect for drought situation.

MATERIALS AND METHODS

The current investigation was conducted at Research cum Instructional farm Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, is situated at central parts of Chhattisgarh and lies at latitude, longitude of 21o4' N, 81o35' E respectively and 290.20 meters above mean sea level. The experimental materials consisted of six drought tolerant donors including landraces *viz*. Chaptigurmatiya (T_1), Moroberekan

(T_2), IR 42342 (T_3), IR 42253 (T_4), IC 336384 (T_5) and IC115875 (T_6) (Testers) and three high yielding rice verities i.e. Karma Mahsuri (L_1), MTU 1010 (L_2) and Swarna (L_3) (lines). Among them three testers Chaptigurmatiya (T_1), IC 336384 (T_5) and IC 115875 (T_6) are the land races. Crossing was carried out by following in Line x Tester Mating Design (Kempthorne, 1957) during Kharf-2014. For crossing, wet cloth method suggested by (Chaisang *et al.* 1967) was followed and maximum numbers of crosses were made to develop sufficient F_1 seeds, resultant 18 crosses long with their parent were raised under normal environment in Randomized Block Design (RBD) replicated twice with spacing of 20x15 cm. during Rabi-2015 and consequent generation (F_3 and F_4 etc.) of these crosses will be use for screening at different stages of drought (RKMP by Kumar), Single seedling was transplanted per hill for each hybrid in two rows of two meter length. Standard packages of practices were followed for regular growth of crop. A total of fifteen yield and yield associated traits were considered for data recording *viz.* flag leaf length (cm.), flag leaf width (cm), days to 50% flowering, plant height (cm.), panicle length (cm), no. of tiller per plant, effective tillers, 100 grain weight, grain length, grain width, paddy L/B ratio, decorticated grain length, decorticated grain width, decorticated grain l/b ratio and grain yield/plant.

RESULTS AND DISCUSSION

Temperament of gene action as considered by ***gca*** and ***sca*** variance is of greater significance in deciding the inheritance of a character and thereby selection of suitable breeding programmes. Amount of genetic variance for different traits is presented in Table 1.The analysis of variance for combining ability (Line x Tester) analysis revealed that, significance differences between the hybrids, lines, testers and line x testers interaction for all the yield associated characters. Studies of combining ability helps in hybridization programme, besides elucidating the nature and magnitude of gene action involved in the inheritance of characters parent with high ***gca*** special effects are desirable for obtaining useful segregants in early generation (Manonmani and Fazullah Khan, 2005).Analysis of variance (ANOVA) for combining ability revealed significant differences between the treatments (genotype) for all the traits studied. Amongst the treatments the MSS due to parents showed significant differences for all the traits except grain yield per plant (Table 1). The MSS due to parents v/s crosses also differed significantly except for effective tillers and decorticated grain l/b ratio. The line showed significantly differences to all the traits except for plant height, effective tillers and decorticated grain width. However, the testers showed significant for all traits except grain yield per plant. All traits showed positive significant differences for line x tester except decorticated grain length and grain yield per plant (Table 1).

The analysis of variance for combining ability (Table 1) showed significant *gca* and *sca* variances for all the characters. The results revealed that, dominance variance (s^2D) was high and additive genetic variance (s^2A) was low in magnitude for all the traits except plant height and no. of tillers per plant. The ratio of (s^2A) / (s^2D) ranged from -0.291 (days to 50% flowering) to 3.500 (decorticated grain width). The ratio of *gca* and *sca* variance is not more than one for all traits except decorticated

Table 1: Analysis of variance (mean square) for combining ability for yield and yield associated traits in rice

	DF	Mean Sum Of Square 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Genotype	26	48.62**	0.25**	57.29**	563.34**	13.29**	151.96**	37.63**	0.23**	1.17**	0.082**	0.325**	0.51**	0.037*	0.16*	73.83**
Parent (P)	8	80.69**	0.11**	78.51**	734.92**	14.10**	54.56**	25.31**	0.32**	2.67**	0.205**	0.815**	0.99**	0.038*	0.30**	10.62
Crosses (C)	17	35.12**	0.34**	36.92**	423.83**	13.11**	195.29**	45.23**	0.08**	0.33	0.028**	0.044**	0.24*	0.027*	0.10	93.35**
P v/s C	1	21.58**	0.016	233.85**	1562.43**	9.90**	194.65**	6.8	2.05**	3.49**	0.012**	1.187**	1.09**	0.205**	0.014	247.48**
Line (L)	2	53.35**	0.14**	145.50**	13.042	5.91**	35.139	18.66	0.73**	6.12**	0.037**	1.051**	1.18**	0.002	0.21**	11.416
Tester (T)	5	87.79**	0.004	64.48**	580.35**	13.30**	54.97**	25.84**	0.11**	1.19**	0.203**	0.733**	1.09**	0.034*	0.37**	9.887
L x T	1	99.90**	0.15**	14.69**	2951.55**	34.47**	91.33**	36.00**	0.57**	3.20**	0.55**	0.754**	0.07	0.134**	0.11*	12.71
Error	26	4.142	0.005	1.78	7.612	1.722	14.017	7.044	0.006	0.169	0.001	0.003	0.047	0.007	0.032	5.631
s^2 (gca)		-0.102	0.033	-3.403	52.924	2.252	50.205	4.458	0.004	-0.013	0.001	-0.001	0.012	0.003	0.009	-0.575
s^2 (sca)		15.13	0.11	23.36	96.61	2.43	30.72	11.42	0.03	0.19	0.01	0.02	0.06	0.00	0.01	41.17
s^2gca/sca		-0.007	0.308	-0.146	0.548	0.928	1.634	0.390	0.133	-0.068	0.077	-0.045	0.214	1.500	0.692	-0.014
s^2A		-0.20	0.07	-6.81	105.85	4.50	100.41	8.92	0.01	-0.025	0.0010	0.00	0.03	0.007	0.019	-1.15
s^2 D		15.13	0.11	23.36	96.61	2.43	30.72	11.42	0.03	0.19	0.01	0.02	0.06	0.00	0.01	41.167
s^2A/s^2 D		-0.013	0.617	-0.291	1.096	1.856	3.269	0.781	0.267	-0.131	0.077	-0.091	0.446	3.500	1.462	-0.028
Degree of dominance		8.70	1.25	1.85	0.96	0.73	0.55	1.13	1.73	2.76	3.16	0.14	1.41	0.00	0.73	5.98

*Significance at 5% level and ** Significance at 1% level. Note: 1-Flag leaf length (cm.), 2- Flag leaf width (cm) ;3- Days to 50% flowering;4- Plant height (cm.) ;5- Panicle length (cm); 6- No. of tiller per plant ;7-Effective tillers ; 8-100 grain weight ;9-Grain length ;10-Grain width;11- Paddy L/B ratio; 12-Decorticated grain length;13-Decorticated grain width; 14-Decorticated grain l/b ratio;15-Grain yield/plant

Table 2: Estimation of General Combining Ability (*gca*) effects of parents (male and female) for yield and yield associated traits in rice.

Parents	*gca* Effects														
Line (L)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
L_1 (Karma Mahsuri)	0.886	0.116**	-0.777	-7.733**	-1.64375**	-5.631**	-1.702*	-0.115**	-0.170	-0.061**	0.016	0.046	-0.058*	0.115*	-0.889
L_2 (MTU 1010)	-1.214*	-0.239**	-0.420	4.571**	1.9325**	-4.336**	-1.044	0.067**	0.147	0.019*	0.034*	0.100	0.025	0.007	-1.386
L_3 (Swarna)	0.327	0.124**	1.196**	3.161**	-0.289	9.968**	2.747**	0.049*	0.023	0.042**	-0.049**	-0.146*	0.033	-0.121*	2.276**
Testers (T)															
T_1 (Chaptigurmatiya)	1.708*	0.241**	-2.503**	11.848**	0.135	-0.665	2.880*	-0.105**	-0.275	0.025	-0.153**	-0.187*	0.025	-0.131	3.214**
T_2 (Moroberekan)	-1.368	0.447**	-1.736**	11.752**	2.268**	1.335	2.147	0.187**	0.285	0.128**	-0.067**	0.412**	0.158**	-0.026	1.964
T_3 (IR 42342)	-3.810**	-0.287**	0.405	-6.356**	-0.146	-5.090**	-3.877**	0.036	0.077	-0.022	0.075**	0.146	-0.108**	0.244**	-0.986
T_4(IR 42253)	-0.760	-0.103**	2.813**	3.319**	1.060	-6.431**	-4.736**	-0.156**	-0.093	-0.056**	0.040	-0.046	-0.091*	0.111	-8.630**
T_5(IC 336384)	4.551**	-0.283**	-0.262	-1.959	-1.014	5.751**	2.206	0.060	0.116	-0.026	0.085**	-0.021	0.025	-0.056	2.859**
T_6(IC 115875)	-0.321	-0.016	1.283**	-18.605**	-2.302**	5.101**	1.381	-0.021	-0.108	-0.048**	0.019	-0.304**	-0.008	-0.143	1.581

*Significance at 5% level and ** Significance at 1% level.; Note: 1-Flag leaf length (cm.),2- Flag leaf width (cm) ; 3- Days to 50% flowering;4- Plant height (cm.) ;5- Panicle length (cm); 6- No. of tiller per plant ;7-Effective tillers; 8-100 grain weight ;9-Grain length;10-Grain width 11- Paddy L/B ratio; 12-Decorticated grain length;13-Decorticated grain width;14-Decorticated grain l/b ratio;15- Grain yield/plant

Table 3: Estimation of Specific Combining Ability (*sca*) effects of 18 hybrids for yield and yield associated traits in rice.

	sca Effects														
Crosses	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
K. M. x Chapti.	-2.040	-0.106*	-1.057	6.007**	1.594	5.332	3.436	0.234**	0.133	0.083**	-0.067	-0.062	0.025	-0.083	5.299**
K. M.x Moro.	2.636	0.177**	1.277	0.013	0.630	-3.368	-2.931	-0.005	-0.267	-0.020	-0.085*	0.288	0.042	0.063	-7.140**
K. M. x IR 42342	0.009	-0.057	-4.765**	-0.789	-2.115*	-0.343	0.694	0.222**	0.302	-0.079**	0.254**	0.054	-0.042	0.127	-0.181
K. M. x IR 42253	5.158**	0.247**	-1.773	6.005**	0.269	4.099	2.453	-0.158**	-0.048	-0.035	0.029	-0.054	-0.108	0.147	6.654**
K. M. x IC 336384	-4.053**	-0.331**	7.602**	-11.525**	-2.107**	-0.885	-2.089	-0.203**	-0.057	0.054*	-0.105*	-0.179	0.025	-0.135	-1.495
K. M. x IC 115875	-1.710	0.071	-1.283	0.290	1.730	-4.835	-1.564	-0.089	-0.063	-0.003	-0.026	-0.046	0.058	-0.119	-3.137
MTU 1010 x Chapti.	0.151	0.311**	3.586**	-0.058	0.737	-7.463**	-5.622	-0.131*	0.086	0.084**	-0.077	0.133	0.092	-0.045	-4.243*
MTU 1010 xMoro.	-0.773	-0.017	-3.279**	-7.897**	-0.586	6.436*	2.911	0.155**	0.886**	0.141**	0.167**	0.183	-0.042	0.138	6.456**
MTU 1010 xIR 42342	1.122	-0.176**	4.003**	2.123	0.106	-2.514	-0.539	-0.161**	-0.250	-0.058*	-0.032	0.050	-0.025	0.046	2.726
MTU 1010 xIR 42253	-4.216**	-0.336**	2.720**	-11.115**	0.697	-5.797*	-4.555*	0.056	-0.180	-0.049*	-0.006	-0.433**	0.058	-0.301*	-12.653**
MTU 1010 xIC 36384	-1.614	-0.118*	-9.329**	2.727	-0.329	-0.731	3.628	-0.004	-0.252	-0.066**	-0.006	-0.033	-0.008	0.006	4.345*
MTU 1010 xIC115875	5.330**	0.336**	2.3001*	14.215**	-0.626	10.069**	4.177*	0.085	-0.290	-0.051*	-0.047	0.100	-0.075	0.157	3.370
Swarna x Chapti.	1.890	-0.205**	-2.529*	-5.948**	-2.33125*	2.132	2.186	-0.103	-0.220	-0.168**	0.144**	-0.071	-0.117	0.128	-1.056
Swarna x Moro.	-1.864	-0.160**	2.004*	7.878**	-0.045	-3.068	0.019	-0.149*	-0.619*	-0.122**	-0.083*	-0.471**	0.000	-0.201	0.684
Swarna x IR 42342	-1.131	0.234**	0.761	-1.334	2.009*	2.857	-0.156	-0.060	-0.052	0.138**	-0.223**	-0.104	0.067	-0.173	-2.546
Swarna x IR 42253	-0.942	0.089	-0.947	5.109**	-0.966	1.699	2.103	0.102	0.228	0.083**	-0.023	0.487**	0.050	0.154	5.999**
Swarna x IC 336384	5.667**	0.450**	1.728	8.799**	2.437**	1.615	-1.539	0.206**	0.309	0.013	0.112**	0.213	-0.017	0.130	-2.850
Swarna x IC 115875	-3.620*	-0.407**	-1.017	-14.505**	-1.105	-5.235	-2.614	0.005	0.353	0.055*	0.073	-0.054	0.017	-0.038	-0.232

*Significance at 5% level and ** Significance at 1% level. [K.M. = Karma Mahsuri, Chapti = Chaptigurmatiya, Moro = Moroberekan] Note: 1-Flag leaf length (cm.),2- Flag leaf width (cm);3- Days to 50% flowering; 4- Plant height (cm.) ;5-Panicle length (cm);6- No. of tiller per plant;7-Effective tillers ;8-100 grain weight;9-Grain length ;10-Grain width;; 11- Paddy L/B ratio; 12-Decorticated grain length ;13-Decorticated grain width;14-Decorticated grain l/b ratio;15- Grain yield/plant

Table 4: PromisingHybrids per se performance with *sca* effects and *gca* status for grain yield per plant.

S. No.	Crosses	Mean	*sca* effects	*gca* effects		*gca* status
				Line	Tester	
1.	Karma Mahsuri x IR 42253	27.93	6.654**	-0.889	-8.630*	L x H
2.	MTU 1010 x Moroberekan	37.83	6.456**	-1.386	1.964	L x H
3.	Swarna x IR 42253	30.44	5.999**	2.276*	-8.630**	H x L
4.	Karma Mahsuri x Chaptigurmatiya	38.42	5.299**	-0.889	3.214**	L x H
5.	MTU 1010 x IC 336384	36.61	4.345*	-1.386	2.859**	L x H

grain width and degree of dominance is more than one for all traits except plant height, panicle length, no. of tillers per plant, paddy L/B ratio and decorticated grain width. Major role of non-additive gene effects in the inheritance of all traits was observed by higher value of variance of specific combining (s^2*gca*) than the variance of general combining ability, ratio of s^2 *gca*/s^2*sca* being less than one and degree of dominance (s^2D/s^2A)1/2 being greater than one. Several workers have reported preponderance of non-additive gene effects for plant height (Banumathy *et al*., 2003; Hosseini *et al*., 2005) and grain yield per plant (Manonmani *et al*., 2005 and Gnanasekaran *et al*., 2006).

General combining ability effects

The mean performance of the parents and *gca* effects has been given in Table 2. Significance and positive mean performance and *gca* effects are preferable for all traits. It is evident that assessment of parents on the basis of mean performance of *gca* effects separately. The table showed that swarna were produced highly positive significant *gca* effects (2.276) for grain yield per plant, flag leaf width, days to 50% flowering, plant height, no. of tillers per plant, effective tillers, 100 grain weight and grain width. Similarly MTU 1010 negative significant *gca* effects (-1.386) for grain yield per plant and positive significant *gca* effect for plant height, panicle length and 100 grain weight.

On other hand among the testers the genotype Chaptigurmatiya was showed high significant *gca* effects (3.214) for grain yield per plant, flag leaf length (1.708), flag leaf width, plant height and effective tillers followed by IC 336384 is positively significant (2.859) for grain yield per plant, flag leaf length, no. of tillers per plant and paddy L/B ratio. While IR 42253 showed negative and significant *gca* effects (-8.630) for grain yield per plant and positive significant *gca* effects for days to 50% flowering and plant height. Similar result given by Hossain *et al.* (2009) and Salgotra *et al.* (2010). Parent that had negative and significant *gca* effects were considered for days to 50% flowering and plant height while for other traits, parents with positively significant *gca* effects were taken in to consideration. Anbumalarmathi (2006) reported that parent with high mean performance may not be able to transmit their superior traits in to hybrids and hence they instead the need for combining ability of parent also. Evaluation of parents based on mean and *gca* effects might result in the identification of parents with good reservoir of superior genes. Hence both *per se* and *gca* effects were taken in to account for parental selection.

Specific combining ability effects

The hybrid combinations with high mean performance, desirable *sca* estimates and involving at least one of the parents with high *gca* would likely to enhance the concentration of favorable alleles (Kenga *et al*., 2004). *Sca* effects estimates (table 3) in present investigation. Specific combining ability (*sca*) of a cross is the estimation and the understanding of the effect of non additive gene action for a trait, Non-additive gene action of a trait is an indicator for the selection of a hybrid combination. The results of *sca* effect of the present study are given in the Table-3. Pre dominance of non additive genes action for grain yield and its components was also reported by Saidaiah *et al.* (2010), Patil*et.al.*(2014) and Yogameenakshi *et al.*2015).The result showed that out of 18 hybrid combination five of them viz. Karma Mahsuri x IR 42253 is highly *sca* effects (6.654) positive significant for grain yield per plant followed by MTU1010 x Morobarekan (6.456) positive significant, Swarna x IR42253(5.999) positive significant, Karma Mahsuri x Chaptigurmatiya (5.299) positive significant and MTU 1010 x IC 336384 (4.345) positive significant at 5% level of degree freedom indicated the preponderance of non additive gene action low × high combining parents. These results coincide with the findings of Sanghera and Hussain (2012) and Bagheri and Jelodar (2010). Highly negative significant *gca* effect for MTU 1010 x IR 42253 for grain yield per plant and positive significant *sca* effects for days to 50% flowering. Karma Mahsuri x Chaptigurmatiya showed positive *sca* effect for short stature followed by Karma Mahsuri x IR 42253. The results were confirmed with the findings of Thakare *et al.*Roy and Mondal (2001),Singh and Kumar (2004), (Thirumeni *et al*., 2000; Manivannan & Ganesan, 2001,Gnanasekaran *et al*., 2006 and El-Refaey *et al.*2009). For panicle length swarna x IR 52342 showed high *sca* effect (2.009) followed by swarna x IC 336384 (2.437). These results are in conformity with the earlier findings of Hasib *et al*., (2001), Panwar (2005), Sabesan (2005) and Saravanan *et al.* (2006).

To get eminence recommendation in segregating generation, the close relative of hybrid must be superior general combiner for the characters to which improvement is required (Gravois and McNew, 1993).In case of hybrids with significant *sca* effects in early segregants generation is likely to be unsuccessful as the *sca* effects cover the true performance of the elected plants. Therefore, it will be helpful to select only those hybrids viewing parents with significant *gca* effects and non significant *sca* effects for recommendation breeding, in view of the fact that it is likely to throw segregants with favorable genes derived from both the parents.(Nadarajan and Rangaswamy, 1990).Therefore the hybrids for recommendation breeding were selected based on significant *gca* effects of both the parents and with non-significant *sca* effects of hybrid for each traits.

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