Journal of Applied and Natural Science 9 (1): 406 - 414 (2017)

JANS

Estimation of combining ability for yield and yield component traits in upland rice (*Oryza Sativa* L.) of Uttarakhand hills

J. P. Aditya* and Anuradha Bhartiya

Crop Improvement Division, ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora - 263 601 (Uttarakhand)
*Corresponding author E mail: jayprakashaditya@gmail.com

Received: June 12, 2016; Revised received: December 26, 2016; Accepted: February 8, 2017

Abstract: Combining ability for grain yield and its component characters in rainfed upland rice (*Oryza sativa* L.) were studied during *Kharif* 2014 using half diallel involving ten parents *viz*., VL *Dhan* 221, *Vivek Dhan* 154, VL 30240, VL 7620, VL 30560, VL 8116, VL 8549, VL 8724, VL 8732 and *Sukradhan*1. Both general combining ability (gca) and specific combining ability (sca) variances were found to be highly significant for the characters *viz*., plant height (gca=85.42; sca=23.12), days to 50% flowering (gca=101.61; sca=42.61), days to maturity (gca=90.37; sca=37.73), tillers per plant (gca=4.63; sca=1.38), panicle per plant (gca=2.36; sca=0.90),kernel length (gca=28.88; sca=23.61), kernel width (gca=1.64; sca=1.92),1000 grain weight (gca=3.60; sca=4.91), grain yield per plot (gca=8.57; sca=3.03), fertile grains per panicle (gca=690.67; sca=300.95) and grains per panicle (gca=1050.58; sca=437.75) indicating the importance of additive and non-additive gene actions in the expression of these traits. However, predominance of non-additive gene action was recorded for all the characters. Parents VL *Dhan* 221, VL 7620, VL 30560, *Sukradhan* 1 were good general combiners for grain yield and related characters. VL *Dhan* 221 and *Vivek Dhan* 154 were good general combiners for plant height and earliness. On the basis of specific combining ability effects, cross combinations *Vivek Dhan* 154 x VL 8549, VL 7620 x VL 30560, VL 8549 x VL 8732, VL 30560 x VL 8116 and VL 30240 x VL 8116 were the best specific combiner for grain yield per plot and other associated characters *viz*., plant height, days to 50% flowering, days to maturity, kernel length and kernal width.

Keywords: Combining ability, Rice (*Oryza sativa* L.), Rainfed upland hill ecosystem, Yield

INTRODUCTION

Rice is a major *kharif* crop of Uttarakahand occupying 2.6 lakh ha area with 6.0 lakh tonnes production and 2307 kg/ha productivity (DES, 2014). It's grown under varied ecologies among which direct seeded in rainfed upland agro ecology occupies substantial area. Under this production condition, the productivity varies from very low (<1000 kg/ha) to low (1000-1500 kg/ha) mainly due to poor adoption of high yielding varieties, low soil fertility with acidic nature (generally, encounter the deficiency of C, N, P and available nutrients and toxicity of iron, aluminum and manganese) and erratic behavior of monsoon. Rainfall is the most important weather element for successful cultivation of rice whereas, temperature, sunlight and bright sunshine hours greatly influence the yield levels in rice. In upland soils, rice crop often suffers with soil moisture stress due to erratic and inadequate rainfall as rain water flows down quickly and unavailability of life saving irrigations (DRD, 2002). For ensuring food and nutritional security of local populace of this region, productivity of rice in rainfed upland hill ecosystem needs to be improved. Developing high yielding varieties for this region is one of the strategies to enhance the productivity of this region. Selection of potentially good parents is one of the major prerequisite for developing high yielding varieties in a breeding programme. Combining ability analysis helps in the identification of parents with high general combining ability (gca) effects and cross combinations with high specific combining ability (sca) effects. The gca effect is controlled by additive genes and fixable in nature and the cross involving parents with high gca will give better transgressive segregants in later generations therefore, selection of parents based on gca effect would have an impact in breeding programme (Singh *et al*., 2011). Diallel analysis is one of the most powerful tools for estimating the general combining ability (GCA) of parents and specific combining ability (SCA) of crosses (Sarkar *et al.,* 2002; Rahimi *et al*., 2010). It also provides information on the additive and dominance variance which may be useful for suggesting an appropriate breeding strategy to be followed for isolation of purelines or exploitation of heterosis. Diallel analysis in rice has been mostly reported in irrigated ecosystem and only limited attempts have been made in rainfed upland hill ecosystem. Nature of gene action and combining ability of rice genotypes of rainfed upland ecosystem adapted for hill region would help to design an efficient breeding strategy for genetic

ISSN : 0974-9411 (Print), 2231-5209 (Online)

improvement of upland rice. Therefore, the present investigation aims to estimate combining ability for grain yield and its component traits in rainfed upland rice (*Oryza sativa* L.).

MATERIALS AND METHODS

Ten rice genotypes *viz.,* VL *Dhan* 221, *Vivek Dhan* 154, VL 30240, VL 7620, VL 30560, VL 8116, VL 8549, VL 8724, VL 8732 and *Sukradhan*1 were crossed in diallel fashion in *Kharif* 2013 without reciprocals. All the ten parents and its resultant $45F_1$ derivative hybrids were planted in randomized block design with three replications in *Kharif* 2014 at Experimental Farm of ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora. The standard agronomic package and practices were followed for raising good crop. The seedling was planted at a spacing of 20 x 15 cm with 2.25 meter row length. Observations on quantitative traits *viz.*, plant height, flag leaf length, flag leaf width, tillers per plant, panicles per plant, panicle length, grains per panicle, fertile grain per panicle, thousand grain weight, kernel length, kernel width were recorded on five randomly selected competitive plants of the row whereas days to 50 per cent flowering, days to maturity and grain yield were recorded on plot basis. The mean value of replicated data was subjected to statistical analysis using INDOSTAT software package (Version 8.1). The combining ability analysis was done following procedure given by Griffing (1956) Method II and Model I.

General combining Ability (GCA) Effects: G*i*= [1/ n+2][(Y*i*. + Y*ii*) – (2/n)Y..

Specific combining Ability (SCA) Effects: S*ij*=Y*ij*-[1/ n+2](Y*i*. + Y*ii* + Y.*j* + Y*jj*) + (2/(n+1)/(n+2))Y..

Where, G*i*= GCA effect of i^{th} parent, n= number of parents, Y*i*=total of the array involving i^{th} as a female parent, Y*ii*= the value of the i^{th} of the array, S*ij* =SCA effect of ij^{th} cross, Y*ij*= the value of *i* x j^{th} cross, Y.*j*= total of the arrays involving j^{th} parent as a male, Y*jj*= the value of the j^{th} parent in the array, Y..= the grand total

RESULTS

Analysis of variance (ANOVA) showed significant differences among the parents and hybrids for the characters *viz*., plant height, days to 50% flowering, days to maturity, tillers per plant, panicle per plant, panicle length, kernel length, kernel width,1000 grain weight, grain yield per plot, fertile grains per panicle and grains per panicle whereas, flag leaf length and flag leaf width were found insignificant (Table 1).

The highly significant mean square due to general combining ability (gca) and specific combining ability (sca) for all the traits *viz*., plant height (gca=85.42; sca=23.12), days to 50% flowering (gca=101.61; sca=42.61), days to maturity (gca=90.37; sca=37.73), tillers per plant (gca=4.63; sca=1.38), panicles per plant (gca=2.36; sca=0.90),kernel length (gca=28.88; sca=23.61), kernel width (gca=1.64; sca=1.92),1000 grain weight (gca=3.60; sca=4.91), grain yield per plot (gca=8.57; sca=3.03), fertile grains per panicle (gca=690.67; sca=300.95) and grains per panicle (gca=1050.58; sca=437.75) except flag leaf length (gca=3.00; sca=3.66), flag leaf width (gca=0.44; sca=0.86) and panicle length (gca=2.05; sca=2.28) indicated that both additive and non additive gene actions were involved in the expression of the traits under study (Table 2). The estimated components of specific combining ability (sca) variance were higher than general combining ability (gca) variance for all the characters *viz*., plant height (σ^2gca=6.23; σ^2sca=12.52), days to 50% flowering (σ^2gca=8.44; σ^2sca=42.35), days to maturity (σ^2gca=7.48; σ^2sca=37.20), flag leaf length (σ^2gca=0.021; σ^2sca=0.925), flag leaf width(σ^2gca=0.021; σ^2sca=0.165), tillers per plant (σ^2gca=0.319; σ^2sca= 0.588), panicles per plant (σ^2gca=0.153; σ^2sca= 0.373), panicle length (σ^2gca=0.005; σ^2sca=0.292), kernel length (σ^2gca=2.31; σ^2sca=22.48), kernel width (σ^2gca=0.118; σ^2sca=1.69),1000 grain weight (σ^2gca=0.230; σ^2sca= 4.076), grain yield per plot (σ^2gca=0.680; σ^2sca=2.62), fertile grains per panicle (σ^2gca=55.54; σ^2sca=276.82) and grains per panicle (σ^2gca=80.42; σ^2sca=352.22) indicating the preponderance of non-additive gene action in the expression of these characters. *Sukradhan*1 was found to be the best general combiner for grain yield per plot followed by VL *Dhan* 221 whereas, VL *Dhan* 221 and *Vivek Dhan* 154 were good general combiner for plant height, days to 50 per cent flowering, days to maturity and panicles per plant (table 3). *Vivek Dhan* 154 was a good general combiner for kernel length and thousand grain weight. Maximum desirable sca effects were exhibited by cross combinations VL *Dhan* 221 x VL 8724 for days to 50 per cent flowering and days to maturity followed by VL 30560 x *Sukradhan*1, VL 30240 x VL 8116, *Vivek Dhan* 154 x VL 8732 and *Vivek Dhan* 154 x VL 30560 (table 4). The cross combinations VL *Dhan* 221 x VL 7620, VL *Dhan* 221 x 8116, VL *Dhan* 221 x VL 8549, *Vivek Dhan* 154 x VL 8549, *Vivek Dhan* 154 x *Sukradhan* 1 and VL 30240 x VL 8549 were the best specific combinations for panicle per plant however, crosses *Vivek Dhan* 154 x VL 8724, *Vivek Dhan* 154 x *Sukradhan*1, VL 7620 x VL 8732, VL 8724 x *Sukradhan*1 were found to be the best specific combinations for panicle length. The result on specific combining ability effects of crosses combinations indicated that crosses *Vivek Dhan* 154 x VL 8549, VL 7620 x VL 30560, VL 8549 x VL 8732, VL 30560 x VL 8116, VL 30240 x VL 8116 were the best specific combinations for grain yield per plant. Maximum sca effect was exhibited by the cross combinations VL 7620 x VL 8549, VL 30560 x VL 8732, VL 8724 x *Sukradhan* 1, VL *Dhan* 221 x *Vivek Dhan* 154, VL 8116 x VL 8549, VL 30240 x VL 8549, VL 7620

Table 1. Analysis of variance for various yield contributing characters.

Source of variance	d.f	Plant height	Days to 50% flowering	Days to maturi-ty	Flag leaf length	Flag leaf width	Tillers per plant	Panicles per plant	Panicle length	Kernel length	Ker-nel width	1000 grain weight	Grain yield per plot	Fertile grains per panicle	Grains per pan-icle
Replications	2	261.32	10.21	0.55	7.33	47.35	206.35	44.37	7.78	30.89	0.39	23.32	3.88	882.84	626.75
Treatments	54	100.51**	157.33**	139.50**	10.64	2.37	5.77**	3.42**	6.73	73.47**	5.61**	14.07**	11.85**	1097.72**	1619.67**
Parents	9	103.94**	98.39**	75.41**	11.44	3.79	3.35	2.30	12.80*	70.84**	6.50**	16.13**	19.96**	1631.87**	2799.51**
Hybrids	44	99.39**	170.98**	154.54**	10.70	2.13	6.35**	3.67**	5.58	75.56**	5.49**	13.75**	9.37**	1008.88**	1404.69**
Parents vs Hybrids	1	118.80	87.58**	54.14**	0.84	0.30	2.00	2.91	2.73	5.32	2.84*	9.53	48.03**	199.63	460.12**
Error	108	31.80	0.76	1.56	8.19	2.09	2.38	1.57	5.97	3.39	0.65	2.49	1.19	72.39	256.57
Total	164	57.22	52.43	46.97	8.99	2.73	5.99	2.70	6.24	26.80	2.28	6.56	4.74	419.88	709.91

**,* Significant at 1% and 5% level of probability, respectively.

Table 2. Combining ability analysis for various yield contributing characters.

Source of variance	d.f	Plant height	Days to 50% flowering	Days to maturity	Flag leaf length	Flag leaf width	Tillers per plant	Panicles per plant	Pani-cle length	Kernel length	Kernel width	1000grain weight	Grain yield per plot	Fertile grains per panicle	Grains per panicle
GCA	9	85.42**	101.61**	90.37**	3.00	0.44	4.63**	2.36**	2.05	28.88**	1.64**	3.60**	8.57**	690.67**	1050.58**
SCA	45	23.12**	42.61**	37.73**	3.66	0.86	1.38*	0.90*	2.28	23.61**	1.92**	4.91**	3.03**	300.95**	437.75**
Error	108	10.60	0.25	0.52	2.73	0.70	0.79	0.52	1.99	1.13	0.22	0.83	0.40	24.13	85.52
σ^2GCA		6.23	8.44	7.48	0.021	0.021	0.319	0.153	0.005	2.31	0.118	0.230	0.680	55.54	80.42
σ^2SCA		12.52	42.35	37.20	0.925	0.165	0.588	0.373	0.292	22.48	1.69	4.076	2.62	276.82	352.22
σ^2GCA/		0.49	0.199	0.201	0.023	0.129	0.543	0.409	0.017	0.102	0.069	0.056	0.258	0.200	0.228

**,* Significant at 1% and 5% level of probability, respectively

Table 3. Estimates of general combining ability (GCA) of parent effects for different characters in rice.

Parents	Plant height	Days to 50% flowering	Days to maturity	Flag leaf length	Flag leaf width	Tillers per plant	Panicles per plant	Panicle length	Kernel length	Kernel width	1000 grain weight	Grain yield per plot	Fertile grains per panicle	Grains per panicle
VL *Dhan* 221	-5.450**	-3.794**	-3.578**	-0.862	-0.007	1.189**	0.761**	-0.279	-0.021	-0.617	-0.28	0.710**	-10.183**	-12.194**
Vivek Dhan 154	-2.117*	-3.961**	-3.661**	-0.059	0.023	0.883**	0.483*	-0.162	0.241**	4.772**	1.237**	-1.379**	-6.239**	-8.889**
VL 30240	-0.978	-3.156**	-3.133**	0.724	-0.002	0.022	-0.517*	0.849*	0.095**	-3.672**	-0.216	-1.448**	-2.044	-6.139*
VL 7620	-0.144	-0.183	0.422*	0.157	0.007	0.161	0.428*	0.257	-0.292**	1.3	-0.762**	0.632**	13.289**	15.556**
VL 30560	1.494	1.872**	1.728**	-0.471	0.009	-0.45	-0.017	-0.276	0.013	-5.533**	-0.061	0.485**	4.317**	10.917**
VL 8116	1.578	-1.156**	-1.328**	0.504	0.023	-0.422	-0.294	0.424	-0.012	1.05	-0.217	-0.09	2.761*	1.889
VL 8549	0.633	1.178**	1.228**	-0.534	-0.043	0.161	0.067	-0.59	0.017	-2.117	-0.126	-0.268	-6.406**	-7.500**
VL 8724	-1.339	3.261**	3.117**	-0.032	0.004	-0.561*	-0.044	-0.126	-0.136**	6.550**	0.342	0.104	10.428**	9.667**
VL 8732	4.161**	3.872**	3.617**	0.396	-0.004	-0.644**	-0.572**	-0.151	0.188**	0.522	0.414	0.174	-3.683**	-0.5
*Sukradhan*1	2.161*	2.067**	1.589**	0.177	-0.01	-0.339	-0.294	0.054	-0.094**	-2.256	-0.332	1.079**	-2.239	-2.806
SE (gi)	0.891	0.137	0.197	0.452	0.228	0.244	0.198	0.386	0.290	0.127	0.249	0.172	1.345	2.53
SE (gi-gj)	1.32	0.204	0.294	0.674	0.340	0.363	0.295	0.575	0.433	0.190	0.371	0.257	2.00	3.77
CD (gi-gj) at 5%	2.63	0.406	0.584	1.33	0.674	0.721	0.586	1.141	0.859	0.377	0.737	0.510	3.97	7.48

**,* Significant at 1% and 5% level of probability, respectively.

Table 4. Estimates of specific combining ability (SCA) effects of hybrid for different characters in rice

Cross combination	Plant height	Days to 50% flowering	Days to maturity	Flag leaf length	Flag leaf width	Tillers per plant	Panicles per plant	Panicle length	Kernel length	Kernel width	1000 grain weight	Grain yield per plot	Fertile grains per panicle	Grains per panicle
VL *Dhan* 221 x *Vivek Dhan* 154	4.5	-3.99	-4.543	-2.61	-0.112	1.194	0.374	0.255	-0.052	-6.04	0.179	-0.157	18.889	26.326
VL *Dhan* 221 x VL 30240	-2.306	-0.462	-0.071	0.173	0.046	-0.611	0.374	-0.489	-0.196	1.404	-1.298	1.546	2.694	-2.424
VL *Dhan* 221 x VL 7620	-0.139	8.232	7.374	2.073	-0.029	1.917	2.096	-1.631	-0.188	6.432	-0.992	-0.934	-1.639	-3.452
VL *Dhan* 221 x VL 30560	-4.778	5.177	6.068	-0.732	0.135	1.194	-0.126	1.336	-0.343	3.932	-0.76	-1.187	-18.667	-29.146
VL *Dhan* 221 x VL 8116	-4.861	-7.129	-6.876	-0.24	-0.012	0.5	1.152	0.169	-0.108	8.349	0.433	-0.245	-19.444	-20.452
VL *Dhan* 221 x VL 8549	-5.583	-8.795	-8.765	-0.968	-0.012	1.25	1.124	1.049	0.096	4.515	1.776	0.732	5.389	2.604
VL *Dhan* 221 x VL 8724	-2.278	-15.212	-14.321	-1.871	0.008	-0.694	0.235	-1.014	-0.165	-9.818	0.167	-0.273	-19.778	-9.896
VL *Dhan* 221 x VL 8732	9.222	7.51	7.179	2.535	-0.217	-0.611	-1.237	0.744	0.018	-32.79	-4.854	-1.076	16	19.937
VL *Dhan* 221 x *Sukradhan*1	1.889	-3.684	-2.793	0.854	0.021	-0.583	-0.182	-0.695	0.737	13.987	5.445	0.752	14.889	18.576
Vivek Dhan 154 x VL 30240	-0.639	5.038	5.013	-0.429	0.016	-2.306	-1.015	0.261	-0.208	-7.985	1.119	0.902	1.75	1.604
Vivek Dhan 154 x VL 7620	-3.472	1.399	-0.21	3.271	-0.059	0.889	-0.293	1.352	0.213	14.71	2.568	-1.512	-11.917	-11.424
Vivek Dhan 154 x VL 30560	-0.444	-6.99	-7.182	-4.602	-0.062	2.167	0.818	-1.614	0.121	11.876	1.51	-0.832	-29.944	-40.785
Vivek Dhan 154 x VL 8116	-0.528	-0.629	-0.126	2.89	0.024	0.806	0.429	0.086	0.303	-16.04	-0.72	-0.29	-15.389	-15.758
Vivek Dhan 154 x VL 8549	-2.917	9.705	9.985	1.329	0.124	1.889	1.402	-0.667	0.414	3.126	-2.797	4.555	0.778	6.631

Contd.

Table 4. *Contd.*

Cross combination	Plant height	Days to 50% flowering	Days to maturity	Flag leaf length	Flag leaf width	Tillers per plant	Panicles per plant	Panicle length	Kernel length	Kernel width	1000grain weight	Grain yield per plot	Fertile grains per panicle	Grains per panicle
Vivek Dhan 154 x VL 8724	1.722	4.288	3.763	0.893	-0.09	-0.722	-0.487	2.269	0.187	-12.207	0.431	-0.251	6.611	12.798
Vivek Dhan 154 x VL 8732	-4.111	-7.323	-6.404	2.198	0.119	-2.972	-1.626	0.861	-0.067	2.487	-2.86	-0.82	1.722	-3.035
Vivek Dhan 154 x *Sukradhan*1	1.556	-4.518	-4.043	2.485	0.124	0.056	1.096	1.722	-0.518	-3.068	-3.175	-2.259	10.278	13.604
VL 30240 x VL 7620	1.722	0.26	-0.404	-1.413	-0.067	0.083	-0.293	-0.959	0.499	4.821	2.097	-1.576	-10.778	-11.841
VL 30240 x VL 30560	-5.25	-0.795	-1.043	-1.085	0.03	-0.306	-0.515	-1.292	0.114	-6.679	0.47	-2.129	-9.139	-14.535
VL 30240 x VL 8116	-0.667	-7.434	-8.321	-0.36	-0.017	1.333	0.763	-0.492	-0.288	-15.263	-2.454	1.013	-8.25	-4.841
VL 30240 x VL 8549	11.278	-3.434	-3.21	1.212	0.049	1.417	2.402	1.455	0.27	-9.429	1.085	-0.709	22.25	23.881
VL 30240 x VL 8724	-8.417	13.149	13.568	-0.224	-0.065	-0.528	-0.821	0.391	0.589	-21.429	0.38	-0.815	17.75	19.715
VL 30240 x VL 8732	-1.583	-5.462	-5.598	-1.618	0.01	0.556	0.04	-0.884	0.072	-0.402	0.382	-1.051	-23.806	-7.119
VL 30240 x *Sukradhan*1	2.75	3.343	2.429	0.568	0.183	-0.083	-0.237	-0.089	-0.156	24.043	0.224	-0.123	-0.917	3.854
VL 7620 x VL 30560	-1.417	1.899	2.735	0.848	0.055	1.222	0.207	1.399	-0.418	7.682	-2.008	2.457	19.528	6.77
VL 7620 x VL 8116	-10.167	3.593	3.79	-1.093	-0.059	-0.139	-1.182	-1.667	-0.213	-3.568	-1.218	0.132	20.417	22.798
VL 7620 x VL 8549	1.778	2.927	2.568	-1.354	0.041	-0.056	-0.876	-1.753	-0.692	18.932	-2.192	-1.623	35.917	45.52
VL 7620 x VL 8724	7.417	-0.823	0.679	-0.124	0.027	-1.333	0.235	1.016	-0.17	-12.735	-2.917	-0.529	-14.583	-9.313
VL 7620 x VL 8732	1.583	-0.101	-0.154	-2.018	-0.065	0.417	0.096	2.341	-0.117	-3.374	-1.089	0.135	-3.806	-3.146
VL 7620 x *Sukradhan*1	2.25	-3.962	-3.126	-1.365	0.041	-0.889	-0.848	-2.098	-0.675	5.404	-0.757	-0.104	-2.917	-3.508

Contd.

Table 4. *Contd.*

Cross combination	Plant height	Days to 50% flowering	Days to maturity	Flag leaf length	Flag leaf width	Tillers per plant	Panicles per plant	Panicle length	Kernel length	Kernel width	1000 grain weight	Grain yield per plot	Fertile grains per panicle	Grains per panicle
VL 30560 x VL 8116	0.861	12.538	11.485	1.535	0.038	-0.861	-0.737	-1.267	0.915	-11.402	1.691	1.88	-0.611	-9.563
VL 30560 x VL 8549	4.472	2.205	1.929	1.84	-0.029	-1.444	-0.098	1.313	-0.694	-12.235	-2.5	-0.809	-6.778	-12.508
VL 30560 x VL 8724	3.111	0.121	0.04	1.237	-0.109	0.278	0.346	-1.584	0.855	13.765	3.478	-3.315	-5.611	-16.341
VL 30560 x VL 8732	-0.389	-0.49	-0.46	3.51	0.099	0.028	0.874	1.208	0.618	-3.874	2.537	-0.984	28.167	28.492
VL 30560 x *Sukradhan*1	-2.722	-12.018	-11.098	-1.171	-0.062	0.722	0.596	-0.364	0.747	-4.763	1.206	-2.09	14.056	23.465
VL 8116 x VL 8549	-1.611	0.566	1.318	-1.002	0.124	-1.806	-0.821	0.247	-0.359	24.848	0.756	-1.668	19.111	24.854
VL 8116 x VL 8724	7.028	-1.518	-0.571	0.196	0.044	0.583	0.624	0.649	-0.497	14.182	0.935	0.727	-15.722	-25.98
VL 8116 x VL 8732	1.194	8.538	6.263	-4.832	-0.081	0	-0.182	-3.226	-0.131	-2.79	0.81	-1.343	3.056	3.187
VL 8116 x *Sukradhan*1	-2.806	5.01	4.624	1.454	0.024	0.694	0.874	1.502	-0.095	10.987	0.995	1.552	-12.389	-16.508
VL 8549 x VL 8724	-2.694	-3.851	-3.46	-0.265	-0.023	-0.333	-0.404	-0.47	0.741	2.015	0.461	-1.029	-35.889	-43.258
VL 8549 x VL 8732	1.806	0.871	0.04	0.807	-0.181	0.083	-0.543	-1.278	-0.01	8.043	4.179	2.268	-4.111	-9.091
VL 8549 x *Sukradhan*1	0.139	3.343	2.068	1.593	0.058	-0.889	-0.487	1.449	0.559	-21.179	2.175	0.996	-1.222	-2.452
VL 8724 x VL 8732	-13.556	5.455	3.485	0.171	0.038	-0.194	-0.432	0.158	-0.487	17.376	0.521	-2.137	-14.944	-7.591
VL 8724 x *Sukradhan*1	-0.889	0.927	0.846	-1.21	-0.023	0.167	-0.71	3.119	-0.228	-0.513	-0.58	0.224	22.278	26.048
VL 8732 x *Sukradhan*1	-0.056	7.982	7.679	-1.571	-0.015	0.25	0.818	-0.089	-0.612	22.515	0.261	0.555	-16.611	-32.119

Table 5. Best general combiners and specific combiners for different characters.

Characters	Best General Combiners	Best Specific Combiners
Plant height	VL *Dhan* 221, *Vivek Dhan* 154	VL 7620 x VL 8116, VL 8724 x VL 8732
Days to 50% flowering	VL *Dhan* 221, *Vivek Dhan* 154, VL 30240	VL *Dhan* 221 x VL 8724, VL 30560 x *Sukradhan* 1, VL *Dhan* 221 x VL 8549, VL 30240 x VL 8116, *Vivek Dhan* 154 x VL 8732, VL *Dhan* 221 x VL 8116, *Vivek Dhan* 154 x VL 30560
Days to maturity	VL *Dhan* 221, *Vivek Dhan* 154, VL 30240	VL *Dhan* 221 x VL 8724, VL 30560 x *Sukradhan* 1, VL 30240 x VL 8116, VL *Dhan* 221 x VL 8549, *Vivek Dhan* 154 x VL 30560, VL *Dhan* 221 x VL 8116, *Vivek Dhan* 154 x VL 8732
Tillers per plant	VL *Dhan* 221, *Vivek Dhan* 154	*Vivek Dhan* 154 x VL 30560,VL *Dhan* 221 x VL 7620, *Vivek Dhan* 154 x VL 8549
Panicles per plant	VL *Dhan* 221, *Vivek Dhan* 154, VL 7620	VL 30240 x VL 8549, VL *Dhan* 221 x VL 7620, *Vivek Dhan* 154 x VL 8549, VL *Dhan* 221 x VL 8116, VL *Dhan* 221 x VL 8549, *Vivek Dhan* 154 x *Sukradhan* 1
Panicle length	VL 30240	VL 8724 x *Sukradhan* 1, *Vivek Dhan* 154 x VL 8724,VL 7620 x VL 8732, *Vivek Dhan* 154 x *Sukradhan* 1
Kernel length	*Vivek Dhan* 154, VL 30240, VL 8732	-
Kernel width	VL 30240, VL 30560	VL *Dhan* 221 x VL 8732, VL 30240 x VL 8724, VL 8549 x *Sukradhan* 1, *Vivek Dhan* 154 x VL 8116, VL 30240 x VL 8116, VL 7620 x VL 8724, VL 30560 x VL 8549, *Vivek Dhan* 154 x VL 8724, VL 30560 x VL 8116
1000grain weight	*Vivek Dhan* 154	VL *Dhan* 221 x *Sukradhan* 1, VL 8549 x VL 8732, VL 30560 x VL 8732,VL 30560 x VL 8549, VL 8549 x *Sukradhan* 1, VL 30240 x VL 7620
Grain yield per plot	VL *Dhan* 221,VL 7620, VL 30560, *Sukradhan* 1	*Vivek Dhan* 154 x VL 8549, VL 7620 x VL 30560, VL 8549 x VL 8732, VL 30560 x VL 8116, VL 30240 x VL 8116
Fertile grains per panicle	VL 7620, VL 30560,VL 8116, VL 8724	VL 7620 x VL 8549, VL 30560 x VL 8732, VL 8724 x *Sukradhan* 1, VL 30240 x VL 8549, VL 7620 x VL 8116, VL 7620 x VL 30560, VL 8116 x VL 8549, VL *Dhan* 221 x *Vivek Dhan* 154
Grains per panicle	VL 7620, VL 30560, VL 8724	VL 7620 x VL 8549, VL 30560 x VL 8732, VL *Dhan* 221 x *Vivek Dhan* 154, VL 8724 x *Sukradhan* 1, VL 8116 x VL 8549, VL 30240 x VL 8549, VL 30560 x *Sukradhan* 1, VL 7620 x VL 8116

x VL 8116 for fertile grains per panicle and grains per panicle. The best general combiner and specific combiner for different characters are listed in the Table 5.

DISCUSSION

In conventional breeding, combining ability of parents and hybrids has important role in varietal improvement of upland rice and diallel mating design is one of the most appropriate and resource (land, labour and cost) effective for the estimation of general combining ability (gca) and specific combining ability (sca) (Asfaliza *et al*., 2012) which provides the information of gene action (additive and non additive) and hence to choose the suitable breeding method for the varietal improvement. The role of additive and non additive gene effects for controlling the traits was also reported by Hong *et al.* (2002) and Rahimi *et al.* (2010) in rice. On the basis of preponderance of additive genetic variance of parents for traits *viz*., VL Dhan 221 (plant height, days to 50% flowering, days to maturity, tillers per plant, panicles per plant and grain yield per plot), *Vivek Dhan* 154 (plant height, days to 50% flowering, days to maturity, tillers per plant, panicles per plant, kernel length and 1000 grain weight), VL 7620 (panicles per plant, grain yield per plot, fertile grains per panicle and grains per panicle) and VL 30240 (days to 50% flowering, days to maturity, panicle length, kernel length and kernel width) were the best general combiners and hybridization among these parents would be useful in rainfed upland rice breeding programme in order to obtain desirable segregants for further selection of promising lines. However, good general combiners may not necessarily produce good specific combinations for different traits (Ramlingam *et al.,* 1997). The presence of non-additive genetic variance offers scope for exploitation of heterosis and cross combinations *viz., Vivek Dhan* 154 x VL 8549 (tillers per plant and panicles per plant), VL 8549 x VL 8732 (1000 grain weight), VL 30240 x VL 8116 (days to 50% flowering and days to maturity) and VL 7620 x VL 8116 (plant height, fertile grains per panicle and grains per panicle) were the best specific combinations for grain yield and most of the characters and could be utilized in future breeding programmes. This was also reported by Jayasudha and Sharma (2009) and Kumar *et al.* (2007) in rice.

Conclusion

Based on the result of present study, it can be concluded that no cross was good for all the characters but some crosses showed good sca effects for a number of characters. Parents *viz.,* VL *Dhan* 221, *Vivek Dhan* 154, VL 7620 and VL 30240 were the best general combiners however, cross combinations *viz., Vivek Dhan* 154 x VL 8549, VL 7620 x VL 30560, VL 8549 x VL 8732, VL 30560 x VL 8116, VL 30240 x VL 8116 and VL 7620 x VL 8116 were the best specific combinations for grain yield and most of the characters and could be utilized in future breeding programmes.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, ICAR-VPKAS, Almora and Head, Crop Improvement Division for providing the necessary facilities to carry out the experiment. The technical support of Sri Devendra Lal and Sri Jagdish Kumar Arya is also duly acknowledged.

REFERENCES

Asfaliza R., Rafii M.Y., Saleh G., Omar O. and Puteh A. (2012). Combining ability and heritability of selected rice varieties for grain quality traits. AJCS 6(12):1718-1723.

DES(2014) Department of Agriculture, Cooperation and Farmers Welfare. *http://eands.dacnet.nic.in/ APY_96_To_06.htm*

DRD(2002). Rice in India - A Status paper. Directorate of Rice Development, Patna, Bihar *http:// drdpat.bih.nic.in/*

Griffing, B. (1956). Concepts of general and specific combining ability in relation to diallel crossing systems. *Australian J. Biol. Sci.,* 9: 463-493

Hong, D. L., Yang, K. Q. and Pan, E. F. (2002). Heterosis of F_1's derived from different ecological types and combining ability of their parents in Japonica Rice (*Oryza sativa* L.). *Chinese J. Rice Sci.,* 16(3): 216-220

Jayasudha S. and Sharma D. (2009). Combining ability and gene action analysis for yield and its components in rice (*Oryza sativa L.*). *Journal of Rice Research* 2 (2): 105-111

Kumar, S., Singh, H. B. and Sharma, J. K. (2007). Combining ability analysis for grain yield and other associated traits in rice. *Oryza* 44 (2): 108-114

Rahimi M., Rabiei B., Samizadeh H. and Ghasemi A. K. (2010). Combining ability and heterosis in rice (*Oryza sativa* L.) cultivars. *J. Agr. Sci. Tech.* 12: 223-231

Ramlingam J. Nadarajan N., Vanniarajan C. and Rangasamy P. (1997). Combining ability studies involving CMS lines in rice. *Oryza.*, 34:4-7

Sarkar, U., Biswas, P. S., Prnassad, B. and Khaleque, M. A. (2002). Heterosis and genetic analysis in rice hybrids. *Pakistan. J. Bio. Sci.,*5(1):1-5

Singh C .M., Babu G. S., Kumar B. , Kishore C., Mehandi S. and Pandey D. S. (2011). Combining ability analysis in rainfed upland rice (*Oryza sativa* L.) Souvenir & Abstracts (Eds. Singh N.P., Basu P.S. and Naimuddin) National Symposium on Biodiversity and Food Security: Challenges & Devising Strategies p.13