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Estimation of Combining Ability for Yield and Yield Components in Rice (*Oryza sativa* L.) Cultivars Using Diallel Cross

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Abstract: In order to estimate combining ability and gene action of a number of rice cultivars, a 5×5 half a diallel cross genetic design has been used. Parents and their hybrids have been evaluated in a randomized complete block design with 3 replicates for yield and 6 yield components in 2007 in Rice Research Station of Iran -Amol. Mean squares of genotypes for all traits were highly significant ($p<0.01$). Significant mean squares of combining ability for all traits showed additive and non-additive effects in control of the related traits. Having nonsignificant $\frac{\text{MS (GCA)}}{\text{MS (SCA)}}$ ratio for all traits but 1000-grain weight show higher importance of nonadditive effects in comparison with additive effects of controlling genes. High relative importance of specific combining ability indicated that all traits but 1000-grain weight are highly affected by impacts of specific combining ability. Generally, Dasht, Neda and Binam were the best parents for general combining ability and Binam×IR62871-175-1-10 and Mashhad Domsiah×Binam were the best hybrids for grain yield and its components.

Key words: Rice, diallel cross, grain yield, general combining ability, specific combining ability

INTRODUCTION

The method of parent selection for hybridization is considered as a basic factor for succession in a breeding program. For generating the hybrid cultivars, suitable homozygous lines have been mostly used. Therefore, in hybrid production, general and specific combining ability (GCA and SCA) should be determined (House, 1985). One solution to reach this information is using quantitative genetic designs, such as diallel cross, which was firstly presented by Jinks and Hyman and Griffing and complemented by Pooni (Shattuck *et al*., 1993). Malini *et al*. (2006) showed that mean squares of specific combining ability were higher than that of general combining ability for plant height, duration of maturity, grain number per panicle, number of panicle, panicle length and grain yield. They consequenced highest non-additive effects on corresponding genes. Pradhan *et al*. (2006) reported significant general and specific combining ability for traits plant height, panicle number per plant, 1000 grain weight, panicle length, spikelets number per plant, grain yield and harvest index in which is shown the importance of additive and non-additive gene effects. Having non-significant

$$\frac{\text{MS (GCA)}}{\text{MS (SCA)}}$$

ratio shows preponderance of non-additive effects on genes responsible for the studied traits. Studies performed by Srivastava and Verma (2004) in 7 rice cultivars showed significant general and specific combining ability for number of days to 50% flowering, plant height, 1000 grain weight, number of productive tiller per plant, panicle length and grain yield. Significant

$$\frac{\text{MS (GCA)}}{\text{MS (SCA)}}$$

ratio for number of days to 50% flowering, plant height, 1000 grain weight and grain yield shows the highest contribution of additive effects on the responsible genes. However, the case for panicle length and number of productive tiller per plant were in contrast. Vanaja *et al*. (2003) by performing a 7×7 diallel cross design reported significant general and specific combining ability effects for yield, number of panicle per m^2, number of spikeletes per panicle, panicle length, number of productive tiller per plant, 1000 grain weight, internodal length and plant height. Although general combining ability effects were significant for all traits except 1000 grain weight, plant height and internodal length, non-additive were obviously severe than additive gene effects. The present study was aimed to determine general and specific combining ability, estimation of their relative importance and investigating for gene effects of 7 quantitative traits in rice cultivars using a half a diallel cross procedure.

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MATERIALS AND METHODS

Two land races of rice (Mashhad Domsiah and Binam), two improved rice cultivars (Dasht and Neda) and one introduced genotype (IR62871-175-1-10) were intercrossed together using a half a diallel cross genetic design. Fifteen entries (5 parents together with 10 hybrids) were grown based on a randomized complete block design with 3 replicates in 2007 in Rice Research Station of Iran-Amol. Data were collected from all plants leaving one border plant on each side of each genotype. Observations were recorded on 7 quantitative characters namely, number of productive tiller per plant, number of spikelets per panicle, number of fertile grain per panicle, number of infertile grain per panicle, 1000 grain weight (g), panicle weight (g) and yield (kg ha^{-1}). To evaluate each trait 10 samples were taken from each plot. After finding significant variation among genotypes, combining ability analyses were carried out using Griffing (1956) method-2, model-B. Ratio of $\frac{\text{MS (GCA)}}{\text{MS (SCA)}}$ were also used to estimate gene action. Baker's (1978) method have been used for estimating the relative importance of GCA and SCA. Data analysis was performed using SAS statistical and Diallel genetic softwares.

RESULTS AND DISCUSSION

The normality test for all traits using Kolomogrove test (Gerami, 1992) verified that all traits except number of infertile grain per panicle were normal. In order to perform the diallel test the number of infertile grain per panicle were transformed using Logarithm method (Log x). Analysis of variance for combining ability showed that mean squares of general and specific combining abilities were significantly varied for all characters (Table 1). It, in turn, implies that both additive and non-additive gene effects are important for improving these traits in the materials under studied. Non-significant $\frac{\text{MS (GCA)}}{\text{MS (SCA)}}$ ratio for all traits except 1000 grain weight indicates that additive gene effects is lower than non additive gene effects. This shows that although the mean square for GCA (additive genetic variance),was significant, the dominant component may be predominant for all the characters but the above one trait, for which additive component may be predominant. Therefore, use of a breeding procedure based on hybridization is the best option for improving such traits. However, for 1000-grain weight, a selection procedure is considered as the best option. Both additive and non-additive gene effects with preponderance of non-additive gene action were true for yield and its components in rice (Vanaja *et al*., 2003; Malini *et al*., 2006; Allahgholipour and Ali, 2006; Bansal *et al*., 2000). In present study, overall Coefficient of Variation (CV) ranged from 2.5 to 9.4 and 1000 grain weight and panicle length showed the lowest and highest variation, respectively (Table 1). According to the method developed by Baker (1978), relative importance of SCA for number of productive tiller per plant, number of spikelet per panicle, number of fertile grain per panicle, number of infertile grain per panicle, panicle weight and yield were obviously higher than 50% (99.3, 96.2, 83.24, 93.54, 98.93 and 73.71%, respectively). Furthermore, relative importance of GCA was higher than 50% only for 1000 grain weight (52.3%, Table 2). It means that the first group of traits are mainly under influence of SCA, but 1000 grain weight is mainly influenced by GCA effects of parents (Baker, 1978; Griffing, 1956). Positive significant GCA effects indicate a target genotype with high proportion of target trait, is able to transfer the character into a new genotype. In contrast, negative significant GCA effects indicate a target genotype contains low proportion of target trait, but still is able to transfer this character into a new genotype (Vejdani and Sepahvand, 1993). Relative value of GCA effects of all parents for the 7 characters have been showed in Table 3. Parent Dasht with positive significant GCA effect increases number of fertile grain per panicle in its hybrids. However, parent

Table 1: Analysis of variance for genotype and combining ability in 5×5 half diallel analysis using Grifing's method-2

		Means sum of squares						
Source	df	No. of spikelets per panicle	No. of productive tiller per plant	Grain yield	1000 grain weight	No. of fertile grain per panicle	No. of infertile grain per panicle	Panicle weight
Replication	2	145.80	2.60	2.09	0.116	8.90	0.038	0.087
Genotype	14	1761.10**	12.55**	24.1000**	17.600**	1609.80**	0.283**	1.138**
GCA	4	1923.30**	12.77**	4869000**	14.070**	617.68**	0.111**	0.330**
SCA	10	1693.60**	12.47**	2189000**	3.050**	2031.03**	0.089**	0.318**
Error	28	28.90	0.45	41826.8	0.154	25.01	0.002	0.037
CV	--	6.31	5.24	7.61	2.500	8.19	5.250	9.400
Means	--	147.65	12.90	4609.7	27.100	104.95	1.440	3.074
gca/sca	--	1.13	1.02	2.22	4.600*	0.304	1.240	1.030

**Significant at 1% level, *Significant at 5% level

Mashad Domsiah with negative significant GCA effect decreases the trait in its hybrids. Four hybrids from Mashad Domsiah×Binam, Mashad Domsiah×Neda, IR62871-175-1-10×Binam and IR62871-175-1-10×Dasht exhibited significant SCA effects for these traits (Table 4). The Dasht cultivar is a suitable parent for transferring number of fertile grain per panicle as one of important yield component into its hybrids. Parents Dasht and Neda contain positive significant GCA effects for number of productive tiller per plant and can increase it into their hybrids. However, Binam and IR62871-175-1-10 with negative significant GCA effects decrease this trait in their hybrids (Table 3). Only one of these hybrids namely Mashad Domsiah × IR62781-175-1-10 showed significant favourable SCA effects for this trait (Table 4). The highest positive significant GCA effects for number of infertile grain per panicle was attributed to Mashad Domsiah and IR62871-175-1-10, but Binam with negative significant GCA effects decreases this trait in its hybrids (Table 3). Four hybrids of Binam × Dasht, IR62871-175-1-10 × Binam, Dasht × Mashad Domsiah and Neda × Mashad Domsiah exhibited negative significant SCA effects for this trait (Table 4). Two of these hybrids have one parent with negative GCA effect. Moreover, decrease in number of infertile grain per panicle is considered as an important target in breeding programs (Momeni, 1995), therefore, these four hybrids are the best for this trait. Binam is a good general carrier for this trait. Positive significant GCA effects in Binam and Neda make these genotypes as source of increasing 1000 grain weight in their hybrids.

Table 2: Variance estimates and relative importance of GCA and SCA for yield and yield component

Characters	Variance estimates of GCA	Variance estimates of SCA	Relative importance (%) of GCA	Relative importance (%) of SCA
No. of spikelets per panicle	32.81	1664.68	3.79	96.20
No. of productive tiller per plant	0.042	12.02	0.69	99.30
Grain yield	382857.1	2147173.1	26.28	73.71
1000 grain weight	1.57	2.904	52.30	47.86
No. of fertile grain per panicle	201.94	2006.01	16.75	83.24
No. of infertile grain per panicle	0.003	0.087	6.45	93.54
Panicle weight	0.0017	0.28	1.20	98.93

Exhibiting negative significant GCA effects in Dasht, Mashad Domsiah and IR62871-175-1-10 imply that using these genotypes can decrease 1000-grain weight in their hybrids (Table 3). Table 4 shows the highest positive significant SCA effects for Mashad Domsiah×IR62871-175-1-10, Dasht×Mashad Domsiah, Dasht×Neda and IR62871-175-1-10 × Binam. Since, increasing in 1000 grain weight in rice breeding is so important, therefore, genotypes Neda and Binam are considered as good general combiners. Genotypes IR62871-175-1-10 and Dasht exhibited positive significant GCA effects for number of spikelet per panicle, however, genotype Binam exhibited negative significant GCA effects (Table 3). Hybrids IR62871-175-1-10×Dasht, IR62871-175-1-10× Mashad Domsiah, Neda×Binam and Mashad Domsiah× Binam presented positive significant SCA effects for this trait (Table 4). Two of these hybrids have at least one parent with positive GCA effect. Genotypes IR62871-175-1-10 and Dasht were a good general combiner. The highest positive and negative significant GCA effects for panicle weight were belonged to Binam and Dasht and Mashad Domsiah, respectively (Table 3). Two hybrids of Binam × IR62871-175-1-10 and Dasht×IR62871-175-1-10 exhibited positive significant SCA effects for this trait (Table 4). Genotypes Dasht and Neda with the highest GCA effect can increase grain yield in their hybrids. However, the Mashad Domsiah with the lowest GCA effect decreases this trait in its hybrids (Table 3). Hybrids Neda×IR62871-175-1-10, Dasht×Binam, IR62871-175-1-10 ×Mashad Domsiah and Neda×Dasht showed negative significant SCA effects, but Binam ×Mashad Domsiah and IR62871-175-1-10×Binam showed positive significant SCA effects for this trait (Table 4).

These results indicated importance of both additive and non-additive gene effects with preponderance of non-additive gene effects of the studied traits. Simple pedigree selection method will be ineffective for improving such characters. However, using population improvement programs like reciprocal recurrent selection allow to accumulate the fixable gene effects as well as to maintain considerable variability and heterozygosity for exploiting non-fixable gene effects will prove to be the most effective method (Joshi, 1979). Since rice is a highly self-pollinated

Table 3: General combining ability effects of 5 parents from 8×8 half diallel analysis using Grifing's method-2

Parent	No. of spikelets per panicle	No. of productive tiller per plant	Grain yield	1000 grain weight	No. of fertile grain per panicle	No. of infertile grain per panicle	Panicle weight
Mashad's Domsiah	-3.58	0.210	-725.06**	-0.99**	-6.41**	0.04*	-0.266**
Neda	0.201	0.522**	223.07**	1.66**	0.82	-0.006	-0.076
Binam	-13.56**	-0.289*	-30.707	1.39**	-2.70	-0.192**	0.134*
IR62871-175-1-10	12.06**	-1.206**	-57.09	-0.76**	0.016	0.158**	-0.086
Dasht	4.89*	0.757**	589.78**	-1.32**	8.27**	0.0001	0.294**
S.E(g)	1.81	0.132	68.47	0.132	1.69	0.015	0.065

**Significant at 1% level, *Significant at 5% level

Table 4: Specific combining ability effects of 10 hybrids from 8×8 half diallel analysis using Grifing's method-2

Hybrid	No. of spikelets per panicle	No. of productive tiller per plant	Grain yield	1000 grain weight	No. of fertile grain per panicle	No. of infertile grain per panicle	Panicle weight
1×2	1.73	-1.99**	324.15	-3.11**	23.50**	-0.126**	0.216
1×3	11.30*	-1.60**	701.45**	-0.16	23.49**	0.057	0.216
1×4	29.50**	3.07**	-943.05**	1.98**	-48.27**	0.480**	-1.022**
1×5	-24.40**	-1.96**	-243.79	0.88*	-16.60**	-0.219**	0.058
2×3	21.79**	0.44	148.70	0.55	-21.56**	0.505**	-0.533**
2×4	-29.20**	-2.32**	-1552.86**	0.65	-19.83**	0.015	-0.37**
2×5	-31.40**	-0.26	-638.08**	2.21**	-21.09**	0.001	-0.651**
3×4	-10.01*	0.33	379.70*	1.59**	23.46**	-0.412**	0.372**
3×5	-12.00**	-1.62**	-518.62**	-1.16**	1.83	-0.138**	-0.401**
4×5	21.30**	-0.74*	-9.13	0.39	11.21*	0.262**	0.371**
$SE(S_{ij})$	4.69	0.34	176.80	0.34	4.36	0.030	0.132

**Significant at 1% level *Significant at 5% level

crop, forming a single seed per pollination, pedigree selection procedure is not useful. So, a possible option is the use of biparental mating among selected crosses or use of a genetic selection procedure such as diallel selective mating to exploit both of additive and non-additive genetic components (Jenson, 1970). The present study showed that genotypes Neda, Dasht and Binam are good general combiner for 5 and 3 characters, respectively (Table 3, 4) and these genotypes can be used in hybridization program. Best hybrids were evaluated for each trait according to the lowest and highest SCA effects. However, hybrid Binam×Mashad Domsiah showed significant SCA effects for yield, number of fertile grain per panicle and number of spikelet per panicle and hybrid Binam × IR62871-175-1-10 showed significant SCA effects for yield, number of fertile grain per panicle, number of infertile grain per panicle, number of spikelet per panicle and 1000 grain weight. Moreover, hybrid Dasht×IR62871-175-1-10 showed positive significant SCA effects for number of fertile grain per panicle, number of spikelet per panicle and panicle weight. Consequently, these hybrids are suitable to be utilized for hybrid rice production program.

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