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ASSESSING THE COMBINING ABILITY OF RICE GENOTYPES IN F_1 GENERATION USING COMPLETE DIALLEL CROSS

I. A. Odhano[1], H. B. Bozdar[2] and M. A. Sial[1]

[1]Nuclear Institute of Agriculture (NIA), Tandojam, Pakistan
[2]Institute of Plant Sciences, University of Sindh, Jamshoro, Pakistan

ABSTRACT

A complete diallel analysis was carried out to determine combining ability of Shandar, NIA-Mehran, NIA-19/A, KS-282 and Shua-92 rice varieties in F_1 during 2017. The objective of the study was to identify potential recombinants for future rice breeding program. The research was conducted at Nuclear Institute of Agriculture, Tandojam. Genotypic mean squares were significant ($P \leq 0.01$) for all of the traits i.e.; days to heading, days to maturity, plant height, number of tillers plant^{-1}, panicle length, grains panicle^{-1} and grain yield plant^{-1} indicating genetic variation. Importance of both additive and non-additive gene action was found with preponderance of additive genetic effects in expression of traits studied. Showing negative GCA effects, NIA-Mehran, NIA-19/A and Shua-92 proved better parent varieties for developing early maturity. While, NIA-Mehran, KS-282 and Shua-92 for developing short stature genotypes. While, Shandar remained the best combiner for yield and yield associated traits with higher positive GCA effects. Cross combination of Shandar × KS-282 was the best with higher negative effects for days to heading and maturity and higher positive effects for grain yield plant^{-1}. NIA-Mehran × Shua-92 gave the highest negative SCA effects indicating best combination for short stature. In case of number of tillers plant^{-1} and grains panicle^{-1}, the cross NIA-19/A × KS-282 was the better combination with the highest positive SCA effects. Shandar × NIA-Mehran manifested the highest value for panicle length. Findings of reciprocal SCA revealed that the reciprocal cross combination of Shua-92 × Shandar was fruitful illustrating negative effects for days to heading and maturity. While, KS-282 × NIA-Mehran was the best reciprocal combination for yield and yield associated traits. It is concluded that rice varieties Shandar and NIA-Mehran could be used to improve yield contributing traits in rice, while, NIA-Mehran and KS-282 may be used to improve early maturity and short stature in rice crop.

Keywords: combining ability, diallel analysis, gene action, quantitative traits, rice

INTRODUCTION

Rice (*Oryza sativa* L.) after wheat and cotton, is the second most important food grain and cash crop of Pakistan. It also feeds more than half of the world's population and is also considered as cash crop of developing world (Gowayed *et al.,* 2020). Rice crop provides 1/5th of the world's caloric requirement to human being Kennedy, (2003). Modelling used for predicting rice production and consumption by populations reveals that the need for grain production will be doubled by 2050 (FAO, 2017). The world's 90% rice is grown and consumed in Asia Papademetriou (2000). Despite the fact that Pakistan is the 12th largest rice producer and 4th largest rice exporter in the world, its average paddy yield is less as compared with some other rice producing countries like China, Indonesia, Bangladesh, Vietnam, Japan etc. The causes of low yield are less availability of high yielding rice varieties, scarcity of water or unavailability of water at proper sowing and transplanting of rice and shortage of quality seed Khaliq (2019). Different traits (morphological and physiological) are directly or indirectly contributing towards grain productivity, hence, understanding the genetic nature of such traits is one of the major objectives in plant breeding (Osundare *et al*., 2017). The study on environment of crop, extent of genotypic variability involving genome of quantitative traits (grain yield and its components) is crucial to improve genetic traits of rice cultivars. Therefore, before selection of suitable traits and adoption of variety with ideal traits it is imperative to analyze the genetic variability of the crop (Babu *et al.,* 2012).

Diallel mating design is one of the most important strategies for hybrid crop production.

Corrresponding author: odhano77@gmail.com

Selection of better parents and making subsequent combinations of superior parents are possible through diallel cross method for estimating heterosis and combining ability Alireza *et al*. (2017). Diallel analysis is useful tool to assess the magnitude and pattern of gene action in quantitative trait development and to estimate combining ability (Aghamiri *et al.,* 2012). This method includes complete and partial diallel crosses. Rukundo *et al.,* 2017 also reported that the magnitude and direction of gene action are estimated through various parameters including combining ability and heterosis analyses. The GCA (general combining ability) and SCA (specific combining ability) determine the involvement of dominant or additive gene action of the parents reflected in crosses. It also helps in identifying and selecting superior parents for developing best performing hybrids (Singh, 2019 and Acquaah, 2007). To fulfill the food requirements of ever increasing population and to enhance export of the country, yield improvement through conventional breeding techniques is still an effective approach to strengthen country's economy. Combining ability estimates are appropriate to design breeding program, goals and direction. The work presented in this paper provides some basic information on the rice breeding material regarding selection of best parents possessing good combining ability for yield and yield contributing traits to be used in future rice breeding program.

MATERIALS AND METHODS

The study was conducted at rice fields of Nuclear Institute of Agriculture (NIA), Tandojam to estimate the combining ability (GCA and SCA) of twenty hybrids developed through full diallel mating system using five parental varieties (Shandar, NIA-Mehran, NIA-19/A, KS-282 and Shua-92). The parental verities mated in all possible combination to develop a complete diallel set of crosses during 2015-16. The seed of parent varieties along with F_1 hybrids (direct = n^2 – n/2) and (reciprocals n^2 – n/2) was grown after sterilization with hydrogen peroxide to make seed free from disease infection. The physico-chemical properties of experimental soil were analyzed and observed that soil was heavy in nature, normal in salinity (0.78 dS m^{-1}), alkaline and deficient in OM (organic matter 0.52%), respectively. Thirty days' old nursery was transplanted in main field in randomized complete block design (RCBD) with three repeats. The distance between plant to plant and row to row was maintained as 20 cm. Five plants from each plot were randomly selected at maturity to record the data regarding yield related traits (plant height, number of tillers $plant^{-1}$, panicle length, grains $panicle^{-1}$ and grain yield $plant^{-1}$). Prior to this, days to first heading and maturity were also noted. The analysis of variance for observed traits was carried out after Steel and Torrie (1980). Further, combining ability analysis was performed following Griffings (1956) model 1, method 1as elaborated by Singh and Chaudhary (1977).

RESULTS AND DICUSSION

The present research work was carried out to evaluate the parent varieties and their hybrids for GCA and SCA effects controlling yield and yield contributing traits of rice to formulate an effective and efficient rice breeding program. The analysis of variance (ANOVA) for the traits under studied is presented in Table 1. The mean squares of the genotypes differed significantly ($P \leq$ 0.01) for all the traits, indicating profuse genetic variability among the material. The mean performance of genotypes including parents and 20 hybrids for the traits studied is given in Table 2. Reciprocal cross NIA-Mehran × Shandar took the highest number of days to heading and maturity (117.3 and 140.7 days), produced the highest number of tillers $plant^{-1}$ (24.3), longest panicles (31.5 cm) with more number of grains per panicle (296). However, the desired early heading and maturity in plants were observed in cross combination KS-282 x NIA/19A (90.7 and 110 days). Short stature plants with mean height of 94.3cm were found in reciprocal crosses KS-282 x Shua-92 and Shua-92 x Shandar respectively. In case of mean grain yield per plant, maximum yield (228g) was produced by NIA/19A x NIA-Mehran (reciprocal cross) followed by NIA/19A x Shandar and NIA-Mehran x Shandar.

Combining ability (Variance and Effects)

The mean squares for combining ability, results of GCA, SCA and reciprocal effects are illustrated in Tables 3-6, respectively. Significance of GCA, SCA and reciprocal mean squares for entire traits suggested that both additive and non-additive gene actions were operative in expression of traits. Bano and Singh (2019) also reported the additive and dominance (non-additive) gene actions involved in expression of quantitative traits. Higher frequency of GCA mean squares indicated preponderance of additive effects as compared to low frequency of dominance effects for all of the traits. Additive genetic variance is fixable and hence useful to improve economic traits in crop plants like rice through selection. Higher general combining ability (GCA) effects for entire traits except number of tillers per plant were shown by parent variety Shandar (Table 4). In breeding program, the positive additive genetic magnitude is considered useful to improve a trait as the GCA reflects additive genetic variance which is fixable. Best general combiner genotypes for the traits days to heading and maturity were NIA-19/A and KS-282, which can be exploited to evolve the early maturing rice varieties. In case of plant height and number of tillers plant^{-1} best general combiners were Shau-92 and NIA-Mehran (Table 4). The best general combiners like Shandar and NIA-Mehran can be used in breeding rice to improve yield and yield contributing traits. KS-282 and NIA-19/A can be best utilized to obtain early maturing rice varieties. Present findings match with previous researchers Elshenawy *et al*. (2018) and Tiwari *et al* also reported significant and positive GCA effects in different parental genotypes for traits like plant height, 100 grain weight, 50% heading and yield plant^{-1}.

Table 1. Mean squares from ANOVA for various traits in F_1 population crossed in complete diallel fashion

S.V	d.f	Mean Squares						
		Days to heading	Days to maturity	Plant height (cm)	No. of Tillers plant^{-1}	Panicle Length (cm)	Grains panicle^{-1}	Grain yield plant^{-1} (g)
Replication	2							
Parents	4	137.73**	317.77**	192.77**	39.00**	15.85**	4654.77**	2166.31**
Hybrids	19	153.98**	211.55**	202.40**	49.53**	12.23**	2712.82**	1893.40**
Genotypes	24	144.94**	222.00**	192.84**	45.71**	12.73**	2923.71**	1860.20**
Error	48	3.52	2.61	5.07	4.04	0.59	54.34	10.61

Table 2. Mean performance for various yield associated traits of five parent varieties and their twenty F_1 hybrids crossed in a full diallel fashion

Genotypes		Days to heading	Days to maturity	Plant height (cm)	No. of tillers plant^{-1}	Panicle length (cm)	Grains panicle^{-1}	Grain yield plant^{-1} (g)
Direct crosses	Shandar x NIA-Mehran	112.0 AB	134.3 BC	111.7 C-G	21.7 A-C	28.2 BC	268 BC	225.67 AB
	Shandar x NIA-19/A	94.7 J-L	115.7 LM	115.7 A-D	13.7 E-J	26.0 C-F	246 C-F	162.33 F-H
	Shandar x KS-282	97.3 G-K	129.3 C-E	113.7 B-F	18.0 A-I	25.3 EF	234 D-G	178.67 E-H
	Shandar x Shua-92	92.3 KL	122.7 G-I	119.7 AB	16.0 C-I	26.5 B-F	246 C-F	201.33 A-E
	NIA-Mehran x NIA-19/A	92.0 KL	111.0 MN	106.3 G-K	22.7 AB	25.3 EF	248 C-E	214.33 A-D
	NIA-Mehran x KS-282	96.0 H-L	124.3 E-H	109.3 D-J	20.7 A-D	26.0 C-F	229 E-H	189.00 D-F
	NIA-Mehran x Shua-92	98.3 G-J	121.0 H-K	99.0 L-N	16.3 B-I	24.7 F	203 I-K	134.00 I-K
	NIA-19/A x KS-282	98.7 F-J	117.0 J-L	109.7 D-J	12.7 G-J	26.7 B-F	220 G-I	96.67 M-O
	NIA-19/A x Shua-92	104.3 D-F	128.3 D-F	110.3 D-I	16.7 B-I	25.3 EF	203 I-K	151.00 H-J
	KS-282 x Shua-92	100.7 E-I	123.7 F-I	94.3 N	12.0 IJ	24.8 F	196 JK	80.67 O
Reciprocals	NIA-Mehran x Shandar	117.3 A	140.7 A	114.7 A-E	24.3 A	31.5 A	296 A	227.00 AB
	NIA-19/A x Shandar	105.7 C-E	130.0 CD	118.3 A-C	20.0 A-E	31.8 A	267 BC	227.67 AB
	NIA-19/A x NIA-Mehran	97.7 G-K	116.0 K-M	111.3 C-H	18.7 A-H	26.7 B-F	245 C-F	228.00 A
	KS-282 x Shandar	110.7 BC	136.7 AB	121.7 A	19.7 A-F	28.0 B-D	265 BC	214.00 A-D
	KS-282 x NIA-Mehran	105.0 C-E	128.3 D-F	97.3 L-N	18.3 A-I	28.5 B	253 CD	197.00 C-E
	KS-282 x NIA-19/A	90.7 L	110.0 N	99.7 K-N	12.3 H-J	25.3 EF	205 IJ	104.33 L-O
	Shua-92 x Shandar	100.7 E-I	128.3 D-F	94.3 N	17.3 B-I	25.3 EF	214 G-J	160.00 G-I
	Shua-92 x NIA-Mehran	105.0 C-E	132.3 B-D	102.7 J-M	21.7 A-C	27.3 B-E	266 BC	200.00 B-E
	Shua-92 x NIA-19/A	96.0 H-L	117.3 J-L	104.3 H-L	13.3 F-J	25.2 EF	212 G-J	130.00 J-L
	Shua-92 x KS-282	94.3 J-L	121.7 H-J	108.3 E-J	9.3 J	26.2 B-F	180 K	86.67 NO
Parents	Shandar	109.7 B-D	139.7 A	118.0 A-C	19.0 A-G	31.3 A	287 AB	219.33 A-C
	NIA-Mehran	95.0 I-L	118.7 I-L	107.3 F-J	22.3 A-C	28.3 BC	265 BC	224.67 A-C
	NIA-19/A	92.3 KL	113.7 L-N	110.3 D-I	15.0 D-J	26.7 B-F	208 H-J	184.33 E-G
	KS-282	102.3 E-G	127.7 D-G	103.7 I-L	13.0 G-J	26.2 B-F	224 F-I	112.67 K-N
	Shua-92	101.0 E-H	131.3 CD	96.3 MN	17.3 B-I	25.7 D-F	193 JK	119.33 K-M
	HSD critical value	5.93	5.13	7.12	6.35	2.42	23.31	27.84

Table 3. Mean squares from ANOVA due to combining ability for various traits in F_1 generation

Source of variation	Mean Squares						
	D.H	D.M	Pl. Ht. (cm)	TPP	P.L (cm)	No. Gr.P.P	GYPP (g)
GCA	63.99**	139.17**	243.92**	43.20**	13.10**	4253.78**	2448.33**
SCA	48.44**	44.97**	31.57**	6.81**	1.83**	392.95**	160.68**
Reciprocal	41.91**	76.96**	25.14**	12.48**	3.12**	244.51**	348.12**

D.H=Days to heading, D.M=Days to maturity, Pl.Ht=Plant height (cm), TPP=Tillers plant^{-1}, P.L=Panicle length (cm), No. Gr.P.P=Number of total grains panicle^{-1} and GYPP=Grain yield /plant (g)

Table 4. General combining ability (GCA) effects of five parents for various traits of rice in F_1 generation

Traits	GCA effects of parents				
	Shandar	NIA-Mehran	NIA-19/A	KS-282	Shua-92
Days to heading	4.31	-0.19	-1.79	-1.89	-0.45
Days to maturity	5.68	-1.25	-4.05	-1.82	1.45
Plant height (cm)	8.35	-3.22	0.61	-2.29	-3.45
No. of tillers plant^{-1}	1.72	2.55	-0.38	-2.15	-1.75
Panicle length (cm)	1.75	0.24	0.04	-0.85	-1.18
Grains panicle^{-1}	29.25	9.55	-1.85	-12.65	-24.31
Grain yield plant^{-1} (g)	16.91	13.42	1.61	-15.75	-16.20

Table 5. Specific combining ability (SCA) effects of ten hybrids for various traits of rice in F_1 generation

Traits	Cross combinations									
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Days to heading	10.15	-2.75	-5.31	-2.75	-0.09	-4.98	-0.25	5.12	2.02	-0.55
Days to maturity	8.29	-3.58	-5.98	-2.25	0.19	-4.55	-0.31	5.75	0.65	-1.75
Plant height (cm)	0.12	0.12	-1.48	7.85	-3.48	2.09	-4.58	-0.08	2.25	-0.85
No. of tillers plant^{-1}	1.45	-1.79	1.48	0.58	1.0	-1.19	-1.25	2.41	-0.15	-2.72
Panicle length (cm)	0.93	0.21	-1.82	-0.24	-0.27	-0.64	-0.97	0.90	-0.52	0.61
Grains panicle^{-1}	8.25	-5.85	-11.9	15.61	7.68	-15.19	-11.35	22.21	-1.12	-9.82
Grain yield plant^{-1} (g)	1.92	-10.79	11.84	8.81	9.16	-7.53	-7.39	5.41	-3.29	-9.45

C_1=Shandar x NIA-Mehran, C_2=Shandar x NIA-19/A, C_3=Shandar x KS-282, C_4=Shandar x Shua-92, C_5=NIA-Mehran x NIA-19/A, C_6=NIA-Mehran x KS-282, C_7=NIA-Mehran x Shua-92, C_8=NIA-19/A x KS-282, C_9=NIA-19/A x Shua-92 and C_{10}=KS-282 x Shua-92

Table 6. Reciprocal effects of ten hybrids for various traits of rice in F_1 generation

Traits	Reciprocal effects									
	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
Days to heading	-2.67	-5.50	-0.17	-9.17	-6.50	2.67	-1.17	-3.17	4.17	3.17
Days to maturity	-3.17	-7.17	6.67	-7.00	-8.67	7.17	-3.67	-7.67	5.50	1.00
Plant height (cm)	-1.50	-1.33	1.17	-1.00	4.50	4.83	2.33	3.50	3.00	-7.00
No. of tillers plant^{-1}	-1.33	-3.17	-0.33	-1.83	2.17	4.17	-0.50	-4.50	1.67	1.33
Panicle length (cm)	-1.67	-2.92	-0.67	-0.75	-1.58	0.33	-0.33	-0.33	0.08	-0.67
Grains panicle^{-1}	-14.00	-10.83	-5.33	-9.50	-2.67	12.00	-5.50	-23.00	-4.33	7.83
Grain yield plant^{-1} (g)	-3.18	-16.62	-13.99	-3.42	8.72	19.15	-6.90	-26.76	5.75	2.76

C_{11}=NIA-Mehran x Shandar, C_{12}=NIA-19/A x Shandar, C_{13}=KS-282 x Shandar, C_{14}=Shua-92 x Shandar, C_{15}=NIA-19/A x NIA-Mehran, C_{16}=KS-282 x NIA-Mehran, C_{17}=Shua-92 x NIA-Mehran, C_{18}=KS-282 x NIA-19/A, C_{19}=Shua-92 x NIA-19/A and C_{20}=Shua-92 x KS-282)

Table 5 depicts desired SCA effects in cross combination of Shandar x KS-282 for the traits days to heading and maturity. The combination of high GCA with low GCA parent for phenological traits giving high SCA effects indicated additive x dominance or dominance x dominance type of gene interaction for the expression of traits. The cross combination of NIA-Mehran x Shua-92 displayed useful value (negative high) for plant height. NIA-19/A x KS-282 and Shandar x Shua-92 exhibited higher SCA effects for the trait grain panicle^{-1} suggesting the epistatic gene action may be due to genetic diversity in the form of heterozygous loci. In case of grain yield plant^{-1}, the cross Shandar x KS-282 and NIA-Mehran x NIA-19/A manifested higher SCA effects. These hybrids can be successfully exploited for varietal improvement as the combination of parents with positive with negative GCA effect. Significant positive SCA effect (predominance of non-additive, inter-allelic interaction), indicated predominance of non-additive gene action. Behera *et al*. (2018) and Zhang *et al* (2015) reported that there are more chances of exploiting good transgressive seggregants in the progeny of such crosses for the improvement of the yield and yield components. Reciprocal combining ability effects presented in Table 6 indicated that the reciprocal combination of Shua-92 x Shandarand NIA19/A x NIA-Mehran could be the best combinations to developed early heading and early maturing rice hybrids, respectively. Incase of plant height reciprocal cross of Shua-92 x KS-282 manifested desired value. The reciprocal cross of KS-282 x NIA-Mehran showed the highest positive SCA effects for the traits (number of tiller plant^{-1}, panicle length, number of grains/panicle and grain yield/plant).

CONCLUSION

It is concluded from the present study that the variety Shandar displayed higher GCA values for almost all yield attributes excluding number of tillers/plant. Best GCA effects for the traits – days to heading and maturity were observed from NIA-19/A and KS-282 rice genotypes. For other traits such as plant height and number of tillers/plant the best general combiners were Shau-92 and NIA-Mehran, respectively. Therefore, it is concluded that the cultivar Shandar and NIA-Mehran can efficiently be utilized to improve number of tillers plant^{-1}, grains/panicle and ultimate yield of paddy. The cultivars, NIA-19/A and KS-282, will prove to be potential parents for developing early maturing genotypes. Exploitation of Shua-92 for evolving short stature lines will be fruitful in rice breeding program.

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AUTHOR’S CONTRIBUTION

I. A. Odhano: Designed and conducted the study

H. B. Bozdar: Performed experiment

M. A. Sial: Data anaysis

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