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Combining Ability Analysis For Yield And Yield Components In F2 Populations Of Rice (*Oryza Sativa L.*)

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ABSTRACT

This study was conducted to investigate general and specific combining ability in F2 populations of rice. The twenty-one F2 populations developed through half diallel mating design and their seven parental lines were sown in the field in three replications at field of Nuclear Institute of Agriculture (NIA), Tandojam, during the Kharif season 2019-20. The analysis of variance results revealed that genotypes, parents, and hybrids mean squares differed significantly (P>0.01) for all studied characters except for the trait yield plant-1, which was non-significant for hybrids. Among the seven parents; minimum days to initial heading (95.07) and days to 90% maturity were recorded in KSK-282, while minimum plant height (94.33 cm) was recorded in IR-6; the maximum number of tillers plant-1 was recorded (21.93) in NIA-102, the maximum panicle length (30.15 cm), total grains panicle-1 (260.88), and grain yield plot-1(12.15 kg) were recorded in Shandar; the maximum panicle weight (4.81 g) and thousand grain weight (33.85 g) was observed in parental line NIA-19/A. Among twenty one hybrids, minimum days to initial heading (97.40) and days to 90% maturity were recorded in cross NIA-19/A × KSK-282; minimum plant height (92.73 cm) was recorded in IR-6 × KSK-282; maximum number of tillers plant-1 (22.80) and panicle length (29.46 cm) were recorded in Shandar × NIA-102; the highest grainspanicle-1 (295.32) was obtained in Shandar × Shadab; the maximum 1000 grain weight (32.66 g) was recorded in Shandar × NIA-19/A; while maximum yield plot-1 (12.58 kg) was obtained in Shua-92 × Shadab. It is concluded from this study that among seven parental lines KSK-282 was found as good general combiner for traits days to initial heading, days to 90% maturity and plant height; Shandar proved good general combiner for traits panicle length, panicle weight and total grains panicle-1, while NIA-102 and NIA-19/A were proved as good general combiners for number of tillers plant-1 and thousand grain weight, respectively. Among 21 hybrids, Shua-92 × Shadab proved to be good specific combiner for panicle length, and yield plot-1, Shandar × Shua-92 proved good specific combiner for panicle weight and thousand grain weight. In contrast, Shandar × NIA-102, NIA-19/A × KSK-282, Shandar × Shadab, Shadab × KSK-282, and NIA-19/A × Shadab proved good specific combiners for days to initial heading, days to 90% maturity, dwarf plant height, number of tillers plant-1, and thousand grain weight respectively. These seven cross combinations are identified as superior crosses and can be utilized in future breeding programs for hybrid crop development.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important members of the grass family, which belongs to the genus *Oryza* that includes wheat, corn, and some other plants (Dogara & Jumare, 2014). After wheat and maize, rice is the third cultivated cereal and staple food crop of more than half of the world's population (FAO, 2014). Rice grains provide up to fifty percent of the dietary calories and have become a significant part of the protein consumption for the people of Asia (Muthayya et al. 2014). Rice grain is rich in minerals, nutrients and vitamins.

Being a main staple food and cash crop, the rice crop plays an important role in the economy of Pakistan. After cotton, rice is the second major exportable commodity and adds around 0.6% to GDP and a 3.1 % contribution to agriculture. During the financial year 2019-20, the rice crop was grown on an area of 3,034 million hectares, which increased by 8.0% as compared to the previous year (GoP, 2020). The high-quality rice varieties grown in Punjab and Sindh provinces not only meet the domestic food demand of the country but also are exported to several foreign countries to earn foreign exchange.

In Sindh province, rice crop is cultivated on around 02 million acres of fertile land, and its yield is nearly 45-50 maundsacre^{-1}. In the world, Pakistan ranks 10th largest rice producing country and fourth in rice exporting countries (Statista 2020-21). Biotic and abiotic factors can cause a reduction in crop production and productivity. Hence, to overcome the lower yields, varietal improvement and genetic studies of the breeding materials is the potentially dominant mechanisms (Zewdu, 2020). The study of combining ability helps to recognize the parental lines that have good combining ability for different traits (Zewdu, 2020).

The estimation of combining ability provides an idea regarding the significance and degree of additive and non-additive types of gene actions in the manifestation of the various traits (Griffing, 1956). The concept of combining ability is generally used for the classification of inbred lines respective to their hybrid performance. The concepts of combining ability have had a significant influence on evaluation and population development of inbred lines in crop breeding. Parents exhibiting an average to high combining ability in all hybrid combinations are considered to have better GCA, while if their potential to combine well in a particular cross is good, they will be considered to have good SCA (Fasahat et al. 2016).

Plant breeders continuously upgrade and improve different traits of newly developed varieties to make them more productive and desirable, as well as improve the taste and cooking characteristics of rice. In rice crop selection for milling, cooking and digestibility qualities is an

essential component to meet industry and consumer as well as export standards.

In order to develop varieties with better grain quality, information regarding the choice of parents to be crossed is essential. The general and specific combining ability analyses provides data regarding nature and direction of gene actions for economically important traits which helps in the recognition of potential parents and their possible cross combinations. Diallel analysis is specially used to understand the nature of gene action expected for various plant characters (Gnanamalar & Vivekanandan 2013). The ability of parents to combine well in different cross combinations can be judged by phenotypic performance and adaptation qualities (Khattak, 1999). The main objective of this research was to identify superior F_2populations having specific combining abilities for yield and its contributing traits for improvement of yield of rice varieties.

MATERIALS AND METHODS

MATERIALS

The plant material used in the present research consisted of seven varieties of rice, viz., NIA-19A, Shua-92, Shadab, NIA-102, Shandar, IR-6, and KSK-282. The twenty-one F_2 population was developed from the above seven parental varieties of rice through a half diallel mating system. The seed of twenty-one F_2 populations and their parents were grown in the field by the dibbling method in 3 replications employing Randomized Complete Block Design. Three seeds hill^{-1} were sown and after thinning one seedling per hill^{-1} ensured a uniform stand of only one plant hill^{-1}. The 30 cm distance between plant-to-plant while 75 cm distance between row-to-row was maintained. The traits studied were plant height (cm), number of tillers plant^{-1}, panicle length (cm), total grains panicle^{-1}, fertility %, 1000 grain weight (g), panicle weight (g), and grain yield plot^{-1} (kg). For recording data of various traits five plants were randomly selected from every replication from each genotype, and the selected plants were properly tagged and guarded. At maturity, the data of different plant characters were recorded. Breeding values of the material were evaluated by analyzing data for yield and different genetic parameters. The collected data were subjected to the ANOVA according to the statistical methods proposed by Gomez and Gomez (1984). The GCA and SCA effects for various traits were analyzed in F_2 population using Griffing's (1956) Method I and Model II.

RESULTS

The mean squares for genotypes, parents, and hybrids are shown in Table 1. The results of ANOVA revealed that genotypes, parents, and hybrids mean squares differ significantly

(P>0.01) for all characters except for the trait yield plant^{-1}, which was non-significant for hybrids, indicating that enough genetic variability existed in the material studied. Therefore, data were further analyzed to assess the GCA of parents and the SCA of hybrids.

TABLE NO. 1: MEAN SQUARES (ANOVA) OF VARIOUS CHARACTERS OF RICE *ORYZA SATIVA* L.

Source of Variance	D.F.	Plant height (cm)	Number of tillers plant^{-1}	Panicle length (cm)	Panicle weight (g)	Total grains panicle^{-1}	Fertility (%)	1000 grain weight (g)	Yield Plot^{-1} (kg)
Replications	2	5.43	2.09	0.08	0.01	73.65	0.19	0.04	1.70
Genotypes	27	90.48**	21.50**	5.27**	2.45**	3569.68**	20.70**	23.83**	3.42**
Parents	6	141.66**	27.83**	7.25**	0.86**	4037.70**	5.64**	31.74**	5.28**
Hybrids	20	79.62**	20.61**	4.93**	1.59**	3511.47**	16.26**	22.50**	2.65^{NS}
Error	54	3.30	0.52	0.08	0.01	19.91	0.04	0.05	1.53

** = Significant at P>0.01 level of Probability

NS=non-significant

MEAN PERFORMANCE OF SEVEN PARENTS AND THEIR 21 F_2 HYBRIDS

Mean performance for the character plant height revealed that among the parents, the highest plant height (116.52 cm) was measured in variety Shandar, whereas the dwarf plants with a mean height (94.33 cm) were observed in variety IR-6. In case of F_2 hybrids, the cross Shandar× Shua-92 produced the tallest plants with (112.60 cm) mean height, while the cross IR-6 × KSK-282 produced dwarf plants (92.73 cm), Table 3.

In case of the trait tillers plant^{-1} among parents, the maximum NTP (21.93) was counted in variety NIA-102, and the minimum number of tillers (13.40) was found in variety IR-6 (Table 2). Among twenty-one F_2 hybrids, maximum (22.80) and minimum (13.06) tiller plant^{-1} were recorded in crosses Shandar × NIA-102 and NIA-19/A × KSK-282, respectively (Table 3). For the trait panicle length, the longest panicles were observed in parent variety Shandar with

a mean length (30.15 cm), whereas the shortest panicle length (25.230 cm) was recorded in variety IR-6 (Table 2). In case of F_2 hybrids, the maximum panicle length (29.47 cm) was recorded in cross combination Shandar × NIA-102, while the minimum panicle length (24.92 cm) was measured in cross combination NIA-19/A × KSK-282 (Table 3).

Heavier panicles with a mean panicle weight of (4.81 g) were produced by the NIA-19/A among the seven parents. On the other hand lightest mean weight of panicle among the parent varieties was noted in IR-6, i.e., (3.3 g) panicle^{-1} (Table 2). In case of F_2 hybrids, the highest panicle weight (6.67 g) was recorded in cross combination Shandar × Shua-92, which was also higher weight than the panicle of the parent variety NIA-19/A. Inversely, the lowest panicle weight (4.54 g) was recorded in the cross combination IR-6 × Shua-92 (Table 3).

The data given in (Table 2) displays that the highest (260.88) and the lowest (167.37) mean number of grains panicle^{-1} among the parents were counted in Shandar and IR-6 respectively. Regarding the same trait the highest mean value (295.32) was noted in F_2 hybrid Shandar x Shadab, while the lowest number of grains panicle^{-1} (183.91) was manifested by the cross combination of IR-6 x KSK-282 in F_2 generation (Table 3).

The mean data regarding fertility % of seven parental lines and their twenty-one F_2 hybrids is shown in (Table2) and 3 which reveal that the highest fertility % among parents (96.67) and hybrids (94.77) was observed in KSK-282 and IR-6 x NIA19/A respectively. However, the parent variety NIA-19/A and cross combination NIA-19/A × Shua-92 manifested the lowest fertility (2.44 %) and (86.29 %), respectively.

In case of 1000 grain weight, the parent varieties NIA-19/A and KSK-282 manifested the heaviest and the lightest grains with mean weight of (33.85 g) and (24.29 g) respectively (Table 2). It can be seen in (Table 3) that the maximum weight of 1000 grains (33.37 g) were observed in cross of NIA-19/A x Shadab. While the minimum weight of 1000 grains (24.61 g) were determined in cross of Shandar x Shadab (Table 3).

The results regarding average performance of parental varieties and their F_2 hybrids for yield plot^{-1} are presented in table 2 and 3. The results depict that the parent variety Shandar produced the maximum grain yield plot^{-1} (12.15 kg) than any other parent variety. While the minimum yield among the parents was recorded as (8.0 kg) plot^{-1} in KSK-282. In case of F_2 hybrids, the maximum yield plot^{-1} (12.58 kg) was obtained in cross Shua-92 × Shadab, whereas the minimum (8.81 kg) yield plot^{-1} was noted in cross Shandar× Shadab (Table 3).

TABLE NO 02. MEAN PERFORMANCE OF SEVEN PARENTAL LINES OF RICE (*ORYZA SATIVA* L.)

S. No.	Parents	Plant height (cm)	Number of tillers plant^{-1}	Panicle length (cm)	Panicle weight (g)	Total grains panicle^{-1}	Fertility (%)	1000 grain weight (g)	Yield Plot^{-1} (kg)
1	IR-6	94.33	13.400	25.23	3.30	167.37	95.61	24.55	9.39
2	Shandar	116.52	19.467	30.15	4.49	260.88	94.46	25.59	12.15
3	NIA-19/A	107.60	18.333	26.99	4.81	193.91	92.44	33.85	10.91
4	Shua-92	105.00	15.300	27.07	4.30	200.04	94.44	26.87	10.02
5	NIA-102	103.73	21.93	27.977	4.35	256.57	94.69	26.69	10.42
6	Shadab	101.00	18.20	27.893	4.58	244.84	95.97	25.80	9.25
7	KSK-282	100.80	14.40	26.240	3.67	194.08	96.66	24.29	8.00
	LSD (5%)	2.97	1.18	0.46	0.16	7.30	0.33	8.18	2.03

TABLE NO 03. MEAN PERFORMANCE OF TWENTY-ONE F_2 HYBRIDS OF RICE (*ORYZA SATIVA* L.)

S: NO	CROSSES	Plant height (cm)	Number of tillers plant^{-1}	Panicle length (cm)	Panicle weight (g)	Total grains panicle^{-1}	Fertility (%)	1000 grain weight (g)	Yield Plot^{-1} (kg)
1	IR-6 × Shandar	109.27	17.93	28.82	5.61	276.20	93.93	25.75	9.65
2	IR-6 × NIA-19/A	107.20	18.13	25.94	6.20	196.35	94.77	29.93	10.09
3	IR-6 × Shua-92	107.33	14.93	26.72	4.54	198.52	91.12	25.29	10.41
4	IR-6 × NIA-102	97.80	21.26	27.45	5.53	206.43	89.18	26.09	10.14
5	IR-6 × Shadab	105.60	15.06	26.25	5.65	232.64	92.26	25.27	10.31
6	IR-6 × KSK-282	92.73	13.93	25.04	4.55	183.91	91.37	25.21	10.06
7	Shandar × NIA-19/A	111.67	17.40	29.25	6.37	226.69	89.65	32.66	10.53
8	Shandar × Shua-92	112.60	17.73	28.04	6.67	289.35	93.29	26.53	11.29
9	Shandar × NIA-102	109.67	22.80	29.46	6.53	291.11	92.48	26.31	11.44
10	Shandar × Shadab	103.73	16.73	28.30	6.47	295.32	91.10	24.61	8.81

11	Shandar × KSK-282	107.93	17.46	28.24	4.85	215.77	90.40	25.55	11.13
12	NIA-19/A × Shua-92	106.33	17.06	26.88	4.77	185.89	86.29	29.98	10.83
13	NIA-19/A × NIA-102	108.33	19.80	26.30	6.18	214.16	90.12	32.23	10.54
14	NIA-19/A × Shadab	102.67	16.33	27.25	6.47	221.21	89.32	33.37	9.59
15	NIA-19/A × KSK-282	100.73	13.06	24.92	5.79	215.40	94.58	28.55	11.81
16	Shua-92 × NIA-102	101.13	21.06	26.40	4.78	206.19	87.06	26.65	9.61
17	Shua -92 × Shadab	101.53	17.26	28.09	5.00	221.25	94.14	24.66	12.58
18	Shua -92 × KSK-282	98.00	13.66	26.29	4.59	195.92	93.13	25.99	11.11
19	NIA-102 × Shadab	106.47	17.86	27.56	5.74	252.83	90.89	25.67	11.80
20	NIA-102 × KSK-282	97.53	21.13	28.37	5.11	232.41	90.01	25.59	11.17
21	Shadab× KSK-282	103.00	18.73	26.44	5.59	227.75	92.94	26.09	12.03
	LSD (5%)	2.97	1.18	0.46	0.16	7.30	0.33	0.34	2.02

COMBINING ABILITY

Every successful breeding program relies on the selection of desirable parent material to be used in a hybridization program. The knowledge of general and specific combining ability and magnitude of genotypic variance for yield and yield components is essential for the exploration of gene action in the breeding population. The concept of combining ability (Griffing, 1956) is used to assess the breeding value of parents as well as hybrids for various morphological and quality traits in both self and cross-pollinated crop plants. The mean squares for combining ability analysis for yield and its related traits are presented in (Table 4). The results revealed highly significant GCA and SCA variances (P>0.01) for all the traits, indicating that both additive and dominant gene actions were playing a role in the expression of traits. However, higher values of GCA variances suggest that the additive gene action is more important than the non-additive gene action in the expression of traits studied.

PLANT HEIGHT (CM)

The highest negative desirable general combining ability effects (-3.65) were observed in KSK-282, followed by IR-6 (-2.86), whereas variety Shandar displayed the highest undesirable positive (5.95) GCA effects (Table 5). Among twenty-one hybrids, eight hybrids showed negative significant, and ten hybrids showed positive significant desirable SCA effects, while three crosses showed non-significant SCA effects (Table 6). The crosses Shandar × Shadab displayed the highest (-5.47) negative SCA effects, followed by IR-6 × KSK-282 (-5.05) (Table 6).

NUMBER OF TILLERS PLANT^{-1}

The general combining ability GCA effects for tillers plant^{-1} are shown in (Table 5), which revealed that among parental lines, NIA-102 produced (3.08) highly significant and positive GCA effects whereas parental line Shandar showed lowest significant positive GCA effects (0.99) and remaining five parental line showed negative GCA effects. Among hybrids, nine crosses expressed positive and significant desirable SCA effects while eleven crosses expressed negative SCA effects for tillers plant^{-1}. The highest positive SCA effects (2.89) were revealed by Shadab × KSK-282 followed by IR-6 × NIA-19/A and IR-6 × NIA-19/A (Table 6).

PANICLE LENGTH (CM)

Among seven parents, three parental lines Shandar, NIA-102 and Shadab showed positive significant GCA effects and four lines IR-6, NIA-102, Shua-92 and KSK-282 showed negative significant effects (Table 5). Among hybrids, eight crosses manifested positive and significant

SCA effects while eleven crosses expressed negative undesirable SCA effects. The highest positive SCA effects (0.83) were revealed by Shua-92 × Shadab followed by IR-6 × Shandar and Shandar×NIA-19/A respectively (Table 6).

PANICLE WEIGHT (G)

The GCA effects for the trait panicle weight (g) are presented in (Table 5). Out of seven parental lines, four lines expressed positive significant GCA effects while rest of the three parental lines exhibited negative significant GCA effects. The highest (0.40) and (0.39) positive significant GCA effect were displayed by variety Shandar and NIA-19/A, respectively, whereas the highest (-0.45) negative GCA effects were displayed by KSK-282, followed by IR-6 and Shua-92 (Table 5). Among hybrids, sixteen crosses revealed positive significant SCA effects, whereas four crosses expressed negative significant SCA effects. The highest (0.93) positive SCA effects were revealed by IR-6 × NIA-19/A, followed by Shandar × NIA-102, NIA-102 × KSK-282 and NIA-19/A × KSK-282, respectively (Table 6).

TOTAL GRAINS PANICLE^{-1}

Among seven parents three parent lines showed positive significant GCA results and remaining four parent lines showed negative significant GCA effects (Table 5). The highest (35.04) positive GCA effects were displayed by parent Shandar followed by variety Shadab (15.54) and NIA-102. In case of hybrids, ten hybrids revealed positive and nine hybrids expressed negative significant SCA effects, respectively. The highest positive SCA effect (40.72) was revealed by Shandar × Shua-92 followed by IR-6 × Shandar and NIA-19/A × KSK-282, respectively (Table 6).

FERTILITY %

The GCA effects for fertility % are described in (Table-5), which showed that IR-6, Shandar, Shadab, and KSK-82 displayed positive but non-significant GCA whereas NIA-19/A, Shua-92 and NIA-102 showed negative but non-significant GCA effects (Table 5). Among twenty-one hybrids, eight hybrids revealed positive significant and thirteen crosses expressed negative significant SCA effects. The maximum positive SCA effects (2.78) were revealed by IR-6 × NIA-19/A, followed by NIA-19/A × KSK-282 whereas the highest (-4.59) negative SCA effects were showed by cross NIA-19A × Shua-92 followed by Shua-92 ×NIA-102 and Shandar × KSK-282 (-3.76 and -2.93), respectively (Table 6).

1000 GRAIN WEIGHT (G)

Among parents the highest (4.15**) positive significant GCA effects were expressed by variety

NIA-19/A, whereas remaining six varieties showed negative significant GCA effects (Table-5). Among twenty-one hybrids, eight hybrids showed negative, and eleven hybrids manifested positive significant SCA effects respectively. The maximum (-1.46) negative significant SCA effects were displayed by cross NIA-19/A × KSK-282, followed by cross Shandar × Shadab (-1.38), whereas the highest (2.73) positive SCA effects were showed by cross NIA-19/A × Shadab followed by Shandar × NIA-19/A (1.87) (Tabel 6).

YIELD PLOT^{-1} (KG)

Among seven parents the IR-6 displayed negative significant (-0.54**) GCA effects while rest of the parents expressed positive and negative non-significant GCA effects (Table 5). The SCA effects for the trait yield plot^{-1}showed those five out of twenty-one hybrids exhibited positive and other four hybrid combinations exhibited negative SCA effects and twelve crosses showed non-significant SCA effects (Table 6). The maximum (1.95) positive SCA effects were displayed by cross Shua-92 × Shadab followed by cross Shadab × KSK-282 (1.68) and NIA-102 × KSK-282 (1.46) (Table-6).

TABLE NO 4. MAN SQUARES (ANOVA) FOR COMBINING ABILITY IN SEVEN PARENTS AND 21 CROSSES FOR VARIOUS TRAITS OF RICE *ORYZA SATIVA* L.

		Mean Squares							
Source	**D.F**	**Plant height (cm)**	**Number of tillers plant^{-1}**	**Panicle length (cm)**	**Panicle weight (g)**	**Total grains panicle^{-1}**	**Fertility (%)**	**1000 grain weight (g)**	**Yield Plot^{-1} (kg)**
GCA	6	101662.77**	2897.67**	6951.10**	257.61**	478953.91**	79398.26**	6916.67**	277.85**
SCA	21	12.04	2.69**	0.51**	0.70**	385.90**	7.36**	1.17**	145.97**
Error	54	1.10	0.17	0.03	0.00	6.64	0.01	0.02	0.51
σ^2g		7260.78	206.79	496.47	18.35	34184.06	5670.79	493.97	9.66
σ^2s		5.82	1.34	0.26	0.37	202.00	3.91	0.61	77.47

V_A	14521.57	413.58	992.94	36.70	68368.12	11341.58	987.93	19.32
V_D	5.82	1.34	0.26	0.37	202.00	3.91	0.61	77.47

** = Significant at P>0.01 level of Probability, *= Significant at P>0.05 level of Probability, N.S = Non-Significant

TABLE NO 5. GENERAL COMBINING ABILITY (GCA) EFFECTS IN SEVEN COMMERCIAL VARIETIES OF RICE *ORYZA SATIVA* L.

Varieties	Plant height (cm)	Number of tillers plant^{-1}	Panicle length (cm)	Panicle weight (g)	Total grains panicle^{-1}	Fertility (%)	1000 grain weight (g)	Yield Plot^{-1} (kg)
IR-6	-2.86**	-1.34**	-0.83**	-0.35**	-19.12**	0.67 NS	-1.16**	-0.54**
Shandar	5.95**	0.99**	1.59**	0.40**	35.04**	0.22 NS	-0.49**	0.32 NS
NIA-19/A	1.98**	-0.18 NS	-0.40**	0.39**	-17.04**	-0.91 NS	4.15**	0.10 NS
Shua-92	0.29 NS	-0.87**	-0.18**	-0.32**	-11.52**	-0.43 NS	-0.47**	0.17 NS
NIA-102	-0.66**	3.08**	0.37**	0.08**	12.82**	-0.96 NS	-0.13**	0.14 NS
Shadab	-1.04**	-0.19 NS	0.17**	0.25**	15.54**	0.53 NS	-0.64**	-0.08 NS
KSK-282	-3.65**	-1.48**	-0.71**	-0.45**	-15.73**	0.88 NS	-1.27**	-0.11 NS

TABLE NO. 6. SPECIFIC COMBINING ABILITY (SCA) AFFECTS IN F_2 GENERATION OF VARIOUS CHARACTERS OF RICE *ORYZA SATIVA* L.

Crosses	Plant height (cm)	Number of tillers plant^{-1}	Panicle length (cm)	Panicle weight (g)	Total grains panicle^{-1}	Fertility (%)	1000 grain weight (g)	Yield Plot^{-1} (kg)
IR-6 × Shandar	1.88**	0.77**	0.80**	0.33**	35.17**	0.81**	0.27**	-0.66**

IR-6 × NIA-19/A	3.79**	2.14**	-0.09 NS	0.93**	7.40**	2.78**	-0.20**	0.00 NS
IR-6 × Shua-92	5.61**	-0.38**	0.46**	-0.02 NS	4.05**	-1.35**	-0.21**	0.24 NS
IR-6 × NIA-102	-2.97**	2.02**	0.64**	0.57**	-12.39**	-2.75**	0.24**	0.01 NS
IR-6 × Shadab	5.21**	-0.92**	-0.36**	0.52**	11.12**	-1.17**	-0.07 NS	0.39 NS
IR-6 × KSK-282	-5.05**	-0.76**	-0.69**	0.12**	-6.36**	-2.41**	0.51**	0.17 NS
Shandar× NIA-19/A	-0.55 NS	-0.92**	0.80**	0.34**	-16.41**	-1.88**	1.87**	-0.43 NS
Shandar × Shua-92	2.07**	0.10 NS	-0.64**	1.36**	40.72**	1.28**	0.36**	0.26 NS
Shandar × NIA-102	0.08 NS	1.22**	0.24**	0.81**	18.14**	1.00**	-0.20**	0.45 NS
Shandar × Shadab	-5.47**	-1.58**	-0.72**	0.59**	19.64**	-1.87**	-1.38**	-1.97**
Shandar × KSK-282	1.34**	0.45**	0.09 NS	-0.33**	-28.65**	-2.93**	0.19**	0.38 NS
NIA-19/A × Shua-92	-0.22 NS	0.60**	0.19**	-0.53**	-10.66**	-4.59**	-0.83**	0.01 NS
NIA-19/A × NIA-102	2.73**	-0.61**	-0.93**	0.47**	-6.73**	-0.23**	1.08**	-0.24 NS
NIA-19/A × Shadab	-2.56**	-0.81**	0.22**	0.59**	-2.39**	-2.53**	2.73**	-0.97**
NIA-19/A × KSK-282	-1.89**	-2.78**	-1.24**	0.61**	23.06**	2.39**	-1.46**	1.29**
Shua-92 × NIA-102	-2.79**	1.34**	-1.06**	-0.21**	-20.23**	-3.76**	0.11 NS	-1.24**

Shua-92	×								
Shadab		-2.01**	0.81**	0.83**	-0.15**	-7.87**	1.82**	-1.36**	1.95**
Shua-92	×								
KSK-282		-2.93**	-1.50**	-0.09 NS	0.12**	-1.94 NS	0.45**	0.60**	0.51 NS
NIA-102	×								
Shadab		3.87**	-2.53**	-0.25**	0.19**	-0.64 NS	-0.90**	-0.70**	1.20**
NIA-102	×								
KSK-282		3.01**	-0.38**	-0.49**	0.73**	5.54**	0.80**	0.36**	1.46**
Shadab	×								
KSK-282		3.39**	2.89**	-0.29**	0.56**	2.83**	-0.70**	0.88**	1.68**

DISCUSSION

PLANT HEIGHT (CM)

The mean squares from ANOVA showed that the genotypes studied differed significantly for the trait under study, which is good to isolate promising segregates with tall, medium and dwarf plants in subsequent generations. For developing tall cultivars, progenies of Shandar and for developing medium plants progenies of NIA-19/A can be used for developing the dwarf plants. IR-6 variety generally produced dwarf plants that would be useful for evolving dwarf genotypes. For the trait plant height, GCA and SCA variances were highly significant that proved influence of additive and non-additive types of gene action. The GCA variance was larger than SCA in magnitude which indicated the importance of additive gene effects for the character plat height (cm). When GCA effects for plant height are considered, NIA19/A, displayed significant positive GCA effects indicating that the trait was conditioned by additive genes. The SCA effect was highly significant for hybrids IR-6 × Shua-92 and IR-6 × Shadab and in later generations promising segregates could be isolated by selection.

TILLERS PLANT-1

The results of ANOVA are presented in (Table 1) showing that the breeding material studied showed genetic diversity for the tillers plant-1 which is displaying the importance of selection to isolate promising segregate in subsequent generations for developing varieties with maximum number of tillers. Use of NIA-102 and Shandar will be meaningful in breeding programs. GCA and SCA variances were highly significant for the trait tillers plant-1 which indicates additive, and non-additive generation for the trait tiller plant-1. But the magnitude of GCA variance was large than SCA variance which indicates the predominance of additive gene

action. NIA-102 and Shandar were good general combiners for tiller plant-1. The analysis of variance for combining abilities showed significant differences among genotypes for all traits studied, suggesting variability among the genotypes, number of effective tillers plant-1 (7.34) and number of non-effective tillers plant-1 (12.59), Significant differences were observed among the lines and testers for all traits studied except effective tillers plant-1 and panicle length (Vanave et al., 2018). When GCA effects are considered for tiller plant-1, NIA-102 and Shandar proved good general combiners for tillers plant-1. SCA effects were important for the hybrids Shadab × KSK-282, IR-6 × NIA-19/A and IR-6 × NIA-102which propose the selection of these hybrids to develop superior varieties with high numbers of tillers.

PANICLE LENGTH (CM)

The results of means square from ANOVA are presented in (Table 2) which showed that the segregating material under study showed genetic variation for the panicle length (cm) which is displaying the importance of selection to isolate promising segregates in subsequent generation for developing varieties with maximum length of panicle. Use of Shandar and NIA-102 will be meaningful in breeding program. The GCA and SCA variances were highly significant for the trait panicle length (cm) which indicates additive, non-additive gene action for the trait panicle length. But the magnitude of GCA variance was larger than SCA variance which indicates the predominance of additive gene action. When GCA effects are considered for panicle length (cm), Shandar proved good general combiners for this trait. The SCA effects were important for the hybrids IR-6 × Shandar and Shandar × NIA-19/Awhich propose that selection of these hybrids for developing superior varieties with maximum length of panicle will be beneficial in future.

PANICLE WEIGHT (G)

Analysis of variance of means demonstrated that breeding material investigated displayed enough variation for panicle weight which suggested isolation of favorable hybrids to develop varieties with maximum panicle weight, to boost the yield potential of rice cultivars. NIA-19/A is recommended to be used in future hybridization program. For the trait panicle weight GCA and SCA variances were highly significant which indicates additive and non-additive gene action for the trait panicle weight (g). But the magnitude of GCA variance was large than SCA variance that indicated the significance of additive gene action. When GCA effects are considered for panicle weight (g) Shandar and NIA-19/A proved good general combiners. SCA effects were important for the genotypes IR-6 × NIA-19/A and Shandar × NIA-102, which propose that these hybrid combinations should be utilized to develop varieties with maximum

panicle weight.

TOTAL GRAINS PANICLE-1

Analysis of variance of means showed that breeding material under study revealed ample differences for total grain panicle-1 which is evidence for selection of desirable genotypes to enhance total grain panicle-1in subsequent generations. Shandar and. NIA-102 can be used as potential parental lines for developing new cultivars with maximum grains. The highly significant GCA and SCA variances were observed for the trait total grains panicle-1 which expressed that total gains panicle-1 was directed by additive and non-additive genes. But the degree of GCA variance was superior as compared to SCA variance which indicates the preponderance of additive gene action. Genetic variability and mean performance of parents and hybrids are important criteria for genotypic evaluation of number of filled grains panicle-1 (36.98), number of unfilled grains panicle-1 (-59.85) however, the parents with high mean value may not transmit this characteristic to their hybrids Kargbo et al. (2019). When GCA effects are considered, Shandar and Shadab displayed highly significant positive GCA effects and good general combiners for total grains panicle-1. Highly significant positive SCA effects were recorded for the hybrids Shandar × Shua-92, IR-6 × Shandar and NIA-19/A × KSK-282 which suggest that selection should be carried out in these genotypes for developing varieties with maximum grains in future breeding programs.

FERTILITY %

Analysis of variance of means showed that the genetic material under study displayed ample diversity for the fertility % which is clued to isolate promising segregates with good fertility percentage in subsequent generations. For developing more fertility percentage in cultivar progenies KSK-282 was one of the potential progenitors. Progenies of Shadab variety generally produced maximum fertile grains after KSK-282 that would be useful for evolving best genotypes. For the trait fertility %, GCA and SCA variances were highly significant which indicate additive and non-additive gene actions. The extent of GCA variance was large than SCA which revealed preponderance of non-additive type of gene action effect for the character fertility %. While considering the SCA effect for fertility percentage (33.58%), the hybrid NIA-19/A × KSK-282 had one of the highest significant SCA effects coupled with yield per plant though it had a negative insignificant SCA effect for filled grains panicle-1. Such behavior has been attributed to over dominance or epistasis Devi et al. (2017). When GCA effects for fertility % are considered, KSK-282 displayed non-significant positive effects indicating that the

trait was conditioned by non-additive genes. SCA effects were highly significant and positive for hybrids IR-6 × NIA-19/A and NIA-19/A × KSK-282 and in later generations promising segregates can be isolated from these hybrid combinations by selection.

1000 GRAIN WEIGHT (G)

Analysis of variance of means showed that breeding material under study revealed ample differences for 1000 grain weight (g) which is evidence for selection of desirable genotypes to enhance 1000 grain weight (g) in subsequent generations. NIA-19/A and Shua-92 can be used as potential parental lines for developing new cultivars with high weight of grains. GCA variance was highly significant while SCA variance was non-significant for the trait 1000 grain weight which express that the trait was governed by additive gene action. On the other hand, Zewdu, (2020) reported the highly significant contribution of SCA variance effects for 1000 grain weight which showed importance of non-additive gene action in the inheritance of the traits. This result corresponds with the findings of Saidaiah et al. (2010), Hasan et al. (2013). When GCA effects are considered NIA-19/A and Shandar displayed positive highly significant GCA effects and proved good general combiners for 1000 grain weight (g). SCA effects were highly significant and positive for the hybrids Shandar × Shua-92 and NIA-19/A × Shadab, which suggest that selection, should be carried out in these genotypes for developing varieties with maximum 1000 grain weight (g) in future breeding program.

YIELD PLOT-1

Analysis of variance of means showed that breeding material under study revealed ample differences for yield plot-1 which is evidence for selection of desirable genotypes to enhance yield plot-1 in subsequent generations. Shandar, and NIA19/A, can be used as potential parental lines for developing new cultivars with high yield plot-1. For the trait yield plot-1, highly significant GCA and SCA variances were observed which express that the trait was governed by additive and non-additive gene action. But the degree of GCA variance was greater than the SCA variance which indicates the preponderance of additive gene action. When GCA effects are considered Shandar and NIA-102proved good general combiners for yield plot-1. The highly significant SCA effects were recorded for the hybrids Shua-92 × Shandar, Shadab × KSK-282, NIA-102 × KSK-282 and NIA-102 × Shadab, which suggests that selection should be carried out in these genotypes for developing varieties with maximum yield in future breeding programs.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

It is concluded from this study that among seven parental lines KSK-282 was found as good general combiner for traits days to initial heading, days to 90% maturity and plant height; Shandar proved good general combiner for traits panicle length, panicle weight and total grains panicle-1, while NIA-102 and NIA-19/A were proved as good general combiners for number of tillers plant-1 and 1000 grain weight, respectively. Among 21 hybrids, Shua-92 × Shadab proved to be good specific combiner for panicle length, and yield plot-1, Shandar × Shua-92 proved good specific combiner for panicle weight and 1000 grain weight, while Shandar × NIA-102, NIA-19/A × KSK-282, Shandar × Shadab, Shadab × KSK-282, and NIA-19/A × Shadab proved good specific combiners for days to initial heading, days to 90% maturity, dwarf plant height, number of tillers plant-1, and 1000 grain weight respectively. These seven cross combinations are identified as superior crosses and can be utilized for hybrid crop development in future breeding programs.

RECOMMENDATIONS

From this study four parental lines KSK-282, NIA-102, Shandar and NIA-19/A are recommended as suitable parents to be included in future breeding programs for development of early maturing and high yielding varieties. Out of 21 crosses following seven crosses Shandar × NIA-102, NIA-19/A × KSK-282, Shandar × Shadab, Shadab ×KSK-282, Shua-92 × Shadab, Shandar ×Shua-92 and NIA-19/A × Shadab, are recommended as superior cross combinations for commercial exploitation of heterosis.

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