J. of Plant Production, Mansoura Univ., Vol. 12 (6):635 - 643, 2021

Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Heterosis and Combining Ability of some Colored Rice Genotypes for Yield Characteristics and Grain Micronutrient Content Using Line X Tester Analysis

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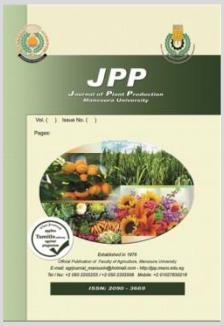

ABSTRACT

Eight exotic colored rice lines and four testers were crossed in line x tester. The resulted 32 F_1 hybrids along with their parents were evaluated in a randomized complete block design (RCBD) with three replications at the Experimental Farm of Rice Research Department, Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during2019 and 2020 growing season, to assess mean performance, general (GCA) and specific (SCA) combining ability as well as identify type of gene action controlling the inheritance of the studied traits. The non-additive gene effects had an important role in the inheritance of all the studied traits more than the additive gene effects. The parental lines Dullar, Black Rice and IRBLKM-TS-[CO] were identified as a good combiners for earliness and KWANG CHANG Ai, Black Rice and Sakha 101 for shortness. Whereas, parental lines: Dullar, Red Rice, IRBLKM-TS-[CO], IRBLTA- CT and Sakha 108 were the best general combiners for grain yield and its components. The hybrid combinations Dullar x Giza 178, Red Rice x Giza 178, B40 x Giza 178, KWANG CHANG Ai x Sakha 108, Dullar x Giza 177 and IRBLTA-CT2 x Sakha 108 had the best SCA effects for grain yield as well as one or more of its components. Moreover, the hybrids Red Rice x Giza 178, IR71567-108-1-2 x Giza177 and B40 x Sakha108 recorded the highest value in Fe and Zn concentrations in grains. These hybrids could be used for improving grain yield and micronutrient content particularly Fe and Zn in rice breeding programs.

Keywords*:* Rice, Color rice, combining ability, heterosis, nutritional value

INTRODUCTION

Rice is one of the most important food crops that feed more than half of the world's population. Rice follows the Poaceae family and it is cultivated three types, which are japonica, indica and javanica, as their cultivation is spread in Asia and some continent of Africa in addition to Latin America. In Egypt, rice is ranked second in terms of agricultural and economic importance after wheat, as it is the second economic crop which planted area nearly 600.000 ha^{-1} and a paddy rice production of 6.0 million tonnes. The average yield of 9.88 t ha^{-1} is regarded one of the highest in the worldwide (RRTC, 2018).

The whole grain of rice contains a high percentage of starch, protein, some vitamins and important mineral elements, most of which are lost due to the bleaching and polishing processes of the grain, but the amount of starch present in the grain remains and with complete dependence on rice in nutrition, especially in some poor places in the world, this has led to the spread of several diseases, including anemia, lack of growth in children and some diseases related to vitamin A deficiency. Rice grain provides 75-80% of starch, 12% water, 7% of protein, fats, B vitamins mainly thiamine, riboflavin and niacin and minerals such as calcium, magnesium, phosphorus, manganese, copper, and iron (Oko *et al*., 2012). Minerals are essential nutrients for human growth and development. They play a vital role in the effective functioning of the human systems. Ca and Mg are known as major minerals which require >100mg/day for the body functions and Zn and Mn are known as trace minerals which require <100mg/day. One of the major reasons for the loss of essential micronutrients from rice is the high polishing rate (Abbas *et al*., 2011).

Based on the color of the rice, there are white rice, red rice and black rice. Black rice is functional rice that contains the highest concentration of anthocyanin pigment compared with rice of other colors. Black rice could increase body resistance to disease, repair liver damage, reduce cholesterol in the blood, prevent kidney function disorders, and prevent cancer or tumors (Aryana *et al.*, 2017) and (Suardi and Ridwan 2009).

Genetic diversity can increase the chances of getting a better genotype through selection. Heritability is a genetic parameter that shows the proportion of genetic relative to phenotype variances of a variety, which indicates if the traits can be inherited in the next generation (Syukur *et al.*, 2015). According to Acquaah 2012, genetic parameters, consisting of genetic diversity, heritability and genetic advance, are essential measures for the success in applying a plant breeding program also, heritability determines the progress of selection, i.e. the greater the heritability value, the greater the selection progress that is achieved and the faster the superior varieties can be released, or vice versa.

Combining ability helps to define the pattern of gene effects in the expression of quantitative traits by identifying potentially superior parents and hybrids (Zhang *et al*., 2015). General Combining Ability (GCA) is attributed to additive gene effects and additive x additive epistasis and is theoretically fixable. On the other hand, Specific Combining Ability (SCA) attributable to non-additive gene effect and may be due to dominance or epistasis or both which is non-fixable (Koze, 2017). The presence of non-additive genetic variance is the primary justification for initiating the hybrid program (Pradhan and Singh *et al.*, 2008). The preponderance of non-additive gene action in the expression of yield and yield-related traits was reported by Thirumalai *et al.*, (2018).

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DOI: 10.21608/jpp.2021.78615.1032

Line X tester design is the best analysis for estimating GCA, SCA and various types of gene actions (Fahmi *et al*., 2017).

So, the aim of this study was having new hybrids from colored and Egyptian varieties with high yield and its components with high nutritional value under Egyptian conditions.

MATERIALS AND METHODS

Plant materials and field experiments

The present investigation was carried out at the Experimental Farm of Rice Department-Agricultural Research Station, Sakha, Kafr El-Sheikh, Egypt, during the two successive seasons 2019 and 2020. The experimental material of the present study comprised of eight parental rice lines namely; Dular, Black Rice, Red Rice, IRBLKM-TS-[CO], IR71567-108-1-2, B40, KWANG CHANG Ai and IRBLTA- CT2 and four testers having diverse agronomical characters namely; Giza 177, Giza 178, Sakha 101 and Sakha 108 The name, pedigree, and origin of used parents are shown in Table 1.

Table 1. Rice parental lines, parentage origin and grain type.

No.	Entries	Pedigree	Origin	Type
1	Giza 177 (T1)	[Giza 171] Ymji No.1 // PiNo.4	Egypt	Japonica
2	Giza 178 (T2)	Giza175/ Milyang 49	Egypt	Indica / Japonica
3	Sakha 101 (T3)	Giza 176/Milyang 79	Egypt	Japonica
4	Sakha 108 (T4)	Sakha101/ HR5824-B-3-2-3// Sakha 101	Egypt	Japonica
5	Dullar (ACC32561) (L1)	DUMAI/LARKOCH	INDIA	Indica
6	Black Rice (Jiegnou9601) (L2)	CHINESE LINE	IRRI	Japonica
7	Red Rice (L3)	UNKNOWEN	CHINA	Indica / Japonica
8	IRBLKM-TS-[CO] (L4)	CO 39*7/TSUYUAKE	IRRI	Indica / Japonica
9	IR71567-108-1-2 (L5)	IR66159-164-5-3-5/IR66452-179-2-6-1-4	IRRI	Indica / Japonica
10	B 40 (L6)	KAOHSIUNG21//SERATUS MALAM/IR5	INDONESIA	Indica
11	KWANG CHANG Ai (L7)	UNKNOWEN	CHINA	Japonica
12	IRBLTA- CT2 (L8)	LIJIANG XINTUAN HEIGU*4/C 105 TTP-2L 9	IRRI	Indica / Japonica

In 2019 growing season, the eight lines and the four testers were sown in three successive sowing dates of planting with ten days intervals in order to overcome the differences in flowering time among parents. After 30 days old seedlings each parent was individually transplanted in the permanent field in three rows, 5 meters long and 20 x 20 cm apart between plants and rows. At flowering time, the eight lines were crossed with the four testers to produce 32 F_1 crosses using bulk emasculation method according to Butany (1961) by using hot water (42-44 °C for 10 min). In 2020 season, the parents and their F_1 crosses were evaluated in a randomized complete block design (RCBD) with three replications. Each genotype (parents and F_1 crosses) was planted in three rows per replicate. Each row was 5.0 m long with the spacing of 20 × 20 cm among rows and hills. All other recommended agricultural rice practices were applied at the proper time.

Data collection

Data were collected on days to heading (day), plant height (cm), number of tillers plant^{-1}, number of panicles plant^{-1}, panicle length (cm), panicle weight (g), fertility %, 1000-grain weight (g) and grain yield (g/p), according to the standard evaluation system for rice (IRRI, 1996). Fe and Zn contents in the grains (were measured in Central Laboratory for Environmental Studies-Kafrelsheikh University (KUCLES) using Atomic Absorption Spectrometry (GBC Avanta E, Victoria, Australia).

Statistical analysis

The obtained data were subjected to ordinary analysis of variances according to Steel and Torrie (1980). General and specific combining ability effects and variances were estimated according to Kempthorne (1957). Heterosis percentages relative to mid parents were calculated according Mather (1949).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance (Table 2) showed highly significant mean squares due to the genotypes and their partitioning (parents, crosses and parents vs. crosses) for all the studied traits. This indicates the existed of a wide diversity among the genetic materials used in this study. Moreover, mean squares due to parents vs. crosses (P vs. C) as an indication to average heterosis were highly significant for all the studied traits. Highly significant differences were detected among L, T and L × T for all the studied traits.

Table 2. Mean squares from the ordinary and line by tester analysis for all the studied traits.

S.O.V	d.f	Days to heading	Plant height	No. of tillers/plant	No. of panicles/ plant
Replications	2	8.85	54.07	17.34	10.30
Genotypes	43	152.92**	720.31**	38.15**	36.95**
Parents (P)	11	182.07**	1271.36**	54.03**	51.89**
Crosses (C)	31	48.20**	540.28**	21.36**	22.06**
P vs. C	1	3078.64**	239.47**	384.03**	334.23**
Lines (L)	7	113.51**	1660.97**	25.69**	24.37**
Testers (T)	3	115.54**	169.32**	88.95**	87.87**
L x T	21	16.81**	219.71**	10.26**	11.90**
Error	86	1.97	13.77	5.98	4.81

***, ** Significant at 0.05 and 0.01 levels of probability, respectively**

Table 2. Cont.

S.O.V	d.f	Panicle weight	Panicle length	Spikelet fertility	1000-grain weight	Grain yield/plant
Replications	2	0.55	9.55	4.25	0.99	0.10
Genotypes	43	1.25*	23.70**	70.00**	14.18**	678.08**
Parents (P)	11	1.79**	15.14**	5.11**	13.95**	110.49**
Crosses (C)	31	1.10**	18.83**	85.90**	14.69**	226.34**
P *vs.* C	1	0.00	268.55**	290.71**	1.08**	20925.56**
Lines (L)	7	1.84**	28.51**	83.87**	5.31**	294.38**
Testers (T)	3	1.04**	44.44**	187.95**	88.42**	277.40**
L x T	21	0.86**	11.95**	72.00**	7.28**	196.37**
Error	86	0.04	1.51	1.38	0.18	13.42

***, ** Significant at 0.05 and 0.01 levels of probability, respectively**

Mean performance

Data in Table 3 shows that the IRBLKM- TS [CO] (L4) and Dullar (L1) as the parental genotypes as well as the cross combinations Dullar x Giza 177 and IRBLKM-TS-[CO] x Giza 177 had the earliest heading. For plant height, the parent Sakha 101(T3) and Black Rice (L2) recorded the lowest value (92.67 and 94.67cm), while the parent B40 gave the highest value (148.67cm). Among the F_1 hybrids, the shortest ones (81.67 cm) were exhibited by the cross IR71567-108-1-2 x Sakha 101.

Table 3. Mean performance of lines, testers and their hybrid rice combinations for studied traits.

Genotypes	Days to heading	Plant height (cm)	No. of tillers/ plant	No. of panicles/ plant
Dullar	85.33	143.67	17.00	15.00
Black Rice	91.67	94.67	13.00	11.33
Red Rice	103.33	105.00	18.67	15.67
IRBLKM-TS-[CO]	82.67	144.00	13.33	11.00
IR71567-108-1-2	89.67	111.00	14.33	11.67
B 40	96.67	148.67	15.33	13.00
KWANG CHANG Ai	95.67	98.00	14.67	12.67
IRBLTA- CT2	93.00	112.00	15.00	13.33
Giza 177	94.33	99.00	21.00	19.00
Giza 178	101.67	100.33	24.33	22.00
Sakha 101	106.00	92.67	23.33	21.33
Sakha 108	107.00	94.33	23.67	21.00
Dullar x Giza 177	96.00	126.67	20.00	17.67
Black Rice x Giza 177	105.33	101.00	18.00	16.33
Red Rice x Giza 177	111.67	104.33	19.67	17.67
IRBLKM-TS-[CO]x Giza 177	96.33	107.00	22.67	20.00
IR71567-108-1-2 x Giza 177	104.67	113.67	19.67	17.33
B40 x Giza 177	104.67	128.33	16.33	14.67
KWANG CHANG Ai x Giza 177	106.67	114.67	21.33	19.33
IRBLTA- CT2 x Giza 177	106.67	112.33	18.67	16.33
Dullar x Giza 178	105.33	139.00	27.33	25.00
Black Rice x Giza 178	102.33	104.33	24.33	22.33
Red Rice x Giza 178	105.33	106.33	26.33	23.67
IRBLKM-TS-[CO]x Giza 178	105.33	107.00	20.33	18.33
IR71567-108-1-2 x Giza 178	103.33	102.67	24.00	21.33
B40 x Giza 178	105.33	135.00	24.00	22.00
KWANG CHANG Ai x Giza 178	106.67	108.67	22.33	20.00
IRBLTA- CT2 x Giza 178	107.67	102.00	25.00	22.33
Dullar x Sakha 101	103.00	133.00	22.33	20.33
Black Rice x Sakha 101	107.00	99.67	20.33	17.67
Red Rice x Sakha 101	111.67	114.33	23.00	19.33
IRBLKM-TS-[CO]x Sakha 101	103.67	123.67	24.67	22.33
IR71567-108-1-2 x Sakha 101	106.67	81.67	19.67	16.00
B40 x Sakha 101	110.00	140.33	17.33	14.00
KWANG CHANG Ai x Sakha 101	108.67	108.00	23.67	21.33
IRBLTA- CT2 x Sakha 101	111.67	120.67	22.33	20.00
Dullar x Sakha 108	103.67	133.00	22.67	17.00
Black Rice x Sakha 108	107.00	100.00	21.00	19.00
Red Rice x Sakha 108	112.67	126.00	23.33	18.67
IRBLKM-TS-[CO]x Sakha 108	104.00	110.67	24.33	21.67
IR71567-108-1-2 x Sakha 108	108.67	118.33	19.33	17.33
B40 x Sakha 108	111.67	132.67	17.67	14.33
KWANG CHANG Ai x Sakha 108	110.33	118.33	22.00	19.67
IRBLTA- CT2 x Sakha 108	111.67	121.00	22.33	20.00
LSD 0.05%	1.31	3.47	2.28	2.05
0.01 %	1.73	4.59	3.02	2.71

***, **Significant at 0.05 and 0.01 levels of probability, respectively.**

The parental genotypes Red Rice and Giza178 as well as the hybrids Duller x Giza 178 and Red Rice x Giza 178 recorded the highest number of tillers and panicles plant^{-1}. Regarding panicle weight in Table 4, the parent Sakha 101 and the cross B40 x Sakha 101 recorded the highest panicle weight 4.90g and 5.04g, respectively.

Table 4. Mean performance of lines, testers and their hybrid rice combinations for yield and it`s components characters.

Genotype	Panicle weight (g)	Panicle length (cm)	Fertility %	1000-grain weight	Grain yield
Dullar	3.89	26.82	90.51	25.06	56.67
Black Rice	2.96	19.70	92.70	27.10	35.33
Red Rice	3.81	22.67	89.93	23.04	55.00
IRBLKM-TS-[CO]	3.74	23.25	91.04	25.56	48.33
IR71567-108-1-2	3.57	18.42	89.74	25.98	47.33
B 40	2.78	22.65	93.96	21.87	45.67
KWANG CHANG Ai	2.41	23.64	89.59	24.89	42.67
IRBLTA- CT2	2.60	19.63	91.35	24.85	47.67
Giza 177	3.58	21.29	92.07	28.01	37.67
Giza 178	4.04	23.21	91.70	22.80	43.67
Sakha 101	4.90	23.30	90.33	28.17	46.67
Sakha 108	4.63	21.54	90.63	28.23	46.33
Dullar x Giza 177	3.44	24.67	87.04	28.84	78.33
Black Rice x Giza 177	2.98	19.67	94.23	29.99	60.00
Red Rice x Giza 177	3.28	20.33	93.55	27.16	71.00
IRBLKM-TS-[CO]x Giza 177	3.88	24.83	94.61	29.73	82.00
IR71567-108-1-2 x Giza 177	3.33	23.88	89.54	25.32	77.00
B40 x Giza 177	3.39	24.67	88.53	28.15	67.67
KWANG CHANG Ai x Giza 177	2.81	25.60	89.27	26.84	65.33
IRBLTA- CT2 x Giza 177	3.40	25.27	93.62	26.32	77.00
Dullar x Giza 178	3.34	23.71	91.68	25.01	85.00
Black Rice x Giza 178	3.77	26.15	79.66	22.18	63.00
Red Rice x Giza 178	3.47	24.78	82.25	23.49	83.33
IRBLKM-TS-[CO]x Giza 178	2.85	23.59	78.70	24.09	69.00
IR71567-108-1-2 x Giza 178	4.07	25.44	91.48	23.16	66.33
B40 x Giza 178	4.31	25.99	92.71	21.92	75.67
KWANG CHANG Ai x Giza 178	3.76	27.82	88.61	22.97	57.67
IRBLTA- CT2 x Giza 178	3.73	24.00	87.93	22.77	66.67
Dullar x Sakha 101	4.48	29.16	88.01	26.14	70.33
Black Rice x Sakha 101	3.34	24.11	96.10	26.93	76.33
Red Rice x Sakha 101	4.87	26.06	87.23	25.83	75.67
IRBLKM-TS-[CO]x Sakha 101	3.82	23.86	86.40	25.63	87.67
IR71567-108-1-2 x Sakha 101	2.97	23.34	94.18	24.76	84.67
B40 x Sakha 101	5.04	29.93	77.32	22.44	66.67
KWANG CHANG Ai x Sakha 101	3.22	25.60	86.39	27.84	78.33
IRBLTA- CT2 x Sakha 101	2.70	24.84	92.53	23.64	86.33
Dullar x Sakha 108	4.08	30.44	85.21	25.07	66.33
Black Rice x Sakha 108	3.52	24.14	93.64	26.86	75.00
Red Rice x Sakha 108	3.58	25.80	81.02	26.61	74.67
IRBLKM-TS-[CO]x Sakha 108	3.85	27.60	81.43	23.74	85.33
IR71567-108-1-2 x Sakha 108	3.44	26.48	88.07	26.53	80.33
B40 x Sakha 108	4.40	31.11	80.33	28.78	59.33
KWANG CHANG Ai x Sakha 108	2.48	26.40	79.82	26.97	81.67
IRBLTA- CT2 x Sakha 108	2.93	22.85	88.41	25.63	85.67
LSD 0.05%	0.187	1.14	1.09	0.396	3.42
0.01 %	0.247	1.52	1.45	0.525	4.53

***, **Significant at 0.05 and 0.01 levels of probability, respectively.**

Large variation among the tested rice genotypes were detected for panicle length. The parents, Duller had the longest panicle length (26.82 cm), while IR71567-108-1-2 recorded the lowest value (18.42 cm). On the other hand, such estimates were maximized in the hybrid B40 x Sakha108 (31.11 cm) followed by the cross Dullar x Sakha 108

(30.44cm). The parental genotype B40 and the hybrid Black Rice x Sakha 101 gave the highest value of fertility 93.96% and 96.10%, respectively. Among the tested parents, Black Rice recorded the heaviest 1000-grain weight (27.10 g) followed by Sakha 108 (28.23g). While, among F_1 hybrids, the highest 1000-grain weight (29.99 g) was observed in the cross Black Rice x Giza 177, followed by IRBLKM-TS-[CO] x Giza 177 (29.73 g). As shown in Table 3, compared with the other parents, Sakha 101 recorded the highest grain yield/plant (46.67 g). While, the parent Black Rice exhibited the lowest grain yield (35.33 g). Among the F_1 hybrids, the crosses IRBLKM-TS-[CO] x Sakha 101, IRBLTA- CT2 x Sakha 101 and IRBLTA- CT2 x Sakha 108 gave the highest mean value with an average of 87.67, 86.33 and 85.67 g, respectively.

General combining ability effects (GCA)

Estimates of GCA effects of individual parent (line and tester) for each trait are shown in Table 5. High positive estimates of GCA effects are desirable for all studied traits, except days to heading which negative estimates are favorable. Results showed that the parental lines Dullar and IRBLKM-TS-[CO] had the highest desirable significant and negative GCA effects for days to heading, indicating that these parents could be considered as good combiners for earliness. Similarly, Black Rice, IRBLKM-TS-[CO], KWANG CHANG Ai and IRBLTA- CT2 showed highly significant and negative GCA effects for plant height, indicating that these parents could be considered as a good combiner for developing short stature genotypes. On the other hand, the highest desirable significant and positive GCA effects were obtained by the parental lines IRBLKM-TS-[CO] for No. of panicles plant^{-1}; Dullar, Red Rice and B40 for panicle weight; Dullar, B 40 and KWANG CHANG Ai for panicle length; Black Rice, IR71567-108-1-2 and IRBLTA- CT2 for spikelet fertility %; Dullar, Black Rice and KWANG CHANG Ai for 1000-grain weight and IRBLKM-TS-[CO] and IRBLTA- CT2 for grain yield/plant. These lines had favorable genes and the improvement in these traits may be attained if they are used in rice hybridization program.

Regarding to the testers, Giza 177 was found to be good general combiner for earliness, spikelet fertility % and 1000-grain weight. The parental tester Giza 178 showed highly significant positive GCA effects for number of tillers and panicles plant^{-1}. The parental tester Sakha 101 showed highly significant positive GCA effects for grain yield.

Table 5. Estimates of general combining ability effects of lines and testers rice genotypes for all study characters.

Lines	Days to heading	Plant height (cm)	No. of tillers/plant	No. of panicles/plant
Dullar	-4.43**	17.28**	1.45*	0.84
Black Rice	-1.01**	-12.97**	-0.97	-0.32
Red Rice	3.91**	-0.72	0.78	0.68
IRBLKM-TS-[CO]	-4.01**	-3.97**	1.36*	1.43*
IR71567-108-1-2	-0.59	-11.97**	-0.97	-1.16*
B 40	1.49**	18.03**	-2.80**	-2.91**
KWANG CHANG Ai	1.66**	-3.64**	0.70	0.93
IRBLTA- CT2	2.99**	-2.05*	0.45	0.51
LSD 0.05%	0.67	1.78	1.18	1.05
0.01 %	0.96	2.54	1.68	1.50
Testers	Days to heading	Plant height (cm)	No. of tillers/plant	No. of panicles/plant
Giza 177	-2.43**	-1.30*	-2.09**	-1.74**
Giza 178	-1.22**	-1.76*	2.57**	2.72**
Sakha 101	1.36**	-0.89	-0.26	-0.28
Sakha 108	2.28**	3.95**	-0.22	-0.70
LSD 0.05%	0.48	1.26	0.83	0.75
0.01 %	0.68	1.80	1.19	1.06

***, **Significant at 0.05 and 0.01 levels of probability, respectively.**

Table 5. Cont.

Lines	Panicle weight	Panicle length	Spikelet fertility %	1000-grain weight	Grain yield
Dullar	0.25**	1.62**	0.19	0.60**	0.65
Black Rice	-0.18**	-1.86**	3.11**	0.82**	-5.77**
Red Rice	0.22**	-1.14**	-1.79**	0.10	1.81*
IRBLKM-TS-[CO]	0.02	-0.41	-2.51**	0.13	6.65**
IR71567-108-1-2	-0.13*	-0.59	3.02**	-0.72**	2.73**
B 40	0.71**	2.55**	-3.08**	-0.34*	-7.02**
KWANG CHANG Ai	-0.51**	0.98**	-1.78**	0.49**	-3.60**
IRBLTA- CT2	-0.39**	-1.14**	2.82**	-1.08**	4.56**
LSD 0.05%	0.09	0.59	0.56	0.20	1.76
0.01 %	0.13	0.84	0.80	0.29	2.51
Testers	Panicle weight	Panicle length	Spikelet fertility %	1000-grain weight	Grain yield
Giza 177	-0.26**	-1.76**	3.50**	2.13**	-2.06**
Giza 178	0.08*	-0.19	-1.17**	-2.47**	-3.52**
Sakha 101	0.23**	0.48*	0.72**	-0.27**	3.90**
Sakha 108	-0.04	1.47**	-3.06**	0.61**	1.69*
LSD 0.05%	0.06	0.42	0.40	0.14	1.24
0.01 %	0.09	0.60	0.57	0.20	1.78

***, **Significant at 0.05 and 0.01 levels of probability, respectively.**

Specific combining ability effect (SCA)

Estimates of SCA effects of the 32 F1 hybrid combinations for all the studied characters are shown in Table (6). The results showed that four crosses Dullar x Giza 177, Red Rice x Giza 178, IRBLKM-TS-[CO] x Giza 177 and B40 x Giza 178 had significant and negative SCA effects for days to heading towards earliness.

Table 6. Estimates of specific combining ability effects of lines and testers rice genotypes.

Hybrid combinations	Days to Heading	Plant hight	No. of Tillers/palnt	No. of Panicles/plant
Dullar x Giza 177	-3.57**	-5.36**	-0.99	-0.59
Black Rice x Giza 177	2.34**	1.22	-0.57	-0.76
Red Rice x Giza 177	3.76**	-1.70	-0.66	-0.43
IRBLKM-TS-[CO]x Giza 177	-3.66**	-3.78*	1.76	1.16
IR71567-108-1-2 x Giza 177	1.26	10.89**	1.09	1.07
B40 x Giza 177	-0.82	-4.45*	-0.41	0.16
KWANG CHANG Ai x Giza 177	1.01	3.55	1.09	0.99
IRBLTA- CT2 x Giza 177	-0.32	-0.36	-1.32	-1.59
Dullar x Giza 178	4.55**	9.09**	1.68	2.28*
Black Rice x Giza 178	-1.86*	8.34**	1.09	0.78
Red Rice x Giza 178	-3.78**	-4.91*	1.34	1.11
IRBLKM-TS-[CO]x Giza 178	4.47**	-3.32	-5.24**	-4.97**
IR71567-108-1-2 x Giza 178	-1.28	0.34	0.76	0.61
B40 x Giza 178	-1.36*	2.68	2.59*	3.03**
KWANG CHANG Ai x Giza 178	-0.20	-3.53	-2.57*	-2.80*
IRBLTA- CT2 x Giza 178	-0.53	-10.24**	0.34	-0.05
Dullar x Sakha 101	-0.36	0.55	-0.49	0.61
Black Rice x Sakha 101	0.22	-2.53	-1.07	-0.89
Red Rice x Sakha 101	-0.03	-0.11	-0.49	-0.22
IRBLKM-TS-[CO]x Sakha 101	-0.11	12.47**	1.93	2.03
IR71567-108-1-2 x Sakha 101	-0.53	-21.53**	-0.74	-1.72
B40 x Sakha 101	0.72	7.14**	-1.24	-1.97
KWANG CHANG Ai x Sakha 101	-0.78	-3.53	1.59	1.53
IRBLTA- CT2 x Sakha 101	0.89	7.55**	0.51	0.61
Dullar x Sakha 108	-0.61	-4.28*	-0.20	-2.30*
Black Rice x Sakha 108	-0.70	-7.03**	0.55	0.86
Red Rice x Sakha 108	0.05	6.72**	-0.20	-0.47
IRBLKM-TS-[CO]x Sakha 108	-0.70	-5.36**	1.55	1.78
IR71567-108-1-2 x Sakha 108	0.55	10.30**	-1.11	0.03
B40 x Sakha 108	1.47*	-5.36**	-0.95	-1.22
KWANG CHANG Ai x Sakha 108	-0.03	1.97	-0.11	0.28
IRBLTA- CT2 x Sakha 108	-0.03	3.05	0.47	1.03
LSD 0.05%	1.35	3.56	2.35	2.11
0.01 %	1.92	5.09	3.35	3.01

***, **Significant at 0.05 and 0.01 levels of probability, respectively.**

Table 6. Cont.

Hybrid combinations	Panicle weight	Panicle length	Fertility %	1000-grain weight	Grain yield
Dullar x Giza 177	-0.13	-0.56	-4.45**	0.45	5.40**
Black Rice x Giza 177	-0.16	-2.09**	-0.18	1.37**	-6.52**
Red Rice x Giza 177	-0.25*	-2.15**	4.04**	-0.74**	-3.10
IRBLKM-TS-[CO]x Giza 177	0.54**	1.63*	5.82**	1.80**	3.06
IR71567-108-1-2 x Giza 177	0.15	0.86	-4.78**	-1.75**	1.98
B40 x Giza 177	-0.63**	-1.50*	0.31	0.70*	2.40
KWANG CHANG Ai x Giza 177	0.00	1.01	-0.25	-1.44**	-3.35
IRBLTA- CT2 x Giza 177	0.48**	2.79**	-0.51	-0.39	0.15
Dullar x Giza 178	-0.58**	-3.09**	4.86**	1.21**	13.52**
Black Rice x Giza 178	0.28**	2.83**	-10.08**	-1.84**	-2.06
Red Rice x Giza 178	-0.41**	0.73	-2.59**	0.19	10.69**
IRBLKM-TS-[CO]x Giza 178	-0.83**	-1.19*	-5.41**	0.76**	-8.48**
IR71567-108-1-2 x Giza 178	0.53**	0.85	1.83**	0.69*	-7.23**
B40 x Giza 178	-0.05	-1.74**	9.15**	-0.93**	11.85**
KWANG CHANG Ai x Giza 178	0.61**	1.66*	3.76**	-0.72*	-9.56**
IRBLTA- CT2 x Giza 178	0.45**	-0.04	-1.52*	0.65*	-8.73**
Dullar x Sakha 101	0.42**	1.68*	-0.70	0.14	-8.56**
Black Rice x Sakha 101	-0.29**	0.11	4.47**	0.71*	3.85*
Red Rice x Sakha 101	0.84**	1.33*	0.49	0.32	-4.40*
IRBLKM-TS-[CO]x Sakha 101	-0.01	-1.60*	0.39	0.10	2.77
IR71567-108-1-2 x Sakha 101	-0.71**	-1.93**	2.64**	0.08	3.69*
B40 x Sakha 101	0.52**	1.52*	-8.12**	-2.62**	-4.56*
KWANG CHANG Ai x Sakha 101	-0.07	-1.23*	-0.36	1.95**	3.69*
IRBLTA- CT2 x Sakha 101	-0.71**	0.11	1.18*	-0.69*	3.52*
Dullar x Sakha 108	0.29**	1.97**	0.28	-1.80**	-10.35**
Black Rice x Sakha 108	0.16	-0.85	5.79**	-0.24	4.73*
Red Rice x Sakha 108	-0.18	0.09	-1.94**	0.23	-3.19
IRBLKM-TS-[CO]x Sakha 108	0.30**	1.16	-0.80	-2.66**	2.65
IR71567-108-1-2 x Sakha 108	0.03	0.22	0.31	0.98**	1.56
B40 x Sakha 108	0.16	1.71**	-1.34*	2.85**	-9.69**
KWANG CHANG Ai x Sakha 108	-0.54**	-1.43*	-3.15**	0.21	9.23**
IRBLTA- CT2 x Sakha 108	-0.22*	-2.86**	0.84	0.43	5.06**
LSD 0.05%	0.18	1.18	1.13	0.40	3.52
0.01 %	0.26	1.68	1.61	0.57	5.02

***, **Significant at 0.05 and 0.01 levels of probability, respectively.**

Regarding plant height, nine crosses showed highly significant desirable SCA effects. The crosses IR71567-108-1-2 x Sakha 101 and IRBLTA- CT2 x Giza 178 and Black Rice x Sakha 108 had the highest desirable effects and considered good specific combiners for short plant stature. The hybrid combinations B40 x Giza 178 and Dullar x Giza 178 showed highly significant and positive SCA effects for number tillers and panicles.

Concerning panicle weight, eleven hybrids gave highly significant positive SAC effects. The best crosses were Red Rice x Sakha 101 and Dullar x Giza178. These crosses could be used in breeding program to improve this trait. Ten hybrids had positive and significant SCA effects for spikelet fertility %.The highest desirable effects were detected by the crosses B40 x Giza 178, IRBLKM-TS-[CO] x Giza 177 and Black Rice x Sakha 108. The hybrid combinations Dullar x Giza 178, Red Rice x Giza 178, B40 x Giza 178, KWANG CHANG Ai x Sakha 108, Dullar x Giza 177 and IRBLTA- CT2 x Sakha 108 had the best SCA effects for grain yield/plant. These crosses could be used in rice breeding programs for improving grain yield and its related traits. These results are in harmony with those obtained by Sanghera and Hussain (2012).

Genetic components

The comparative estimates of general (σ^2GCA) and specific combining ability (σ^2SCA) variances showed that the value of the σ^2GCA variance was less than the value of σ^2SCA variance (Table 7). Moreover, the ratio of σ^2GCA/σ^2SCA was less than unity for all studied traits. These results indicated that the non-additive gene effects played a major role in the genetic expression of these traits. The results revealed that the estimate of dominance genetic variance (σ2 D) was higher than the additive genetic variance (σ^2 A) for all studied traits. Concerning heritability estimates in broad sense (h^2_b%), the results indicated that the heritability values were high for the all studied traits, except No. of tillers plant^{-1} and No. of panicles plant^{-1} , they had low values being 22.40 and 35.69 respectively. However, heritability estimates in the narrow sense (h^2_n) were low for all traits under study. These results indicated that a major part of the total genotypic variance was non-additive in nature for these traits. Contribution of lines, testers and line x tester interaction is presented in Table (6). The contribution of lines was greater than testers for most study characters except No. of tillers plant^{-1}, No. of panicles plant^{-1} and 1000 grain weight were 26.82, 24.94 and 8.17 %. Contribution of testers was more than lines and line × tester interactions in No. of tillers plant^{-1}, No. of panicles plant^{-1} and 1000-grain weight with value of 40.78, 38.54 and 58.25 %. On the other hand, line × tester interactions contributed more than lines and testers for four traits. These traits were Panicle weight (53.10%), Panicle length (42.97%), Spikelet fertility % (56.78%), and grain yield plant^{-1} (58.77%). These results are in agreement with those obtained by Hasan *et al.*, (2015) and Anis *et al.*, (2016).

Table 7. Estimates of genetic components and contribution of lines, testers and line x tester to the total variance in rice genotypes.

Genetic parameters	Days to heading	Plant height (cm)	No. of tillers/ plant	No. of panicles/plant	Panicle weight	Panicle length	Spikelet fertility %	1000-grain weight	Grain yield
σ^2GCA	0.50	5.07	0.17	0.16	0.00	0.10	0.15	0.11	0.29
σ^2 SCA	4.95	68.65	1.43	2.36	0.28	3.48	23.54	2.37	60.98
σ^2GCA/ σ^2SCA	0.101	0.073	0.11	0.067	0	0.028	0.006	0.046	0.004
σ^2 A	1.00	10.15	0.35	0.31	0.01	0.20	0.31	0.23	0.57
σ^2 D	4.95	68.65	1.43	2.36	0.028	3.48	23.54	2.37	60.98
σ^2 A/ σ^2 D	0.202	0.147	0.244	0.131	0.357	0.057	0.013	0.097	0.009
h^2_b %	75.10	85.13	22.85	35.69	88.53	70.91	94.54	93.67	82.10
h^2_n %	12.67	10.96	4.46	4.16	1.90	3.90	1.22	8.28	0.76
Contribution (%) of lines	53.18	69.42	27.15	24.94	37.78	34.19	22.05	8.17	29.37
Contribution (%) of Testers	23.20	3.03	40.30	38.54	9.12	22.84	21.17	58.25	11.86
Contribution (%) of Line x Tester	23.62	27.55	32.55	36.52	53.10	42.97	56.78	33.58	58.77

Heterosis

Heterosis relative to mid parents for all the studied characters is presented in Table 8. There was a negative and significant heterosis for all studied traits. For plant height, the crosses IR71567-108-1-2 x Sakha 101, IRBLKM-TS-[CO] x Giza 178, IRBLKM-TS-[CO] x Giza 177, IRBLKM-TS-[CO] x Sakha 108 recorded negative significant heterosis for plant height. On the other hand positive and significant heterotic effects were detected by most of the crosses for number of tillers and panicles plant^{-1}. The cross Dullar x Giza 178 recoded the highest positive and significant effects. Regarding panicle weight, the hybrids exhibited positive and significant heterotic effects. For panicle length, the hybrids had the highest positive and significant heterotic effects. For grain yield, IRBLKM-TS-[CO] x Giza 177 and Black Rice x Sakha 101 gave the highest significant heterosis.

Minerals components

Gómez-Galera *etal.*, (2010) reported that, iron (Fe) and zinc (Zn), are the most important metal elements, and presented in low quantities of staple food, such as rice and wheat. In some parts of Africa and Asia, people even cannot afford enough food for their kids and families. Fe deficiency is one of the leading risk factors of disability and death worldwide. It is estimated to affect two billion people in the world Sperotto *et.al*., (2012). Slamet-Loedin *etal*., (2015), Alloway (2009), Kobayashi *et.al*.,(2010) and Bashir *et.al*., (2012) all mention that Fe-deficiency anemia can impair cognitive and physical development in children and the reduction of daily productivity in adults. Adequate Zn nutrition is also important for the growth of children, immune function, and neurobehavioral development. So, Fe and Zn deficiency has emerged as a major and common problem for the health of humans and for this increasing Fe/Zn content of rice has a great potential to mitigate widespread Fe/Zn deficiency problem in humans.

Table 9, data showed that the minerals content (Fe and Zn) in brown grains was higher in some genotypes under this study. Sakha 108 and Dullar have the highest minerals content (850& 635.6mg/kg for Fe and 115.25, 93.75 mg/kg for Zn). For the hybrids, the crosses Red Rice x Giza 178, IR71567-108-1-2 x Giza177 and B40 x Sakha 108 gave the highest content (650,567.5 and 620 mg Fe/kg and 215.75, 54.75 and 68mg Zn/ kg respectively.

Table 8. Heterosis % for F_1 crosses under study for all studied characters (vegetative, yield and it`s components).

Hybrid combinations	Days to Heading	Plant hight	No. of Tillers/palnt	No. of Panicles/plant
Dullar x Giza 177	6.86**	4.39**	5.26**	3.94**
Black Rice x Giza 177	13.25**	4.30**	5.88**	7.68**
Red Rice x Giza 177	12.99**	2.28**	-0.83**	1.93**
IRBLKM-TS-[CO]x Giza 177	8.84**	-11.93**	32.07**	15.37**
IR71567-108-1-2 x Giza 177	13.77**	8.25**	11.35**	15.53**
B40 x Giza 177	9.60**	3.62**	-10.10**	-8.31**
KWANG CHANG Ai x Giza 177	12.28**	16.41**	19.59**	22.07**
IRBLTA- CT2 x Giza 177	13.88**	6.47**	3.72**	1.020
Dullar x Giza 178	12.65**	13.93**	32.25**	35.13**
Black Rice x Giza 178	5.85**	7.00**	30.35**	33.99**
Red Rice x Giza 178	2.76**	3.56**	22.46**	25.67**
IRBLKM-TS-[CO]x Giza 178	14.64**	-12.41**	7.96**	11.09**
IR71567-108-1-2 x Giza 178	8.00**	-2.83**	24.15**	26.70**
B40 x Giza 178	6.21**	8.43**	21.02**	25.71**
KWANG CHANG Ai x Giza 178	8.10**	9.58**	14.51**	15.37**
IRBLTA- CT2 x Giza 178	10.61**	-3.92**	27.12**	26.40**
Dullar x Sakha 101	7.66**	12.54**	10.73**	11.91**
Black Rice x Sakha 101	8.26**	6.40**	6.41**	8.20**
Red Rice x Sakha 101	6.69**	4.25**	9.52**	4.48**
IRBLKM-TS-[CO]x Sakha 101	9.89**	4.50**	34.58**	38.13**
IR71567-108-1-2 x Sakha 101	9.03**	-19.80**	4.46**	-3.03**
B40 x Sakha 101	8.55**	16.29**	-10.34**	-18.43**
KWANG CHANG Ai x Sakha 101	7.77**	13.28**	24.57**	25.47**
IRBLTA- CT2 x Sakha 101	12.23**	17.91**	16.51**	15.40**
Dullar x Sakha 108	7.80**	11.76**	11.48**	-5.55**
Black Rice x Sakha 108	7.71**	5.82**	14.53**	17.53**
Red Rice x Sakha 108	7.14**	26.42**	10.20**	1.82**
IRBLKM-TS-[CO]x Sakha 108	9.66**	-7.12**	31.51**	35.43**
IR71567-108-1-2 x Sakha 108	10.51**	-0.70	1.73*	6.09**
B40 x Sakha 108	9.66**	9.19**	-9.38**	-15.70**
KWANG CHANG Ai x Sakha 108	8.87**	23.04**	14.76**	16.83**
IRBLTA- CT2 x Sakha 108	11.67**	17.28**	15.49**	16.51**
LSD 0.05%	0.803	2.12	1.40	1.25
0.01 %	1.06	2.81	1.85	1.66

***, **Significant at 0.05 and 0.01 levels of probability, respectively**

Table 8. Cot.,

Hybrid combinations	Panicle weight	Panicle length	Fertility %	1000-grain weight	Grain yield
Dullar x Giza 177	-7.89**	2.55**	4.65**	8.68**	66.05**
Black Rice x Giza 177	-8.87**	-4.02**	1.99**	8.83**	64.38**
Red Rice x Giza 177	-11.23**	-7.51**	2.80**	6.40**	53.23**
IRBLKM-TS-[CO]x Giza 177	6.01**	11.49**	3.33**	10.99**	90.69**
IR71567-108-1-2 x Giza 177	-6.85**	20.27**	-1.5**	-6.20**	81.17**
B40 x Giza 177	6.60**	12.29**	-4.82**	12.87**	62.39**
KWANG CHANG Ai x Giza 177	-6.17**	13.95**	-1.7**	1.47**	62.63**
IRBLTA- CT2 x Giza 177	10.03**	23.5**	2.12**	-0.41**	80.45**
Dullar x Giza 178	-15.76**	-5.21**	0.631	4.51**	69.42**
Black Rice x Giza 178	7.71**	21.88**	-13.6**	-11.10**	59.49**
Red Rice x Giza 178	-11.23**	8.02**	-9.1**	2.48**	68.90**
IRBLKM-TS-[CO]x Giza 178	26.73**	1.54**	-13.87**	-0.37**	50.00**
IR71567-108-1-2 x Giza 178	6.96**	22.22**	0.838**	-5.04**	45.78**
B40 x Giza 178	26.39**	13.34**	-0.129**	-1.85**	69.39**
KWANG CHANG Ai x Giza 178	16.59**	18.76**	-2.24**	-3.66**	33.58**
IRBLTA- CT2 x Giza 178	12.34**	12.04**	-3.93**	-4.42**	45.98**
Dullar x Sakha 101	1.93*	16.36**	-2.66**	-1.78**	36.11**
Black Rice x Sakha 101	-15.01**	12.13**	5.01**	-2.55**	86.17**
Red Rice x Sakha 101	11.82**	13.37**	-3.21**	0.878**	48.85**
IRBLKM-TS-[CO]x Sakha 101	-11.57**	2.51**	-4.72**	-4.59**	84.56**
IR71567-108-1-2 x Sakha 101	-29.87**	11.88**	4.6**	-8.55**	80.14**
B40 x Sakha 101	31.25**	30.27**	-16.09**	-10.31**	44.40**
KWANG CHANG Ai x Sakha 101	-11.90**	9.07**	-3.96**	4.93**	75.35**
IRBLTA- CT2 x Sakha 101	-28.00**	16.04**	1.86**	-10.78**	83.01**
Dullar x Sakha 108	-4.22*	25.89**	-5.91**	-5.91**	28.79**
Black Rice x Sakha 108	-7.24**	17.07**	2.15**	-2.90**	83.68**
Red Rice x Sakha 108	-15.46**	16.71**	-10.25**	3.80**	47.37**
IRBLKM-TS-[CO]x Sakha 108	-8.16**	23.24**	-10.35**	-11.73**	80.28**
IR71567-108-1-2 x Sakha 108	-16.09**	32.53**	-2.34**	-2.12**	71.53**
B40 x Sakha 108	18.75**	40.80**	-12.96**	14.89**	28.97**
KWANG CHANG Ai x Sakha 108	-29.54**	17.12**	-11.41**	1.54**	83.52**
IRBLTA- CT2 x Sakha 108	-18.94**	11.00**	-2.83**	-3.42**	82.27**
LSD 0.05%	0.114	0.703	0.672	0.242	2.09
0.01 %	0.151	0.931	0.890	0.321	2.77

***, **Significant at 0.05 and 0.01 levels of probability, respectively**

Table 9. Fe and Zn mg/km content in lines, testers and their crosses.

Genotypes	Fe (mg/kg)	Zn(mg/kg)
Dullar	635.6	93.75
Black Rice	395	85.75
Red Rice	362.5	76.75
IRBLKM-TS-[CO]	322.5	70.75
IR71567-108-1-2	320	58.25
B 40	417.5	77.75
KWANG CHANG Ai	330	55.25
IRBLTA- CT2	467.5	84
Giza 177	597.5	68.75
Giza 178	417.5	70.75
Sakha 101	290	59.25
Sakha 108	850	115.25
Dullar x Giza 177	365	59.5
Black Rice x Giza 177	362.5	53.75
Red Rice x Giza 177	550	76
IRBLKM-TS-[CO]x Giza 177	317.5	39.5
IR71567-108-1-2 x Giza 177	567.5	54.75
B40 x Giza 177	350	58
KWANG CHANG Ai x Giza 177	382.5	67.5
IRBLTA- CT2 x Giza 177	342.5	48.25
Dullar x Giza 178	390	95
Black Rice x Giza 178	450	48
Red Rice x Giza 178	650	215.75
IRBLKM-TS-[CO]x Giza 178	456	50
IR71567-108-1-2 x Giza 178	452.5	42.25
B40 x Giza 178	455	58.25
KWANG CHANG Ai x Giza 178	460	52
IRBLTA- CT2 x Giza 178	455	54
Dullar x Sakha 101	262	35.75
Black Rice x Sakha 101	335	38
Red Rice x Sakha 101	324	34.68
IRBLKM-TS-[CO]x Sakha 101	345	42.5
IR71567-108-1-2 x Sakha 101	337.5	35
B40 x Sakha 101	325	61.75
KWANG CHANG Ai x Sakha 101	327.5	43.25
IRBLTA- CT2 x Sakha 101	330	46
Dullar x Sakha 108	410	48.75
Black Rice x Sakha 108	453	46.54
Red Rice x Sakha 108	400	42
IRBLKM-TS-[CO]x Sakha 108	280	54.75
IR71567-108-1-2 x Sakha 108	322.5	39.75
B40 x Sakha 108	620	68
KWANG CHANG Ai x Sakha 108	312	35.25
IRBLTA- CT2 x Sakha 108	332.5	57.45

CONCLUSION

The tendency to devise new rice lines and varieties with a high nutritional value and a high content of nutrients such as iron, zinc and others with an increase in the yield and its components is one of the new trends of the breeding programs in Egypt and the world with the aim of using them to help treat some nutritional diseases such as anemia and immunodeficiency in children and women.

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قوة الهجين والقدره علي التالف لبعض تراكيب الارز الملونة لصفات المحصول ومحتوى الحبوب من العناصرالغذائية باستخدام تحليل السلاله X الكشاف

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تم تهجين ثمانية أباء ملونة كسلالات مع أربعة كشافات فى موسم٢٠١٩ ، و تقييم ٣٢ هجين مع ابائهم فى قطاعات كاملة العشوائية فى ثلاث مكررات بالمزرعة البحثية لقسم بحوث الارز- محطة البحوث الزراعية بسخا – محافظة كفرالشيخ –مصر خلال موسم ٢٠٢٠ لدراسة متوسط الاداء ، القدره العامه و الخاصه للتالف بالاضافه الى تعريف الفعل الجينى المتحكم فى توريث الصفات المدروسة. تم دراسة كل من عدد الايام للتزهير، إرتفاع النبات (سم)، عدد الفروع للنبات ، عدد السنابل للنبات ،طول السنبلة (سم)، وزن السنبلة (جم)، نسبه الخصوبة %، وزن الاف حبة (جم) و محصول الحبوب (جم/ للنبات) و كذلك محتوي الحبوب من العناصر الغذائية كالحديد والزنك. أظهرت النتائج اختلافات معنوية بين الاباء والهجن والاباء x الهجن لكل صفات الدراسة. علاوة على ذلك ، هناك تباينات معنوية بين السلالات والكشافات والتفاعل بينهم لكل صفات الدراسة. وكان لتأثيرات الجين غير المضيف دورا هاما فى وراثة كل الصفات تحت الدراسه أكثر من تاثيرات الجين المضيف. تعتبر السلالات-Dullar, Black Rice and IRBLKM TS-[CO]الأفضل فى التبكير والسلالات KWANG CHANG Ai والارز الاسود مع الصنف سخا ١٠١الاقل طولا. بينما السلالات Dullar ، Red Rice، IRBLKM-TS-[CO] و IRBLTA- CT2 مع سخا ١٠١ كانت أفضل لمحصول الحبوب وبعض مكوناته. أما الهجن: Dullar x Giza 178, Red Rice x Giza 178, B40 x Giza178, KWANG CHANG Ai x Sakha 108 , Dullar x Giza 177 IRBLTA-CT2 x Sakha108 كانوا الأفضل فى تأثير القدره الخاصه على التالف لمحصول الحبوب وبعض مكوناته أيضا. علاوة على ذلك فان الهجن: Red Rice x Giza 178، IR71567-108-1-2 x Giza 177 و B40 x Sakha108 سجلت أعلى القيم لمحتوى الحبوب من الحديد والزنك. هذه الهجن يمكن استخدامها لتحسين محصول الحبوب ومحتوى العناصر الغذائية خاصه الحديد والزنك فى برامج تربيه الأرز.