Minufiya J. Agric. Res. Vol.39 No. 1(1): 105 - 120 (2014) "http://www.mujar.net"

COMBINING ABILITY AND HETEROSIS FOR GRAIN YIELD AND ITS COMPONENT OF RICE (*ORYZA SATIVA* L.). UNDER WATER STRESS CONDITION

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(Received : Oct. 28 , 2013)

ABSTRACT: *The present investigation was carried out at the Farm of Elgemaiza Agricultural Research Station, during 2011 and 2012 summer seasons. Combining ability analysis was estimated in rice through A 6 x 6 diallel set analysis involving 6 diverse parents Sakha 101, Sakha 102, Sakha 105, IET1444, Reiho and Milyang 54 for grain yield and its related characters, at Elgemaiza. The ratio of variances due to general combining ability and specific combining ability (ó2 GCA / ó2 SCA) was more than unity, indicating the preponderance of additive genes in controlling, plant height, days to 50% heading, number of panicles/plant and grain yield/plant. Moreover, additive x additive type of gene interaction played an important role in the inheritance of most of all studied characters. On the contrary, Predominance of non-additive gene action controlled the expression of panicle length; number of filled grains/panicle and 100-grain weight. Among the parents, Sakha 101 was found to be significantly superior general combiner for all studied traits except plant height. The genotypes Sakha 105, IET1444 and Milyang 54 were good general combiners for days to 50% heading, plant height, number of panicles / plant and grain yield / plant, and Sakha 102 for days to 50% heading. Concerning, cross combinations, ten hybrids were superior for most for all studied characters. The cross Sakha 101 X Reiho gave high SCA effects for plant height, days to 50% heading, number of filled grains/panicle and grain yield/plant, cross Reiho X Milyang 54 for plant height,100- grain weight and grain yield / plant, cross Sakha 105 X Milyang 54 for days to 50% heading and 100-grain weight, cross Sakha 105 X IET1444 for days to 50% heading, cross Sakha 101 X Sakha 105 for sterility % and 100- grain weight, crosses Sakha 102 X IET1444, Sakha 102 X Milyang 54 and Sakha 101 X Milyang 54 for sterility % and grain yield / plant, cross Sakha 102 X Reiho for 100- grain weight and cross Sakha 105 X Reiho for grain yield / plant. Crosses, Sakha 105 X IET1444, Sakha 101 X IET1444, Sakha 101 X Sakha 105 and Sakha 102 X Sakha 105 can be rated as the best crosses based on their heterosis in most of the studied traits included grain yield. Thus, it can be exploited in subsequent generations to improve most of the studied traits. Highest crop water use efficiency 0.59 (kg / m^3) was recorded from one m^3 irrigation water for the parent Sakha 101 and crosses; Sakha101 X IET1444, (0.58 (kg/m^3), Sakha105 X IET1444 (0.56 kg/m^3) and Sakha101 X Sakha105 (0.55 kg/m^3). Also, data indicated the significant effect of irrigation method on FWUE %. The maximum FWUE % value was recorded for the first parent (Sakha 101) followed by IET1444 and Sakha 105. Whereas, the minimum value was recorded for Reiho rice variety. On the other hand, the highest value of FWUE % was found in cross Sakha 101 X IET1444, followed by crosses; Sakha 105 X IET1444 and Sakha 101 X Sakha 105. The parents Sakha101, IET1444 and Sakha 105, and crosses Sakha 101 X IET1444, Sakha 105 X IET1444 and Sakha 101 X Sakha105, could be recommended for growing under water stress conditions to obtain the highest rice grain yield and the highest value of water saving at the same time.*

Key words: *Combining ability, Grain yield, Stress Conditions.*

INTRODUCTION

Rice an important cereal crop. More than half of the world's population depends on rice for calories intake and protein, especially in developing countries. The world population, particularly in that of the rice consuming countries, is increasing at a faster rate. Crop improvement in rice depends on the magnitude of genetic variability and the extent to which the desirable genes are heritable. Rice water stress is one of the most limiting factors of rice production in Egypt, as well as in other rice producing countries. The water stress can adversely affect the yield and milling quality of the grains. Soil deficit in water due to deficit in nutritional elements especially with soils in a much-reduced condition. The success of rice breeding will be limited if rice selection is only based on breeders' practices under field conditions without biometrical analysis. Quantitative genetic analysis should be dealt to have more effect in rice selection. Combining ability has been extensively used for choosing suitable parents in crossing programs to combine traits of interest in high-yielding background. Combining ability analysis also provides estimates of genotypic variance components, useful for genetic enhancement of crops (Dhakar and Vinit 2006). Considering that hybrids offer good opportunity to improve yield levels, as evident from several other self-pollinated crops such as rice. GCA (general combining ability) and SCA (specific combining ability) values would be needed for good combiners and proper choice of male and female parents in hybridization programs and rice selection. Heterosis is considered to be one of the outstanding achievements of plant breeding. At the current growth of population, rice requirement increases dramatically. Hence, it is a challenging task for ensuring food and nutritional security to the country. Heterosis may be positive or negative. Depending upon breeding objectives, both positive and negative heterosis are useful for crop improvement. In general, positive heterosis is desired for yield, and negative heterosis for early maturity (Jine *et al*. 2005). However, although early maturity is an important character, it is associated with low yield potential and it's unlikely for early maturing cultivars to produce higher yield than late maturing ones in absence of drought stress (Nour, 1989). Drought stress during vegetative growth, flowering and terminal period of rice cultivation, can interrupt floret initiation (which cause spikelet sterility) and grain filling, respectively (Wiekham, 1977). On the other hand, it has been proposed that grain filling is closely linked to the whole plant senescence (Mady, 2004). Usually, water stress at grain filling period increases remobilization of assimilates (reserved in the stems and sheaths of rice and contribute 10-40% of the final grain weight) from the straw to the grains. The main objective of this research is to study the variations among the cultivars studied and their crosses for the traits which as related with drought tolerance.

MATERIALS AND METHODS

The present investigation was carried out at El-gemiza Agricultural Research Station, during 2011 and 2012 summer seasons. Six Egyptian rice cultivars, namely, Sakha 101, Sakha 102, Sakha 105, IET1444, Reiho and Milyang 54 were crossed in half_ diallel to estimate the general and specific combining abilities and the type of heterosis as better parent (heterobeltiosis) for grain yield and its related characters. Parentag, type of rice and drought tolerance of these rice cultivars, are given in Table (1).

Table (1): Parentage and type group of rice cultivars

Cultivar	Parentage	Type	Drought tolerance
Sakha 101	Giza 176 / Milyang 54 79	Japonica	Moderate
Sakha 102	Gz 4096-7-1 / Giza 177	Japonica	Sensitive
Sakha 105	GZ5581 / GZ3416	Japonica	Tolerant
IET 1444	TN 1 / CO 29	Indica	Tolerant
Reiho	Akihikari / Ayanishki	Japonica	Sensitive
Milyang 54	Korean variety	Indica	Moderate

The six Egyptian rice cultivars were chosen based on their considerable level of variability in yield and its related characters and grown with ten days intervals to over come the differences in flowering time for the purpose of hybridization during 2011 summer season at Sakha Agricultural Research Station. Thirty days old seedlings from fifteen cross combination along with the six parents were transplanted in a randomized complete block design with three replications during 2012 summer season at El-gemiza farm station. In each replication, the size of the plot was 5 rows with a length of 5 meters, with plant spacing of 20 x 20 cm. The three central rows were used for data collection and observation. Flush water irrigation was added after twelve days and the agronomic practices were added as recommended.Twenty plants were randomly taken from each parent and each F1 cross, from each replicate. Data were collected on eight rice traits, viz; plant height (cm), days to 50% heading, panicle length (cm), number of panicles / plant, number of filled grains / panicle, sterility%, 100-grain weight and grain yield /plant (g).

A- Statistical analysis:

The means data were subjected to ANOVA and combining ability studies, using diallel generations due to the presence of nonadditive gene analysis, Method 2 and Model 2 (Griffings, 1956). The data for each measurement were tabulated and analyzed by Fisher's analysis of variance (Steel and Torrie, 1980). The diallel analysis was used to evaluate traits that had significant variation among the parents. Significant differences in phenotypes were assumed to imply that genetic differences were present. Simple additive – dominance model approach of Hayman (1954a), (1954b), Jinks (1954) and Singh and Chaudhary (1979) as modified by Mather and Jinks (1982) was followed for genetic analysis and for the estimation of components of genetic variation. The significance of components of variation in F_1 generation was tested by Hayman (1958) and Mather and Jinks (1971). When the value of a parameter divided by its standard error, exceeds 1.96, then, it was significant.

Estimation of heterosis:

Useful heterosis for each trait of individual cross was calculated as the percentage increase of F1, performance above the better parent performance. Heterosis over better-parent % was estimated as follows:

$$H\ (\%) = \frac{F1 - BP \times 100}{BP}$$

Where, F1 = Mean value of the first generation, while BP= Mean value of the better-parent. Appropriate LS.D value was calculated to test the significance of the heterotic effects, according to the following formula, suggested by Wynne *et al.* (1970).

$$\text{L.S.d. for better parent heterosis} = t\ \frac{(\sqrt{2Mse})}{r}$$

Where: t = tabulated "t" value at the specified level of probability for the experimental error degrees of freedom. MSE = the experimental error mean squares of the analysis of variance, and r = number of replications.

B- Water relations

1- Monitoring soil moisture

Soil samples were collected two days after each irrigation from three successive layers (20 cm each) to determine soil moisture contents (Table 2).

2- Climatologic elements

Values of the climatological elements were obtained from The Meteorological Station at El-Gemiza, Gharbia governorate (Table 3), situated at 30 to 47 N latitude and 31 longitude and 15 m altitude. It represents the circumstances and conditions of the North Delta. Average values of temperature, air relative humidity (RH%) and wind speed were recorded daily during the two studying seasons.

Table (2). Soil moisture contents of the experimental site.

Soil depth, (cm)	Field capacity (F.C) %	Permanent wilting point (PWP) %	Available water (AW) (cm)	Bulk density, (g/cm^3)
0-20	43.00	23.50	21.70	1.12
20-40	39.20	22.30	17.00	1.32
40-60	35.10	19.60	16.00	1.54

Table (3). Average meteorological data for the two seasons (2011 and 2012).

Month	Temperature (C)	RH (%)	wind velocity, (Km/hr.)
June	24.95	55.14	117.00
July	26.90	59.18	105.00
August	27.13	62.19	76.00
20 Sept.	25.23	84.25	101.00

3- Estimation of crop coefficient (KC)

Crop coefficient was estimated, according to FAO (1990) as follows:

$$KC = \frac{ETc}{ETp}$$

ETc = Actual evapotranspiration (mm/day).
ETp = Potential evapotranspiration calculated by the modified Penman equation (mm/day), and Kc = Crop coefficient.

The amount of water needed for land preparation for nursery or permanent field was recorded, beside the amount of water needed for raising the nursery or through the first nine days after transplanting (seedling establishment period), as well as the amount of water used to replenish the plots. Water depth at every irrigation was kept at 5 cm height.

4- Water consumptive use

Total of water applied; i.e., the amount of water delivered each plot plus amount of water applied in both nursery and permanent field for applying water treatments, was measured for each cultivar.

Soil moisture content was determined before and after each irrigation to calculate water consumptive use, according to Iseraelson and Hansen (1962), as follows:

$$Cu = \sum_{i=I}^{n=1} \frac{\theta_2 - \theta_1}{100} \times Bd \times D \times 4200\ m^2$$

Where:

Cu = Water consumptive use in each irrigation (m^3/fed.), θ_2 = Soil moisture percent after irrigation (%, d.b), θ_1 = Soil moisture percent before irrigation (%, d.b), Bd = Soil bulk density in (g/cm^3), n = Number of irrigations, $_I$ = Number of soil layers, D = Depth of soil layer (cm) and 4200 m^2 = Area of fed.

5- Crop water use efficiency (CWUE)

It was calculated, according to Hansen *et al*. (1980) by the following equation:

$$CWUE\ (kg/m^3) = \frac{\text{Yield (kg/fed)}}{\text{Water consumptive use } (m^3/fed)}$$

6- Field water use efficiency (FWUE)

It was calculated according to Michael (1978) by the following equation:

$$FWUE\ (kg/m^3) = \frac{\text{Yield (kg/fed)}}{\text{Water applied } (m^3/fed)}$$

RESULTS AND DISCUSSION

Analysis of variance

Analyses of variance for the studied traits under investigation are presented in Table (4). The genotypes mean square exhibited highly significant for all the studied traits indicating wide range of genetic variability among the studied genotypes and this is a primary requirement for further computation. Mean squares values of parents and crosses were found to be highly significant for all traits except parents for panicle length which was significant. Parents Vs crosses mean squares were highly significant for all agronomic, yield and its related characters. Both general and specific combining ability variance were found to be highly significant for all traits, indicating the importance of both additive and non-additive genetic variances in determining the performance of these eleven traits. General combining ability/specific combining ability ratio was used to clarify the nature of the genetic variance involved. With the exception of all traits under investigation, GCA/SCA ratios were found to be greater than unity for all characters under studied except Panicle length, number of filled grains/panicle and 100-grain weight, indicating that the additive and additive x additive types of gene action were of greater importance in the inheritance of all the studied characters except these three mentioned traits which have been controlled by non-additive genetic variance. Therefore, it could be concluded that the presence of large amounts of additive effects suggests the potentiality for obtaining further improvement of the characters studied. Also, selection procedure based on the accumulation of additive effects would be very successful in improving these characters. However, to maximize selection advance, procedures which are known to be effective in shifting gene frequency when both additive and non-additive genetic variation, are involved. The obtained results are in agreement with those previously observed by Annadurai and Nadarajan (2001), El-Abd (2003), Abd El-Lattef (2004), Hammoud (2004), and Sinha *et al.* (2006).

Table (4): Mean squares estimates of ordinary and combining ability analyses for some yield and its component characters during the 2011 and 2012 seasons.

S.O.V.	d.f	Plant height (cm)	Days to heading (days)	Panicle length (cm)	No. of panicles /plant	No. of filled grains /panicle	Sterility %	100-grain weight(g)	Grain yield/plant (g)
Replications	3	15.25	8.27	1.29	0.801	79.84	1.87	0.86	23.47
Genotypes	20	199.84**	301.53**	20.19**	16.83**	1438.85**	12.41**	18.85**	396.52**
Parents (P)	5	239.42**	278.48**	2.62*	49.74**	851.29**	41.94**	16.21**	601.24**
Crosses (Cr)	14	199.48**	290.45**	21.94**	3.92**	124.42**	4.46**	20.15**	179.48**
P. vs Cr.	1	190.37**	298.29**	60.48**	39.32**	4315.11**	41.35**	19.34**	2198.61**
Error	60	9.87	4.98	0.94	0.89	71.28	0.97	2.01	15.91
G.C.A	5	132.84**	194.39**	3.78**	8.11**	131.54**	7.42**	3.21**	203.74**
S.C.A	15	27.46**	30.45**	4.97**	3.84**	381.79**	2.97**	4.48**	59.32**
Error	60	2.58	0.890	0.24	0.25	17.42	0.37	0.38	5.18
GCA / SCA		3.89	4.94	0.68	3.64	0.42	2.99	0.53	4.59

*and ** significant at 0.05 and 0.01 probability levels, respectively.

Mean performance of parents and their F_1 generation

Evidently, Table 5 shows that the tallest plants were observed in IET1444 followed by Sakha 101, Sakha 102 and Sakha 105. While, the shortest ones were exhibited in Milang 54 and Reiho rice varieties. Sakha 102 and Reiho followed by Milyang 54 and Sakha 105 were the earlier rice cultivars, while IET1444 and Sakha 101 were the latest rice cultivars. In addition, IET1444 had the longest panicle (19.62cm), followed by Sakha 101 and Reiho, while Sakha 102 and Milyang 54 gave the shortest panicle length (13.54 and 12.36, respectively.). Sakha 101, Sakha 105, Sakha 102 and IET1444 gave the highest number of panicles/ plant. On the other hand more filled grains /panicle (119.85 fertile grains) was recorded for IET1444 followed by Sakha 101 (112.36), Sakha 105 (109.34) and Sakha 102 (103.62). Lowest sterility% was recorded for Reiho (10.84%) followed by IET1444 (15.63%). On the contrary, the highest sterility% was recorded for Sakha 102 (32.36%). Heaviest grains (2.63 g /100 grains) was recorded from Sakha 101, followed by Sakha 105 (2.52 g /100 grains) and Sakha 102 (2.42 g /100 grains). Highest grain yield/plant (26.89 g/plant) was obtained from Sakha 101 followed by IET1444 (25.88 g /plant). While Reiho rice variety gave the lowest rice grain yield (16.92 g /plant). The parental mean values of grain yield were ranged between 1.776 and 2.823 t. /fed., for Reiho and Sakha 101, respectively under 12 days of water stress condition. These results were agreed with Abd El-Lattef (2004), Hammoud (2004), and Sinha *et al*. (2006).

The F_1 mean values of plant height were ranged between 55.45 cm for Sakha 105 X Reiho and 80.24 cm for Sakha 105 X IET1444 rice crosses, which agreed with the target of rice breeders for select short stature rice genotypes, resistant to lodging and suitable for mechanical harvesting. Moreover, all rice crosses were earlier than the late rice cultivar, IET1444 from almost 1 to 19 days. Eight rice crosses; Sakha 102 X Milyang 54 (100.62), Sakha 101 X Sakha 102 (102.38), Sakha 105 X Milyang 54 (103.27), Reiho X Milyang 54 (103.71), Sakha 101 X Sakha 105 (104.12), Sakha 102 X Sakha 105 (104.34), Sakha 105 X Reiho (104.35) and Sakha 102 X Reiho (104.51 days) were earlier than the earliest rice cultivar, Sakha 102 (105.36 days). The highest estimated values of panicle length and number of panicles /plant were recorded on Sakha 101 X IET1444 rice cross. Moreover, the largest number of filled grains /panicle was detected for Sakha 101 X Sakha 105 (118.45 grains) followed by Sakha 101 X IET1444 (116.53 grains) and Sakha 105 X IET1444 (115.18 grains). On the contrary, the smallest number of filled grains/panicle (90.48 grains) was recorded for Sakha 102 X Milyang 54. Lowest sterility% (12.34%) was recorded from cross Sakha 102 X IET1444 followed by (13.54%) for IET1444 X Reiho. The heaviest 100-grain weight was obtained for Sakha 101 X Sakha 102, Sakha 102 X IET1444, Sakha 101 X IET1444 and Sakha 102 X Sakha 105 rice crosses. Maximum grain yield /plant was observed for Sakha 101 X IET1444 (26.47 g), followed by Sakha 105 X IET1444 (25.89 g) and Sakha 101 X Sakha 10 (25.83 g), almost it was ranged between 2.664 and 2.779 tons / faddan., indicating possibility of increasing grain yield through hybridization followed by selection in any traditional breeding program.

Estimates of general (GCA) and specific (SCA) combining ability

Obviously, estimates of GCA showed that the parents Sakha 101, Sakha 105 and IET1444 were found to be good general combiners for grain yield/plant (Table 6). High GCA effect of Sakha 101 was associated with its high GCA effect for panicle length, number of panicles /plant, number of filled grains /panicle and 100-grain weight. The good combining ability of cultivar Sakha 105 was due to high length of its panicle and its heavies grains, while the high estimates of general combining ability of cultivar IET1444 for grain yield /plant was due to its highest estimates of panicle length and number of panicles /plant. The results also revealed that among the studied parents, Sakha 105 followed by Sakha 101, Reiho and IET1444 were the best general combiners for short plant height. Moreover, Sakha 102, IET1444 and Milyang 54 were the best general combiners for earliness.

Table (5): Mean performance of the six parents and their F_1 generation of 6 x 6 diallel cross for some yield and its component characters.

genotypes	Plant height (cm)	Days to 50 % heading	Panicle length (cm)	No. of panicles /plant	No. of filled grains /panicle	Sterility %	100-grain weight (g)	Grain yield /plant (g)
Sakha 101	78.34	107	17.35	12.46	112.36	29.35	2.63	26.89
Sakha 102	68.25	105	13.54	11.62	103.62	32.36	2.42	24.23
Sahka 105	66.31	105	14.87	11.94	109.34	22.84	2.52	25.74
IET 1444	85.42	119	19.62	10.95	119.85	15.63	2.32	25.88
Reiho	52.84	105	14.31	9.42	99.65	10.84	2.21	16.92
Milyang 54	50.12	105	12.36	9.86	89.37	26.82	2.31	19.84
Sakha 101/ Sakha 102	75.14	102	15.45	12.64	111.34	28.63	2.53	23.26
Sakha 101 / Sakha 105	69.28	104	15.89	11.42	118.45	25.36	2.41	25.38
Sakha 101 x IET1444	79.41	117	19.36	12.85	116.53	17.53	2.48	26.47
Sakha 101 / Reiho	66.25	106	16.27	10.42	102.84	19.36	2.25	21.28
Sakha 101 / Milyang54	59.42	105	15.81	10.63	99.84	22.41	2.13	20.36
Sakha 102 / Sakha 105	68.54	104	13.27	11.65	107.18	28.46	2.42	24.97
Sakha 102 / IET1444	76.32	117	18.74	10.92	105.94	12.34	2.51	23.47
Sakha 102 / Reiho	62.42	104	11.82	9.32	98.64	25.32	2.23	10.69
Sakha 102 / Milyang54	59.45	100	12.34	9.64	90.48	28.41	2.36	20.26
Sakha 105 / IET1444	80.24	117	18.36	11.25	115.81	17.64	2.41	25.89
Sakha 105 / Reiho	55.45	104	14.71	10.84	103.62	16.35	2.13	17.94
Sakha 105/ Milyang 54	58.29	103	14.26	10.26	105.64	23.56	2.36	17.35
IET1444 / Reiho	63.51	110	17.61	9.28	112.36	13.54	2.12	18.45
IET1444 / Milyang 54	58.54	108	15.84	9.74	105.82	24.36	2.36	20.36
Reiho / Milyang 54	55.82	103	12.84	9.36	100.4	28.61	2.21	18.26
LSD at 0.05	2.15	3.22	1.84	2.64	4.62	1.13	0.12	2..31
LSD at 0.01	3.49	4.26	2.99	3.62	5.41	1.56	0.84	3.15

Table (6): Estimates of general combining ability (GCA) effects for some yield and its component characters.

Parents	Plant height (cm)	Days to 50 % heading	Panicle length (cm)	No of panicles /plant	No. of filled grains /panicle	Sterility %	100-grain weight (g)	Grain yield /plant (g)
Sakha 101	-2.79**	5.28**	0.51**	1.26**	6.96**	-1.72**	0.65**	6.55**
Sakha 102	1.48	-6.34**	-0.54 **	-0.68*	1.04	-0.85*	-0.96**	-5.94**
Sahka 105	-3.14**	1.42**	0.15	-0.99**	-1.98**	0.94**	0.19*	3.28**
IET 1444	-1.72**	-3.54**	0.43**	1.55**	1.02	1.35**	-0.63**	1.95**
Reiho	-2.50**	6.65**	-1.05**	-0.73**	-3.32**	-0.98**	-0.15	-3.22**
Milyang 54	7.84**	-3.25**	0.45**	-0.84**	-4.29**	0.97**	0.59**	-3.74**
S.E. at 0.05	0.53	0.47	0.15	0.13	1.12	0.51	0.17	0.72
S.E. at 0.01	0.62	0.68	0.21	0.21	2.34	0.88	0.29	1.34

*and ** significant at 0.05 and 0.01 probability levels, respectively.

Therefore, it may be concluded that crosses involving these parents would result in the identification of superior sergeants with favorable genes for grain yield/plant and its components and other studied traits. High GCA effects are related to additive and additive X additive components of genetic variation, the parents with higher positive significant GCA effects are considered as good combiners, while those with negative GCA effects are poor general combiners except in case of plant height, earliness and sterility%. Similar results were obviously recorded by Iftekharuddaula *et al.* (2004), Shehata (2004), Satish and Seetharamaiah (2005), Sharma *et al.* (2005), Dhakar and Vinit (2006) El-Abd *et al.* (2007) and Abd ellattef et al (2011).

The estimates of specific combining ability of the 15 crosses for the eight agronomic studied, traits are presented in (Table 7). It is observed that nine crosses exhibited positive and significant SCA for grain yield /plant. The promising combinations for grain yield along with at lest two of yield component characters were Sakha 101 X Reiho, Sakha 101 X Milyang 54, Sakha 102 X IET1444, Sakha 102 X Sakha 105 and Reiho X Milyang 54. It is observed that majority of the crosses with high SCA for grain yield were involved with low / high or high / low or high / high or low / low general combining parents. But very few crosses showing low / low general combiners showed high SCA .The cross combinations showing high negative SCA for days to 50% heading (earliness), were Sakha 105 X Milyang 54, Sakha 105 X IET1444, Sakha 101 X Reiho, Sakha 101 X Sakha 105 and Sakha 102 X Sakha 105. For plant height, negative estimates of SCA are desirable and the good specific combiners were Sakha 101 X Sakha 102, Sakha 101 X Reiho, Sakha 102 X IET1444, Sakha 105 X IET1444 and IET1444X Milyang 54. The cross combinations viz., Sakha 101 X Milyang 54, Sakha 101 X Sakha 105, Sakha 102 X IET1444 and IET1444 X Reiho and Sakha 102 X Milyang 54 were good specific combiners for panicle length. The best specific combiners for number of panicles /plant were Sakha 101 X Reiho, IET1444 X Milyang 54, Sakha 101 X Milyang 54, Reiho X Milyang 54 and Sakha 101 X Sakha 105. The cross combinations, Sakha 101 X Reiho, IET1444 X Milyang 54, Reiho X Milyang 54, Sakha 102 X IET1444, Sakha 101 X IET1444, Sakha 101 X Sakha 105 and Sakha 102 X Sakha 105 showed higher SCA for number of filled grains / panicle. Also, cross combinations Sakha 102 X Milyang 54, Sakha 101 X Sakha 105, Sakha 101 X Sakha 102 and Sakha 102 X IET1444 showed high negative sterility%. Five crosses namely, Sakha 102 X Reiho, Sakha 101 X Sakha 105, Sakha 101 X Sakha 102, Sakha 105 X Milyang 54 and Reiho X Milyang 54, exhibited highly significant and positive SCA effects for100-grain weight. Moreover, these cross combinations also included the parents which recorded either good or poor GCA for this trait. Through, there is a preponderance of non additive gene action for grain yield and most of the yield components in the hybrids resulted in high amount of vigor in F_1, selection can be postponed to later generations. These findings were in agreement with those of Singh and Kumar (2004), Yu *et al.* (2004), Bagheri *et al.* (2005), Rosamma and Vijayakumar (2005), Allahgholipour and Ali (2006) and Soni *et al.* (2006).

Estimates of better parent heterosis

A large number of crosses exhibited high estimates of heterosis in a desirable direction for different traits under study. The estimates of heterosis for different traits are presented in (Table 8). A greater magnitude of heterosis ranged between (-13.49 and -55.74%) was observed in nine crosses for grain yield /plant. The availability of sufficient hybrid vigour in several crosses in respect of grain yield suggests that a hybrid breeding program could profitably be undertaken in rice under water stress conditions. The cross Sakha 102 X Milyang 54 exhibited highest negative heterosis (-4.49%) for days to 50% heading followed by Sakha 101 X Sakha 102 (-2.82%), Sakha105 X Milyang 54 (-2.24%) and Reiho X Milyang 54 (-1.82%). Appearance of significant and negative heterosis for days to 50% heading indicated the possibility of exploiting heterosis for earliness. For plant height, six crosses i.e., Sakha101 X Milyang 54 (24.15%), Sakha 105 X IET1444 (21.07%), Sakha 105 X Reiho (16.36%), Sakha 101 X Reiho (15.40%), Sakha 105 X Milyang 54 (12.03%) and Sakha 102 X IET1444 (11.82%), recorded significant heterosis in a desirable positive direction. Five crosses i. e., IET1444 X Reiho (-25.64%), Sakha 102 X Milyang 54 (-12.85%), Sakha 101 X Sakha 105 (-11.56%), Sakha 102 X Reiho (-8.34%) and Sakha 101 X Sakha 102 (-4.06%) exhibited highly significant and negative estimates of heterosis for panicle length. Moreover, highly significant and Positivete estimates of heterosis were observed for number of panicles /plant in seven crosses. On the other hand, no desirable heterosis was found among all studied crosses for number of filled grains/panicle which exhibited either non-significant or highly significant estimates in negative direction. Out of fifteen studied crosses, only Sakha 101 X Sakha 105 and Sakha 101 X Reiho exhibited highly significant and positive estimates of heterosis for number of filled grains /panicle. The estimated heterosis values for sterility% showed highly significant and negative desirable in only three crosses i.e., Sakha 101 X Milyang 54, Sakha 101 X Sakha 105 and Sakha 102 X IET1444. Most studied crosses recorded highly significant heterosis in negative direction for100- grain weight.

Table (7): Estimates of specific combining ability (SCA) effects for studied characters.

Crosses	Plant height (cm)	Days to 50 % heading	Panicle length (cm)	No. of panicles /plant	No. of filled grains /panicle	Sterility %	100-grain weight (g)	Grain yield /plant (g)
Sakha 101/ Sakha 102	-4.92**	3.41**	-2.95**	-1.29**	3.99	-3.04**	1.98**	4.97**
Sakha 101 / Sakha 105	0.93**	-5.14**	3.98**	0.54**	12.98**	-4.12**	2.06**	-5.98**
Sakha 101 x IET1444	8.89**	-1.97**	-1.97**	-0.68**	14.68**	2.05**	-0.98**	4.05**
Sakha 101 / Reiho	-4.63**	-5.42**	-0.42*	2.41**	29.86**	-0.62*	-2.97**	8.97**
Sakha 101 / Milyang54	2.06**	4.02**	1.93**	0.94**	-16.38**	2.12**	-2.06**	8.95**
Sakha 102 / Sakha 105	4.95**	-4.98**	0.99**	-2.89**	11.47**	1.09**	0.98**	4.08**
Sakha 102 / IET1444	-3.82**	-5.12**	3.01**	0.25	14.98**	-2.84**	-2.09**	5.36**
Sakha 102 / Reiho	1.19	-8.97**	-2.06**	-1.63**	-9.04**	1.99**	3.98**	0.36
Sakha 102 / Milyang54	3.82**	-3.01**	4.23**	-1.22**	-35.12**	-4.36**	-2.79**	8.59**
Sakha 105 / IET1444	-5.29**	-6.98**	-2.65**	-1.63**	12.64**	3.04**	-0.54	-0.74
Sakha 105 / Reiho	3.08**	-4.95**	0.39	-2.46**	3.71	1.23**	-3.06**	6.98**
Sakha 105/ Milyang 54	0.45	-7.23**	-1.69**	-0.54**	-5.09*	2.04**	1.98**	-3.02**
IET1444 / Reiho	-0.73	-3.25**	2.08**	-0.92**	-18.23**	1.99**	-1.87**	1.02
IET1444 / Milyang 54	-3.98**	1.99**	-0.22	1.63**	16.98**	-0.35	-1.65**	-0.36
Reiho / Milyang 54	9.45**	0.97	0.84**	0.94**	16.75**	0.63*	1.57**	5.06**
S. E. At 0.05	1.53	1.03	0.40	0.26	4.21	0.36	0.55	1.23
S.E. at 0.01	1.84	1.27	0.49	0.48	5.72	0.84	0.65	2.84

*and ** significant at 0.05 and 0.01 probability levels, respectively.

Table (8): Estimates of heterosis as a deviation from better parent of the fifteen rice crosses for some yield and its component characters.

Crosses	Plant height	Days to 50 % Heading	Panicle length (cm)	No of panicles /plant	No. filled grains /panicle	Sterility %	100-grain weight (g)	Grain yield /plant (g)
Sakha 101/Sakha 102	-4.06*	-2.82**	-10.95**	1.44**	-.090	-2.45	-10.01**	-13.49**
Sakha 101/Sakha105	-11.56**	-1.17*	-8.41**	-8.95**	5.42*	-13.59**	-8.36**	-5.61*
Sakha 101 x IET1444	1.36	11.19**	-1.32*	3.13**	-2.17	12.15*	-5.70**	-1.56
Sakha 101 / Reiho	15.40**	0.18	-6.22**	-16.37**	8.47**	78.15**	-14.04**	-20.90**
Sakha 101/Milyang54	24.15**	0.85	-9.81**	-14.68**	-11.14**	-16.44**	-19.01**	-24.28**
Sakha 102/Sakha 105	0.24	-0.95	-10.75**	-2.42**	-1.97	24.60**	-3.96*	-2.99
Sakha 102 / IET1444	11.82**	11.65**	-4.45**	-6.02**	-11.60**	-21.04**	-3.86*	-9.34**
Sakha 102 / Reiho	-8.54	-1.14*	-16.29**	-19.79**	-4.81	133.57**	-7.85**	-55.74**
Sakha 102/Milyang54	-12.85**	-4.49**	-8.86**	17.03**	-12.68**	5.92*	-2.47	-16.38**
Sakha 105 / IET1444	21.07**	11.06**	-6.42**	5.77**	-3.37	12.85**	-3.86*	0.03
Sakha 105 / Reiho	16.36**	-1.23*	1.07*	9.21**	-5.23	50.83**	-15.47**	-30.30**
Sakha 105/Milyang54	12.03**	-2.24**	-3.41**	14.07**	-3.38	3.15	-6.34**	-32.59**
IET1444 / Reiho	-25.64	4.73**	-12.53**	15.25**	-6.24*	24.90**	-8.65**	-28.70**
IET1444 / Milyang 54	0.14	2.82**	-19.26**	-8.02**	-11.70	55.85**	-1.27	-21.36
Reiho / Milyang 54	5.06**	-1.82**	-10.27**	-5.07**	0.76	163.29**	-4.23	-7.96**

*and ** significant at 0.05 and 0.01 probability levels, respectively.

From the foregoing discussion, it may be concluded that the crosses, Sakha 105 X IET1444, Sakha 101 X IET1444, Sakha 101 X Sakha 105 and Sakha 102 X Sakha 105 can be rated as the best crosses based on their heterosis in most of the studied traits including grain yield. Thus, it can be exploited in subsequent generations to improve most of the studied traits. Similar results were reported by several scientists like, Kumar *et al*. (2004), Verma and Sirvastava (2004), Zhen *et al*. (2004), Jin *et al*. (2005), Saravanan *et al.* (2006), and Shanthala *et al.* (2006).

Water intervals

Estimates of amount of water applied, water consumptive use (m3/ fed) and actual and potential evapotranspiration (ETc mm and ET day), are presented in Table (9). The results indicated that total water applied and water consumptive use were 4783.63 and 3954.01 m^3/ fed., respectively. While the highest water applied and water consumptive use values were 1397.52 and 1050.01 m^3 / fed., respectively, recorded in August. On the other hand, the lowest values were 952.63 and 872.13 m3 /fed., respectively, recorded in September.

Data in Table (9), also showed that values of ETc increased in August and July followed by June, it was 7.29, 7.11 and 6.18 mm / day, respectively. While in September, it was 6.05 mm / day. Concerning potential evapotranspiration (ETp mm / day), the highest ETp (7.72 mm / day) was recorded from August followed by July and June , while the lowest ETp (6.14 mm / day) was recorded from September. Estimations of (ETp mm / day) the data showed insignificant differences among them in pre-harvest period; e.g., months June, July and August values. However, the evapotranspiration (ETp mm / day) decreased in emergence stage, while, it gradually increased with increasing the age of plant, but decreased again with pre-harvest period in September.

Concerning crop coefficient values (Kc) in Table (9), it is clear that the effect of crop characteristics on crop water requirements was indicated by crop coefficient, which represented the relationship between potential (ETp) and actual crop evapotranspiration (ETc). The values of crop coefficient for irrigation pattern (kc) (Table 9) showed slight increase after planting, but decreased again at the end of growth season. It could be noticed that the nearest values to average (KC%) was that of relative equation. Same results were reported earlier by Nasir *et al.* (2002), Hussain *et al*. (2003), Azam *et al*. (2005) and Abd Ellattef *et al* (2011).

Estimates of grain yield (Kg / fed), crop water use efficiency (CWUE) and field water use efficiency (FWUE) are tabulated in Table (10). The results indicated that the average of grain yield (kg/fed.) was significantly affected by the studied genotypes. The maximum values (2823.45 Kg / fed.) was found for the first parent (Sakha 101) followed by IET1444 (2717.40 Kg / fed.), Sakha 105 (2702.71 Kg / fed.), Sakha 102 (2544.15 Kg / fed.) and Milyang 54 (2083.20 Kg / fed.). While, the minimum value was recorded by Reiho (1776.60 Kg / fed.). For the cross combinations, the highest average grain yield (2779.53 Kg / fed.) was recorded for the first cross, Sakha 101 X IET1444, followed by crosses Sakha 105 X IET1444 (2718.45 Kg / fed.), Sakha 101 X Sakha 105 (2664.90 Kg / fed.), Sakha 102 X Sakha 105 (2621.85 Kg / fed.), Sakha 102 X IET1444 (2464.35 Kg / fed.) and Sakha 101 X Sakha 102 (2442.30 Kg / fed.). The lowest value (1122.45 Kg / fed.) was recorded for the cross, Sakha 102 X Reiho. These results agreed with those obtained by Efisue *et al*. (2004) who showed that grain yield potential in upland rice was found to be between (2.5 and 4.2 t/ ha).

Crop and field water use efficiency (CWUE and FWUE):

Data in Table (10) also, illustrated that crop water use efficiency was considerably affected by irrigation methods. The maximum CWUE % value (0.59 kg/m^3) was recorded for the first parent Sakha101 followed by IET1444, Sakha 105 and Sakha 102, being 0.56, 0.56 and 0.53 (kg / m^3), respectively. The minimum value (0.37 kg / m^3) was obtained for Reiho. On the other hand, cross Sakha101 X IET1444, gave the highest value 0.58 (kg / m^3) of crop water use efficiency, followed by the crosses Sakha 105 X IET1444 and Sakha101 X Sakha 105, being 0.56 and 0.55 (kg / m^3), respectively.

Table (9). Water applied m^3/fed., water consumptive use, actual (ETc and potential (ETp) evapotranspiration (mm / day), and values of crop coefficient (kc).

Months	Water applied M^3/fed.	Water consumptive use m^3/fed.	Actual Evapotr-Anspiration (ETc) mm/day	Potentail Evapotr-anspiration (ETp) mm/day	K.C%
June	1066.54	949.54	6.18	6.64	0.93
July	1366.94	1041.52	7.11	7.42	0.96
August	1397.52	1090.82	7.29	7.72	0.94
20 Sep.	952.63	872.13	6.05	6.14	0.98
Total	4783.63	3954.01	26.63	27.92	3.81
Mean	1195.90	988.50	6.68	6.98	0.95

Table (10). Crop and field water use efficiency under drought condition.

Genotypes	Grain yield kg/Fadden	CWUE (kg/m^3)	FWUE (kg/m^3)
Sakha 101	2823.45	0.59	0.71
Sakha 102	2544.15	0.53	0.64
Sahka 105	2702.71	0.56	0.68
IET 1444	2717.40	0.56	0.68
Reiho	1776.60	0.37	0.44
Milyang 54	2083.20	0.43	0.52
Sakha 101 X Sakha 102	2442.30	0.51	0.61
Sakha 101 X Sakha 105	2664.90	0.55	0.67
Sakha 101 X IET1444	2779.53	0.58	0.70
Sakha 101 X Reiho	2234.40	0.46	0.56
Sakha 101 X Milyang 54	2137.80	0.44	0.54
Sakha 102 X Sakha 105	2621.85	0.54	0.66
Sakha 102 X IET1444	2464.35	0.51	0.62
Sakha 102 X Reiho	1122.45	0.23	0.28
Sakha 102 X Milyang 54	2127.30	0.45	0.53
Sakha 105 X IET1444	2718.45	0.56	0.68
Sakha 105 X Reiho	1883.70	0.39	0.47
Sakha 105 X Milyang 54	1821.75	0.38	0.46
IET1444 X Reiho	1937.25	0.40	0.48
IET1444 X Milyang 54	2136.75	0.44	0.54
Reiho X Milyang 54	1917.30	0.40	0.48
Average	2240.83	0.40	0.56

Also, data indicated the considerable effect of irrigation method on FWUE. The maximum FWUE value was recorded for the first parent (Sakha 101) followed by IET1444, Sakha 105 and Sakha 102. Whereas, the minimum value was recorded for Reiho rice variety. On the other hand, the highest value of FWUE was found in cross Sakha 101 X IET1444, followed by crosses Sakha 105 X IET1444 and Sakha 101 X Sakha 105. These results were in harmony with those obtained by Ahmed *et al.* (2002), Akbar *et al*. (2002) and Yasin *et al*. (2003).

From the foregoing results, the parents Sakha101, IET1444 and Sakha 105, as well as the crosses Sakha 101 X IET1444, Sakha 105 X IET1444 and Sakha 101 X Sakha105, could be recommended for growing under drought conditions as upland rice to obtain the highest rice grain yield beside saving irrigation water at the same time.

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تقدير القدرة على التآلف وقوة الهجين لمحصول الحبوب و مكوناته في الأرز تحت ظروف الإجهاد المائي

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مركز البحوث و التدريب في الأرز – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية – الجيزة – مصر.

الملخص العربي

أجريت دراسة القدرة على التآلف وقوة الهجين مقارنة بأفضل الآباء لمحصول الحبوب باستخدام نظام الهجن التبادلية بين ستة تراكيب وراثية مختلفة وذلك بدون الهجن العكسية، بمحطة البحوث الزراعية بسخا والجميزة وذلك أثناء موسمي 2011 و2012. تحت ظروف نقص الإجهاد المائي حيث تمت عملية الري كل 12 يوم دون إشباع التربة. أوضحت النتائج أن النسبة بين كل من تباين القدرة العامة على التآلف إلى تباين القدرة الخاصة على التآلف أعلى من الواحد مشيرة إلى أهمية الفعل المضيف للجين في التحكم في صفات ارتفاع النبات، عدد الأيام إلى التزهير، عدد النورات الدالية / نبات، و محصول الحبوب / نبات. على الجانب الأخر من ذلك، أكدت النتائج على أهمية الفعل الجيني السيادي في التحكم في السلوك الوراثي لصفات طول النورة الدالية، عدد الحبوب الممتلئة / النورة الدالية ووزن المائة حبة. بين الآباء، كان الصنف سخا 101 أكثر الآباء قدرة عامة على التآلف لجميع الصفات المدروسة عدا التبكير، . وكانت التراكيب الوراثية سخا 105 و IET1444 أفضل الآباء قدرة عامة على التآلف لصفات التبكير ، والصنف سخا 104 لصفات طول النورة الدالية، وزن 100 حبة، محصول الحبوب. كما اظهر الصنفين سخا 102 و سخا 105 قدرة فائقة على التآلف لصفة التبكير. هذا وقد أعطت التراكيب الوراثية سخا 101 X سخا 105 ، سخا 105 X IET1444 و سخا 101 X IET1444 أعلى قدرة خاصة على التآلف لصفتي عدد الحبوب الممتلئة / النورة الدالية و محصول النبات / نبات. أظهرت عشرة هجن قدرة خاصة على التآلف مرغوبة وعالية المعنوية وسالبة، لصفات طول النبات، وعدد الأيام الى التزهير والنسبة المئوية للعقم. إضافة إلي ذلك كانت التراكيب الوراثية IET1444 X سخا 101 وسخا 105 X سخا101 أفضل الهجن قدرة خاصة علي التآلف لصفات طول النورة الدالية , وزن ال100 حبة.كما كانت أفضل كفائة للاستهلاك المائى

للاباء Sakha 101, Sakha 105 ,IET1444 وكذلك التراكيب الوراثية سخا 101 X سخا 105 ، سخا 105 X IET1444 و سخا 101 X IET1444 كما أوضحت النتائج أن كمية المياه المضافة للتراكيب الوراثية المدروسة تراوحت بين 3954.01 الى 4783.63 متر مكعب للفدان كما ان المتر المكعب من المياه أعطى اعلي كمية حبوب تراوحت بين 560 و530 للأصناف سخا 101 و IET1444 سخا 105 وكذلك الهجن الناتجة من هذه الآباء سخا 101 X سخا 105 ، سخا 105 X IET1444 و سخا 101 X IET1444 التي أعطت 0.55 و 0.56 و 0.58كيلو جرام حبوب من المتر المكعب من المياه .

بناء على النتائج المشار إليها يمكن التوصية بزراعة الآباء سخا 101 و IET1444 سخا 105 وكذلك الهجن الناتجة منها سخا 101 X سخا 105 ، سخا 105 X IET1444 و سخا 101 X IET1444 تحت ظروف الإجهاد المائي وذلك لتفوقهما في محصول الحبوب وذلك بإستخدام اقل كمية مياه.