Menoufia J. Plant Prod., Vol. 2 February (2017): 65 - 80

GENETIC BEHAVIOR OF SOME ROOT AND GRAIN QUALITY TRAITS UNDER WATER DEFICIT AND NORMAL CONDITIONS IN RICE (*ORYZA SATIVA* L.)

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Received: Dec. 13, 2016 **Accepted: Dec. 29 , 2016**

ABSTRACT: *Four rice genotypes differed in drought tolerance were crossed. Six populations (P1, P2, F1, F2, BC1 and BC2) of two rice crosses namely; Sakha 102 x IR 83142-B-60-B-(cross I) and Giza 159 x Takanari 1 (cross II) were raised in a randomized complete block design during the three successive summer seasons from 2014 to 2016 at the farm of Rice Research Agricultural station, Sakha, Kafr El-Sheikh, Egypt. This study aimed to determine heterosis, gene action, heritability, genetic advance and phenotypic correlation response to select and predict by the new lines for some root traits (Root length, Root volume, Number of roots/plant and Root/Shoot ratio %) and some grain quality traits. Flush water irrigation was added every 12 days intervals. The results indicated that highly significant and positive heterosis as a deviation from mid- and better- parent were obtained for all root and grain quality, except for grain shape in the first cross and for grain length in the second cross which showed highly significant and negative estimates of heterosis as a deviation from mid-parent. In addition, incomplete dominance to over-dominance was operative for most of the studied traits.*
Additive gene effect (d) and dominance gene effect (h) were more important in the genetic system for all the studied characters, additive x additive gene effects (i), additive x dominance (j) and dominance x dominance (l) gene effects were involved in the genetic control of all characters, except some exceptions. Heritability in broad sense was high in most traits of the two studied crosses, except cross I for root/ shoot ratio under normal condition. The highest value of heritability estimates (95.95 %) was recorded for root volume in the cross I under normal condition. The narrow sense heritability was moderate to low in most traits of the two crosses. High values of predicted genetic advance were estimated for most traits of the studied traits. Significant or highly significant positive phenotypic correlation was found between most of the studied characters for the two studied crosses especially between root and grain quality characters with grain yield/ plant, except amylose content trait.
In general the cross Giza 159 x Takanari 1 could be grown under water deficit for further screening and selecting desirable root and grain quality traits at the same time.

Key words: *Rice crosses, genetic parameters, root and grain quality traits, drought tolerance.*

INTRODUCTION

In Egypt, annually more than one and half million feddans are cultivated with rice, producing about 6.5 million tons of rice, with an average of 4.2 tons/ fed, (10 tons/ ha.) RRTC (2013). This average ranked at the first among the rice producing countries in the world. This production meet the needs of local consumption, and the rest is exported abroad. But, with the expected increase of population, the production should be increased.

Global climate change is expected to increase the occurrence and severity of drought episodes due to increasing temperatures and evapotranspiration. Therefore, food security in the twenty-first century will increasingly depend on the release of new cultivars with improved adaptation to drought conditions. However, selection for drought tolerance is difficult due to a complex genotype by environment interactions.

Drought is a major abiotic stress limiting rice production in the world. About 30 % of the world's rice producing areas suffer from moisture stress and water deficit, in both rainfed and irrigated areas. About 18 million tons of rice valued at US $ 650 million is lost annually due to drought, Pandey *et al.* (2005). For this reason, breeding for drought tolerance become of high priority in rice breeding program, especially in Egypt because of the limited irrigation water available in the River Nile. Some rice planted areas, especially those located at terminal of irrigation canals in the northern part of the Nile Delta suffer from shortage in irrigation water during different growth stages, which are considered to be one of the most serious constraints to rice production Abd Allah (2009).

In addition, after the relative success of the Green Revolution, food security has consistently been challenged by (i) population growth, (ii) urbanisation, and (iii) climate change. It is therefore now essential, not only to grow more high quality rice per hectare, but also to equip these varieties with tolerance to environmental stresses Brar and Khush (2013). To this end, significant investment has been made in many countries to improve yield and stress tolerance, while retaining quality Singh *et al*. (2000); Inthapanya *et al.* (2006); Mackill *et al.* (2006); Tomita (2009) and Boualaphanh *et al.* (2011). The current tools of quality evaluation are not sophisticated enough to define the quality each market requires, let alone enable selection for it.

The present investigation aimed to determine heterosis, degree of dominance, genetic variance, heritability, genetic advance and phenotypic correlation coefficient among some root and grain quality characters under water deficit conditions.

MATERIALS AND METHODS

The present investigation was carried out at Sakha Agricultural Research station Farm, Sakha, Kafr El-Sheikh, Egypt, during 2014, 2015 and 2016 seasons to study the genetic behavior of some root and grain quality traits in rice under water deficit and normal conditions, i.e., root length (cm), root volume (cm^3), number of roots/ plant, root/ shoot ratio, grain length (mm), grain shape (mm), hulling %, milling %, head rice % and amylose content %.

According to the obtained results the four genotypes were crossed to produce F_1 hybrid seeds of two crosses namely; I - Sakha 102 (sensitive) x IR 83142-B-60-B-(tolerant). II - Giza 159 (moderate) x Takanari 1 (tolerant). Six populations, i.e., P_1, P_2, F_1, F_2, BC_1 and BC_2 of each cross were obtained and utilized in this study.

In 2014 season, the four parental cultivars were grown in three successive dates of planting with fifteen days interval in order to overcome the differences in flowering time between parents. Thirty days old seedlings of each parent were individually transplanted in the permanent field in seven rows. Each row was 5m long and contained 25 hills spaced 20 cm apart. At flowering time, hybridization between parents was carried out following the technique proposed by Jodon (1938) and modified by Butany (1961). And the aforementioned two crosses were produced.

In 2015 season, parents and F_1 hybrid seeds of the two crosses together with their parental lines were planted under normal conditions. At heading, parents were crossed again to produce the F_1 hybrid seeds of the two crosses following the same technique. Moreover, some of F_1 plants were left to be self pollinated in order to produce F_2 seeds, while some other F_1 plants were crossed with their own parents to produce BC_1 and BC_2 seeds. At harvest, seeds of different generations were individually harvested to be grown in the next season. Subsequently, in the summer season of 2016, seeds of P_1, P_2, F_1, BC_1, BC_2 and F_2 of each cross were sown under drought conditions. Six population of each cross (parents, $F_{1'S,}$ $F_{2'S,}$ $BC_{1,}$ and BC2) were planted in a randomized complete block design experiment with three replications. Each replicate contained 10 rows of each of P_1, P_2 and 5 rows of each of F_1, BC_1 and BC_2 and 20 rows of F_2. Rows were 5 m long and 20 x 20 cm apart. In all growing seasons of the study, all cultural practices were applied as recommended. The six populations in 2016 season were planted under water deficit conditions (water deficit was imposed by using flush irrigation every 12 days without standing water after irrigation). Hand weeding was done when it was needed. Sixty plants from each P_1, P_2 and $F_{1,}$ 90 plants from each BC_1 and BC_2 and 200 plants from each F_2 populations were taken at random. These plants were individually harvested and threshed separately to determine the grain yield/plants and yield components.

Heterosis was estimated according to Falconer and Mackay (1996). Furthermore, appropriate L. S. D. values were calculated to test the significance of heterotic effects according to the formula suggested by Wynne *et al.* (1970). The relative potence ratio (P) was used to determine the degree of dominance and its directions according to the formula given by Mather and Jinks (1971). Estimation of gene effects were suggested by Mather (1949) and Hayman (1958). Expected genetic variances of VBC_1, VBC_2 and VF_2 in terms of additive ($^1/_2$ D) and dominance ($^1/_4$ H) are derived by Mather (1949). Heritability in both broad and narrow senses were determined by Powers *et al*. (1950) and Warner (1952), respectively. Expected and predicted values of genetic advance (GS and GS %) were calculated according to Johnson *et al.* (1955). The phenotypic correlation coefficient was performed according to the procedure of Dewey and Lu (1959).

RESULTS AND DISCUSSION

1- Means of the parents and their generation:

The best source of information about the question of base on these estimates is that derived by fitting a model to the mean of the basic generation, i.e., P_1, P_2, F_1, F_2, BC_1 and BC_2, which are presented in Tables 1 and 2. The results revealed that wide range of means was recorded among the two parents in most of the studied traits under water deficit and normal conditions. The F_1 mean values were higher than the highest parent for root length, root volume, number of roots/ plant, root/ shoot ratio, hulling %, milling %, head rice % and amylose content % in both studied crosses under water deficit and normal conditions, and it was also higher than the highest parent for grain length in the cross I under water deficit and normal conditions.

Besides, the F_1 mean values were intermediate between the two parents for grain shape in the two crosses and grain length in the cross II (Giza 159 x Takanari 1) under water deficit and normal conditions. On the other hand, the F_2 mean values were higher than the highest parent for root volume in the cross II and number of roots/ plant in the two crosses under water deficit and normal conditions, and both root/ shoot ratio and head rice % in the cross II under normal condition, While for the other traits, F_2 mean values were intermediate between the two parents, except hulling % in both crosses under water deficit condition, head rice % in the cross II under water deficit condition was lower than the lowest parent. Moreover, BC_1 mean values were higher than the highest parent for root length in the cross II under water deficit condition and in the cross I (Sakha 102 x IR 83142-B-60-B) under normal condition, root volume in the cross II under water deficit and the cross I under normal condition, number of roots/ plant in both crosses under water deficit and the crosses I and II under normal condition, root/ shoot ratio in the cross II, hulling % and head rice % in the cross II under normal condition and milling % in the cross II under water deficit condition. BC_2 mean values were higher than the highest parent for root length, number of roots/ plant, root volume under normal conditions while were intermediate between the two parents for grain length in the cross I under normal condition, head rice % in the cross II and amylose content % in the cross I under water deficit condition and the cross I under normal condition.

Table 1: Means and standard error of the six populations for rice root characters in the two studied crosses under water deficit (D) and normal (N) conditions.

Characters	Cross		Mean performance and standard error					
			P_1	P_2	F_1	BC_1	BC_2	F_2
Root length (cm)	I	D	21.23±0.17	25.22±0.19	28.43±0.23	24.87±0.13	25.9±0.12	22.22±0.53
		N	26.03±0.12	29.83±0.11	38.35±0.11	29.90±0.11	34.37±0.11	27.58±0.35
	II	D	18.87±0.17	21.38±0.17	25.81±0.20	22.22±0.12	22.52±0.14	19.94±0.46
		N	21.97±0.13	26.78±0.12	32.03±0.12	25.92±0.11	27.35±0.13	24.30±0.29
Root volume (cm^3)	I	D	40.52±0.53	60.42±0.54	106.2±0.72	58.98±0.54	65.5±0.37	49.39±1.49
		N	53.87±0.18	80.87±0.14	119.96±0.31	84.51±0.32	94.98±0.12	68.67±1.11
	II	D	19.40±0.35	23.53±0.36	75.05±0.64	36.15±0.56	39.98±0.61	33.42±1.43
		N	30.13±0.30	34.26±0.42	93.82±0.26	54.71±0.29	71.85±0.30	52.02±0.91
Number of roots/plant	I	D	125.97±0.76	141.3±1.18	194.5±1.59	150.36±1.2	162.78±1.3	143.41±3.2
		N	174.13±0.63	242.7±0.47	353.2±0.66	244.1±0.60	267.45±0.65	244.02±2.65
	II	D	96.60±1.20	73.28±0.93	192.81±2.0	157.9±2.12	150.25±1.7	132.71±4.47
		N	176.85±0.32	123.4±0.18	259.8±0.24	213.8±0.60	238.32±0.65	205.05±2.10
Root/Shoot ratio (%)	I	D	0.36±0.01	0.43±0.013	0.60±0.01	0.36±0.01	0.48±0.01	0.42±0.020
		N	0.43±0.01	0.78±0.01	0.94±0.01	0.53±0.01	0.71±0.01	0.71±0.02
	II	D	0.34±0.01	0.31±0.01	0.54±0.01	0.51±0.10	0.50±0.01	0.40±0.020
		N	0.49±0.01	0.53±0.01	0.88±0.01	0.57±0.01	0.70±0.01	0.56±0.02

Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159x Takanari 1, D: water deficit, N: normal conditions.

Table 2: Means and standard errors of the six populations of grain quality characters for the two studied crosses under water deficit (D) and normal (N) conditions.

characters	crosses		Mean performance and standard error					
			P_1	P_2	F_1	BC_1	BC_2	F_2
Grain length (mm)	I	D	7.59±0.013	7.74±0.015	7.83±0.01	7.67±0.014	7.70±0.012	7.64±0.025
		N	7.98±0.01	8.49±0.01	8.67±0.01	8.09±0.01	8.60±0.01	8.44±0.03
	II	D	6.98±0.016	9.96±0.015	8.33±0.014	7.55±0.013	8.30±0.011	7.61±0.03
		N	7.90±0.01	10.80±0.01	9.05±0.01	8.55±0.01	8.99±0.01	8.45±0.03
Grain shape (mm)	I	D	2.16±0.01	2.88±0.012	2.39±0.01	2.44±0.014	2.73±0.015	2.27±0.027
		N	2.21±0.01	2.87±0.01	2.38±0.01	2.65±0.01	2.59±0.01	2.28±0.02
	II	D	2.12±0.01	3.30±0.01	2.51±0.011	2.18±0.01	2.48±0.012	2.44±0.026
		N	2.20±0.01	3.32±0.01	2.55±0.01	2.18±0.01	2.66±0.01	2.41±0.02

Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159x Takanari 1, D: water deficit, N: normal conditions.

Table 2: Cont.

characters	crosses		Mean performance and standard error					
			P_1	P_2	F_1	BC_1	BC_2	F_2
Hulling (%)	I	D	80.08±0.12	79.80±0.11	82.31±0.12	78.53±0.13	79.91±0.22	78.39±0.48
		N	83.91±0.14	81.93±0.13	85.01±0.13	83.88±0.14	82.08±0.13	83.29±0.33
	II	D	79.07±0.13	77.87±0.12	80.42±0.13	78.95±0.13	78.36±0.12	77.45±0.29
		N	83.41±0.11	81.78±0.13	84.93±0.14	83.6±20.13	82.28±0.13	82.94±0.33
Milling (%)	I	D	69.88±0.11	66.87±0.12	71.00±0.13	68.98±0.12	68.33±0.11	67.80±0.33
		N	72.16±0.12	69.76±0.12	72.53±0.11	69.57±0.11	71.00±0.13	70.61±0.35
	II	D	68.95±0.14	67.02±0.12	70.18±0.11	68.58±0.12	68.30±0.12	67.86±0.33
		N	71.13±0.12	69.92±0.11	71.97±0.12	70.01±0.12	70.23±0.14	69.50±0.33
Head rice (%)	I	D	62.02±0.10	57.03±0.12	63.05±0.12	59.08±0.12	58.40±0.11	59.77±0.32
		N	62.93±0.12	59.80±0.11	63.40±0.13	61.01±0.13	60.30±0.12	61.97±0.32
	II	D	60.10±0.04	60.90±0.03	62.27±0.12	60.21±0.12	61.02±0.11	59.56±0.29
		N	62.06±0.13	62.28±0.16	63.70±0.15	62.40±0.13	62.95±0.14	62.60±0.37
Amylose content (%)	I	D	21.02±0.12	25.32±0.14	29.00±0.12	23.37±0.10	25.51±0.11	24.89±0.33
		N	19.67±0.13	24.31±0.13	25.47±0.12	23.81±0.11	24.47±0.12	23.72±0.30
	II	D	20.98±0.12	25.02±0.14	28.72±0.12	22.67±0.12	24.02±0.13	24.60±0.30
		N	19.41±0.13	24.13±0.15	25.05±0.12	22.07±0.12	23.03±0.13	23.55±0.30

Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159x Takanari 1, D: water deficit, N: normal conditions.

2- Estimates of heterosis and degree of dominance:

As shown in Tables 3 and 4 the degree of dominance was greater than unity (±1.0) for root length, root volume, number of roots/ plant, root/ shoot ratio, hulling %, milling %, head rice % and amylose content in both crosses and the cross I for grain length under water deficiency and normal conditions, suggesting the importance of over-dominance in controlling these traits. However, the degrees of dominance were lesser than unity for grain shape in both crosses and grain length in the cross II under water deficit and normal conditions. The ratios which were between zero and unity, suggesting partial or incomplete dominance and might play a remarkable role in the inheritance of these traits. The same results were previously obtained by Abd-Allah (2000), Abd El- Lattef and Mady (2009), El-Abd *et al.* (2008), Hijam *et al.* (2012) and Ravikumar *et al.* (2014).

It is clear in Tables 3 and 4 that significant and highly significant and positive estimates of heterosis as a deviation from mid- and better-parents were obtained for root length, root volume, number of roots/plant, root/shoot ratio, hulling %, Milling %, head rice % and amylose content % in both crosses, while for grain length in cross I under both water deficit and normal conditions.

While for the other remaining traits, i.e. grain length in cross II and grain shape in both crosses exhibited highly significant negative heterosis as a deviation from mid-parents under both water deficit and normal conditions. Similar results were reported earlier by Abd El-Lattef *et al.* (2008), Ganapathy and Ganesh (2008), Abd-Allah (2009), Hassan *et al.* (2011), Mall *et al*. (2011), Concepcion *et al*. (2015) and Guimaraes *et al.* (2016).

Table 3: Estimates of heterosis as a deviation from mid-parents (MP), better-parent (BP) and degree of dominance of rice root characters, for the two studied crosses under water deficit (D) and normal (N) conditions.

Characters	Cr.	Heterosis %				Degree of dominance (N)	Degree of dominance (D)
		MP		BP			
		N	D	N	D		
Root length (cm)	I	22.41**	37.27**	12.73**	28.52**	-14.26	-20.18
	II	28.22**	31.40**	20.68**	19.59**	4.52	3.18
Root volume (cm^3)	I	110.57**	78.05**	75.89**	48.33**	-5.6	-3.89
	II	249.57**	191.38**	218.85**	173.84**	-25.9	-29.87
Number of roots/ plant	I	45.54**	69.50**	37.65**	45.56**	-7.94	-4.22
	II	126.98**	73.08**	99.59**	46.92**	9.25	4.1
Root/ Shoot ratio (%)	I	51.06**	54.35**	38.77**	20.40**	-5.76	-1.92
	II	68.75**	71.79**	58.82**	64.99**	16.03	-17.41

*, **: Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.
Crosses I: Sakha 102x IR 83142-B-60-B, II: Giza 159 x Takanari 1, D: water deficit, N: normal conditions.

Table 4: Estimates of heterosis as a deviation from mid-parents (MP), better-parent (BP) and degree of dominance of rice grain quality characters, for the two studied crosses under water deficit (D) and normal (N) conditions.

Characters	Cr.	Heterosis %				Degree of dominance (N)	Degree of dominance (D)
		MP		BP			
		N	D	N	D		
Grain length (mm)	I	2.22**	5.38**	3.29**	8.75**	-2.14	-1.73
	II	-1.65**	-3.15**	19.33**	14.59**	0.09	0.2
Grain shape (mm)	I	-5.20**	-6.54**	10.52**	7.43**	0.36	0.5
	II	-7.19**	-7.83**	18.58**	15.60**	0.33	0.38
Hulling (%)	I	2.96**	2.51**	2.77**	1.31**	16.47	2.11
	II	2.48**	2.82**	1.70**	1.82**	3.25	2.87
Milling (%)	I	3.82**	2.21**	1.59**	0.51	1.73	1.31
	II	3.23**	2.04**	1.79**	1.17**	2.28	2.38
Head rice (%)	I	5.91**	3.30**	1.65**	0.73	1.41	1.29
	II	2.90**	2.45**	2.21**	2.26**	-4.26	-13.55
Amylose content (%)	I	25.13**	15.82**	37.93**	29.47**	-2.7	-1.5
	II	24.85**	15.04**	36.86**	29.04**	-2.83	-1.38

*, **: Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.
Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159xTakanari 1, D: water deficit, N: normal conditions.

3- Estimates of genetic components of generation mean:

As shown in Tables 5 and 6 that mean effect parameter (m) was highly significant for all the studied root and grain quality traits. Additive gene action (d) played an important role in the inheritance of all the studied characters, except root length and root/ shoot ratio in the cross II under water deficit condition, grain length in the cross I under water deficit condition and milling % in the cross II under both water deficit and normal conditions. Moreover, dominance gene action (h) played a greater role in the inheritance of all the studied traits in both crosses, except root/ shoot ratio and grain length, hulling % and milling % in the cross I under normal condition and in the cross II under normal condition for grain shape, hulling %, head rice % and amylose content % in the cross II under normal condition.

Table 5: Genetic components of generation means of rice root characters for the two studied crosses under water deficiency (D) and normal (N) conditions.

Characters	Cross		Genetic components of generation mean					
			m	d	h	i	J	l
Root length (cm)	I	D	22.22**	-1.02**	17.85**	12.65**	0.96**	-10.86**
		N	27.58**	-4.47**	28.62**	18.21**	-2.57**	-14.19**
	II	D	19.94**	-0.30	15.41**	9.73**	0.95**	-7.34**
		N	24.33**	-1.42**	17.00**	9.35**	0.98**	-3.06*
Root volume (cm^3)	I	D	49.39**	-6.51**	107.22**	51.40**	3.43**	13.14
		N	68.67**	-10.47**	136.88**	84.30**	3.02**	-68.62**
	II	D	33.42**	-3.83**	72.15**	18.57**	-1.76*	22.18**
		N	52.02**	-17.13**	106.65**	45.02**	-15.07**	-46.10**
Number of roots/ plant	I	D	143.41**	-12.42**	113.49**	52.63**	-4.76*	-22.65
		N	244.02**	-23.27**	192.01**	47.15**	11.00**	53.01**
	II	D	132.71**	7.65**	193.31**	85.45**	-4.00	-146.42**
		N	205.05**	-24.52**	193.72**	84.01**	-51.25**	-168.34**
Root/ Shoot ratio (%)	I	D	0.42**	0.11**	0.22*	0.022	-0.08**	0.27
		N	0.71**	-0.17**	-0.02	-0.35	0.004	0.96**
	II	D	0.40**	0.012	0.62**	0.41**	-0.0002	-0.72**
		N	0.56**	-0.12**	0.67**	0.30**	-0.1**	-0.06

m: mid-parent value.
d and h: pooled additive and dominance effects, respectively.
i, j and l: pooled additive x additive, additive x dominance and dominance x dominance gene interaction, respectively.
*, **: Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.
Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159xTakanari 1, D: water deficit, N: normal conditions.

Table 6: Genetic components of generation means of rice grain quality characters for the two studied crosses under water deficiency (D) and normal (N) conditions.

Characters	Cross		Genetic components of generation mean					
			m	D	h	i	j	l
Grain length (mm)	I	D	7.64**	-0.03	0.34**	0.17	0.044*	0.09
		N	8.44**	-0.50**	0.07	-0.37**	-0.25**	0.80**
	II	D	7.61**	-0.74**	1.13**	1.27**	0.74**	0.62**
		N	8.45**	-0.43**	0.95**	1.24**	1.01**	0.48**
Grain shape (mm)	I	D	2.27**	-0.28**	1.14**	1.27**	0.07**	-1.77**
		N	2.28**	0.05**	1.20**	1.30**	0.39**	-2.01**
	II	D	2.44**	-0.29**	-0.61**	-0.41**	0.29**	1.53**
		N	2.41**	-0.48**	-0.18	0.02	0.07**	0.90**
Hulling (%)	I	D	78.39**	-1.37**	5.70**	3.33	-1.51**	4.27
		N	83.29**	1.80**	0.87	-1.31	0.81**	5.14**
	II	D	77.45**	0.58**	6.77**	4.82**	-0.01	-1.65
		N	82.94**	1.33**	2.39	2.46	0.52*	3.19*
Milling (%)	I	D	67.80**	0.65**	6.06**	3.45*	-0.85**	0.66
		N	70.61**	-1.42**	0.25	-1.31	-2.62**	7.16**
	II	D	67.86**	0.28	4.50**	2.30	-0.67**	0.26
		N	69.50**	-0.22	3.91**	2.46	-0.83**	2.04
Head rice (%)	I	D	59.77**	0.68**	-0.60	-4.12**	-1.80**	14.31**
		N	61.97**	0.71**	-3.24*	-5.27**	-0.85**	12.18**
	II	D	59.65**	-0.81**	5.63**	3.87**	-0.39*	-0.77
		N	62.60**	-0.55**	1.82	0.30	-0.43	0.75
Amylose content (%)	I	D	24.89**	-2.13**	4.03**	-1.79	0.01	8.36**
		N	23.72**	-0.66**	5.15**	1.67	1.65**	-3.31*
	II	D	24.60**	-1.35**	0.68	-5.03**	0.66**	15.09**
		N	23.55**	-0.96**	-0.73	-4.00**	1.40**	7.43**

m: mid-parent value.
d and h: pooled additive and dominance effects, respectively.
i, j and l: pooled additive x additive, additive x dominance and dominance x dominance gene interaction, respectively.
*, **: Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.
Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159xTakanari 1, D: water deficit, N: normal conditions.

Additive x additive type of gene interaction (i) had played an effective role in the inheritance of all traits in the two crosses, except root/ shoot ratio in the cross I under both water deficit and normal conditions, grain length in the cross I under water deficiency condition, grain shape in the cross II under normal condition, hulling % in the cross I under water deficiency and normal conditions and the cross II under normal condition, milling % in the cross II under both water deficit and normal conditions and the cross I under normal condition, head rice % in the cross II under normal condition and amylose content % in the cross I under water deficit and normal conditions. These findings suggest that additive gene effects made a significant contribution to the inheritance of the studied characters in these crosses. Additive gene effects can be exploited in early generations because the dominance effects were also non-significant and lower in magnitude than these additive effects. Similar results were reported by Shehata *et al*. (2004), Manickavelu *et al.* (2006), Kumar *et al*. (2006), El-Abd *et al.* (2008), Hassan *et al*. (2011), Hijam *et al.* (2012), Ravikumar *et al.* (2014) and Guimaraes *et al.* (2016).

Additive x dominance type of gene interaction (j) played an important role in the inheritance of all the studied characters, except number of roots/ plant in the cross II under water deficit condition, root/ shoot ratio in the cross II under water deficit condition and the cross I under normal condition, hulling % in the cross II under water deficit conditions and head rice % in the cross II under normal condition. Dominance x dominance type of gene interaction (l) had played an important role in the inheritance of all the studied characters, except root volume and number of roots/ plant in the cross I under water deficit condition and root / shoot ratio in the cross II under normal condition and the cross I under water deficit condition, grain length in the cross I under water deficit condition, hulling % in cross I under water deficit conditions, milling % in the cross II under water deficit and normal conditions and the cross I under water deficit condition, head rice % in the cross II under both water deficit and normal conditions. In contrast, dominance gene action; additive x dominance and dominance x dominance type of gene interaction showed highly significant values, indicating that these factors are significant contributors to the variation of generation means and played an important role in the inheritance of such characters. Since additive gene effects were insignificant for these characters, simple selection procedure in the early generations may not contribute significantly to the improvement of these characters. The additive components in these traits can be successfully exploited through pedigree method of selection because of major contribution of additive gene effects in late generations of segregating populations. These results were in agreement with those obtained previously by Shehata *et al*. (2004), Manickavelu *et al.* (2006), Kumar *et al*. (2006), El-Abd *et al.* (2008), Hassan *et al*. (2011), Hijam *et al.* (2012), Ravikumar *et al.* (2014) and Guimaraes *et al.* (2016).

4- Estimates of genetic variance, heritability and genetic advance:

Data summarized in Tables 7 and 8 revealed that additive genetic variance (½ D) was higher than dominance genetic variance (¼ H) for all the studied characters under water deficiency and normal conditions, indicating that additive component of genetic variance was predominant in the expression for all the studied characters. Heritability in broad sense estimates were larger than their corresponding ones of narrow sense heritability for all the studied crosses. High broad sense heritability and high genetic advance were estimated for some root and grain quality characters. Narrow sense heritability ranged from low to moderate in both studied crosses. Similar results were reported by Toorchi *et al.* (2002), Gomez and Kalamani (2003), Abd El-Lattef *et al.* (2008) Hijam *et al.* (2012) and Concepcion *et al*. (2015).

Table 7: Estimates of additive genetic variance ($^1/_2$ D), dominance genetic variance ($^1/_4$ H), broad and narrow-sense heritabilities and genetic advance (G.S %) of rice root characters for the two studied crosses under water deficiency (D) and normal (N) conditions.

Characters	Cross		Genetic variance		Heritability %		G.S	G.S %
			$^1/_2$ D	$^1/_4$ H	Broad-sense	Narrow-sense		
Root length (cm)	I	D	0.53	-0.29	85.32	12.20	13.42	60.38
		N	0.22	-0.11	89.01	22.06	16.09	58.35
	II	D	0.39	-0.21	83.59	15.89	15.21	76.27
		N	0.13	-0.06	81.15	38.34	23.02	94.75
Root volume (cm^3)	I	D	4.03	-2.16	83.38	19.50	60.04	121.57
		N	2.38	-1.18	95.95	9.58	22.09	32.17
	II	D	3.43	-1.59	89.09	33.68	99.78	298.51
		N	1.50	-0.77	86.41	21.46	40.65	78.14
Number of roots/plant	I	D	18.23	-8.98	85.92	30.69	207.52	144.69
		N	13.28	-6.60	94.91	11.27	61.61	25.24
	II	D	32.47	-14.68	88.84	37.79	348.03	262.52
		N	8.05	-3.70	98.48	17.6	76.24	37.18
Root/ Shoot ratio (%)	I	D	0.001	-0.0006	71.20	31.32	1.67	399.12
		N	0.0009	-0.0005	60.46	42.33	2.09	293.84
	II	D	0.0008	-0.0004	80.36	39.31	1.91	469.39
		N	0.0008	-0.0004	71.49	47.25	2.36	418.65

Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159xTakanari 1, D: water deficit, N: normal conditions.

Table 8: Estimates of additive genetic variance (1/2 D), dominance genetic variance (1/4 H), broad and narrow-sense heritabilities and genetic advance (G.S %) of rice grain quality characters for the two studied crosses under water deficiency (D) and normal (N) conditions.

Characters	Cross		Genetic variance		Heritability %		G.S	G.S %
			$^1/_2$ D	$^1/_4$ H	Broad-sense	Narrow-sense		
Grain length (mm)	I	D	0.0009	-0.0004	72.27	59.18	3.08	40.35
		N	0.002	-0.001	87.36	24.93	1.80	21.37
	II	D	0.001	-0.001	77.91	28.05	1.93	25.38
		N	0.002	-0.001	86.43	27.17	1.98	23.45
Grain shape (mm)	I	D	0.001	-0.0004	83.31	59.11	3.30	145.51
		N	0.001	-0.0006	80.89	34.63	2.02	88.64
	II	D	0.001	-0.0005	82.90	37.84	2.04	83.69
		N	0.0008	-0.0004	76.03	51.96	2.54	105.11

Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159xTakanari 1, D: water deficit, N: normal conditions.

Table 8: Cont.

Characters	Cross		Genetic variance		Heritability %		G.S	G.S %
			$^1/_2$ D	$^1/_4$ H	Broad-sense	Narrow-sense		
Hulling (%)	I	D	0.40	-0.18	93.52	29.89	29.91	38.16
		N	0.18	-0.09	83.03	34.23	23.68	28.43
	II	D	0.14	-0.07	80.07	36.49	22.15	28.59
		N	0.18	-0.09	84.37	32.99	22.59	27.24
Milling (%)	I	D	0.19	-0.09	93.52	26.70	18.31	27.00
		N	0.22	-0.11	88.44	25.31	18.68	26.46
	II	D	0.18	-0.09	80.07	28.99	19.87	29.29
		N	0.19	-0.09	87.08	31.82	22.12	31.83
Head rice (%)	I	D	0.18	-0.09	86.20	25.95	17.44	29.19
		N	0.17	-0.08	84.51	33.25	21.97	35.45
	II	D	0.14	-0.06	92.56	33.25	20.01	33.55
		N	0.23	-0.11	83.69	29.89	22.79	36.41
Amylose content (%)	I	D	0.19	-0.1	84.35	22.40	15.32	61.57
		N	0.15	-0.08	80.74	30.15	19.00	80.09
	II	D	0.15	-0.07	81.83	36.23	22.69	92.24
		N	0.14	-0.07	78.77	37.45	23.42	99.43

Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159xTakanari 1, D: water deficit, N: normal conditions.

5- Estimates of phenotypic correlation coefficients:

The phenotypic correlation coefficients among all possible pairs of grain yield component traits are presented in Tables 9 and10.

Lucidly, grain yield was positively and strongly correlated with each of root length, root volume, number of roots/ plant, root/ shoot ratio, grain length, grain shape, hulling %, milling % and head rice % in the two studied crosses under both water deficiency and normal conditions. Therefore, any selection based on these traits will bring the desired improvement in grain yield. Amylose content showed insignificant negative and positive correlation with most other grain quality traits. Root length was highly significant and positive associated with root volume, number of roots/ plant and root/ shoot ratio in the studied crosses. However, a highly significant and positive estimate of phenotypic correlation coefficient was recorded between grain length and grain shape, hulling %, milling % and head rice %. Present findings coincide with the results of Abd El-Lattef and Mady (2009), Hassan *et al.* (2011) and Zulqarnain *et al.* (2012).

Therefore, any selection based on these traits will bring the desired improvement in grain yield. Amylose content showed insignificant negative and positive correlation with most other grain quality traits. Root length was highly significant and positive associated with root volume, number of roots/ plant and root/ shoot ratio in both studied crosses. However, a highly significant and positive estimate of phenotypic correlation coefficient was recorded between grain length and grain shape, hulling %, milling % and head rice %. Present findings coincide with the results of Abd El-Lattef and mady (2009), Hassan *et al.* (2011) and Zulqarnain *et al.* (2012).

Table 9: Phenotypic correlation coefficient among all possible pairs of root characters in the F_2 generation of the crosses I and II under water deficiency (D) and normal (N) conditions.

Characters	Cross		1	2	3	4
1- Root length (cm)	I	D				
		N				
	II	D				
		N				
2- Root volume (cm^3)	I	D	0.818**			
		N	0.73**			
	II	D	0.775**			
		N	0.81**			
3- Number of roots/plant	I	D	0.818**	0.943**		
		N	0.82**	0.84**		
	II	D	0.795**	0.949**		
		N	0.67**	0.84**		
4- Root/ shoot ratio	I	D	0.943**	0.846**	0.852**	
		N	0.74**	0.73**	0.86**	
	II	D	0.409**	0.632**	0.627**	
		N	0.64**	0.79**	0.72**	
5- Grain yield/plant (g)	I	D	0.936**	0.863**	0.879**	0.953**
		N	0.82**	0.82**	0.94**	0.84**
	II	D	0.674**	0.857**	0.863**	0.724**
		N	0.65**	0.80**	0.75**	0.75**

*, ** Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.
Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159xTakanari 1, D: water deficit, N: normal conditions.

Table 10: Phenotypic correlation coefficient among all possible pairs of grain quality characters in the F_2 generation of the crosses I and II under water deficiency (D) and normal (N) conditions.

Characters	Cross		1	2	3	4	5	6
1- Grain length (mm)	I	D						
		N						
	II	D						
		N						
2- Grain shape	I	D	0.564**					
		N	0.62**					
	II	D	0.782**					
		N	0.02					
3- Hulling (%)	I	D	0.751**	0.537**				
		N	0.92**	0.57**				
	II	D	0.841**	0.733**				
		N	0.74**	0.06				
4- Milling (%)	I	D	0.798**	0.567**	0.691**			
		N	0.82**	0.55**	0.83**			
	II	D	0.759**	0.732**	0.748**			
		N	0.82**	0.03	0.78**			
5- Head rice (%)	I	D	0.814**	0.578**	0.672**	0.736**		
		N	0.81**	0.56**	0.85**	0.74**		
	II	D	0.620**	0.617**	0.675**	0.583**		
		N	0.74**	0.05	0.69**	0.71**		
6- Amylose content (%)	I	D	0.029	-0.125	-0.057	-0.067	0.048	
		N	-0.32*	-0.36**	-0.29*	-0.32*	-0.33*	
	II	D	0.114	0.071	-0.015	0.086	-0.038	
		N	-0.27*	0.14	-0.27*	-0.25	-0.35*	
7- Grain yield/plant (g)	I	D	0.950**	0.581**	0.794**	0.810**	0.846**	-0.002
		N	0.91**	0.59**	0.92**	0.81**	0.83**	-0.29*
	II	D	0.948**	0.820**	0.880**	0.779**	677**	0.068
		N	0.84**	0.08	0.74**	0.79**	0.72**	-0.30*

*, ** Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.
Crosses I: Sakha 102 x IR 83142-B-60-B, II: Giza 159xTakanari 1, D: water deficit, N: normal conditions.

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السلوك الوراثي لبعض صفات الجذر وصفات جودة الحبوب فى الأرز تحت الظروف الطبيعية وندرة المياة

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الملخـص العربى

أجريت هذه التجربة بالمزرعة البحثية بمحطة بحوث الارز – سخا – كفرالشيخ – مصـر وذلك خلال مواسم زراعة الأرز 2014, 2015 و2016 وذلك بهدف دراسة السلوك الوراثى بعض صفات الجذر وصفات جودة الحبوب فى الأرز تحت ظروف ندرة المياة وذلك باستخدام العشائر الستة (الأب الأول, الأب الثانى, الجيل الأول, الجيل الثانى, الهجين الرجعى الأول والهجين الرجعى الثانى) لهجينين من الأرز هما سخا 102 × اي ار 83142-بي-60-بي (الهجين الأول) و جيزة 159 × تكانارى 1 (الهجين الثانى). وتم تصميم قطاعات كاملة العشوائية فى ثلاثة مكررات وقيمت التجربة تحت ظروف ندرة المياه وذلك باستخدام الرى السطحى كل 12 يوم وكذلك تحت الظروف الطبيعية وكان الرى فيها كل أربعة أيام, وتم تقدير كل من قوة الهجين كإنحراف عن متوسط وأفضل الأبوين، الفعل الجينى المضيف والسيادى، درجة التوريث بالمعنى العريض والضيق، التحسين المتوقع من الإنتخاب وكذلك معامل الإرتباط المظهرى بين جميع الأزواج الممكنة لبعض صفات الجذر وصفات جودة الحبوب (طول الجذر، حجم الجذر، عدد الجذور/ نبات، نسبة الوزن الجاف للمجموع الجذرى إلى الخضري، طول الحبة، شكل الحبة، النسبة المئوية للتقشير، النسبة المئوية للتبييض النسبة المئوية للتدريج ومحتوى الأميلوز في الحبة.

وأشارت النتائج المتحصل عليها من الأباء والجيل الأول والأجيال الإنعزالية إلى وجود مدى واسع بين متوسطات القيم وبعضها, وكذلك وجد تأثير كل من السيادة الجزئية والسيادة الفائقة لهذه الصفات. كذلك أوضحت النتائج أن النسبة المئوية لقيم قوة الهجين عند قياسها كإنحراف عن قيم متوسط وأفضل الأبوين كانت عالية المعنوية موجبة فى كلا الهجينين لصفات طول الجذر، حجم الجذر، عدد الجذور/ نبات، نسبة الوزن الجاف للمجموع الجذرى إلى الخضرى، النسبة المئوية للتقشير، النسبة المئوية للتبييض، النسبة المئوية للتدريج ومحتوى الأميلوز فى الحبة، كذلك كانت قوة الهجين عالية المعنوية وسالبة كإنحراف عن قيم متوسط الأبوين لصفات شكل الحبة فى كلا الهجينين وطول الحبة فى الهجين الثانى.

أظهرت النتائج أن كلاً من التأثير المضيف والسيادى للجين لعبا دورًا هامًا في وراثة معظم الصفات المدروسة فى كلا الهجينين. كذلك لعب كل من الفعل الجينى المضيف × المضيف , المضيف × السيادى والسيادى × السيادى دورًا هامًا فى وراثة هذه الصفات عدا بعض الاستثناءات.

أوضحت النتائج أن درجة التوريث بالمعنى الواسع كانت عالية لكل الهجن فى كل الصفات المدروسة ماعدا الهجين رقم (1) لصفة نسبة الوزن الجاف للمجموع الجذرى إلى الخضري تحت الظروف الطبيعية وكانت أعلى قيمة لدرجة التوريث (95.95) لصفة حجم الجذر فى الهجين رقم (1) تحت الظروف الطبيعية، وكذلك أظهرت النتائج قيمًا عالية للتحسين المتوقع بالإنتخاب لمعظم الصفات المدروسة تحت كلتا الظروف لذلك يوصى بالإنتخاب المباشر فى الأجيال المبكرة لهذة الصفات, بينما كانت درجة التوريث بالمعنى الضيق من متوسطة إلى منخفضة.

كما سجلت النتائج ان محصول الحبوب قد تلازم تلازما قويًا وموجبًا مع كل من طول الجذر، حجم الجذر،عدد الجذور/ نبات، نسبة الوزن الجاف للمجموع الجذرى إلى الخضرى، طول الحبة، شكل الحبة، النسبة المئوية للتقشير، النسبة المئوية للتبييض والنسبة المئوية للتدريج تحت كلتا الظروف .

توصى الدراسة بأن الهجين جيزه 159 × تكانارى1 هو أفضل الهجن التي نستطيع أن نوصى به للنمو تحت ظروف ندرة المياه وذلك لحصوله على أعلى القيم لصفات الجذور وصفات جودة الحبوب في نفس الوقت.