INHERITANCE OF SOME RICE ROOT CHARACTERS AND PRODUCTIVITY UNDER WATER STRESS CONDETIONS

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Abstract

This study was implemented during three successive seasons; 2011, 2012 and 2013 at the experimental farm of Rice Research and Training Center, Sakha, Kafr El-Sheikh, Egypt. Six rice genotypes with different water stress tolerance were crossed Three crosses viz; cross I {Tsuyuake (tolerant) X Sakha 103 (sensitive)} were produced, cross II {Zenith (tolerant) X Sakha 104 (moderate)} and cross III {BL1 (moderate) X Sakha 106 (sensitive)}. Six populations of P1, P2, F1, BC1, BC2, and F2 for each cross were used in the present study. Results indicated that high differences between the six parents for all root characters, as well as, grain yield and its related traits under water stress conditions. Parent Tsuyuake gave the highest mean values for most of the studied traits, while, the lowest mean values were recorded for Sakha 106 rice cultivar. Highly significant positive heterosis and heterobeltiosis was estimated for some root characters and grain yield and its component especially in crosses I and II. Negative over dominance were recorded for root fresh weight, days to 50% heading, plant height and grain yield/plant in cross III, as well as, 100 grain weight in the three crosses and sterility percentage in crosses I and III. Low and positive inbreeding depression values were estimated for 100 grain weight in crosses I and III. Epistatic gene effect had a significant contribution in inheritance of all studied characters. Additive genetic variance was greater than the dominance genetic variance for root volume and grain yield/plant in cross II, root fresh weight and days to 50% heading in crosses II and III, root / shoot ratio in crosses I and III ,as well as, plant height and panicle length in the three crosses. Heritability in broad sense ranged from low to intermediate and high in the three crosses but was low in narrow sense. Low predicted genetic advance (3.99) for root number / plant to high value (30.15) for root length in the cross III were found. Tsuyuake and Zenith may be useful genotypes in breeding program for water stress condition. This conclusion might be useful for rice breeders in planning a selection program for improving root characters and productivity of rice under stress conditions.

Kay words: *Rice, Root characters, Grain yield, Six population, Heterosis, Heritability, Inbreeding depression, Genetic advance.*

INTRODUCTION

Water stress is the major constraint for rice growing under rainfed lowland and upland conditions. Rice area is annually supposed to be million faddans, but it highly increased during the last five years due to high net return of rice comparing to other summer crops. To provide a basis for integrating physiological research with plant breeding objectives we define water stress resistance in terms of relative yield of genotypes. Therefore, a water stress tolerance genotype will be one which has a higher grain yield than others when all genotypes are exposed to the same stress. A major reason for the slow progress in breeding for water stress tolerance in rice is the complexity of the water stress environment, which often results in the lack of clear identification of the target environments (Fukai *et al*., 1996).

The improvement strategy being used in Egypt considers three mechanisms that influence yield in the water stress prone targets: yield potential as an important mechanism for water stress (where, yield loss is less than 50 %), water stress escape (appropriate phenology) and water stress tolerance traits of sterility and days to heading. The plant breeding program uses rapid generation advance techniques that enable early yield testing in the target population of environments through inter-station and on farm trials. Although progress can be made by selection for yield in the target environments using root traits that are associated with water stress tolerance can hasten that progress.

Root characters responsible the adaptability to water stress are root length and root / shoot ratio. The deep roots of rice plant help to explore different levels of soil moisture (Bashar, 1987). The selection for desirable root characters through grain yield and its components has been a major objective in breeding for water stress tolerance of rice. Therefore the present study aimed to determine the inheritance of some rice root characters and grain yield and its related traits witch can be used as selection criteria for selecting water stress tolerant genotypes.

MATERIALS AND METHODS

Field experiment was carried out at the experimental farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, during three successive rice seasons; 2011, 2012 and 2013. Six rice varieties differing in water stress tolerance level namely; Tsuyuake, Sakha 103, Zenith, Sakha 104, BL 1 and Sakha 106 were used in this study.

The six genotypes were crossed to produce F_1 hybrid seeds of three crosses; cross I {Tsuyuake (tolerant) X Sakha 103 (sensitive)}, cross II {Zenith (tolerant) X Sakha 104 (moderate)} and cross III {BL1 (moderate) X Sakha 106 (sensitive)}. Six populations P_1, P_2, F_1, BC_1, BC_2 and F_2 for each cross were utilized to determine the genetic parameters, heterosis, heritability and genetic advance of all studied characters.

Field experiment procedures:

In 2011 season rice genotypes seeds were taken from the pure stock of the Rice Research and Training Center (RRTC) collection and grown at RRTC experimental farm in three planting dates with ten days interval in order to overcome the differences in flowering time between the parents. Thirty days old seedlings of each parent were individually transplanted in seven rows. Each row was 5 m long and included 25 hills. At flowering time, hybridization between parents was carried out, following the technique proposed by Jodon (1938). In 2012 season, parents and F_1 hybrid seeds of the three crosses were planted under normal conditions. At heading, parents were crossed again to produce more F_1 hybrid seeds of the three crosses. Moreover, some of F_1 plants were left for self-pollination 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. Seeds of different generations were individually harvested to be grown in the next season (2013). Eighteen stocks of different generations (6 parents, $3F_1'$ s, 3 BC_1' s, 3 BC_2' s and $3F_2'$ s,) were sown on May 15^{th} in a randomized complete blocks design experiment with three replications. Each replicate contained 10 rows of each P_1, P_2 and 4 rows of each F_1, BC_1, BC_2 and 20 rows of F_2. Rows were 5 m long and 20 x 20 cm apart and the rest cultural practices were applied as recommended. Flushing water irrigation every 12 days was used (15 days after transplanting). At maximum tillering stage, a metal cylindrical sampler, 20 cm in diameter and 50 cm high, was forced into the soil, including one hill, to obtain its root system up to 50 cm depth and root characters were measured for all the studied materials. At harvest 30 plants from P_1, P_2 and F_1,s, 60 plants from BC_1's and BC_2's and 200 plants from each F_2 population were taken individually at random and threshed separately to determine grain yield/plant and its components. Root length, root number/plant, root volume, root fresh weight, root/shoot ratio, days to 50 % heading, plant height, panicle length, number of panicles/plant, 100 grain weight, sterility % and grain yield / plant were studied or estimated.

Soil physical properties:

Soil physical properties of the experimental site shown in Table (1), were determined, according to FAO (1976) and Black (1965)

Table 1. Soil physical properties of the experimental site in 2013 season.

Soil depth (cm)	Particle size distribution			Soil texture
	Sand %	Silt %	Clay %	
0-20	16.23	20.18	62.59	Clay
20-40	18.34	29.27	50.45	Clay
40-60	21.56	31.54	49.16	Clay

Monitoring soil moisture:

Soil samples were collected before and two days after each irrigation from 3 successive layers (20 cm each) to determine soil moisture content (Table 2).

Table 2. Soil moisture contents of the experimental site in 2013 season.

Soil depth(cm)	Field capacity (F.C) (%)	Permanent wilting point (PWP) (%)	Available water(AW) (cm)	Bulk density (g/cm^3)
0-20	41.13	25.42	16.48	1.22
20-40	35.46	23.26	12.63	1.36
40-60	26.53	21.28	15.42	1.25

Metrological elements:

Values of the climatologic elements were obtained from the meteorological station at El- karaka, Kafr El-Sheikh, Governorate, situated at 30 to 47 N latitude and 31 longitude and 15 m altitude. Air temperature (**°C**), air relative humidity (RH) and wind speed were recorded daily during 2013 season (Table 3).

Table 3. Mean of some meteorological data in 2013 season.

Month	°C	RH(%)	Wind velocity(Km/day)
June	21.35	66.54	112.34
July	23.54	72.69	100.58
August	26.58	74.78	88.91
Sept.	24.32	82.36	91.46

Radition method:

ETo = C X (W.Rs.)

Where:

ETo = potential crop evapotranspiration in mm/day

C = adjustment factor which depends on mean humidity and daytime wind condition

W = weighting factors which depend on temperature and altitude

Rs = the solar radiation expressed in equivalent evaporation in m/day.

Estimation of crop coefficient (KC):

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

KC = **ETc / ET_P**

Where:

ETc = actual evapotranspiration, mm/day

ETp = potential evapotranspiration calculated by the modified penman equation, mm/day

Kc = crop coefficient, dimensionless.

Estimation of the potential evapotranspiration **(ETp):**

ETp was estimated for 4 months from June until September by radiation method.

The amount of water needed for land preparation for nursery or permanent field was recorded, besides 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 for replenish the plots. Water depth at every irrigation was kept at 5 cm height.

Water relations:

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

Water consumptive use:

Soil moisture content was determined before and after each irrigation to calculate water consumptive use, according to Israelsen and Hansen (1962) as the following formula:

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

Where:

Cu = water consumptive use in each irrigation (cm^3)

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 irrigation times

I = number of soil layer

D = depth of layer of the soil (cm).

$4200m^2$ = area of fed.

Crop water use efficiency (CWUE):

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

$$CWUE. (Kg/m3) = \frac{\text{Yield (kg/fed)}}{\text{Water consumptive use } (m^3/fed)}$$

Field water use efficiency (FWUE):

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

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

Statistical and genetic analysis:

The data under field condition of the present study were subjected to the proper statistical analysis of Randomized Complete Block Design, as described by Snedecor and Cochran (1967). Significance of the genetic effects is tested in a similar manner as done in case of scaling tests. The amount of heterosis expressed in individual cross was determined by comparing the F_1 mean performance to the mid-parent and better-parent average values and it was estimated by the formula of Mather (1949) and Mather and Jinks (1971). The relative potence ratio (P) was used to determine the nature of dominance and its directions according to the formula given by Mather and Jinks (1971). Inbreeding depression (I.d.) was estimated according to Mather and Jinks (1971). Heritability in both broad and narrow sense and expected genetic variance of VBC_1, VBC_2 and F_2 in terms of additive by Mather (1949). Phenotypic correlation coefficient between most of the studied characters and grain yield were determined, according to Burton (1995).

RESULTS AND DISCUSSION

A - Mean values:

The mean values of twelve rice characters in the six populations for the three studied crosses are presented in Table (4).

Table 4. Mean performance and standard error of the different generations for studied rice root as well as grain yield and its related characters of the three tested crosses.

character	cross	P1	P2	F1	BC1	BC2	F2
Root length (cm)	I	30.26±2.23	16.32±2.55	30.55±2.11	26.32±3.11	15.32±2.14	25.36±3.12
	II	28.42±3.71	19.54±2.32	28.95±3.42	22.36±2.13	16.41±2.13	22.13±3.25
	III	19.64±1.42	13.65±3.41	18.25±2.15	17.56±1.99	12.63±1.89	19.27±2.19
Root number / plant	I	212.34±5.12	132.54±4.31	196.35±5.32	150.26±6.31	131.22±3.41	152.13±6.41
	II	154.35±4.13	141.28±5.16	148.53±5.26	146.45±5.81	135.48±3.62	149.15±5.47
	III	139.45±5.14	120.63±2.33	139.16±4.87	132.36±4.43	119.63±4.48	132.16±6.31
Root volume (cm^3)	I	65.34±2.49	35.34±3.65	66.43±3.22	55.13±3.62	35.11±4.67	48.17±5.52
	II	54.38±3.15	42.84±2.31	52.22±3.24	50.29±4.84	40.62±3.32	46.32±4.36
	III	42.63±2.19	30.48±3.12	40.18±5.16	36.41±5.33	25.13±4.56	31.18±2.82
Root fresh weight/plant (g)	I	50.24±149	26.84±2.54	51.48±1.45	42.25±3.61	25.34±3.41	39.15±4.41
	II	46.38±2.16	35.62±3.12	46.85±3.41	40.12±2.42	30.26±2.63	32.58±3.51
	III	41.26±1.59	24.85±2.46	22.18±2.33	25.78±2.93	22.16±1.85	29.18±2.62
Root/shoot ratio %	I	29.56±2.14	19.29±2.44	29.99±2.72	20.54±1.55	18.63±1.34	20.13±2.23
	II	24.62±1.77	17.94±1.79	21.62±1.24	19.82±2.13	15.41±2.39	17.29±1.98
	III	21.35±3.25	16.24±3.64	18.49±2.75	20.15±3.24	16.20±1.77	18.52±1.96
Days to 50 % heading (days)	I	110.36±4.41	96.24±3.81	102.74±4.11	108.25±5.61	92.35±2.78	100.25±4.51
	II	105.42±3.22	91.89±1.92	99.35±5.24	102.21±4.52	90.62±3.16	108.41±2.62
	III	103.26±6.14	94.92±6.64	92.61±4.21	99.36±6.31	94.35±2.21	102.39±3.41
Plant height (cm)	I	89.35±2.63	72.45±2.31	91.63±2.64	77.24±3.41	74.36±5.63	85.41±4.53
	II	87.45±4.55	79.26±4.25	89.72±5.26	75.54±5.57	75.41±2.84	83.58±2.85
	III	85.62±2.41	69.27±5.76	66.41±3.77	79.41±4.66	70.13±3.53	71.48±1.23
Panicle length (cm)	I	23.26±4.32	18.62±2.68	22.53±2.14	20.15±2.65	17.41±3.21	20.54±1.87
	II	20.34±2.61	15.41±1.79	18.74±1.73	19.62±1.43	14.63±2.13	19.63±1.53
	III	16.54±2.51	14.63±3.22	15.89±2.18	15.41±2.38	13.26±2.11	18.74±1.32
Number of panicles/plant	I	16.28±3.42	13.24±2.47	19.72±1.39	14.63±1.94	12.88±1.56	15.25±1.82
	II	14.26±2.63	12.94±1.61	16.84±2.87	13.71±2.22	15.27±1.99	14.31±2.41
	III	12.31±3.14	10.59±2.41	13.61±1.77	11.85±2.51	9.23±1.87	14.52±1.64
100 grain weight (g)	I	2.64±0.21	2.41±0.11	2.53±0.83	2.51±0.31	2.31±0.22	2.41±0.81
	II	2.51±0.33	2.35±0.22	2.41±0.32	2.43±0.42	2.25±0.26	2.46±0.62
	III	2.41±0.15	2.21±0.21	2.34±0.25	2.33±0.36	2.20±0.37	2.25±0.51
Sterility %	I	12.35±1.83	25.73±1.74	29.14±2.26	19.36±2.69	26.30±1.83	29.18±1.12
	II	15.42±1.64	28.51±1.63	25.12±3.24	16.41±2.13	27.18±2.91	25.34±2.21
	III	19..63±1.63	26.41±1.34	30.54±1.62	19.12±2.46	27.19±1.44	30.24±2.42
Grain yield/plant (g)	I	32.65±3.84	17.81±2.57	36.41±3.25	29.58±2.45	16.48±2.81	30.42±1.66
	II	25.42±2.63	20.63±2.84	29.82±2.15	23.61±2.58	20.13±3.61	29.81±1.12
	III	20.64±1.99	15.78±1.76	14.63±2.13	18.74±1.99	14.28±1.32	18.53±2.64

I. Tsuyuake (tolerant)XSakha 103 (sensitive).

II. Zenith (tolerant) X Sakha 104 (moderate).

III. BL 1 (moderate) X Sakha 106 (sensitive).

The results showed that there are high differences between the six parents for all root, yield and related characters this was expected due to the genetic background of these genotypes. The Tsuyuake variety gave the highest mean values in the studied characters, while the lowest mean values were recorded for Sakha 106. The F_1 mean values were higher than the highest parent for root volume, root / shoot ratio, in cross I, root length, root fresh weight, plant height and grain yield / plant in crosses I and II and number of panicles / plant in the three crosses. While the lowest F_1 means were recorded for root fresh weight, days to 50% heading and grain yield / plant in cross III. Also the F_1 mean values were higher than the means of two parents in the three crosses for the remaining studied characters. These results indicated the presence of partial and over-dominance for these traits which were verified by the computed values of potence ratio, heterosis and heterobeltosis. It is well known that the higher root characters enable plant to grow safely under water stress condition so Tsuyuake, Zenith and their crosses could be recommended under water stress condition. On the other hand the F_2 mean values were lower than the F_1 in the three crosses for most of the three crosses. These results indicated the existence of significant inbreeding depression in F_2 generation. Moreover, the F_2 mean values were higher than the F_1 for root length, root fresh weight, root / shoot ratio, plant height, number of panicles / plant and grain yield / plant in cross III, root number/plant in cross II and days to 50% heading and panicle length in crosses II and III. These results indicated transgressive segregation. While BC_1 and BC_2 mean values tended towards the mean values of the recurrent parents with some exceptions.

Finally, from the foregoing results, it could be concluded that, the expression of heterosis in the F_1 be followed by considerable inbreeding depression in F2 performance, indicating that the non additive gene effects governed the inheritance of such characters. This is logic and expected since there is a tendency towards homozygosity which is accelerated by 40 % for each generation. The most desirable genotypes for root, grain yield and its related characters studied were the parents, Tsuyuake and Zenith and their crosses, proving to be useful genotypes in breeding program for water stress condition. The results are in agreement with those reported by Souframanian *et al*., (1997), Abd-Allah (2000) and Abd El-lateif *et al*., (2006).

1- genetic parameters:

1-1. Estimates of heterosis, nature of dominance and inbreeding depression:

It's clear that from Table (5), highly significant and positive estimates of heterosis as a deviation from mid and better-parent were exhibited in the three crosses for most of the studied characters. Highly significant positive heterotic effects from amid- parent was recorded for root length, root volume and number of panicles / plant in the three crosses, root fresh weight, sterility % and grain yield / plant in crosses I and II and plant height, root /shoot ratio in cross I and root number/plant in crosses I and III. Highly significant and positive heterosis relative to better parent were recorded for number of panicles / plant and sterility % in the three crosses and number of days to 50 % heading, plant height and grain yield / plant in crosses I and II. On the other hand significant negative heterosis was recorded in the remaining studied characters in the three studied crosses.

Table 5. Estimates of heterosis as a deviation from mid (MP) and better parents (BP) and degree of dominance and inbreeding depression of some rice root and yield and its component characters in the three studied crosses.

Characters	Cross	Heterosis		Degree of dominance	Inbreeding depression
		M.P.	B.P.		
Root length (cm)	I	31.17**	0.96	1.22	29.33**
	II	20.37**	1.86	1.01	35.82**
	III	9.64**	-7.08**	0.66	2.36
Root number/plant	I	13.87**	-7.53**	0.5	56.48**
	II	0.48	3.77	0.07	44.05**
	III	7.01**	-0.21	1.23	41.63**
Root volume (cm^3)	I	31.96**	1.67	2.33	55.60**
	II	7.43**	-3.97	0.56	32.01**
	III	9.92**	-5.75*	1.2	41.92**
Root fresh weight/plant (g)	I	34.20**	2.47	1.03	45.19**
	II	14.27**	1.01	1.41	56.32**
	III	-32.90**	-46.24**	-1.13	-12.86**
Root/shoot ratio %	I	22.78**	1.45	1.56	52.55**
	II	1.60	-12.19**	0.14	30.27**
	III	-1.62	-13.40**	-0.26	7.63
Days to 50 % heading (days)	I	-0.54	6.75*	-0.14	44.92**
	II	0.70	8.12**	0.14	38.07**
	III	-6.54*	-2.43	-1.44	34.85**
Plant height (cm)	I	13.26**	26.47**	1.23	42.67**
	II	7.64*	13.20**	1.51	42.89**
	III	-14.25**	-4.13	-1.37	23.04**
Panicle length (cm)	I	7.59*	-3.14	0.61	18.12**
	II	4.84	-7.87*	0.21	2.58
	III	1.96	-3.93	0.01	-8.88
Number of panicles/plant	I	33.60**	21.13**	3.21	32.33**
	II	23.82**	18.09**	3.11	19.61**
	III	18.86**	10.56**	2.56	-1.56
100 grain weight (g)	I	0.20	-4.17	-1.12	1.26
	II	-0.82	-3.98	-1.25	-2.96
	III	1.30	-2.90	-1.32	1.17
Sterility %	I	23.26**	35.95**	-1.61	14.69**
	II	14.36**	26.91**	-0.53	12.67**
	III	32.67**	55.58**	-2.14	14.58**
Grain yield / plant (g)	I	44.31**	11.52**	1.53	21.32**
	II	29.51**	17.31**	2.61	11.75**
	III	-19.66**	-29.12**	-14.36	-14.46**

I. Tsuyuake (tolerant)XSakha 103 (sensitive).
II. Zenith (tolerant) X Sakha 104 (moderate).
III. BL 1 (moderate) X Sakha 106 (sensitive).
*and**are significant at 0.05 and 0.01 levels

Degree of dominance Table (5) were greater than positive one unity for root length, root fresh weight, plant height, and grain yield / plant in crosses I and II, number of panicles / plant, in the three crosses, root number in cross III, root volume in crosses I and III and plant height and grain yield / plant in crosses I and II. While negative over dominance was recorded for root fresh weight, days to 50% heading, plant height and grain yield / plant in cross III and 100 grain weight and sterility % in the three crosses. Meanwhile, partial dominance was recorded for all the remaining studied characters in the three studied crosses. Concerning the inbreeding depression, highest significant and positive inbreeding depression were recorded for root number/plant (56.48) in cross I followed by root fresh weight (56.32) in cross II and root volume (55.60) in cross I, while the lowest insignificant inbreeding depression was recorded for 100 grain weight (1.17) in cross III.

Finally, from the above maintained results it could be indicated that the average percentages of heterosis as a deviation from mid- and better- parent were highly significant and positive in most of the studied root characters, yield and its related traits in the three studied crosses, while, it was differed from character to character and from cross to another. The cross I, (Tsuyuake X Sakha 103) showed higher value of heterosis followed by cross II, (Zenith X Sakha 104), for root length, root volume, root fresh weight, number of panicles / plant, plant height and grain yield / plant. They showed highly significant positive heterotic effects proving to be useful hybrid combination for improving these characters in breeding for water stress tolerance program. In addition the significant heterosis as a deviation from mid-and better parent always accompanied by low and insignificant inbreeding depression in most of the studied characters in the three studied crosses indicated the importance of additive gene action which could profitably be utilized in improving these characters. These results were agreement with this obtained by Abd El-Aty *et al*., (2002), EL-Abd (2003), Abd El-lateif (2004), Abd El-lateif *et al*., (2006), Hammoud (2004), Hammoud *et al.,* (2006) and EL-Abd *et al*., (2007).

1-2: Estimates of gene action and effects of genes:

Estimate values of A, B and C scaling test for root, yield and its related characters in the three crosses were determined. Most of the computed parameters of scaling test were statistically significant. Thus in turn indicated the presence of non-allelic interaction, besides that genotype x environment type of gene interactions was important in the inheritance of root, yield and its related traits. As shown in Table (6), additive, dominance and all three types of gene interaction were positive or negative significant and highly significant in the three studied crosses for root number/plant, root volume, root fresh weight, days to 50 % heading, plant height, number of grains

/ panicle and grain yield / plant. The role of additive and dominance genetic variance was more pronounced than the other types of gene interaction in cross I for most of the studied characters. While the additive (d) was more important than dominance for root number/plant, root volume, sterility %, root length, root fresh weight, days to 50 % heading and grain yield / plant in crosses I and II and root / shoot ratio and plant height in cross III. On the contrary, the dominance genetic variance (H) was more important than additive for root length, root number/plant, root / shoot ratio, days to 50 % heading, plant height, panicle length, sterility % and grain yield / plant in the three crosses, 100 grain weight in crosses I and II and root fresh weight in crosses II and III. On the other hand the additive by additive genetic variance (i) of interaction played an important role for root length, root number/plant, plant height, sterility % in the three crosses, root volume in cross I, root fresh weight in crosses I and III, days to 50 % heading in crosses II and III and 100 grain weight and grain yield / plant in crosses I and III. In addition the individual types of digenic epistatic gene effects, the significant additive x dominance gene effects (j) were more frequently than the other types of digenic epistatic, but the estimates of the dominance x dominance gene effects (l) have relatively greater magnitude for the studied characters. Two of these epistatic gene effects apparently counteract each other. The additive x additive gene effects which were mostly significant and positive indicating enhancing effect in the inheritance. The additive x dominance gene effects exhibited less frequently than the other two types. In contract, most of the dominance x dominance gene effects was negative and significant suggesting a diminishing effect due to this type of gene effect and undesirable epistasis.

Finally epistatic gene effect had a significant contribution in the inheritance of studied characters. At least one epistatic gene effect was significant for the studied characters in the three crosses. The additive x additive gene interactions appears to contribute more to epistatic effect than any other source of epistasis. Also, these findings suggest that epistatic effect could be an important major contributor to gene actions in characters of the materials under study. These findings agreed with Acharya *et al*., (1999), Abd-Allah (2000) Abd El-Aty *et al*., (2002), Abd El-lateif *et al*., (2006) and EL-Abd *et al*., (2007).

Table 6. Genetic components of generation mean for some rice root characters, as well as, grain yield and its related traits.

Characters	Crosses	Genetic component of means				
		d	H	i	j	l
Root length	I	11.26**	8.34**	-18.23**	4.23	42.35**
	II	6.54*	8.24**	-12.35**	1.53	39.23**
	III	5.45	6.26**	-18.24**	2.65	28.36**
Root number/plant	I	19.35**	63.54**	-46.35**	-21.36**	69.34**
	II	11.25**	59.82**	34.25**	4.25	62.35**
	III	13.59**	52.11**	-26.38**	3.56	59.34**
Root volume (cm^3)	I	20.54**	19.36	-12.11**	5.23	64.23**
	II	10.24**	17.43*	-4.25	4.36	24.25**
	III	11.89**	13.91**	-2.53	5.36	32.65**
Root fresh weight (g)	I	17.32**	13.39	-22.26**	5.23	46.32**
	II	10.25**	14.84**	12.35	4.56	21.36**
	III	3.25	19.91**	-22.64**	5.53	37.28**
Root/shoot ratio (%)	I	2.54	9.37**	-4.13	-3.23	34.25**
	II	4.36	8.87*	0.53	0.52	15.24**
	III	4.98*	8.49*	0.27	1.51	1.32
Days to 50 % heading (days)	I	16.85**	41.23**	0.63	9.25**	10.58**
	II	12.64**	39.25**	48.82**	5.23	56.34**
	III	5.42	40.84**	-22.68*	0.52	17.24**
Plant height (cm)	I	3.25	31.93**	-38.71**	-5.54	79.32**
	II	4.25	32.07**	-32.91**	-4.41	76.54**
	III	9.48**	33.34**	14.23**	1.06	-26.34**
Panicle length (cm)	I	3.25	7.71*	-6.25	0.54	17.31**
	II	5.14*	7.64*	-10.45**	2.51	15.63**
	III	2.64	7.91*	-16.59**	1.43	20.41**
Number of panicles/plant	I	2.34	6.23	-8.29	0.53	23.61**
	II	-2.14	5.59	-0.77	-3.64	2.31
	III	2.18	4.63	-61.13**	1.26	24.35**
100 grain weight (g)	I	0.21	4.04*	0.34*	0.12	0.27
	II	0.33	4.07*	-0.41**	0.13	0.62
	III	0.18	3.90	0.21	0..81	-0.28
Sterility (%)	I	-7.33*	19.54**	-26.58**	-0.54	31.29**
	II	-11.56**	12.71**	-14.84**	-4.53	21.37**
	III	-8.24**	11.94**	-28.36**	-4.23	41.72**
Grain yield/plant (g)	I	13.45**	8.74*	-30.69**	5.54	61.85**
	II	4.12*	11.62**	-30.26**	0.58	47.26**
	III	3.24	12.67**	-8.23	1.53	7.56*

I. Tsuyuake (tolerant)XSakha 103 (sensitive).
II. Zenith (tolerant) X Sakha 104 (moderate).
III. BL 1 (moderate) X Sakha 106 (sensitive).
*and**are significant at 0.05 and 0.01 levels

1-3: Estimates of genetic variance, heritability and genetic advance:-

Additive genetic variance (1/2 D), dominance genetic variance (1/4 H), broad and narrow- sense heritability and genetic advance (G.S. %) estimates of the studied characters for the three studied crosses were shown in Table (7).

Table 7. Estimates of additive genetic variance, dominance genetic variance, broad and narrow-sense heritability and genetic advance for some rice root characters, grain yield and its related traits in the three studied crosses.

Characters	Crosses	Genetic variance		Heritability %		GS %
		1/2 D	1/4 H	Broad sense	Narrow sense	
Root length (cm)	I II III	9.36 6.23 6.54	12.38 8.45 11.266	84.12 63.26 89.45	36.25 27.64 31.58	16.24 30.15 24.48
Root number	I II III	60.26 62.35 60.45	89.34 65.41 69.45	98.02 84.23 97.26	39.45 41.36 45.98	5.12 4.15 3.99
Root volume (cm^3)	I II III	6.34 8.21 4.73	11.45 6.25 8.74	97.91 30.43 38.70	12.36 17.15 12.59	19.28 18.72 11.25
Root fresh weight (g)	I II III	10.54 20.15 12.36	15.36 8.42 10.59	64.32 87.41 75.26	25.49 62.35 41.78	20.28 14.62 11.71
Root /shoot ratio%	I II III	9.31 6.45 8.48	8.34 9.48 7.34	85.12 88.35 83.56	45.26 35.68 44.15	8.36 17.267 15.41
Days to 50 % heading (days)	I II III	30.28 45.98 42.59	36.48 40.25 39.78	66.35 78.70 79.54	31.59 41.78 41.17	7.26 7.99 6.24
Plant height (cm)	I II III	36.48 44.89 36.45	25.48 29.78 31.26	71.76 87.23 94.36	42.35 53.26 50.18	10.13 6.25 8.42
Panicle length (cm)	I II III	8.12 9.16 9.18	6.58 5.16 8.44	71.05 73.26 94.42	40.19 47.25 50.24	16.48 21.45 17.22
Number of panicles/plant	I II III	6.23 5.11 6.33	8.41 6.54 7.16	93.33 78.57 92.85	40.24 35.29 42.58	6.54 10.26 9.41
100 grain weight (g)	I II III	0.28 0.11 0.13	0.32 0.22 0.26	22.05 16.25 25.91	8.27 7.06 14.79	5.27 4.89 6.21
Sterility %	I II III	15.31 11.65 10.45	10.24 12.58 14.89	86.21 92.24 81.35	51.72 44.26 33.58	15.26 14.31 10.43
Grain yield/plant (g)	I II III	13.69 12.56 8.12	16.45 10.36 9.42	96.65 75.42 94.63	43.56 41.17 44.46	14.61 18.57 20.12

I. Tsuyuake (tolerant)XSakha 103 (sensitive).
II. Zenith (tolerant) X Sakha 104 (moderate).
III. BL 1 (moderate) X Sakha 106 (sensitive).
1/2 D: additive genetic variance 1/4 H: dominance genetic variance
GS %: genetic advance

Additive genetic variance was higher than the dominance genetic variance for root volume in cross II, root fresh weight and days to heading in crosses II and III, root / shoot ratio in crosses I and III, and panicle length in the three crosses, sterility % in cross I and grain yield / plant in cross II. The relative magnitude of the additive genetic variance was approximately two times that of the dominance genetic variance in each cross. On the contrary dominance genetic variance estimates were higher than the additive genetic variance for root length, root number/plant, number of panicles / plant and 100 grain weight in the three crosses, root volume in crosses I and III, root fresh weight and days to 50 % heading in cross I, root / shoot ratio in cross II, sterility % in crosses II and III and grain yield in crosses I and III. These results indicated that, dominance genetic variance was more important than the additive genetic variance especially in the three studied crosses for most of the studied characters. These findings proved that the dominance type of gene effects appeared to be the most effective in the genetic control of the studied roots characters, yield and its related treats in the present materials. Broad- sense heritability estimates ranged from low (16.25 %) for 100 grain weight in cross II to high (98.02 %) for root numbers/plant in cross I. On the other hand, heritability in narrow sense were low (7.06 %) for 100 grain weight in cross II to intermediate (62.35 %) for root fresh weight in cross II. These results indicated that the selection for these characters will be more effective in late generations. Moreover, moderate to low values of predicted genetic advance were estimated for the three crosses. Moderate values of predicted genetic advance (30.15) were recorded for root length in cross II. While, low estimates of expected genetic advance (3.99) was found to be for root volume in cross III. Low genetic advance with low heritability for this trait could be expected because they are under polygenic control, additive and dominance components of variation were significant in the inheritance of this trait, but dominance component was higher than the additive one. It suggested that early generation selection may not be effective in improving this trait. Similar results were obtained by Abd El-Aty *et al*., (2002), Abd El-lateif *et al*., (2006), EL-Abd *et al*., (2007), Abd-Allah *et al*., (2010), Ashfaq (2011), Abd El-lattef and Badr (2007) and Gouda *et al*., (2012).

Finally, the breeder can easily improve some root characters, yield and related traits by simple breeding methods. The previous results of genetic variances and heritability estimates for studied root characters, yield and its related traits revealed that the dominance genetic variance had more important role in the inheritance of most of these characters than the additive genetic one, and this findings differ from character to another and also between crosses. Heritability estimates in broad sense were low to high in most cases indicating the effect of the environmental condition on these characters. Moreover, heritability estimates in narrow sense were mostly low. This was expected due to the high estimates of dominance genetic variance at most characters. This in turn suggested that these traits behaved in a quantitative manner on improving of grain yield and its related traits could be achieved in late generation. This conclusion may be useful to the breeder for rice in planning a selection program for improvement the yield in such crosses, also, the use of hybridization of their improvement under water stress condition.

2: Phenotypic correlation coefficients among all possible pairs of the studied traits:

The phenotypic correlation coefficient was estimated among all possible combinations of root characters, yield and its related traits in the F_2 generation of the three studied crosses. The results presented in Table (8), could be discussed as follow: the phenotypic correlation coefficient were positively highly significant for root length with root volume, panicle length and grain yield / plant in the three crosses. Also root number was highly significant and positive with root volume, plant height, 100 grain weight and grain yield / plant on the other hand root volume was highly significant and positive with number of panicles / plant and grain yield / plant in the three crosses. Moreover panicle length was highly significant correlated with number of panicles / plant and grain yield in the three crosses. Number of panicles / plant and 100 gain weight were highly significant and positive correlated with grain yield / plant in the three crosses. On the contrary, negatively significant and highly significant phenotypic correlation coefficient was recorded between plant height and grain yield / plant in crosses I and II. Also negative significant phenotypic correlation coefficient was recorded between 100 grain weight and panicle length in cross I.

Finally the grain yield / plant was highly significant and positively correlated with root length, root number/plant, root volume, panicle length, number of panicles / plant and 100 grain weight in the three studied crosses. On the contrary, the grain yield / plant were highly significant and negatively correlated with plant height in the first tow crosses. Similar results were obtained by Abd Allah (2000), Abd El-Aty *et al*., (2002), Hammoud (2004), Hammoud *et al.,* (2006), Kanbar *et al*., (2010), Muthuramu *et al*., (2010), Hosseini *et al*., (2012) and Abd-Allah *et al*., (2013).

Table 8. Phenotypic correlation coefficients among all possible pairs of the studied characters.

	Root length	Root number	Root volume	Dyes to 50% heading	Plant height	Panicle length	Number of panicles/plant	100 grain weight
Root number/plant	-0.25 -0.26 -0.22	------						
Root volume (cm^3)	0.46** 0.40** 0.41**	0.39** 0.37** 0.45**	------					
Days to 50 % heading (days)	0.22 0.24 0.23	0.22 0.23 0.19	0.12 0.21 0.17	-------				
Plant height (cm)	0.36 0.38* 0.30	0.38** 0.36** 0.38**	0.25 0.20 0.23	-0.15 -0.19 -0.27	-------			
Panicle length (cm)	0.45** 0.46** 0.53**	0.46** 0.39** 0.31	0.39** 0.37** 0.21	0.40* 0.39** 0.34*	0.46** 0.48** 0.29	------		
Number of panicles/plant	0.34** 0.35* 0.19	0.30 0.25 0.30	0.40** 0.36** 0.36**	0.25 0.16 0.11	-0.16 -0.21 -0.21	0.48** 0.39** 0.44**	--------	
100 grain weight (g)	0.30 0.36* 0.18	0.36** 0.38** 0.33*	0.27 0.22 0.19	0.39** 0.26 0.24	0.26 0.22 0.12	-0.35* -0.29 -0.22	-0.32* -0.28 -0.16	------
Grain yield/plant (g)	0.50** 0.52** 0.40**	0.56** 0.42** 0.36**	0.42** 0.46** 0.40**	0.21 0.23 0.11	-0.44* -.41** -0.15	0.48** 0.56** 0.46**	0.56** 0.49** 0.40**	0.52** 0.51** 0.46**

*and**are significant at 0.05 and 0.01 levels

B- Water intervals

Estimates of amount of water applied, water consumptive use m^3/ fed: and actual evapotranspiration in (ETC mm / day) are presented in Table (9). Results in Table (9) clarified that total water applied and water consumptive use was 5197and 3733 m^3/ fed respectively. While the highest water applied and water consumptive use values were 1495 and 1014 m^3 / fed. recorded in August. On the other hand, the lowest values were 1002 and 726 m^3 /fed. recorded in September. Data in Table (9), also, showed that values of ETC increased in July and August followed by June being 7.22, 7.41 and 6.99 mm / day respectively. While in September it was 6.12 mm / day. The potential evapotranspiration (ETp mm / day) (Table 9), was decreased in emergence stage, while, it increased gradually with increase age of plants and decreased in pre-harvest period in September, after that ETp (mm / day) increased in June and July.

Table 9. Water applied m^3/fed., water consumptives, actual evapotranspirationin/day and values of crop coefficient (kc) by radiation inethod.

Months	Water applied m^3/fed	Water consumptive Use m^3/fed.	Evapotranspration mm/day	EtP mm/day M.P.	Radiation
June	1237	991	6.99	6.25	1.00
July	1463	1002	7.22	6.11	1.11
August	1495	1014	7.41	5.99	1.12
September	1002	726	6.12	5.32	0.96
Total	5197	3733	27.79	23.6	4.19
Mean	1299.25	933	6.93	5.91	1.04

Crop coefficient (Kc, %):

Table (9), indicated that the effect of crop characteristics on crop water requirements are show by crop coefficient which represents the relationship between reference potential (ETp) and actual crop evapotranspiration (Etc).

The values of crop coefficient for irrigation pattern (kc) showed slight increase after planting and decreased again at the end of season. It could be noticed that the nearest values to average of estimating water consumptive use in rice. These results agreed with the obtained by Nasir *et al*., (2002), Hussain *et al*., (2003) and Azam *et al*., (2005).

Estimates of grain yield (Kg / fed), crop and field water use efficiency (CWUE %) and field water use efficiency (FWUE %) are presented in Table (10). Data indicated that the average of grain yield was significantly affected by breeding. The maximum value of 3760 Kg / fed. was found for the F_1 generation followed by the first parent (Tsuyuak) being 3360 Kg / fed in cross I. While the minimum value was recorded by BC_2 it was 1470 Kg / fed in the third cross. From the foregoing results, the highest average yield of 2800 Kg / fed. was recorded for the first cross (Tsuyuake x Sakha 103) followed by cross II (Zenith x Sakha 104) being 2555 Kg / fed. respectively. While, lowest value1732 Kg / fed. was recorded for the cross III (BL1 x Sakha 106).

Crop and field water use efficiency (CWUE, %):

Data in Table (10) indicated that crop water use efficiency was significantly affected by flashing water irrigation methods. The maximum CWUE, % values (0.91) were found for the F_1 generation followed by parent Tsuyuake was 0.86 kg / m^3 in cross I. While the minimum value was recorded by BC_2 generation it was 0.32 kg / m^3in cross III.

Table 10. Crop and field water use efficiency under drought conditions.

Character	Cross	P1	P2	F_1	BC_1	BC_2	F_2	Average
Grain yield Kg/fed.	I	3360	1785	3780	3045	1680	3150	2800
	II	2625	2100	3045	2415	2100	3045	2555
	III	2100	1575	1470	1890	1470	1890	1732
Average		2695	1820	2765	2450	1750	2695	2362
CWUE %	I	0.86	0.47	0.91	0.81	0.45	0.84	0.75
	II	0.70	0.56	0.82	0.64	0.56	0.81	0.68
	III	0.56	0.42	0.39	0.49	0.32	0.50	0.45
Average		0.74	0.48	0.73	0.64	0.46	0.71	0.62
FWUE %	I	0.64	0.34	0.72	0.58	0.32	0.60	0.53
	II	0.50	0.40	0.58	0.46	0.40	0.58	0.48
	III	0.41	0.30	0.28	0.36	0.26	0.36	0.33
Average		0.51	0.34	0.52	0.46	0.33	0.51	0.44

I. Tsuyuake (tolerant)XSakha 103 (sensitive).

II. Zenith (tolerant) X Sakha 104 (moderate).

III. BL 1 (moderate) X Sakha 106 (sensitive).

On the other hand, cross I gave the highest mean values 0.75 kg / m^3 of crop water use efficiency followed by cross II (0.68 kg / m^3). These data showed that the highest crop water use efficiency (0.75 and 0.68 kg / m^3) was recorded from 1 m^3flushing water irrigation in cross I (Tsuyuake x Sakha 103) and cross II (Zenith X Sakha 104), respectivaly. Also data indicated that the significant effect of flushing water irrigation method on FWUE, %. The maximum FWUE, % value was recorded for the F_1 generation followed by parent Tsuyuake in cross I, while the minimum value was recorded in BC_2 generation in cross III. On the other hand the highest value of FWUE, % was found in cross I followed by crosses II and III. These results agree with those obtained by Khan *et al.*, (1999), Akbar *et al.*, (2002), Yasin *et al.*, (2003) and Ahmed and Karube (2005).

From the obtained results cross I (Tsuyuake x Sakha 103) and cross II (Zenith X Sakha 104) could be recommended to be grown under water stress condition to obtain the highest rice grain yield (kg grains / m^3 water) and highest value of water saving in the same time.

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توارث بعض صفات الجذور والإنتاجية في الأرز تحت ظروف الإجهاد المائى

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مركز البحوث والتدريب في الأرز ، معهد بحوث المحاصيل الحقلية ، مركز البحـوث الزراعيـة ، سخا ، كفرالشيخ ، مصر

أجريت هذه الدراسة بالمزرعة البحثية لمركز البحوث و التدريب في الأرز خلال المواسم الزراعيه٢٠١١، ٢٠١٢ و ٢٠١٣ بهدف دراسة صفات الجذور ومحصول الحبوب والصفات المرتبطة بة للنبات الفردي وعلاقتها بتحمل الجفاف في الأرز حيث إستخدمت ستة أصناف هي تسيوكا (متحمل لنقص الرطوبة الأرضية) وسخا ١٠٣ (حساس لنقص الرطوبة الأرضية) زنث (متحمل لنقص الرطوبة الأرضية) و سخا ١٠٤ (متوسط التحمل لنقص الرطوبة الأرضية) و ب ال ١(متوسط التحمل لنقص الرطوبة الأرضية) و سخا ١٠٦ (حساس لنقص الرطوبة الأرضية) وتم إجراء التهجين بين هذه الأصناف والحصول على ثلاثة هجن هي:الهجين الأول (تسيوكا x سخا١٠٣) الهجين الثاني (زنث x سخا ١٠٤) والهجين الثالث (ب ال ١x سخا ١٠٦) وذلك بهدف تقدير مكونات التباين الوراثي في كل من الآباء والجيل الأول والجيل الرجعى مع الأب الأول والجيل الرجعى الثاني مع الأب الثاني والجيل الثاني، وذلك عن طريق تقدير ستة مكونات وراثية هي المتوسط والتباين المضيف والتباين السيادي والتفاعل بينهما وتأثيرهما على الصفات المدروسة تحت ظروف نقص الرطوبة الأرضية. وكانت النتائج كالآتي :

وجد من الدراسة أن هناك تباين كبير في مختلف الصفات المدروسة بالنسبة للآباء تحت ظروف نقص الرطوبة الأرضية وخاصة صفات الجذور حيث أعطت الأصناف تسيوكا وزنث قيم أعلي متفوقا على باقي الآباء بالنسبة لمعظم الصفات المدروسة كما أعطت نباتات الجيل الأول قيم أعلى من أفضل الآباء لمعظم الصفات المدروسة وخاصة محصول الحبوب للنبات الفردي في الهجينين الأول والثاني مما يشير لوجود سيادة فائقة لبعض الصفات المدروسة بينما تراوحت قيم باقي الصفات من سيادة كاملة إلى جزئية. و جاءت قيم الجيل الثاني أعلى من الجيل الأول في عشرة صفات وخاصة الجيل الثاني والثالث مما يشير إلى وجود إنعزال فائق الحدود. أيضا جاءت باقي القيم مساوية تقريبا لمتوسط الآباء في معظم الصفات وأقل من قيم الجيل الأول مما يشير إلى تأثر تلك الصفات بالتربية الداخلية. لعبت قوة الهجين دورا كبيرا في معظم الصفات المدروسة حيث أشارت النتائج إلى وجود معنوية عالية لقوة الهجين في معظم الصفات ماعدا صفة طول الجذر وصفة طول الدالية ووزن الـ١٠٠ حبة منسوبة لأفضل الأباء في الثلاثة هجن المدروسة. كما لعب كلا من التأثير المضيف والسيادي دوراً كبير في معظم الهجن المدروسة وخاصة الهجين الأول والثاني. كما كان للتفاعل بينهما خاصة التأثير المضيف × المضيف دورا هاما في معظم الصفات ما عدا نسبة

المجموع الجذري إلى الخضري في كل الهجن المدروسة. بينما لعب التأثير المضـيف × السـيادي دورا هاما في صفة عدد الجذور وعدد الأيام حتى ٥٠ % تزهير في الهجين الأول. وجـد أن قـيم التباين الوراثي المضيف أعلي من قيم التباين الوراثي السيادي لصفة طول النبـات وطـول الداليـة بالنبات الفردي في الثلاثة هجن المدروسة. بينما كانت قيم التباين الوراثي السيادي أعلي مـن قـيم التباين الوراثي المضيف في باقي الصفات لمختلف الهجن المدروسة. تراوحت قيمة درجة التوريـث في المدى الواسع من متوسطة إلي مرتفعة في مختلف الصفات بينما تراوحت قيمة درجة التوريـث في المدى الضيق من منخفضة (٧.٠٦%) لصفة وزن الـ١٠٠حبة في الهجين الثاني إلي متوسـطة (٦٢.٣٥%) لصفة وزن الجذر الأخضر في الهجين الثاني. كما جاءت نسبة التحسين المتوقـع مـن الإنتخاب من منخفضة إلي مرتفعة وكان الهجين الثاني أعلي القيم إرتفاعا في معظم الصفات مقارنـة بباقي الهجن المدروسة. كان هناك ارتباط معنوي موجب بين محصـول النبـات الفـردي ومعظـم الصفات المدروسة وخاصة طول الجذر للنبات الفردي وعدد الجذور وحجم الجذر و طـول الداليـة وعدد الداليات بالنبات الفردي ووزن ١٠٠ حبة في الثلاثة هجن المدروسة. كما أوضحت النتـائج أن كمية المياه المضافة للهجن المدروسة تراوحت بين ٥١٩٧ إلى ٣٧٣٣ متر مكعب للفـدان كمـا أن المتر المكعب من المياه أعطى ٧٥٠ و ٦٨٠ جرام من محصول حبوب الأرز وخاصة في الهجـين الأول والثاني على التوالي ولذا وبناء على النتائج المشار إليها يمكـن التوصـية بزراعـة نباتـات الهجينين الأول والثاني تحت ظروف نقص الرطوبة الأرضـية لإعطائهمـا أعلـي كميـة حبـوب وإستمرار برنامج التربية للحصول علي إنعزالات لنباتات أرز أكثر تحملا لنقص المياه.