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HETEROSIS AND COMBINING ABILITY FOR YIELD AND ITS COMPONENTS AND SOME ROOT CHARACTERS IN RICE UNDER WATER STRESS CONDITIONS

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ABSTRACT

Eight rice varieties having diverse morphological and agronomical characters were crossed in all possible combinations (excluding reciprocals) and parents and crosses were investigated during 2005 and 2006 growing seasons. The results indicated that variance due to both general combining ability (GCA) and specific combining ability (SCA) was highly significant for all traits indicating the importance of both additive and non-additive gene effects in the inheritance of all traits. However, an estimation of GCA effect of parents revealed that the rice variety IET 1444 appeared to be better combiner for all the studied traits except plant height and 100 grain yield, whereas, Milyang 85 was the best combiner for plant height, root volume and a high number of both panicles and roots / plant. Nine crosses: Balado x Milyang 85, Sakha 101 x Milyang 85, Giza 177 x Sakha 101, Giza 177 x IR 66158, Giza 177 x IET 1444, Balado x IET 1444, Sakha 104 x Milyang 85, Sakha 104 x IET 1444 and Giza 178 x Balado showed the highest SCA effect for grain yield /plant, and identified as the most desired combinations for developing high yielding hybrid rice varieties. On the other hand, they also recorded highly significant and positive estimates of heterosis when measured as a deviation from both mid-parent and better parent for most of the studied traits. High estimates of broad sense heritability were recorded for all traits; while, low (22.14 %) to moderate (51.62 %) estimates of narrow sense heritability were observed for sterility % and number of panicles / plant, respectively. Furthermore, high heritability coupled with high expected genetic advance were noted for number of roots / plant, plant height, root volume, sterility % and number of panicles / plant indicating the effectiveness of selection in early generation to improve these traits. Highly significant and positive estimates of phenotypic correlation coefficients were recorded between grain yield / plant and each of panicle length, number of panicles / plant, root length and number of roots / plant.

Key words: ***Rice, Heterosis, Combining ability, Heritability, Grain yield, Root traits.***

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops in Egypt as regards to its contribution to foreign currency. The cultivated rice area in Egypt has been increasing gradually since the beginning of the Egyptian Rice Program. The main target of The National Rice Program in Egypt is decreasing the total cultivated area in normal soil, conversely in water stress condition soil, with carrying out high yield potentiality from unit area. Water stress tolerance in dry land culture in the end of irrigated canal has been identified as a complex and growth stage-specific trait largely associated with a volume and deep root system (Chang and Loresto 1986). The breeding of yield-rich and qualitatively better rice varieties is not possible without prior knowledge of their genetic properties. The breeders, therefore, try to combine the desired properties of different varieties.

Diallel analysis is the first step in most plant breeding programs aimed at improving yield and other related parameters. It is the most popular method used by breeders to obtain information on value of varieties as parents, and to assess the gene action in various characters (Pickett 1993 and Duvick 1999). It is a powerful method to measure the nature of gene action involved in quantitative traits (Baker 1978). Sprague and Tatum (1942) introduced the concept of general combining ability (GCA) and specific combining ability (SCA). Griffing (1956) developed a range of diallel analytical procedures that help breeders to develop appropriate selection strategies and compare heterotic patterns at the early period of hybridization breeding. The present investigation aims to study the nature of gene action for yield and its components, and some root characteristics in rice under water stress condition and to investigate the percentage of heterosis, broad and narrow sense heritability, degree of dominance, the expected genetic advance, phenotypic correlation coefficients among all possible pairs of the studied traits and combining ability of genotypes for the traits by using a half diallel analysis.

MATERIALS AND METHODS

The present investigation was carried out at the farm of Rice Research and Training Center (RRTC), Sakha, Kafr El Sheikh Governorate, Egypt during summer of 2005 and 2006 seasons. The aim of this study was to estimate the general and specific combining ability, additive and non-additive gene effects of the selected genotypes using a 8 x 8 half diallel analysis, to determine the expression of heterosis for the different studied characteristics, and to measure the broad and narrow sense heritabilities, degree of dominance, the expected genetic advance, and the phenotypic correlation coefficients among all possible pairs of the studied traits under water stress condition.

Eight rice varieties having diverse morphological and agronomical characters namely, Giza 177, Giza 178, Sakha 101, Sakha 104, IR 66158, Balado, Milyang 85, and IET 1444 were crossed in a half-diallel mating scheme in the 2005 season. The hybridization model was followed by Mather and Jinks (1982).

In 2006 summer season, the 28 F_1 hybrids along with 8 parents were grown in a randomized complete block design with four replications. Thirty days old single seedling per hill was transplanted at a spacing of 20 X 20 cm with five-meter long rows having three rows in each genotype / replicate. The experiment was conducted under water stress condition (weekly irrigation system) to represent the irrigated system of farmer lands in the end of irrigated canals, with normal package of practices and needed base plant protection measures.

Observations were recorded on twenty competitive plants of the middle row of each plot / replicate. for nine yield components and root traits, i. e. plant height, panicle length, number of panicles / plant, 100 grain weight, sterility %, root length, root volume, number of roots / plant and grain yield / plant. Root characters were estimated at the maximum tillering stage following the method of Morita *et al* (1988). The combining ability analysis was done following Griffing's (1956), Model 1, Method 2, where parents, and one set of F_1's were included to estimate the effects of general (GCA) and specific (SCA) combining ability and variance components. The GCA: SCA ratio was estimated to study the performance of the effects and to measure the relative importance of additive gene or non-additive gene effects (Singh and Chaudhary 1979). Heritability (h^2) is the portion of the total phenotype variance among individuals that is attributable to genetic variance (Wricke and Webe, 1986, and Fehr 1987). Heritability and heterosis were estimated according to Folconer 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). However, the expected genetic advance under selection (Δg) was calculated as given by Johanson *et al* (1955). The phenotypic correlation coefficient was performed according to the procedure of Dewey and Lu (1959).

RESULTS AND DISCUSSIONS

Analysis of variance

It is clear from (Table 1) that the analysis of variance revealed significant differences among the studied genotypes. These findings indicated that the genotypes had a wide genetic diversity. These results emphasized the importance of combining ability studies and indicated good prospects for selection of suitable parents and crosses for the development of appropriate varieties and hybrids. Moreover, estimates of highly significant GCA, SCA variances and also the mean sum of squares due to parents vs crosses for all characters indicated the importance of both additive and non-additive genes in the expression of all studied characters. Hence, any approach that facilitates simultaneous exploration of additive and non-additive gene effects would be most desirable for the improvement of these traits.

The proportion of GCA, which indicated additive and heritable gene effects, is in all cases greater than the SCA, which shows non-additive gene effects. The ratio of σ^2_{gca} / σ^2_{sca} was less than unity for all the characters except 100 grain yield indicating the preponderance of non-additive genetic

Table 1. Analysis of variance for genotypes and combining ability for different characters in a 8 x 8 diallel crosses.

Sources	df	Mean squares for yield components traits				
		Plant height (cm)	Panicle length (cm)	No of panicles /plant	100 grain weight (g)	Sterility %
Replications	3	0.51	0.56	0.02	0.01	1.41
Genotypes	35	810.0**	33.8**	111.4**	0.19**	147.3**
Parents (P)	7	314.2**	8.6**	140.4**	0.12**	60.6**
Crosses (Cr)	27	878.5**	38.8**	88.3**	0.22**	142.5**
P vs. Cr	1	762.3**	32.5**	98.9**	0.20**	125.6**
GCA	7	583.2**	18.8**	85.4**	0.17**	69.4**
SCA	28	107.3**	5.9**	13.5**	0.01**	28.7**
Error	105	3.01	0.82	0.83	0.01	1.09
GCA/SCA		056	0.36	0.67	1.64	0.25

Table 1. cont.

Sources	df	Mean squares for yield and some root traits			
		Root length	Root volume	Roots /plant	Grain yield/plant
Replications	3	2.06	13.68	16.12	0.94
Genotypes	35	66.4**	564.9**	27675.9**	80.8**
Parents (P)	7	64.7**	48.1**	2889.0**	52.7**
Crosses (Cr)	27	64.25**	622.8**	28233.8**	82.7**
P *vs.* Cr	1	64.34**	504.5**	23015.8**	76.6**
GCA	7	40.7**	341.7**	13752.4**	66.5**
SCA	28	10.6**	91.1**	5210.6**	8.63**
Error	105	0.9	1.38	25.37	1.02
GCA/SCA		0.41	0.38	0.26	0.86

** = Significant at $P < 0.01$.

variance in the inheritance of all traits except 100 grain weight which is supposed to controlled by additive genetic variance .It also suggested greater importance of non-additive gene action in their expression and indicated very good prospect for the exploration of non-additive genetic variation for grain yield and its component and the studied root characters, except 100 grain weight through hybrid breeding. Occurrence of both additive and non-additive gene effects with preponderance of non-additive gene action for yield and important yield components in rice were reported by several scientists like Manuel and Prasad (1992), Ramalingam *et al* (1993), Vijay Kumar *et al* (1994), Sharma *et al* (1996), Ganesan *et al* (1997), Peng and Virmani (1999), Bansal *el al* (2000) and Satyanarayana *et al* (2000).

Mean performance

Regarding the parental and hybrids mean values, Table (2) emphasized that IET 1444 followed by Sakha 104 and Balado were the

Table 2. Mean performance of eight rice parents and their F_1 generation for all the studied characters under water stress condition.

Genotypes	Plant height	Panicle length	Panicles number	100 grain weight	Sterility %	Root length (cm)	Root volume	Roots number	Grain yield / plant
Giza 177	84.69 b	21.94 ab	18.56 d	2.88 ab	14.94 d	16.63 d	28.63 d	211..28 f	19.80 de
Giza 178	79.28 c	21.69 ab	14.63 e	2.40 bc	18.94 b	22.86 e	27.13 cd	251.81 c	22.00 bc
Sakha 101	61.19 g	19.75 bc	12.81 ef	2.44 abc	17.69 bc	23.88 bc	29.13 bc	227.13 e	21.28 cd
Sakha 104	73.31 de	19.81 bc	10.63 f	2.56 a	16.25 cd	24.88 bc	31.38 b	248.31 cd	24.63 b
IR 66158	70.44 ef	20.81 ab	21.31 c	2.10 d	24.56 a	18.81 d	27.31 cd	278.28 b	17.87 e
Balado	76.13 d	21.88 ab	22.44 bc	2.70 a	18.31 bc	25.50 b	29.44 bc	236.44 de	24.28 bc
Milyang 85	88.06 a	18.06 c	24.63 b	2.31 cd	15.50 d	23.88 bc	33.88 a	268.28 b	21.56 bc
IET 1444	67.81 f	22.31 a	27.31 a	2.41 cd	11.00 e	29.63 a	35.63 a	292.38 a	29.68 a
C. V. % for Parents	2.7	7.2	8.8	5.4	8.2	7.3	6.2	2.8	9.2
Giza 177 X Giza 178	92.00 f	27.13 b	20.88 j-m	2.21 h-l	21.88 f-i	25.75 d-h	29.88 ijk	321.50 hi	23.44 efg
X Sakha 101	64.19 l	24.56 b-e	20.00 lm	2.48 b-g	17.13 i-l	20.31 m	33.44 ghi	296.56 l	26.86 cde
X Sakha 104	88.81 gh	19.75 gh	18.44 m	2.54 a-d	23.88 d-g	21.63 j-m	38.13 gh	206.69 n	24.94 d-g
X IR 66158	94.31 ef	19.56 gh	25.38 f-i	2.15 h-l	31.13 ab	22.88 g-m	26.38 lm	392.13 de	22.88 fgh
X Balado	104.63 c	21.63 efg	23.38 hij	2.79 a	21.38 f-j	29.28 bc	29.38 i-l	208.81 n	26.38 def
X Milyang 85	108.81 b	20.25 fgh	22.56 i-l	2.23 d-h	26.13 c-f	21.31 klm	48.88 e	378.06 e	23.00 fg
X IET 1444	63.63 l	24.38 b-e	29.63 abc	2.39 e-h	18.28 h-l	31.44 ab	84.00 bcd	402.86 d	34.66 a
Giza 178 X Sakha 101	64.06 l	23.75 d-g	18.63 m	2.46 b-g	20.00 kl	28.94 d-g	36.13 g	221.63 n	21.88 gh
X Sakha 104	87.63 h	17.81 h	23.06 ijk	2.40 f-j	19.88 g-j	24.69 e-j	36.63 g	306.88 i-l	24.86 d-g
X IR 66158	91.37 fg	23.50 c-f	26.86 d-g	2.10 klm	26.94 b-e	24.19 e-l	37.88 jkl	318.13 hi	18.87 j
X Balado	97.94 d	23.86 cde	19.31 m	2.61 abc	23.86 d-g	29.78 bc	26.44 klm	438.13 c	26.81 cde
X Milyang 85	103.69 c	25.13 bcd	28.38 f-l	2.20 h-l	36.00 a	21.06 lm	61.28 de	303.06 kl	19.87 hi
X IET 1444	74.31 jk	26.18 bc	28.12 c-f	2.12 j-m	22.38e-h	31.38 ab	66.8 bc	461.50 b	29.00 bc
Sakha 101X Sakha 104	81.62 l	17.88 h	15.13 n	2.59 abc	19.13 g-k	22.06 i-m	25.63 lm	248.19 m	26.94 cd
X IR 66158	76.28 j	20.06 gh	20.28 klm	2.31 g-l	33.28 a	26.81 c-f	28.63 jkl	298.81 kl	19.81 hi
X Balado	82.69 i	24.31 b-g	23.81 g-l	2.56 a-e	21.13 g-j	28.06 e-i	23.81 m	222.19 n	24.28 d-g
X Milyang 85	97.13 de	19.75 gh	23.50 hij	2.31 g-l	30.44 abc	22.63 h-m	52.19 cde	316.94 hij	27.13 cd
X IET 1444	72.50 l	25.13 bcd	26.25 d-h	2.44 c-g	18.63 h-k	27.13 cde	49.28 e	388.06 f	31.69 ab
Sakha 104 X IR 66158	83.38 l	19.81 gh	13.38 n	1.94 lm	19.81 g-j	16.94 n	33.06 ghi	333.38 fg	24.50 d-g
X Balado	95.13 de	17.75 h	20.88 j-m	2.71 ab	23.50 d-g	23.81 f-l	42.38 f	206.00 n	26.06 c-f
X Milyang 85	108.50 b	19.56 gh	25.50 e-l	2.53 g-k	33.13 a	24.38 e-k	48.44 e	348.75 fg	27.31 cd
X IET 1444	66.19 l	23.63 cde	28.94 bcd	2.42 c-g	16.63 jkl	31.31 ab	54.06 bcd	408.69 d	32.94 a
IR 66158 X Balado	94.31 ef	21.44 efg	28.44 cde	2.39 e-h	27.38 bcd	28.56 bcd	31.81 hij	318.94 h-k	23.13 fg
X Milyang 85	98.13 d	21.19 efg	19.19 m	1.88 m	34.06 a	23.13 g-m	57.75 b	358.81 f	18.38 ij
X IET 1444	83.94 l	22.63 d-g	32.25 a	2.26 l-m	17.81 bcd	25.88 d-h	62.13 a	383.44 e	23.50 efg
Balado X Milyang 85	112.38 a	22.38 d-g	25.25 f-i	2.34 f-i	20.88 g-j	29.38 bc	30.44 ijk	453.50 bc	32.25 a
X IET 1444	75.00 jk	24.25 b-e	27.13 c-f	2.63 a-f	21.81 f-i	25.13 e-i	32.81 ghi	461.81 b	33.31 a
Milyang 85 X IET 1444	73.00 k	31.19 a	31.69 ab	2.48 c-g	13.87 l	34.25 a	63.25 a	499.06 a	26.81 cde
C. V. % for Crosses	2.4	9.7	8.0	6.5	12.3	7.6	6.3	3.4	7.9

highest yielding rice genotypes under the study. On the contrary, IR 66158 and Giza 177 were the lowest yielding varieties. Moreover, IET 1444 proved to be superior in terms of i longest panicle, many panicles / plant, less sterile grains, longest root, high root volume and numbers / plant comparing with other studied genotypes. However, the desirable estimated values for plant height and 100 grain weight were recorded for Milyang 85 and Balado rice varieties, respectively. On the other hand, the highest F_1 mean values of grain yield / plant, root length, root volume and number of roots / plant were recorded for Giza 177 x IET 1444 and Sakha 104 x IET 1444 rice genotypes. Moreover, the hybrids, Balado x Milyang 85, Milyang 85 x IET 1444, IR 66158 x IET 1444 and Giza 177 x Balado showed the tallest plants, longest panicles, more panicles productivity, and heavy grains, respectively comparing with other rice hybrids. It indicated that if the yield and its components were the most important selection criteria, these mentioned hybrids will be the best in a breeding program; otherwise, if grain yield and the root characteristics are important in the breeding program, the rice crosses Giza 177 x IET 1444 and Sakha 104 x IET 1444 will be the best choice. For most of the studied characteristics, hybrids in general had higher values than parental lines. This indicated importance of heterosis.

Estimates of general and specific combining ability effects

General combining ability effects

The estimates of general combining ability effect are an important indicator of the potential of parental lines for generating superior breeding populations. A negligible or negative combining ability effect indicates a poor ability to transfer its genetic superiority to hybrids (Cruz and Regazzi 1994). The largest significant positive values have the largest effects. On the other hand, the largest significant negative values have the smallest effects except in case of sterility % and plant height traits (Tenkouano *et al* 1998). Obviously, Tables (3 & 4) indicated that one parent i. e., IET 1444 was found to be an overall good general combiner for most of the traits under consideration with the exception of 100 grain yield and plant height traits. Excluding IET 1444, the good general combiners for different characters are Milyang 85, Balado and Giza 177 for plant height; Giza 178 for panicle length; Milyang 85, Balado and IR 66158 for number of panicles / plant; Balado, Sakha 104, Sakha 101 and Giza 177 for 100 grain weight; Sakha 104, Giza 177 and Balado for sterility %; Balado for root length; Milyang 85 for root volume and both Milyang 85 and IR 66158 rice parents for number of roots/plant.

However, some of the parents with high mean values exhibited low GCA effects. Hence, both performances *per se* and GCA effects should be taken into account for parental selection. The parent IET 1444 was selected

Table 3. Estimates of general combining ability (gca) of parents for different studied traits in rice.

Parents	Plant height (cm)	Panicle length (cm)	No. of panicles / plant	100 grain weight (g)	Sterility %	Root length (cm)	Root volume	No. of roots / plant	Grain yield / plant (g)
Giza 177	2.666**	0.253	-0.642**	0.057**	-1.191**	-1.963**	-3.394**	-23.744**	-0.463**
Giza 178	1.041**	1.184**	-1.261**	-0.049**	0.597**	0.244	-2.331**	0.519	-1.894**
Sakha 101	-9.828**	-0.366*	-3.061**	0.063**	-0.647**	-0.775**	-3.394**	-45.563**	-0.363*
Sakha 104	-0.122	-2.278**	-3.723**	0.067**	-1.309**	-1.088**	-0.319	-32.006**	1.213**
IR 66158	0.347	-0.878**	0.427**	-0.236**	4.797**	-1.944**	-2.000**	8.488**	-4.056**
Balado	5.522**	0.047	0.927**	0.205**	-0.528**	1.650**	-6.531**	-9.000**	1.531**
Milyang 85	11.866**	-0.303*	1.852**	-0.101**	2.297**	-0.156	7.869**	32.244**	-0.650**
IET 1444	-11.491**	2.341**	5.483**	-0.005	-4.016**	4.031**	10.100**	69.063**	4.681**
SE (gi)	0.513	0.269	0.270	0.019	0.309	0.277	0.348	1.490	0.299
SE (gi-gj)	0.776	0.406	0.408	0.029	0.467	0.419	0.526	2.253	0.452

Table 4. Selection of parents based on mean and general combining ability (gca) effect.

Character	Mean	gca effect
Plant height (cm)	P7, P1, P2	P7, P6, P1
Panicle length (cm)	P8, P1, P6	P8, P2
No. of panicles number/ plant	P8, P7, P6, P5	P8, P7, P6, P5
100 grain weight (g)	P6, P1, P4	P6, P4, P3, P1
Sterility %	P8, P1, P7, P4	P8, P4, P1, P3
Root length (cm)	P8, P6, P4	P8, P6
Root volume	P8, P7, P4, P6	P8, P7
Roots number	P8, P5, P7, P2	P8, P7, P5
Grain yield / plant (g)	P8, P4, P6, P7	P8, P6, P4

as the best one since it had high mean values for most of root traits and was also a good general combiner for most of yield components traits. Similarly, Milyang 85 and Balado rice parents are also judged as being very good parents. It is obvious that none of the parents were found to be good for all the traits. Hence, it would be desirable to have multiple crosses involving the parents viz., IET 1444, Milyang 85 and Balado and practicing a selection in the segregating generations to isolate superior genotypes (Table 4). Similar results were recorded previously by El Abd (1995), Abd Allah (2000) and Abd El Aty (2001).

Specific combining ability effects

High specific combining ability effects were caused by the dominance and interaction or epistatic effects (non-fixable genes) that existed between the crossed parents. The same can be used as an index to determine the usefulness of a particular cross-combination in the exploitation of heterosis. As shown in Table (5) none of the F_1 hybrids displayed simultaneously significant specific combining ability estimates favorably for all the traits studied. However, 11 out of 28 combinations possessed significant desirable SCA effects for grain yield / plant involving all three kind of combinations between the parents of high and low GCA effects, such as Balado x IET 1444 and Giza 104 x IET 1444 (high x high); Giza 177 x IET 1444, Giza 178 x Balado, Giza 178 x IET 1444 and Balado x Milyang85 (high x low); and Giza 177 x Sakha 101, Giza 177 x IR 66158 and Sakha 101 x Milyang 85 (low x Low) where the majority were derived from former cross-combinations. Moreover, 16 hybrids exhibited significant SCA effects for at least two among the three studied root characters. In addition, 18, 8, 15, 6, and 7 hybrids were the best cross combinations among the studied hybrids for plant height, panicle length, number of panicles / plant, 100 grain weight and sterility %, respectively. Furthermore, the hybrid. Milyang 85 x IET 1444 was the greatest cross combination, it showed significant favorable SCA effects for seven yield components and root traits, followed by Sakha

Table 5. Estimates of specific combining ability (sca) of hybrids for different studied traits in rice.

Hybrid	Plant height	Panicle length	Panicles number	100 grain weight	Sterility %	Root length	Root volume	Roots number	Grain yield / plant
Giza 177 X Giza 178	3.950**	3.622**	0.134	-0.171**	0.076	2.420**	-2.317**	26.253**	0.863
X Sakha 101	-12.994**	2.609**	1.059**	-0.014	-3.430**	-1.999**	2.308**	47.897**	2.457**
X Sakha 104	1.925**	-0.291	0.159	0.044	3.893**	-0.374	0.920	-56.035**	-0.743
X IR 66158	6.956**	-1.879**	2.947**	-0.048	5.126**	1.733**	-7.148**	88.909**	2.463**
X Balado	12.293**	-0.741	0.447	0.155**	0.701	4.514**	1.383**	-76.916**	-0.624
X Milyang 85	9.938**	-1.766**	-1.291**	-0.107**	2.626**	-1.617**	6.483**	51.090**	-0.818
X IET 1444	-11.894**	-0.285	2.140**	-0.041	1.064*	4.320**	9.377**	38.772**	5.413**
Giza 178 X Sakha 101	-11.494**	0.866*	0.303	0.060	-2.342**	1.420**	3.933**	-51.803**	-0.799
X Sakha 104	2.363**	-3.159**	5.402**	0.007	-1.805**	0.483	1.358**	19.890**	0.313
X IR 66158	5.644**	1.128**	4.753**	0.008	-0.849	0.839	-5.710**	-9.354**	-3.106**
X Balado	7.031**	0.265	-2.997**	0.080**	1.101*	2.808**	-2.617**	125.134**	2.244**
X Milyang 85	6.438**	2.178**	2.140**	-0.025	9.714**	-4.074**	7.796**	-48.172**	-2.512**
X IET 1444	0.419	0.597	1.259**	-0.205**	3.401**	2.051**	9.815**	73.447**	1.282**
Sakha 101X Sakha 104	7.231**	-1.547**	-0.735	0.081**	-1.311**	-1.124**	-8.579**	4.284	1.157**
X IR 66158	1.388	-0.760	0.240	0.109**	6.708**	4.483**	-3.898**	17.415**	-0.699
X Balado	2.650**	2.565**	3.303**	-0.082**	-0.092	-0.861*	-4.179**	-41.722**	-1.849**
X Milyang 85	10.744**	-1.647**	2.065**	-0.026	6.395**	-1.492**	9.796**	11.784**	3.207**
X IET 1444	9.475**	1.084**	1.184**	0.003	0.895	-1.180**	4.627**	13.090**	2.438**
Sakha 104 X IR 66158	-1.194	0.903*	-5.972**	-0.267**	-6.067**	-5.080**	-2.535**	38.422**	2.413**
X Balado	5.381**	-2.085**	1.028**	0.064*	2.945**	-1.799**	11.308**	-71.466**	-1.612**
X Milyang 85	12.413**	0.078	4.728**	-0.017	9.745**	0.570	2.971**	30.040**	1.819**
X IET 1444	-6.543**	1.469**	4.534**	-0.019	-0.442	3.320**	6.365**	53.159**	2.113**
IR 66158 X Balado	4.100**	0.203	4.440**	0.042	0.714	3.808**	2.427**	-2.022	0.719
X Milyang 85	1.569	0.303	-5.735**	-0.159**	4.576**	0.176	13.965**	-0.391	-1.849**
X IET 1444	10.738**	-0.904*	3.697**	-0.075**	4.639**	-1.261**	16.108**	-12.585**	-2.056**
Balado X Milyang 85	10.643**	0.565	-0.172	-0.136**	-3.286**	2.833**	-8.817**	111.784**	6.438**
X IET 1444	-3.375**	-0.204	-1.929**	0.049	3.964**	-5.605**	-8.673**	83.278**	2.169**
Milyang 85 X IET 1444	-11.719**	7.084**	1.709**	0.205**	-6.799**	5.326**	7.365**	79.284**	-2.149**
SE (sii)	1.574	0.823	0.828	0.061	0.948	0.850	1.066	4.568	0.916
SE (sii-sjj)	1.901	0.994	1.001	0.073	1.145	1.027	1.288	5.519	1.106

104 x IET 1444 and Giza 177 x Sakha 101 for 6 traits; and Giza 177 x IET 1444 for 5 traits. These hybrids involved also all kinds of parental combinations such as high x high, high x low and low x low. This suggests that either additive x additive, additive x dominance and/or dominance x dominance genetic interactions were predominant. The superiority of these crosses may be due to complementary and duplicate type gene interactions. Hence, these hybrids are expected to produce desirable segregants and could be exploited successfully in breeding programs. Similar findings were reported earlier by Katre and Jambhale (1996) and Ramalingam *et al* (1997).

Estimates of heterosis and degree of dominance

Heterosis of hybrids over their respective mid-parent (MPH), and better (BPH), and their degree of dominance for yield components and root traits were listed in Tables (6 & 7), respectively. Four crosses namely, Giza 177 x Giza 178, Giza 178 x IR 66158, Giza 178 x Milyang 85 and Sakha 101 x Balado showed highly significant and positive estimates of heterosis for plant height, panicle length and number of panicles / plant, when it was measured as a deviation from both mid and better parents, while, the highest positive estimates of mid and better heterosis values were observed in crosses, Balado x Milyang 85 (36.88% & 27.61%) for plant height; Milyang 85 x IET 1444 (54.49% & 39.78%) for panicle length, (6.61% & 5.11%) for 100 grain weight and (82.01% & 77.54%) for root volume; Giza 178 x Sakha 104 (82.67% & 57.69%) for number of panicle / plant; Giza 177 x IR 66158 (29.10% & 21.59%) for root length; Giza 178 x Balado (79.01% & 73.62%) for number of roots / plant; and Balado x Milyang 85 (40.79% & 32.99%) for grain yield / plant, respectively. These results suggested the possibility of developing yield components traits from these cross combinations. Moreover, most of the other remaining crosses exhibited significant heterosis in negative direction for the above mentioned traits. Only one cross, namely Sakha 104 x IR 66158 showed significant desirable negative mid parent heterosis for sterility %. Evidently, the degree of dominance was higher than unity in 23, 22, 19, 15, 25, 18, 25, 28 and 19 crosses for plant height, panicle length, number of panicles / plant, 100 grain weight, sterility %, root length, root volume, number of roots / plant and grain yield / plant, respectively indicating the important of over-dominance in the inheritance of these traits in these crosses. While partial or incomplete dominance played an important role in the inheritance of these mentioned traits in 5, 4, 7, 12, 3, 7, 0, and 5 crosses, respectively. The investigated values of degree of dominance were less than unity. Furthermore, complete dominance controlled panicle length, number of panicles / plant, 100 grain weight, root length, root volume and grain yield / plant in 2, 1, 1, 1, 1 and 2 crosses, respectively. However, no dominance was observed in Giza 178 x Balado cross for number of panicles / plant; Giza 177 x Sakha 101 and

Table 6. Estimates of percentage of heterosis over mid-parent (MP), better parent (BP) and degree of dominance (P) in some yield components characters in rice.

Genotype	Plant height			Panicle length			Panicles number.			100 grain weight			Sterility %		
	MP	BP	p	MP	BP	p	MP	BP	p	MP	BP	p	MP	BP	p
Giza 177 X Giza 178	12.05**	8.29**	3.5	24.36**	23.65**	42.5	25.80**	12.46**	2.2	-12.31**	-15.43**	-3.3	31.8**	46.45**	-3.2
X Sakha 101	-12.16**	-24.45**	-0.7	17.84**	11.97**	3.4	27.49**	7.74**	1.5	-94.29**	-97.06**	-1.0	4.98**	14.65**	-0.6
X Sakha 104	12.23**	4.53	1.7	-5.39**	-9.97**	-1.1	26.34**	-0.67	1.0	0.85**	0.26**	1.5	53.11**	59.84**	-12.6
X IR 66158	21.38**	11.01**	2.3	-8.48**	-10.83**	-3.2	27.27**	19.06**	4.0	-7.58**	-14.94**	-0.9	57.59**	108.38**	-2.4
X Balado	29.90**	23.15**	5.5	-1.28	-1.42	-9.0	14.02**	4.18**	1.5	6.35**	4.48**	3.6	28.57**	43.10**	-2.8
X Milyang 85	25.78**	23.57**	14.4	1.25	-7.69**	0.1	4.49**	-8.38**	0.3	-2.53**	-8.10**	-0.4	71.67**	74.90**	-38.7
X IET 1444	-16.70**	-25.11**	-1.5	10.17**	9.24**	12.0	29.16**	8.47**	1.5	-1.29**	-5.65**	-0.3	40.73**	65.91**	-2.7
Giza 178 X Sakha 101	-8.77**	-19.16**	-0.7	14.63**	9.51**	3.1	35.76**	27.35**	5.4	3.37**	1.54**	1.8	11.31**	13.08**	-7.2
X Sakha 104	14.87**	10.57**	3.8	-14.16**	-17.87**	-3.1	82.67**	57.69**	5.2	-7.30**	-11.09**	-1.7	15.22**	22.31**	-2.6
X IR 66158	22.09**	15.30**	3.8	10.59**	8.36**	5.1	47.83**	24.63**	2.6	-10.0**	-14.26**	-2.0	25.84**	47.60**	-1.8
X Balado	26.06**	23.58**	13.0	8.18**	7.71**	19.0	-0.89	-20.68**	-0.0	4.98**	-0.47**	0.9	28.89**	29.110**	-167.7
X Milyang 85	23.98**	17.78**	4.5	26.42**	15.85**	2.9	29.30**	3.08*	1.2	-6.36**	-8.83**	-2.7	107.41**	128.81**	-13.2
X IET 1444	1.06	-6.23*	0.1	19.03**	17.37**	13.4	34.13**	2.97*	1.1	-12.18**	-13.00**	-13.0	82.99**	103.41**	-2.1
Sakha 101 X Sakha 104	21.38**	11.34**	2.4	-9.64**	-9.78**	-61.0	29.07**	18.08**	3.1	4.48**	1.98**	1.8	12.71**	17.69**	-3.0
X IR 66158	16.86**	8.25**	2.3	-1.08	-3.60**	-0.4	18.68**	-4.98**	0.8	-0.80**	-7.09**	-0.1	87.40**	87.99**	-3.8
X Balado	20.43**	8.61**	1.8	16.82**	11.14**	3.3	38.11**	6.13**	1.3	1.23**	-2.36**	0.3	17.36**	19.44**	-10.0
X Milyang 85	30.15**	10.29**	1.7	4.46**	0.00	1	28.84**	-4.57**	0.8	-3.22**	-7.09**	-0.8	83.43**	96.37**	-12.7
X IET 1444	12.40**	6.92**	2.4	19.47**	12.60**	3.2	30.84**	-3.89**	0.9	3.80**	1.04**	1.4	29.88**	69.32**	-1.3
Sakha 104 X IR 66158	16.00**	13.73**	8.0	-2.46*	-4.80**	-1.0	-16.24**	-37.24**	-0.6	-18.38**	-25.28**	-2.0	-2.91*	21.92**	0.1
X Balado	27.31**	24.98**	14.6	14.84**	-18.86**	-3.0	26.28**	-6.96**	0.7	4.84**	3.30**	3.8	38.98**	44.62**	-6.0
X Milyang 85	34.47**	23.21**	3.8	3.30**	-1.26	0.7	44.68**	3.65**	1.1	-6.22**	-12.06**	-0.9	108.66**	113.71**	-46.0
X IET 1444	-6.20**	-9.72**	-1.6	12.17**	5.88**	2.1	52.55**	5.95**	1.2	0.40**	-4.87**	0.1	22.02**	51.14**	-1.1
IR 66158 X Balado	28.69**	23.88**	7.4	0.44	-2.00	0.2	30.00**	26.74**	11.7	-2.60**	-11.79**	-0.3	27.69**	49.48**	-1.9
X Milyang 85	23.81**	11.43**	2.1	9.00**	1.80	1.3	-16.46**	-22.08**	-2.3	-15.06**	-17.22**	-5.8	70.04**	119.76**	-3.1
X IET 1444	21.42**	19.16**	11.3	4.93**	1.40	1.4	32.64**	18.08**	2.6	-6.94**	-10.56**	-1.7	56.41**	152.84**	-1.5
Balado X Milyang 85	36.88**	27.61**	5.1	12.05**	2.29	1.3	7.30**	2.54*	1.6	-5.65**	-12.50**	-0.7	23.47**	34.68**	-2.8
X IET 1444	4.21*	-1.48	0.7	9.76**	8.68**	9.9	9.05**	-0.69	0.9	3.69**	-2.33**	0.5	48.82**	98.30**	-2.0
Milyang 85 X IET 1444	-6.33**	-17.10**	-0.5	54.49**	39.78**	5.2	22.02**	16.01**	4.3	6.61**	5.11**	4.6	4.72**	26.14**	-0.3
L.S.D. 0.05	4.166	4.811		2.179	2.516		2.193	2.532		0.161	0.186		2.509	2.897	
L.S.D. 0.01	5.475	6.323		2.864	3.307		2.882	3.327		0.211	0.244		3.297	3.807	

Table 7. Estimates of percentage of heterosis over mid-parent (MP), better parent (BP) and degree of dominance (P) in grain yield and some root characters in rice.

Genotype	Root length			Root volume			Roots number			Grain yield / plant		
	MP	BP	p	MP	BP	p	MP	BP	p	MP	BP	p
Giza 177 X Giza 178	31.42**	14.12**	2.1	13.27**	10.14**	4.7	38.91**	27.77**	4.5	12.95**	6.53**	2.2
X Sakha 101	0.31	-14.92**	0.0	22.15**	14.81**	3.5	35.30**	30.57**	9.7	30.37**	25.00**	7.1
X Sakha 104	4.22**	-13.07**	0.2	23.25**	11.95**	2.3	-9.46	-15.75*	-1.3	13.35**	1.79	1.2
X IR 66158	29.10**	21.59**	4.7	-4.13**	-7.10**	-1.3	61.20**	42.46**	4.7	22.41**	17.31**	5.2
X Balado	38.87**	14.71**	1.8	6.70**	-0.21	1.0	-6.72	-11.70	-1.2	16.00**	4.64**	1.5
X Milyang 85	5.25**	-10.73**	0.3	64.29**	44.28**	4.6	57.12**	40.02**	4.7	12.02**	6.66**	2.4
X IET 1444	35.95**	6.12**	1.3	76.33**	51.58**	4.7	59.87**	37.69**	3.7	40.54**	16.42**	2.0
Giza 178 X Sakha 101	11.71**	8.64**	4.1	28.44**	24.03**	8.0	-7.42	-11.92	-1.4	1.16	-0.57	0.7
X Sakha 104	4.08**	-0.75	0.8	25.21**	16.73**	3.5	23.51**	21.96**	18.5	5.65**	0.26	1.1
X IR 66158	16.92**	7.20**	1.9	2.41	2.06	7.0	22.09**	16.85*	4.9	-20.37**	-27.84**	-2.0
X Balado	23.80**	16.67**	3.9	-6.52**	-10.19**	-1.6	79.01**	73.62**	25.5	15.95**	10.56**	3.3
X Milyang 85	-9.29**	-11.78**	-3.3	68.03**	51.29**	6.1	16.20**	12.25	4.6	-8.75**	-9.66**	-8.7
X IET 1444	20.24**	5.91**	1.5	76.89**	55.79**	5.7	69.67**	57.85**	9.3	12.21**	-2.31	0.8
Sakha 101X Sakha 104	-9.49**	-11.31**	-4.6	-15.29**	-18.33**	-4.1	3.80	-0.05	1.0	17.75**	9.95**	2.5
X IR 66158	25.62**	12.30**	2.2	1.44	-1.72	0.4	18.96**	8.56	2.0	1.28	-6.76**	0.2
X Balado	1.52	-1.72	0.5	-18.68**	-19.11**	-34.9	-4.15	-6.05	-2.1	6.59**	0.00	1.0
X Milyang 85	-9.05**	-12.56**	-2.3	65.67**	54.06**	8.7	27.51**	17.38*	3.2	26.71**	25.79**	36.5
X IET 1444	1.40	-8.44**	0.1	52.12**	38.25**	5.2	36.69**	21.44**	2.9	24.42**	6.73**	1.5
Sakha 104 X IR 66158	-22.46**	-31.91**	-1.6	12.67**	5.38**	1.8	28.08**	21.12**	4.9	15.63**	0.00	1.0
X Balado	-5.46**	-6.62**	-4.4	39.36**	35.06**	12.4	-14.49*	-16.03*	-7.9	6.92**	6.38**	13.5
X Milyang 85	0.00	-2.01	0.0	48.47**	42.99**	12.7	35.35**	29.17**	7.4	18.59**	11.48**	2.9
X IET 1444	14.91**	5.70**	1.7	61.38**	51.75**	9.7	52.02**	39.78**	5.9	21.57**	10.95**	2.3
IR 66158 X Balado	28.91**	12.01**	1.9	12.11**	8.07**	3.2	23.48**	14.78*	3.1	9.79**	-4.64**	0.6
X Milyang 85	8.34**	-3.14*	0.7	88.76**	70.48**	8.3	31.61**	30.36**	32.8	-6.82**	-14.78**	-0.7
X IET 1444	6.84**	-12.66**	0.3	97.42**	74.39**	7.4	35.10**	31.15**	11.6	-1.18	-20.84**	-0.0
Balado X Milyang 85	18.99**	15.20**	5.8	-3.85**	-10.15**	-0.6	78.78**	67.69**	11.9	40.79**	32.99**	7.0
X IET 1444	-8.84	-15.19**	-1.2	0.86	-7.89**	0.0	74.65	57.95**	7.1	23.52**	12.21**	2.3
Milyang 85 X IET 1444	28.04**	15.61**	2.6	82.01**	77.54**	32.6	77.48**	70.69**	19.5	4.63**	-9.68**	0.3
L.S.D. 0.05	2.195	2.536		2.823	3.259		12.093	13.964		2.424	2.799	
L.S.D. 0.01	2.886	3.333		3.710	4.284		15.894	18.353		3.186	3.678	

Sakha 104 x Milyang 85 for root length; Balado x IET 1444 for root volume; and the two rice crosses, IR 66158 x Balado and IR 66158 x IET 1444 for grain yield / plant. High percentage of heterosis for yield per plant was also reported by Zhang *et al* (1994), Alzona and Arrauadeau (1995) and Li *et al* (1997). They suggested that epistasis might be an important genetic basis of heterosis in rice. Exploitation of heterosis for increasing grain yield in rice was also reported by Virmani *et al* (1991).

Estimates of genetic variances, heritability and expected genetic advance

It is evident from Table (8) that the dominance genetic variance was greater than additive genetic variance, almost two to three times, for all the studied traits except number of panicles / plant and grain yield / plant which controlled by high additive genetic variance. The highest estimated values of environmental variance were recorded for number of roots / plant and plant height traits. High estimates of broad sense heritability were observed for all the studied traits. It ranged from 94.70 to 99.63% for root length and number of roots / plant, respectively. These findings indicated that the studied traits had high genetic variance, (both additive and dominance genetic variance) with low environmental variance. Moreover, low to moderate estimates of narrow sense heritability were exhibited for all traits ranged from 22.14% to 51.62% for sterility % and number of panicles / plant, respectively. On the other hand high heritability coupled with moderate to high expected genetic advance were noted for number of roots / plant, plant height, root volume, sterility % and number of panicles / plant, revealing substantial contribution of additive variance in phenotypic expression, and indicating the effectiveness of selection in early generation to improve these traits. Falconer and Mackay (1996) demonstrated that the lower narrow sense heritability was caused by low additive effects and high dominant gene action. These results are in harmony with the combining ability analysis.

Table 8. Estimates of additive (σ^2A), dominance (σ^2D) and environmental ($\sigma^2 e$) variances; broad (h^2_b) and narrow (h^2_n) sense heritabilities % and expected genetic advance % (Δg) for the studied traits.

Character	Variance components			Heritabilities %		Δg %
	σ^2A	σ^2D	$\sigma^2 e$	h. b	h. n	
Plant height cm)	95.173	104.315	3.012	98.51	46.99	28.87
Panicle length (cm)	2.580	5.037	0.823	90.24	30.57	5.401
Panicles number/ plant	14.380	12.644	0.834	97.01	51.62	10.547
100 grain weight (g)	0.032	0.010	0.004	90.41	68.19	0.40
Sterility %	8.151	27.58	1.092	97.03	22.14	12.13
Root length (cm)	6.020	9.695	0.879	94.70	36.28	7.95
Root volume	50.104	89.749	1.383	99.02	35.48	24.24
Roots number /plant	1708.4	5185.2	25.4	99.6	24.7	170.7
Grain yield/plant (g)	11.570	7.609	1.020	94.95	57.28	8.79

Phenotypic correlation coefficients

Lucidly, Table (9) articulates that significant and positive estimates of phenotypic correlation coefficient were recorded between panicle length and each of number of panicles/plant, root length, root volume and number of roots/plant. Moreover, number of panicles/plant was strongly correlated with the three root traits. Root length was positively and significantly associated with root volume and number of roots / plant. However, highly significant and positive estimates of phenotypic correlation coefficients were exhibited between root volume and number of roots/plant. Plant height was strongly associated with sterility %. On the contrary, 100 grain weight was negatively and significantly correlated with each of sterility %, root volume and number of roots/plant. However, grain yield / plant was positively and significantly correlated with each of number of panicles / plant, 100 grain weight, root length and number of roots / plant. These results indicate that grain yield / plant will be increased by increasing number of panicles / plant, 100 grain weight, root length and number of roots / plant. Either insignificant positive or negative estimates of phenotypic correlation coefficients were found between other pairs of the studied traits. These results were in close agreement with those reported earlier by El Hissewy and Bastawisi (1998) and Kumar *et al* (1998).

Table 9. Estimates of phenotypic correlation coefficients among all possible pairs of the studied characters.

Character	Plant height (cm)	Panicle length (cm)	No. of panicles / plant	100 grain weight (g)	Sterility %	Root length (cm)	Root volume	No. of roots/ plant
Plant height	1							
Panicle length	-.255	1						
No. of panicles	.086	.469**	1					
100 grin weight	-.136	-.025	-.139	1				
Sterility %	.582**	-.193	.118	-.466**	1			
Root length	-.151	.501**	.574**	.216	-.212	1		
Root volume	.014	.340*	.538**	-.338*	.193	.346*	1	
No. of roots/pl.	.086	.502**	.585**	-.358*	.121	.503**	.506**	1
Grain yield/pl.	-.176	.345*	.366*	.350*	-.371*	.549**	.296	.478**

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قوة الهجين والقدرة على التآلف للمحصول ومكوناته و بعض صفات الجذر في الأرز تحت ظروف الإجهاد المائي.

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أجريت كل التهجينات الممكنة (ما عدا العكسية) بين ثمانية أصناف من الأرز متباينة في صفاتها المظهرية والزراعية، بمزرعة مركز البحوث والتدريب في الأرز – سخا – كفرا لشيخ – مصر خلال موسم زراعة الأرز 2005 وتم دراسة الاباء والهجن فى موسم 2006 وذلك بهدف:

-دراسة طبيعة الفعل الجينى المتحكم في وراثة مختلف الصفات المدروسة.

-دراسة القدرة على التآلف لمختلف التراكيب الوراثية المستخدمة في الدراسة.

-تقدير النسبة المئوية لقوة الهجين وذلك عند قياسها كانحراف عن متوسط الأبوين وعن قيمة الأب الأعلى. وتقدير درجة السيادة.

-تقدير النسبة المئوية لكل من درجة التوريث بمعناها الواسع والضيق والتحسين الوراثي المتوقع من الانتخاب.

-تقدير معامل الارتباط المظهري بين جميع الأزواج الممكنة للصفات المدروسة.

وسجلت البيانات على صفات طول النبات (سم)، طول النورة الدالية (سم)، عدد النورات الدالية / نبات، وزن أل 100 حبة (جم)، النسبة المئوية للعقم، طول الجذر (سم)، حجم الجذر، عدد الجذور / نبات و محصول النبات الفردى.

وأوضحت النتائج أن كل من تباين القدرة العامة على التآلف والقدرة الخاصة على التآلف كان عالى المعنوية لجميع الصفات المدروسة موضحا أهمية كل من التأثير المضيف وغير المضيف للجين في وراثة جميع الصفات. كما أشارت تقديرات تأثير القدرة العامة على التآلف إلى أن الصنف اى اى تى 1444 كان أفضل الآباء قدرة على التآلف لجميع الصفات المدروسة فيما عدا صفتى طول النبات و وزن أل 100 حبة. في حين كان الصنف ميلونج 85 أفضل الآباء قدرة على التآلف لصفات طول النبات، حجم الجذر، وزيادة عدد كل من النورات الدالية والجذور / نبات.

وكانت تأثيرات القدرة الخاصة على التآلف مقياسا دقيقا للدلالة على قوة الهجين. فكانت الهجن التسع بلاكو x ميلونج 85 ، سخا 101 x ميلونج 85 ، جيزة 177 x سخا 101 ، جيزة 177 x اى أر 66158 ، جيزة 177 x اى اى تى 1444 ، بلاكو x اى اى تى 1444 ، سخا 104 x ميلونج 85 ، سخا 104 x اى اى تى 1444 و جيزة 178 x بلاكو أفضل التراكيب الوراثية التي يمكن استخدامها في تحسين المحصول، حيث سجلت أعلى قيما لتأثيرات قدرتها الخاصة على التآلف لصفة محصول النبات الفردى. كما سجلت قيما عالية المعنوية وموجبة للنسبة المئوية لقوة الهجين وذلك عند قياسها كانحراف عن متوسط الأبوين وعن قيمة الأب الأعلى لمعظم الصفات المدروسة متضمنة على الأقل صفة من صفات طول النورة الدالية، عدد النورات الدالية / نبات، عدد الجذور / نبات و محصول النبات الفردى.

كما أظهرت النتائج أن درجة التوريث بمعناها الواسع كانت عالية لجميع الصفات. بينما لوحظ أن درجة التوريث بمعناها الضيق كانت منخفضة (22.14%) إلى متوسطة (51.62%) لصفتى النسبة المئوية للعقم و عدد النورات الدالية / نبات على الترتيب. علاوة على ذلك فقد كانت كل من النسبة المئوية لدرجة التوريث والتحسين المتوقع من الانتخاب عالية لصفات طول النبات، عدد النورات الدالية / نبات، النسبة المئوية للعقم، حجم الجذر وعدد الجذور / نبات مبينة أهمية الانتخاب في الأجيال المبكرة لتحسين هذه الصفات. كما أشارت النتائج إلى أن تقديرات معامل الارتباط المظهرى كانت عالية المعنوية وموجبة بين محصول النبات الفردى وكل من طول النورة الدالية وعدد النورات الدالية / نبات وطول الجذر و عدد الجذور / نبات.