GENETIC VARIABILITY AND INHERITANCE OF DROUGHT AVOIDANCE MECHANISM IN RICE (ORIZA SATIVA L.)

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ABSTRACT

The present investigation was carried out at the farm of the Rice Research and Training Center, Sakha, Kafr EL Sheikh, Egypt during 2006, 2007 and 2008 rice growing seasons. Five rice cultivars, i.e., IET1444, Gaori, Giza178, Sakha104 and Giza177 beside F_1 and F_2 populations of the crosses, IET 1444 x Giza 177, Gaori x Giza 177, Giza 178 x Giza 177 and Sakha 104 x Giza 177, were grown under drought conditions, to investigate the gene system of root and shoot characters related to avoidance mechanisms; and to determine the relationship among these traits. The results showed varietal differences for root xylem vessel number and area at all growth stages and the maximum growth of root xylem vessel number occurred at 50 days after sowing for all the varieties except IET 1444. The F_1 mean value for grain yield / plant (35) was higher than the mean values for mid- parent (21.5), high parent (24) and F_2 populations (22), this results also implying that the presence of over dominance for this trait. Significant inbreeding depression associated with significant heterosis for all the studied traits except for root xylem vessel area and root length, indicating that non-additive gene effects governed the inheritance of these traits. The number of effective factor pairs estimated was high for the five traits viz. root xylem vessel number, root xylem vessel area, root thickness, relative water content and grain yield / plant, while it was low for the remaining traits.

Most of the characters studied were controlled by polymeric genes with additive and dominance effects. Heterosis was observed for most traits studied. The broad sense heritability estimates were relatively high for all studied traits, in most cases. Root xylem vessel number was directly correlated with all root character studied. The segregation of leaf rolling in all crosses studied; at F_2 generation was found to fit a ratio of 1 rolled to 2 unrolled implying therefore that segregation is at one locus only. The transgressive sergeants for drought resistance were detected in all crosses studied which were varied from 6.35% to 10.23% in the F_2.

INRODUCTION

Rice (*Oryza sativa L.)* is the staple food of sixty percent of the world populations and is now planted on about 150 million hectares. It is grown in more than 100 countries of the world. About nineteen million hectares are planted to upland rice, which is about fifteen percent of the world rice area. Water deficit, during the reproductive stage, is most damaging to rice crop (*Matsushima, 1968),* Drought tolerance is a heritable and complex trait; however, the identification of such complex trait is difficult because of the climatic changes and location of specific nature of water stress in crops. Meanwhile, rice breeders in the world have been paying more attention to breeding for filled resistance to drought.

Generally, four mechanisms are involved in drought tolerance namely escape, avoidance, tolerance and recovery *(Chang et al., 1972; Loresto and Chang, 1981).* Among the four mechanisms, the components of avoidance mechanism, which can easily be identified, are deep and thick roots, higher root to shoot ratio, early stomata closure, high cultivar resistance and elasticity in leaf rolling. The plants characteristics minimize severe water stress or shorten the duration of water stress, thereby, maintaining a fair level of water potential in the plant *(O'Toole and Chang, 1978).*

Choosing parents for crossing is one of the most important steps in breeding programs. No selection methods can identify good cultivars if the parents used in the program are not suitable. Breeders have different approaches to parent choice and have achieved success in different ways. Root development has long been recognized as an important factor in determining the adaptability of a given plant species to varying water conditions. Root characteristics, responsible for the adaptations to drought stress, are root length, root thickness, root number, root dry weight and root to shoot ratio. *Haque (1985)* showed that rice plants with deep and thick roots had more xylem vessels than those with shorter and thinner roots.

A leaf rolling was the first visual symptom of drought reaction and occurs real due to the inability of leaves to sustain the transpiration demand of the plant *(Blum, 1988).* Leaf rolling, during stress, reduces the leaf surface exposure to sunlight energy to decrease transpiration leads to closure of stomata, so that gaseous exchange and CO_2 entry into cells are reduced and photosynthesis is decreased. Leaf rolling is the most important criterion found useful in assessing levels of drought tolerance in large scale screening (*Chang et. al. 1974*).

Meanwhile, it was found that the root xylem vessel number and area were positively correlated with drought resistance. This present investigation aims (1) to study the relationship between root xylem vessels and other root and shoot characters; (2) to determine the inheritance pattern and heritability of such traits and (3) to study the genetic control of the root xylem vessels and the related components in drought avoidance and gain in formation on the relationships among them.

MATERIALS AND METHODS

The present investigation included two experiments; the first one was carried out to evaluate some rice cultivars for their tolerance to drought by studying the root xylem vessel number and xylem vessel area of a rice root. The second experiment was carried out for five rice cultivars namely, IET 1444, Gaori, Giza 178, Sakha 104 and Giza 177 with their crosses, which grown under drought conditions, during 2006 and 2007 rice growing seasons in a randomized complete block design (RCBD) and replicated three times to study the inheritance of root xylem vessels and the other drought avoidance components..

The plants of each replication for each cultivar were grown in 20 cm x 2 cm spacings. Secondary roots (1 cm from the tip) from the test plants of each replication of all varieties were sampled at 20, 30, 40, 50 and 60 days after sowing to determine the changes in xylem vessel number and xylem vessel area at the vegetative stage of growth. All sections were made by use of microtome for anatomical features. The microtome procedure was done, following the technique of Johansen (1940). The crosses were made in RRTC greenhouse in 2007 season as follows:-

(1) IET 1444 x Giza 177; (2) Gaori x Giza 177, (3) Giza 178 x Giza 177 and (4) Sakha 104 x Giza 177. F_1 seeds were planted in a concrete bed in glasshouse to produce F_2 seeds. Parental cultivars, F_1 plants and F_2 populations were grown under drought conditions in 2008 season. For each cross combination, 75 F_2 plants, fifteen F_1 plants and fifteen plants for each parent were randomly planted in three replications following RCB design. All recommended cultivars practices were followed. Weeds were chemically controlled by applying 2 liters of Saturn/feddan, four days after transplanting. Nitrogen fertilizer was applied at 40Kg N/fed rate. Flush irrigation was used every twelve days in afternoon and this was observed as

sufficient to differentiate the differences in lines and segregating generations for their recovery ability.

The data for root characters ;viz., root xylem vessel numbers , root xylem vessel area, root thickness, root length, root number /plant, root volume and root dry weight, were taken at maximum tillering stage. Some shoot characters, such as plant height, tiller number /plant, leaf area and relative water content, was recorded at reproductive stage. Leaf rolling observation was recorded at different hours of day from early morning to late evening, during the vegetative stage, starting from transplanting date to panicle initiation stage after each irrigation period (every twelve days). Grain yield /plant was recorded after harvesting. The mean of each trait, variance and the coefficient of variation (CV) of the cultivars were computed following RCB design. The genetic analysis consisted of the mean analysis, potence ratio, heterosis, heritability in broad sense. Number of effective factor pairs and phenotypic correlations was done among traits in F_2.

The mean analyses, based on the genetic model by *Gamble (1962)* were done to estimate the additive and dominance effects. For estimating the magnitude of dominance in the F_1, the potence ratio (hp) was estimated by using *Griffing (1950).* The numbers of effective factor pairs was computed by *Burton (1951)* formula. Herterosis of all traits was computed from the F_1 hybrids using the formula of Williams and *Gilbert (1966).* The broadsense heritability, in F_2 generation, was computed as described by *Allard (1960).* The phenotypic correlation coefficients were calculated, by *Webber and Moorthy (1952)* formula. Leaf rolling was recorded, based on methods proposed by *Loresto and Chang (1981); IRRI (1988) and De Datta et al. (1988).*

Soil water relations:

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm down to a depth of 60 cm. Soil samples, also, were collected just before each irrigation,48 hrs after irrigation. Field capacity was determined in the field. Permanent wilting point and bulk density were determined, according to *Klute (1986)* to a depth of 60cm. The average values are presented in Table (1).

Table (1): Some soil constants determined before each irrigation.

Soil depth(cm)	F.C. (%)	W.P. (%)	Bulk density g/cm^3
0-15 cm	45.68	24.70	1.12
15-70 cm	41.30	22.40	1.18
30-45 cm	38.75	20.28	1.23
45-60 cm	35.16	18.60	1.30
Mean	40.22	21.50	1.21

Where, F.C. % = Field capacity, W.P. % = Permanent wilting

Table (2): Scores and symptoms for leaf rolling and drought tolerance at vegetative stage. Modified from *Loresto and Chang (1981); IRRI (1988) and De-Datta et al. (1988).*

Scores	Reaction	Leaf rolling	Leaf firing
0	Highly resistant	No symptoms of stress	No symptoms
1	Resistant	No rolling	Slight leaf tip drying
3	Moderately resistant	Partially rolled, unrolled in evening	Leaf tip drying extended to ¼ in top three leaves
5	Intermediate	Partially; unrolling at late evening and early morning.	Half of young leaf blades dried, all lower leaf dried.
7	Susceptible	Complete, unrolling in morning	¾ of yang leaf blade dried.
9	Highly susceptible	Like tube; no unrolling in morning	All leaves dried

RESULTA AND DISCUSSION

(A) Studies on xylem vessel number and xylem vessel area of rice root:

(1) Root xylem vessels number:

The cultivars studied had from three to five xylem vessels at twenty days after sowing and the number differentially increased to a range of four to nine at 60 days after sowing (Table 3). The data, also, showed that the cultivars IET 1444 and Gaori, produced the highest number of xylem vessels, while, the cultivar Giza 177, produced the lowest number and Giza 178 was intermediate. The cultivars, IET 1444 and Gaori significantly produced higher number of root xylem vessel than the other varieties in all sampling dates. While, the cultivars Sakha 104 and Giza 177 consistently produced the lowest numbers of root xylem vessel at all stages of growth. In general, the growth pattern of root xylem vessel number of the four cultivars, Gaori, Giza 178, Sakha 104 and Giza 177 were similar. While, there was a continuous increase in root xylem vessel from one sampling date to another for IET1444. Also, from the data it can be observed that there was a rapid increase in root xylem vessels from 20 DAS to 60 DAS for the three cultivars, IET 1444, Gaori, and Giza 178. While, there was a little increase from 20 DAS to 60 DAS for the two varieties Sakha 104 and Giza 177. The same results were found by *Abd Allah (2004).*

(2) Root xylem vessels area:

From the data shown in Table (3) the xylem area, which was considered to be one of the most important components in the drought avoidance mechanism varied, generally, among the five cultivars studied. Significant differences in root xylem vessel size were observed among the cultivars at each stage of growth. IET 1444, again, showed the highest value in mean root xylem vessel area in all stages of growth and was followed by Gaori. The cultivars Sakha 104 and Giza 177, recorded the lowest mean values for this trait. IET 1444 and Giza 178 showed a rapid increase in xylem vessel area from 20 to 30 DAS, but declined from 40 to 50 DAS. A sharp increase was, again, observed at 60 DAS. Gaori and Sakha 104 had similar growth pattern. The mean values were increased by increasing the number of days after sowing in mean xylem vessels for the cultivar, Giza 177.

Combined analysis of variance, for cultivars over time is presented in Table (4). The analysis showed highly significant differences among cultivars and sampling dates for root xylem vessel number and area. Moreover, cultivars x time interactions also highly significant only for vessel number. The two rice cultivars (V1 vs. VT) did not significantly differ in xylem vessel number. On the other hand, all other comparisons showed significant differences for this trait.

Combined analysis of variances also shows significant differences among cultivars and sampling dates Table (4). There was no significant interaction between variety and time which indicate that, at any stage of growth, varietal differences in the size of xylem vessel could be observed. These results were in agreement with those obtained by *Abd Allah (2004) and Fukai et al. (1999).*

From the data obtained it was found that the influence of environment on the expression of a character was observed in this

Table (3): Mean root xylem vessel number and area values of the studied rice cultivars measured at five different times of growth.

Cultivars	20 DAS		30 DAS		40 DAS		50 DAS		60 DAS	
	Vessel number.	Vessel area.	Vessel number.	Vessel area.	Vessel number.	Vessel area.	Vessel number.	Vessel area.	Vessel number.	Vessel area.
IET 1444	5.18 a	2000.00 a	6.80 b	2143.70 a	8.70 a	1997.30 a	8.30 a	1740.80 b	9.50 a	2190.60 a
Gaori	5.30 b	1520.00 b	6.34 b	1612.20 b	7.53 b	1768.15 a	8.04 a	1663.41 b	7.70 b	1515.35 b
Giza 178	5.10 a	1370.00 bc	5.56 c	1569.00 b	7.04 b	1540.10 b	7.53 b	1455.13 c	7.45 b	1444.00 b
Sakha 104	4.20 c	687.00 d	4.86 a	795.00 c	4.90 c	895.00 c	5.30 c	825.40 a	4.70 c	736.17 c
Giza 177	3.13 c	576.00 d	4.12 c	650.19 c	4.16 c	630.14 c	4.75 c	660.00 a	4.45 c	740.00 c

Notes:
-DAS= Days after sowing.
- Means followed by the same letters are not significantly different at 0.05 levels.

Table (4): Combined analysis of variance for the two root characteristics of five rice cultivars over time.

S.O.V.	df	Mean squares	
		Root xylem vessel number	Root xylem vessel area
Replications	2	0.085	52310.00
Cultivars (V)	4	23.50**	3216534.00**
Error (a)	8	0.150	28325.00
Sampling dates (T)	4	18.20**	624658.00**
(V x T)	16	1.20**	27341.00
(V4 vs. Rest) x T	4	1.65**	58462.00
(Among Rest) x T	12	0.88**	31782.00
(V1, v2) Vs. (V3, v5) x T	4	3.35**	236820.00*
(V1vs. V2) x T	4	0.150	0.98734
V3 vs. V5) x 5	4	1.10**	4825.00
Error (b)	40	0.17	21960.00
cv (a) %	-	5.30	11.30
cv (b) %	-	5.50	11.60

*, ** : Significant at 0.05 and 0.01 levels, respectively.

study. The root xylem vessel number was more affected by the environment than the xylem vessel area.

A study on the genetics of root xylem vessel numbers and area and leaf area is very important under stress conditions, because the number and size of xylem are closely related to the capacity of the plant to transport water and nutrients absorbed from the soil, while, leaf area is related to transpiration. Most of the previous reports indicated that increasing the number and area of root xylem could lead to decreasing resistance to water conductance.

(B) Inheritance of root xylem vessels and other related characters:

1-IET 1444 x Giza 177:

The mean performances, genetic components and heritability, heterosis, number of effective pairs factors, inbreeding depression and potence ratio are presented in Tables 5, 6, and 7, respectively.

IET1444 had a higher mean root xylem vessel number (9.50), while, Giza 177 had markedly lower mean root xylem vessel number (4.45). The F_1 population mean was 6.50, which was lower than the mid-parent value of 6.97. The F_2 populations mean value was 9.70, which was higher than the F_1 mean (Table 5). The F_1 values were between both mid-parent and high parent, indicating the presence of partial dominance for this trait, which was verified by the computed negative value of potence ratio (-0.15).

The additive effect for root xylem vessel number (Table 6) was more than (2.52), while, the dominance gene effect was (-6.40), indicating that some dominant alleles were controlling the low root xylem vessel number. This was confirmed by the potence ratio estimated , indicating partial dominance for genes controlling low root xylem vessel number. The estimated number of effective factor pairs was 4.60. The heterosis value was low (- 6.74), indicating that there was a superiority of the F_1 hybrids over the mid-parent. The heritability estimate was moderately high (60%). It is probable that a relatively high additive genetic variation had contributed to this high estimate (Table 7).

Regarding root xylem vessel area, the data presented in Table (5) showed that IET 1444 had much higher mean value of 2190.60 μ^2 than the other cultivars. The mean of the F_1 was 1980.0 μ^2. A wide range of variation was observed in both parents and in F_1 hybrids. Comparing mean values, the F_1 values were between both mid- parent (1465.00

Table (5): Mean performances of P_1, P_2, F_1 and F_2 populations of some rice crosses at maximum tillering stage for the characters studied.

Characters	IET 1444 x Giza 177				Gaori x Giza 177				Giza 178 x Giza 177				Sakha 104 x Giza 177			
	P_1	P_2	F_1	F_2	P_1	P_2	F_1	F_2	P_1	P_2	F_1	F_2	P_1	P_2	F_1	F_2
Root x. v.no	9.50	4.45	6.50	9.70	7.70	4.45	6.60	5.50	7.45	4.45	6.25	5.40	4.70	4.45	4.75	4.50
R. x. v.a	2190.6	740.0	1980.0	1159	1515.35	740.0	1050	1320	1444.0	740.0	1115.0	985.0	736.17	740.0	680.0	560.0
R. thickness	1.75	0.95	1.45	1.38	1.48	0.95	1.35	1.25	1.38	0.95	1.18	1.00	0.85	0.95	1.00	0.95
R. length	27.00	22.00	28.0	24.0	25.00	22.0	29.00	32.00	31.00	22.00	35.0	28.0	40.00	22.00	37.00	35.00
R. no./plant	122.00	165.0	199.0	148	145.00	165.0	220.0	198.0	238.00	165.0	315.0	275.0	195.00	165.0	190.0	170.0
R. volume	30.00	20.00	48.0	33.0	34.00	20.00	3.00	36.00	46.00	20.00	85.0	68.0	35.00	20.00	43.00	32.00
R. d.w	1.60	0.65	2.10	1.70	1.85	0.65	2.30	1.90	2.87	0.65	3.68	3.15	3.20	0.65	2.80	2.20
R. W. C.	98.00	61.00	98.0	85.0	78.00	61.00	95.00	75.00	75.00	61.00	68.0	65.0	65.00	61.00	62.00	63.00
Leaf area	18.00	23.00	28.0	19.0	19.00	23.00	22.00	20.00	13.00	23.00	35.0	18.0	22.00	23.00	28.00	22.00
Grain yield	24.00	19.00	35.0	22.0	33.00	19.00	36.00	28.00	28.00	19.00	38.0	23.0	20.00	19.00	25.00	21.00

Notes:
N = Number of effective pairs factors
R. volume= Root volume
R. x. v.a= Root xylem vessel area
Root x. v.no = Root xylem vessel numbers
R. d.w= Root dry weight
R. thickness = Root thickness
I.d. = Inbreeding depression
R. length= Root length
R. W. C= Relative water content
R. No./plant = Root numbers / plant

μ^2) and lower parent (740.0 μ^2), indicating that the presence of partial dominance for this trait, which was verified by the computed values of potence ratio. The dominance gene effect was about two times higher (1642.00) than the additive effect (725.00) (Table6), indicating the lack of additive effect. The number of effective factor pairs (Table 7) was estimated to be 3.00. The heterosis value was 35.12 and the heritability was moderately low (48%), indicating that non-additive gene effect played an important role in the inheritance of root xylem vessel area (Tables 6 and 7).

With respect to root thickness, the mean root thickness of IET 1444 was 1.75 mm and that of Giza 177 was 0.95 mm. Comparing mean values, the F_1 population value was (1.45mm) higher than the mid-parent (1.35) and the lower parent (Table 5), indicating the presence of partial and over -dominance of the lower parent for this trait.

The F_2 value was less (1.38) than that of the F_1. The value for the additive effect (0.40) was higher than the dominance effect (0.14). The number of effective factors pairs was estimated to be 3.00, the heterosis was 7.40%, the inbreeding depression was 4.82 % and the heritability estimate was 54% (Table 7).

For root length the two parents differed by 5.00 cm, the mean of F_1 population was 28.00 cm while, was longer than IET 1444 (27.00 cm). The F_1 value was 28.00 cm higher than the high-parent (Table 5), indicating the existence of over dominance and was ascertained, again, by the respective value of potence ratio, which was exceeding unity (1.40). The dominance effect (8.00) was four times higher than the additive one (2.50) for this trait, indicating that the non-additive gene action played an important role in the inheritance of root length (Table 6). The estimated number of effective factors pairs was, only, 1.62, heterosis was 14.28 %, inbreeding depression was 14.28% and the heritability estimate was 45% (Table 7). These findings were in agreement with those obtained by Abd Allah (2005).

For root numbers/plant, the parents differed markedly in root number values. IET 1444 had a mean root number of 122.00 and Giza 177 of 165.00 Comparing mean values (Table 5), it was found that the F_1 performance exceeded the higher parent and F_2 values, indicating the existence of over-dominance and was ascertained again by the respective value of potence ratio, which was exceeding unity(2.54) .

It is clear from the data in Table (6) that the additive effect was -21.50. The negative sign could be due to the higher value of Giza

Table (6): Genetic components (a, d) and heritability (Hb) for the characters studied in some crosses.

Characters	IET 1444 x Giza 177			Gaori x Giza 177			Giza 178 x Giza 177			Sakha 104 x Giza 177		
	Additive (a)	Dominance (d)	Heritability (Hb) (%)	Additive (a)	Dominance (d)	Heritability (Hb) (%)	Additive (a)	Dominance (d)	Heritability (Hb) (%)	Additive (a)	Dominance (d)	Heritability (Hb) (%)
Rootx. v.no	2.52	-6.40*	60.00	1.62	2.20	50.00	1.50	1.70	36.00	0.125	0.50	74.00
R. x. v.a	725.00**	1642.00**	48.00	387.0**	-590**	50.00	352.00**	260.00**	67.00	1.91	240.00**	63.00
R.thickness	0.40	0.14	54.00	0.265	0.20	40.00	0.215	0.360	88.00	0.05	0.10	50.00
R. length	2.50	8.00*	45.00	1.50	-6.00*	31.00	4.50*	14.00**	82.00	9.00*	4.00*	36.00
R. no./plant	-21.50**	102.00**	37.00	-10.00*	44.00**	67.00	36.50**	80.00**	38.00	15.00**	40.00**	16.00
R. volume	5.00*	30.00**	65.00	7.00*	4.00*	47.00	13.00**	34.00**	60.00	7.50*	22.00**	32.00
R. d.w	0.475	0.80	78.00	0.60	0.80	72.00	1.11	1.06	70.00	1.27	1.20	58.00
R. W. C.	-2.50	18.00**	53.00	-5.00	4.00*	57.00	7.00*	6.00*	63.00	2.00	2.00	55.00
Leaf area	18.50**	26.00**	65.00	8.50*	40.00**	60.00	-5.00*	34.00**	50.00	-0.50	12.00**	60.00
Grain yield	2.50	26.00**	63.00	7.00*	16.00**	55.00	4.50*	30.00**	58.00	0.50	8.00**	62.00

Notes:

***, ** : Significant at 0.05 and 0.01 levels, respectively.**

177, than cultivar IET 1444 as the second parent (P_2) in the formula. The dominance effect was very high (102.00). The potence ratio was higher than unity, indicating over-dominance of genes for high root number. The numbers of effective factor pair's estimate (Table 7) was 0.78. The heterosis was (38.67); inbreeding depression was (25.62) and the heritability estimates was moderately low (37%).

With regard to root volume, IET 1444 had a higher (30.00 ml) mean root volume than that of Giza 177 (20.00 ml). The F_1 population with a range of variation and mean of 48.00 ml, markedly exceeded the high parent value (Table 5). This finding indicates the presence of over-dominance and was confirmed by the value of potence ratio, which was exceeding unity (4.60). The dominance effect (Table 6) was six times higher (30.00) than that of additive effect (5.00). The estimated number of effective factor pairs was 1.95. The heterosis was 92.00, inbreeding depression was 31.25 and the heritability estimate was moderately high (65 %) (Table 7). *Abd Allah (2005)* reported similar findings.

For root dry weight, IET 1444 had heavier mean dried root at (1.60g) than that of Giza 177 (0.65g). The F_1 mean value was 2.10g and it was higher than that of the F_2 population (1.70g) and, also, the high parent (1.60). This result indicated that the existence of over dominance for this trait. The additive gene effect (Table 6) was lower (0.49) than the dominance gene effect (0.80). The number of effective factor pairs was (1.60) and the heterosis was 86.66. Inbreeding depression (Table 7) was 19.04 and the potence ratio was (2.04). Heritability estimate was high (78%). These results indicate that the dominance gene action played an important role in the inheritance this character. Similar results were found by *Jonaliza et al. (2004).*

The mean relative water content of IET 1444 was 98.00 and that of Giza 177 was 61.00. The F_1 population mean had a relatively higher value as compared to either one of the parents (Table, 5), indicating the presence of over-dominates for this trait, which was verified by the computed positive value of potence ratio (1.00). The value for additive effect (18.50) was higher than the dominance one (-167.80), indicating that the additive genetic variance was important in the inheritance of such character. The number of effective factor pairs was estimated to be 1.78. The F_1 expression of heterosis was 39.00, followed by a considerable inbreeding depression in the F2 performance (13.20), indicating that non -additive gene effect governed the inheritance of such trait. The F_1 values (28.00) was higher than that of the mid- parent (20.50, high parent (230.00) and F2

Table (7): Heterosis (H), number of effective pairs factors (N), inbreeding depression (I.d) and potence ratio (Ph) For the characters studied in some crosses.

Characters	IET 1444 x Giza 177				Gaori x Giza 177				Giza 178 x Giza 177				Sakha 104 x Giza 177			
	Pote . ratio	Heter. (%)	N	I.d (%)	Potence .ratio	Heter. (%)	N	I.d (%)	Pote. ratio	Heterosis (%)	N	I.d (%)	Pote. ratio	Heter . (%)	N	I.d (%)
Rootx. v.no	-0.15	-6.74*	4.60	49.23**	0.35	8.73*	4.90	16.66**	0.25	5.04*	0.16	13.60**	2.00	3.93	0.14	5.26
R. x. v.a	0.71	35.12**	3.00	41.46**	-0.19	6.88*	14.0	-25.70**	0.06	2.10	2.50	11.65**	0.50	7.85*	0.50	17.64**
R. thickness	0.25	7.40*	3.00	4.82*	0.07	12.50*	4.10	7.40*	0.09	1.28	0.50	15.25**	2.00	11.11*	1.30	5.00
R. length	1.40	14.28**	1.62	14.28**	3.66	23.40**	0.04	-10.34**	1.88	32.07**	0.70	20.00**	0.66	19.35*	4.60	5.40
R. no./plant	2.54	38.67**	0.78	25.62**	6050	41.90**	0.23	10.00**	3.00	57.50**	0.42	12.69**	0.66	5.55*	0.07	10.52*
R. volume	4.60	92.00**	1.95	31.25**	0.42	40.74**	1.15	5.26	4.00	157.57**	1.85	20.00**	2.00	56.36**	2.00	25.58**
R. d.w	2.04	86.66**	1.60	19.04**	2.16	84.00**	1.18	17.39**	1.92	109.09**	2.10	14.40**	0.69	45.83**	0.98	21.41**
R. W. C.	1.00	36.50**	1.55	32.14**	3.00	4.76	1.12	9.00*	0.14	0.20	0.90	4.41	-0.50	-1.58	0.63	1.61
Leaf area	3.00	39.00**	1.78	13.20*	0.50	36.69**	2.20	21.05**	3.40	94.44**	5.50	48.50**	6.00	24.44**	0.50	21.42**
Grain yield	5.40	62.79**	2.18	37.14**	1.42	38.46**	2.36	22.22**	3.00	61.70**	2.65	39.47**	6.00	28.20**	0.75	16.00**

Notes:
Pote. = Potenc ratio. Heter. = Heterosis.

(19.00) mean values for leaf area (Table 5). These findings indicate the existence of over- dominance and were ascertained by the respective value of potence ratio, which exceeded the unity (3.00).

The dominance effect (18.00) of leaf area was higher than the additive effect (-2.50), indicating that some additive alleles controlled the high relative water content (Table 6). The estimated number of effective factor pairs (Table 7) was 1.55. The heterosis value was 36.50 %. The heritability estimate was moderately low (53 %). Such result implies that the non-additive genetic variance had contributed to this value of heritability. The F_1 mean value for grain yield / plant (35.01) was higher than that for mid- parent (21.50), high parent (24.00) and F_2 populations (22.00) , this results also implying that the presence of over -dominance for this trait (Table 5). The potence ratio was 5.40. The dominance effect (26.00) was higher than the additive effect (2.50). The estimated number of effective factors pairs was 2.18 and the heritability estimate was moderately high (63%). Significant heterosis (62.79%) was associated with considerable inbreeding depression (37.14%), indicating that the non- additive gene effects governed the inheritance of these traits (Table 7).

2- Gaori X Giza 177:

The mean performances, genetic components and heritability, heterosis, number of effective pairs factors, inbreeding depression and potence ratio are presented in Tables 5, 6, and 7 ,respectively.

Comparing mean values (Table 5), it was found that the F_1 performance exceeded the higher parent for some traits; viz., root length, root number / plant, root dry weight, relative water content, and grain yield / plant. This finding indicated the existence of over-dominance and was ascertained by the respective value of potence ratio which was exceeding unity (3.66, 6.50, 2.16, 3.00 and 1.42, respectively). While, The F1 performance for the other traits ;viz., root xylem vessel number, root xylem vessel area, root thickness, root volume and leaf area was between both mid parent and high parent, indicating the presence of partial dominance for these traits which was verified by the computed values of potence ratio. Highly significant positive heterotic effects were obtained for all studied traits, except for root xylem vessel area (-6.88).

With respect to genetic component (Table 6), the values for the dominance effect were higher than the additive one value for root xylem vessel number (2.20) , root number / plant (44.00) , root dry weight (0.80) , leaf area (40.00), relative water content (4.00) and grain yield / plant (16.00). On the other hand, the values for the additive effect were higher than the dominance effect for root xylem vessel area (387.00), root thickness (0.265), root length (1.50), and root volume (7.00). The numbers of effective factor pairs estimated were high for the five traits, root xylem vessel number, root xylem vessel area, root thickness, relative water content and grain yield / plant, while, it was low for the remaining traits (Table 7).

The heritability estimate was moderately high for root dry weight (72%), root numbers / plant (67%), relative water content (60%), and leaf area (57%). While, it was low for the others. Significant inbreeding depression was associated with significant heterosis for all studied traits, except for root xylem vessel area and root length, indicating that the non- additive gene effects governed the inheritance of these traits. These findings are in agreement with those found by *Abd Allah (2005).*

3-Giza 178 X Giza 177:

The mean performances ; genetic components and heritability; heterosis, number of effective pairs factors, inbreeding depression and potence ratio are presented in Tables 5, 6, and 7 ,respectively.

The F_1 values were higher than the high parent value for root length (35), root number /plant (315), root volume (85), root dry weight (3.68), leaf area (35) and grain yield / plant (38), indicating the presence of over-dominance of the higher parent for these traits which was verified by the values of potence ratio (1.88, 3.00, 4.00, 1.92, 3.40, and 3.00, respectively (Table 5). While, it was between mid and high -parents for root xylem vessel number, root xylem vessel area and root thickness, indicating the presence of partial and over - dominance of the lower parent for these traits, which were verified by the computed negative value of potence ratio.

Regarding genetic components (Table 6), it was found that the values of the dominance effects were higher than these of the additive effect for all studied traits except for root dry weight (1.06), relative water content (6.00) and root xylem vessel area (260.00).

The numbers of effective factors pairs estimate were high for leaf area (5.50), followed by grain yield / plant (2.65), root xylem vessel area (2.50) and root dry weight (2.10). While, it was low for the other traits (Table 7).

The heritability estimate was high for root thickness (88%), followed by root length (82 %), root dry weight (70) and root xylem area (67%). While, it was moderately high for root volume (66%), relative water content (63%), and grain yield / plant (58%). The heritability values for the remaining traits were found to be relatively low. Significant heterosis was associated with significant inbreeding depression for all studied traits, except for root thickness and relation water content, indicating that the non- additive gene effects governed the inheritance of all studied characters except for two latter one.

This might be logic and expected because, there was a tendency towards homozygosity, which was accelerated by 50% for each salfed generation.

4- Sakha 104 x Giza 177:

The mean performances, genetic components and heritability, heterosis, number of effective pairs factors, inbreeding depression and potence ratio are presented in Tables 5, 6, and 7 ,respectively.

The F_1 values were higher than high parent values (Table 5) for root xylem vessel number (4.75), root thickness (1.00) , root volume (43), leaf area (28) and grain yield plant (25) . The values of potence ratio were 2.00, 2.00, 2.00, 6.00, and 6.00, respectively. On the other hand, it was between mid- parent and high- parent for the other traits studied. These results were verified by the values of potence ratios of these traits.

For genetic components (Table 6), values for the dominant effects were higher than these of the additive effects for the characters, root xylem vessel area (240), root thickness (0.10) , root number (40) , root volume (22) , leaf area (12) and grain yield/ plant (8.00) . While, it was lower than the additive effect for root length (4.00), root dry weight (1.20) and relative water content (2.00).

The numbers of effective factor pairs were low for all studied traits, except for root length (4.60), and root volume (2.00). The heritability estimates (Table 7) were moderately high for root xylem vessel number (74%), root xylem vessel area (63%) , grain yield /plant (62%), leaf area (60 %),and root dry weight (58%). While it was low for the others.

Significant heterosis was associated with significant inbreeding depression for root volume, root dry weight, leaf area and grain yield plant. On the other hand insignificant heterosis was associated with insignificant inbreeding depression for xylem vessel number, root xylem vessel area, root thickness, root number /plant and relative water content, indicating that this might be due to the effect of linkage on F_2 performance (Table 6).

Significant heterosis in F_1 associated with insignificant inbreeding depression in F_2 and was obtained for root length. This, also, might be due to the effect of additive gene effect.

The number of effective factor pairs for most of the traits under study varied from 0.07 to 5.50. The traits under study seemed to be controlled by a few genes of the polymeric model.

From the foregoing discussions, it could be concluded that in IET 1444 x Giza 177 cross, the root xylem vessel area, root length, root numbers, root volume, root dry weight, leaf area, relative water content and grain yield/ plant seemed to be controlled by dominant alleles. While, the root xylem vessel numbers and root thickness seem to be controlled by additive effect with a large number of genes. In Gaori x Giza 177 cross, the root xylem vessel area, root thickness, root length and root volume were controlled by additive gene effect. Some of them had large number of genes and the others had polygenes. On the other hand, root xylem vessel number, root number, root dry weight, leaf area, relative water content and grain yield /plant were controlled by dominant gene effect. In Giza 178 x Giza 177 cross, dominance and additive gene effects, with a few genes controlled the root xylem vessel numbers, root xylem vessel area, root thickness, root length, root numbers, root volume, root dry weight, and relative water content. On the other hand, leaf area and grain yield /plant were controlled by dominance gene effects. In Sakha 104 x Giza 177, root length, root numbers, root volume, root dry weigh and relative water content are controlled by dominance and additive effects with a few numbers of genes except root length. While, the root xylem vessel number, root xylem vessel area, root thickness, leaf area and grain yield /plant were controlled by dominant gene effects with a few genes.

Genetics of leaf rolling:

The susceptible cultivars and crosses were to started to show the rolling symptoms before irrigation by three days (9 days after irrigation) in the morning and evening (Table 8). While, the resistant cultivars did not roll at early morning hours, but, rolling started at around one p.m. as the plant transpiration demand increased before irrigation (after twelve days from irrigation). These results were recorded based on the methods proposed by *Loresto and Chang (1981), IRRI (1988) and De Datta et al. (1988)*, (Table 8). The

Table (8): Reaction of F_2 populations for leaf rolling and unrolling and transegressive segregation (T.S.) of drought tolerance in F_2 of different crosses.

Parents/Crosses	Expected		X^2 (df=1)	Observed			T.S. in F_2 Populations	
	Rolled	Unrolled		Rolled	Unrolled	Total	No. of lines	% of F_2 lines
IET 1444 x Giza 177	113.50	113.50	48.65	61.00	166.00	227.00	104.00	10.23
Giza 178 x Giza 177	85.50	85.50	85.50	68.00	103.00	171.00	144.00	8.54
Sakha 104 x Giza 177	79.50	79.50	79.50	48.00	111.00	159.00	113.00	9.12
Sakha 101 x Giza 177	144.50	144.50	144.50	91.00	178.00	289.00	128.00	6.35
TOTAL	423.00	423.00	423.00	268.00	578.00	846.00		

segregation for this trait in all crosses studied; at F_2 generation, which was shown in table (8) was found to fit a ratio of 1 rolled to 2 unrolled, implying therefore that segregation is at one locus only. The X^2- values for these traits were 48.65, 85.50, 79.50 and 144.50 for the four crosses studied which was lower than the tabular X^2 value with one degree of freedom. The relationship of leaf rolling and drought tolerance character was found for the parents or lines which had no leaf rolling and had a score of 0 to 3 for drought tolerance. Plants showing leaf rolling at early stage of stress appeared to have poor drought tolerance. Leaf rolling also reduced the photosynthetic surface and light absorption area and thus leads to reduce assimilate levels. The cultivars, like IET 1444, which started rolling after eight days from irrigation and unrolled with morning and evening had score from 1-2 for drought tolerance (Table 2). The cultivars, Gaori and Giza 178, started rolling at mid-day till evening during late stage of stress (from 7 to 10 day) had a score of five for drought tolerance. While, the other cultivar, Giza 177 started rolling within a week after irrigation at mid-day and evening and had a score of nine for drought tolerance. These findings suggest a close relationship between leaf rolling and drought tolerance.

Transgressive segregation in the crosses involving the tolerant cultivars were recorded based on leaf rolling observation. The transgressive sergeants (table, 8) for drought tolerance were detected in all crosses studied which varied from 6.35 to 10.23% in the F_2. These results might indicate that these superior lines had a better leaf rolling and consequently better drought resistance than their corresponding tolerant parents and that could be due to drought tolerance.

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الملخص العربي

التباين الوراثى وميكانيكيات تجنب الجفاف فى الأرز

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معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية

أجرى هذا البحث بمزرعة مركز البحوث والتدريب فى الارز – سخا – كفر الشيخ – مصر خلال مواسم زراعة الأرز ٢٠٠٦، ٢٠٠٧ ، ٢٠٠٨ .
تضمن هذا البحث خمسة اصناف من الأرز وهى جيزة ١٧٧ ،جيزة ١٧٨ ، سخا ١٠٤ ، إى تى ١٤٤٤ ، جاورى بالإضافة إلى أربعة هجن ناتجة عنها فى الجيلين الأول و الثانى حيث تم تقييم الأصناف الأبوية و هجن الجيل الأول فى موسم ٢٠٠٧ وتقييم الأباء وهجن الجيل الأول والجيل الثانى فى موسم ٢٠٠٨ وذلك بغرض دراسة النظام الجينى لصفات الجذور والصفات الخضرية التى لها علاقة بميكانيكية تجنب الجفاف وكذلك تحديد العلاقة بين تلك الصفات.
أوضحت النتائج وجود اختلافات صنفية بالنسبة لصفات عدد الأوعية الخشبية ومساحة الوعاء الخشبى عند كل مراحل نمو النبات المختلفة ، وأن أقصى مرحلة لنمو عدد الأوعية الخشبية كانت عند ٥٠ يوم من الزراعة لكل الأصناف المدروسة عدا الصنف أى اى تى ١٤٤٤.
كما أوضحت النتائج بأن متوسط قيم الجيل الأول لصفة محصول الحبوب بالنبات كانت أعلى من متوسط قيم الأب الأعلى والأب الأوسط وكذلك الجيل الثانى ، وهذا يدل على وجود سيادة فائقة لتلك الصفة.
ووجد أيضا تلازم معنوى بين قيم التدهور الناتج عن التربية الداخلية وقيم قوة الهجين فى كل الصفات المدروسة عدا صفة مساحة الوعاء الخشبى وصفة طول الجذر ، وهذا يوضح تحكم التأثير الجينى المضيف فى وراثة تلك الصفات. وكان عدد أزواج العوامل الوراثية المتحكمة فى الصفات عدد الأوعية الخشبية ، مساحة الوعاء الخشبى، سمك الجذر ، محتوى الماء بالورقة ومحصول الحبوب /نبات كبير بينما كان عدد تلك العوامل منخفضا فى باقى الصفات المدروسة.
لوحظ وجود تأثير لكل من الجينات المضيفة والسائدة لمعظم الصفات ، وكانت قيم درجة التوريث عالية فى كل الصفات التى تم دراستها.
أوضحت النتائج وجود علاقة تلازم بين عدد الأوعية الخشبية وكل صفات الجذور، وأن بعض صفات الجذور مثل صفة سمك الجذر وطول الجذر

وعدد ومساحة الوعاء الخشبى يمكن دراستها فى الأجيال المبكرة. أيــضا أنعزلــت صفة التفاف الاوراق فى كل الهجن المدروسة فى الجيل الثانى بنــسبة ١:٢ وهــذا يؤكد بأن الانعزال قد حدث فى موقع واحد بالنسبة لتلك الصفة . أيضا لوحظ وجود انعزال فائق الحدود فى كل الهجن المدروسة ويتراوح مــن ٦,٣٥-١٠,٢٣ فــى الجيل الثانى.