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GENETIC BEHAVIOR AND COMBINING ABILITY FOR SOME TRAITS OF ROOT, PHYSIOLOGICAL AND GRAIN QUALITY TRAITS IN RICE UNDER WATER STRESS CONDITIONS

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ABSTRACT

Eight local and exotic cultivars of rice were crossed to obtain 28 F_1 crosses, through half diallel mating design. Griffing 1956 Method 2, Model 1 was employed for this purpose. The eight parents and their 28 F_1s (excluding reciprocals) were grown in a randomized block design with three replications at RRTC Farm, Sakha, Kafr El-sheikh, Egypt. Data were collected on seven root, agro- physiological and grain quality traits under both normal and water deficit conditions. GCA and SCA were significant for all the studied traits under both water deficit and normal conditions. GCA\SCA ratios were found to be greater than unity for root length and grain length traits under water deficit conditions and grain length under normal conditions. This finding indicates that additive and additive x additive types of gene action were of greater importance in the inheritance of these traits. On the other hand, GCA\SCA ratios were found to be less than unity for the rest of the studied traits, indicating that the non-additive type of gene action including dominance was of great importance in the inheritance of these traits. The estimates of gca effects indicated that parents, Balado and Wab 878 were good combiners for amylose content under both normal and water stress condition. The parent Wab 450 was a good general combiner for root length, root volume and chlorophyll content. In addition, Gaori and GZ 1368 were the best combiners for root/shoot ratio and milling %. Sakha 104 was a good combiner for only milling %. Moreover, The cross combinations, Sakha 102 X GZ 1368, Wab 450 X Gaori and IET1444 X Gaori appeared to be the best ones for root length and root volume since it exhibited a significantly positive sca effect and some of them involved parents with high gca under water stress condition. Moreover, the cross combinations, Sakha 102 X Gaori, Sakha 104 X IET 1444, IET 1444 X Wab 878 and IET 1444 X GZ 1368 exhibited high sca and included at least one parent having good gca for milling % under water stress condition. Results further indicated that 19. 7 and 8 crosses had significant positive better parent heterosis for root volume, root/shoot ratio and chlorophyll content under water stress condition, respectively. Mid-parents heterosis expression in milling % did not show consistency over the studied condition, indicating character x environment interaction. Moreover, highly significant negative estimates of heterosis mid parent were recorded in Sakha 102 X Balado, Sakha 102 X Wab 878, Sakha 104 X Wab 450, Balado X Gaori, Balado X GZ 1368 and Wab 450 X IET 1444 rice genotypes for grain length under both conditions. On the other hand, IET 1444 X Gaori rice hybrid exhibited either highly significant positive estimates of heterosis for root volume, root/shoot ratio or negative for amylose content %. The phenotypic correlation coefficients were found to be highly significant positive between root length and each of root volume, root/shoot ratio and chlorophyll content %. Root volume was phenotypically associated with root/shoot ratio and chlorophyll content %. Moreover, chlorophyll content was correlated with root/shoot ratio. Regarding grain quality traits, grain length was significantly and positively correlated with milling % and amylose content % under both conditions

Keywords: Rice – root traits – chlorophyll content – grain quality – combining ability, heterosis.

INTRODUCTION

Drought, like many other environmental stresses, has adverse effects on crop yield. Low water availability is one of the major causes for crop yield reductions affecting the majority of the farmed regions around the world. Drought tolerance is a complex trait, expression of which depends on action and interaction of different morphological, physiological and biochemical traits. Rice breeders have the common goal of identifying traits that confer an advantage under drought. They also have worked to identify lines with superior performance in the target environments, in order to gradually accumulate favorable alleles in improved cultivars and used the current knowledge about how plants grow to hypothesize which traits might be advantageous, and have then looked for genetic variation in those traits that can be correlated with yield in the target environments. Hence, breeders tend to work from yield to alleles to traits (ideotype).

Combining ability is defined as the ability of a parent line in hybrid combinations (Kambal and Webster, 1965). It plays an important role in selecting superior parents for hybrid combinations and in studying the nature of genetic variation (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). The GCA:SCA ratio is studied as parameter of the genetic variability in a diallel analysis. It estimates the type of gene action, which controls a particular characteristic (Quick, 1978; Sayed, 1978). When the ratio is high, it means the effect of the additive genes is prevalent. If the ratio is lower, it means the effect of no additive genes is prevalent in determining a particular character. If GCA variance is higher than SCA variance, the greater is the magnitude of additive genetic effects. Otherwise, the non-additive or dominant genetic variances are prevalent (Baker, 1978). The closer this ratio is to unity the greater the magnitude of additive genetic effects.

The need of further studies on combining ability, type of gene action and heterosis for studied traits under water stress conditions as one of the important objectives of research for the development of acceptable varieties. Therefore, the present study was suggested to study. Combining ability effects, the nature of gene action heterosis for some root, physiological and grain quality traits on a half diallel crosses of eight rice genotypes under water deficit conditions.

MATERIALS AND METHODS

A half diallel set was made in 2007 summer season using eight local and exotic rice genotypes viz., Sakha 102, Sakha 104, Balado, Wab 450, IET 1444, Wab 878, Gaori, and GZ 1368 excluding reciprocals at the Experimental Farm of Rice Research and Training Center, Sakha, Kafr El-Sheikh, Egypt. The parents and F_1s were evaluated in randomized complete block design with three replications during summer 2008. Each genotype was planted in four rows per replicate. Row was five meters length with the spacing of 20 x 20 cm among rows and plants, three to four seedlings 30 days old seedlings for each genotype were transplanted per hill. However, the outer two rows were used as borders, while, the inner two rows were used for root, physiological and grain quality traits evaluation. Flush irrigation was used every 8 days for the water stress conditions. Recommended cultural practices were followed for the two conditions. For root measurements, 20 rice plants from each genotype were grown in plastic bag, one plant per bag. The bag was 20 cm in diameter and 0.5 m in height with holes on the top and down two sides. Bags were placed with water deficit treated basin. The studied root traits, root length (cm), root volume (cm^3) and root/soot ratio were scored at the maximum tillering stage. To measure these traits, the plastic bag containing the soil and roots was pulled out from the basins. The lowest visible root in the soil after removing the plastic bag was scored as the maximum root length (in centimeters). The body of soil and roots was cut from the basal node of the plant and the soil was washed away carefully to collect roots, then the above mentioned root traits were measured.

Chlorophyll was extracted from the fully expanded third leaf at panicle initiation stage by 80% acetone at 17°C. Spectrophotometric measurements were made by Super Scan 3 Spectrophotometer. Chlorophyll content was determined by using the specific absorption coefficient of Mckinney (1941).

In laboratory, grain qualities of thirty-six rice genotypes were investigated. Cleaned paddy samples from each genotype were dried to 13 % moisture contents and milled. Husking machines used were Satake Rubber Roll Husker. The resulting brown rice was milled for 75 second in a Satake grain-testing mill TM05. Milled rice out-turn was expressed as percent of milled rice. Milled grain length was measured with the help of Dial Caliper on fifteen randomly selected full healthy rice grains. Rice sample were floured after storage for four months. The amylase content (A.C) determined cooking behavior and eating quality of cooked rice was estimated. Based on amylose content, milled rice was classified as waxy (1-2% amylose), very low (>2-9% amylose), low (>9-20% amylose), intermediate (>20-25% amylose) and high (25-33% amylose), Juliano (1971).

Combining ability was analyzed according to Griffing, (1956). Tests of significance for general and specific combining ability were M.S. (g)/ M.S. and M.S. (s) / M.S. (e), respectively, referred to Griffing, (1956) as his method 2, model I. The heterosis were estimated as the deviation of the F1 mean value from the mid- and better-parent mean values as suggested by Matzinger *et al*. (1962) and Fonsecca and Patterson (1968), respectively. The following formulae were used for the estimation of mid-parent (MP) and better-parent (BP) heterosis for all the traits:

$$\text{Heterosis over the mid-parent} = [(F1 - MP) / MP \times 100],$$

$$S.E.\ (F1 - MP) = (3Me / 2r)^{1/2},$$

$$\text{Heterosis over the better-parent} = [(F1 - BP) / BP \times 100], \text{ and}$$

$$S.E.\ (F1 - BP) = (2Me / r)^{1/2}.$$

Where, Me = error mean squares for parents and F1s from an individual environment; MP = mean mid-parent value = (P1 + P2) / 2; P1 = mean performance of parent one; P2 = mean performance of parent two; BP = mean of better-parent value; r = number of replications. The phenotypic correlation coefficients were calculated as per the method of Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance

The ANOVA for combining ability for 7 traits in 8 x 8 half diallel set (Table 1 and 2) revealed that variances due to the general combining ability (gca) and the specific combining ability (sca) were significant for all the studied traits, indicating the important of both additive and non-additive gene action in the inheritance of all traits. Moreover, the gca variance was greater than the sca variance for all the studied traits, indicating the preponderance of additive gene action for these traits except milling % and amylose content under normal conditions. The gca/sca ratio was greater than unity for root length (1.07) under water stress conditions and grain length (1.16),(1.13) under normal and water stress conditions exhibited that additive gene action was played remarkable role in the inheritance of these traits.

Table (1): Analysis of variance for combining ability under water stress condition.

S.O.V	d.f	Root traits			Physiological traits	Grain quality traits		
		Root length, cm	Root volume cm^3	Root: Shoot ratio, %	Chlorophyll Content	Grain length, mm	Milling, %	Amylose content, %
Replications	2	9.34	32.25	0.03	27.94	0.03	17.7	2.37
Genotypes	35	31.64**	3416.92**	0.14**	33.23**	0.87**	125.17**	15.81**
g.c.a	7	109.02**	5146.42**	0.23**	42.38**	3.19*	207.16*	20.51*
s.c.a	28	12.30**	2984.54**	0.12**	30.94**	0.29**	104.67**	14.63**
Error	70	2.41	10.27	0.01	7.07	0.01	6.74	0.99
g.c.a/s.c.a		1.07	0.17	0.20	0.14	1.13	0.20	0.14

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

Table (2): Analysis of variance for combining ability under normal irrigation.

S.O.V	d.f	Root traits			Physiological traits	Grain quality traits		
		Root length, cm	Root volume, cm^3	Root: Shoot ratio, %	Chlorophyll Content	Grain length, mm	Milling, %	Amylose content, %
Replications	2	8.78	27.84	0.039	30.74	0.07	3.19	0.19
Genotypes	35	69.92**	7019.75**	1.25**	50.44**	1.011**	29.63**	18.82**
g.c.a	7	130.90**	14434.62**	1.87**	115.38**	3.70**	26.77**	5.17*
s.c.a	28	54.68**	5166.03**	1.09**	34.21**	0.33**	30.34**	22.23**
Error	70	2.78	9.17	0.013	7.92	0.02	0.96	0.07
g.c.a/s.c.a		0.24	0.28	0.17	0.41	1.16	0.087	0.023

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

On the contrary, the gca/sca ratio was lower than unity for root volume, root/shoot ratio, chlorophyll content, milling % and amylose content this in terms under both conditions in addition, root length under normal conditions revealed that predominance of non-additive gene action in the inheritance of these traits (Table 1). Similar results were obtained previously by Wang *et al.* (2003) and El-Abd and Abd Allah (2004)

General and specific combining ability effects:

The estimates of gca effects indicated that the parent IET 1444 was a good combiner for root length and root volume under both conditions. The parent Sakha 102 may be focused for root/shoot ratio and grain length under both conditions. Moreover, parents, Balado and Wab 878 were good combiners for chlorophyll content and amylose content under both conditions. Wab 878 were good combiners for milling percentage and amylose content under both conditions The parent Wab 450 was a good general combiner for root length, root volume, chlorophyll content under both conditions. In addition, Gaori and GZ 1368 were the best combiners for root/shoot ratio, grain length and milling % under both conditions. Sakha 104 was a good combiner for grain length and milling %, (Tables 3 and 4).

Some of the parents with high mean values exhibited low gca effects and vice versa. Hence both per se and gca effects should be taken into account for parental selection. The parent IET 1444 was selected as the best one since it had high mean values coupled with high gca for root length and root volume. Similarly, each of Balado and Wab 450 are also judged as being very good parents for at least three traits. 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, Balado and Wab 450, and make a selection in the segregating generations to isolate superior genotypes (Table 3 and 4).

Table (3): Estimates of general combining ability (GCA) effects for the studied traits under water stress condition.

Parents	Root length, cm	Root volume, cm^3	Root : Shoot ratio, %	Chlorophyll content	Grain length, mm	Milling, %	Amylose content, %
Sakha 102	-2.22**	-10.62**	0.17**	0.02	-0.28**	-0.09	0.13**
Sakha 104	-1.49**	-11.22**	-0.03**	-1.01**	-0.11**	2.77**	0.53**
Balado	-0.19*	-1.35**	-0.06**	1.59**	0.39**	-1.02**	-1.26**
Wab 450	2.24**	7.17**	-0.05**	1.97**	0.37**	-1.36**	0.43**
IET 1444	3.37**	29.07**	-0.02**	-0.31	0.13**	-5.34**	1.01**
Wab 878	0.14	-5.29**	-0.08**	-0.77**	0.22**	1.38**	-1.25**
Gaori	-1.12**	-5.49**	0.01**	-0.20	-0.45**	1.36**	0.13**
GZ 1368	-0.72**	-2.25**	0.08**	-1.29**	-0.27**	2.31**	0.27**
S.E (gi): 0.05	0.15	0.64	0.0008	0.44	0.0008	0.42	0.06
0.01	0.20	0.87	0.001	0.60	0.001	0.57	0.08
S.E (gi-gj):0.05	0.34	1.46	0.001	1.00	0.002	0.96	0.14
0.01	0.46	1.99	0.002	1.37	0.002	1.30	0.19

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

Table (4): Estimates of general combining ability (GCA) effects for the studied traits under normal irrigation.

Parents	Root length, cm	Root volume, cm^3	Root : Shoot ratio, %	Chlorophyll content	Grain length, mm	Milling, %	Amylose content, %
Sakha 102	-2.22**	-10.62**	0.17**	0.02	-0.28**	-0.09	0.13**
Sakha 104	-1.49**	-11.22**	-0.03**	-1.01**	-0.11**	2.77**	0.53**
Balado	-0.19*	-1.35**	-0.06**	1.59**	0.39**	-1.02**	-1.26**
Wab 450	2.24**	7.17**	-0.05**	1.97**	0.37**	-1.36**	0.43**
IET 1444	3.37**	29.07**	-0.02**	-0.31	0.13**	-5.34**	1.01**
Wab 878	0.14	-5.29**	-0.08**	-0.77**	0.22**	1.38**	-1.25**
Gaori	-1.12**	-5.49**	0.01**	-0.20	-0.45**	1.36**	0.13**
GZ 1368	-0.72**	-2.25**	0.08**	-1.29**	-0.27**	2.31**	0.27**
S.E (gi): 0.05	0.15	0.64	0.0008	0.44	0.0008	0.42	0.06
0.01	0.20	0.87	0.001	0.60	0.001	0.57	0.08
S.E (gi-gj):0.05	0.34	1.46	0.001	1.00	0.002	0.96	0.14
0.01	0.46	1.99	0.002	1.37	0.002	1.30	0.19

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

Specific combining ability (sca) is considered to be the best criterion for the selection of superior hybrids. Among the studied crosses, the cross IET 1444 X Gaori recorded favorable sca effects for five traits. The cross IET 1444 X GZ 1368 recorded favorable sca effects for four traits. Moreover, the hybrids Sakha 102 X Balado and Wab 450 X GZ 1368 showed desirable sca effects for three traits. While, the crosses Sakha 102 X Sakha 104, Sakha 102 X Wab 878, Sakha 104 X Wab 878, Sakha 104 X GZ 1368, Balado X Wab 450, Balado X Wab 878, Balado X Gaori, Balado X GZ 1368, Wab 450 X IET 1444 and Wab 878 X GZ 1368 were good specific combiners for two traits. On the other hand, the crosses Sakha 102 X Wab 450, Sakha 102 X Gaori, Sakha 104 X Balado, Sakha 104 X IET 1444, Balado X IET 1444, Wab 450 X Wab 878, Wab 450 X Gaori, IET 1444 X Wab 878 and Gaori X GZ 1368 exhibited superior sca effects for only one trait. None of the hybrids exhibited superior sca effects for all the traits under both conditions. (Table 5).

The cross combination, IET1444 X Gaori appeared to be the best one for root length, root volume and root/shoot ratio since it exhibited a significantly positive sca effect and involved parents with high gca under both conditions. Moreover, the crosses combinations, Sakha 102 X Gaori, Wab 450 X GZ 1368 and IET 1444 X GZ 1368 exhibited high sca and included at least one parent having good gca for milling % under both conditions. Therefore, the influence of additive and/or additive x additive gene action was observed in these crosses combination for milling %. Similarly, Sakha 104 X GZ 1368 and Wab 450 X GZ 1368 were designated as being good cross combinations for chlorophyll content, all of them included GZ 1368 as a male parent which appeared to be a poor general combiner for this trait. In addition, Sakha 102 X Wab 878, IET 1444 X Gaori and Wab 878 X GZ 1368 were found to be the best cross combinations for grain length and amylose content under both conditions. (Table 5). Same results were recorded earlier by Paramasivam *et al.* (1995) and Raju *et al.* (2002).

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Estimates of heterosis

The superiority of hybrids, particularly over the better-parents, is useful in assessing the feasibility of commercial exploitation of heterosis and identifying the parental combinations capable of producing the highest level of transgressive segregants. In this study, because the parents are highly adapted varieties, heterosis over the mid-parent and over the better-parent has high practical significance. Investigations about the degree of heterosis are important for deciding the directions of future breeding programs. In the present investigation, both mid and better parent heterosis were determined. The range of heterosis and number of crosses showing significant desirable heterosis over mid-parent and better-parent for all the seven characters are presented in Table 7. Maximum heterosis over the mid and better-parent for root volume was 416.97% and 309.56%, respectively under water stress conditions, 130.69% and 89.52% under normal conditions. Furthermore, the highest estimated values of heterosis over mid and better-parent were observed for root/shoot ratio (83.17% and 48.48 %),(144.63% and 144.63%) under drought stress and normal conditions, respectively. chlorophyll content (29.97% and 19.47%) under drought stress conditions,(17.74% and 16.13%) under normal conditions. grain length (-9.88% and -3.51%) under drought stress conditions,(-9.95% and -0.11%) under normal conditions and amylose content % (-24.78% and -20.65%) under drought stress conditions,(-23.20% and -19.04%) under normal conditions.

Results further indicated that 19. 7 and 8 crosses had significant positive mid parent heterosis for root volume, root/shoot ratio and chlorophyll content under water stress conditions while, 21, 11 and 4 crosses under normal conditions. Mid parent Heterosis expression in root length and milling % in 2 and 1 under water stress conditions and 15 and 0 under normal conditions, respectively. indicating character x environment interaction.

It is clear from (Table 6 and 7) that most of the studied hybrids were superior for root volume; their estimated values of heterosis were highly significant with positive direction for this trait, out of them, Balado X Gaori, Wab 450 X Gaori, IET 1444 X Gaori, and Wab 878 X Gaori, which included Gaori as a male parent under both conditions. Moreover, highly significant negative estimates of heterosis for mid parent were recorded in Sakha 102 X Balado, Sakha 102 X Wab 878, Sakha 104 X Wab 450, Balado X Gaori, Balado X GZ 1368 and Wab 450 X IET 1444 rice genotypes for grain length under both conditions. On the other hand, IET 1444 X Gaori rice hybrid exhibited either highly significant positive estimates of heterosis for root volume, root/shoot ratio or negative for amylose content % under water stress conditions. While, Gaori X GZ 1368 under normal conditions. Among the studied crosses, Sakha 104 X GZ 1368 recorded significant and positive heterosis for chlorophyll content % under both conditions. The results also revealed that very few crosses appeared to be having desirable heterosis for root length, milling % and amylose content % under the present investigation. These results were in harmony with that observed by Reddy and Nerkar (1995), Veni *et al.* (2005) and Verma and Srivastava (2005).

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Phenotypic correlation coefficients

Obviously, as shown in (Table 8), the phenotypic correlation coefficients were found to be highly significant positive between root length and each of root volume, root/shoot ratio and chlorophyll content %. Root volume was phenotypically associated with root/shoot ratio and chlorophyll content %. Moreover, chlorophyll content was correlated with root/shoot ratio under both conditions. Regarding grain quality traits, grain length was significantly and positively correlated with each of milling % and amylose content % under both conditions. (Table 9). Similar results were recorded by Yolanda and Das (1995), Zhou *et al.* (2002) and Wang *et al.* (2003).

Table (8): Estimates of phenotypic correlation coefficients all possible pairs of root and chlorophyll content traits under water stress and normal irrigation.

Trait	Root length, cm		Root volum, cm^3		Root/Shoot ratio	
	S	N	S	N	S	N
Root length, cm	-	-				
Root volume, cm^3	0.493**	0.664**	-	-		
Root/Shoot ratio	0.419**	0.462**	0.552**	0.620**	-	-
Chlorophyll content	0.409**	0.336*	0.295**	0.322*	0.294*	0.370*

***and ** significant at 0.05 and 0.01 probability levels, respectively.**
S = water stress , N = normal irrigation

Table (9): Estimates of phenotypic correlation coefficients all possible pairs of grain quality traits under water stress and normal irrigation.

Trait	Grain length, mm		Milling, %	
	S	N	S	N
Grain length, mm	-	-		
Milling, %	0.288*	0.317*	-	-
Amylose content, %	0.295*	0.304*	-0.152	-0.128

***and ** significant at 0.05 and 0.01 probability levels, respectively.**
S = water stress , N = normal irrigation

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السلوك الوراثي والقدرة على الإئتلاف لبعض صفات الجذر والصفات الفسيولوجية وصفات جودة الحبوب فى الأرز تحت ظروف الاجهاد المائي.

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تم التهجين بين ثمانية تراكيب وراثية بنظام التهجين التبادلى (دايلل) فى إتجاة واحد وذلك فى تجربة اقيمت فى المزرعة البحثية لمركز البحوث والتدريب فى الأرز سخا – كفر الشيخ – مصر وذلك خلال مواسم زراعة الأرز 2007 – 2008 وذلك بهدف دراسة طبيعة الفعل الجينى المتحكم فى وراثة الصفات المدروسة ولاكتشاف سلوك القدرة على التالف للتراكيب الوراثية المستخدمة فى الدراسة. وتمت الدراسة على بعض صفات الجذر والصفات الفسيولوجية وصفة جودة الحبوب فى الجيل الثانى.

أوضحت النتائج تفوق تباين القدرة العامة على الإئتلاف على تباين القدرة الخاصة على الإئتلاف لمعظم الصفات المدروسة مما يدل على أهمية التأثير المضيف للجين فى هذة الدراسة ، كانت النسبة بين القدرة العامة على الإئتلاف إلى القدرة الخاصة على الإئتلاف أكبر من الواحد الصحيح لصفة طول الجذر تحت ظروف الإجهاد الرطوبى، طول الحبة تحت كلتا الظروف موضحا" أن الفعل المضيف للجين قد لعب دورا" عظيما" فى وراثة هاتين الصفتين وعلية فإنة يمكن إجراء التحسين الوراثى لهما بسهولة. على النقيض من ذلك كانت تأثيرات الفعل السيادى للجين بارزة لصفات حجم الجذر، النسبة المئوية للمجموع الجذرى إلى المجموع الخضرى، النسبة المئوية لمحتوى الحبوب من الأميلوز، النسبة المئوية لمحتوى الكلوروفيل بالورقة تحت كلتا الظروف بالإضافة إلى طول الجذر تحت الظروف الطبيعية موضحتا" أن التحسين الوراثى لهذة الصفات تحت ظروف الإجهاد المائى تكون غاية فى الصعوبة. أوضحت تأثيرات القدرة العامة على الإئتلاف أن الأباء بالادو، واب 878 كانت أفضل الأباء لصفة النسبة المئوية لمحتوى الحبوب من الأميلوز تحت كلتا الظروف، كان الأب واب 450 أفضل الأباء لصفات طول الجذر، حجم الجذر، النسبة المئوية لمحتوى الكلوروفيل بالورقة. إضافة إلى ذلك كانت الأباء جاورى، جى زد 1368 أفضل الأباء لصفتى النسبة المئوية للمجموع الجذرى إلى المجموع الخضرى والنسبة المئوية لتصافى التبييض، كان الصنف سخا 104 أفضل الأباء لصفة النسبة المئوية لتصافى التبييض.

فضلا" عن ذلك أظهرت التراكيب الوراثية سخا 102 x جى زد 1368 ، واب 450 x جاورى ، أى إى تى 1444 x جاورى أفضل قدرة خاصة على الإئتلاف لصفتى طول الجذر وحجم الجذر حيث كانت عالية المعنوية وموجبة وفى نفس الوقت بعضها اشتمل على أباء ذات قدرة عامة على الإئتلاف عالية المعنوية وموجبة، كما كانت التراكيب الوراثية سخا 102 x جاورى، سخا 104 x أى إى تى 1444 ، أى إى تى 1444 x واب 878 وأى إى تى 1444 x جى زد 1368 أفضل الهجن قدرة خاصة على الإئتلاف واشتملت على أحد أفضل الأباء فى القدرة العامة على الإئتلاف للنسبة المئوية لتصافى التبييض تحت ظروف الإجهاد الرطوبى.

كما أشارت التجارب إلى أن قوة الهجين كانت عالية المعنوية وموجبة فى 19، 7، 8 هجينا" وذلك عند قياسها كإنحراف عن قيم الأب الأفضل لصفات حجم الجذر، النسبة المئوية للمجموع الجذرى إلى المجموع الخضرى والنسبة المئوية لمحتوى الكلوروفيل بالورقة على الترتيب تحت ظروف الإجهاد الرطوبى.

أظهرت النتائج أن قوة الهجين كانحراف عن قيم متوسط الأبوين لصفة النسبة المئوية لتصافى التبييض لم تظهر ملائمة مستمرة تحت ظروف الدراسة، دل ذلك على التفاعل بين الصفة

والظروف البيئية. فضلا" عن ذلك تم تسجيل قوة هجين عالية المعنوية وسالبة كانحراف عن قيم متوسط الأبوين للتراكيب الوراثية سخا 102 x بالادو، سخا 102 x واب 878 ، سخا 104 x واب 450, بالا دو x جاورى , بالا دو x جى زد 1368, واب 450 x أى إى تى 1444 وذلك لصفة طول الحبة تحت كلتا الظروف، كما أظهر الهجين أى إى تى 1444 x جاورى قوة هجين عالية المعنوية وموجبة لحجم الجذر، النسبة المئوية للمجموع الجذرى إلى المجموع الخضرى، كما أظهر معنوية عالية وسالبة للنسبة المئوية لمحتوى الحبوب من الأميلوز.

كما أظهرت النتائج أن طول الجذر قد تلازم تلازما" قويا" وموجبا" مع كل من حجم الجذر، النسبة المئوية للمجموع الجذرى إلى المجموع الخضرى و النسبة المئوية لمحتوى الكلوروفيل بالورقة. إضافة إلى ذلك، فقد كانت قيم معامل الارتباط الظاهرى عالية المعنوية وموجبة بين حجم الجذر، النسبة المئوية للمجموع الجذرى إلى المجموع الخضرى و النسبة المئوية لمحتوى الكلوروفيل بالورقة. فضلا" عن ذلك، فقد كانت قيم معامل الارتباط الظاهرى معنوية وموجبة بين النسبة المئوية لمحتوى الكلوروفيل بالورقة و النسبة المئوية للمجموع الجذرى إلى المجموع الخضرى. بالاضافة إلى ذلك، صفات جودة الحبوب فقد كانت قيم معامل الارتباط الظاهرى عالية المعنوية وموجبة بين طول الحبة وكل من النسبة المئوية لتصافى التبييض، النسبة المئوية لمحتوى الحبوب من الأميلوز تحت كلتا الظروف.

قام بتحكيم البحث

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Table (5): Estimates of specific combining ability (SCA) effects for the studied traits under water stress and normal conditions.

Genotypes	Root length, cm		Root volume. Cm^3		Root / Shoot ratio		Chlorophyll content,%		Grain length, mm		Milling , %		Amylose content, %	
	S	N	S	N	S	N	S	N	S	N	S	N	S	N
Sakha 102 xSakha 104	1.05	2.00**	7.34**	47.02**	0.27**	0.50**	0.48	0.25	0.37**	0.64**	0.15	1.31**	-0.85**	-0.25
x Balado	1.09*	1.94**	-2.85	54.59**	0.28**	0.79**	-0.95	-3.17	-0.25**	-0.27**	-13.76**	-12.95**	1.77**	1.11**
x Wab 450	-0.67	3.20**	-6.05**	40.95**	0.24**	0.35**	-3.21*	-0.35	-0.10**	0.01*	-6.56**	1.75**	0.63**	1.24**
x IET 1444	-4.47**	-4.39**	-13.62**	-44.80**	-0.35**	-1.07**	0.01	-1.37	0.25**	0.35**	-2.80	1.80**	0.69**	0.80**
x Wab 878	-1.57**	-1.09	-3.92	-39.97**	-0.11**	-0.58**	1.74	-1.03	-0.42**	-0.54**	1.19	-0.04	-1.03**	-2.01**
x Gaori	-2.64**	-1.89**	-9.05**	-45.50**	-0.15**	-0.76**	0.51	0.95	0.13**	0.09**	5.61**	3.41**	1.47**	1.04**
x GZ 1368	2.95**	-4.45**	16.70**	-31.87**	-0.21**	-0.47**	-2.33	1.67	0.29**	0.23**	2.42	-3.78**	0.70**	3.15**
Sakha 104 x Balado	0.35	6.94**	4.74*	3.49	-0.02**	-0.22**	-2.85	1.98	-0.03**	-0.25**	0.66	1.80**	0.50*	2.24**
x Wab 450	-4.07**	3.20**	-15.79**	-18.80**	-0.22**	0.01**	-1.73	-5.15**	-0.30**	-0.20**	0.23	-0.83**	1.70**	1.97**
x IET 1444	0.45	-5.39**	-15.02**	-58.24**	-0.01**	-0.97**	2.52	3.85*	-0.25**	-0.26**	5.20**	0.13	0.66**	1.43**
x Wab 878	0.69	5.90**	6.34**	31.92**	-0.04**	0.75**	-0.65	-4.46**	0.41**	0.25**	-0.34	-0.19	-1.10**	-2.42**
x Gaori	1.29*	-1.22	-2.79	26.72**	-0.11**	0.43**	1.88	-0.91	0.04**	-0.02**	0.88	-0.05	1.27**	1.74**
x GZ 1368	1.55*	0.54	-0.69	-3.97	-0.09**	-0.03**	4.90**	4.67**	-0.32**	-0.007*	-4.86**	-2.29**	2.33**	2.85**
Balado x Wab 450	1.62**	5.14**	-20.32**	-9.90**	-0.16**	-0.49**	0.59	-1.12	0.26**	0.15**	5.34**	-0.42*	-1.22**	-2.32**
x IET 1444	2.49**	-5.12**	-22.22**	-76.67**	-0.08**	-0.86**	2.44	4.05*	0.47**	0.43**	-1.07	2.33**	-1.10**	-1.57**
x Wab 878	-1.27*	-0.49	51.47**	31.49**	0.07**	0.07**	0.17	1.56	0.19**	0.39**	-8.22**	1.82**	0.59**	4.21**
x Gaori	-1.00	-2.29**	34.34**	6.95**	0.01**	-0.14**	1.41	1.01	-0.65**	-0.65**	1.67	-1.10**	0.20	-1.02**
x GZ 1368	-1.40**	-1.85**	3.77	1.25	0.009**	0.30**	6.16**	2.43	-0.10**	-0.24**	2.32	-0.56**	-0.16	0.78**
Wab 450 x IET 1444	-2.94**	-1.19	97.24**	79.69**	0.11**	-0.26**	-0.97	-0.12	-0.23**	-0.33**	-13.84**	-1.62**	2.22**	2.45**
x Wab 878	-0.70	-0.22	23.94**	-6.47**	-0.05**	-0.05**	-3.81*	0.39	-0.11**	-0.32**	3.45*	-0.85**	4.02**	4.24**
x Gaori	1.89**	-0.35	6.14**	-21.34**	0.003	0.31**	-1.97	-2.82	0.11**	0.07**	-5.63**	-1.98**	-2.62**	-2.59**
x GZ 1368	-0.84	1.40*	0.57	-5.04**	0.30**	0.60**	6.91**	6.32**	0.17**	0.03**	4.72**	2.09**	3.20**	2.31**
IET 1444 x Wab 878	1.49**	6.17**	-33.95**	6.09**	-0.19**	-0.10**	2.01	-1.56	0.67**	0.60**	7.70**	-0.21	0.31	-0.03
x Gaori	2.42**	5.37**	36.24**	66.55**	0.44**	0.20**	0.91	-3.98*	-0.20**	-0.15**	-5.47**	0.04	-3.97**	-4.07**
x GZ 1368	0.02	7.47**	52.00**	79.52**	0.29**	0.30**	-1.63	-4.09*	-0.19**	-0.05**	5.50**	0.76**	1.75**	0.23
Wab 878 x Gaori	-0.34	-0.65	-3.72	-0.60	0.46	0.46**	2.67	-2.97	-0.15**	-0.003	0.21	-1.87**	-0.70**	3.00**
x GZ 1368	0.25	2.77**	-16.95**	8.35**	-0.26	-0.26**	1.92	1.51	-0.24**	-0.17**	-3.54*	1.37**	-1.10**	-2.08**
Gaori x GZ 1368	-1.47**	-2.02**	-23.42**	20.15**	-0.36**	0.41**	-4.97**	-2.63	0.21**	0.30**	00.99	0.44*	-3.46**	-3.62**
S.E (Sij) :0.05	1.07	1.23	4.56	4.07	0.005	0.005	3.14	3.51	0.006	0.01	2.99	0.42	0.44	0.44
:0.01	1.31	1.51	5.57	4.97	0.006	0.007	3.83	4.29	0.008	0.012	3.65	0.52	0.53	0.53
S.E (Sij-Ski) :0.05	2.08	2.40	8.88	7.92	0.011	0.011	6.11	6.84	0.01	0.019	5.82	0.83	0.85	0.85
:0.01	2.55	2.94	10.85	9.68	0.013	0.013	7.47	8.36	0.01	0.024	7.12	1.02	1.04	1.04

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

S = water stress , N = normal irrigation

Table (6): Estimates of heterosis as a deviation from mid and better parent of the twenty eight rice crosses for some root, physiological and grain quality traits under water stress condition..

Genotype	Root length, cm		Root volume, cm^3		Root : Shoot ratio		Chlorophyll content, %		Grain length, mm		Milling, %		Amylose content, %	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Sakha 102 x Sakha 104	1.54	-1.54	1.67	0.00	26.79**	6.59	1.77	-5.83	5.93**	9.13**	-2.33	-4.32	5.87	6.54
x Balado	2.22	0.00	27.68**	2.28	46.87**	3.29	-0.35	-3.02	-2.67**	7.52**	-24.49**	-25.28**	15.16**	19.76**
x Wab 450	-11.81**	-25.26**	54.75**	20.45*	49.59**	1.09	-11.89**	-15.87**	-1.21	9.13**	-19.45**	-19.88**	19.13**	24.85**
x IET 1444	-21.24**	-33.67**	21.13**	-5.69	-48.48**	-62.63**	1.02	-5.28	5.70**	10.88**	-10.50**	-17.88**	8.20*	17.24**
x Wab 878	-12.69**	-18.43**	-3.82	-14.76	-23.18*	-41.75**	4.67	-2.23	-3.40**	2.95**	0.79	0.40	0.27	4.77
x Gaori	-16.68**	-16.68**	-11.30	-32.96**	-24.84**	-35.16**	-0.79	-3.84	1.00	1.34	5.20	4.76	1.70	16.71**
x GZ 1368	9.76	8.95	81.36**	65.90**	-25.00**	-34.06*	-1.44	-13.27*	4.16**	5.91**	4.04	2.39	12.38**	13.39**
Sakha 104 x Balado	5.35	0.00	54.19**	21.99*	-13.13	-30.64**	0.08	-4.99	-0.65	6.33**	-2.06	-3.05	9.68*	6.32
x Wab 450	-19.72**	-33.67**	7.15	-17.57*	-48.93**	-61.29	-4.07	-14.93**	-4.08**	2.66**	-4.53	-5.99*	26.35**	33.29**
x IET 1444	2.55	-14.90**	14.85**	-9.49	-6.79	-22.58**	13.86*	12.26*	-1.61	0.12	6.45*	-4.14	9.36**	17.70**
x Wab 878	2.89	-6.59	30.81**	14.27	-28.44*	-37.09**	4.20	3.15	6.31**	9.88**	-0.35	-2.01	1.42	6.66
x Gaori	7.82	4.54	11.75	-16.48	-34.37**	-36.36*	8.41	3.32	-0.91	1.73	-8.63**	-10.12**	2.05	16.30**
x GZ 1368	10.07	5.95	12.18	1.08	-22.13*	-26.08	26.18**	19.47**	-4.74**	-3.51**	-3.61	-7.04*	22.23**	22.55**
Balado x Wab 450	2.45	-11.56**	78.46**	71.74**	-21.73	-27.02	3.01	-4.14	2.00**	2.00*	-1.65	-2.17	5.16	5.95
x IET 1444	10.43*	-4.24	43.14**	-4.42	-5.12	-9.75	14.53**	10.22	6.58**	11.99**	-8.17**	-16.55**	-4.10	8.37
x Wab 878	-4.82	-9.19	344.74**	295.67**	11.90	0.00	7.76	3.29	2.87**	6.41**	-16.58**	-17.14**	5.60	6.09
x Gaori	-2.22	-4.34	342.92**	309.56**	-0.97	-22.72	8.31	7.86	-9.88**	-0.80	-3.38	-4.00	-7.59	10.82*
x GZ 1368	-2.93	-4.34	114.33**	84.95**	9.43	-15.94	29.97**	17.16**	-2.21**	6.11**	1.40	-1.22	4.34	9.51*
Wab 450 x IET 1444	-14.27**	-14.71**	416.97**	238.64**	61.64**	43.90*	-1.70	-11.72*	-1.92*	3.05**	-28.36**	-34.59**	22.03**	39.07**
x Wab 878	-8.75*	-17.87**	262.45**	211.82**	-8.86	-23.40	-9.39*	-18.93**	-1.03	2.37	-0.23	-0.37	36.02**	36.41**
x Gaori	1.86	-13.67**	236.16**	222.47**	4.08	-22.72	-6.87	-13.68**	-0.78	9.21**	-12.95**	-13.05**	-12.42**	5.95
x GZ 1368	-7.39	-21.03**	147.56**	106.86**	74.25**	27.53**	22.20**	3.34	0.77	9.36**	4.99	2.80	32.78**	40.46**
IET 1444 x Wab 878	3.52	-6.38	-7.96	-34.18**	-43.18**	-46.80**	11.98*	11.51	10.66**	12.36**	9.69**	0.28	3.51	17.58**
x Gaori	8.75*	-7.43	209.37**	98.74**	83.17**	48.48**	6.22	2.63	-2.55**	1.86	-11.23**	-18.86**	-24.78**	-20.65**
x GZ 1368	0.63	-13.82**	221.23**	134.82**	65.45**	31.88**	7.16	0.10	-1.51	1.56	10.05**	2.47	13.10**	21.39**
Wab 878 x Gaori	-2.81	-9.19	61.07**	33.84**	-13.27	-28.98	10.09*	5.95	-2.45**	3.60**	-0.87	-0.91	-11.53**	6.66
x GZ 1368	0.71	-5.25	-13.47	-16.44	18.96	0.00	16.77**	9.51	-2.54**	2.08*	-2.00	-3.92	-0.27	5.17
Gaori x GZ 1368	-5.25	-5.95	-30.53**	-43.85**	-58.51**	-59.42**	-5.99	-14.93**	0.52	1.86	3.63	1.57	-20.97**	-10.20*
L.S.D 0.05	2.19	2.53	4.48	5.23	0.14	0.16	3.76	4.34	0.14	0.16	3.66	4.22	1.4	1.62
0.01	2.91	3.37	5.96	6.95	0.18	0.21	5.00	5.77	0.18	0.21	4.86	5.61	1.86	2.15

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

Table (7): Estimates of heterosis as a deviation from mid and better parent of the twenty eight rice crosses for some root, physiological and grain quality traits under normal irrigation.

Genotype	Root length, cm		Root volume, cm3		Root : Shoot ratio		Chlorophyll content, %		Grain length, mm		Milling, %		Amylose content, %	
	MP	BP	MP	BP	MP	MP	MP	BP	MP	BP	MP	BP	MP	BP
Sakha 102 xSakha 104	16.77**	11.08	115.67**	79.72**	28.50**	28.50**	-1.06	-3.40	10.15**	13.52**	-1.18	-1.40	15.33**	17.27**
x Balado	7.92	4.16	130.69**	81.68**	29.36**	29.36**	-5.00	-6.69	-3.04**	9.88**	-23.93**	-24.45**	17.06**	19.03**
x Wab 450	21.81**	12.50*	110.90**	89.52**	12.97*	12.97*	-3.77	-13.15**	0.05	11.83**	-1.16	-1.39	22.85**	24.91**
x IET 1444	-16.98**	-28.30**	-38.06**	-57.88**	-80.85**	-80.85**	-6.75	-7.70	7.87**	13.13**	0.68	0.09	8.88**	19.50**
x Wab 878	3.45	2.75	-54.26**	-63.56**	-58.30**	-58.30**	-7.28	-14.47**	-4.39**	1.82	-3.02**	-3.67**	2.55**	4.27**
x Gaori	-15.23**	-18.98**	-60.11**	-66.06**	-59.57**	-59.57**	-5.44	-14.97**	1.69	2.09	1.40	1.40	4.16**	21.05**
x GZ 1368	-20.58**	-25.00**	-50.01**	-61.45**	-45.52**	-45.52**	8.13	4.16	4.99**	6.63**	-9.02**	-9.44**	27.12**	29.33**
Sakha 104 x Balado	50.03**	47.78**	42.11**	32.35**	-41.37**	-41.37**	8.79	4.37	-3.68**	5.63**	-0.46	-0.92	26.73**	26.73**
x Wab 450	42.89**	38.50**	8.03	-0.81	34.26**	34.26**	-12.25**	-22.47**	-3.62**	4.28**	-1.85	-1.85	30.48**	30.48**
x IET 1444	-6.11	-22.24**	-43.45**	-64.94**	-79.13**	-79.13**	7.27	3.69	-0.96	0.73	1.28	0.46	14.97**	28.50**
x Wab 878	52.20**	43.85**	77.76**	24.02**	114.63**	114.63**	-13.10**	-21.57**	4.09**	7.47**	-0.30	-0.74	3.74**	3.74**
x Gaori	4.18	-5.05	88.13**	38.08**	95.09**	95.09**	-7.76	-18.79**	-1.07	2.35	-0.51	-0.73	10.15**	30.48**
x GZ 1368	20.95**	20.03**	65.42**	50.00**	46.45**	46.45**	17.74**	16.13**	0.55	2.01	-3.97**	-4.64**	29.19**	33.68**
Balado x Wab 450	42.19**	35.82**	21.90**	4.91	-64.33**	-64.33**	-0.20	-8.44	-1.03	0.21	-4.16	-4.60**	1.97**	1.97
x IET 1444	-12.05**	-26.27**	-71.15**	-82.59**	-83.29**	-83.29**	11.20*	10.33*	5.17**	13.27**	1.46	0.17	-4.30*	6.95**
x Wab 878	15.73**	10.97	72.82**	15.88**	1.12	1.12	3.47	-2.93	3.63**	9.89**	-0.38	-0.40	33.68**	33.68**
x Gaori	-8.22	-15.19**	45.11**	1.84	-6.21	-6.21	-0.18	-8.76*	-9.95**	2.49	-4.87**	-5.53**	-6.99 **	10.16**
x GZ 1368	0.77	-1.47	74.27**	69.31**	54.60**	54.60**	15.66**	9.50	-3.79**	7.18**	-4.42**	-5.53**	13.17**	17.11**
Wab 450 x IET 1444	8.57	-12.12**	117.92**	40.23**	-38.70**	-38.70**	-3.37	-11.98**	-3.67**	2.36	-1.80	-2.59*	19.61**	33.68**
x Wab 878	25.39**	15.08**	25.26**	-7.75**	13.17	13.17	-3.75	-6.01	-4.56**	-0.11	-1.83	-2.26*	39.03**	39.03**
x Gaori	7.15	-5.05	11.77**	-12.84**	64.70**	64.70**	-11.84**	-12.19**	-2.04	9.96**	-3.82**	-4.04**	-9.70**	6.95**
x GZ 1368	24.81**	21.89**	78.57**	50.02**	111.90**	111.90**	17.25**	2.36	-1.09	8.70**	1.60	0.89	26.09**	30.48**
IET 1444 x Wab 878	34.86**	17.15**	23.57**	-0.70	-31.86**	-31.86**	-8.43*	-14.72**	9.51**	11.13**	0.84	-0.41	4.78**	17.11**
x Gaori	17.98**	6.06	86.63**	41.18**	-11.45**	-11.45**	-15.56**	-23.36**	-1.30	3.93**	0.81	0.22	-23.20**	-19.04**
x GZ 1368	33.73**	10.09*	129.54**	37.18**	-8.13*	-8.13*	-5.78	-10.13	1.40	4.66**	1.53	1.41	4.40**	12.50**
Wab 878 x Gaori	42.12**	36.72**	25.62**	15.88**	68.00**	68.00**	-14.16**	-16.52**	-0.49	6.42**	-3.02**	-3.69**	12.86**	33.68**
x GZ 1368	29.91**	21.90**	58.36**	4.65	2.64	2.64	5.15	-6.25	-1.20	3.53*	1.20	0.04	0.25	3.74**
Gaori x GZ 1368	-7.67	-16.44**	100.67**	38.53**	91.48**	91.48**	-6.38	-18.55**	2.95*	4.98**	-0.47	-0.93	-17.98**	-6.50**
L.S.D 0.05	2.34	2.72	4.28	4.94	0.16	0.16	3.96	4.58	0.20	0.22	1.38	1.60	0.36	0.42
0.01	3.11	3.61	5.69	6.57	0.21	0.21	5.26	6.09	0.26	0.29	1.83	2.12	0.47	0.55

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