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COMBINING ABILITY FOR SOME AGRONOMIC CHARACTERS IN GRAIN SORGHUM UNDER SALINE CONDITIONS AND BIOCHEMICAL GENETIC MARKERS FOR SALINITY TOLERANT GENOTYPES

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ABSTRACT

Twenty-four hybrids and their parents of grain sorghum were evaluated under normal and saline soils at Nubaria Agric. Res. Stat. in 2003 and 2004 growing seasons. The genetic analysis was conducted using line x tester analysis.

Significant differences were found among years, genotypes, salinity treatments, parents and their F_1's for all studied traits. Analysis of variance of salinity sensitivity index (SI) exhibited significant differences among crosses, parents, crosses vs parents and for male and female effects indicating the important role of some heterotic effect in sorghum for salinity tolerance. Regarding SI, the most salinity tolerant parents were (ICSR89025) m_2 and (ICSR90015) m_4 (0.74 and 0.65, respectively) among males and f_3 (ICSA-37), f_6 (ATX631) and f_2 (ICSA-14) (0.39, 0.60 and 0.61, respectively) among females. Based on both yield under saline conditions and SI, there were four promising hybrids viz. H_3 (ICSA-1 x ICSR 89038), H_7 (ICSA-14 x ICSR 89038), H_{14} (ICSA-70 x ICSR 89025), and H_{24} (ATX631x ICSR 90015), where SI were 0.44, 0.54, 0.09 and 0.48, respectively.

Estimates of general combining ability effects showed that ICSA14, ICSA 37, ICSR 89025 and ICSR 90015 were the best general combiners for yield and salinity tolerance and the hybrids H_3, H_7, H_{14} and H_{24} were the best regarding SCA effects for SI while H_1 had significantly positive SCA effect for grain yield. Results indicated that both additive and non-additive gene effect were important to improve grain yield of sorghum grown under saline conditions.

The tolerant parents were distinguished with five common bands which were not found at the sensitive genotypes at MW 255.81, 188.62, 162.62, 43.78 and 32.12 KDa, except the female f_6 which lacked two bands at MW 255.81 and 188.62 KDa. Most of these common bands were present in the most tolerant hybrids. Generally, the electrophoretic patterns of water soluble protein could be a useful tool for the identification and characterization of the tolerant grain sorghum genotypes for salt stress conditions.

Key words: *Grain sorghum, Sorghum bicolor, Combining ability, Salinity tolerance, SDS protein electrophoresis.*

INTRODUCTION

Undoubtedly, plant breeders have made a significant achievement in the past few years for improving salinity tolerance in a number of potential crops using artificial selection and conventional breeding approaches. Successful management of salt affected agronomic systems is largely dependent on information about crops salt tolerance or relative yield expected for a given root zone salinity (April *et al* 1998).

Grain sorghum have categorized as a moderately tolerant crop and its threshold salinity level ranges from 4.9 to 6.8 E.C. (Maas and Hoffman 1977). Also, François *et al* (1984) demonstrated that grain sorghum is moderately tolerance to salinity and yield reduction was due primarily to lower weight per head rather than a reduced number of heads. Vegetative growth was less affected by increasing soil salinity than was grain yield.

Grain sorghum was significantly more salt tolerant at germination than at later stages of growth. Salinity tolerance is difficult to measure because of its complexity. Not only are there a number of genes controlling salinity tolerance whose effect interacts strongly with environmental conditions but there are two major and distinct components of salinity tolerance, which can often be difficult to distinguish (Munns 2002). Grain yield is apparently affected more by salinity than vegetative growth (Patel *et al* 1975).

Substantial genotypic differences exist among various cultivars of sorghum in the growth stage for their response to saline conditions. Tayler *et al* (1975), Padmanathon and Rao (1975) and Igartua *et al* (1995) studied the relationship between several agronomic, physiological and salinity tolerance traits where eleven public inbred lines and one cultivar were exposed to salinity gradients (NaCl and KaCl 1:1) developed with a triple line source sprinkle system. The traits most affected by salinity were grain yield, number of grains per panicle, harvest index and leaf area. Wery *et al* (1994) pointed out that reduction in leaf area is an important adaptive mechanism for salinity stress and it is usually the first strategy, a plant adopts when water becomes limiting.

Jena (1994) reported that it is possible that the salinity tolerance of genotypes can be improved through selective of genotypes with higher salt tolerance. SDS-PAGE of water-soluble proteins was successfully used for the identification and characterization of grain sorghum genotypes and different field crops (Abdel Tawab *et al* 1993 and 1998, Shadi *et al* 1999, El-Menshawi *et al* 2003 and Rashed *et al* 2004).

The objectives of this study were 1- to select the best grain sorghum hybrid that could be cultivated under saline conditions. 2- to determine the general (GCA) and specific (SCA) combining ability effects and to identify the mode of gene action for salinity tolerance and 3- to identify and characterize the tolerant grain sorghum genotypes to saline stress using SDS protein analysis.

MATERIALS AND METHODS

The present investigation was divided into two parts: one part was conducted in experimental farms at Nubaria Station, Agric. Res. Cent. (ARC) and the second part was carried out at the laboratory.

Experimental sites

Six cytoplasmic male sterile lines (A-lines) of grain sorghum (*Sorghum bicolor*) i.e. ICSA-1, ICSA-14, ICSA-37, ICSA 70, ICSA 88015 and ATX631 and four restorer lines (R- lines) i.e. ICSR 89016, ICSR 89025, ICSR 89038 and ICSR 90015 were chosen on the basis of previous screening experiment for salinity tolerance (Grain sorghum breeding program, Egypt 2002). The parents and their twenty-four hybrids were evaluated during the two successive seasons 2003 and 2004.

A randomized complete block design (RCBD) with three replications was used at two sites (normal and saline areas) to study the effect of soil salinity on growth, yield and yield components. Each genotype was planted in one row plot, 4 meter long, 0.7 m width. Planting were done at 20 cm between hills and thinned to two plants/hill. Three soil samples were obtained at different depths from the soil surface in Nubaria station; the mechanical and chemical analyses of the soil and water properties are presented in Table (1).

All other agronomic practices were done as usual and plant protection operations were given as and when necessary. Data were recorded on days to 50% heading, plant height (cm), leaf area (cm^2), 1000 kernel weight (g.) and grain yield/plant (g.). The genetic analysis was conducted by using line x tester analysis according to Kempthorne (1957). General (GCA) and specific (SCA) combining abilities were estimated according to Singh and Chaudhury (1977).

Table 1. Mechanical and chemical analysis of the soil at the experiment sites.

Properties and components	Type of soil	
	Normal area	Saline area
Sand %	69.50	69.50
Silt %	18.0	18.5
Clay %	12.3	12.6
Texture	Sandy loam	Sandy loam
Organic matter %	0.360	0.21
$CaCO_3$%	23.60	23.05
Soil:		
EC(Mmhos/cm)in season 2003	1.76	6.83
EC(Mmhos/cm)in season 2004	1.56	6.33
pH	8.31	7.87
Water:		
EC (Mmhos/cm)	0.80	0.80
pH	7.1	7.1
Soluble cations (- equiv./L):		
Ca^{++}	2.16	19.3
Mg^{++}	1.40	11.35
Na^{+}	7.78	35.03
K^{+}	0.81	4.20
Soluble anions (- equiv./L):		
CO_3^{-}	--	--
HCO_3^{-2}	2.90	8.30
Cl^{--}	6.00	28.70
SO_4^{-2}	3.00	33.00

Salinity sensitivity index (SI) was calculated for grain yield according to Fischer and Maurer (1978) as follows: SI = (1-Ys/Yc)/S. where Ys= mean grain yield of the genotypes under salinity, Yc= mean grain yield of the same genotypes under control, S= salinity intensity= 1- (mean Ys of all genotypes/mean Yc of all genotypes). This analysis was used previously by El-Menshawi *et al* (2003).

Laboratory screening

Electrophoretic methods: The grains of eight tolerant genotypes, three females (ICSA-14, ATX631 AND ICSA 70), two males (ICSR 89025 and ICSR 90015) and 3 hybrids (ICSA 70 x ICSR 89025), (ICSA 1 x ICSR 89038) and (ATX631 x ICSR 90015) and six sensitive genotypes : one female (ICSA 88015), 2 males (ICSR 89016 and ICSR 89038) and 3 hybrids (ICSA 14 x ICSR 89016), (ICSA-1 x ICSR 89016) and (ICSA 88015 x ICSR 89016) were used in SDS- protein electrophoresis analysis based on sensitivity index value. Sodium dodecyle sulphate polyacrylamide gel electrophoresis (SDS- PAGE) was performed on water soluble protein fractions according to the method of Laemmli (1970), as modified by Studier (1973). The SDS protein gel was scanned and analyzed using Gel Doc 2000 Bio Rad System.

RESULTS AND DISCUSSION

Analysis of variance

A combined analysis of variance was conducted to determine the importance of years, salinity treatments, genotypes and their interaction effects. Significant differences were found among years because of variation in climatic between the two growing seasons (Table 2.).

Table 2. Mean squares from combined analysis of variance of grain yield/plant, 1000 kernel weight, days to 50% heading, plant height and leaf area under control and salt conditions at Nubaria (across 2003-2004 seasons).

Source of variation	df	Grain yield/ plant (g)	1000 kernel weight (g)	Days to 50% heading	Plant height (cm)	Leaf area (cm2)
ear (Y)	1	6920.94**	15451.27**	2110.75**	3612.25	123359.09
alinity levels (S)	1	37728.11**	2440.21**	7678.68**	76917.66**	476324.34*
x S	1	661.22*	12.01	0.48	3196.48	476324.34**
rror a	8	84.74	48.80	6.69	809.71	60158.32
enotypes (G)	33	1015.38**	122.92**	126.94**	5576.56**	107586.30**
rosses	23	621.20**	46.06**	102.36**	3283.92**	106329.48**
rosses vs parents	1	11925.15**	1548**	969.63**	81442.51**	199783.16*
arents	9	810.54**	160.99**	96.15**	3005.98**	100554.15*
ale effects (M)	3	941.5**	29.52*	94.38**	3136.89**	58091.11
emale effects (F)	5	836.32**	119.8**	275.93**	6006.12**	135608.35**
x F effects	15	485.44**	24.78**	46.09**	2405.92**	106217.53**
x Y	33	855.93**	33.92**	60.24**	1502.64**	156693.84**
x S	33	160.21**	12.76**	20.26**	678.31**	44234.74**
ale effect x S	3	172.92*	38.73**	20.82**	1292.67*	52494.09
emale effect x S	5	38.84	5.24	33.39**	1305.16**	52928.06
x M effects x S	15	180.87**	13.71*	12.25**	724.47	62539.00
x Y x S	33	190.62**	21.66**	57.85**	846.38**	44234.74**
rror	264	49.71	7.70	2.64	372.55	42086.987

Also, significant differences existed among genotypes, salinity treatments, parents and their F_1's for all studied traits. The significance of parents vs crosses showed the presence of heterotic effect. All genotypes x years, genotypes x salinity treatments and genotypes x years x salinity treatments interactions were highly significant for all studied traits. This would reflect that the performance of genotypes varies with different environments. These results are in agreement with those of El Hawary (1986), Uiery and Frederick (1997) and Mourad *et al* (1999).

Mean squares of the 24 crosses tested were partitioned into males, females and male x female component. Mean squares due to both males and females and their interactions with salinity were significant for all studied traits except for male GCA effect for leaf area, which exhibited insignificance for the interaction with salinity. Mean squares due to the interaction among female GCA and salinity treatments was also insignificant for grain yield and 1000 kernel weight.

Mean performance

Grain yield and 1000-kernel weight were greatly affected by soil salinity level as shown in Table (3). Grain yield was reduced to 75% while 1000 kernel weight was reduced to 86% and this reflect that grain yield was more affected by salinity stress through deleterious effect on seed number rather than seed weight. The top three yielding hybrids under salinity conditions were H_8, H_6, H_{10}, producing 74.32, 73.72 and 71.17g seeds per plant, respectively. The top three hybrids showing the highest 1000 kernel weight under salinity conditions were H_9, H_{14} and H_{15} exhibiting 33.82, 32.92 and 34.75g per 1000 kernels, respectively. Days to 50% heading tended to increase in response to salinity effect by 9 days as compared to control treatment. Crosses H_{11}, H_{14}, H_{16}, H_{18}, H_{19} and H_{20} were the significantly earlier than the average of all genotypes tested under salinity conditions (Table 3).

Similarly, plant height was reduced significantly to 148.65 cm in saline conditions as compared with control, treatment (175.51 cm). Crosses H_4, H_6, H_{13}, H_{15}, H_{17} and H_{18} were the least affected hybrids by salinity treatments, regarding plant height.

Table 3. Average of sensitivity index, grain yield/plant, 1000 kernel weight, days to 50% heading, plant height, leaf area for 24 hybrids and their parents under control and saline conditions across 2003 and 2004 seasons.

No.	Crosses	SI	Grain yield/plant (g)		1000 kernel weight (g)		Days to 50%heading		Plant height (cm)		Leaf area (cm^2)	
			Cont	Stress	Cont	Stress	Cont	Stress	Cont	Stress	Cont	Stress
H_1	ICSA-1 x ICSR 89016	1.99	90.48	55.42	33.30	30.23	72.67	81.17	165.33	144.17	389.00	355.67
H_2	ICSA-1 x ICSR 89025	1.07	77.97	63.15	30.97	27.20	75.83	81.33	170.83	135.17	408.33	386.20
H_3	ICSA-1 x ICSR 89038	0.44	85.17	63.15	31.87	29.10	75.33	80.67	131.67	117.67	517.17	494.00
H_4	ICSA-1 x ICSR 90015	1.28	71.67	58.23	38.13	26.50	73.17	79.50	199.17	170.67	482.12	444.03
H_5	ICSA-14 x ICSR 89016	2.20	85.68	65.48	36.02	29.45	74.33	80.33	184.50	133.17	454.50	439.37
H_6	ICSA-14 x ICSR 89025	1.03	89.18	73.72	34.15	29.60	71.67	79.83	213.33	180.17	622.83	412.67
H_7	ICSA-14 x ICSR 89038	0.54	81.80	65.02	35.63	28.68	71.17	79.33	180.00	155.0	377.53	356.28
H_8	ICSA-14 x ICSR 90015	0.82	97.93	74.32	36.15	31.05	72.83	77.67	237.50	156.17	688.17	665.37
H_9	ICSA-37 x ICSR 89016	0.32	64.65	55.62	35.43	33.82	68.83	82.33	205.50	150.83	524.53	462.42
H_{10}	ICSA-37 x ICSR 89025	0.81	82.90	71.17	37.30	30.80	71.17	83.50	166.50	167.17	475.45	458.92
H_{11}	ICSA-37 x ICSR 89038	0.10	79.50	52.60	34.55	32.75	61.0	74.00	181.67	164.83	493.70	414.08
H_{12}	ICSA-37 x ICSR 90015	0.64	93.35	65.68	34.18	28.23	68.67	77.83	187.83	162.33	420.08	381.87
H_{13}	ICSA 70 x ICSR 89016	1.19	79.50	55.27	36.72	32.40	71.00	81.00	199.50	178.00	362.58	347.00
H_{14}	ICSA 70 x ICSR 89025	0.09	79.28	61.50	38.08	32.92	66.33	71.67	188.33	149.83	476.37	462.67
H_{15}	ICSA 70 x ICSR 89038	1.74	78.47	55.50	38.08	34.75	67.33	76.00	180.00	175.83	513.08	500.50
H_{16}	ICSA 70 x ICSR 90015	0.89	80.02	62.83	35.82	31.78	68.50	75.33	190.00	172.00	448.25	436.33
H_{17}	ICSA 88015x ICSR 89016	1.54	87.57	53.87	35.88	30.32	67.67	77.33	188.33	175.50	507.58	500.50
H_{18}	ICSA 88015x ICSR 89025	1.14	84.10	69.60	32.85	30.65	67.33	75.00	199.33	174.67	463.33	402.37
H_{19}	ICSA 88015x ICSR 89038	0.97	68.45	47.83	33.48	30.07	65.67	73.33	179.17	162.33	457.83	383.17
H_{20}	ICSA 88015x ICSR 90015	0.79	89.13	64.53	36.30	29.90	66.67	74.33	194.17	164.50	374.33	360.75

Table 3. Cont.

No.	Crosses	SI	Grain yield / plant (g)		1000 kernel weight (g)		Days to 50%heading		Plant height (cm)		Leaf area (cm^2)	
			Cont	Stress	Cont	Stress	Cont	Stress	Cont	Stress	Cont	Stress
H_{21}	ATX631 x ICSR 89016	0.11	64.68	47.78	34.52	32.55	70.00	80.00	174.17	156.83	419.53	371.97
H_{22}	ATX631 x ICSR 89025	1.16	80.18	54.95	30.47	24.90	68.67	81.50	162.50	122.00	449.00	437.67
H_{23}	ATX631 x ICSR 89038	0.89	88.78	62.70	33.35	30.40	66.33	75.17	176.67	162.50	471.67	436.22
H_{24}	ATX631 x ICSR 90015	0.48	71.90	64.18	34.73	27.17	72.67	83.00	175.00	146.83	415.45	377.25
m_1	ICSR 89016	1.50	75.72	57.80	29.57	27.43	69.17	83.17	173.33	150.17	419.33	386.17
m_2	ICSR 89025	0.74	74.53	58.73	34.18	29.40	72.17	84.00	158.33	132.50	429.00	382.42
m_3	ICSR 89038	1.81	69.15	40.68	35.92	30.17	71.33	75.67	134.17	111.00	611.83	508.92
m_4	ICSR 90015	0.65	69.62	44.03	32.93	29.57	73.17	82.33	163.33	138.33	510.75	488.83
f_1	ICSA-1	1.32	48.48	37.87	25.95	21.47	75.50	85.00	134.17	95.83	519.33	431.33
f_2	ICSA-14	0.61	73.47	60.27	24.98	19.57	78.83	87.33	177.50	141.67	548.33	476.83
f_3	ICSA-37	0.39	59.97	53.02	31.77	26.07	70.00	82.00	143.33	119.17	714.00	546.83
f_4	ICSA-70	1.25	78.67	55.02	32.37	24.67	73.17	84.33	157.33	124.17	498.50	394.00
f_5	ICSA 88015	1.96	59.25	42.43	28.10	21.13	71.00	77.50	143.33	107.83	770.83	584.17
f_6	ATX631	0.60	67.08	60.83	33.30	28.18	73.67	83.33	157.50	134.83	503.33	413.50
Mean crosses			81.35	61.00	35.0	30.20	70.11	78.38	184.38	157.42	466.91	413.23
	Males		72.25	50.52	33.5	29.14	73.46	60.71	157.29	133.00	492.73	441.95
	Females		64.49	51.57	29.41	23.50	73.70	83.25	152.19	120.58	592.41	472.44
General mean			77.30	58.07	33.80	28.91	70.91	79.58	175.51	148.65	506.80	438.46
	L.S.D. $_{0.05}$ for genotypes		8.15		3.21		1.88		22.30		237.00	
	L.S.D. $_{0.05}$ for salinity		1.98		0.78		0.46		5.41		57.48	
	L.S.D. $_{0.05}$ for interaction		11.52		4.53		2.65		31.54		335.18	

Leaf area was also significantly reduced by salinity. Moreover, crosses H_3, H_8, H_{13} and H_{17} were not drastically affected by salinity stress and had the largest leaf area as compared to the over all average for all hybrids. Data presented in Table (3) proved that salinity caused significant depression effect on all vegetative growth characters and this might be attributed to the high osmotic potential in the root zone of the plants and also the toxic effect of soil on the growth. These results are in agreement with Hassanein (1984), El Hawary (1986) and Mourad (1989),

In general, hybrids were less affected by salinity stress than their parents as shown in Table (3) and this might be attributed to the hybrid vigor phenomenon. These results are in harmony with Igartua *et al* (1995) and Mourad *et al* (1999).

Salinity sensitivity index (SI)

Analysis of variance for salinity sensitivity index (SI) is presented in Table (4). Mean squares due to crosses, parents, and for both males and females effects were significant indicating that all genotypes varied significantly in their response to salinity and there was significant average heterosis due to genes controlling tolerance to salinity since the mean square due to crosses vs parents was highly significant.

Table 4. Combined analysis of variance of salinity sensitivity index (SI) for the sorghum hybrids and their parental lines across 2003 and 2004 seasons.

Source of variation	df	M.S.
Years	**1**	**0.1413****
Crosses	**23**	**0.605****
Parents	**9**	**0.501****
Crosses vs parents	**1**	**0.099****
Female effects	**5**	**0.709****
Male effects	**3**	**1.351****
Male x female effects	**15**	**0.44****
Error	**33**	**0.003**

SI is a value that measures salt sensitivity hence, the smaller value of SI the greater degree of tolerance of a given genotype. Regarding SI, the most salinity tolerant parents were m_2 (ICSR 89025) and m_4 (ICSR 90015) (0.74 and 0.65, respectively) among males and f_2 (ICSA-37), f_6 (ATX631) and F_3 (ICSA-14) (0.39, 0.60 and 0.61, respectively) among females as shown in Table (3). On the other hand, the tested hybrids could be classified into two distinct groups according to SI value (Table 3). The highest one included the tolerant hybrids (H_3, H_7, H_8, H_9, H_{10}, H_{11}, H_{12}, H_{14}, H_{16}, H_{19},

H_{20}, H_{21}, H_{23} and H_{24}). The others were salt sensitive and showed SI values higher than unity. Based on both yield under saline conditions and susceptibility index used in this investigation, four promising hybrids viz H_3 (ICSA-1 x ICSR 89038), H_7 (ICSA-14 x ICSR 89038), H_{14} (ICSA 70 x ICSR 89025) and H_{24} (ATX631 x ICSR 90015) were selected (Fig. 1.) Data presented in Table (5) reflect the average performance of the selected four hybrids against all tested hybrids.

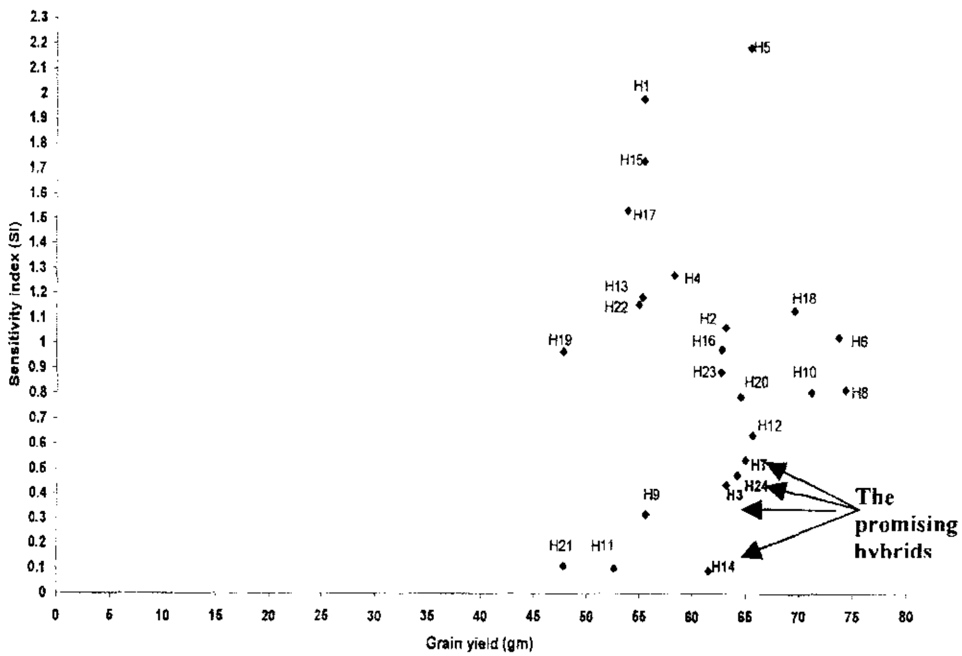

Fig . 1. The mean values of grain yield (g) and sensitivity index (SI) under saline condition for 24 hybrids of grain sorghum.

Table 5. Mean performance of all hybrids and selected ones at control and salinity conditions and reduction % for grain yield/plant (g), plant height (cm) and leaf area (cm^2) (means 2003 and 2004 seasons).

Trait	Item	Control	Salinity stress	Reduction %
rain yield/plant (g.)	All hybrids (24)	81.4	61.0	20.4
	Selected hybrids (4)	77.78	63.45	14.4
Plant height (cm)	All hybrids (24)	184.4	154.4	30.0
	Selected hybrids (4)	168.75	142.21	26.5
Leaf area (cm^2)	All hybrids (24)	467.0	413.0	54.0
	Selected hybrids (4)	446.65	422.55	24.1

Combining ability

General combining ability (GCA) effects

General combining ability (GCA) effects showed that the three maternal lines f_2 (ICSA-14), f_3 (ICSA-37) and f_6 (ATX631) were the best combiners indicating that these three females were the most tolerant genotypes to salinity and have the ability to transmit their tolerance to their offspring. Among males m_2 (ICSR 89025) and m_4 (ICSR 90015) also were the best combiners for SI and grain yield, as shown in Table (6). While the other parental lines showed positive insignificant GCA effect for SI and yield revealing that they contributed to the most sensitive hybrids.

Table 6. Estimates of general combining ability effects for sensitivity index, grain yield/plant, 1000 kernel weight, days to 50% heading, plant height and leaf area of ten sorghum inbred lines under salinity conditions at Nubaria across 2003 and 2004 seasons.

No	Pedigree	SI	Grain yield/ plant (g.)	1000 kernel weight (g.)	Days to 50% heading	Plant height (cm)	Leaf area (cm^2)
	Males						
m_1	ICSR 89016	0.4**	-4.0**	0.8*	1.3**	0.4	-30.4
m_2	ICSR 89025	-0.3**	2.8*	-0.8	0.2	-2.2	38.0
m_3	ICSR 89038	0.2**	-2.1	0.1	-1.5**	-7.0*	-7.1
m_4	ICSR 90015	-0.3**	3.3**	-0.1	-0.1	8. 8**	-0.5
SE g_i		0.02	2.4	0.9	0.5	6.4	68.4
SE $(g_i - g_j)$		0.03	3.4	1.4	0.8	9.1	96.7
	Females						
f_1	ICSA-1	0.2**	-0.5	2.0*	3.2**	-16.6**	-23.7
f_2	ICSA-14	-0.2**	8.0**	-0.02	1.6*	9.1**	106.2
f_3	ICSA-37	-0. 3**	-0.5	0.8	0.2	2.4	-4.4
f_4	ICSA-70	0.1**	-2.1	2.5**	-2.1*	8.3**	-15.0
f_5	ICSA 88015	0.4**	-0.5	0.01	-3.3**	8.1*	-27.1
f_6	ATX631	-0.2**	-4.3**	-1.6*	0.4	11.3**	-36.0
SE g_i		0.02	2.88	1.02	0.66	7.88	83.82
SE $(g_i - g_j)$		0.03	4.08	1.60	1.54	11.14	118.49

Specific combining ability (SCA) effects

Estimates of SCA effects for sensitivity index (SI) (Table 7) revealed that 11 out of the 24 hybrids showed negative (favorable) significant SCA effects for SI. The highest desirable SCA effects towards salinity tolerance resulted from H_3 (ICSA-1 x ICSR 89038), H_7 (ICSA-14 x ICSR 89038), H_{11} (ICSA-37 x ICSR 89038), H_{14} (ICSA 70 x ICSR 89025), H_{16} (ICSA 70 x ICSR 90015) and H_{24} (ATX631 x ICSR 90015).

Table 7. Estimates of specific combining ability effects for sensitivity index (SI), grain yield/plant, 1000 kernel weight, days to 50% heading, plant height, leaf area under salinity conditions across 2003 and 2004 seasons.

No.	Genotypes	SI	Grain yield/plant (g)	000 kernel weigh (g)	Days to 50% heading	Plant height (cm)	Leaf area (cm^2)
H_1	ICSA-1 x ICSR 89016	0.42334**	6.3052*	0.08	-1.8472*	-0.0035	-31.8753
H_2	ICSA-1 x ICSR 89025	-0.0133	0.451	-0.6337	0.1319	-21.566	-87.2378
H_3	ICSA-1 x ICSR 89038	-0.6088**	-6.5406*	0.4663	-0.1389	4.4132	70.1997
H_4	ICSA-1 x ICSR 90015	-0.1509**	2.3469	-1.3649	2.5486*	9.1424	-58.1379
H_5	ICSA-14 x ICSR 89016	0.4657**	4.0907	-0.2941	0.2778	2.4965	103.2267
H_6	ICSA-14 x ICSR 89025	-0.1161*	-6.6531*	1.7476	-0.9722	5.5174	3.8246
H_7	ICSA-14 x ICSR 89038	-0.3322**	-2.8948	-1.0531	0.8889	0.9132	-75.1212
H_8	ICSA-14 x ICSR 90015	0.428**	-0.4906	0.0594	-0.3819	19.0174*	165.1497
H_9	ICSA-37 x ICSR 89016	-0.028	3.5511	1.4427	2.6806*	-4.2534	-24.7712
H_{10}	ICSA-37 x ICSR 89025	0.0763	-1.4531	1.4448	-3.3819*	-7.8577	-11.842
H_{11}	ICSA-37 x ICSR 89038	-0.334**	3.4156	0.6573	0.0139	7.2465	-36.3941
H_{12}	ICSA-37 x ICSR 90015	0.1894*	-2.1281	-2.551	0.1809	-15.066*	-17.0212
H_{13}	ICSA 70 x ICSR 89016	-0.1441*	5.5997	-0.5448	2.0139*	-22.7118	78.0344
H_{14}	ICSA 70 x ICSR 89025	-0.7638**	-3.6378	-0.549	0.8264	-5.5243	-190.6032*
H_{15}	ICSA 70 x ICSR 89038	0.9286**	-2.5379	0.1511	1.4444	6.8715	7.026
H_{16}	ICSA 70 x ICSR 90015	-0.3033**	0.033	1.1531	0.993	5.684	70.5219
H_{17}	ICSA 88015x ICSR 89016	0.0512	-10.3983**	-0.9594	0.0556	-1.2951	-3.6552
H_{18}	ICSA 88015x ICSR 89025	0.2315**	10.9413**	0.749	-2.4445*	16.9757**	38.6761
H_{19}	ICSA 88015x ICSR 89038	0.053	-9.0101**	1.5191	-1.0555*	21.8021**	28.9622
H_{20}	ICSA 88015x ICSR 90015	0.3492**	3.6774	1.1233	-0.5764	8.0729	112.6913
H_{21}	ATX631 x ICSR 89016	-0.2919**	5.5274	-2.0601	-1.0972	-7.0313	-52.4545
H_{22}	ATX631 x ICSR 89025	0.378**	-0.9267	-1.233	-0.1597	-6.9687	-0.542
H_{23}	ATX631 x ICSR 89038	-0.183**	2.892	0.5962	-0.3472	-8.4479	-63.1774
H_{24}	ATX631 x ICSR 90015	-0.3049**	-2.11	0.054	3.2361**	-7.4271	-25.4795
SE S_{ij}		0.044	5.76	2.23	1.32	14.76	167.58
SE S_{ij}-S_{ik}		0.062	8.12	3.20	1.88	22.28	236.88
SE S_{ij}-S_{kl}		0.02	2.87	1.13	0.66	7.88	83.95

These results indicated that the desirable SCA effect for SI might come from two parents possessing good GCA or from one parent with good GCA and another with poor GCA. Regarding SCA effects for grain yield, Table (7) indicated that H_1 (ICSA-1 x ICSR 89016) and H_{18} (ICSA 88015x ICSR 89025) had significantly positive SCA effects for grain yield. Coefficient of correlation was calculated between SCA effects for grain and SCA effects for SI. It was ($r=0.19$, $P=0.375$), indicating that there are no association between the two effects calculated on the average means over all treatments and locations. These results clearly confirm the fact that additive and non-additive effects played an important role in the inheritance of salinity tolerance and also they are important to improve grain yield of sorghum grown under saline conditions.

In general, hybrids as a group flowered earlier, were taller, had higher 1000 kernel weight and grain yield and were more salinity tolerant than parents (Table 3). This means that hybrids have advantage in terms of yield adaptability under such environmental stress.

SDS-PAGE protein banding patterns

Water soluble proteins were fractionated by using one dimensional SDS-PAGE. Analysis of water soluble proteins in two groups (tolerant and sensitive for saline stress conditions) of 14 grain sorghum genotypes are presented in Table (8) and Figure (2). The first group contains five tolerant females and males (f_2, f_3, f_6, m_2 and m_4) and three tolerant hybrids (f_2 x m_4, f_3 x m_4 and f_6xm_4) depend on salinity sensitivity index (Table 3). The second group contains three sensitive parents (f_5, m_1 and m_3) and three sensitive hybrids (f_2xm_1, f_5xm_1 and f_4xm_1) (Table 3).

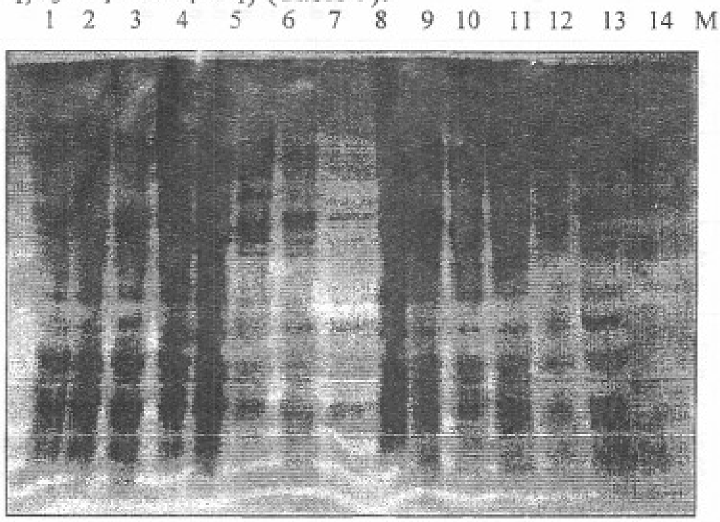

Fig. 2.	SDS Electrophoretic patterns of water soluble protein in 14 grain sorghum genotypes

Table 8. Densitometer analysis of water soluble proteins (SDS-PAGE) showing band number (B.no), relative mobility (Rm), molecular weight (MW) and intensity as a percentage o total concentration of some grain sorghum genotypes.

B.no.	Rm	MW (KDa)	Tolerant (T.) Females			T. Males		T. Hybrids			Sensitive (S.) Hybrids			S. Males		S. females
			F2	F3	F6	M2	M4	F2xm4	F3 x m4	F6 x m1	F2 x m1	F5 x m1	F4 x m1	M3	M1	F5
1	0.03	255.81	0.27	0.34		0.40	0.41									
2	0.05	225.00									0.40	0.43	0.44	0.45	0.29	
3	0.07	188.62	0.30	0.39		0.17	0.17	0.29	0.22							
4	0.09	162.62	0.31	0.41	0.29	0.49	0.49									
5	0.10	151.06	0.31	0.44	0.29			0.30				0.51	0.50			
6	0.11	146.58												0.45	0.29	0.26
7	0.12	142.69						0.29					0.47			
8	0.13	137.21				0.50	0.51									
9	0.14	134.77									0.50	0.43	0.41	0.36	0.27	
10	0.17	122.73			0.26	0.43	0.49	0.27								
11	0.18	117.77		0.40								0.45	0.34	0.32		
12	0.19	116.46	0.29				0.51		0.22							
13	0.21	110.62	0.42		0.27			0.29				0.45		0.32	0.25	
14	0.25	98.79			0.42			0.29	0.32	0.19						
15	0.26	94.91	0.34	0.48	0.38				0.28	0.16	0.52	0.53	0.46		0.29	0.29
16	0.29	89.72				0.51	0.54	0.33						0.38		0.25
17	0.32	84.42	0.33	0.47	0.36	0.51	0.53	0.28	0.24	0.15	0.55	0.54	0.45	0.33	0.24	0.24
18	0.33	79.47	0.29	0.47	0.38	0.47	0.51	0.24	0.22	0.14	0.50	0.44		0.27	0.22	0.24
19	0.37	73.54				0.46	0.49				0.48	0.37	0.31	0.25		
20	0.40	70.52				0.44	0.48								0.21	0.22
21	0.43	67.02				0.43	0.48				0.48	0.36			0.18	
22	0.47	63.50	0.29	0.41	0.31	0.39	0.46	0.21		0.12	0.47	0.33	0.27	0.25	0.18	0.21
23	0.50	57.42	0.28			0.32		0.24								
24	0.53	56.12		0.34			0.45		0.24							0.24
25	0.54	55.19	0.23		0.32					0.14					0.21	
26	0.55	54.18		0.34		0.35		0.21	0.23		0.47		0.23	0.27		
27	0.56	52.28				0.36	0.46					0.34				
28	0.57	51.31			0.27				0.23							0.22
29	0.63	43.78	0.32	0.34	0.39	0.44	0.30	0.25	0.26	0.13						
30	0.64	42.29									0.19	0.39	0.33	0.31	0.23	0.22
31	0.65	40.91				0.47	0.53	0.27	0.25	0.17						
32	0.67	38.19									0.52	0.38	0.31	0.31		
33	0.73	32.12	0.45	0.34	0.52	0.51	0.55	0.30		0.21						
34	0.77	30.03									0.53	0.45	0.38	0.37	0.28	0.30
35	0.79	28.17				0.38	0.50		0.39	0.20	0.32	0.35				
36	0.83	25.35	0.24	0.26	0.29	0.23	0.29							0.22	0.19	0.29
37	0.91	21.66										0.23	0.21			0.21

30.03 KDa could easily distinguish the sensitive crosses from the tolerant group. Most of these bands resembled the sensitive parents.

It is evident from these results that the electrophoretic patterns of water soluble proteins could be a useful tool for the identification and characterization of the tolerant grain sorghum genotypes for salt stress conditions. This result is in agreement with results of El-Menshawi *et al* (2003) who found that SDS-PAGE protein banding patterns for water soluble fraction of seed storage proteins was successful in locating biochemical genetic markers related to salt tolerance in sorghum. The tolerant hybrids and parents exhibited almost the same banding patterns.

REFERENCES

Abdel Tawab, F. M., M. A. Rashed, Eman M. Fahmy and F. M. El Domyati (1993). Soybean cultivar identification by biochemical genetic markers. Annals Agric. Sci. 2: 455-463.

Abdel Tawab, F. M., Eman M. Fahmy, A. Bahieldin, A. J. Allam and A. H. Heggy (1998). Molecular finger printing and phytogenetic relationships in sugar cane (*Saccharum* spp.). Proceeding of the International Congress on Molecular Genetics 1: 131-148.

April, L. Ulery. Jennifer, A. Teed, Martines Th. Van Genuchten and Michael, C. Shamnon (1998). Salt data. A Database of plant yield response to salinity. Agron. J. 90: 556-562.

El-Hawary, M. A. M. (1986). Evaluation of salt tolerance in some grain sorghum genotypes. M. Sc. Thesis. Fac. of Agric. Al Azhar University.

El- Menshawi, M. M., Naglaa, A. Ashry and Clara R. Azzam (2003). Evaluation of some grain sorghum hybrids under saline conditions and identification of salinity tolerant genotypes using some biochemical genetic markers. Egypt. J. Plant Breed. 7(2): 183-203.

Fischer, R. E. and R. O. Maurer (1978). Drought resistance in wheat cultivars.1-Grain yield response. Aust. J. Res. 21: 897-912.

François, L. E., H. M. Varghese and T. Donovan (1984). Salinity effect on seed yield, growth and germination of grain sorghum. Agron. J. 76(5): 741-744.

Hassanein, A. M. (1984). Effects of soil salinity and sowing dates on growth and yield of grain sorghum. Al-Azhar J. Agric. Res. 11: 379-390.

Igartua, E., M.P. Gracia and J. M. Laso (1995). Field responses of grain sorghum to salinity gradient. Field Crops Res. 42(1): 15-25.

Jena, K. K. (1994). Production of inter-genetic hybrid between *Oryza sativa* L. and *Proteres coarctata*. J. Curr. Sen. 67: 744-746.

Kemplhorne, O. (1957). An introduction to genetic statistics. John Willy and Sons, New York.

Laemmli, U. K. (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. Nature 227: 680-685.

Maas, E. V. and G. J. Hoffman (1977). Crop salt tolerance current assessment. J. Irrig. Drainage Div. Ann. Soc. Civ. Eng. 103-115.

Mourad, A. E. A. A.(1989). Physiological and morphological response of some grain sorghum cultivars to salinity. M. Sc. Thesis, Fac. of Agric., Ain Shams University.

Mourad, A.E. A. A., M. M. El-Menshawi and K. K. T. El-Affendi (1999). Morphological, yield and yield component response of some grain sorghum genotypes. Egypt. J. Appl. Sci. 14 (2): 99-109.

Munns, R (2002). Comparative physiology of salt and water stress. Plant, Cell and Environment 25:239-250.

Padmanathon, G. and J. S. Rao (1975). Effect of soil salinity on germination and growth of sorghum varieties at seedling stage. Madras Agric. J. G_2 (9): 537-540 (C.F. Field Crops Abst., 41(4), 3380, 1980).

Patel, P. M., A. Wallace and F. F. Wallihon (1975). Influence of salinity and N,P fertility levels on mineral content and growth of sorghum in sand culture. Agron. J. 76: 622-625.

Rashed, M. A., J. H. AL Shabi, A. M. Atta, M. A. Salam, KH. Fahmy and S. H. Abdel Aziz (2004). Assessment of genetic diversity for some Egyptian and Yemanian sorghum cultivars (*Sorghum bicolor* L.) using different molecular genetic analyses. Proceed. Int. Conf. Eng. and Appl. (April, 8(1): 263-277).

Shadi, A. I., M. A. Rashed, M. I. Sarwat, M. A. Tag El Din and A. F. Abo Doma (1999). Salt tolerance evaluation of some maize inbreds (*Zea mays* L.) as detected by biochemical and genetic indices. Annals Agric. Sci. 44(2):459-477.

Singh, R. K. and J. B. Chaudhury (1977). line x tester analysis. In biometrical methods in quantitative genetic analysis. pp. 178-185, Kalyani Pub. New Delhi.

Studier, F. W. (1973). Analysis of bacteriophage T_1 early RNAs and proteins of Slab gels. J. Mol. Bio. 79: 237-248.

Tayler, R. M., E. F. Young and R. L. Rivera (1975). Salt tolerance in cultivars of grain sorghum. Crop Sci. 15: 434-435.

Uiery, S. F. and F. E. Frederick (1997). Sorghum response to saline industrial cooling water applied at three growth stages. Agron. J. 89: 392-396.

Wery, J., S. N. Silem, E. J. Kinghts, R. S. Malthorts and R. Cousion (1994). Screening techniques and source of tolerance to extremes of moisture and air temperature in cool season feed legumes. Euphytica 73: 73-83.

قدرة التآلف لبعض الصفات المورفولوجية لذرة الحبوب الرفيعة تحت الظروف الملحية والادلة الوراثية البيوكيميائية للتراكيب الوراثية المتحملة للملوحة

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تم تقييم أربعة وعشرين هجينا من الذرة الرفيعة وأبائهم فى تجربة حقلية بمحطة بحوث النوبارية تحت ظروف الملوحة الارضية والظروف العادية وذلك فى الموسمين المتتاليين ٢٠٠٣ و ٢٠٠٤ .

كان متوسط مجموع المربعات الراجع لكل من التراكيب الوراثية والسنوات والملوحة عالية المعنوية لكل الصفات المدروسة. وأظهر التحليل الإحصائي لمعامل الحساسية (SI) وجود فروق معنوية بين الاباء وبين الامهات وكذلك التفاعل بينهما مشيرا الى أهمية دور قوة الهجين فى تحمل الملوحة فى الذرة الرفيعة.

وكانت أفضل الاباء تحملا للملوحة هما (ICSR 90015) m_4 , (ICSR 89025) m_2 (معامل حساسيتهما ٠,٦٥-٠,٧٤ على التوالى). أيضا السلالات الامية ICSA-14, ICSA-37, ATX631 أظهرت تحمل للملوحة (معامل حساسيتهم ٠,٣٩- ، ٠,٦١ ، ٠,٦٠ على التوالى).

كما أوضحت النتائج ان أفضل الهجن تحملا للملوحة وذات إنتاجية عالية فى نفس الوقت هم: H_3 (ICSA-1 x ICSR 89038), H_7 (ICSA-14x ICSR 89038), H_{14}(ICSA-70 x ICSR 89025), H_{24}(ATX631 x ICSR 90015) والتى كانت معاملات حساسيتهم٠,٤٤، ٠,٥٤، ٠,٠٩، ٠,٤٨ على التوالى. وبتقدير القدرة العامة والخاصة على التآلف للمحصول ومعامل الحساسية وجد ان السلالة الامية f_6 (ATX631), f_3 (ICSA-37), f_2 (ICSA-14) إنها أكثر السلالات تحملا للملوحة وأيضا السلالتين الابويتين m_2(ICSR 89025), m_4 (ICSR 90015) ، بينما أفضل الهجن تحملا للملوحة هى H_3 (ICSA-1 x ICSR 89038), H_7 (ICSA-14 x ICSR 89038), H_{14} (ICSA 70 x ICSR 89025), H_{24} (ATX631 x ICSR 90015). كما أظهرت النتائج السابقة إن كلا من التأثير المضيف و التأثير غير المضيف يلعب دورا هاما فى تحسين هجن الذرة الرفيعة تحت الظروف الملحية.

كما أظهرت نماذج التفريد الكهربي للبروتينيات الذائبة المستخلصة من حبوب الذرة الرفيعة إن التراكيب الوراثية الأبوية المتحملة للملوحة تميزت بخمس حزم بروتينية ذات وزن جزيئى ٢٥٥,٨١، ١٨٨,٦٢، ١٦٢,٦٢، ٤٣,٧٨، ٣٢,١٢ كيلو دالتون ماعدا الام f_6 والتى فقدت الحزمتين ذات الوزن الجزيئى ٢٥٥,٨١ ، ١٨٨,٦٢ كيلو دالتون. وقد وجد ان هذه الحزم الخمسة لم تظهر فى التراكيب الوراثية الحساسة للملوحة كما انها ظهرت فى معظم الهجن المتحملة للملوحة. وبوجه عام فقد أظهرت نتائج التفريد الكهربى إن حزم البروتين المنفردة يمكن ان تكون أداة فعالة لتحديد و تصنيف التراكيب الوراثية المتحملة للملوحة لكى يوصى باستخدامها فى برامج التربية لتحمل الملوحة فى الذرة الرفيعة.

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