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HETEROSIS, COMBINING ABILITY AND BIOCHEMICAL GENETIC MARKERS FOR SALT TOLERANT GENOTYPES IN GRAIN SORGHUM

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ABSTRACT

Three cytoplasmic male sterile (A-lines) i.e. ICSA37 (f1), ICSA88015 (f2) and ATX631 (f3) and four restorer lines (R- lines) i.e. ICSR89016 (m1), ICSR89025 (m2), ICSR89038 (m3) and ICSR 90015 (m4) and their twelve hybrids of grain sorghum [Sorghum bicolor(L.)Moench]were evaluated under normal and saline soil conditions for days to 50% heading, plant height, leaf area, 1000 kernel weight and grain yield per plant at Nubaria Agric. Res. Stat., in 2004 growing season. The genetic analysis was conducted using line x tester analysis. The obtained data revealed highly significant differences between environments for all studied traits. Mean squares due to genotypes, crosses and parents were significant for all studied traits under normal and saline conditions except 1000 kernel weight for crosses and parents under normal conditions. Mean squares due to interaction of genotypes with environments were highly significant for all studied traits except for 1000 kernel weight, indicating inconsistent response of these genotypes from normal to saline conditions. Variances due to the interaction among each of male general combining ability (GCA), female GCA and specific combining ability (SCA) with environments (E) were significant for all studied traits except male GCA x E for leaf area, female GCA x E for leaf area and 1000 kernel weight and SCA x E for 1000 kernel weight and grain yield per plant, which were insignificant. This indicates that, both additive and non-additive gene effects were influenced by environments.

Salinity susceptibility index (SI) indicated that, the best salt tolerant hybrids were f2 x m2, f2 x m3, f2 x m4, f1 x m2, f1 x m3 and f3 x m3 and the best salt tolerant parental lines were f3, f1 and m2. Heterosis over better parents showed that, the best hybrids under normal and saline conditions were f2 x m2, f2 x m3 and f1 x m3 for grain yield per plant and some of the other studied traits. The best general combiner for grain yield per plant and some of the other studied traits was the female line f2 under saline conditions. The best SCA hybrid was f2 x m2 under both normal and saline conditions for grain yield per plant and some of the other studied traits. SDS protein banding pattern under saline conditions showed that, the tolerant grain sorghum genotypes are distinguished with nine common bands which were not found at the sensitive genotypes at MW of 245.31, 219.35, 140.66, 100.57, 67.22, 62.47, 58.13, 36.19 and 33.57 KDa. In general, the electrophoretic patterns of leaf total proteins could be a useful tool for the identification and characterization of the tolerant grain sorghum genotypes.

Key words: *Grain sorghum, Heterosis, Combining ability, Salinity tolerance, Susceptibility index, SDS-PAGE.*

INTRODUCTION

Salinity is a major abiotic stress that pose a threat to agricultural production in many parts of the world. Salinity can affect any process in the plant life cycle, so that tolerance will involve a complex interplay of characters. Salt stress is a major constraint that affects sorghum production almost everywhere the crop is grown. Salinity occurs mainly as a result of either an accelerated redistribution of salts in the soil profile due to high water table in most areas or due to the use of insufficient irrigation water to leach salts out of the soil. Grain sorghum is categorized as a moderately tolerant crop and its threshold salinity level ranges from 4.9 to 6.8 EC. (Maas and Hoffman1977).

Additional basic information is needed on the magnitude of heterosis in grain sorghum under saline soil conditions. The grain sorghum hybrid program starts with testing various parental lines for their combining ability and heterosis effects under saline soil conditions. Heterosis and combining ability in grain sorghum under normal and saline soil conditions were studied by several investigators using line x tester analysis (Reddy and Joshi 1993, Mahmoud 1997, EL-Menshawi and EL-Bakry 2004 and EL-Menshawi *et al* 2003 and 2005). SDS protein electrophoretic technique provides distinct unvarying genetic markers and has been successfully applied for the identification of grain sorghum genotypes and different field crops (Shadi *et al* 1999, Afiah *et al* 1999, Rashed *et al* 2004 and EL-Menshawi *et al* 2003 and 2005). Therefore, the objectives of this study were, 1- to select the best grain sorghum hybrids that could be cultivated under saline conditions. 2- to determine general and specific combining ability effects under normal and saline conditions. and 3- to identify the biochemical genetic markers for salt tolerant genotypes using SDS protein electrophoretic patterns.

MATERIALS AND METHODS

The present investigation was divided into two parts: the first part (Field Experiments) was conducted in the Experimental Farm at Nubaria Station of the Agric. Res. Cent. (ARC) and the second part (Protein Electrophoresis) was carried out at the laboratory of Agronomy Dept., Fac. of Agric., Ain Shams University.

Field Experiments

Three cytoplasmic male sterile lines (A-lines) of grain sorghum [*Sorghum bicolor* (L.)Moench] i. e. ICSA-37 (f1), ICSA88015 (f2) and ATX631 (f3) and four restorer lines (R- lines) i.e. ICSR89016 (m1). ICSR89025 (m2), ICSR89038 (m3) and ICSR 90015 (m4) were obtained as pure lines from Sorghum Res. Section, Field Crop Res. Institute, ARC, Giza, Egypt to produce twelve single crosses (using line x tester scheme) in 2003 season. The parental lines and their respective twelve hybrids were evaluated in the field under two sites (normal and saline areas) in 2004 growing season.

Each experiment was conducted in a randomized complete block design with three replications to study the effect of soil salinity on growth, yield and yield components. The experimental plot included three rows of four meters long and 70 cm wide. Planting was done in hills spaced at 20 cm apart and hills were thinned at 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).

Table 1. Mechanical and chemical analyses of the soil at the experimental sites.

Properties and components	Type of soil	
	Normal area	Saline area
Sand %	69.50	69.50
Silt %	18.00	18.50
Clay %	12.30	12.60
Texture	Sandy loam	Sandy loam
Organic matter %	0.360	0.21
CaCO3 %	23.60	23.05
Soil:		
EC(Mmhos/cm)	1.56	6.33
pH	8.31	7.87
Water:		
EC(Mmhos/cm)	0.80	0.80
pH	7.10	7.10
Soluble cations(-equiv./L):		
Ca^{++}	2.16	19.30
Mg^{++}	1.40	11.35
Na^{+}	7.78	35.03
K^{+}	0.81	4.20
Soluble anions(-equiv./L):		
HCO_3^-	2.90	8.30
Cl^-	6.00	28.70
SO_4^{-2}	3.00	33.00

The common agricultural practices of growing grain sorghum were applied properly as recommended in the district. Days to 50% heading, plant height (cm), leaf area (cm^2), 1000 kernel weight (g.) and grain yield per plant (g.) were recorded on a sample of 10 guarded plants in the middle row of each plot. The genetic analysis was conducted by using line x tester analysis according to Kempthorne (1957). General and specific combining abilities were estimated according to Singh and Chaudhury (1977). Heterosis relative to better parent was estimated according to Bhatt (1971).

The salinity susceptibility index (SI) was used to characterize the relative stress resistance of all genotypes. The susceptibility indices were calculated independently using original data for grain yield per plant using a generalized formula (Fischer and Maurer1978) as follows:

SI = (1 – Yd / Yp) / S,Where

SI = An index of salinity susceptibility

Yd = Performance of a genotype under salinity soil stress.

Yp = Performance of the same genotype under normal soil.

S= Salinity intensity = 1 – (mean Yd of all genotypes/mean Yp of all genotypes).

Protein Electrophoresis

Two leaves of each of the; sensitive grain sorghum genotype (m3, m4, f2, f1 x m4, f3 x m2 and f3 x m4) and tolerant ones (f3, f1, m2, f2 x m2, f2 x m3 and f2 x m4) groups were used for SDS-protein analysis. Sodium dodecylsulphate polyacrylamide gel electrophoresis (SDS-PAGE) was performed on total proteins according to the method of Laemmli (1970) as modified by Studier (1973). The SDS-protein gel was scanned and analyzed using Gel Doc 2000 BioRad System.

RESULTS AND DISCUSSION

Analysis of variance

Mean squares for all studied traits under normal and saline conditions are presented in Table (2). Highly significant differences between environments were found for all studied traits. Mean squares due to genotypes, crosses and parents were significant for all recorded traits under normal and saline conditions except1000 kernel weight for crosses and parents under normal conditions. This indicates that, variability existed among these parental lines which increases the chance of good new recombinations. Parents versus crosses mean squares were significant for all studied traits under both environments except for leaf area under saline conditions, indicating the presence of heterotic effect.

Mean squares due to the interaction of genotypes with environments were highly significant for all studied traits except for 1000 kernel weight, indicating inconsistent responses of these genotypes from normal to saline conditions. Similar results were reported by Mourad *et al* (1999) and EL-Menshawi *et al* (2003 and 2005). The partitioning of genetic variations among males, females and male x female revealed that variance due to male general combining ability (GCA) effect, female GCA effect and specific combining ability (SCA) effect were significant for all studied traits under both environments, except male GCA effect for plant height, leaf area and 1000 kernel weight under normal environment, female GCA effect for plant height, 1000 kernel weight and grain yield per plant under normal environment and 1000 kernel weight under saline environment and SCA effect for 1000 kernel weight under both normal and saline environments.

Table 2. Mean squares for all studied traits of twelve hybrids and seven parents of grain sorghum under normal and saline environments (Env.)

Source of variance	Env.	Df	Days to 50% heading	Plant height	Leaf area	1000 Kernel weight	Grain yield per plant
Env.(Salinity) (S)	Combined	1	2145**	12007**	351374**	720.48**	18110**
Replicates	normal	2	1.33	36.84	941	6.70	85.75
	salinity	2	3.91	167.11	627	7.29	38.46
Genotypes(G)	normal	18	72.59**	2133**	167.36**	21.82*	745.90**
	salinity	18	50.17**	1778**	15128**	31.43**	744.12**
Crosses (C)	normal	11	69.42**	473**	14004**	16.94	558.56**
	salinity	11	57.72**	933**	18752**	18.67*	556.75**
C vs. p	normal	1	201.8 1**	25896**	43792**	74.89*	5026**
	salinity	1	123**	13941**	229	109.02**	5175.75**
Parents(P)	normal	6	56.86**	1216**	17236**	21.92	375.98**
	salinity	6	24.19**	1299**	10966**	41.90**	349.02**
GCA males (m)	normal	3	13.88**	140	2868	11.97	695.69**
	salinity	3	87.51**	692**	12912**	39.84**	1127**
GCA females(f)	normal	2	204.53**	8[illegible]	58522**	18.72	161.90
	salinity	2	113**	851**	42607**	2.02	202.58*
SCA (m x f)	normal	6	52.16**	769**	4733**	18.83	622.22**
	salinity	6	24.40**	1081**	13721**	13.63	543.75**
G x S	combined	18	34.64**	337**	5348**	13.11	224.39**
C x S	combined	11	46.11**	453**	5768**	16.85	140.71**
C vs P x S	combined	1	5.03	920**	25174**	1.87	0.41
P x S	combined	6	18.54**	27	1274	8.13	415.28**
GCA (m) x S	combined	3	24.91**	515**	1886	39.45**	153.96*
GCA (f) x S	combined	2	138.22**	310*	1643	7.62	276.17**
SCA x S	combined	6	26.02**	470**	9085**	8.64	88.93
Error	normal	36	2.52	74	1196	10.29	52.93
	salinity	36	3.34	66	737	7.51	46.52
	combined	72	2.93	70	967	8.90	49.73

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

Mean squares due to the interaction among each of male GCA, female GCA and SCA with environment (S) were significant for all studied traits except male GCA X S for leaf area, female GCA X S for leaf area and 1000 kernel weight and SCA X S for 1000 kernel weight and grain yield per plant which were insignificant, indicating that both additive and non-additive gene effects were influenced by environments.

Mean performance and salinity susceptibility index (SI)

Means for all studied traits as affected by both environments are presented in Table (3). Values showed the parental diversity and the genotypic differential response from normal to saline conditions. Regarding no. of days to 50% heading, the twelve hybrids under normal conditions ranged from 65 (f1 x m4) to 84 (f3 x m4) days. In the same time, heading date delayed under saline conditions which ranged from 74.33 (f2 x m2) to 86.67 (f1 x m1) days. No. of days to 50% heading for the parental lines under normal conditions ranged from 70 (f2 and f3) to 81 (m4) days, while under saline conditions it ranged from 80.33 (m3) to 87.67 (m4) days.

Table 3. Mean performance of Grain sorghum, parental lines and crosses under normal and saline environments.

Genotypes	Days to 50% heading		Plant height cm		Leaf area cm^2		1000 Kernel weight g		Grain yield per plant g		Salinity susceptibility index
	normal	salinity	normal	salinity	normal	salinity	normal	salinity	normal	salinity	
Parental lines											
ICSA-37(f1)	74.33	81.33	130.00	115.00	562.83	448.73	23.33	16.53	58.93	47.03	0.65
ICSA-88015(f2)	70.00	80.67	126.67	111.67	511.33	441.00	21.20	16.87	55.47	32.33	1.35
ATX-631 (f3)	70.00	84.67	128.33	118.33	452.83	345.00	27.47	21.47	60.50	58.67	0.10
ICSR-89016(m1)	76.33	84.33	173.33	156.67	375.83	323.00	25.87	21.47	82.00	48.67	1.31
ICSR-89025(m2)	80.00	86.00	156.67	146.67	364.33	322.67	27.73	23.07	71.67	52.70	0.85
ICSR-89038(m3)	76.33	80.33	115.00	96.67	452.00	407.33	28.67	26.80	71.00	33.83	1.69
ICSR-90015(m4)	81.00	87.67	133.33	126.67	531.00	457.58	27.20	17.90	83.67	32.27	1.98
Hybrids											
f1 xm1	67.67	86.67	206.67	163.33	631.67	487.17	31.33	26.33	86.67	57.80	1.08
f1x m2	69.00	84.67	198.33	156.67	602.25	496.30	30.53	22.30	67.00	52.67	0.69
f1 x m3	68.33	75.00	170.00	160.00	521.67	452.50	28.40	27.07	80.33	61.37	0.76
f1 x m4	65.00	81.67	163.33	153.33	564.50	272.77	28.53	18.53	108.33	71.67	1.09
f2 x m1	75.00	79.00	175.00	161.67	528.08	442.67	31.07	24.13	80.17	54.67	1.03
f2 x m2	70.00	74.33	181.67	171.67	556.75	454.00	26.27	24.67	103.33	88.67	0.46
f2 x m3	70.00	75.67	188.33	165.00	568.83	390.67	25.33	24.67	97.33	81.00	0.54
f2 x m4	70.33	79.00	181.67	160.00	510.08	382.50	28.93	21.73	89.67	72.07	0.63
f3 x m1	73.00	83.00	178.33	156.67	441.50	331.00	25.47	20.73	93.67	65.00	0.99
f3 x m2	73.33	84.00	170.00	103.33	433.67	268.83	24.53	23.93	78.67	39.67	1.60
f3 x m3	72.67	77.33	176.67	163.33	490.92	331.17	28.80	25.60	70.67	51.00	0.90
f3 x m4	84.00	86.00	191.67	168.33	411.33	346.83	30.40	21.73	106.17	65.20	1.25
Grand mean	72.96	81.65	165.53	145.00	500.60	389.56	27.42	22.40	81.33	56.12	
LSD 0.05	2.63	3.63	14.23	13.70	31.73	44.97	5.31	4.54	12.18	11.28	

With respect to plant height the twelve hybrids under normal conditions ranged from 163.33 cm (f1 x m4) to 206.67 cm (f1 x m1), while under saline conditions the height of plants were reduced. The short hybrid was 103.33 cm (f3 x m2) and the tallest hybrid was 171.67cm (f2 x m2). Plant height for the parental lines under normal conditions ranged from 115cm (m3) to 173.33cm (m1), while under saline conditions it varied from 96.67cm (m3) to 156.67cm (m1).

For leaf area, the hybrids under normal conditions ranged from 411.33 (f3 x m4) to 631.67 (f1 x m1) cm^2. Under saline conditions the hybrids varied from 268.83 (f3 x m2) to 496.30 (f1 x m2) cm^2. The parental lines varied under normal conditions from 364.33 (m2) to 562.83 (f1) cm^2, while under saline conditions it ranged from 322.67 (m2) to 457.58 (m4) cm^2. Wery *et al* (1994) indicated that the reduction in leaf area is an important adaptive mechanism for salinity stress. Regarding 1000 kernel weight the hybrids under normal conditions varied from 24.53 (f3 x m2) to 31.33 (f1 x m1) g and varied from 18.53 (f1 x m4) to 27.07 (f1 x m3) g under saline conditions. The parental lines varied under normal conditions from 21.20 (f2) to 28.67 (m3) g and ranged from 16.53 (f1) to 26.80 (m3) g under saline conditions. With respect to grain yield per plant, the twelve hybrids under normal conditions ranged from 67 (f1 x m2) to 108.33 (f1 x m4) g. On the other hand, under salinity stress the range of hybrids was from39.67 (f3 x m2) to 88.67 (f2 x m2) g. The parental lines ranged under normal conditions from 55.47(f2) to 83.67(m4)g and ranged from 32.27 (m4) to 58.67(f3) g under saline conditions. Grain yield was more affected by salinity stress through deleterious effect on seed number rather than seed weight. The top three yielding hybrids under normal conditions were f1 x m 4, f3 x m4 and f2 x m2 producing 108.33, 106.17 and 103.33g seeds per plant, respectively. While, the top three yielding hybrids under salinity stress were f2 x m2, f2 x m3 and f2 x m4 producing 88.67, 81.00 and 72.07g seeds per plant, respectively. These results are in agreement with Igartua *et al* 1995, Mourad *et al* 1999 and EL-Menshawi *et al* (2003 and 2005).

Salinity susceptibility index "SI", is a value that measures salt sensitivity, can be used to differentiate the overall genotypes tolerance (EL-Menshawi *et al* 2003 and 2005). SI values (Table 3) varied between parental lines and their respective hybrids for grain yield per plant. The twelve hybrids ranged from 0.46 (f2 x m2) to 1.60 (f3 x m2) while, the parental lines varied from0.10 (f3) to 1.98 (m4). The best salt tolerant hybrids were f2 x m2, f2 x m3, f2 x m4, f1 x m2, f1 x m3 and f3 x m3 and the other hybrids were salt sensitive. The best salt tolerant parental lines were f3, f1 and m2 and the other parental lines were salt sensitive.

Heterosis

Table (4) represents percentage of heterosis relative to the better parents under normal and saline conditions. For days to 50% heading, the negative value of heterosis for this trait is desireable. Four and eight out of the twelve hybrids showed significant desirable heterobeltiosis under normal and saline conditions, respectively for this trait.

Table 4. Percentage of heterosis over better parent for all studied traits under normal and saline conditions.

Hybrids	Days to 50% heading		Plant height		Leaf area		1000 Kernel weigh:		Grain yield per plant	
	normal	salinity	normal	salinity	normal	salinity	normal	salinity	normal	salinity
f1 x m1	-8.97**	6.56**	19.23**	4.26**	12.23**	8.56**	21.13**	22.67**	5.69*	18.77**
f1 x m2	-7.17**	4.10**	26.60**	6.82**	7.00**	10.60**	10.10**	-3.32	-6.51*	-0.06
f1 x m3	-8.07**	-6.64**	30.77**	39.13**	-7.31**	0.84	-0.93	1.00	13.15**	30.47**
f1 x m4	-12.56**	0.41	22.50**	21.05**	0.30	-40.39**	4.90	3.54	29.48**	52.37**
f2 x m1	7.14**	-2.07**	0.96	3.19*	3.28	0.38	20.10**	12.42**	-2.24	12.33**
f2 x m2	0.00	-7.85**	15.96**	17.05**	8.88**	2.95	-5.29	6.94*	44.19**	68.25**
f2 x m3	0.00	-5.81**	48.68**	47.76**	11.25**	-11.41**	-11.63**	-7.96**	37.09**	139.41**
f2 x m4	0.48	-2.07**	36.25**	26.32**	-3.94*	-16.41**	6.37	21.42**	7.17**	122.89**
f3 x m1	4.29**	-1.58*	2.88*	0.00	-2.50	-4.06	-7.28*	-3.42	14.23**	10.80**
f3 x m2	4.76**	-0.79	8.51**	-29.55**	-4.23*	-22.08**	-11.54**	3.76	9.77**	-32.39**
f3 x m3	3.81**	-3.73**	37.66**	38.03**	8.41**	-18.70**	0.47	-4.48	-0.47	-13.07**
f3 x m4	20.00**	1.57*	43.75**	32.89**	-22.54**	-24.20**	10.68**	1.24	26.89**	11.14**

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

The best heterosis estimates under normal conditions were exhibited by f1 x m4, f1 x m1 and f1 x m3 while, the best hybrids under saline conditions were f2 x m2, f1 x m3 and f2 x m3 for this trait. Regarding plant height , eleven and ten out of the twelve hybrids showed significant heterobeltiosis under normal and saline conditions, respectively. With respect to leaf area, five and two out of the twelve hybrids showed positive and significant heterosis under normal and saline conditions, respectively. For 1000 kernel weight, four and four out of the twelve hybrids exhibited positive and significant heterosis under normal and saline conditions, respectively. The best hybrids for heterosis of this trait under normal conditions were f1 x m1 and f2 x m1 and under saline condition were f1 x m1 and f2 x m4. For grain yield per plant, nine and nine out of the twelve hybrids showed positive and significant (desirable) heterosis under normal and saline conditions, respectively. The best hybrids for heterobeltiosis in grain yield under normal conditions were f2 x m2, f2 x m3, f1 x m4 and f3 x m4 and under saline conditions were f2 x m3, f2 x m4, f2 x m2 and f1 x m4.

From the previous results, it indicated that two hybrids under saline conditions (f2 x m3 and f2 x m4) showed considerable heterobeltiosis for grain yield per plant and some of the other studied traits. Therefore, these two hybrids would be efficient and prospective in grain sorghum breeding programs. The existence of heterosis for different characters in grain sorghum crosses using cytoplasmic male sterile and restorer lines had been demonstrated by several investigators (Reddy and Joshe 1993, EL-Menshawi *et al* 2003 and EL-Menshawi and El-Bakry 2004).

Combining ability effects

Estimates of GCA effects for each inbred line in each studied trait under normal and saline conditions are presented in Table (5). For days to 50% heading, negative (favorable) significant GCA effects were observed for the parental lines f1 and m3 under normal conditions and f2 and m3 under saline conditions. The parental lines f3 and m4 under normal conditions and f1, f3, m1 and m4 under saline conditions showed positive and significant GCA effects for this trait. Regarding plant height,the parental lines f2 and m3 exhibited positive and significant GCA effects under saline conditions while, the parental lines f3 and m2 under the same conditions showed negative and significant GCA effects. For leaf area, the female line f1 under normal conditions and the parental lines f1, f2 and m1 under saline conditions exhibited positive and significant GCA effects. The parental lines f3 and m4 showed negative and significant GCA effects under both environments. For 1000 kernel weight, the male lines m3 and m4 under saline conditions showed positive and negative GCA effects, respectively.

Table 5. Estimates of general combining ability effects for the parental lines evaluated under normal and saline environments for all studied traits.

Parental lines	Days to 50% heading		Plant height		Leaf area		1000 Kernel weight		Grain yield per plant	
	normal	salinity	normal	salinity	normal	salinity	normal	salinity	normal	salinity
Females										
ICSA-37(f1)	-4.03**	1.47**	2.78	1.39	58.25**	39.15**	1.40	0.11	-2.92	-2.52
ICSA-88015(f2)	-0.19	-3.53**	-0.14	7.64**	19.17	29.43**	-0.40	0.35	4.13	10.70**
ATX-631 (f3)	4.22**	2.06**	-2.64	-9.03**	-77.42**	-68.58**	-1.00	-0.45	-1.21	-8.18**
SEgi	0.46	0.53	2.48	2.34	9.98	7.84	0.93	0.79	2.10	1.97
SE(gi-gj)	0.65	0.75	3.51	3.31	14.12	11.09	1.31	1.12	2.97	2.79
Males										
ICSR-89016(m1)	0.36	2.36**	4.86	3.61	11.98	32.24**	0.99	0.28	-1.67	-4.24
ICSR-89025(m2)	-0.75	0.47	1.53	-13.06**	9.12	18.34	-1.19	0.18	-5.50*	-3.06
ICSR-89038(m3)	-1.19*	-4.53**	-3.47	5.83*	5.37	3.41	-0.79	2.33*	-5.72*	1.06
ICSR-90015(m4)	1.58**	1.69**	-2.92	3.61	-26.47*	-54.00**	0.99	-2.79**	12.89**	6.25**
SEgi	0.53	0.61	2.87	2.70	11.53	9.05	1.07	0.91	2.43	2.27
SE(gi-gj)	0.75	0.86	4.05	3.82	16.30	12.80	1.51	1.29	3.43	3.22

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

For grain yield per plant, the female lines f2 and f3 under saline conditions showed positive and negative GCA effects, respectively. The male lines m2 and m3 under normal conditions showed negative and significant GCA effects while the female line m4 exhibited positive and significant GCA effects under both conditions for grain yield.In general, the parental lines f2 and m4 showed the highest significant GCA effects under saline condition for grain yield indicated that these parental lines are good combiners for increasing grain yield under salin condition.

Specific combining ability effects for all studied traits under normal and saline conditions are presented in Table (6). For days to 50% heading, four and three out of the twelve hybrids showed positive and significant SCA effects under normal and saline conditions, respectively. On the other hand four and two out of the twelve hybrids showed negative and significant SCA effects under normal and saline conditions, respectively.

Table 6. Specific combining ability effects for twelve grain sorghum crosses under normal and saline environments for all studied traits.

Hybrids	Days to 50% heading		Plant height		Leaf area		1000 Kernel weight		Grain yield per plant	
	normal	salinity	normal	salinity	normal	salinity	normal	salinity	normal	salinity
f1 xm1	-0.19	2.31*	17.22**	1.39	39.67	27.74	0.64	2.49	2.75	1.17
f1x m2	2.25*	2.19*	12.22**	11.39*	13.11	50.77**	2.02	-1.44	-13.08**	-5.14
f1 x m3	2.03*	-2.47*	-11.11*	-4.17	-63.72**	21.91	-0.51	1.18	0.47	-0.57
f1 x m4	-4.08**	-2.03	-18.33**	-8.61	10.94	-100.42**	-2.16	-2.24	9.86*	4.54
f2 x m1	3.31**	-0.36	-11.53*	-6.53	[illegible]	-7.04	2.18	0.05	-10.79*	-15.19**
f2 x m2	-0.58	-3.14**	-1.53	20.14**	6.69	18.20	-0.44	0.69	16.21**	17.63**
f2 x m3	-0.14	3.19**	10.14*	-5.42	22.53	-30.20	-1.78	-1.46	10.43*	5.84
f2 x m4	-2.58**	0.31	2.92	-8.19	-4.39	19.04	0.04	0.72	-15.85**	-8.28*
f3 x m1	-3.11**	-1.94	-5.69	5.14	-14 83	-20.70	-2.82	-2.55	8.04	14.03**
f3 x m2	-1.67	0.94	-10.69*	-31.53**	-19.81	-68.97**	-1.58	0.75	-3.13	-12.49**
f3 x m3	-1.89*	-0.72	0.97	9.58*	[illegible]	3.50	2.29	0.28	-10.90*	-5.28
f3 x m4	6.67**	1.72	15.42**	26.81**	6.56	81.36**	[illegible]	[illegible]	5.99	3.74
SESij	0.92	1.06	4.96	4.68	19.97	15.88	1.85	[illegible]	4.20	3.94
SE(Sij-Skl)	1.30	1.49	7.02	6.62	28.24	22.17	2.62	[illegible]	[illegible]	5.57

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

For plant height, four and four out of the twelve hybrids exhibited positive and significant SCA effects under normal and saline conditions, respectively. Four and one out of the twelve hybrids showed negative and significant SCA effects for plant height under normal and saline conditions, respectively. Regarding leaf area, one and two out of the twelve hybrids under normal and saline conditions, respectively showed positive and negative SCA effects, respectively. For grain yield per plant, three and two out of the twelve hybrids exhibited positive and significant SCA effects under normal and saline conditions, respectively. Four and three out of the twelve hybrids under normal and saline conditions, respectively showed negative and significant SCA effects. The best SCA effect under normal and saline conditions for grain yield was shown by the hybrid f2 x m2. Combining ability in grain sorghum was investigated by several investigators using line x tester analysis (Jagadeshawar and Shinde 1992, Mostafa *et al* 1992, Reddy and Joshe 1993 and EL-Menshawi *et al* 2003 and 2005).

SDS-Protein electrophoresis

Total proteins were fractionated by using one dimensional SDS-PAGE. Protein electrophoresis analysis was successfully used for the identification and characterization of grain sorghum genotypes and different field crops (Abdel-Sattar and Ahmed 2004 and EL-Menshawi *et al* 2003 and 2005). Analysis of total proteins of two groups (sensitive and tolerant to salinity stress conditions) of twelve grain sorghum genotypes are illustrated in Table (7) and Figure (1). The first group contains three sensitive parental lines (m3, m4 and f2) and three sensitive hybrids (f1 x m4, f3 x m2 and f3 x m4) depending on salinity sensitivity index Table (3).The second group contains three tolerant parental lines (f3, f1 and m2) and three tolerant hybrids (f2 x m2, f2 x m3 and f2 x m4).

Substantial differences between the two studied groups in their molecular weights (MW), relative mobilities (Rm) and intensity of bands were recorded. Thirty five bands were detected with different molecular weights ranging from 248.60 to 21.17 KDa. Two universal bands were commonly present in all twelve sorghum genotypes at MW 201.13 and 38.23 KDa. The six sensitive grain sorghum genotypes at the first group were distinguished with three common bands, which were not found at the tolerant group, of MW 71.18, 65.18 and 61.50 KDa. The six tolerant grain sorghum genotypes at the second group showed nine common bands, which were not found at the sensitive group, of MW 245.31,219.35, 140.66, 100.57, 67.22, 62.47, 58.13, 36.19 and 33.57 KDa.

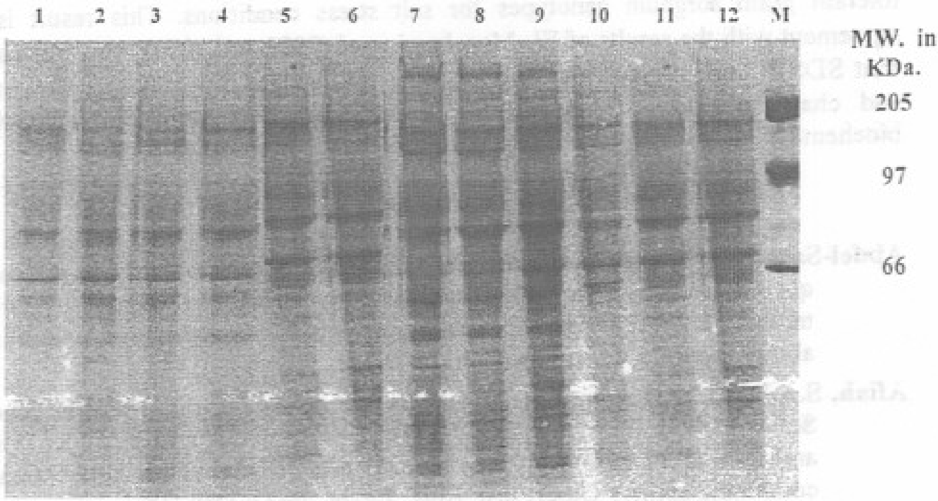

Figure (1):SDS Electrophoretic patterns of leaf total protein for the most sensitive and tolerant grain sorghum genotypes under saline conditions.

Table 7. Densitometer analysis of water soluble proteins (SDS-PAGE) showing band number (B.no.), relative mobility (Rm), molecular weight (Mw) and intensity as a percentage of total concentration for some grain sorghum genotypes.

B. no.	R.m	M.W. KDa	Sensitive (S.) Parents			S. Hybrids			Tolerant (T.) Hybrids			T. Parents		
			1	2	3	4	5	6	7	8	9	10	11	12
			m3	m4	f2	f1 x m4	f3 x m2	f3 x m4	f2 x m4	f2 x m3	f2 x m2	m2	f1	f3
1	0.01	248.60	0.18	0.23			0.27	0.28						
2	0.03	245.31							0.67	0.65	0.63	0.28	0.29	0.28
3	0.04	230.11	0.19	0.28			0.25	0.27						
4	0.07	219.35							0.40	0.42	0.41	0.30	0.27	0.21
5	0.09	210.18	0.18	0.27	0.18		0.23	0.25	0.40	0.43	0.43	0.31	0.28	0.28
6	0.11	204.16					0.78	0.77						
7	0.12	201.13	0.49	0.52	0.48	0.53	0.63	0.57	0.83	0.84	0.88	0.58	0.66	0.43
8	0.14	190.15	0.29	0.35	0.37									
9	0.15	170.53	0.28	0.26	0.29				0.80	0.88	0.79	0.33	0.47	0.30
10	0.22	140.66							0.91	0.92	0.83	0.35	0.44	0.33
11	0.23	132.55					0.28	0.29						
12	0.25	117.93	0.21	0.17	0.18	0.22								
13	0.27	110.65					0.33	0.35	0.37	0.33	0.38	0.22	0.33	0.34
14	0.29	104.77					0.63	0.65						
15	0.31	100.57							0.99	0.99	0.99	0.54	0.62	0.65
16	0.33	96.33	0.38	0.42	0.41	0.44								
17	0.37	83.25					0.53	0.55						
18	0.39	78.16							0.33	0.31	0.30			
19	0.44	75.31	0.29	0.38	0.37	0.38								
20	0.45	73.22					0.41	0.40	0.52	0.49	0.53	0.31	0.33	0.35
21	0.49	71.18	0.27	0.35	0.38	0.33	0.29	0.30						
22	0.58	67.22							0.63	0.62	0.63	0.55	0.57	0.55
23	0.65	65.18	0.21	0.24	0.21	0.22	0.28	0.28						
24	0.67	64.22										0.21	0.23	0.25
25	0.70	63.59	0.19	0.21	0.15	0.23	0.18	0.22	0.40	0.41	0.38			
26	0.72	62.47							0.66	0.63	0.61	0.20	0.23	0.25
27	0.75	61.50	0.16	0.17	0.18	0.16	0.25	0.18						
28	0.78	58.13							0.28	0.25	0.22	0.17	0.18	0.19
29	0.79	44..21					0.27	0.31	0.35	0.35	0.37			
30	0.85	39.23	0.27	0.29	0.28	0.28	0.29	0.30	0.29	0.27	0.38	0.15	0.23	0.29
31	0.87	37.42					0.29	0.30	0.31					
32	0.90	36.19							0.25	0.24	0.26	0.18	0.22	0.27
33	0.91	33.57							0.26	0.24	0.27	0.18	0.20	0.28
34	0.93	25..69							0.21	0.21	0.20			
35	0.95	21.17			0.19	0.17								

Numbers inside the table represent proper intensity percentages of each band.

It is evident from these results that the electrophoretic patterns of total 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 the results of EL-Menshawi *et al* (2003 and 2005) who indicated that SDS-PAGE protein banding patterns was successful in the identification and characterization of the tolerant grain sorghum genotypes and locating biochemical genetic markers related to salt tolerance in grain sorghum.

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قوة الهجين والقدرة على التآلف والادلة الوراثية البيوكيميائية للتراكيب الوراثية المتحملة للملوحة فى ذرة الحبوب الرفيعة

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يهدف البحث إلى دراسة قوة الهجين والقدرة على الائتلاف فى ذرة الحبوب الرفيعة تحت الظروف المثلى وظروف الملوحة الارضية بمحطة بحوث النوبارية التابعة لمركز البحوث الزراعية وكذلك التعرف على الادلة الوراثية البيوكيماوية لتحمل الملوحة حيث تم التهجين بين ثلاث سلالات عقيمة الذكر وأربع سلالات معيدة للخصوبة وتم تقييم السلالات والهجن فى موسم ٢٠٠٤ فى تصميم تجريبى قطاعات كاملة العشوائية من ثلاثة مكررات وتم أخذ القراءات على صفات عدد الايام حتى طرد القنديل . إرتفاع النبات(سم)، مساحة الورقة (سم٢)، وزن١٠٠٠ حبه (جرام)وإنتاجيه النبات من الحبوب (جرام) ويمكن تلخيص أهم النتائج فيما يلى:-

١-أظهر تباين البيئات فروقا معنوية كبيرة فى كل الصفات تحت الدراسة.

٢- كان متوسط مجموع المربعات الراجع إلى كل من التراكيب الوراثيه والهجن والسلالات الابوية عالى المعنويه لكل الصفات المدروسه تحت كلا من الظروف المثلى وظروف الملوحة الارضية ما عدا وزن ١٠٠٠ حبه للهجن والسلالات الابوية تحت الظروف المثلى.

٣- أظهر تباين التفاعل بين التراكيب الوراثية والبيئة فروقا معنوية لكل الصفات المدروسه ما عدا وزن ١٠٠٠ حبه.

٤- أوضح تباين التفاعل بين كل من القدرة العامة والخاصة على التآلف والبيئة أنه عالى المعنوية لمعظم الصفات تحت الدراسة ما عدا تباين تفاعل القدرة العامة على التآلف للاباء مع البيئة لصفة مساحة الورقة وتفاعل القدرة العامة على التآلف للامهات مع البيئة لصفات مساحة الورقة ووزن١٠٠٠ حبه وتفاعل القدرة الخاصة على التآلف مع البيئة لصفات وزن١٠٠٠ حبه ومحصول النبات الفردى من الحبوب مشيرا إلى تأثر كلا من الفعل الجينى المضيف والفعل الجينى الغير مضيف بالتغير فى ظروف البيئة.

٥- أظهر معامل الحساسية للملوحة (SI) أن أفضل الهجن المتحملة للملوحة هى f2 x m2, f2 x m3 وf1 x m2, f1 x m3, f3 x m3 وf2 x m4 وأفضل السلالات الابوية المتحملة للملوحة هى f3 و f1 و m2.

٦- أظهرت قوة الهجين بالنسبة لافضل الاباء أن أفضل الهجن تحت كلا البيئتين هى f2 x m2, f2 x m3 وf1 x m3 لصفة محصول النبات الفردى من الحبوب وبعض الصفات الاخرى.

٧-كانت أحسن التراكيب الوراثيه الابوية بالنسبة للقدرة العامة على التآلف فى صفة محصول النبات من الحبوب وبعض الصفات الاخرى هى السلالة الامية f2 تحت ظروف الملوحة.

٨-كان أفضل الهجن بالنسبة للقدرة الخاصة على التآلف تحت كلا من الظروف المثلى وظروف الملوحة الارضية لصفة محصول النبات الفردى من الحبوب وبعض الصفات الاخرى هو الهجين f2 x m2 .

٩- أظهرت نماذج التفريد الكهربى للبروتينات تميز التراكيب الوراثية المتحملة للملوحة بتسعة حزم بروتينية ذات وزن جزيئى ١٠٠،٢٢٫٦٧،٤٧،٦٢٫١٣،٥٨،١٩٫٣٦ .٢١٩،٦٦٫١٤٠،٥٧ .٣٥، ٢٤٥٫٣١و ٣٣٫٥٧ كيلو دالتون وبوجة عام فقد أظهرت نتائج التفريد الكهربى ان حزم البروتين المنفردة يمكن أن تكون أداة فعالة لتحديد وتصنيف التراكيب الوراثية المتحملة للملوحة لكى يوصى بإستخدامها فى برامج التربية لتحمل الملوحة فى الذرة الرفيعة.