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Combining Ability and Heterosis using Line by Tester Analysis on some Hybrids of Grain Sorghum under Normal and Saline Soil

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Abstract

Twenty F_1 grain sorghum crosses, their parents (four CMS A-lines and five male R-lines) and one commercial check hybrid (H-306) were evaluated for yield and six other characters in 2020 and 2021 seasons at Arab El-Awamer Station, Assiut, Egypt under salt (S) and normal (N) soils. The obtained combined analysis showed highly significant differences between salinity treatments, genotypes and their interaction for all studied traits. The means of genotypes under normal soil were higher than the means of genotypes under salt soil for all traits except days to 50% flowering. Meanwhile, mean squares due to lines, testers and their interaction were significant or highly significant for almost studied traits. Mean crosses were higher than mean parent for all studied traits except days to 50% flowering. The best parents for general combining ability effects were BTX-807 and ICSV-112 for grain yield / plant under all environments (two salinity treatments and two years). The desirable crosses for specific combining ability for grain yield/plant were ICSA-88015 x ICSV-112, ATX-807 x RSH–19, ATX-807 x RSH-27, ASH-15 x Indian Exotic 27 and ASH-20 x ICSV-295) under all environments. The better crosses for heterosis relative to better parents were (ICSA-88015 x ICSV-112, ATX -807 x ICSV-112, ATX-807 x RSH–19, ATX-807 x RSH-27 and ASH-15 x Indian Exotic 27) under all environments. The best crosses for grain yield plant under normal and salt soil were ATX-807 x RSH-27and ASH-15 x Indian Exotic 27.

Keywords*: Sorghum, plain and saline lands, Assiut.*

Introduction

Sorghum *(Sorghum bicolor* (L.) Moench), aC_4 plant, is the fifth most important cereal in the world (Ighbal, 2015). This plant is well adapted to semi-arid and arid regions because of its tolerance to a biotic stress such as drought and salinity (Marsalis *et al.*, 2010). Sorghum is famous for its strong stress resistances and wide adaptability, Moreover, salt tolerance is one of its main characteristics (Igartua *et al.*, 1994). Enhancing sorghum production on saline-alkaline land is one of the best choices for effective use of this marginal soil. Domestic and overseas studies on plant tolerance to soil salinity and alkalinity in sorghum have led to many achievements. These mainly include the improvements in genetics and breeding, physiology, production, and evaluation of saline-alkaline resistance. Increased tolerance of sorghum to salt has been related to its ability to overcome reduced uptake of K+ and Ca_2+ and /or accumulation in the leaves of toxic ions, especially Na+ and Cl^- (Lacerda *et al.*, (2003). Numerous studies re-

ported that there are high genetic variations in sorghum genotypes in response to salinity (Krishnamurthy *et al*., (2007) and Netondo *et al*., (2004). These genetic variations can be monitored to search for the most salt tolerant genotypes. This monitoring analysis should be done at the most critical and sensitive stage of plant growth (Lauchli and Epstein, (1990). Krishnamurthy *et al*., (2007), Nimir *et al*., (2014), Nimir *et al*.,(2015) and Ali *et al*., (2020) they reported reduction in seedling emergence by increasing salinity levels in sorghum, but the responses varied depending on the genotype. Salinity is one of the major factor which causes inhibitory effects on plant growth. The reduction in growth under saline conditions is more severe in arid and semi-arid regions due to adverse effects on metabolic and physiological processes (Krishnamurthy *et al*., (2007), Rengasamy, (2006) and Bonilla *et al*., (2004).

So, the objective of this investigation is to evaluate the Combining ability and heterosis using line by tester analysis on some hybrids of grain sorghum under normal and saline soil.

Materials and Methods

This investigation was carried out during 2020 and 2021 seasons at Arab El-Awamer Agric. Res. Station, Assiut, Egypt, to evaluate 30 sorghum genotypes. The twenty crosses were developed from crossed between four introduced cytoplasmic male sterile lines (ICSA-88015, ATX-807, ASH-15 and ASH-20) and five restorer lines (Indian Exotic 27, ICSV-112, ICSV-295, RSH–19 and RSH-27) by line x tester design in 2019 summer season at Shandweel Agric. Res. Station. The parents, twenty crosses and check hybrid H-306 were evaluated under two salinity treatments (i.e. normal (N) and saline (S) soil conditions (Tables 1 and 2). A randomized complete block design with three replications was used for normal soil and saline soil (stress). The experimental unit was one row, four- meter- long and 20 cm between hills. After full emergence, seedlings were thinned to secured two plants/hill. The other recommended cultural practices of sorghum production in the two years were implemented. Data were recorded on plant height (cm), days from sowing to 50% flowering, panicle length (cm), panicle width (cm), 1000 grain weight (g), grain yield per plant (g) and the percentage of total protein in grains. Grain yield was adjusted to 14 % grain moister. Analysis of variance for four environments, normal soil and salt soil in two years and combined analysis of variance across four environments were done after testing the homogeneity of errors using Barttlet (1937) according to Gomez and Gomez (1984). Line by tester analysis was performed according to Kempthorne (1957). Heterosis was calculated as the percentage of deviation from better parent according to the following formula:

$H = m F_1 – m B.P / m B.P \times 100$

Where, $F_1$and B.P are means for the F_1 hybrid and best parent, respectively. Test of significance was made by using LSD. Some physical and chemical properties of normal and saline soil are given in

Table 1 and 2. Origin of the parental lines and the check are given in Table 3.

Stress susceptibility index was calculated according to Fischer and Maurer (1978) equation:

$SS1= (1- Y_S / Y_N) / (1- Y_{MS} / Y_{MN})$

Where Y_S is the yield under salt stress (salt soil).

Y_N is the non – salt stressed yield (normal soil).

Y_{MN} is the mean yield for all genotypes under normal soil.

Y_{Ms} is the mean yield for all genotypes under salt soil.

S.S.I values > 1.0 indicate relatively stress susceptible genotype and < 1.0 indicate relatively stress tolerance genotype.

Table 1. Some physical and chemical properties of normal soil.

Chemical properties									
pH (1:1)	**EC ds/m (1:1)**	**Soluble cations (meg / L)**				**Soluble anions (meg / L)**			
		Ca^{++}	**Mg^{++}**	**Na^{+}**	**K^{+}**	**$CO_3^{+}HCO_3^{-}$**	**CL^{-}**	**Available phosphorus (ppm)**	**Total nitrogen (%)**
8.37	0.33	1.43	1.16	0.19	0.75	1.68	1.47	8.31	0.009

Physical properties									
Particle size distribution (%)			**Texture class**	**Moisture content (Volumetric %)**			**O.M (%)**	**$CaCO_3$ (%)**	**Bulk density**
Sand	Silt	Clay		S.P	F.C	W.P.			
89.9	7.1	3.0	Sandy	23.3	10.9	4.5	0.19	30.9	1.63

Table 2. Some physical and chemical properties of saline soil.

Chemical properties									
pH (1:1)	**EC ds/m (1:1)**	**Soluble cations (meg / L)**				**Soluble anions (meg / L)**			
		Ca^{++}	**Mg^{++}**	**Na^{+}**	**K^{+}**	**$CO_3^{+}HCO_3^{-}$**	**CL^{-}**	**Available phosphorus (ppm)**	**Total nitrogen (%)**
8.30	4.68	15.67	12.52	8.21	10.75	20.68	19.47	7.26	0.007

Physical properties									
Particle size distribution (%)			**Texture class**	**Moisture content (Volumetric %)**			**O.M (%)**	**$CaCO_3$ (%)**	**Bulk density**
Sand	Silt	Clay		S.P	F.C	W.P.			
89.9	7.1	3.0	Sandy	23.3	10.9	4.5	0.19	30.9	1.63

Table 3. Origin of the parental lines and check.

No.	**Cytoplasmic male sterile lines (CMS lines)**		**Restorer lines**		**Check (H-306):**	
	Name	**Origin**	**Name**	**Origin**	**Name**	**Origin**
1	ICSA-88015	India	Indian Exotic 27	India	H-306	Egypt
2	ATX -870	USA	ICSV-112	India		
3	ASH-15	Egypt	ICSV-295	India		
4	ASH-20	Egypt	RSH – 19	Egypt		
5	-	-	RSH-27	Egypt		

Results and Discussion

The combined analysis of variance for seven traits across four environments (two salinity treatments and two years) Table 4, showed significant differences between two years for total protein percentage. Also the differences between two salinity treatments were highly significant for all studied traits.

Table 4. Combined analysis of variance for 30 genotypes of grain sorghum across two salinity treatments (N and S) and two years.

S.O.V	d.f	Mean squares						
		Plant height	Days to 50%flowering	Panicle height	Panicle width	1000-grain weight	Grain yield per plant	Total protein (%)
Years (Y)	1	31.27	8.100	2.010	0.870	10.75	4.923	6.162*
Rep. within years	4	62.02	10.416	4.842	0.664	35.84	81.98	0.756
Salinity treatments (T)	1	11961.2**	1400.3**	599.9**	93.94**	1803.6**	16931.9**	15.50**
YxT	1	12.21	1.878	0.971	0.038	0.900	2.225	0.775
Genotypes (G)	9	5672.5**	175.7**	72.62**	4.510**	1477.2**	741.4**	53.95**
G x Y	9	9.776	3.106	1.36	0.095	36.78	5.122	0.177
G x T	29	64.49**	20.30**	7.119**	0.591**	339.4**	110.4**	1.886**
G x Y x T	9	7.390	1.056	0.708	0.079	20.21	4.652	0.162
Error	36	16.78	3.043	1.049	0.171	26.001	14.45	0.316

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 5. The effects of salinity treatments on seven traits for 30 genotypes of grain sorghum across two salinity treatments (N and S) and two years.

Salinity treatments	Plant height(cm)	Days to 50% flowering	Panicle height (cm)	Panicle width (cm)	1000grain weight (g)	Grain yield per plant(g)	Total protein(%)
Normal soil	157.7	80.1	20.9	6.4	30.1	55.9	10.88
Saline soil	145.4	83.5	18.8	5.5	25.1	42.9	10.86
F test	**	**	**	**	**	**	**

The effects of salinity treatments on seven traits are shown in Table 5. The results showed the means under normal soil were higher than the salinity soil for all studied traits. The mean squares due to genotypes and their interaction with salinity treatments were highly significant for all studied traits, meaning that the genotypes were differ from one to other, also the differences between genotypes were affected by salinity treatments. The mean performance of 30 genotypes for seven traits across four environments is presented in table 6.

Table 6. The mean performance for 30 genotypes of grain sorghum for seven traits over the four environments (salinity treatments and two years).

No.	Genotype	Plant height	Days to 50% flow-ering	Panicle length	Panicle width	1000-grain weight	Grain yield per plant	Total Protein (%)
1	ICSA-88015 X Indian Exotic 27	137.6	85.9	21.9	6.7	26.2	58.7	11.5
2	ICSA-88015 X ICSV-112	132.7	86	25.3	6.02	28.2	63.4	13.5
3	ICSA-88015 X ICSV-295	183.9	88.5	19.1	6.2	28.9	36.6	11.2
4	ICSA-88015 X RSH – 19	174.8	83.6	18.1	5.9	28.6	42.02	13.7
5	ICSA-88015 X RSH-27	169.5	79.2	17.8	6.8	32.2	48.3	14.1
6	ATX -807 X Indian Exotic 27	165.05	81.6	16.7	6.2	27.9	41.4	14.9
7	ATX -807 x ICSV-112	164.6	81.9	21.3	7.7	31.1	58.8	8.9
8	ATX-807 x ICSV-295	164.5	78.3	17.9	6.1	23.1	46.8	13.8
9	ATX-807 x RSH – 19	176.4	81.6	22.9	7.02	30.6	58.7	13.4
10	ATX-807 x RSH-27	177.9	82.4	25.2	7.4	29.7	65.5	13.4
11	ASH-15 X Indian Exotic 27	180.4	84.2	24.6	6.9	31.1	65.7	7.2
12	ASH-15 X ICSV-112	179.3	82.4	22.7	6.9	24.2	56.8	13.5
13	ASH-15 X ICSV-295	158.1	77.1	17.1	5.7	29.2	43.9	9.9
14	ASH-15 X RSH – 19	168.4	84	18.5	5.9	24.8	48.8	9.8
15	ASH-15 X RSH-27	165.1	80.3	17.6	6.2	27.5	44.7	9.2
16	ASH-20 X Indian Exotic 27	166.4	81.4	17.5	6.1	26.4	48.8	8.9
17	ASH-20 X ICSV-112	196.6	79.7	20.1	5.9	27.9	53.9	9.2
18	ASH-20 X ICSV-295	164.3	82.1	20.7	6.0	25.9	53.3	7.5
19	ASH-20 X RSH – 19	162.5	86	19.5	6.1	26.1	45.8	9.3
20	ASH-20 X RSH-27	166.6	77.1	19.4	5.9	26.1	48.8	11.4
21	Indian Exotic 27	155.4	82.1	19.1	5.3	29.3	49.02	10.4
22	ICSV-112	136.2	79.1	18.6	5.6	28.4	45.5	12.2
23	ICSV-295	147.7	81.2	19.3	5.3	29.6	48.8	11.3
24	RSH – 19	170.1	82.4	18.3	5.3	27.9	43.6	9.9
25	RSH-27	142.8	88.9	16.4	6.5	27.6	48.1	11.5
26	ICSB-88015	117.5	83.0	16.6	5.3	27.8	42.4	10.6
27	BTX -807	133.8	82.3	16.6	5.0	27.3	40.9	10.7
28	BSH-15	118	83.7	18.5	5.1	27.9	40.6	9.4
29	BSH-20	129.9	83.7	19.5	5.8	29.0	39.1	10.2
30	H-306 (Check)	148.1	80.6	22.4	6.1	26.7	52.4	10.6
LSD 0.05		4.68	1.99	1.17	0.47	5.81	4.34	0.63

The results over all environments showed that the means of plant height of almost genotypes were higher than the mean of the check (H-306). The means of genotypes no. 8, 13 and 20 were significantly earliness than the check (H-306) for 50% day to flowering. For panicle length, the genotypes no.2, 10 and 11 showed higher significantly means than the check. The genotypes no. 1, 5, 7, 9, 10, 11, 12 and 25 were significantly higher means of panicle width than the means of the check. The genotypes no. 5, 7, 9 and 11 were higher than the check (H-306) for 1000-grain weight. The genotypes no. 1, 2, 4, 5, 6, 8, 9, 10, 12, 20, 22, 23 and 25 were significantly surpassed the check for total protein %. For grain yield per plant the genotypes no. 1, 2, 7, 9, 10, 11 and 12 exceeded significantly the means of the check (H-306).

Mean performance of 30 genotypes under normal and salt soil across two years are shown in Table 7. The results indicated that plant height for the crosses in saline soil ranged from 130.3 cm (ICSA-88015 x ICSV-112) to 190.7 cm

(ASH-20 x ICSV-112) with an average of 162.1 cm. While, plant height for the parental lines ranged from 111.0 cm (BSH-15) to 161.0 cm (RSH–19) with an average of 132.7cm. Under normal soil the plant height for the parental lines ranged from 122.3 cm (ICSB-88015) to 179.2 cm (RSH–19) with an average of 145.3 cm. Whereas, the crosses ranged from 135.2 cm (ICSA-88015 X ICSV-112) to 202.5 cm (ASH-20 X ICSV-112) with an average of 173.3 cm. General most of the crosses were taller than their parents in the two cases (under the normal and saline soil over two years), reflecting the presence of hybrid vigor. Meanwhile all genotypes (parental and crosses) under normal soil were higher than salt soil and also the crosses were significantly taller than the check hybrid (H-306).

Table 7. Means performance for 30 genotypes under normal and salt soil across two years.

No.	Genotype	Plant height (cm)		Days to 50% flowering		Panicle length (cm)		Panicle width(cm)	
		S	N	S	N	S	N	S	N
		Com.	Com.	Com.	Com.	Com.	Com.	Com.	Com.
1	ICSA-88015 X Indian Exotic 27	130.9	144.3	88.9	83.0	20.5	23.4	6.1	7.3
2	ICSA-88015 X ICSV-112	130.3	135.2	90.0	82.0	22.7	24.9	5.6	6.4
3	ICSA-88015 X ICSV-295	181.2	186.6	90.0	87.0	18.0	20.2	6.1	6.4
4	ICSA-88015 X RSH – 19	168.2	181.4	87.4	79.8	16.4	19.8	5.5	6.3
5	ICSA-88015 X RSH-27	164.0	175.1	83.2	75.2	17.2	18.4	6.6	7.1
6	ATX -807 X Indian Exotic 27	156.2	173.9	83.0	80.2	16.4	17.2	5.8	6.5
7	ATX -807 x ICSV-112	157.5	171.7	84.4	79.5	17.5	25.2	6.2	7.4
8	ATX-807 x ICSV-295	153.0	176.1	83.2	73.3	16.8	19.2	5.5	6.7
9	ATX-807 x RSH – 19	172.0	180.8	82.4	80.9	20.9	24.9	6.6	7.4
10	ATX-807 x RSH-27	176.7	179.2	85.5	79.2	24.2	26.1	6.5	8.2
11	ASH-15 X Indian Exotic 27	176.1	184.7	86.2	82.2	23.9	25.3	5.9	8.0
12	ASH-15 X ICSV-112	176.2	182.4	84.5	80.2	20.6	24.9	6.3	7.6
13	ASH-15 X ICSV-295	152.7	163.4	82.3	71.8	16.4	17.8	5.7	5.7
14	ASH-15 X RSH – 19	160.9	176.0	85.0	83.0	17.8	19.3	5.4	6.4
15	ASH-15 X RSH-27	159.5	170.6	83.9	76.7	17.2	18.1	5.6	6.8
16	ASH-20 X Indian Exotic 27	160.7	172.0	83.2	79.7	16.7	18.4	5.3	6.8
17	ASH-20 X ICSV-112	190.7	202.5	82.5	76.9	19.4	20.9	5.3	6.5
18	ASH-20 X ICSV-295	161.9	166.7	83.3	80.9	19.9	21.5	5.2	6.8
19	ASH-20 X RSH – 19	155.0	170.1	86.2	85.8	18.7	20.4	5.5	6.6
20	ASH-20 X RSH-27	159.4	173.9	81.7	72.4	19.3	19.5	4.9	6.9
Average		162.1	173.3	84.8	79.4	19.0	21.2	5.7	6.9
21	Indian Exotic 27	150.9	159.8	79.0	79.2	17.0	21.1	4.7	5.9
22	ICSV-112	128.0	144.4	80.7	79.8	16.0	21.2	5.1	6.1
23	ICSV-295	139.7	155.7	82.2	80.2	18.0	20.7	5.0	5.7
24	RSH – 19	161.0	179.2	83.4	81.4	17.2	19.4	4.9	5.7
25	RSH-27	137.5	148.1	88.0	89.9	15.4	17.5	6.2	6.8
26	ICSB-88015	112.7	122.3	85.5	80.5	15.3	17.9	4.8	5.8
27	BTX -807	126.3	141.3	81.9	82.7	15.2	18.2	4.6	5.4
28	BSH-15	111.0	125.0	83.5	83.9	16.7	20.3	4.4	5.7
29	BSH-20	128.0	131.9	84.4	83.0	17.1	21.9	5.4	6.3
Average		132.7	145.3	83.1	82.2	16.4	19.7	5.01	5.9
30	H-306 (Check)	141.5	154.7	82.5	78.7	21.1	23.6	5.9	6.5
	LSD 0.05	4.97	4.46	1.97	2.05	1.13	1.23	0.48	0.7

S= salt soil, N= normal soil

For, no. of days to 50% flowering for the crosses ranged from 81.7day (ASH-20 X RSH-27) to 90.00 (ICSA-88015 x ICSV-112 and ICSA-88015 x ICSV-295) with an average 84.8 day under saline soil. Whereas, the parental lines it ranged from 79.0 day (Indian Exotic 27) to 88.0 (RSH-27) with an average 83.1day. Under normal soil the parental lines ranged from 79.2 days (Indian Exotic 27) to 89.9 (RSH-27) with an average 82.2 day, and for the crosses it ranged from 71.8 day (ASH-15 x ICSV-295) to 87.0 (ICSA-88015 X ICSV-295) with an average of 79.4 day. In general, most of the F_1 crosses were earlier than their parents under two environments. These results are in harmony with these obtained by Al-Naggar *et al.* (1999), Mahmoud (2002), Amir (2004) and Mahmoud *et al.* (2013).

For panicle length for the evaluated genotypes under the salt and normal soil in the two seasons and combined across seasons Table 7 showed that panicle length under saline soil, ranged from 15.2 (BTX-807) to 18.0 (ICSV-295) with an average of 16.4 cm for the parental lines. Whereas, the crosses ranged from 16.4 cm (ICSA-88015 x RSH–19 and ATX-807 x Indian Exotic 27) to 24.20 cm (ATX-807 x RSH-27) with an average of 19.0 cm. Meanwhile, under normal soil, parents ranged from 17.5 (RSH-27) to 21.9 cm (BSH-20) with an average of 19.7 cm. whereas, for the crosses ranged from 17.15 (ATX-807 X Indian Exotic 27) to 26.10 cm (ATX-807 x RSH-27) with an average of 21.2 cm. General most of the crosses had panicle length more than the parents under two types of soils. On other hand, panicle width for the crosses under salt soil ranged from 4.9 (ASH-20 x RSH-27) to 6.6 cm (ICSA-88015x RSH-27) and (ATX-807 x RSH–19) with an average of 5.7cm, while, for the parental lines ranged from 4.4 (BSH-15) to 6.2 cm (RSH-27) with an average of 5.01 cm. Under normal soil the crosses ranged from 5.7 (ASH-15 X ICSV-295) to 8.2 cm (ATX-807 x RSH-27) with an average of 6.9 cm. whereas, for the parental lines ranged from 5.4 (BTX -807) to 6.7 cm (RSH-27) with an average of 5.9 cm. In general, all means of genotypes under normal soil are higher than under saline soil.

For 1000-grain weight, the parental lines under salt soil ranged from 23.8 (BSH-15) to 27.6 g (Indian Exotic 27) and (ICSV-295) with an average of 26.0 g., while, for the crosses ranged from 21.4 (ATX-807 x ICSV-295) and (ASH-15 x ICSV-112) to 30.80g (ICSA-88015 x RSH-27) with an average of 25.5 g. Under normal soil the parental lines ranged from 28.9 (RSH-27) to 31.9g (BSH-15) with an average of 30.6 g, while the crosses ranged from 24.7 (ATX-807 x ICSV-295) to 33.9g (ATX-807 x RSH–19) with an average of 29.9 g. For the percentage of total protein, the crosses under salt soil ranged from 6.7 (ASH-15 X ICSV-112) to 14.4 (ATX-807 x ICSV-112) with an average of 11.2%.While, the parental liens ranged from 9.25 (RSH–19) to 11.4 (ICSV-112) and (ICSV-295) with an average of 10.31%. The crosses under normal soil ranged

from 7.6 (ASH-15 x ICSV-112) to 15.4 (ATX -807 x ICSV-112) over two years with an average of 11.5%. While, the parental lines ranged from 9.4 (BSH-15) to 12.9 (ICSV-112) with an average of 11.01%.

For grain yield per plant under the salt soil in the crosses ranged from 26.5 (ICSA-88015 x ICSV-295) to 56.8 (ICSA-88015 x ICSV-112) with an average of 43.83 g, whereas, for the parental lines it ranged from 34.8 (BTX-807) to 44.1 (ICSV-112) with an average of 39.2 g. Under normal soil the crosses ranged from 43.7 (ATX -807 x Indian Exotic 27) to 76.7g (ATX-807 x RSH-27) with an average of 59.2 g. While, the parental lines ranged from 42.5 (BSH-20) to 56.4g (Indian Exotic 27) with an average of 49.2 g. The means of genotypes (parents and their crosses) under normal soil were higher than under salt soil. Three crosses (ICSA-88015 x ICSV-112, ATX-807 x RSH-27and ASH-15 x Indian Exotic 27) were significantly out yielded than check (H-306) for grain yield /plant under salt soil. Meanwhile, seven crosses were significantly surpassed the check under normal soil (no.1, 2, 7, 9, 10, 11, and 12).

Table 7. continue

No.	Genotype	1000-grain weight (g)		(%)Total Protein in seeds		Grain yield per plant (g)		SSI
		S	N	S	N	S	N	
		Com.	Com.	Com.	Com.	Com.	Com.	
1	ICSA-88015 X Indian Exotic 27	24.3	28.0	11.1	12.0	45.6	71.8	1.4
2	ICSA-88015 X ICSV-112	27.4	28.9	13.2	13.9	56.8	70.0	0.72
3	ICSA-88015 X ICSV-295	24.2	33.5	10.8	11.6	26.5	46.6	1.6
4	ICSA-88015 X RSH – 19	26.9	30.2	13.5	13.8	37.7	46.3	0.71
5	ICSA-88015 X RSH-27	30.8	33.5	13.7	14.8	44.5	52.0	0.55
6	ATX -807 X Indian Exotic 27	27.0	28.9	13.9	14.4	39.2	43.7	0.40
7	ATX -807 x ICSV-112	29.8	32.4	14.4	15.4	48.8	68.8	1.11
8	ATX-807 x ICSV-295	21.4	24.7	9.2	8.7	41.9	51.8	0.73
9	ATX-807 x RSH – 19	27.4	33.9	13.4	14.3	49.2	68.4	1.07
10	ATX-807 x RSH-27	27.6	31.9	13.3	13.6	54.3	76.7	1.12
11	ASH-15 X Indian Exotic 27	29.4	32.9	12.2	14.8	55.8	75.5	1.00
12	ASH-15 X ICSV-112	21.4	26.9	6.7	7.6	47.4	66.2	1.09
13	ASH-15 X ICSV-295	26.6	31.8	13.1	13.9	39.7	48.2	0.67
14	ASH-15 X RSH – 19	24.0	25.7	10.4	9.50	39.6	57.9	1.2
15	ASH-15 X RSH-27	24.9	30.2	9.90	9.45	34.6	54.7	1.4
16	ASH-20 X Indian Exotic 27	23.2	29.7	9.25	9.05	46.3	51.2	0.37
17	ASH-20 X ICSV-112	25.2	30.7	9.15	8.75	46.7	61.1	0.90
18	ASH-20 X ICSV-295	24.4	27.5	9.50	8.95	45.7	60.9	0.96
19	ASH-20 X RSH – 19	21.6	30.5	7.80	7.25	35.5	56.1	1.4
20	ASH-20 X RSH-27	24.4	27.8	9.40	9.20	40.75	56.8	1.08
Average		25.5	29.9	11.2	11.5	43.8	59.2	
21	Indian Exotic 27	27.6	30.9	10.1	10.7	41.7	56.4	1.27
22	ICSV-112	26.4	30.4	11.4	12.9	44.1	46.9	0.29
23	ICSV-295	27.6	31.7	11.4	11.2	44.0	53.6	0.88
24	RSH–19	25.1	30.7	9.25	10.5	35.1	52.1	1.6
25	RSH-27	26.3	28.9	11.3	11.7	43.7	52.5	0.82
26	ICSB-88015	25.3	30.3	10.1	11.1	36.8	48.0	1.18
27	BTX -807	25.2	29.4	10.2	11.3	34.8	47.0	1.3
28	BSH-15	23.8	31.9	9.4	9.40	37.0	44.3	0.81
29	BSH-20	26.7	31.3	9.8	10.5	35.8	42.5	0.76
Average		26.0	30.6	10.3	11.01	39.2	49.2	
30	H-306	23.80	29.7	11.1	10.2	45.6	59.2	
	LSD 0.05	1.16	1.28	0.63	0.66	4.77	3.95	

Nine crosses revealed to be tolerant to salinity were their SSI less than unity. These crosses in ranking for salt tolerance were ICSA-88015 x ICSV-112, ICSA-88015 x RSH– 19, ICSA-88015 x RSH-27, ASH-20 x Indian Exotic 27, ATX -807 x Indian Exotic 27, ASH-15 x ICSV-295, ATX-807 x ICSV-295 , ASH-20 x ICSV-112 and ASH-20 x ICSV-295. Also, the tolerant parental lines for SSI (in ranking) were ICSV-112, ICSV-295, RSH-27, BSH-15 and BSH-20. It is clear results that those tolerant parents were combined in the previous tolerant crosses. Consequently, their tolerant genes inherited to their progenies.

The line x tester analysis of variance of 29 genotypes (20 crosses and 9 parents *i.e.* 4 lines and 5 testers) of grain sorghum under normal and salt soil for all the studied traits in 2020 season are presented in Table 8.

Table 8. Line x tester analysis of variance of 20 F_1's and 9 parents for seven traits under normal and salt soil in 2020 studied season.

S.O.V	d.f	Mean squares													
		Plant height		Days to 50% flowering		Panicle length		Panicle width		1000-grain weight		Grain yield per plant		% total Protein	
		S	N	S	N	S	N	S	N	S	N	S	N	S	N
Rep.	2	0.20	37.16	14.72	1.24	5.05	2.80	0.34	0.59	0.19	4.64	78.78	44.52	0.73	5.24
Genotypes (G)	28	1258.2**	1150.6**	35.78**	51.26**	16.73**	22.97**	0.95**	1.55**	17.39**	16.68**	145.1**	289.9**	11.77**	14.69**
Parents (P)	8	783.9**	965.9**	29.51**	32.08**	4.49**	7.73**	0.84**	0.56**	5.89**	3.13*	45.98	65.86**	2.34**	2.48**
Parents vs. Crosses	1	15387.6**	13997.3**	14.05	117.4**	91.83**	36.95**	7.84**	16.00**	2.63	2.98	336.7**	2024.7**	15.93**	8.96**
Crosses (C)	19	714.3**	552.2**	39.56**	55.85**	17.93**	28.65**	0.63**	1.21**	23.01**	23.11**	176.8**	293.0**	15.51**	20.14**
Lines (L)	3	418.6**	438.13**	46.19**	28.58**	2.70	16.31**	1.89**	1.26**	22.59**	4.85**	70.65*	92.69**	48.44**	60.77**
Testers (T)	4	165.7**	110.0**	62.64**	92.52**	9.26**	40.09**	0.15	2.02**	17.75**	5.17**	256.7**	333.0**	2.25**	3.18**
Lines x Testers (LxT)	12	971.2**	728.2**	30.21**	50.44**	24.63**	27.92**	0.47*	0.93**	24.86**	33.66**	176.7**	329.7**	11.71**	15.63**
Error	56	18.41	17.76	3.82	2.05	1.02	1.00	0.24	0.10	0.84	1.24	23.15	12.64	0.28	0.52

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Data cleared significant or highly significantly differences among genotypes and their partition; crosses (C), parents (P) and P vs C for all traits under two types of soil, except for parents (P) for grain yield per plant under salt soil and parents vs crosses (P vs C) for days to 50% flowering in salt soil and 1000-grain weight in salt and normal soil. Partitioning sum of squares of crosses to their contributions (lines, testers and lines × testers interaction) showed highly significant differences for all traits except for panicle length for lines in salt soil and panicle width for testers in salt soil.

Table 9. Line x tester analysis of variance of 20 F1's and 9 parents for seven traits under normal and salt soil in 2021 studied season.

O.V	d.f	Mean squares													
		Plant height		Days to 50% flowering		Panicle length (cm)		Panicle width		1000-grain weight		Grain yield per plant		% total Protein	
		S	N	S	N	S	N	S	N	S	N	S	N	S	N
Rep.	2	33.77	59.89	6.51	1.98	0.43	1.11	0.15	0.19	0.45	4.91	1.26	34.24	0.02	0.44
Genotypes (G)	28	1251.4**	1256.5**	905.8**	48.47**	20.21**	21.43**	1.37**	1.58**	16.40**	15.58**	145.2**	307.6**	10.17**	17.38**
Parents (P)	8	842.8**	998.9**	218.7**	33.23**	2.17	8.25**	0.87**	0.64**	3.82**	3.72*	57.19**	68.81**	2.05**	2.21**
Parents vs.Crosses	1	16649.8**	15010.5**	27.82**	176.0**	160.5**	43.78**	15.21**	18.34**	4.70*	13.86**	458.4**	1708.9**	15.34**	2.02*
Crosses (C)	19	613.0**	641.1**	659.3**	48.18**	20.43**	25.81**	0.85**	1.09**	22.31**	20.66**	165.7**	334.4**	13.33**	24.58**
Lines (L)	3	338.0**	588.9**	152.9**	25.11**	0.58	11.65**	2.68**	0.86**	36.03**	13.54**	46.12**	70.47**	43.15**	76.57**
Testers (T)	4	147.2**	121.6**	211.2**	67.04**	12.57**	23.70**	0.19	0.98**	10.42**	2.83	260.2**	353.3**	1.67**	5.84**
Lines x Testers (LxT)	12	837.0**	827.4**	295.2**	47.65**	28.01**	30.05**	0.61**	1.18**	22.84**	28.38**	164.2**	394.0**	9.75**	17.82**
Error	56	14.08	15.60	3.88	2.33	1.21	1.12	0.22	0.13	0.93	1.59	11.5	12.75	0.30	0.36

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

The line x tester of variance of twenty nine genotypes (20 crosses and 9 parents) of grain sorghum for seven traits under normal and salt soil in 2021 season are presented Table 9. Data cleared highly significantly differences among genotypes and their partition, crosses (C), parents (P) and parents vs. crosses(P vs C) for all the studied traits in two types of soil, except parents for panicle length (salt soil). Partitioning sum of squares of crosses to their contributions (lines, testers and lines × testers interaction) showed highly significant differences for all traits except lines for panicle length for lines in salt soil and testers for panicle width in salt soil and 1000-grain weight in normal soil.

Estimates of general combining ability (GCA) effects of the lines and testers for all studied traits under normal and salt soil in 2020 and 2021 seasons are presented in Table 10. For plant height, the lines BSH-15 and BSH-20 had positive and significant or highly significant GCA effect under the two types of soil in both years, these lines had favorable genes for tallness. The tester RSH-27 had positive and significant GCA effect in the two seasons in salt soil, while the tester RSH-19 had positive and highly significant GCA effects in both seasons in normal soil. These testers had favorable genes for tallness. GCA effects for days to 50% flowering showed that the line BSH-20 had desirable effects in two the seasons in two types of soil. Also, the tester line RSH-27 had negative (favorable) and highly significant GCA effects in the two seasons and two types of soils, respectively). These lines were the best for earliness. For panicle length, the line BTX -807 had desirable GCA effects in normal soil in two seasons while, the tester line ICSV-112 had positive and significant or highly significant in the two seasons and both types of soil. These lines may have favorable genes for panicle length and could be considered as

good combiners for panicle elongation. Regarding panicle width, the lines BTX-807 had positive and highly significant in the two soils and both seasons. While, the tester RSH-27 had positive and significant or highly significant GCA effects in both two seasons in normal soil. These lines may have favorable gene effects for increasing panicle width and could be considered as good combiners for this trait. For 1000-grain weight the line ICSB-88015 had positive and highly significant in the two seasons and two types of soils. While, the tester RSH-27 had positive and highly significant in two seasons in salt soil and in 2019 in normal soil. These lines had favor gene for heavier 1000- grain weight. For grain yield per plant, GCA effects showed that the line BTX-807 and tester ICSV-112 had positive and significant or highly significant GCA effects in two seasons for both types of soils. These lines would be considered best combiners for grain yield / plant. Similar results were obtained by Bakheit *et al*., (2004), Hussien (2015), Tag El-Din (2015) and El- Sagheer (2019). For the percentage of protein, the lines ICSB-88015 and BTX-807 had positive and highly significant GCA effects in two types of soils and both seasons. The tester Indian Exotic 27 had positive and significant or highly significant GCA effects in the two seasons in two types of soils, respectively. The current results showed that the parents behave different responses for general combining ability (GCA) effects for different traits.

Table 10. Estimates of general combining ability effects of parents for all studied traits under two types of soil in 2020 and 2021 seasons.

Genotype		Plant height (cm)				Days to 50% flowering			
		S		N		S		N	
		2020	2021	2020	2021	2020	2021	2020	2021
Line	ICSB-88015	-7.5183**	-6.9417***	-8.088**	-9.3033**	2.517**	2.6**	2.067**	1.8**
	BTX -807	0.9817ns	0.8717ns	3.205**	3.0433**	-0.617ns	-0.067ns	-0.667ns	-1.067**
	BSH-15	3.1417**	2.6983**	2.372*	2.0433*	-0.35ns	-0.933ns	-0.6ns	-0.8*
	BSH-20	3.395**	3.3717***	2.512*	4.2167**	-1.55**	-1.6**	-0.8*	0.067ns
Tester	Indian Exotic 27	-6.3083**	-6.095***	-4.187**	-4.7867**	1.983**	1.25*	2.15**	1.417**
	ICSV-112	1.425ns	1.655ns	-0.778ns	-0.9783ns	0.4ns	0.333ns	0.15ns	0.167ns
	ICSV-295	-0.0583ns	0.1717ns	-0.57ns	0.5383ns	0.0667ns	0 ns	-1.35**	-1.083*
	RSH – 19	1.7583ns	2.005ns	3.972**	3.78**	1.4*	1.917**	2.983**	2.833**
	RSH-27	3.1833*	2.2633*	1.563ns	1.4467ns	-3.85**	-3.5**	-3.933**	-3.333**

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 10. Continue.

Genotype		Panicle length (cm)				Panicle width (cm)			
		S		N		S		N	
		2020	2021	2020	2021	2020	2021	2020	2021
Line	ICSB-88015	-0.287ns	0.133ns	0.115ns	0.007ns	0.135ns	0.253*	-0.248**	-0.132ns
	ATX -807	0.107ns	0.2 ns	1.288**	1.187**	0.362**	0.347**	0.4183**	0.322**
	ASH-15	0.553*	-0.207ns	-0.152ns	-0.273ns	-0.018ns	-0.007ns	-0.055ns	0.035ns
	ASH-20	-0.373ns	-0.127ns	-1.252**	-0.92**	-0.478**	-0.593**	-0.115ns	-0.225*
Tester	Indian Exotic 27	-0.105ns	0.795*	-0.297ns	-0.125ns	-0.053ns	0.05ns	0.35***	0.19ns
	ICSV-112	1.228**	0.77*	3.003**	2.383**	0.063ns	0.025ns	0.067ns	0.115ns
	ICSV-295	-1.222**	-1.213**	-1.913**	-1.292**	-0.1033ns	-0.217ns	-0.5333**	-0.443**
	RSH – 19	-0.138ns	-1.022**	-0.022ns	-0.3ns	-0.07ns	0.025ns	-0.3**	-0.1183ns
	RSH-27	0.237ns	0.67*	-0.772**	-0.667*	0.163ns	0.117ns	0.417**	0.257*

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 10. Continue.

Genotype		1000-grain weight (g)				Grain yield per plant (g)			
		S		N		S		N	
		2019	2020	2019	2020	2019	2020	2019	2020
Line	ICSB-88015	1.04**	1.173**	0.582*	1.172**	-1.562ns	-1.617ns	-2.028*	-1.753ns
	BTX -807	0.9**	1.2**	0.382ns	0.352ns	3.205*	2.47**	3.038**	2.233*
	BSH-15	-0.36ns	-0.3ns	-0.378ns	-0.602ns	-0.635ns	-0.157ns	1.025ns	1.48ns
	BSH-20	-1.58**	-2.073**	-0.585*	-0.922**	-1.008ns	-0.697ns	-2.035*	-1.96*
Tester	Indian Exotic27	0.07ns	0.647*	-0.385ns	0.135ns	2.352ns	3.415**	1.54ns	1.087ns
	ICSV-112	0.662*	0.063ns	-0.01ns	-0.457ns	6.152**	6.007**	6.723**	7.845**
	ICSV-295	-1.597**	-1.303**	-0.71*	-0.457ns	-5.957**	-4.71**	-7.602**	-7.088**
	RSH – 19	-0.697*	-0.47ns	0.073ns	0.068ns	-2.59ns	-4.043**	-1.977ns	-2.163*
	RSH-27	1.562**	1.063**	1.032**	0.71ns	0.043ns	-0.668ns	1.315ns	0.32ns

** Significant at 0.05 and 0.01 levels of probability; respectively.

Table 10. Continue.

Genotype		% Total Protein in grains			
		S		N	
		2020	2021	2020	2021
Line	ICSB-88015	1.303**	1.112**	1.385**	1.902**
	BTX -807	1.577**	1.592**	1.752**	1.728**
	BSH-15	-0.617**	-0.575**	-0.508**	-0.785**
	BSH-20	-2.263**	-2.128**	-2.628**	-2.845**
Tester	Indian Exotic 27	0.357*	0.368*	0.7583**	1.123**
	ICSV-112	-0.218ns	-0.115ns	-0.275ns	-0.343ns
	ICSV-295	-0.643**	-0.573**	-0.5417*	-0.71**
	RSH – 19	0.123ns	0.043ns	-0.208ns	-0.21ns
	RSH-27	0.382*	0.277ns	0.267ns	0.14ns

*, ** Significant at 0.05 and 0.01 levels of probability; respectively.

Estimates of specific combining ability (SCA) of 20 crosses under two types of soil in the two seasons are presented in Table 11. For plant height, the desirable crosses for CSA effects were no. 3,4,5, 11,12 and 17 under two types of soil in both seasons. For days to 50% flowering, the desirable crosses for SCA effects were no. 4, 5,8,17 and 20 in two seasons and both soils, indicating that these crosses could be considered the best combination for earliness. For panicle length, the desirable crosses for SCA effects were no. 9, 10, 11and 18 in both seasons and the two soils. For panicle width, desirable crosses for SCA effects were no. 9, 10, 11, 12 and 18 had positive and significant or highly significant SCA effects in the two seasons in normal soil. These crosses were considered as best combinations for panicle width. For 1000-grain weight, desirable crosses for SCA effects were no. 7, 11and 13 in two seasons in two types of soil, respectively. While, the crosses no. 2, 9, 10 ,11 and 18 had positive and significant or highly significant in two seasons in two types of soil for grain yield/plant. In general, crosses which had positive and significant SCA effects for grain yield per plant were high in grain yield per plant. These results are in line with those reported by Haussmann *et al.*, (1999), Mahmoud (2002), Amir (2004), Mahmoud (2007), Amir (2008), Mahmoud *et al.*, (2013), Tag El-Din (2015) and El-Sagheer (2019). For the percentage of protein, the crosses no. 2, 4, 5,7,11 and 13 desirable SCA effects for the percentage of protein in two seasons in two types of soil.

Table 11. Estimated of specific combining ability effects of 20 crosses for all studied traits under two types of soil in 2020, 2021 seasons.

No.	Genotype	Plant height (cm)				Days to 50% flowering			
		S		N		S		N	
		2020	2021	2020	2021	2020	2021	2020	2021
1	ICSA-88015 X Indian Exotic 27	-20.27**	-15.33**	-15.95**	-15.45**	-0.183ns	0.483ns	-0.15ns	-0.217ns
2	ICSA-88015 X ICSV-112	-26.23**	-26.11**	-26.90**	-29.99**	3.733**	3.4**	0.85ns	0.033ns
3	ICSA-88015 X ICSV-295	26.85**	25.61**	22.06**	22.10**	2.067ns	2.733*	6.017**	7.617**
4	ICSA-88015 X RSH – 19	11.00**	11.78**	13.36**	12.59**	-3.6**	-3.85**	-4.317**	-4.633**
5	ICSA-88015 X RSH-27	8.643**	4.05ns	7.43**	10.75**	-2.017ns	-2.767*	-2.4**	-2.8**
6	ATX -807 X Indian Exotic 27	-0.532ns	-0.938ns	1.22ns	2.873ns	-0.717ns	-0.85ns	-0.083ns	-0.35ns
7	ATX -807 x ICSV-112	-7.832**	-6.355**	-5.388*	-2.235ns	-0.467ns	-1.267ns	0.583ns	0.9ns
8	ATX-807 x ICSV-295	-10.68**	-9.538***	-0.197ns	-0.285ns	-1.133ns	-2.6*	-3.25**	-4.85**
9	ATX-807 x RSH – 19	8.168**	5.962**	1.562ns	-0.36ns	-2.467*	-0.183ns	-1.25ns	-0.1ns
10	ATX-807 x RSH-27	10.88**	10.87**	2.803ns	0.0067ns	4.783**	4.9**	4.0**	4.4**
11	ASH-15 X Indian Exotic 27	18.31**	16.04**	12.12**	15.44**	0.35ns	0.35ns	1.183ns	2.05*
12	ASH-15 X ICSV-112	9.642**	9.652**	9.945**	5.665*	-0.733ns	-1.4ns	1.517ns	0.967ns
13	ASH-15 X ICSV-295	-11.84**	-13.03**	-11.80**	-12.19**	-2.067ns	-0.4ns	-6.317**	-5.117**
14	ASH-15 X RSH – 19	-5.925*	-6.198**	-4.538ns	-2.027ns	1.267ns	0.683ns	1.017ns	1.633ns
15	ASH-15 X RSH-27	-10.18**	-6.457**	-5.73*	-6.893**	1.1833ns	0.767ns	2.6**	0.467ns
16	ASH-20 X Indian Exotic 27	2.488ns	0.228ns	2.613ns	-2.867ns	0.55ns	0.017ns	-0.95ns	-1.483ns
17	ASH-20 X ICSV-112	24.42**	22.81**	22.34**	26.56**	-2.533*	-0.733ns	-2.95***	-1.9*
18	ASH-20 X ICSV-295	-4.328ns	-3.038ns	-10.07**	-9.625**	1.133ns	0.267ns	3.55**	2.35*
19	ASH-20 X RSH – 19	-13.25**	-11.54**	-10.38**	-10.20**	4.8**	3.35**	4.55**	3.1**
20	ASH-20 X RSH-27	-9.337**	-8.463**	-4.503ns	-3.867ns	-3.95**	-2.9*	-4.2**	-2.067*

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 11. Continue

No	Genotype	Panicle height (cm)						Panicle width (cm)	
		S		N		S		N	
		2020	2021	2020	2021	2020	2021	2020	2021
1	ICSA-88015 X Indian Exotic 27	0.912ns	1.525*	1.977**	2.485**	0.107ns	0.063ns	0.223ns	0.457*
2	ICSA-88015 X ICSV-112	2.578**	2.883**	1.51*	0.21ns	-0.51ns	-0.245ns	-0.393*	-0.368ns
3	ICSA-88015 X ICSV-295	0.262ns	0.3ns	0.593ns	0.3183ns	0.39ns	0.097ns	0.24ns	0.157 ns
4	ICSA-88015 X RSH – 19	-2.055**	-1.958**	-1.832**	-0.94ns	-0.41ns	-0.478ns	-0.127ns	-0.235ns
5	ICSA-88015 X RSH-27	-1.697**	-2.75**	-2.248**	-2.073**	0.423ns	0.563*	0.057ns	-0.01ns
6	ATX -807 X Indian Exotic 27	-2.648**	-3.675**	-4.83**	-5.428**	-0.353ns	-0.363ns	-0.81***	-1.163**
7	ATX -807 X ICSV-112	-3.048**	-2.317**	0.103ns	-0.137ns	0.097ns	-0.105ns	0.007ns	0.145ns
8	ATX-807 X ICSV-295	-1.198*	-1.1ns	-1.747**	-1.728**	-0.337ns	-0.463ns	-0.127ns	-0.063ns
9	ATX-807 X RSH – 19	2.385**	2.375**	2.528**	2.613**	0.397ns	0.562*	0.407*	0.445*
10	ATX-807 X RSH-27	4.51**	4.717**	3.945**	4.68**	0.197ns	0.37ns	0.523**	0.637**
11	ASH-15 X Indian Exotic 27	4.005**	4.732**	4.31**	4.632**	0.193ns	0.19ns	0.863**	0.79**
12	ASH-15 X ICSV-112	1.138ns	-0.343ns	1.11ns	1.057ns	0.31ns	0.482ns	0.547**	0.665**
13	ASH-15 X ICSV-295	-1.545*	-1.493*	-1.673**	-1.702**	-0.023ns	0.123ns	-0.72**	-0.61**
14	ASH-15 X RSH – 19	-0.828ns	-0.785ns	-1.498*	-1.693**	-0.357ns	-0.352ns	-0.353ns	-0.302ns
15	ASH-15 X RSH-27	-2.77**	-2.11**	-2.248**	-2.293**	-0.1233ns	-0.443ns	-0.337ns	-0.543*
16	ASH-20 X Indian Exotic 27	-2.268**	-2.582**	-1.4567*	-1.688**	0.053ns	0.11ns	-0.277ns	-0.083ns
17	ASH-20 X ICSV-112	-0.668ns	-0.223ns	-2.723**	-1.13ns	0.103ns	-0.132ns	-0.16ns	-0.442*
18	ASH-20 X ICSV-295	2.482**	2.293**	2.827**	3.112**	-0.03ns	0.243ns	0.607**	0.517*
19	ASH-20 X RSH – 19	0.498ns	0.368ns	0.802ns	0.02ns	0.37ns	0.268ns	0.073ns	0.092ns
20	ASH-20 X RSH-27	-0.043ns	0.143ns	0.552ns	-0.313ns	-0.497ns	-0.49ns	-0.243ns	-0.083ns

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 11. Continue

No.	Genotype	1000-grain weight (g)				Grain yield per plant (g)			
		S		N		S		N	
		2020	2021	2020	2021	2020	2021	2020	2021
1	ICSA-88015 X Indian Exotic27	-2.923**	-2.64**	-2.815**	-2.6217**	0.162ns	0.758ns	12.12**	14.22**
2	ICSA-88015 X ICSV-112	0.318ns	0.31ns	-1.99**	-1.397ns	9.162**	7.833**	5.27*	5.4617*
3	ICSA-88015 X ICSV-295	-1.457**	-0.79ns	2.843**	3.737**	-10.53**	-10.15**	-3.105ns	-3.605ns
4	ICSA-88015 X RSH – 19	1.277*	0.3767ns	-0.64ns	-0.788ns	0.103ns	-2.417ns	-9.397**	-8.563**
5	ICSA-88015 X RSH-27	2.785**	2.7433**	2.602**	1.07ns	1.103ns	3.975*	-4.888*	-7.513**
6	ATX -807 X Indian Exotic 27	-0.283ns	0.2ns	-1.382*	-1.302ns	-10.64**	-10.16**	-18.98**	-20.07**
7	ATX -807 x ICSV-112	2.558**	3.017**	2.31**	2.257**	-3.272ns	-4.687*	0.303ns	-0.858ns
8	ATX-807 x ICSV-295	-3.65**	-3.783**	-5.19**	-4.943**	-0.197ns	1.463ns	-2.338ns	-3.125ns
9	ATX-807 x RSH – 19	1.817**	0.883ns	3.693**	3.132**	6.003*	5.63**	8.337**	8.683**
10	ATX-807 x RSH-27	-0.442ns	-0.317ns	0.568ns	0.857ns	8.103**	7.755**	12.68**	15.37**
11	ASH-15 X Indian Exotic 27	4.143**	3.367**	3.478**	3.518**	10.37**	8.665**	13.73**	13.65**
12	ASH-15 X ICSV-112	-3.848**	-4.517**	-2.23**	-2.457**	-3.398ns	-0.96ns	-2.317ns	-0.938ns
13	ASH-15 X ICSV-295	2.143**	3.417**	3.437**	2.343**	2.31ns	0.99ns	-4.858*	-5.1383*
14	ASH-15 X RSH – 19	-0.89ns	-0.417ns	-4.113**	-3.615**	-1.623ns	0.69ns	-0.117ns	-0.863ns
15	ASH-15 X RSH-27	-1.548**	-1.85**	-0.572ns	0.21ns	-7.657**	-9.385**	-6.442**	-6.713**
16	ASH-20 X Indian Exotic 27	-0.937ns	-0.927ns	0.718ns	0.405ns	0.108ns	0.738ns	-6.873**	-7.807**
17	ASH-20 X ICSV-112	0.972ns	1.19*	1.91**	1.597*	-2.492ns	-2.187ns	-3.257ns	-3.665ns
18	ASH-20 X ICSV-295	2.963**	1.157*	-1.09ns	-1.137ns	8.417**	7.697**	10.30**	11.87**
19	ASH-20 X RSH – 19	-2.203**	-0.843ns	1.06ns	1.272ns	-4.483ns	-3.903ns	1.177ns	0.743ns
20	ASH-20 X RSH-27	-0.795ns	-0.577ns	-2.598**	-2.137**	-1.55ns	-2.345ns	-1.348ns	-1.14ns

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 11. Continue

No.	Genotype	% Total protein in grains			
		S		N	
		2020	2021	2020	2021
1	ICSA-88015 X Indian Exotic 27	-1.903**	-1.662**	-2.285**	-1.943**
2	ICSA-88015 X ICSV-112	0.938**	0.922**	1.215**	0.857*
3	ICSA-88015 X ICSV-295	-1.17**	-1.02**	-1.1183**	-0.71*
4	ICSA-88015 X RSH – 19	1.197**	0.93**	0.8817*	0.923**
5	ICSA-88015 X RSH-27	0.938**	0.83*	1.3067**	0.873*
6	ATX -807 X Indian Exotic 27	0.657*	0.758*	0.215ns	0.097ns
7	ATX -807x ICSV-112	1.798**	1.542**	1.915**	2.563**
8	ATX-807 x ICSV-295	-3.043**	-2.933**	-3.3183**	-3.937**
9	ATX-807 x RSH – 19	0.59ns	0.45ns	1.015*	1.163**
10	ATX-807 x RSH-27	-0.002ns	0.183ns	0.1733ns	0.113ns
11	ASH-15 X Indian Exotic 27	1.35**	1.058**	2.2083**	2.677**
12	ASH-15 X ICSV-112	-3.108**	-2.692**	-3.525**	-3.757**
13	ASH-15 X ICSV-295	3.05**	2.967**	3.675***	3.643**
14	ASH-15 X RSH – 19	-0.35ns	-0.183ns	-0.692ns	-1.023**
15	ASH-15 X RSH-27	-0.942**	-1.15**	-1.667**	-1.54**
16	ASH-20 X Indian Exotic 27	-0.103ns	-0.155ns	-0.138ns	-0.83*
17	ASH-20 X ICSV-112	0.372ns	0.228ns	0.395ns	0.337ns
18	ASH-20 X ICSV-295	1.163**	0.986**	0.762ns	1.003**
19	ASH-20 X RSH – 19	-1.437**	-1.197**	-1.205**	-1.063**
20	ASH-20 X RSH-27	0.005ns	0.137ns	0.1867ns	0.553ns

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

The magnitude of SCA effects of the crosses along with the mean performances indicated that the highest SCA effect with highest mean grain yield per plant was recorded in the crosses 2,9,10,11 and

18 showed significant and positive SCA effects for grain yield/plant with desirable mean grain yield/plant. The results are in conformity with the findings of Amsalu and Bapat (1990), Rafiq *et al.*, (2002) and Kaul *et al.,* (2003).

Heterosis

Estimates of combined heterosis for 20 crosses for the seven study traits as a percentage of the better parent in two types of soil in both seasons are presented in Table 12. The best crosses for heterosis relative the better parent in two types of soil in the two years were no. 3,5,6,7,8,10,11,12,13,15,16,17, 18 and 20 for plant height, no.5, 10,12,13,15 and 20 for earliness, no.1,2,7,9,10,11 and 12 for panicle length, No. 1,3,4,6,7,8,9, 11,12 and 14 for panicle width, no. 5,7,9 and 10 for 1000- grain weight, no. 2,7,9,10 and 11 for grain yield / plant and no. 1,2,4,5,6,7,9,10,11 and 13 for total protein% in seed. The obtained results expressed the genetic variability for current crosses for heterosis. Consequently, the crosses no. 2, 7, 9, 10 and 11 which possessed the positive and highly significant heterosis for grain yield matched the same trend for protein%, and three of them *i.e.* no. 7, 9 and 10 matched the same trend for seed index and one of them no.10 possessed the same trend for earliness and could be the best cross. These results are harmony with those obtained by Amir (1999), Hoveny *et al*., (2001), Mahmoud (2002), Abd El-Halim (2003), Tag El-Din (2015) and El-Sagheer (2019).

Table 12. Heterosis of 20 crosses as percentage from the better parent under two types of soil in 2020 and 2021 seasons.

No.	Genotype	Plant height (cm)				Days to 50% flowering			
		S		N		S		N	
		2020	2021	2020	2021	2020	2021	2020	2021
1	ICSA-88015 X Indian Exotic 27	-15.67**	-10.75**	-10.24**	-9.17**	8.98**	9.47**	3.72**	2.49**
2	ICSA-88015 X ICSV-112	1.44NS	2.2*	-5.25**	-7.45**	12.76**	11.93**	2.48**	1.24*
3	ICSA-88015 X ICSV-295	30.0**	29.45**	20.28**	19.38**	7.2**	9.35**	7.02**	8.23**
4	ICSA-88015 X RSH – 19	4.38**	4.52**	2.09**	0.33NS	0.39NS	0 NS	-0.82NS	-2.86**
5	ICSA-88015 X RSH-27	19.81**	18.68**	17.23**	19.32**	-10.62**	-10.37**	-15.36**	-17.28**
6	ATX -807 X Indian Exotic 27	3.02**	3.98**	7.43**	10.18**	3.23**	3.67**	-2.8**	-3.25**
7	ATX -807 x ICSV-112	22.58**	23.64**	17.42**	20.39**	1.61*	2.04**	-4.4**	-3.25**
8	ATX-807 x ICSV-295	9.11**	9.98**	13.2**	12.97**	-0.4NS	-0.41NS	-10.8**	-11.79**
9	ATX-807 x RSH – 19	7.93**	5.75**	1.81**	0NS	-1.97**	1.18NS	-3.2**	-1.22*
10	ATX-807 x RSH-27	27.57**	29.39**	21.73**	20.4**	-6.59**	-4.81**	-11.24**	-12.5**
11	ASH-15 X Indian Exotic 27	16.93**	16.46**	13.68**	17.47**	1.56*	0.39NS	-1.98**	-1.99**
12	ASH-15 X ICSV-112	38.0**	37.51**	27.44**	25.19**	-1.56*	-2.76**	-3.97**	-4.78**
13	ASH-15 X ICSV-295	9.83**	8.79**	5.17**	4.73**	-3.52**	-1.97**	-15.08**	-13.55**
14	ASH-15 X RSH – 19	0.46NS	-0.62NS	-2.07**	-1.48*	1.95**	1.18NS	-1.19*	-0.8NS
15	ASH-15 X RSH-27	13.9**	18.05**	15.41**	15.06**	-10.26**	-10.37**	-12.73**	-16.54**
16	ASH-20 X Indian Exotic 27	6.62**	6.42**	7.86**	7.3**	1.98**	2.44**	-4.38**	-3.64**
17	ASH-20 X ICSV-112	48.03**	48.26**	36.11**	41.2**	-3.57**	0.41NS	-9.16**	-5.67**
18	ASH-20 X ICSV-295	15.42**	16.39**	6.37**	7.75**	0.4NS	1.22NS	-3.19**	-2.02**
19	ASH-20 X RSH – 19	-3.97**	-1.44*	-5.27**	-4.81**	5.51**	3.53**	3.19**	3.64**
20	ASH-20 X RSH-27	14.7**	17.07**	16.33**	18.58**	-17.22**	-15.19**	-20.6**	-18.38**

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 12. Continue

No	Genotype	Panicle Length (cm)				Panicle width (cm)			
		S		N		S		N	
		2020	2021	2020	2021	2020	2021	2020	2021
1	ICSA-88015 X Indian Exotic 27	10.92**	30.46**	10.93**	10.08**	20.41**	28.97**	20.9**	28.74**
2	ICSA-88015 X ICSV-112	38.8**	43.66**	22.05**	12.03**	4.52NS	17.22**	3.31*	4.23**
3	ICSA-88015 X ICSV-295	-3.31*	3.17NS	-3.23*	-1.13NS	19.48**	23.29**	8.05**	12**
4	ICSA-88015 X RSH – 19	-6.5**	-3.53NS	-0.51NS	5.06**	8.05**	17.24**	5.75**	10.86**
5	ICSA-88015 X RSH-27	7.81**	10.19**	3.2*	2.77NS	4.32NS	9.09**	4.98**	3.41*
6	ATX -807X Indian Exotic 27	-7.28**	-0.4NS	-16.24**	-21.24**	18.06**	22.92**	14.69**	9.25**
7	ATX -807 x ICSV-112	6.22**	11.64**	20.94**	15.94**	20.65**	21.85**	20.99**	19.58**
8	ATX-807 x ICSV-295	-9.19**	-4.28*	-8.87***	-5.35**	9.74***	13.7**	17.96***	16**
9	ATX-807 x RSH – 19	21.22**	22.35**	27.77**	29.84**	28.86**	41.67**	31.74***	30.29***
10	ATX-807x RSH-27	49.58**	58.85**	42.07**	44.81**	4.32NS	7.49**	21.89**	19.51**
11	ASH-15 X Indian Exotic 27	33.52**	47.7**	20.9**	18.76**	21.53**	31.65**	35.03**	34.27**
12	ASH-15 X ICSV-112	28.15**	18.7**	18.9**	4.69**	17.42**	26.49**	22.1**	23.28**
13	ASH-15 X ICSV-295	-8.64**	-8.75**	-15.48**	-12.32**	8.44**	18.49**	-0.6NS	0NS
14	ASH-15 X RSH – 19	5.35**	1.37NS	-4.87**	-4.67**	6.04*	16.08**	10.24**	10.67**
15	ASH-15 X RSH-27	-0.79NS	7.32**	-12.18**	-9.52**	-7.03**	-11.23**	1.99NS	-1.95NS
16	ASH-20 X Indian Exotic 27	-8.9**	4.21*	-17.27**	-14.83**	-4.85NS	4.49NS	5.73**	10.22**
17	ASH-20 X ICSV-112	7.77**	19.19**	-8.03**	-0.76NS	-1.82NS	-0.64NS	3.12*	1.59NS
18	ASH-20 X ICSV-295	8.46**	12.85**	-5.15**	1.83NS	-7.27**	1.92NS	5.73**	9.68**
19	ASH-20 X RSH – 19	6.63**	8.63**	-5.76**	-7.8**	0.61NS	7.05**	1.04NS	8.06**
20	ASH-20 X RSH-27	5.68**	20.81**	-10.3**	-11.01**	-20.54**	-21.39**	2.49NS	0.98NS

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 12. Continue

No.	Genotype	1000-grain weight (g)				Grain yield per plant (g)			
		S		N		S		N	
		2020	2021	2020	2021	2020	2021	2020	2021
1	ICSA-88015 X Indian Exotic 27	-15.38**	-8.57**	-11.01**	-7.59**	4.62NS	14.1**	28.39**	26.67**
2	ICSA-88015 X ICSV-112	5.1**	2.38*	-7.39**	-5.05**	27.79**	30.1**	44.54**	45.21**
3	ICSA-88015 X ICSV-295	-15.38**	-10.25**	3.5**	8.25**	-40.99**	-38.27**	-13.91**	-11.89**
4	ICSA-88015 X RSH – 19	8.84**	4.42**	-2.72**	-1.4NS	7.14*	-1.73NS	-9.1**	-13.0**
5	ICSA-88015 X RSH-27	17.81**	15.7**	15.37**	6.67**	1.73NS	1.63NS	2.87NS	-4.99**
6	ATX -807 X Indian Exotic 27	-6.44**	1.96*	-6.98**	-5.99**	-9.55**	-2.61NS	-18.69**	-26.15**
7	ATX -807 x ICSV-112	13.12**	12.64**	5.98**	7.2**	10.7**	10.62**	43.66**	4.09**
8	ATX-807x ICSV-295	-23.8**	-20.99**	-22.69**	-21.5**	-6.09*	-3.2NS	-3.14NS	-3.46NS
9	ATX-807 x RSH – 19	9.85**	6.63**	1.76**	9.54**	40.49**	34.04**	35.99**	26.62**
10	ATX-807x RSH-27	4.96**	4.27**	10.42**	6.54**	29.46**	19.08**	46.17**	45.9**
11	ASH-15 X Indian Exotic 27	4.89**	8.08**	4.27**	1.53NS	30.78**	37.0**	36.83**	31.32**
12	ASH-15 X ICSV-112	-16.18**	-21.28**	-12.82**	-18.57**	1.86NS	13.16**	35.09**	47.27**
13	ASH-15 X ICSV-295	-7.45**	-0.36NS	2.33*	-3.88**	-9.17**	-10.13**	-11.51**	-8.68**
14	ASH-15 X RSH – 19	-4.85**	-4.29**	-18.59**	-20.51**	3.29NS	11.23**	15.29**	7.4**
15	ASH-15 X RSH-27	-4.07**	-7.16**	-4.17**	-6.84**	-16.73**	-24.78**	5.74**	2.65NS
16	ASH-20 X Indian Exotic 27	-17.64**	-14.2**	-3.27**	-7.08**	5.79NS	16.3**	-5.97**	-12.09**
17	ASH-20 X ICSV-112	-2.67**	-8.34**	1.52NS	-5.21**	3.05NS	9.08**	26.75**	33.82**
18	ASH-20 X ICSV-295	-8.89**	-14.96**	-12.73**	-13.75**	4.08NS	3.65NS	10.83**	16.93**
19	ASH-20 X RSH – 19	-19.95**	-17.79**	-0.98NS	-4.58**	-2.65NS	-1.3NS	11.8**	3.98*
20	ASH-20 X RSH-27	-5.97**	-11.17**	-9.49**	-13.23**	-3.22NS	-10.36**	9.63**	6.69**

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 12. Continue

No.	Genotype	% Total protein in grains			
		S		N	
		2020	2021	2020	2021
1	ICSA-88015 X Indian Exotic 27	7.72**	10.14**	7.28**	13.37**
2	ICSA-88015 X ICSV-112	13.52**	16.82**	13.46**	7.83**
3	ICSA-88015 X ICSV-295	-5.49**	-5.65**	-0.89NS	6.29**
4	ICSA-88015 X RSH – 19	37.58**	33.11**	28.98**	27.36**
5	ICSA-88015 X RSH-27	23.82**	18.1**	23.08**	23.34**
6	ATX -807 X Indian Exotic 27	35.05**	37.67**	31.99**	26.18**
7	ATX -807x ICSV-112	23.1**	26.73**	22.25**	19.84**
8	ATX-807x ICSV-295	-19.36**	-18.45**	-17.16**	-25.59**
9	ATX-807 x RSH – 19	33.01**	31.33**	30.43**	23.82**
10	ATX-807 x RSH-27	17.94***	16.62**	16.52**	15.27**
11	ASH-15 X Indian Exotic 27	20.58**	21.84**	31.96**	33.85**
12	ASH-15 X ICSV-112	-36.9**	-30.93**	-41.21**	-49.35**
13	ASH-15 X ICSV-295	14.45**	14.88**	24.85**	21.26**
14	ASH-15 X RSH – 19	11.62**	11.11**	-1.31NS	-12.5**
15	ASH-15 X RSH-27	-9.71**	-14.54**	-18.52**	-20.75**
16	ASH-20 X Indian Exotic 27	-9.32**	-6.48**	-12.11**	-18.01**
17	ASH-20 X ICSV-112	-21.41**	-18.62**	-26.37**	-33.42**
18	ASH-20 X ICSV-295	-16.18**	-16.67**	-19.82**	-20.96**
19	ASH-20 X RSH – 19	-20.88**	-19.93**	-31.06**	-32.19**
20	ASH-20 X RSH-27	-15.88**	-16.91**	-20.8**	-20.46**

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

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القدرة علي الائتلاف وقوة الهجين لبعض الهجن في محصول الذرة الرفيعة تحت ظروف الأراضي العادية والملحية

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الملخص

تم تقييم عدد 20 هجين من الذرة الرفيعة للحبوب و أبائهم (4 سلالات عقيمة ذكريا و 5 سلالات معيدة للخصوبة) والهجين التجاري شندويل - 306 للمقارنة وذلك لصفة محصول الحبوب وستة صفات أخري في محطة عرب العوامر بأسيوط وذلك خلال موسمي 2020 و2021 م تحت ظروف التربة العادية والتربة الملحية. وقد أوضحت نتائج التحليل المشترك وجود اختلافات عالية المعنوية بين الأرض العادية والأرض الملحية كذلك بين التراكيب الوراثية والتفاعل بين التراكيب الوراثية ومعاملات الملوحة لكل الصفات المدروسة. متوسطات التراكيب الوراثية تحت ظروف الأرض العادية أعلي منها تحت ظروف الأرض الملحية لكل الصفات محل الدراسة ما عدا صفة عدد الأيام حتى 50% تزهير من النباتات. التباين الراجع للسلالات والكشافات والتفاعل بينهما معنوي الي عالي المعنوية في معظم الصفات التي تم دراستها. متوسط الهجن أعلي من متوسط الاباء لجميع الصفات ما عدا صفة عدد الأيام لتزهير 50% من النباتات. كانت أفضل الاباء في القدرة العامة علي الائتلاف هي ICSV-112 و BTX -807 لصفة المحصول تحت كل البيئات (2 معاملات ملوحة x سنتين). الهجن المرغوبة بالنسبة للقدرة الأئتلافية الخاصة لصفة المحصول كانت

(ICSA-88015 X ICSV-112, ATX-807 x RSH–19, ATX-807 x RSH-27, ASH-15 x Indian Exotic 27 and ASH-20 x ICSV-295).

تحت كل البيئات . أفضل الهجن في قوة الهجين نسبة لأفضل الآباء هي :

(ICSA-88015 x ICSV-112 , ATX-807 x ICSV-112, ATX-807 x RSH–19, ATX-807 x RSH-27, and ASH-15 x Indian Exotic 27).

أفضل الهجن في محصول حبوب للنبات تحت ظروف الأرض الملحية و الأرض العادية هي :

(ATX-807 x RSH-27 and ASH-15 x Indian Exotic 27).