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HETEROSIS AND COMBINING ABILITY IN GRAIN SORGHUM UNDER SALINE CONDITION

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ABSTRACT

These exotic genotypes, (ICBA- 1,2,3,4 and 5) as well as Dorado as a local genotype of grain sorghum were crossed in a complete diallel cross system to produce F_1's. Parents and hybrids were evaluated in field traits in 2004 at Ras Sudr, South Sinai , Egypt under two irrigation water salinity levels i.e. 4000 and 7000 ppm. Mean squares due to parents were significant for all studied traits characters under both salinity levels. Data indicated that heterosis related to the better parents was manifested for all studied traits. The highest positive and significant heterosis for grain yield was 10.40% (ICBA-4 × ICBA-3) under 4000 ppm. However, -3,28 % (Dorado × ICBA-4) was the highest negative heterosis under 7000 ppm. ICBA-2 and ICBA-3 as well as the local variety Dorado had the highest positive and significant GCA effects for all the studied characters under low and high salinity levels. ICBA-1 × ICBA-2 was earliest for 50% heading under low salinity level. While, ICBA-5 × ICBA-4 was the best SCA effects under high salinity levels. ICBA-3 × ICBA-1 had the shortest plant SCA effects under low salinity 4000 ppm. However, ICBA-2 × ICBA-4 was preferred plant height SCA effects under high level 7000 ppm. Dorado × ICBA-5 had the tallest panicle length SCA effect under both salinity levels. Dorado × ICBA-3 was largest panicle width SCA effect under 4000 ppm. While, ICBA-5 × ICBA-4 was the best panicle width under 7000 ppm . Dorado × ICBA-4 and ICBA-3 were the heaviest grain weight for SCA effects under both salinity levels. However, ICBA-5 × ICBA-4 and Dorado × ICBA-4 were best crosses for grain yield/ plant SCA effects under 4000 and 7000 ppm respectively. SCA variance was more important than that of GCA for grain yield and its components.

The hybrids (ICBA-5 × ICBA-4) and the reciprocal (Dorado × ICBA-4) out yielded other tested hybrids under different environments and thus we recommend further testing of this hybrids in the evaluation traits in order to release. It was improved the commercial sorghum hybrids under saline condition and it use sorghum genotypes ICBA-3, 4 and ICBA-5 with the local variety i.e. Dorado.

Keywords: Sorghum, Grain, Heterosis, Hybrid, Crosses, Combining ability, Reciprocals.

INTRODUCTION

The major objective of grain [Sorghum bicolor L.Moench] breeders is to derive parental genotypes that will produce high yielding hybrids, while maintaining or improving other agronomic characters under saline conditions. Information on the relative importance of general and specific combining ability is of value in the development of efficient breeding programs in crop species which are amenable to commercial productions of F_1 hybrids seeds. Additional basic information is needed on heterosis in sorghum to aid the breeder in developing hybrids . The grain sorghum hybrids program starts with testing various parental genotypes for their combining ability and heterosis effect in order to identify the best ones on hybrids combinations.

Grain yield improvements in the small grain cereals have been achieved largely by increasing harvest index without a significant change in biomass (Ashraf 1994, Bahadouryia and Saxena 1997 and Bidinger *et al* 2003) , Sorghum hybrid produce more biomass as compared with their parents (Mostafa and El- Menshawi 2001). Heterosis in sorghum grain yield results mainly from heterosis expressed in a large number of kernels per panicle, mostly in the lower panicle branches. The large panicle in the hybrids is initiated earlier and develops faster than in its parents. Bahadouryia and Saxena (1997) found that heterosis for grain yield depended on heterosis for grains/panicle and panicle length. Hybrids were found to flower several days earlier than their parents. Al-Naggar *et al* (1999), Hovny *et al* (2001) and Mostafa and El-Menshawi (2001) used male sterile lines to produce hybrids, they reported that hybrids were earlier, taller, had higher 1000-grain weight and higher grain yield than their best parents. Andrews *et al*. (1997), Haussmann *et al* (1999), Hovny *et al* (2000) and Sayed (2003) were found that both grain sorghum and pearl millet F_1 single crosses whether were made by using cytoplasmic male sterility or by other ways were much better than their parental lines in grain yield, as well as, grain quality. They also reported the importance of early generation testing was to select for combining ability.

Combining ability in grain sorghum was studied by several workers using diallel analysis. Radwan *et al* (1997) , Haussmann *et al* (1999), Mostafa and El-Menshawi (2001), Hovny *et al* (2000) and Bidinger *et al*. (2003)] . These authors reported that in F_1 hybrids between eleven cytoplasmic male sterile lines and two restorer lines of grain sorghum appeared both additive and non additive gene effect were significant for grain yield, 1000- grain weight, plant height and leaf area and those reported that general (GCA) and specific (SCA) combing ability were important in the inheritance of grain yield and other related components in some crosses.

The objectives of this study were to estimates heterosis and combining ability for forage production and identify parents that could be used to improve hybrid genotypes under saline condition at Ras Sudr, South Sinai, Egypt because a forage breeding program under this respect may have to consider several desirable treats of genetic improvement for seed forage productivity under Egyptian desert to improve animal wealth. This investigation will discuss some growth and forage yield for parents and crosses to provide the greatest forage of sorghum productivity under saline condition throughout hybridization between exotic sorghum genotypes were more tolerant for salinity and its had best growth character and yield under saline condition when compared with the local genotypes and selections to get new crosses which more adapted salinity conditions each of soil or water irrigation .

MATERIALS AND METHODS

Five exotic of grain sorghum genotypes (*Sorghum Bicolor (L.) Moench*) from ICBA (International Center for Biosaline Agriculture) i.e. ICBA -1,2,3,4 and 5) were used in this study. These genotypes were differing in plant height, panicle length and all most growth characters and grain yield under saline condition and these results were deducted in summer season (2003) at Ras Sudr , South Sinai , Egypt and it were evaluated throughout program of improving salt tolerance, forage production system to salt project and their use two levels of salinity irrigation water at 4000 and 7000 ppm through plant life. The Dorado, local grain sorghum was used the check genotypes with the exotic genotypes in respective traits . Dorado , ICBA -1,2,3,4 and 5 were crossed in a complete diallel cross technique under saline conditions at Ras Sudr Station of the Desert Research Center (DRC) in (2004). Crosses were made by using hand and plastic bages emasculations and pollention techniques . Crossing was done by bagging the panicles both parents , Just before anthesis to prevent contamination from foreign pollen under low level of irrigation water salinity (4000 ppm) to produce F_1 seeds. Pollen were collected from each male parent and placed on the pollinated female panicles. Table (1) showed the name , pedigree, entry name and origin for six sorghum genotypes were used in this study.

The parents hybrids and their reciprocal crosses were evaluated in the field trail at Ras Sudr Research Station in (2005) under two irrigation water salinity levels i.e. 4000 and 7000 ppm through growing season . The experimental design was used a randomized complete block design under both salinity levels. Plot area was 3 m long and 2.8m width, 70 cm apart in rows were used , planting was done in hills of 20cm apart plant to plant. Thinning was done after three weeks of sowing (date of sowing was 2^{nd} June for each two experiments) by leaving two plants / hill, every plot was consisted four rows.

Table (1): Name, pedigree, origin and grain color for six sorghum genotypes were used

No	Name	Pedigree	Origin	Grain Color
P_1	ICBA -1	ICSV-1041	Indian	White
P_2	ICBA -2	ICSV-112	Indian	Red
3	ICBA -3	SP- 47529	Omani	Green
4	ICBA -4	ICSV.745	Sudan	Mixture
5	ICBA -5	ICSR – 93046	Syria	White
6	Dorado	ARC, Egypt	Egypt	Green

All other agronomic practices were done as recommended for grain sorghum production to evaluate and select the best genotypes under two levels of irrigation water salinity (4000 and 7000 ppm) using 6 parents and 15 crosses as well as, their reciprocals (15) to estimate some growth and yield characters. Growing season (2006), all parents and their F_1 crosses to produce F_2 seeds were used. The plot consisted of four rows, two rows for parents (P_1 and P_2) and two rows for F_1 for the same parents hybrids and their reciprocals under both salinity levels .

Data were recorded for days to 50% heading , plant height , panicle length, panicle width , 1000 grain weight and grain yield / plant. The randomize complete block design were used in each experiments. Analysis of variance was accorded by Steal and Torre (1980). Combining ability analysis for the crosses and their parental genotypes was carried out according to Griffing (1956).

Percentage of heterosis was determined using Singh and Chaudhary (1977) equation as following:

$$\text{Heterosis \%} = \frac{\bar{F}_1 - \overline{Bp}}{\overline{BP}} \times 100$$

Where $\bar{F}_1$ and $\overline{BP}$ are the means of the F_1 and better parent, respectively. Heterosis percentage exceeding the least significant (LSD) difference between two means of the better parent was considered significant.

RESULTS AND DISCUSSION

Average performance of all studied traits under two salinity levels 4000 and 7000 ppm of irrigation water at Ras Sudr, South Sinai Governorate, Egypt are presented in Table (2). Average performance of days to 50% flowering of the parents ranged from 100 days for Dorado to 103 days for ICBA-5 under the low salinity level of irrigation water (4000 ppm). While, under high salinity level (7000 ppm), average performance were ranged from 71.0 days for ICBA-1 to 74 days for ICBA-4. While, days of 50% flowering for the crosses ranged from 62.0 to 74.0 days, most crosses and their reciprocals were flowered earlier than the average of the parental genotypes except ICBA-2 × ICBA-4 (74 days) had later than that means for parental genotypes. Under low salinity level, average performance for plant height /plant of the parent ranged from 143 cm ICBA-5 to 187 cm ICBA-1. The range of the hybrids for plant height ranged from 132 cm ICBA-2 × ICBA-4 to 202 cm ICBA-1 × ICBA-3 and ICBA-3 × Dorado. While, the average performance of plant height for the reciprocals ranged from 132 cm ICBA-4 × ICBA-1 to 200 cm ICBA-4 × ICBA-2. Plant height of the parents ranged from 102 cm ICBA-3 to 126 cm for ICBA-4 and 125 cm for ICBA-5. The range of the hybrids for plant height ranged from 90 cm for cross ICBA-2 × ICBA-4 to 130 cm for cross ICBA-3 × ICBA-5. While, the plant height for the reciprocals ranged from 90 cm (ICBA-4× ICBA-1) to 162 cm for (Dorado × ICBA-4) under irrigation water salinity levels 7000 ppm . In general, most crosses and their reciprocals were taller than the parental genotypes mean of plant height for all crosses and their reciprocals (121 cm) were taller than mean average (118.2 cm) for the mean parental genotypes under low levels of irrigation water salinity 4000 ppm. These results were in agreement with that obtained by Mostafa and El-Menshawy (2001) and Mervat et al. (2003). Under low salinity irrigation water(4000ppm), panicle length of the parental genotypes ranged from 28cm ICBA-4 to 30 cm ICBA-1 and ICBA-5. Average performance of panicle length was the direct hybrid ranged from 27 cm ICBA-5 × Dorado to 31 ICBA-3 × ICBA-4. While, the reciprocals hybrids were ranged from 26 cm ICBA-4 × ICBA-2 to 32 Dorado × ICBA-1.

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Under high salinity level of irrigation water (7000 ppm), panicle length of the parental genotypes ranged from 19 cm (ICBA-3) to 23 cm for ICBA-2 and ICBA-5. Panicle length was the direct hybrids ranged from 20.0 cm (ICBA-1 × ICBA-2), (ICBA-1 × ICBA-4), and (ICBA-3 × ICBA-4) to 28 cm (ICBA-1 × ICBA-3).While, the reciprocals hybrids ranged from 20.0 cm by (ICBA-3 × ICBA-2) to 27 cm by (ICBA-4 × ICBA-1). The average performance of parental genotypes were the shortest panicle length than their crosses and reciprocals were noticed taller than parental genotypes under the same respective (7000 ppm). The panicle width was opposite ,whereas, the parental genotypes were larger than crosses and their reciprocals and its averages were 6.5 cm when compared the average 5.6 cm for the crosses and reciprocals. Sorghum is a moderately crop for salinity tolerance and these study showed that sorghum growth characters were decreased by increasing irrigation water salinity level from 4000 to 7000 ppm. We are notice decreasing in plant height, panicle length and panicle width and were preferred earliest for days of flowering and the shortest genotypes and their crosses under this respect.

Under low salinity level 4000 ppm, average performance of 1000 grain weight were ranged from 17.33 gm for Dorado to 31.00 gm for ICBA-5. While, the direct hybrids were ranged from 18.13 gm for ICBA-4 × Dorado to 28.93gm for ICBA-1 × ICBA-2, the reciprocal Dorado × ICBA-4 was the lowest weight of grain. While, Dorado × ICBA-3 was the heaviest weight of average performance for 1000-grain weight .Under high salinity level of water irrigation (7000 ppm),1000 –grain weight for the parental genotypes ranged from (20.37 gm) ICBA-2 to (26.5 gm) ICBA-5 with average 24.72 gm for them. While, mean average of 1000-grain weight for crosses and reciprocals were 26.80 gm. The direct crosses ICBA-2 × ICBA-3 (31 gm) and the reciprocal (Dorado × ICBA-4) (32 gm) were heaviest 1000-grain weight than the average of crosses and their reciprocals . These results showed that hybridization was improved the 1000-grain weight under saline conditions. Mostafa and El-Menshawi (2001), Bidinger *et al*. (2003), Mervat *et al*. (2003) and Sayed (2003) were deducted these results.

Under low salinity levels of water irrigation (4000 ppm), average performance of grain yield / plant of the parental genotypes ranged from 124.43 gm for ICBA-3 to 127.41 gm for ICBA-5. The performance average of hybrid ranged from 117.77gm for cross ICBA-2 × ICBA-4 to 135.9gm for cross ICBA-1 × ICBA-4 . While, the reciprocal ICBA-4 × ICBA-1 was the lowest value for grain yield / plant, (125.07 gm). However, Dorado × ICBA-4 was the heaviest value of grain yield /plant performance average (138.1 gm).Grain yield / plant of the parental genotypes was ranged from 122.4 gm for ICBA-4 to 128.5 gm for ICBA-5 with an average of mean parental genotypes (126.27 gm) under high level of irrigation water salinity. These results indicated that grain yield / plant was decreased by increasing salinity from 4000 up to 7000 ppm. Grain yield/plant for the crosses varied from 115.13 gm (ICBA-2 × ICBA-4) to 119.70 gm (ICBA-1 × Dorado). Most of the crosses were lower grain yield / plant than the average of the parental genotypes under high level of salinity, grain yield / plant of the reciprocal crosses ranged from 115.33 gm (Dorado × ICBA-1) to 119 gm (Dorado × ICBA-5). Also, the reciprocal hybrids had lower grain yield than the parental average. These results were took the same ways for the same respect under the low levels of salinity (4000 ppm) where Dorado × ICBA-4 or ICBA-5 were heaviest grain yield/ plant. The results showed that sorghum genotypes and crosses were moderately salinity tolerant and therefore it was recommended to use the selection methods for improving sorghum grain yield/plant, This agreed with Ashraf (1994) , Al- Naggar *et al*. (1999) , El-Bakry *et al*. (2000), Hovney (2000) , Ali *et al*. (2001), Bidinger *et al*. (2003), Mervat *et al*. (2003), Bakheit *et al* (2005) , Hassaballa *et al*. (2005) and Soliman (2005) whose obtained the differences between genotypes.

Finally these results revealed that the crosses (ICBA-1 × ICBA-4) and the reciprocal (Dorado × ICBA-4 or ICBA-5) had the high yielding ability suggesting that most of crosses were earlier flowering , heaver grain weight and the highest grain yield / plant than their parents under saline condition and it was used the selection criteria under this respect.

Heterosis effects

Heterosis percentage estimates for 30 hybrids under irrigation water salinity levels i.e. (4000 and 7000 ppm) at Ras Sudr, South Sinai, Egypt, for the studied traits are presented in Table (3).

Under low irrigation of water salinity levels (4000 ppm), heterosis percentage as better parents were estimated and manifested for days to 50% heading, the cross ICBA-5 × Dorado and the reciprocal Dorado × ICBA-3 were earlier for heading. While, the cross ICBA-2 × ICBA-4 and the reciprocal ICBA-4 × ICBA-1 were shorter than the better parent heterosis for plant height. Whereas, for panicle length, the cross (ICBA-3 × ICBA-4) and reciprocal Dorado × ICBA-3 were taller than that heterosis percentage of better parents. The cross (ICBA-2 × ICBA-5) and eight crosses were the best heterosis percentage and the reciprocal (Dorado × ICBA-2) were highly significant and positive heterosis percentage for panicle width. However, the cross (ICBA-3×Dorado) and this reciprocal (Dorado × ICBA-3) were heavier than grain weight, for grain yield / plant, the cross (ICBA-1 × ICBA-4 and ICBA-4 × Dorado and their reciprocal Dorado × ICBA-4 had higher grain yield/ plant than the respective better parents under the same order. The best estimate of heterosis under low irrigation water salinity was 14.56 % for earliness (Dorado × ICBA-3), 29.41% for plant height (ICBA-4 × ICBA-1) 6.59% for panicle length , (ICBA-3 × ICBA-4) 16.67 for panicle width (Dorado × ICBA-2), 100.69% for 1000-grain weight (Dorado × ICBA-3) 10.4% for grain yield (ICBA-1 × ICBA-3).

Under high salinity level of irrigation water (7000 ppm) heterosis percentage estimates for number of days to heading were negative and highly significant for all the hybrids except (ICBA-2 × ICBA-3) was positive and not reach the significant. For plant height, seventeen crosses showed positive and significant heterosis values while thirteen crosses showed negatives significant ones.

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The highest heterosis percentage preferring for plant height (-28.57%) was shown by (ICBA-2× ICBA-4). For panicle length, seventeen crosses showed positive and significant value of heterosis, the tallest panicle length heterosis (38.09%) was shown by the cross (ICBA-3× Dorado). For panicle width four crosses showed positive and significant heterosis percentage, the largest panicle width heterosis (33.33%), while fifteen crosses showed negative and significant was exhibited by the cross (ICBA-4 × ICBA-3), heterosis percentage for 1000-grain weight under high salinity level were positive and significant for nineteen crosses, the heaviest positive value was 100.69% for the cross (Dorado × ICBA-3. For grain yield/plant heterosis percentage under high salinity level, ranged from --9.99% to 0.05 % . The highest estimate of heterosis for grain yield was -0.054% for the cross ICBA-2× ICBA-3 and -9.99% for (Dorado × ICBA-1).

In general, heterosis above the better parent in this study was manifested for all studied traits. The existence of heterosis for different characters in grain sorghum crosses using varietal crosses had been demonstrated by several workers (Pillal *et al*. (1995), Al-Naggar et al. (1999) , El-Bakry *et al*. (2000), Bidinger *et al*. (2003), Bakheit *et al*. (2005) and Soliman (2005). Most of these workers reported significant magnitudes of heterosis for grain yield and its components. Finally four crosses (ICBA-2 × ICBA-3), -0.05%, (Dorado × ICBA-4) -3.28% for grain yield of sorghum under salinity level 7000 ppm thus, it could be use the crosses (ICBA-3 × ICBA-4) and (ICBA-3 × Dorado) were the best parents in hybridization in sorghum under saline condition to produce the best crosses for improving sorghum. In addition to, exhibiting the highest heterosis percentage , these two crosses are also amongst the highest yielding genotypes under this respect. These crosses are recommended for further large scale studies for yielding and other traits performance before releasing as new variety. These results were in harmony with those obtained by Ali *et al*. (2001), Moustafa and El-Menshawi (2001), Bidinger *et al*. (2003), Presterl and Weltizem (2003), Bakheit *et al.* (2005) and Soliman (2005).

Analysis of Variance

Analysis of variance for studied traits under salinity level of irrigation water (4000 and 7000 ppm) and these reciprocals were presented in Table (4). Highly significant mean squares due to genotypes, crosses, parents *vs* crosses were observed for all studied traits under both salinity irrigation water levels. These results are in agreement with those obtained by Andrew *et al*.(1997), Radwan *et al*. (1999), Hovny *et al.* (2000) , Ali *et al*. (2001) , Siles *et al*. (2004) and Bakheit *et al*. (2005)

Mean squares from the analysis of variance indicated the presence of significant variance due to GCA and SCA for all the studied traits. The significance of the reciprocals indicated the presence of maternal effects. The ratio of GCA / SCA were ranged from (3.8) for flowering days to (3.02) for plant height and (29.7) for panicle length to (1.63) for panicle width, as well as (6.14) for 1000-grain weight and 2.05 for grain yield/ plant and the result of GCA/ SCA ratio indicating that additive gene effect was controlled in inheritance of all studied traits under high levels of irrigation water salinity

(7000 ppm). These results were deducted to improve sorghum under saline condition using selection methods after hybridization. Mervat *et al*. (2003) and Soliman (2005). They are noticed the same results under normal conditions.

General combining ability effects (GCA)

The GCA effects of the parental genotypes for the studied traits under two salinity levels of irrigation water (4000 and 7000 ppm) at Ras Sudr conditions were presented in Table (5).

For 50% heading days, GCA effects appeared significantly negative for the genotypes (ICBA-3), While, GCA effect was significantly positive for ICBA-1 and ICBA-2 and these true was observed under low salinity level 4000 ppm. However, under high salinity level 7000 ppm, GCA effect was significantly negative for ICBA-2 and ICBA-5. However, ICBA-1 was appeared significantly positive GCA effects if compared with the other parents, these results for GCA effects indicated their earlier flowering crosses under saline conditions. For plant height, negative GCA effects and significant were exhibited by genotypes ICBA-3, and Dorado,

Under both irrigation water salinity levels 4000 and 7000 ppm. positive and significant GCA effects was recorded by ICBA-1 under low salinity level . While, ICBA-2 and ICBA-5 under high salinity level and these results were indicated that preferred the shortest plant under saline condition. ICBA-2 was significantly positive GCA effects for panicle length under both irrigation water salinity levels, while, ICBA-1 was negative and significant GCA effect under this respect. Dorado and ICBA-5 were contrasted between positive and negative significantly GCA effects for panicle length by increasing salinity in irrigation water from 4000 to 7000 ppm. For panicle width, GCA effects were differed for all parents used under both irrigation water salinity levels 4000 and 7000 ppm except Dorado genotypes was negative GCA effect under both levels, but it was not reached to significantly. For 1000 grain weight, Dorado was positive and significant GCA effect under low salinity level. However, ICBA-3 positive and significant GCA effect under high salinity level, and the GCA effects for other genotypes under this study were contrasted under both irrigation water salinity levels 4000 and 7000 ppm. Al-Naggar et al (1999), El-Bakry et al. (2000), El-Hosary et al. (2004), El-Menshawi and El-Bakry (2004) and Hassaballa (2005). They found that GCA effects for growth and yield of sorghum character were differed under drought and normal environments. However, Haussmann (1999) was found grain yield / plant GCA effect was positive and significant under the arid and semi arid area.

For grain yield / plant, ICBA-1, ICBA-2 and ICBA-5 were negative and highly significant GCA effects under both irrigation water salinity levels. While, ICBA-3 was positive and significantly under the same respect. However, Dorado was differed GCA effect from positive significantly under low salinity to negative significantly under high salinity level.

These results are in agreement with those obtained by Hovny (2000), Hovny *et al.* (2000), Bidnger *et al*. (2003) , Mervat *et al*. (2003) and Abo- El-Wafa *et al*. (2005).

In general, ICBA- 3 and ICBA-4 showed the highest significant GCA effects for grain yield indicating that these genotypes are good combiners for increasing grain yield of their hybrids under saline condition.

Specific Combining Ability (SCA).

Estimates of SCA effects are presented in Table (6) under 4000 ppm, significant negative SCA effects were observed in nine crosses for days to 50% heading and plant height respectively, as well as, five crosses for panicle length, four crosses for panicle width, eight cross for 1000-grain weight and nine crosses for grain yield under low salinity irrigation levels 4000 ppm, eight crosses for panicle length, two crosses for panicle width, nine crosses for 1000-grain weight and seven crosses for grain yield. Under high salinity irrigation level 7000 ppm and nine crosses for plant height, 50% heading days shown by the crosses (ICBA-3× ICBA-4), (ICBA-4 × ICBA-5) and (Dorado × ICBA-4). Whereas, the other hybrids and their reciprocals were differed with increasing water salinity in irrigation from 4000 to 7000 ppm. For specific combining ability (SCA) where, some crosses were positive the results appeared some others were negative. However, the third parts of crosses were not reached the significantly each of positive or negative and these were true under both salinity levels , respectively.

Under high level of irrigation water salinity, the favorable significant SCA effect were shown by cross ICBA-2 × ICBA-4 for 50 % heading days, ICBA-4 × Dorado for plant height , ICBA-1 × ICBA-5 for panicle length, and panicle width. While, the cross Dorado × ICBA-3 for 1000- grain weight and ICBA-4 × Dorado cross for grain yield / plant and these results showed that both GCA and SCA were important in the inheritance of grain yield and its components. This result was harmony with that obtained by Haussmann *et al* (1999), Hovney *et al* (2000), Presterl and Weltziem (2003), Sayed (2003), Mervat *et al*. (2003), Bakheit *et al*. (2005), Hassaballa *et al* (2005) and Soliman (2005) who pointed out that SCA effects of considerable magnitude and important in the inheritance of grain yield and its components.

In conclusion, the ICBA-1, 2 and 3 were a good combiner with the female line Dorado and ICBA-4 .Moreover, the parental lines (males) used in this study had the ability to restorer fertility of the hybrids and could be used commercially in hybrid seed production on grain Sorghum under saline condition through the hybridization and selection methods to improve crops of forage under this respect in summer season by using radish water and soil such as Ras Sudr region- South Sinai, Egypt.

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تقدير قوة الهجين وقدرة الائتلاف لمحصول الذرة الرفيعة للحبوب

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أجريت هذه الدراسة لتقدير قوة الهجين والقدرة العامة والخاصة علي التآلف لعدد ٣٠ هجين من السورجم وذلك بمحطة بحوث رأس سدر – جنوب سيناء التابعة لمركز بحوث الصحراء خلال أعوام ٢٠٠٤ وحتى ٢٠٠٥ / ٢٠٠٦ وذلك بالتهجين الدائري بين ٥ آباء مستوردة من المركز الدولي للزراعات الملحية ICBA والصنف المحلي دورادو Dorado خلال الموسم الزراعي ٢٠٠٤ وتم تقييم الهجن والآباء في تصميم قطاعات كاملة العشوائية تحت مستويين من ملوحة مياه الري خلال عام ٢٠٠٥ وتم تسجيل النباتات لبعض الصفات مثل ميعاد الطرد ٥٠% من السنابل ، طول النبات ، طول الداليات (السنابل) وقطر أو عرض الداليات (السنابل) ، وزن ١٠٠٠ حبة ، محصول الحبوب / نبات

ويمكن تلخيص أهم النتائج كما يلي :-

- متوسط مجموع المربعات لمعظم الصفات المدروسة كان معنوياً تحت مستوى الملوحة ٤٠٠٠ و ٧٠٠٠ جزء في المليون.
- كان التأثير المضيف وغير المضيف دوراً هاماً في توريث كافة الصفات تحت الدراسة كما كان التأثير الأبوي دوراً في اختلاف السلوك الوراثي للهجن حيث تباينت الصفات في سلوكها الوراثي ما بين الهجن المباشرة والعكسية تحت مستويات الملوحة المختلفة .
- كانت قوة الهجين سالبة ومعنوية في معظم الصفات المدروسة تحت ظروف الملوحة وكان الهجين العكسي ICBA-4×ICBA-3 أحسن الهجن في المحصول تحت ظروف الملوحة المنخفضة حيث كان معنوياً وموجباً بينما الهجين ICBA-4 × Dorado أحسن الهجن في محصول الحبوب تحت ظروف الملوحة المرتفعة
- كانت قوة الهجين معنوية وسالبة لمعظم الصفات وعلي وجه الخصوص محصول الحبوب للنبات ،وكان الهجين Dorado ×ا ICBA-1 أحسن تحت ظروف الملوحة المنخفضة بينما كان الهجين ICBA-3 × ICBA-5 أحسن تحت الملوحة العالية .
- كانت الآباء ICBA-1 ، ICBA-2 ، ICBA-4 أحسن الآباء في التهجينات مع الصنف المحلي دورادو وذلك في الحبوب أو في صفات النمو المدروسة.
- أوضحت النتائج أن التأثير المضيف كان فعالاً لكل الصفات تحت الدراسة حيث كانت نسبة القدرة العامة للخاصة أكبر من الوحدة في كل الصفات وكانت أحسن الصفات للهجن ICBA-5 × ICBA-1 ، ICBA-4 × ICBA-5 ، ICBA-3 × Dorado في حين كان الهجين ICBA-1 × ICBA_5 والهجين العكسي ICBA-3 × ICBA-5 أحسن في قدرته الخاصة علي التآلف تحت ظروف الملوحة المرتفعة مما يعكس بوضوح أن تحسين وإنتاج هجن تجارية من السورجم تحت ظروف الملوحة يتم من خلال التهجينات ثم الانتخاب .

قام بتحكيم البحث

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Table 2: Average performance of six parental genotypes of sorghum and their 30 hybrids for grain yield and its attributes under two levels of irrigation water salinity 4000 and 7000 ppm at Ras Sudr.

Genotypes	50% days		Plant height		Panicle length		Panicle width (cm)		1000 grain weight		Grain yield	
	4000	7000	4000	7000	4000	7000	4000	7000	4000	7000	4000	7000
ICBA-1	101	71	187	122	30	22	6	7	23.00	26.47	127.30	128.13
ICBA-2	101	73	172	119	29	23	6	6	30.67	20.37	126.47	126.13
ICBA-3	102	72	175	102	29	19	7	6	20.33	24.37	124.43	123.60
ICBA-4	100	73	144	126	28	22	7	6	26.00	22.93	126.20	122.40
ICBA-5	103	74	143	125	30	23	7	7	31.00	26.50	127.41	128.50
Dorado	100	72	175	115	29	21	6	6	17.33	24.17	125.83	123.03
Mean of parental lines	101.2	72.5	166	118.2	29.2	21.7	6.3	6.5	24.14	24.72	125.35	126.27
ICBA-1 × ICBA-2	92	70	191	129	29	20	6	5	28.93	24.00	128.46	116.03
ICBA-1 × ICBA-3	98	71	202	128	30	28	6	5	28.60	28.00	129.30	117.32
ICBA-1 ×ICBA-4	101	72	162	114	30	20	7	5	25.30	26.00	135.90	117.63
ICBA-1 × ICBA-5	94	70	194	106	29	26	7	5	27.8	27.00	135.30	116.75
ICBA-1 × Dorado	102	71	147	104	29	26	6	6	28.03	30.00	132.17	119.70
ICBA-2 × ICBA-3	101	70	172	129	29	26	6	6	28.16	31.00	130.23	117.10
ICBA-2 × ICBA-4	104	74	132	90	29	21	6	5	25.43	18.00	117.77	115.13
ICBA-2 × ICBA-5	99	69	164	99	30	23	7	4	25.51	26.4	118.00	117.00
ICBA2 × Dorado	96	71	185	125	28	24	6	6	27.23	28.00	135.73	119.17
ICBA-3 × ICBA-4	100	68	191	129	31	20	6	6	25.40	25.00	128.40	117.07
ICBA-3 × ICBA-5	99	69	188	130	30	24	6	5	24.4	27..14	129.0	116.90
ICBA-3 × Dorado	102	67	202	128	30	29	7	6	25.90	30.00	135.77	115.23
ICBA-4 × ICBA-5	105	68	198	129	28	23	6	6	26.4	25.41	129.50	115.90
ICBA-4 × Dorado	95	69	162	114	29	21	7	6	18.13	20.00	135.57	116.70
ICBA-5 × Dorado	88	65	164	110	27	24	7	5	19.90	25.40	131.50	117.00
ICBA-2 × ICBA-1	101	62	147	104	30	26	6	4	27.53	28.00	129.67	116.23
ICBA-3 × ICBA-1	98	69	172	129	30	24	6	4	26.33	27.00	125.63	116.00
ICBA-4 × ICBA-1	104	68	132	90	29	27	7	7	25.33	30.00	125.07	116.33
ICBA-5 × ICBA-1	102	67	140	91	30	25	7	7	27.10	28.00	127.10	115.90
Dorado × CBA-1	101	63	185	125	32	21	6	6	29.37	26.00	129.97	115.33
ICBA-3 × ICBA-2	92	69	177	127	30	20	7	5	28.03	22.00	128.60	117.20
ICBA-4 × ICBA-2	86	69	200	132	26	26	5	6	27.30	26.00	123.57	116.87
ICBA-5 × ICBA-2	191	68	184	130	27	24	6	4	26.00	25.00	130.10	117.00
Dorado × ICBA -2	92	70	183	141	28	23	7	6	27.87	24.00	138.47	116.07
ICBA-4 × ICBA-3	83	64	198	117	30	24	6	8	25.87	28.00	139.33	117.43
ICBA-5 × ICBA-3	84	65	190	120	31	23	7	8	31.50	29.11	132.10	117.00
Dorado× ICBA-3	82	62	173	128	31	22	6	7	40.80	29.00	134.10	117.10
ICBA-5 × ICBA-4	85	64	166	127	29	24	5	7	29.10	30.00	131.00	118.80
Dorado× ICBA-4	85	65	197	162	31	25	7	7	22.40	32.00	138.10	119.00
Dorado× ICBA-5	84	66	187	124	30	26	8	6	25.10	30.00	128.00	119.00
Mean of hybrids	95	70.0	176	121	29.4	24	6.2	5.6	26.9	26.8	130.50	127.00

Table (3) : Heterosis percentage of the better parent of 30 hybrids for grain yield and its attributes under irrigation water salinity (4000 and 7000 ppm) at Ras Sudr.

Hybrids	50% heading (days)		Plant height(cm)		Panicle length(cm)		Panicle width (cm)		1000 - grain weight (gm)		Grain yield / plant	
Salinity level	**4000**	**7000**	**4000**	**7000**	**4000**	**7000**	**4000**	**7000**	**4000**	**7000**	**4000**	**7000**
ICBA-1 × ICBA-2	-8.91**	-4.11**	2.14**	5.74**	-3.33**	-13.04**	0.00	-28.57**	-174.0**	-9.33**	0.91	-9.44**
ICBA-1 × ICBA-3	-2.97**	-2.74*	8.02**	4.92**	0.00	17.86**	-14.29**	-28.57**	24.35**	5.78**	1.57	-8.44**
ICBA-1 × ICBA-4	0.00	-1.37	-13.37**	-9.52**	0.00	-9.09**	0.00	-28.57**	-18.39**	-1.78**	6.76**	-8.19**
ICBA-1 × ICBA-5	-6.93**	-4.11**	3.74**	-15.20**	-3.33**	13.04**	0.00	-28.57**	-10.32**	1.89	6.19**	-9.14**
ICBA-1 × Dorado	0.99	-2.74*	-21.39**	-14.75**	-3.33**	13.04**	0.00	-14.29**	21.87**	13.34**	3.83*	-6.58**
ICBA-2 × ICBA-3	-0.98	-2.74*	-1.71	8.40**	0.00	13.04**	-14.29**	0.00	-8.18**	27.21**	4.72**	-0.05
ICBA-2 × ICBA-4	2.97	1.37	-23.26**	-28.57**	0.00	-8.69**	-14.29**	16.67**	-17.09**	-21.50**	2.97*	-7.16**
ICBA-2 × ICBA-5	-3.88**	-6.75**	-4.65**	-20.80**	0.00	0.00	0.00	-57.14**	-17.71**	-0.38	-7.57**	-10.40**
ICBA2 × Dorado	-4.95**	-2.74*	5.71**	5.04**	-3.45**	4.35**	0.00	0.00	-11.22**	15.85**	-6.70**	-7.27**
ICBA-3 × ICBA-4	-1.96*	-8.11**	9.14**	2.38*	6.89**	-9.09**	-14.29**	0.00	-2.31*	2.59*	7.55**	-3.58**
ICBA-3 × ICBA-5	-3.39*	-6.76**	7.43**	4.00**	0.00	4.35**	-14.29**	-28.57**	-21.29**	2.42*	0.78	-9.02**
ICBA-3 × Dorado	0.00	-6.94**	15.43**	11.30**	3.45**	38.09**	0.00	0.00	27.40**	23.29**	5.52**	-6.77**
ICBA-4 × ICBA-5	1.94*	-8.11**	37.50**	2.38*	-6.67**	0.00	-14.29**	-14.29**	-14.84**	-4.11**	1.68*	-9.81**
ICBA-4 × Dorado	-5.00**	-5.48**	-7.43**	-9.52**	0.00	-4.55**	0.00	0.00	-30.27**	-17.25**	7.42**	-9.18**
ICBA-5 × Dorado	-14.56**	-12.16**	-6.29**	-12.00**	-10.00**	4.35**	0.00	-28.57**	-35.81**	-4.15**	3.21*	-8.95**
ICBA-2 × ICBA-1	0.00	-15.07**	-21.39**	-14.75**	0.00	13.04**	0.00	-42.86**	-10.24**	5.78**	1.86*	-9.28**
ICBA-3 × ICBA-1	-5.10**	-4.17**	-8.02**	5.74**	0.00	4.43**	0.00	-28.57**	14.48**	2.00*	-1.31	-9.47**
ICBA-4 × ICBA-1	2.97*	-6.85**	-29.41**	-28.57**	3.33**	22.73**	0.00	0.00	-2.58*	13.34**	-1.75*	-9.21**
ICBA-5 × ICBA-1	-0.97	-9.46**	-25.13**	-27.20**	0.00	8.70**	0.00	0.00	-12.58**	5.67**	-0.24	-9.81**
Dorado × ICBA-1	0.00	-12.50**	-1.07**	2.46*	3.33**	-4.54**	0.00	-14.29**	27.70**	-1.76*	2.10*	-9.99**
ICBA-3 × ICBA-2	-9.80**	-5.48**	1.14	6.72**	3.45**	-13.04**	0.00	-16.67**	-8.61**	-9.73**	1.90*	-5.07**
ICBA-4 × ICBA-2	-14.85**	-5.48**	16.28**	4.76**	-10.34**	13.04**	-28.57**	0.00	-10.99**	13.39**	-2.29*	-7.34**
ICBA-5 × ICBA-2	5.83**	-8.11**	6.98**	4.00**	-10.00**	4.35**	-14.29**	-42.86**	-16.13**	-5.67**	2.11*	-8.95**
Dorado × ICBA-2	-8.91**	-4.11**	4.57**	18.49**	-3.45**	0.00	16..67**	0.00	-9.13**	-0.70	9.49**	-7.97**
ICBA-4 × ICBA-3	-18.63	-12.33**	13.14**	-7.14**	3.45**	9.09**	-14.29**	33.33**	-0.50	14.90**	10.40**	-4.99**
ICBA-5 × ICBA-3	-18.47**	-12.16**	8.57**	-4.00**	3.33**	0.00	0.00	14.29**	1.61*	9.85**	3.68*	-8.95**
Dorado × ICBA-3	-19.61**	-13.89**	-1.14**	11.30**	8.90**	4.76**	-14.29**	16.67**	100.69**	18.99**	6.57**	-8.51**
ICBA-5 × ICBA-4	-17.48**	-13.51**	15.28**	0.79**	-3.45**	4.35**	-28.57**	0.00	-6.13**	13.21**	2.82*	-7.55**
Dorado× ICBA-4	-15.00**	-10.96**	12.57**	28.57**	3.33**	8.70**	0.00	0.00	-27.74**	20.75**	9.43**	-3.28*
Dorado× ICBA-5	-18.45**	-10.81**	6.86**	-0.81	0.00	13.04**	14.29**	-14.29**	-19.03**	13.21**	0.46	-7.39**

***and ** indicate significant at 5 and 1 % probability level, respectively.**

Table 4: Analysis of variance of sorghum for combining ability for yield and its attributes of sorghum under two salinity levels 4000 and 7000 ppm at Ras Sudr.

S.O.V	d.f	50% heading (days)		Plant height		Panicle length (cm)		Panicle width (cm)		1000-grain weight (g)		Grain yield (ard/ fed)	
		4000	7000	4000	7000	4000	7000	4000	7000	4000	7000	4000	7000
Replication	2	3.18	4.50	13.7	17.16	2.37	3.51	0.70	1.07	3.17	4.80	20.18	14.17
Genotypes	35	5.90**	7.16**	1399.1**	145**	130.3**	144.4	1.99**	2.41	40.59**	51.7*	845.1**	771.4**
GCA	5	4.80**	17.16**	1245.3**	171.1**	147.2**	170.8	2.10**	5.71	41.77**	46.7**	541.7**	645.1**
SCA	15	2.51**	4.51**	66.4**	56.7**	4.77**	5,76	0.70**	3.51	5.10**	7.61	205.1**	314.6**
Reciprocal	15	4.84*	6.88*	440.7*	341.0**	35.6**	40.1	0.33**	1.66	7.76**	4.71	244.4**	350.1**
Residual	70	2.55	7.11	10.00	8.10**	3.30	3.1	0.41	2.51	1.55	2.00	24.11	26.6
GCA/ SCA	--	1.91	3.8	18.75	3.02	30.86	29.7	3.00	1.63	8.19	6.14	2.64	2.05

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

Table 5 *:* General combining ability effects of sorghum traits under salinity of irrigation water (4000 and 7000 ppm) at Ras Sudr, South Sinai, Egypt.

Parent	50% heading (days)		Plant height (cm)		Panicle length (cm)		Panicle width (cm)		1000-grain weight (gm)		Grain yield (ard/fed)	
	4000	7000	4000	7000	4000	7000	4000	7000	4000	7000	4000	7000
ICBA-1 P_1	3.94**	3.6**	9.78**	-14.84**	-0.46**	-0.43**	0.43*	-0.18	-0.30*	0.21	-0.74**	-0.84**
ICBA-2 P_2	4.75**	-1.75*	3.84*	12.31**	0.54**	0.78**	-0.19*	0.16	-0.25	-1.78**	-1.00**	-1.34*
IACBA-3 P_3	-8.68**	-1.32	-5.93*	-5.41*	-0.32*	0.05	0.62**	-0.08	-0.56**	1.54**	1.27*	2.19**
ICBA-4 P_4	0.41	-0.27	-3.79	3.75	1.28**	0.20	0.18	0.13	0.27	-0.37	0.16	3.48**
ICBA-5 P_5	-0.52	-0.67*	3.31	7.14**	-3.38**	0.59*	-0.41**	0.11	-3.05**	0.18	-0.37*	-2.19**
Dorado P_6	0.14	0.70	-7.30**	-10.88**	2.17**	-1.19**	-0.19	-0.22*	2.17**	0.19	0.46**	-1.33**
S.E. (gl – gi)	0.87	0.59	3.87	4.09	0.51	0.44	0.40	0.26	0.68	0.62	0.34	0.81

Table 6: Specific combining ability effects of sorghum characters under salinity of irrigation water (4000 and 7000 ppm) at Ras Sudr.

Genotypes	50% heading (days)		Plant height		Panicle length (cm)		Panicle width (cm)		1000-kernel weight (g)		Grain yield (ard/ fed)	
	4000	7000	4000	7000	4000	7000	4000	7000	4000	7000	4000	7000
ICBA-1 × ICBA-2	-6.38**	-0.195*	8.56**	15.21**	0.24	-0.68*	-0.35	-0.48*	0.52	1.27*	-1.47**	1.16*
ICBA-1 × ICBA-3	-1.05	-1.17*	3.67	13.66**	-2.98**	1.42**	-0.24	0.08	0.30	1.23*	1.47**	0.54
ICBA-1 × ICBA-4	0.95	-1.62*	-5.22*	-5.46*	-0.54	1.76*	0.24	0.19	3.30*	1.32*	1.00**	0.10
ICBA-1 × ICBA-5	0.84	1.70*	-4.5	-6.5	1.41	3.4	1.53	1.71	2.21	0.99	0.71	1.00
ICBA-1 × Dorado	2.73**	2.49**	-5.22*	-11.45**	1.35*	-0.34	0.65*	0.08	1.63*	0.67	1.64**	-0.51
ICBA-2 × ICBA-3	3.63**	0.16	14.11**	11.98**	2.57**	-0.46	0.43	0.08	2.02*	-3.80**	-0.37	1.09*
ICBA-2 × ICBA-4	2.51**	1.94**	0.28	-39.68**	-2.76**	-0.46	-0.57*	-0.14	-8.32**	0.83	-2.42**	-8.50**
ICBA-2 × ICBA-5	3.17**	1.11	3.51	11.66	3.16	2.11	-1.11	1.81	3.41	1.6	2.11	0.41
ICBA-2 × Dorado	-2.38**	0.16	12.11**	20.56**	2.13*	-1.24**	0.32	0.19	0.52	-1.42*	0.86*	6.10**
ICBA-3 × ICBA-4	0.48	0.52	0.94	-0.08	-0.67	0.42	1.08**	-0.05	1.47*	-0.31	1.31*	1.09*
ICBA-3 × ICBA-5	4.70**	0.50	2.14	-7.11	2.00	3.00	2.11	1.80	2.00	4.00	1.55	2.14
ICBA-3 × Dorado	2.14**	-0.03	5.05*	-9.30**	2.44**	1.19**	0.52*	-0.51	2.25*	0.38	-0.91*	7.60**
ICBA-4 × ICBA-5	1.51*	0.0	3.11	4.76	1.55	2.11	1.71	2.00	1.88	1.10	1.99	3.51
ICBA-4 × Dorado	-5.86**	0.52	-0.84	5.59*	-1.11	-0.81	0.52*	-0.05	-3.41*	-3.89*	0.91*	\0.27
ICBA-5 × Dorado	-3.15*	1.88*	-1.71	3.51	4.71	0.00	1.00	1.77	2.51	0.77	3.00	1.41
ICBA-2 × ICBA-1	0.59	-2.37**	11.16**	-2.63	-0.22	-0.25	-159**	0.17	-0.41	2.14*	-0.88*	-3.11**
ICBA-3 × ICBA-1	-0.52	3.63**	-11.17**	-9.30**	-0.67	-0.37	-1.14**	-0.16	-1.63*	-3.69*	0.28*	-3.06**
ICBA-4 × ICBA-1	1.37*	0.75*	0.05	30.69**	0.2**	-1.37**	0.52*	-0.05	3.59**	2,69	0.52*	-0.70
ICBA-5 × ICBA-1	1.51*	1.11	2.51	19.71	1.7	1.00	-2.00	0.66	2.11	2.11	1.44	-1.00
Dorado X ICBA-1	1.80*	-3.03**	-5.17	-14.97**	-1.78*	1.19**	0.07	-0.38*	-1.86*	2.67*	-1.22**	-2.16**
ICBA-3 × ICBA-2	5.90**	1.43**	-9.49**	-15.13**	0.43	0.27	-0.73*	0.52*	-2.00*	-0.96	0.16	-2.25**
ICBA-4 × ICBA-2	-1.10	1.21**	-8.71*	-4.35	0.54	-2.61**	-0.28	-0.59*	-2.56*	-1.50*	-0.50*	-8.14**
ICBA-5 × ICBA-2	2.50*	1.00*	-3.51	-1.00	1.00	-1.51	-1.00	1.11	-2.81*	-3.11**	-2.11**	-1.00*
Dorado X ICBA -2	4.90**	1.10**	-6-06*	-0.13	1.65*	-0.95*	-0.28	-0.14	0.11	2.56*	-1.00*	-8.38
ICBA-4 × ICBA-3	-3.32**	-0.12	-5.04*	18.98**	-1.13*	0.60*	0.93*	-0.25	-1.22*	-2.82*	-0.96*	3.61*
ICBA-5 × ICBA-	-2.71*	-2.51*	-2.11	16.71	-1.51	-1.71	0.99	3.11	-2.5	-1.41*	2.61	3.51
Dorado X ICBA-3	-3.10**	-3.79**-	-2.93	-2.68	-1.90*	0.82*	8.71*	-0.08	-0.44	7.80**	0.10	1.91*
ICBA-5 × ICBA-4	-3.00*	-5.11**	14.50	-3.00	3.11	0.31	6.11	4.11	1.41	2.51	4.00	3.71
Dorado× ICBA-4	-3.87**	2.68**	27.95**	8.98**	0.76*	1.83**	0.05*	0.19	4.78	-3.53*	1.91**	9.19**
Dorado × ICBA-5	3.71**	3.11*	10.3	5.17	4.11	4.00	1.31	1.55	3.66	1.71	1.81	1.71
S.E. (S_i- S_{ig})	1.07	0.73	4.74	5.01	0.75	0.54	0.49	0.35	0.71	0.98	0.42	1.00
S.E. (SCA effect)	1.51	1.03	6.71	7.08	1.06	0.77	0.69	0.49	1.01	1.39	0.60	1.42

***and** indicate significant at 5 and 1% level of probability , respectively**