1491 Salinity induced changes on stomatal response, bio-physical parameters, solute accumulation and growth in cotton (*gossypium spp*.)

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Rationale: Salinity effects are more conspicuous in arid and semiarid areas where 25% of the irrigated land is affected by salts. Salinity inhibition of plant growth is the result of osmotic and ionic effects and the different plant species have developed different mechanisms to cope with these effects. An understanding of the physiological mechanism of salt tolerance of plants is an important effective approach to salinity problem.

Objectives: The investigation was carried out to find out the effects of salt stress on plant growth, stomatal response and solute accumulation in different cotton genotypes and to identify relatively salt tolerant genotype.

Methods : Six genotypes were evaluated under four salinity levels both in pot culture and field conditions in a split plot design with three replications

Results : The genotypes RAHS-14, LRA-5166 and AK-235 showed less reduction in seed germination, shoot and root vigour index, leaf area and total dry matter both at 60 days when compared to susceptible genotype, Dhumad. Salinity stress increased the stomatal density but reduced stomatal breadth and length. The genotypes differed significantly for stomatal density, stomatal breadth and stomatal length on both the leaf surfaces. Photosynthetic rate, stomatal conductance and transpiration rate decreased with an increase in the salinity. The genotypes NHH-44 and LRA-5166 had higher photosynthetic rate as well as higher transpiration at all the salinity levels.

Conclusions: The genotypes differed widely in their response to salinity and different genotypes may have different adaptations against salinity stress. Based on the study, the genotypes NHH-44, RAHS-14 and AK-235 are found more tolerant to salinity stress and the genotype Dhumad found sensitive.

INTERPRETIVE SUMMARY

Soil salinity has caused heavy loss of natural resources in India. Out of 320 mha of land in the country about 175 mha (53%) are suffering from degradation in some form or the other and out of which, 8.5 m.ha is salt affected (Anon, 2006). This problem is faced in 8 out of the 15 agro-climatic zones of India.

Although, cotton is classified as salt tolerant crop, cotton seeds are particularly vulnerable to salinity stress encountered between sowing and seedling establishment. The effects on salinity on cotton range from reduction in germination percentage, vigour, biophysical and biochemical parameters etc., Therefore, a prior information regarding the physiological mechanisms or characters conferring tolerance towards salinity stress at various growth stages is a pre-requisite for successful breeding for salt tolerance.

With this in view, experiments were conducted both in pot culture and field conditions using various salinity gradients with six cotton genotypes. The results indicated that salinity stress induced changes in stomatal response, osmolyte accumulation and bio-physical characters and genotypes differed widely in their response to salinity. Although, RAHS-14, AK-235, LAR-5166 and NHH-44 were found to be on par with yield, but *G. herbaceum* genotype RAHS-14 was identified as salt tolerant because of its physiological mechanism to tolerate salt stress and intrinsic resistance to diseases and pests when compared to *G. hirsutum* genotypes LRA-5166 and NHH-44.

ABSTRACT

An understanding of the physiological mechanism of salt tolerance of plants is an important effective approach to salinity problem. The present investigation was carried out to identify the relative salt tolerance of some important cotton varieties belonging to three cultivated cotton species at different levels of salinity under pot and field conditions.

In pot culture experiment, seed germination, shoot and root vigour indices, leaf area and toatal dry mater at 60 DAS decreased with increase in salinity levels. The genotypes NHH-44, RAHS-14, LRA-5166 and AK-235 recorded comparatively less reduction for these characters at higher salinity levels when compared to susceptible genotype Dhumad. The genotypes differed significantly for stomatal density, stomatal breadth and stomatal length on both the leaf surfaces. Salinity increased the stomatal density but reduced the stomatal length and breadth. Further, the genotypes, NHH-44, LRA-5166, RAHS-14 and AK-235 had comparatively higher photosynthetic rate, stomatal conductance and transpiration rate at all the salinity levels, whereas, maximum reductions were observed in Dhumad. Free proline and sugar contents were increased due to salinity in all the genotypes. Irrespective of the salinity levels the genotype NHH-44 accumulated significantly higher proline and least in Dhumad and for sugars it was highest in RAHS-14 while significantly lowest was recorded in Ak-235. These characters had significant positive correlation with seed cotton yield and total dry matter.

The results of the field experiment conducted under natural soil salinity gradient indicated that total dry matter at harvest and yield were reduced significantly due to salinity. The genotype NHH-44 recorded significantly higher dry matter and seed cotton yield and least was recorded in Dhumad. The genotypes NHH-44 and LRA -5166 recorded a lesser percent reduction in yield over control.

A superior genotype with better salt tolerance can be identified with the characteristics of better performance in growth and development and having lesser yield reduction and higher yield potential under higher salinity.

The area under salinity is increasing at a rapid pace with 2 m ha added every year globally. In India, about 8.5 m ha are classified as saline affected. Cotton is grown as a source of excellent natural fibre, food and feed.

Despite the existence of genetic variation for salt tolerance within the species and many methods available for expanding the source of genetic variability, only limited number of varieties have been developed with improved tolerance based upon selection on agronomic characters such as yield or survival under saline conditions. An understanding of the physiological mechanism of salt tolerance of plants is an important effective approach to salinity problem. Breeding for salt tolerance might be more successful if selection is based directly on physiological mechanisms or characters conferring tolerance. With this background, an investigation was carried out, to find out the genotypic variability for germination and growth and to study the salinity induced changes on stomatal response, physiological, biophysical and biochemical characters at an early stage of the crop.

MATERIALS AND METHODS

Pot Culture Experiment

Growth conditions and treatments

A pot culture experiment with six cotton genotypes, AK-235 (*G.arboreum*), RAHS-14, Dhumad and Jaydhar (*G.herbaceum*) and NHH-44 and LRA-5166 (*G.hirsutum*) was carried out for two years during 2001 and 2002 at ARS, Dharwad. These genotypes were grown in pots of size 2.0 x 1.5 x 1.5 feet. The pots were filled with finally ground soil samples of natural soil salinity gradients brought from ARS, Gangavati. From these soils, four salinity levels of 0.8, 4.5, 8.0 and 14.8 dSm^{-1} were fixed for the experiment and later on pots were irrigated with water containing NaCl, NaHCO3, MgSo4 and CaCl2 in the ratio of 4: 1.7: 1 (Na: Mg: Ca) to maintain the required electrical conductivity. At regular intervals, ECe of the soil was maintained till the experiment was completed. The treatment combinations were allotted to pots in a split plot design with three replications.

Field experiment

The above mentioned genotypes were also evaluated under field conditions at comparatively similar salinity levels at ARS, Gangavati where natural soil salinity gradient exists.

Germination and growth analysis

Germination and growth analysis were done at 60 days after sowing (DAS). Shoot and root vigour indices were calculated as described by Abdul-Baki and Anderson (1973).

Photosynthesis, Stomatal Conductance and Transpiration

Measurements of photosynthesis (µmol CO_2,m^{-2}. Sec^{-1}), Stomatal conductance (µmol CO_2 . m^{-2}. Sec^{-1}) and transpiration (E, mmol. m^{-2}. sec-1) were made on the top fully expanded leaf at 60 DAS using portable photosynthesis system (LI-COR-6400, Inc. Lincoln, NE, USA).

Stomatal density and size

The study of stomatal frequency in epidermal cells was made by following the xylene thermocole method (Koti, 1997).

Soluble Sugar and Proline Content

Sugar content was estimated in oven dried samples by anthrone method (Dobois *et al*, 1951). Free proline content was determined calorimetrically (Bates *et al.,* 1973.)

Experimental Design and Statistical Analysis

The experimental design applied was factorial with six genotypes and four salt levels along with three replications. The means and their standard deviations were used for comparing different treatments and the co-efficient of correlation and the F-test were used for studying correlation between variables (Gomez and Gomez, 1984).

RESULTS

Pot culture Experiment

Germination, Shoot and Root Indices and Growth

Germination per cent decreased significantly with an increase in salinity levels from 0.8 dSm^{-1} to 14.8 dSm^{-1} (Table 1). Genotypes differed significantly with respect to the extent of reduction in germination under salinity stress. Among the genotypes, AK-235 (28%) followed by LRA-5166 and NHH-44 (30%) and RAHS-14 (32%) had lower reduction in germination per cent at highest salinity level (14.8 dSm^{-1}) compared to Dhumad.

Genotypes differed to a large extent in the reduction of shoot and root vigour indices under salinity stress (Table1). Shoot vigour index was found to be more sensitive than root vigour index. Dhumad had higher reduction in shoot vigour index (73%). While, RAHS-14, NHH-44 and LRA-5166 recorded comparatively higher shoot vigour index at all salinity levels. Lower reduction in root vigour index was observed in AK-235 (44%) and the maximum reduction in root vigour index was noticed in Dhumad (56%).

Total dry matter at 60 DAS differed significantly among genotypes and salinity levels. The genotype NHH-44 maintained significantly higher total dry matter at all the salinity levels. The genotypes AK-235 (39%), NHH-44 and RAHS-14 (45% each) had lower reduction of dry matter at highest salinity level (14.8dSm^{-1}). Whereas, the genotype Dhumad had the highest reduction of dry matter (76%).

The genotypes NHH-44 and LRA-5166 maintained higher leaf area at all salinity levels, whereas, Dhumad recorded lower leaf area. The genotype NHH-44 (31%) recorded lower reduction in leaf area at highest salinity level over control, whereas, Dhumad (53%) had maximum reduction. The genotypes which showed lesser reduction in leaf area produced more dry matter at higher salinity.

Correlation studies showed a significant positive correlation of leaf area with total dry matter at harvest and yield indicating that the early differences in leaf expansion resulted in differences in final dry matter and yield

Stomatal Density and Size

Stomata is such a character which influence transpiration rate, stomatal conductance and photosynthesis to a great extent and play an important role on growth and development of plant. The data on stomatal density indicated that the number of abaxial stomata was more than the number of adaxial stomata regardless of salinity(Table 3). In general, the genotypes having higher reduction in leaf area recorded larger increase in stomatal density. The genotype LRA-5166 had maximum number of stomata both on abaxial and adaxial leaf surfaces. Genotype NHH-44 showed smaller increase in stomatal density on both surfaces

(10% on lower and 18% on upper surfaces respectively) along with AK-235 (10%) on lower surface and LRA-5166 (18%) on upper surface, whereas, Dhumad (27%) on upper surface had maximum increase in stomatal density.

Stomatal length and breadth on abaxial leaf surface decreased with increasing salinity significantly (Table 4). On lower leaf surface, maximum reduction in stomatal breadth was observed in AK–235 and Jaydhar while Dhumad had minimum reduction but it recorded higher reduction in stomatal length. In general, the genotypes having higher reduction in stomatal breadth had lower reduction in stomatal length and vice versa.

Photosynthetic Rate, Stomatal conductance and Transpiration

Biophysical characters like photosynthetic rate, stomatal conductance and transpiration rate decreased with an increase in the salinity level (Table 5). Among the genotypes, species belonging to *G. hirsutum* had comparatively higher values for these characters. The genotype, NHH-44 had maximum photosynthetic rate at all salinity levels and had a lesser reduction in photosynthesis (32%) along with AK-235 (27%) while, maximum reduction in photosynthesis was observed in Jayadhar (40%). The salt tolerant genotypes which recorded lower reduction in leaf area maintained higher photosynthetic rate even under saline conditions.

Similarly, stomatal conductance and transpiration rate decreased with increase in salinity level. The genotypes NHH-44 and LRA-5166 belonging to *G. hirsutum* had comparatively higher stomatal conductance and transpiration compared to other species of cotton at all salinity levels. Higher reduction in stomatal conductance and transpiration rate under saline conditions resulted in reduced dry matter.

Solute Accumulation: Soluble Sugar and Proline Content

Solute accumulation was considered as a suitable screening parameter for salinity tolerance (Ashraf *et al*., 1991). Osmoregulation through accumulation of soluble sugars in roots and leaves are characteristics of salinity stressed plants (Rathert, 1983). The proline and sugar content in leaves of different cotton genotypes increased with increase in salinity levels and genotypes differed significantly in their ability to accumulate free proline under salinity stress. Genotypes NHH-44, RAHS-14 and LRA-5166 at 60 DAS accumulated more proline at higher salinity levels (Table 6).

Higher rate of sugar accumulation was observed between S_2 (4.5 dSm^{-1}) and S_3 (8.0 dSm^{-1}) salinity levels (Table 6). Among the genotypes, RAHS-14 and LRA-5166 maintained higher soluble sugar content because of their higher constitutive level of sugar, whereas, AK-235 though recorded lower sugar content at higher salinity but per cent induction was highest (36%) as compared to 10% in LRA-5166.

Field Experiment

Yield and Yield Components

Seed cotton yield decreased with increase in salinity stress. Among the six genotypes tested under natural soil salinity gradients at ARS Gangavati, the genotypes NHH-44 and RAHS-14 recorded significantly higher seed cotton yield when compared to other genotypes, however, AK-235 was on par with these genotypes (Fig.1). The genotypes NHH-44 (18%) and LRA-

5166 (18%) recorded lesser per cent reduction in their yields at higher salinity level (S4) over control compared to other genotypes, where as, significantly higher reduction was noticed in Dhumad (72%).

Similar to seed cotton yield, yield components showed significant variations among different genotypes across salinity levels. Among the genotypes, RAHS-14 (16.62) and Jaydhar (16.50) recorded higher number of bolls, whereas, boll weight was minimum in these genotypes. However, NHH-44 (11%) and LRA-5166 (19%) recorded least reduction in boll number at highest salinity level compared to control and as well maintained higher boll weight compared to other genotypes. Higher total dry matter and boll weight contributed for increased seed cotton yield under salinity.

DISCUSSION

In pot culture experiment, seed germination, shoot and root vigour indices, leaf area and total dry mater at 60 DAS decreased with increase in salinity levels from 0.8 to 14.8 dSm-1 (Table 1). Genotypic response varied differently under salinity stress. Among the genotypes, RAHS-14, LRA-5166 and AK-235 showed lesser reduction for these characters at higher salinity levels compared to susceptible genotype Dhumad and these genotypes found to be salt tolerant. Similar relationship is reported by Phogat et al., 2001. The reduction in germination under saline conditions could be due to decreased water potential of soil water resulting in decreased absorption of water by the seeds (Chazen and Neumann,1994). The genotypes which showed minimum reduction in leaf area also recorded minimum decrease in dry matter. The decrease in leaf area is attributed to reduction in cell size rather than cell number (Curtis and Lauchi, 1987) due to reduction in osmotic potential of leaf cells (Patil *et al*., 1996).

In general, the number of abaxial stomata was more than the adaxial stomata regardless of salinity (Table 3) and the genotypes which had higher reduction in leaf area recorded larger increase in stomatal density. However, the genotype LRA-5166 had maintained higher number of stomata both on abaxial and adaxial leaf surfaces. The stomatal length and breadth on abaxial leaf surface decreased with increase in salinity. (Table 4). In general the genotypes showing higher reduction in stomatal breadth had lower reduction in stomatal length and vice versa. The changes in stomatal density and size was mainly attributed to changes in leaf area under salt stress (Curtis and Lauchli, 1987). Similarly, Buttery *et al*., (1992) reported an increase in stomatal density as a result of moisture stress in soybean and they presumed that this was brought about by a decrease in leaf expansion. This was further supported by Jones (1977) who reported negative relationship between stomatal density and leaf size under stress conditions.

Photosynthetic rate, stomatal conductance and transpiration rate decreased with an increase in the salinity levels. Among the genotypes, species belonging to *G. hirsutum* had comparatively higher values for these characters. The genotype, NHH-44 had maximum photosynthetic rate at all salinity levels and had a lesser reduction in photosynthesis (32%) along with AK-235 (27%). Maximum reduction in photosynthesis was observed in Jayadhar (40%). Similar results of decrease in photosynthetic rate under saline conditions were reported by Jhu and Frederick (1999) and under water stress by Leidi *et al*. (1993). The salt tolerant genotypes which recorded lower reduction in leaf area maintained higher photosynthetic rate even under saline conditions. Reduction in photosynthesis under saline conditions is because of inhibition of 14-CO_2 fixation and decreased activities of key enzymes RuBP-carboxylase and PEP-carboxylase (Sankha and Huber,1974), depressed activities of chloroplast (Nieman and Clark,1976) and end product inhibition (Rawson and Munns,1984).

Similarly, reduction in stomatal conductance and transpiration rate under saline conditions has been reported by Ashraf and O'leary (1996) which resulted in smaller reduction in total dry matter and seed cotton yield. Photosynthetic rate, stomatal conductance and transpiration rate had significant positive correlation with total dry matter at 60 DAS and harvest as well as with seed cotton yield, while, significant negative correlation was observed with stomatal density of both abaxial and adaxial leaf surface.

The proline and soluble sugar contents in leaves of different cotton genotypes increased with increase in salinity levels and genotypes differed significantly in their ability to accumulate osmolytes under salinity stress. Genotypes NHH-44, RAHS-14 and LRA-5166 accumulated more proline at higher salinity levels (Table 6). Increased accumulation of proline imparts certain degree of tolerance against salinity. Chu *et al*., (1976) suggested that the accumulation of proline under salt stress followed as a consequence of reduction in cell osmotic potential.

The genotypes RAHS-14 and LRA-5166 had higher sugar content. Osmoregulation through accumulation of soluble sugars in roots and leaves are characteristics of salinity stressed plants (Rathert,1983 and Prakash and Prathapasenan,1989).

Seed cotton yield reduced significantly to the extent of 21 and 48 per cent at 8.5 and 14.8 dSm-1 salinity levels respectively. Among the genotypes, the percent reduction was least in LRA-5166 and highest in Dhumad.

From the foregoing discussion, it could be concluded that genotypes differed widely in their response to salinity and plants can have different adaptations to cope up salinity stress. The information thus generated would be useful in breeding cotton for salt tolerance and in obtaining higher seed cotton yield. Based on the study, the genotypes LRA-5166, AK-235 and RAHS-14 were found to be better suited for salinity stress. Although, RAHS-14, NHH-44, LRA-5166 and AK-235 produced on par yield but only *G. herbaceum genotype* RAHS-14 was identified as salt tolerant because of its physiological mechanism to tolerate salt stress and its intrinsic tolerance to diseases and pests when compared to *G.hirsutum* genotypes NHH-44 and LRA-5166 which required more number of insecticidal sprays for completion of their life cycle as compared to RAHS-14.

From the above results, it can be inferred that the following characters serve as a tool for identification of salinity tolerance at early stages of crop growth. Lower reduction in seed germination, leaf area and total dry matter, higher shoot and root vigor indices and osmotic potential at higher salinity levels; higher accumulation of proline and sugar; increased stomatal frequency and maintenance of higher photosynthetic rate, stomatal conductance and transpiration rate at higher salinity levels.

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Table 1. Effect of salinity on germination,shoot vigour index and root vigour index in cotton genotypes (Pooled)**

Genotypes	Germination percentage					Shoot vigour index					Root vigour index				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
NHH-44	93.12	89.15	78.92	65.22	81.60	1509	1230	853	554	1037	810	615	513	398	584
LRA-5166	90.35	86.87	74.34	63.36	78.73	1328	1009	729	482	887	768	556	468	368	540
RAHS-14	89.97	81.24	73.52	61.54	76.57	1080	821	573	412	724	657	496	360	295	452
DHUMAD	86.13	79.17	66.93	55.41	71.91	1069	752	442	294	639	637	530	388	282	459
JAYADHAR	89.15	80.49	70.95	60.14	75.81	990	749	539	373	663	597	491	376	301	441
AK-235	87.67	82.30	74.17	63.33	76.98	929	811	608	405	688	579	496	386	323	446
Mean	89.40	83.28	73.14	61.50	76.83	1152	895	624	420	773	675	531	415	328	487
For comparing		**SEm±**		**CD at 5%**		**SEm±**			**CD at 5%**		**SEm±**			**CD at 5%**	
Genotypes(G)		1.81		5.02		24.99			69.27		15.12			41.91	
Salinity(S)		1.37		4.74		12.76			44.16		9.33			26.92	
Interaction(GxS)		3.62		NS		49.99			138.57		30.23			83.79	

S_1-0.8 dSm^{-1} S_2-4.5 dSm^{-1} S_3-8.0 dSm^{-1} S_4-14.8 dSm^{-1} ** Mean of 2000-01 and 2001-02

Table 2. Effect of salinity on total dry matter (g/plant) and leaf area (dm2/plant) at 60 DAS in cotton genotypes (pooled)**

Genotypes	Total dry matter (g/plant)					Leaf area (dm2/plant)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
NHH-44	5.84	4.71	3.92	3.21	4.42	25.61	23.19	20.92	17.63	21.84
LRA-5166	5.35	4.28	3.27	2.66	3.89	24.31	22.36	18.16	15.41	20.06
RAHS-14	4.43	3.72	3.36	2.43	3.49	24.56	21.29	17.61	14.39	19.46
DHUMAD	3.50	2.58	1.72	0.84	2.16	22.58	19.46	14.87	10.68	16.90
JAYADHAR	3.72	3.39	2.54	1.51	2.79	23.87	20.78	16.72	13.57	18.74
AK-235	4.35	3.62	3.11	2.65	3.43	25.12	20.18	16.59	15.68	19.89
Mean	4.53	3.72	2.99	2.22	3.38	24.34	21.54	17.48	14.56	19.48
For comparing	**SEm± CD at 5%**					**SEm± CD at 5%**				
Genotypes(G)	0.14 0.39					0.49 1.36				
Salinity(S)	0.08 0.28					0.31 1.07				
Interaction(GxS)	0.27 0.75					1.17 3.24				

S_1-0.8 dSm^{-1} S_2-4.5 dSm^{-1} S_3-8.0 dSm^{-1} S_4-14.8 dSm^{-1} ** Mean of 2000-01 and 2001-02

Table 3. Effect of salinity on stomatal density (no.mm^{-2}) on abaxial and adaxial leaf surfaces at 50 DAS in cotton genotypes

Genotypes	Abaxial					Adaxial				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
NHH-44	227.6	232.8	234.5	251.3	236.6	121.5	127.4	136.3	143.2	132.1
LRA-5166	232.3	240.8	248.4	256.7	244.6	129.6	137.0	143.1	152.4	140.5
RAHS-14	221.8	229.3	236.6	247.1	233.7	120.9	125.5	133.3	146.6	131.6
DHUMAD	227.7	237.6	247.2	259.6	243.0	121.3	132.6	144.2	153.7	138.5
JAYADHAR	224.6	233.4	243.3	254.3	238.2	123.5	131.5	142.6	151.2	137.2
AK-235	226.5	231.8	242.6	248.8	237.4	121.5	129.7	137.6	145.9	133.7
Mean	226.8	234.3	242.1	253.0	239.1	123.1	130.6	139.5	148.8	135.5
For comparing	**SEm± CD at 5%**					**SEm± CD at 5%**				
Genotypes(G)	6.93 19.21					3.93 10.89				
Salinity(S)	4.06 14.05					2.67 9.24				
Interaction(GxS)	13.85 38.39					7.85 21.76				

S_1-0.8 dSm^{-1} S_2-4.5 dSm^{-1} S_3-8.0 dSm^{-1} S_4-14.8 dSm^{-1} ** Mean of 2000-01 and 2001-02

Table 4. Effect of salinity on stomatal breadth(μm) and stomatal length (μm) of abaxial leaf surface at 50 DAS in cotton genotypes (Pooled)**

Genotypes	**Stomatal breadth**					**Stomatal length**				
	S_1	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
NHH-44	19.27	18.68	17.83	17.45	18.31	27.38	26.34	26.83	26.03	26.65
LRA-5166	18.25	17.83	17.15	16.11	17.34	25.89	24.68	23.74	23.55	24.47
RAHS-14	17.32	16.74	15.79	15.12	16.24	24.49	24.12	23.78	22.69	23.77
DHUMAD	14.13	13.84	13.52	12.82	13.58	23.54	21.50	20.64	19.81	21.37
JAYADHAR	15.49	14.65	13.74	13.32	14.30	24.65	23.52	22.68	21.34	23.05
AK-235	16.14	15.62	14.15	13.78	14.92	24.71	23.94	22.76	21.82	23.31
Mean	16.77	16.23	15.36	14.77	15.78	25.11	24.02	23.41	22.54	23.77
For comparing	**SEm± CD at 5%**					**SEm± CD at 5%**				
Genotypes(G)	0.46 1.28					0.69 1.91				
Salinity(S)	0.29 1.00					0.48 1.66				
Interaction(GxS)	0.92 NS					1.38 NS				

S_1-0.8 dSm^{-1} S_2-4.5 dSm^{-1} S_3-8.0 dSm^{-1} S_4-14.8 dSm^{-1} ** Mean of 2000-01 and 2001-02

Table 5. Effect of salinity on photosynthetic rate (µmol CO_2/m^2/Sec), Stomatal conductance (µmol CO_2/m^2/Sec) and rate of transpiration (m. mol /m^2/ sec) at 60 DAS in cotton genotypes

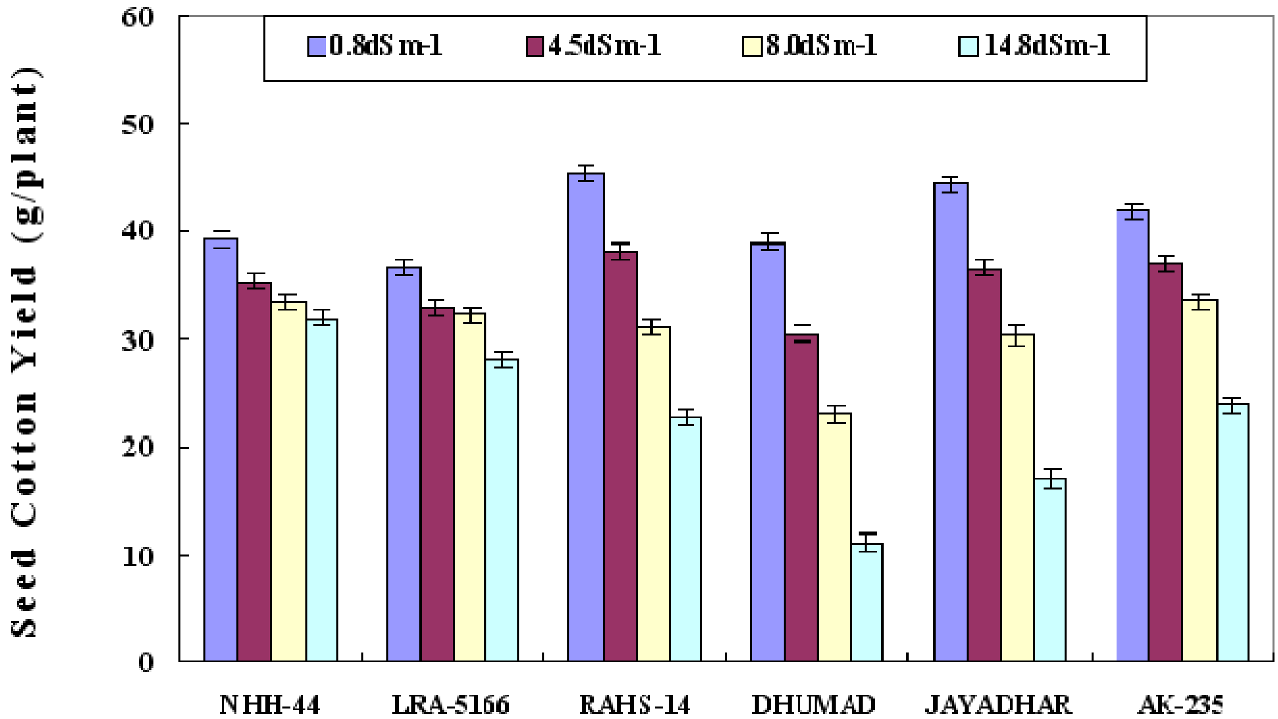
Genotypes	Photosynthetic rate					Stomatal conductance					Tranpiration				
	S_1	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
NHH-44	37.54	34.15	29.52	25.36	31.64	0.446	0.389	0.336	0.223	0.349	12.92	11.75	9.83	8.31	10.71
LRA-5166	34.79	31.81	27.65	24.53	29.70	0.414	0.326	0.284	0.174	0.300	12.24	11.23	9.21	7.36	10.01
RAHS-14	30.65	28.89	24.71	20.65	26.23	0.325	0.264	0.208	0.178	0.244	9.25	7.94	7.27	6.14	7.65
DHUMAD	29.58	25.69	23.56	19.54	24.59	0.301	0.231	0.201	0.170	0.226	8.34	7.31	6.58	5.67	6.98
JAYADHAR	30.16	26.21	22.12	18.35	24.21	0.295	0.234	0.195	0.163	0.222	8.96	7.46	6.79	5.88	7.27
AK-235	29.81	27.83	23.72	21.69	25.76	0.312	0.258	0.189	0.181	0.235	9.26	7.68	7.26	5.91	7.53
Mean	32.09	29.10	25.21	21.69	27.02	0.349	0.284	0.236	0.182	0.263	10.16	8.90	7.82	6.55	8.36

For comparing	Photosynthetic rate SEm±	Photosynthetic rate CD at 5%	Stomatal conductance SEm±	Stomatal conductance CD at 5%	Tranpiration SEm±	Tranpiration CD at 5%
Genotypes(G)	0.80	2.22	0.008	0.022	0.25	0.69
Salinity(S)	0.56	1.94	0.005	0.017	0.12	0.42
Interaction(GxS)	1.60	NS	0.016	0.044	0.50	NS

Table 6. Effect of salinity on proline (µg/g dry weight) and sugar contents (mg/g dry weight) at 60 DAS in cotton genotypes

Genotypes	Proline (µg/g dry weight)					Sugar (mg/g dry weight)				
	Salinity levels					Salinity levels				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
NHH-44	59.6	74.8	85.4	99.7	79.9	22.5	24.2	26.7	27.2	25.2
LRA-5166	54.6	68.3	81.2	96.6	75.2	26.6	27.9	30.2	29.4	28.5
RAHS-14	53.1	66.3	82.4	95.3	74.3	26.9	29.3	32.6	32.1	30.2
DHUMAD	47.5	54.2	69.3	79.4	62.6	22.5	24.2	26.7	27.2	25.2
JAYADHAR	49.7	55.9	72.5	90.3	67.1	21.6	22.1	25.4	24.6	23.4
AK-235	51.4	63.6	79.7	94.4	72.3	17.6	21.4	24.2	23.9	21.8
Mean	52.7	63.9	78.4	92.6	72.0	23.0	24.9	27.6	27.4	25.7
For comparing	**SEm± CD at 5%**					**SEm± CD at 5%**				
Genotypes(G)	2.14 5.93					0.81 2.25				
Salinity(S)	1.83 6.33					0.53 1.83				
Interaction(GxS)	4.27 11.84					1.48 NS				

S_1-0.8 dSm^{-1} S_2-4.5 dSm^{-1} S_3-8.0 dSm^{-1} S_4-14.8 dSm^{-1} ** Mean of 2000-01 and 2001-02



Genotype

Fig. 1. Effect of salinity on seed cotton yield (g/plant) in cotton genotypes