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Physiological Basis of Salt Tolerance in Groundnut (*Arachis hypogaea* L.)

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A B S T R A C T

A laboratory experiment was carried out to evaluate 26 groundnut genotypes for salt tolerance as well as to assess physiological basis for salt tolerance. Twenty seeds of each genotype were allowed to germinate for 72 hours at 28±1^{o}C and then transferred to plastic beakers containing neutral sand. 7 days old seedlings were then subjected to different treatments *viz.* Control (plants receiving Hoagland nutrient solution adjusted to pH 6.3) and Salinity treatment (plants receiving Hoagland nutrient solution plus 200 mM NaCl adjusted to pH 6.3). The treatments were repeated on every third day and data were collected on 35-day old plants for different growth parameters. The tolerance index (expressed as Stress Responsive Index for total plant dry weight) of the genotypes ranged from 47.57% to 96.40%. Out of all the genotypes KDG-197 (TI 96.40%) was found to be the most tolerant under a salinity followed by R2001-2(TI 87.92%), VG-315 (TI 84.05%), TCGS1157 (77.59%) and TG 51(73.67%). While the genotypes Girnar3 (TI 47.57%), OG52-1 (TI 49.09%), TVG-0856 (TI 49.28%) and J86 (TI 50.66%) were the most susceptible genotypes based on their relative performance under stress in respect of total dry weight. The extent of reduction in sugar content in the five tolerant genotypes varied from 2.70%-49.82% over that of control while it was 51.83-70.32% for the four susceptible genotypes. Increase in leaf proline content over control recorded from tolerant and susceptible genotypes are 531.52-780.16% and 76.14 - 449.43% respectively. The extent of increase in protein content in the tolerant genotypes ranged from 34.25-144.01% over control. Among all the genotypes, Girnar 3 registered maximum increase (31.48%) in Electrolytic leakage (EL) of the leaf under stress.

Introduction

Groundnut (*Arachis hypogaea* L.) is an annual legume and the 13th most important food crop and 4th most important oilseed crop of the world. In India, groundnut is an important oilseed, food and feed crop grown in an area of 6.45 million ha with a total production of 6.57 million tons based on an average of the last five years (FAO, 2005). However, different growth stages of this crop is often subjected to various types of abiotic stress like drought, salinity, high temperature etc which may cause yield loss. Soil salinity, spread in about 2.0 m ha of coastal and saline areas (Chhabra and Kamra, 2000) in the major groundnut growing states of India, is one of the most important abiotic factors that significantly affect seedling, vegetative and reproductive growth, seed quality and productivity. Groundnut yields have been reported to be severely affected with an increase in soil and water salinity (Girdhar *et al* 2005; Nithila *et al* 2013). It can affect seed germination and inhibit root and shoot growth. It interferes with water absorption leading to osmotic stress; it enhances accumulation of Na^+ and Cl^- ions which at higher concentration may lead to cytotoxicity, impaired enzymatic function and imbalance of other elements. The cellular metabolism, biochemical as well as photosynthetic activities are all adversely affected by salt stress (Abogadallah, 2010 and Cokkizgin, 2012). One of the most effective ways to overcome salinity problems is the introduction of salt-tolerant crops. It has been reported that differences in salt tolerance exist, not only among different species, but also within certain species (Murillo-Amador *et al* 2001). Success of selection depends upon the amount of genetic variation present in the population. Evidence collected from various species suggests that salt tolerance is a developmentally regulated, stage-specific phenomenon, so that tolerance at one stage of development may not be correlated with tolerance at other developmental stages (Shannon, 1986).

Therefore, specific stages throughout the ontogeny of the plant, such as germination and emergence, seedling growth and its vigour, should be evaluated separately during the assessment of germplasm for salt tolerance. Such assessments may help in the development of cultivars with salt tolerance characteristics throughout the ontogeny of the plant (Bayuelo-Jimenez *et al* 2002).Information on salt tolerance of local groundnut varieties is scanty. The objective of the present study is therefore to screen twenty six genotypes commonly raised in Laboratory condition in sand culture to determine which genotypes can tolerate saline environments and studies on the physiological basis for salt tolerance thus help extend the present frontiers for their cultivation.

Materials and Methods

The laboratory experiment was carried out in Departmental Laboratory of Plant Physiology, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, Nadia, West Bengal. Screening of germplasm for salinity tolerance was done with 26 genotypes of groundnut (Table 1). The seeds of all the genotypes were collected from AICRP on Groundnut, Kalyani Centre.

The seeds of 26 genotypes of groundnut were surface sterilized with 0.1% $HgCl_2$ (w/v) solution for 3 minutes followed by thorough washing in distilled water. Twenty seeds were arranged in petridish of 9 cm diameter on Whatman No.1 filter paper and moistened with normal distilled water. The whole set were allowed to germinate for 72 hours at a temperature of 28 ± 1^oC and relative humidity around 80%. Then the germinated seeds were transferred to plastic beakers of capacity 1 liter containing neutral sand. Two replications for each genotype were made and six germinated seeds were transferred to each beaker. Full strength Hoagland solution was prepared as per modification of Epstein was supplemented to each beaker as nutrient medium. pH of the nutrient solution was adjusted to 6.3 each time during application of the solution. The beakers were supplemented with fresh Hoagland solution at every 3rd day. When the seedlings were 7 days old, different treatments were initiated. The treatments were- (i) Control- plants receiving Hoagland nutrient solution adjusted to pH 6.3 (ii) Salinity treatment- plants receiving Hoagland nutrient solution plus 200 mM NaCl adjusted to pH 6.3. The treatments were repeated on every 3rd day. Data were collected on 35-day old plants for different growth parameters.

Growth parameters of seedlings like Length of root (cm), Length of shoot (cm), Total length of seedling (cm), Fresh weight of root (mg), Fresh weight of shoot (mg), Fresh weight of leaf (mg), Total fresh weight of seedling (mg), Dry weight of root (mg), Dry weight of shoot (mg), Dry weight of leaf (mg), Total dry weight of seedling (mg) and Stress response index (SRI)were measured to determine the effect of salinity treatment on seedling growth in comparison to non-stress control. Stress response index (SRI) was calculated in each case as per Chen *et al* (2007). It was calculated using the following formula:

$$SRI = \frac{\text{Average value from stressed}}{\text{Average value from control plants}} \times 100$$

For the study of physiological basis of salt tolerance some physio-biochemical analysis was also done. Extraction and estimation of total soluble sugar was done following the method of Yoshida *et al* (1972).The soluble protein content in the leaf was estimated following the methods of Lowry *et al* (1951). Proline content was determined from the germinating seed embryonic axis as per the method of Mohanty and Sridhar (1982). Electrolyte leakage was determined as described method by Guo *et al* (2006). Conductivity was again determined. The electrolyte leakage was calculated as the ratio of conductivity before boiling to that after boiling.

$$EL\ (\%) = \frac{(Cb-Cw)}{(Ca-Cw)} \times 100$$

Where,

C_b = conductivity before boiling
C_a = conductivity after boiling
C_w = conductivity of distilled water

The experiment was set up following completely randomized design (CRD). The data were taken in triplicates and the mean data in all the cases were subjected to statistical analysis following two factor factorial design using INDOSTAT version 7.1 software. The 26 genotypes were analyzed for genetic similarity based on Euclidean distance using NTSYS-PC version 2.0 software. Dendrogram was constructed by Sequential Agglomerative Hierarical Nested (SAHN) clustering using the Un-weighted Pair Group Method with Arithmetic Mean (UPGMA) algorithm.

Results and Discussion

Clustering of genotypes

Twenty six genotypes of groundnut collected from AICRP on Groundnut, Kalyani centre, were evaluated for tolerance against 200 mM NaCl salinity in sand culture using modified Hoagland solution. The mean data under stress and unstressed control condition were used for calculation of stress response index (SRI) for each genotype. Perusal of the data indicated that salinity stress reduced the length of root, shoot and total plant in all the cases except only with very few exceptions as evidenced from SRI values < 100%. Out of all the genotypes, KDG-197 and TCGS1157 showed SRI of 117.89 and 123.11 %, respectively, for root length indicating increase in root length under stress. OG52-1 showed the highest reduction in shoot length (SRI 48.59%) as well as whole plant length (SRI 56.26%) registering most drastic effect of salinity stress in these two characters. Salinity stress caused reduction in fresh and dry weight of 35-day old plant as well as its different parts except for root in few genotypes. Among all the genotypes, KDG-197, VG-09221 and R2001-2 recorded SRI > 100% for fresh and dry weight of root. Other three genotypes, viz., AK-343, TG-74 and VG-315 also registered SRI exceeding 100% for root fresh weight and very high SRI for root dry weight. On the contrary, OG52-1, Girnar 3 and ICGV-03042 had very low mean values of SRI for both fresh and dry weight of root. The genotype KDG-197 exhibited the highest mean SRI for fresh and dry weight of leaf and total plant under stress in the present experiment. While the lowest SRI for dry weight of shoot, leaf and total plant was recorded by Girnar 3 (Table 3).The tolerance index (expressed as SRI for total plant dry weight) of the genotypes ranged from 47.57% to 96.40%. Out of all the genotypes KDG-197 (TI 96.40%) was found to be the most tolerant under a salinity stress of 200 mM NaCl and it was closely followed by R2001-2(TI 87.92%), VG-315 (TI 84.05%), TCGS1157 (TI 77.59%) and TG 51(73.67%).

While the genotypes Girnar3 (TI 47.57%), OG52-1 (TI 49.09%), TVG-0856 (TI 49.28%) and J86 (TI 50.66%) were the most susceptible genotypes based on their relative performance under stress in respect of total dry weight (Tables 2-5, Plate 1-2).

On the basis of stress response index (SRI) of root length, dry weight of root, length and fresh weight of whole plant and STIs, the twenty six genotypes were grouped following Sequential Agglomerative Hierarical Nested (SAHN) clustering on the basis of Euclidean distance. The dendrogram showed that the genotype KDG-197 separated out as a monogenotypic distinct cluster from the remaining genotypes.

Other 25 genotypes were distributed among different clusters. The four tolerant genotypes, VG-315, TCGS1157, R2001-2 and TG 51, belonged to a big cluster B which was separated from the other big cluster A at the level of coefficient value 3.36. The cluster A was further divided into two sub-clusters A1 and A2 at 2.87 coefficient level. The four most susceptible genotypes, J86, TVG-0856, OG52-1 and Girnar3, were distributed in different sub-clusters under A2 (Fig. 1).

Physiological studies in tolerant and susceptible genotypes

The mean data for four important biochemical parameters (viz. total soluble sugar, proline, soluble protein and electrolyte leakage) in the leaves of five tolerant (KDG-197, VG-315, TCGS1157, R2001-2 and TG 51) and four susceptible genotypes (J86, TVG-0856, OG52-1 and Girnar 3) have been presented in table 6. Perusal of the data indicated that all the nine genotypes showed reduction in leaf sugar content under salinity stress. The five tolerant genotypes registered 2.70% to 49.82% reduction in sugar content over that of control whereas the extent of reduction in the four susceptible genotypes varied from 51.83-70.32% over control. Salinity stress in the present experiment caused remarkable increase in leaf proline content in the selected genotypes under study except in Girnar 3 which only registered 76.14% increase over control. In the present experiment, the tolerant genotypes registered 531.52-780.16% increase in proline content over control with R2001-2 showing the highest increase. On the contrary, the susceptible genotypes recorded 76.14-449.43% increase over control in the leaf proline content. All the nine genotypes recorded increase in leaf soluble protein content under 200 mM NaCl treatment. The susceptible genotypes exhibited 1.58-42.58% increase in leaf protein content with the most susceptible genotype (Girnar 3) registering the minimum increase over control. The extent of increase in protein content in the tolerant genotypes ranged from 34.25-144.01% over control. Among all the genotypes, KDG-197 registered then maximum increase in soluble content under salinity stress and it was also the most tolerant genotype identified in the present experiment. The genotypes under study exhibited increase in electrolyte leakage (EL) of the leaf when exposed to salinity treatment. Among all the genotypes, Girnar 3 registered maximum increase (31.48%) in EL of the leaf under stress and it might be noted this genotypes was the most susceptible among all. Two genotypes, KDG-197 (6.48%) and R2001-2 (3.00%) registered very small increase in EL% in comparison with the unstressed control and ranked at the top among the tolerant genotypes.

Plate.1 Effect of salinity stress on seedling growth of Tolerant genotypes of groundnut

Plate.2 Effect of salinity stress on seedling growth of susceptible genotypes of groundnut

Table.1 List of genotypes used in the experiment

Sl. No.	Genotype	Sl. No.	Genotype	Sl. No.	Genotype
1	AK-335	10	VG-09221	19	TG-75
2	KDG-197	11	ICGV-07038	20	ICGV-03042
3	ICGV-05155	12	ICGV-06138	21	OG52-1
4	AK-343	13	TG-74	22	Girnar3
5	ICGV-03043	14	TVG-0856	23	CGMG-2010
6	Dh235	15	JCG-3005	24	R2001-2
7	ICGV-06420	16	LGN163	25	CTMG11
8	J86	17	VG-315	26	TG-51
9	JCG-2141	18	TCGS1157		

Table.2 Effect of salinity stress on length of root, shoot and whole plant of 26 genotypes of groundnut

Genotype		Root length (cm)		Shoot length (cm)		Total length (cm)	
		Control	Treatment	Control	Treatment	Control	Treatment
1	AK-335	4.80	4.37(-9.09)	8.79	6.71(-23.63)	13.59	11.08(-18.49)
2	KDG-197	5.48	6.46(+17.89)	11.59	9.30(-19.76)	17.07	15.76(-7.68)
3	ICGV-05155	6.12	5.56(-9.20)	10.50	7.74(-26.32)	16.62	13.29(-20.06)
4	AK-343	5.30	4.40(-17.03)	8.61	6.74(-21.68)	13.91	11.14(-19.89)
5	ICGV-03043	5.82	5.60(-3.83)	9.23	6.09(-34.08)	15.06	11.69(-22.38)
6	Dh235	5.21	4.67(-10.37)	8.53	6.69(-21.60)	13.74	11.36(-17.32)
7	ICGV-06420	4.67	3.12(-33.26)	7.04	5.22(-25.81)	11.71	8.34(-28.83)
8	J86	5.63	4.37(-22.48)	12.00	8.10(-32.50)	17.63	12.47(-29.30)
9	JCG-2141	6.70	5.01(-25.22)	8.07	6.50(-19.42)	14.77	11.51(-22.03)
10	VG-09221	6.80	4.59(-32.50)	8.91	7.16(-19.68)	15.71	11.75(-25.24)
11	ICGV-07038	6.04	4.20(-30.50)	8.72	6.41(-26.46)	14.76	10.61(-28.13)
12	ICGV-06138	5.72	4.74(-17.08)	9.16	6.27(-31.51)	14.88	11.02(-25.96)
13	TG-74	3.73	3.04(-18.41)	10.03	5.08(-49.37)	13.76	8.12(-40.95)
14	TVG-0856	4.05	2.93(-27.63)	7.06	4.80(-31.98)	11.11	7.73(-30.39)
15	JCG-3005	6.34	4.41(-30.41)	9.40	6.70(-28.72)	15.74	11.11(-29.42)
16	LGN163	5.57	4.67(-16.17)	11.41	7.62(-33.19)	16.98	12.29(-27.61)
17	VG-315	4.63	3.90(-15.83)	9.93	9.09(-8.49)	14.57	12.99(-10.82)
18	TCGS1157	5.52	6.80(+23.25)	8.92	6.00(-32.72)	14.45	12.80(-11.42)
19	TG-75	5.32	4.33(-18.55)	8.56	5.36(-37.45)	13.89	9.69(-30.22)
20	ICGV-03042	4.32	3.75(-13.34)	9.80	7.08(-27.76)	14.12	10.82(-23.39)
21	OG52-1	6.13	4.18(-31.90)	9.46	4.60(-51.39)	15.60	8.78(-43.74)
22	Girnar3	3.32	2.37(-28.69)	6.75	4.32(-36.03)	10.08	6.69(-33.61)
23	CGMG-2010	4.42	4.34(-1.74)	10.11	7.75(-23.31)	14.53	12.10(-16.75)
24	R2001-2	5.87	5.72(-2.50)	9.69	6.98(-28.00)	15.56	12.70(-18.38)
25	CTMG11	6.08	5.51(-9.33)	8.74	5.62(-35.68)	14.82	11.13(-24.90)
26	TG-51	5.59	5.18(-7.39)	8.10	6.29(-22.35)	13.69	11.47(-16.24)
		S.E. m(±)	C.D. 5%	S.E. m(±)	C.D. 5%	S.E. m(±)	C.D. 5%
Genotype(G)		0.07	0.14	0.11	0.22	0.14	0.28
Treatment(T)		0.02	0.04	0.03	0.06	0.04	0.08
G×T		0.10	0.20	0.16	0.31	0.20	0.40

Means showing the same letters in a column do not differ significantly at a 5% probability level.
Data in parentheses indicate percentage increase (+) or decrease (-) over control

Table.3 Effect of salinity stress on fresh weight of 35-day old plant and its different parts in 26 genotype of groundnut

Genotype		Root Fresh Weight(g)		Shoot Fresh Weight(g)		Leaf Fresh Weight(g)		Total Fresh Weight(g)	
		Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
1	AK-335	1.20	0.89(-25.9)	2.32	1.25(-46.20)	1.90	0.77(-59.23)	5.42	2.91(-46.28)
2	KDG-197	2.02	2.09(3.47)	2.98	2.87(-3.69)	2.34	1.84(-21.48)	7.35	6.80(-7.44)
3	ICGV-05155	1.39	0.89(-36.21)	2.17	1.99(-8.43)	1.78	1.23(-30.96)	5.34	4.10(-23.16)
4	AK-343	1.18	1.22(3.11)	2.29	1.48(-35.13)	1.87	0.91(-51.16)	5.34	3.61(-32.29)
5	ICGV-03043	0.95	0.72(-24.47)	1.93	1.17(-39.31)	1.58	0.73(-54.01)	4.47	2.62(-41.39)
6	Dh235	1.90	1.56(-17.72)	2.91	1.98(-31.85)	2.38	1.23(-48.46)	7.19	4.78(-33.52)
7	ICGV-06420	1.50	1.23(-17.78)	2.31	1.40(-39.31)	1.89	0.87(-54.06)	5.69	3.50(-38.52)
8	J86	1.64	1.63(-0.81)	2.16	1.66(-23.00)	1.77	1.03(-41.70)	5.57	4.32(-22.40)
9	JCG-2141	1.45	0.32(-77.70)	2.63	1.76(-32.95)	2.15	1.09(-49.38)	6.23	3.18(-49.01)
10	VG-09221	1.21	1.58(30.58)	2.25	1.75(-22.34)	1.84	1.08(-41.13)	5.30	4.41(-16.73)
11	ICGV-07038	1.24	1.18(-5.09)	2.47	1.30(-47.43)	2.02	0.80(-60.40)	5.72	3.28(-42.69)
12	ICGV-06138	1.16	0.70(-39.77)	2.21	1.15(-48.11)	1.81	0.71(-60.70)	5.17	2.56(-50.58)
13	TG-74	0.96	1.20(25.34)	1.54	1.23(-19.96)	1.26	0.76(-39.26)	3.76	3.20(-14.91)
14	TVG-0856	1.20	0.83(-30.92)	2.54	1.23(-51.64)	2.08	0.76(-63.30)	5.82	2.82(-51.58)
15	JCG-3005	1.31	1.06(-19.34)	2.26	2.06(-9.00)	1.85	1.27(-31.35)	5.42	4.38(-19.13)
16	LGN163	1.34	0.81(-39.65)	1.72	1.15(-32.95)	1.41	0.71(-49.29)	4.46	2.67(-40.06)
17	VG-315	1.44	1.74(20.88)	2.59	2.38(-8.23)	2.12	1.47(-30.66)	6.15	5.59(-9.10)
18	TCGS1157	1.81	1.76(-2.76)	2.84	2.07(-27.00)	2.32	1.28(-44.76)	6.98	5.12(-26.60)
19	TG-75	1.31	1.06(-19.13)	2.26	1.44(-36.52)	1.85	0.89(-51.89)	5.42	3.38(-37.58)
20	ICGV-03042	2.32	0.91(-60.78)	2.14	1.26(-41.19)	1.74	0.78(-55.26)	6.20	2.94(-52.50)
21	OG52-1	1.83	1.08(-40.88)	2.63	1.54(-41.37)	2.15	0.95(-55.59)	6.60	3.57(-45.83)
22	Girnar3	1.99	1.07(-46.40)	2.59	1.49(-42.47)	2.12	0.92(-56.60)	6.70	3.48(-48.08)
23	CGMG-2010	1.08	1.18(8.95)	1.87	1.78(-4.64)	1.53	1.10(-27.73)	4.48	4.06(-9.23)
24	R2001-2	1.49	1.56(4.25)	2.65	2.16(-18.26)	2.17	1.34(-38.31)	6.31	5.06(-19.77)
25	CTMG11	1.85	1.14(-38.31)	2.47	1.33(-46.29)	2.02	0.82(-59.41)	6.34	3.29(-48.03)
26	TG-51	1.64	1.21(-26.42)	1.97	1.94(1.36)	1.61	1.20(-25.26)	5.22	4.35(-16.60)
		S.E. m(±)	C.D. 5%	S.E. m(±)	C.D. 5%	S.E. m(±)	C.D. 5%	S.E. m(±)	C.D. 5%
	Genotype(G)	0.02	0.04	0.03	0.05	0.14	0.28	0.15	0.29
	Treatment(T)	0.01	0.01	0.01	0.01	0.04	0.08	0.04	0.08
	G×T	0.03	0.05	0.04	0.08	0.20	0.39	0.21	0.42

Means showing the same letters in a column do not differ significantly at a 5% probability level.
Data in parentheses indicate percentage increase (+) or decrease (-) over control

Table.4 Effect of salinity stress on fresh weight of 35-day old plant and its different parts in 26 genotype of groundnut

Genotype		Root dry weight(g)		Shoot dry weight(g)		Leaf dry weight(g)		Total dry weight(g)	
		Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
1	AK-335	0.10	0.09(-12.88)	0.34	0.21(-38.83)	0.20	0.09(-54.11)	0.65	0.39(-39.49)
2	KDG-197	0.16	0.21(+33.31)	0.61	0.58(-4.40)	0.34	0.28(-19.40)	1.11	1.07(-3.89)
3	ICGV-05155	0.10	0.06(-40.00)	0.33	0.23(-29.30)	0.19	0.10(-45.63)	0.62	0.40(-35.48)
4	AK-343	0.13	0.12(-5.15)	0.44	0.31(-28.26)	0.26	0.14(-45.46)	0.83	0.58(-30.52)
5	ICGV-03043	0.09	0.07(-28.51)	0.37	0.20(-46.36)	0.21	0.09(-57.81)	0.68	0.35(-49.01)
6	Dh235	0.12	0.08(-33.33)	0.41	0.23(-43.55)	0.25	0.11(-56.75)	0.78	0.42(-45.50)
7	ICGV-06420	0.15	0.15(-0.00)	0.39	0.22(-42.25)	0.23	0.10(-55.89)	0.76	0.47(-38.43)
8	J86	0.20	0.13(-35.00)	0.51	0.26(-48.69)	0.30	0.12(-59.56)	1.00	0.51(-49.17)
9	JCG-2141	0.20	0.15(-25.00)	0.46	0.26(-44.59)	0.27	0.12(-57.30)	0.94	0.52(-44.33)
10	VG-09221	0.10	0.10(-0.00)	0.41	0.27(-33.87)	0.24	0.12(-49.32)	0.75	0.50(-33.33)
11	ICGV-07038	0.10	0.11(+13.75)	0.36	0.23(-35.52)	0.21	0.10(-51.57)	0.66	0.44(-34.16)
12	ICGV-06138	0.12	0.08(-33.33)	0.29	0.19(-34.48)	0.15	0.09(-40.00)	0.56	0.36(-35.93)
13	TG-74	0.09	0.08(-11.11)	0.25	0.19(-23.69)	0.15	0.09(-40.00)	0.49	0.36(-26.35)
14	TVG-0856	0.13	0.08(-39.46)	0.35	0.18(-48.12)	0.21	0.08(-61.90)	0.69	0.34(-51.20)
15	JCG-3005	0.24	0.08(-66.67)	0.48	0.37(-22.23)	0.28	0.17(-41.16)	1.00	0.62(-38.00)
16	LGN163	0.13	0.06(-52.64)	0.24	0.16(-34.24)	0.14	0.07(-50.00)	0.51	0.30(-41.82)
17	VG-315	0.13	0.12(-5.29)	0.60	0.55(-8.83)	0.36	0.25(-30.84)	1.09	0.91(-15.96)
18	TCGS1157	0.17	0.13(-23.53)	0.50	0.43(-14.66)	0.30	0.19(-35.96)	0.97	0.75(-22.42)
19	TG-75	0.17	0.11(-37.24)	0.47	0.33(-30.00)	0.27	0.14(-47.57)	0.91	0.58(-36.40)
20	ICGV-03042	0.17	0.06(-64.01)	0.28	0.22(-21.43)	0.16	0.10(-36.74)	0.61	0.38(-37.50)
21	OG52-1	0.19	0.09(-53.56)	0.46	0.25(-44.93)	0.27	0.11(-59.26)	0.92	0.45(-50.91)
22	Girnar3	0.16	0.10(-40.78)	0.46	0.23(-50.36)	0.27	0.10(-62.96)	0.89	0.43(-52.06)
23	CGMG-2010	0.13	0.10(-23.08)	0.39	0.30(-24.56)	0.23	0.13(-42.86)	0.76	0.53(-29.96)
24	R2001-2	0.11	0.10(-6.09)	0.44	0.41(-5.36)	0.26	0.18(-28.59)	0.80	0.70(-12.45)
25	CTMG11	0.17	0.09(-45.12)	0.49	0.34(-30.82)	0.29	0.15(-47.68)	0.94	0.58(-38.16)
26	TG-51	0.15	0.10(-31.13)	0.61	0.50(-17.94)	0.36	0.23(-37.60)	1.12	0.83(-26.40)
		S.E. m(±)	C.D. 5%	S.E. m(±)	C.D. 5%	S.E. m(±)	C.D. 5%	S.E. m(±)	C.D. 5%
	Genotype(G)	0.017	0.04	0.05	0.10	0.02	0.04	0.06	0.12
	Treatment(T)	0.005	0.01	0.01	0.03	0.01	0.01	0.02	0.03
	G×T	0.025	0.05	0.07	0.14	0.03	0.06	0.08	0.17

Means showing the same letters in a column do not differ significantly at a 5% probability level.
Data in parentheses indicate percentage increase (+) or decrease (-) over control

Table.5 Stress response index (SRI) of 26 genotypes of groundnut under 200mM NaCl for different growth parameters

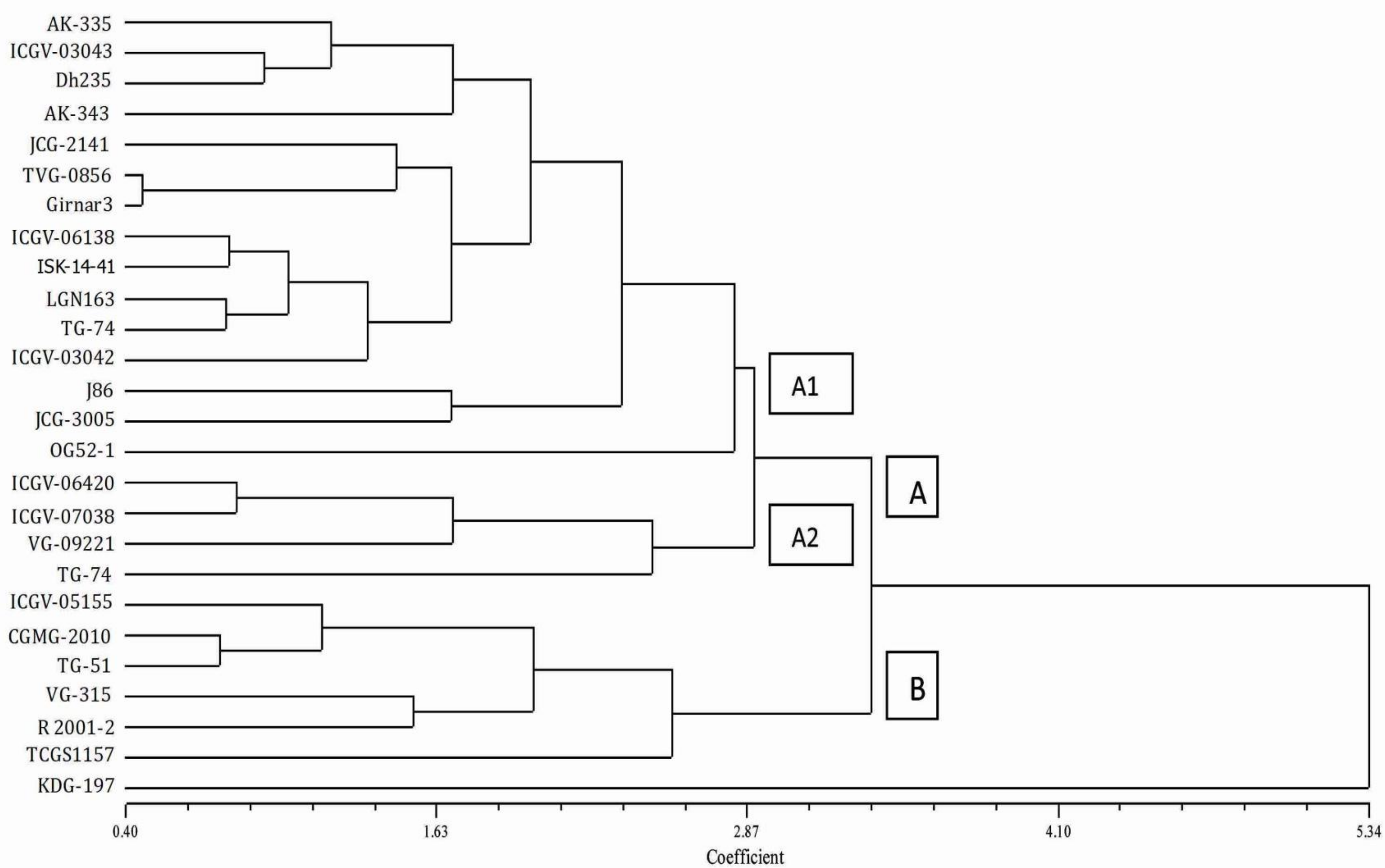
Genotype		(Stress response Index)SRI										
		Root Fresh Weight (g)	**Shoot Fresh Weight (g)**	**Leaf Fresh Weight (g)**	**Total Fresh Weight (g)**	**Root Dry Weight (g)**	**Shoot Dry Weight (g)**	**Leaf Dry Wright (g)**	**Total Dry Weight (TI) (g)**	**Root Length (cm)**	**Shoot Length (cm)**	**Total Length (cm)**
1	AK-335	74.37	53.83	40.67	53.75	87.10	60.87	46.36	60.51	90.97	76.34	81.51
2	KDG-197	103.47	96.31	78.43	92.52	133.33	95.08	80.25	96.40	117.89	80.24	92.32
3	ICGV-05155	63.79	91.50	69.13	76.84	63.33	71.02	54.10	64.52	90.75	73.65	79.95
4	AK-343	103.11	64.79	48.95	67.71	92.31	71.91	54.77	69.76	83.02	78.32	80.11
5	ICGV-03043	75.52	60.77	45.91	58.66	71.43	52.98	40.35	51.47	96.16	65.92	77.62
6	Dh235	82.28	68.21	51.53	66.40	69.44	56.80	43.26	54.51	89.57	78.43	82.68
7	ICGV-06420	82.04	60.74	45.89	61.44	97.78	58.15	44.29	61.84	66.74	74.11	71.17
8	J86	99.19	77.07	58.23	77.60	65.57	51.44	39.18	50.66	77.51	67.50	70.70
9	JCG-2141	22.30	67.03	50.64	50.96	75.00	55.59	42.35	55.87	74.78	80.58	77.95
10	VG-09221	130.58	77.75	58.74	83.21	106.90	66.26	50.47	66.37	67.50	80.32	74.77
11	ICGV-07038	95.43	52.55	39.70	57.31	113.79	63.88	48.66	66.33	69.50	73.51	71.87
12	ICGV-06138	60.23	52.03	39.31	49.42	66.67	65.52	61.16	64.29	82.88	68.51	74.04
13	TG-74	125.35	80.09	60.50	85.09	96.15	75.53	57.53	73.65	81.52	50.65	59.03
14	TVG-0856	69.08	48.40	36.56	48.42	60.53	51.28	39.06	49.28	72.37	68.02	69.61
15	JCG-3005	80.66	90.95	68.71	80.87	34.72	77.46	59.00	62.00	69.59	71.28	70.60
16	LGN163	60.35	67.08	50.68	59.90	50.00	66.77	50.86	58.17	83.83	66.81	72.39
17	VG-315	121.11	91.80	69.35	90.90	92.11	91.03	69.34	84.05	84.17	91.51	89.18
18	TCGS1157	97.43	73.00	55.15	73.40	76.47	85.37	65.03	77.59	123.11	67.24	88.60
19	TG-75	80.66	63.61	48.06	62.42	62.75	69.99	53.31	63.60	81.45	62.53	69.78
20	ICGV-03042	39.22	58.88	44.49	47.47	34.00	79.41	60.49	61.96	86.58	72.21	76.61
21	OG52-1	59.12	58.69	44.34	54.14	47.27	54.35	41.40	49.09	68.10	48.59	56.26
22	Girnar3	53.60	57.49	43.44	51.89	59.18	49.31	37.56	47.57	71.49	63.97	66.45
23	CGMG-2010	108.95	95.49	72.14	90.77	76.92	75.27	57.33	70.04	98.27	76.69	83.25
24	R2001-2	104.24	81.78	61.79	80.23	100.00	94.40	71.91	87.92	97.50	72.00	81.62
25	ISK-14-41	61.87	53.76	40.62	51.95	54.90	69.90	52.28	61.05	90.67	64.32	75.12
26	TG-51	73.78	98.75	74.60	83.45	68.89	81.62	62.17	73.67	92.61	77.65	83.76

Table.6 Effect of salinity stress on total soluble sugar, proline, soluble protein and electrolyte leakage in tolerant and Susceptible genotypes

Genotype		Sugar (mg/g dry wt)		Protein (mg/g fresh wt)		Proline (micro mol/g fresh wt)		Electrolytic Leakage (%)	
		Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
1	KDG-197	148.00	144.00(-2.70)	79.99	195.19(144.02)	146.64	1166.97(695.81)	69.67	74.18(6.47)
2	R2001-2	136.00	104.80(-22.94)	80.36	179.87(123.83)	126.2	1110.76(780.16)	65.10	67.05(3.00)
3	VG-315	122.40	97.60(-20.26)	94.76	220.30(132.48)	144.08	1149.08(697.53)	71.74	82.64(15.20)
4	TCGS1157	63.20	56.80(-10.13)	125.59	168.61(34.25)	146.64	1166.97(695.81)	74.95	86.55(15.48)
5	TG 51	226.40	113.60(-49.82)	106.76	196.30(83.87)	89.16	563.05(531.51)	76.44	84.97(11.16)
6	J86	131.20	63.20(-51.83)	169.72	200.92(18.38)	133.86	735.49(449.45)	57.96	69.19(19.38)
7	TVG-0856	320.00	127.20(-60.25)	103.62	147.75(42.59)	109.59	566.88(417.27)	68.63	80.75(17.70)
8	OG52-1	295.20	124.80(-57.73)	125.22	164.18(31.11)	154.3	666.25(331.79)	75.05	94.67(26.14)
9	Girnar3	354.40	105.20(-70.32)	152.36	154.76(1.58)	325.46	573.27(76.14)	70.92	93.24(31.47)
		S.E.m(±)	C.D. 5%	S.E.m(±)	C.D. 5%	S.E. m(±)	C.D. 5%	S.E.m(±)	C.D. 5%
Genotype(G)		1.85	3.75	2.33	4.72	11.72	23.78	1.18	2.38
Treatment(T)		0.87	1.77	1.10	2.22	5.53	11.21	0.55	1.12
G×T		2.61	5.30	3.29	6.67	16.58	33.63	1.66	3.37

Means showing the same letters in a column do not differ significantly at a 5% probability level.
Data in parentheses indicate percentage increase (+) or decrease (-) over control

Fig.1 Dendrogram showing the clustering of 26 groundnut genotypes on the basis of salt tolerance



The salt tolerance relatively depends upon the intensity of salinity and relative performance of genotypes. Salt generally alters a wide array of metabolic processes culminating in stunted growth, reduced enzyme activities and photosynthetic carbon metabolism. The suppression of plant growth under salt-stress may either be due to osmotic reduction in water availability or to excessive accumulation of ions, known as specific ion effect. In this experiment five tolerant and four susceptible genotype showed remarkable difference in terms of different growth parameter and tolerance index under 200mM Salinity stress. The results are in agreement with those of Ghoulam *et al*2002 who reported that salinity caused a significant reduction in growth parameters of shoot and roots of sugarbeet. Sugars usually lower the osmotic potential of the cells favoring the holding of more bound water and reducing loss of turgidity. Therefore the accumulation of soluble sugars in the soluble pool suggests a protective role through osmoregulation (Singh and Rai 1983). In present study, reduction in sugar accumulation under salinity treatment might be attributed to inhibition of carbohydrate synthesis due to reduced rate of photosynthesis induced by salinity stress.

Tolerant genotype KDG-197 was the least affected among all the genotypes while susceptible genotype Girnar 3 was the most affected by salinity stress. Proline also induces the expression of salt-stress-responsive proteins and may improve the plant adaptation to salt-stress (Khedr *et al* 2003). The dramatic increase in proline content in the leaves under salinity stress was consistent with the role of proline as a compatible solute for osmotic adjustment during osmotic shock. However, in addition to its function as osmoregulator, proline might also play the role of osmoprotectant in stabilizing protein and scavenging. In this experiment higher accumulation of leaf proline in the salt tolerant genotypes might help them in osmotic adjustment in a better way as compared to the susceptible ones. this can be related to earlier findings in which Aazami *et al* (2010), found that an increase in proline content under salinity stress was probably due to the capacity of some plants to accumulate organic (sucrose, fructose and glucose) and inorganic (Na, K and Cl) metabolites in the cytoplasm to reduce the water potential and change the osmotic gradient, assuring the water flow to the plant and thereby might increase tolerance. The increase in leaf protein might be attributed to synthesis of some stress proteins induced by NaCl treatment. However, the tolerant and susceptible genotypes showed significant differences among them in respect of such increase. This results are consistent with Tort and Turkyilmaz (2004), Kapoor and Srivastava (2010). Electrolytic leakage is a valid, simple and quantitative indicator to the injury occurred to plasma membrane after exposure to salinity stress. The current study provided experimental evidence that the tolerant genotypes showed lesser extent of membrane damage as indicated by the change in EL% under stress over control. Similarly, Lechno *et al* 1997 observed the same increasing trend of electrolyte leakage in salt sensitive cucumber cultivar as compared to the salt tolerant cultivar. This phenomenon was already observed by several authors in cucumber (Kaya *et al* 2001) and sugar beet (Ghoulam *et al* 2002).

The research revealed that KDG-197, R2001-2, VG-315, TCGS1157 and TG-51genotypes of *Arachis hypogaea* can withstand salt stress and produce good seedling vigour in sand culture with salinity up to 200mM NaCl, while other genotypes Girnar 3, OG52-1, TVG-0856 and J86 are highly susceptible to salt stress. Those that can withstand salt stress hold immense promise to be grown in the coastal saline areas, and can be used in breeding programmes for developing salt-tolerant variants of groundnut.

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