Variation in sensitivity to salinity in groundnut cultivars during seed germination and early seedling growth

Rukam Singh, Deepak Issar, PV Zala and **PC Nautiyal***
National Research Centre for Groundnut (NRCG), PB # 5, Ivenagar Road, Junagadh 362 001, Gujarat, India
*Corresponding author: nautiyal@nrcg.res.in

Groundnut (*Arachis hypogaea*) is an important oilseed and is emerging as a food crop in India. However, the average yield is 998 kg ha^{-1}, mainly due to cultivation of the crop (80%) in rain-dependent system. Also, the crop encounters several biotic and abiotic stresses. Drought, high temperature and salinity are the major abiotic constraints. Groundnut is mainly grown in the states of Andhra Pradesh, Gujarat, Tamil Nadu, Karnakata, Maharastra and Rajasthan in summer (January–June) and rainy season (June–October). In India, out of 329 million ha of available land under cultivation, about 175 million ha (53%) is suffering from degradation in some form or the other (http://megcooperation.gov.in). About 7.61 million ha is saline land, out of which 1.2 million ha of land is in the coastal tracts of Gujarat. Thus soil salinity is an emerging problem in these areas, where groundnut is a major crop and preferred by the farmers due to its importance as fodder. Salinity in this area is increasing with an alarming rate, mainly because of seepage of sea water into land and mixing with groundwater. The increasing electrical conductivity (EC) of groundwater is making it unsuitable for irrigation. Limited work has been attempted so far, on groundnut salinity stress at the National Research Centre for Groundnut (NRCG), Junagadh, Gujarat. A protocol for screening large number of germplasm accessions for salinity tolerance has been developed (Nautiyal et al. 1998) and some groundnut cultivars have been tested for toxicity of ions of different salts (Nautiyal et al. 1989, 1994). Also, the performance of groundnut cultivars under saline water irrigation in black clay soils of Saurashtra (Girdhar et al. 2005) and sandy soils of Bhuj (Nautiyal et al. 2000) has been tested. Especially in Kutch-Bhuj region where underground borewell water is having high TDS, it could be utilized for crop sown in June and subsequent crop may be rain-dependent or irrigated with normal water. In this case, tolerance during germination stage is critical for field emergence and early seedling vigor. Therefore, the objective of this study was to evaluate groundnut cultivars for sensitivity to salinity during germination and early seedling stage under laboratory conditions, before testing them under real field situations.

Materials and methods

An experiment was conducted with twenty-seven groundnut cultivars belonging to Spanish and Valencia botanical groups. After thorough drying in June, pods were stored in galvanized bins at ambient laboratory conditions (average temperature 35ºC and RH 70%). Germination test was conducted after two months of storage. The treatments constituted different concentrations of sea water prepared by mixing with tap water: T_1 = 20% sea water and 80% tap water (EC 10 dS m^{-1} s^{-1}); T_2 = 40% sea water and 60% tap water (EC 18 dS m^{-1} s^{-1}); T_3 = 60% sea water and 40% tap water (EC 25 dS m^{-1} s^{-1}); and T_4 = 80% sea water and 20% tap water (EC 31 dS m^{-1} s^{-1}). A control was maintained by using tap water (EC 1.0 dS m^{-1} s^{-1}). Germination study was conducted in petriplates on Whatman No. 1 filter paper, replicated three times. One-hundred and fifty seeds of each cultivar, after surface sterilization with 1% $HgCl_2$ were placed in petriplates having ten seeds of each cultivar in each treatment and replication. Ten ml of saline water was poured over the filter paper and the plates were shifted to an incubator at 28±1°C and arranged in complete randomized design (CRD). Observation on seed germination was recorded daily and 1 or 2 ml of respective treatment solution, depending on requirement, was applied.

Germination percentage was recorded seven days after incubation following ISTA (1999) protocols and a seed able to protrude radicle was considered germinated. Observations such as daily germination, radicle length and hypocotyl length were recorded up to seven days and various seed vigor parameters were calculated following

the formula suggested by Mugnisjah and Nakamura (1984):

Germination rate (GR) = (100/n) ($N_3/_3 + N_5/_5$)

Germination speed (GS) = (100/n) ($N_1/_1 + N_2/_2 + N_3/_3 + N_4/_4 + N_5/_5 + N_6/_6 + N_7/_7$)

Germination capacity (GC) = (100/n) G_3

Standard germination (StG) = (100/n) ($N_3 + N_5$)

Coefficient of velocity of germination (CVG) = 100 ($N_1 + N_2 + \ldots + N_7$)/($N_{1\times1} + N_{2\times2} + N_{3\times3} + N_{4\times4} + N_{5\times5} + N_{6\times6} + N_{7\times7}$)

Vigor index (VI) = (1/2) (100/n) ($H_4 + R_4$)

where n is number of germinated seeds; N_1, $N_2 \ldots N_7$ indicate number of normal seedlings at one, two … seven days after germination and $_1$, $_2 \ldots _7$ indicate one, two … seven days after the start of germination test; G_3 is number of seedlings with more than 2 cm radicle length three days after germination; H_4 is number of seedlings with hypocotyl length more than average four days after germination; R_4 is number of seedlings with root plus hypocotyl length more than average four days after germination.

Seedling vigor index (SVI) was calculated following modified formula of Abdul-Baki and Anderson (1973):

SVI = Germination (%) × Root length (cm) + Number of secondary roots

Since SVI alone is unable to reflect the seed vigor parameters such as GR, GS, GC, StG and CVG, therefore, all these parameters including SVI, germination percentage, root length, hypocotyl length and number of secondary roots were considered to determine salinity tolerance index (STI). The STI was calculated by assigning equal points (10) to each character to assess on a 1–10 scale based on the performance in T_4, except in case of number of secondary roots, which was assessed in T_2. The points scored in each parameter (total 10) were summed up and expressed as STI.

Results and discussion

Wide genotypic differences were observed in various parameters recorded under highest salinity, ie, T_4 such as germination percentage (Table 1), SVI (Table 2) and seed vigor parameters (Table 3). Based on STI, the salinity tolerant and salinity susceptible cultivars were identified (Table 4). Various interactions between levels of salinity and cultivars were significant; for example, average germination percentage in control was 95% and reduced to 36% in T_4. Similarly, in case of cultivars, germination was >70% in tolerant genotype in T_4, whereas it was completely inhibited in susceptible (Table 1). Cultivars Kopergaon 3, MH 2, Gangapuri, Tirupati 4, ICGV 86590 and GG 4 showed >70% germination in T_4, but cultivars TMV 12, ICGS 44 and VRI 4 showed about 44% reduction in germination and this salinity level was considered as 50% lethal dose (LD_{50}) for these cultivars and became a demarcation line between the tolerant and susceptible cultivars. Further, among the five top ranking cultivars, three belong to Valencia group (Table 3). However, in susceptible cultivars, ie, DH 3-30, ICG (FDRS) 10, Jawan, VG 9521 and Co 3, germination percentage ranged between 0.0 and 7% in T_4. Though germination percentage decreased with increasing salinity levels, genetic variations in the sensitivity to salinity was wide in T_3 and T_4 only. Reduction in germination percentage over control under salinity stress (average of T_1 to T_4) also varied among the cultivars and was 4% in Kopergaon 3 and MH 2 and 72% in GG 3 (Table 1). Similarly, SVI decreased with increasing salinity, ranging between 1157 in ICGV 86590 in control and 0.0 in several cultivars in T_4 (Table 2). In T_4, SVI reduced drastically and the highest SVI was found in Kopergaon 3 (173) followed by MH 2 (145). Average SVI values decreased from 632 in control to 27 in T_4 and the sensitivity of cultivars to salinity varied maximum in this level. Among the cultivars, the reduction in SVI due to salinity ranged between 26% in TG 37-A and 86% in ICG (FDRS) 10. Various parameters of seed and seedling vigor calculated under salinity stress also decreased, but the magnitude of difference varied in each parameter; for example, GR decreased from 39 in control to 13 in T_4 and CVG decreased from 23 in control to 14 in T_4 (Table 3).

Apart from germination, average root length also decreased with increasing salinity levels and ranged between 6.3 cm in control and 0.4 cm in T_4 (Fig. 1). The magnitude of variations in root length in T_4 was between 0.0 in cultivars Co 3, Jawan, DH 3-30, VG 9521 and ICG (FDRS) 10 and 1.97 cm in GG 4. The average hypocotyl length under salinity stress decreased in the following order: 1.64 cm (control) > 0.83 cm (T_1) > 0.40 cm (T_2) > 0.13 cm (T_3) and > 0.03 cm (T_4). However, the hypocotyl length in T_4 was higher in cultivars TG 37-A, Kopergaon 3, ICGS 44, ICGV 86590 and GG 4 and lesser in GG 3, ICG (FDRS) 10, OG 52-1, VG 9521 and DH 3-30 (Fig. 2). Hypocotyl length reduced to half at each increase in the salinity level and was affected more than root length; in addition, about 18 cultivars did not show any hypocotyl growth in T_4.

Growth and initiation of secondary roots affected adversely due to salinity and only a few cultivars were able to develop secondary roots (Fig. 3). For example,

Table 1. Germination (%) of groundnut cultivars under control and different salinity levels[1].

Cultivar	Control	T_1	T_2	T_3	T_4
Kopergaon 3	99	98	98	93	93
MH 2	98	98	98	95	87
Gangapuri	98	98	98	96	80
Tirupati 4	98	98	98	87	80
ICGV 86590	99	98	98	93	73
GG 4	99	98	93	80	73
SB XI	98	93	98	93	67
TMV 12	97	93	93	73	53
ICGS 44	93	93	80	60	53
VRI 4	93	87	93	53	53
TG 37-A	87	67	60	47	40
JL 220	95	93	93	93	33
GAUG 1	99	98	98	87	33
GG 7	93	93	87	87	33
OG 52-1	90	87	80	60	33
MH 4	98	98	98	93	20
TMV 7	98	97	87	73	13
DH 8	93	87	80	73	13
Jyoti	93	87	67	27	13
TPG 41	99	98	73	67	7
BSR 1	98	87	53	40	7
GG 3	93	60	20	17	7
Co 3	83	40	33	17	7
VG 9521	98	98	80	60	0
Jawan	98	97	93	53	0
ICG (FDRS) 10	87	40	47	20	0
DH 3-30	98	98	67	13	0
CD (P = 0.05)	19.4	23.4	21.8	32.5	18.1
Average	95	88	80	65	36
Maximum	99	98	98	96	93
Minimum	53	33	7	7	0

1. T_1 = 20% salinity; T_2 = 40% salinity; T_3 = 60% salinity; T_4 = 80% salinity.

among the cultivars, number of secondary roots ranged between 39 and 1 in control and 6.3 and 0.0 in T_2 and completely inhibited in T_3 and T_4. Thus higher salinity levels were found detrimental to the growth of secondary roots more than any of the parameters studied in this experiment. Based on number of secondary roots, cultivars Kopergaon 3, MH 2, Gangapuri, VRI 4 and MH 4 were found relatively tolerant, whereas Co 3, ICG (FDRS) 10, Tirupati 4, GG 3 and VG 9521 were susceptible. All the vigor parameters such as GR, GS, GC, StG and CVG were affected adversely with increasing salinity levels (Table 3). The ranking of cultivars based on STI, ranged between 90 and 0.0; however, among the top five, ie, Kopergaon 3, GG 4, MH 2, ICGV 86590 and Gangapuri, three belong to Valencia botanical group (Table 4). These results showed that the effect of salinity was more on seedling vigor and not on the initial germination process per se. Such toxicity due to salinity during seed germination is usually associated with a significant decrease in the seed K^+ content, which could reduce metabolic functions and ultimately reduce germination and seedling growth (Rehman et al. 1996) and osmotic effects due to declining solute potential or toxic effects due to uptake and/or accumulation of some ions in the seed (Tobe et al. 2001).

In many plant species sensitivity to salinity is known to vary between growth stages (Mass and Hoffman 1977) and it is not necessary that the cultivar tolerant to salinity during germination stage will show similar sensitivity during other stages such as vegetative and reproductive.

Table 2. Seedling vigor index (SVI) of groundnut cultivars under control and different salinity levels[1].

Cultivar	Control	T_1	T_2	T_3	T_4
Kopergaon 3	799	723	312	199	173
MH 2	943	586	341	170	145
Gangapuri	1059	710	423	230	101
Tirupati 4	814	783	268	187	56
ICGV 86590	1157	584	368	120	39
GG 4	133	190	127	37	39
SB XI	626	517	293	98	37
TMV 12	884	502	443	223	30
ICGS 44	328	341	57	72	24
VRI 4	571	472	369	96	18
TG 37-A	655	732	378	87	14
JL 220	639	513	363	176	12
GAUG 1	1121	490	341	61	9
GG 7	573	455	237	77	9
OG 52-1	480	307	272	48	7
MH 4	476	514	288	81	3
TMV 7	69	16	98	0	2
DH 8	526	206	137	5	2
Jyoti	570	404	258	73	1
TPG 41	709	251	140	135	0
BSR 1	571	419	139	53	0
GG 3	268	147	1	2	0
Co 3	668	640	349	203	0
VG 9521	822	732	240	20	0
Jawan	715	570	292	12	0
ICG (FDRS) 10	173	59	27	9	0
DH 3-30	716	528	178	4	0
CD (P = 0.05)	114.2	78.4	77.2	94.5	54.9
Average	632	459	250	92	27
Maximum	1157	783	443	230	173
Minimum	69	16	1	0	0

1. T_1 = 20% salinity; T_2 = 40% salinity; T_3 = 60% salinity; T_4 = 80% salinity.

However, this study pointed out that genetic potential for tolerance to salinity during germination and early seedling stage in cultivars Kopergaon 3, GG 4, MH 2, ICGV 86590, Gangapuri and ICGS 44 could be utilized either by cultivating directly in problem areas or further improving the tolerance level by conventional breeding methods and/or adopting the modern biotechnological tools. However, detailed work on salinity tolerance in groundnut is required with a long-term breeding strategy to utilize the genetic potential to improve present-day cultivars.

Table 3. Range of values of various seed vigor parameters in control and different salinity levels in groundnut cultivars[1].

Treatment[2]	GR	GS	GC	StG	CVG
Control					
Maximum	47	145	100	200	25
Minimum	18	32	13	87	21
Average	39	109	72	187	23
T_1					
Maximum	42	135	100	200	24
Minimum	5	11	0	27	13
Average	36	93	69	175	22
T_2					
Maximum	42	126	100	200	24
Minimum	2	7	0	13	13
Average	32	74	50	155	21
T_3					
Maximum	41	95	53	200	24
Minimum	0	0	0	0	0
Average	24	50	11	119	19
T_4					
Maximum	41	91	33	200	23
Minimum	0	0	0	0	0
Average	13	24	2	65	14

1. GR = Germination rate; GS = Germination speed; GC = Germination capacity; StG = Standard germination; CVG = Coefficient of velocity of germination.
2. T_1 = 20% salinity; T_2 = 40% salinity; T_3 = 60% salinity; T_4 = 80% salinity.

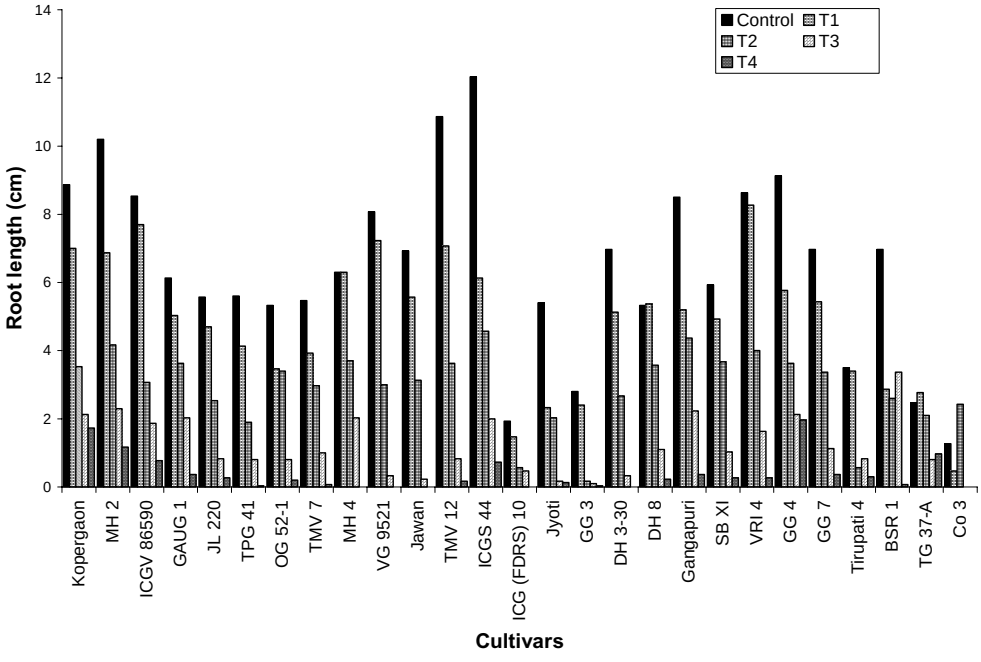

Figure 1. Root length of groundnut cultivars under different levels of salinity (T1 = 20% salinity; T2 = 40% salinity; T3 = 60% salinity; T4 = 80% salinity).

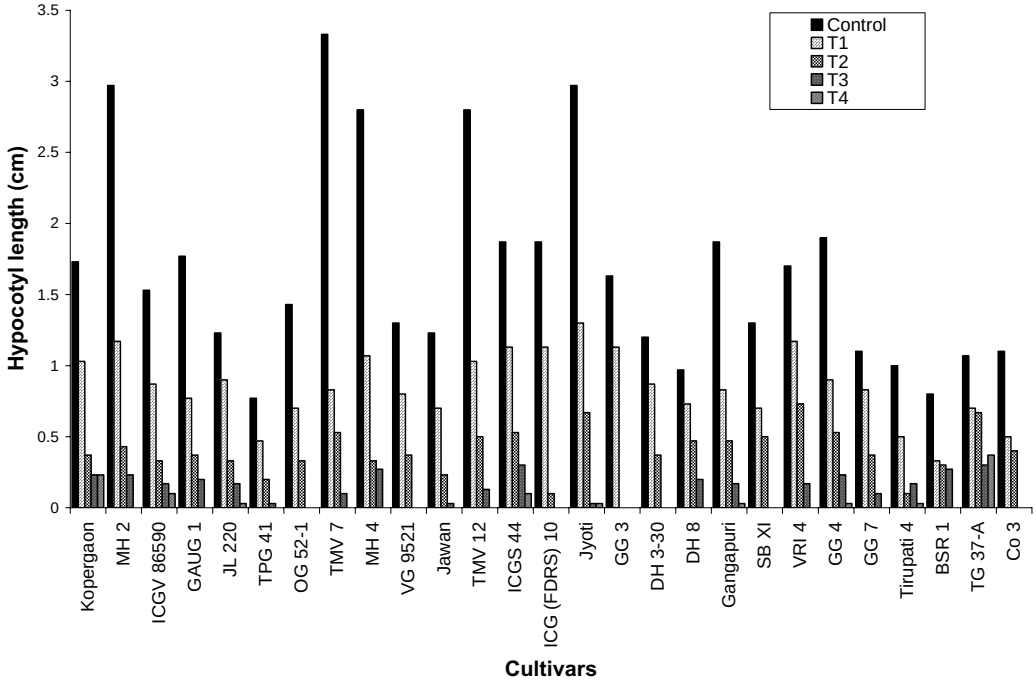

Figure 2. Hypocotyl length of groundnut cultivars under different levels of salinity (T1 = 20% salinity; T2 = 40% salinity; T3 = 60% salinity; T4 = 80% salinity).

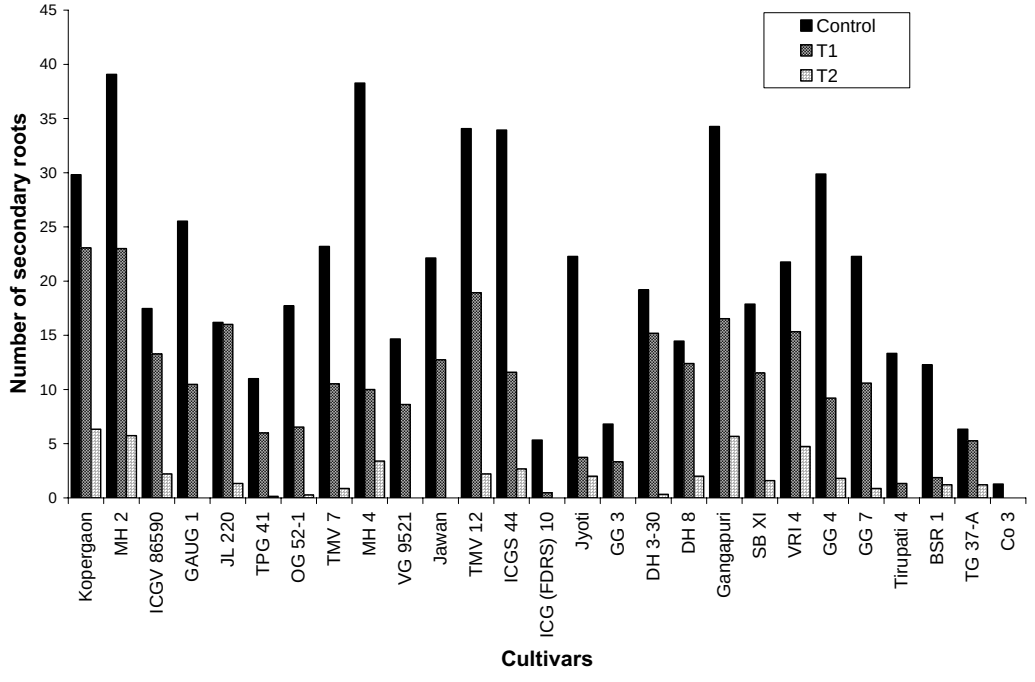

Figure 3. Number of secondary roots of groundnut cultivars under different levels of salinity (T1 = 20% salinity; T2 = 40% salinity).

Table 4. Salinity tolerance index (STI) of groundnut cultivars.

Cultivar	Botanical group	STI
Kopergaon 3	Valencia	90
GG 4	Spanish	71
MH 2	Valencia	67
ICGV 86590	Spanish	57
Gangapuri	Valencia	56
ICGS 44	Spanish	42
TG 37-A	Spanish	42
TMV 12	Spanish	39
VRI 4	Spanish	39
SB XI	Spanish	33
GAUG 1	Spanish	28
MH 4	Valencia	25
GG 7	Spanish	25
Tirupati 4	Spanish	24
JL 220	Spanish	23
OG 52-1	Spanish	22
TPG 41	Spanish	18
DH 8	Spanish	17
Jyoti	Spanish	16
BSR 1	Spanish	14
TMV 7	Spanish	12
GG 3	Spanish	8
DH 3-30	Spanish	1
Co 3	Spanish	1
VG 9521	Spanish	0
Jawan	Spanish	0
ICG (FDRS) 10	Spanish	0

References

Abdual-Baki AA and **Anderson JD.** 1973. Relationship between decarboxilation of glutamic acid and vigour in soybean seed. Crop Science 13:222–226.

Girdhar IK, Bhalodia PK, Misra JB, Veena Girdhar and **Devi Dayal.** 2005. Performance of groundnut, *Arachis hypogaea* L. as influenced by soil salinity and saline water irrigation in black clay soils. Journal of Oilseeds Research 22(1):183–187.

ISTA. 1999. International rules for seed testing. Seed Science and Technology 27 (Supplement).

Maas EV and **Hoffman GJ.** 1977. Crop salt tolerance current assessment. Journal of the Irrigation and Drainage Division 103:115–134.

Mugnisjah WR and **Nakamura S.** 1984. Vigour of soybean seed produced from different nitrogen and phosphorus fertilizer application. Seed Science and Technology 12:475–482.

Nautiyal PC, Bandyopadhyay A, Koradia VG and **Madhubhai Mankad.** 2000. Performance of groundnut germplasm and cultivars under saline water irrigation in the soil of Mundra in Gujarat, India. International *Arachis* Newsletter 20:80–82.

Nautiyal PC, Joshi YC and **Ravindra V.** 1994. Responses of groundnut (*Arachis hypogaea* L.) genotypes to salinity. Bio-science Research Bulletin 10(1):59–62.

Nautiyal PC, Joshi YC and. **Ravindra V.** 1998. A method for screening groundnut germplasm for salinity tolerance. Food Legume Newsletter 24:8.

Nautiyal PC, Ravindra V and **Joshi YC.** 1989. Germination and early seedling growth of some groundnut (*Arachis hypogaea* L.) cultivars under salt stress. Indian Journal of Plant Physiology 32:251–253.

Rehman S, Harris PJC, Bourne WF and **Wilkin J.** 1996. The effect of sodium on germination and the potassium and calcium contents of *Acacia* seeds. Seed Science and Technolology 25:45–57.

Tobe K, Zhang LP, Qiu G-YY, Shimizu H and **Omasa K.** 2001. Characteristics of seed germination in five non-halophytic Chinese desert shrub species. Journal of Arid Environment 47:191–201.

Citation: Rukam Singh, Deepak Issar, PV Zala and PC Nautiyal. (2007) Variation in sensitivity to salinity in groundnut cultivars during seed germination and early seedling growth. Journal of SAT Agricultural Research 5(1).