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Screening and selection of groundnut genotypes for tolerance of soil salinity

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Abstract

Field screening of 127 groundnut (*Arachis hypogaea* L.) genotypes was undertaken for two consecutive seasons at the experimental farm of Fruit Research Station, Mangrol, Junagadh, Gujarat, India to identify salinity tolerant genotypes based on plant mortality and seed yield. The plant mortality increased with the advancement of crop stages and a clearcut demarcation between salinity tolerant and sensitive genotypes was noticed at 90 days onwards. During summer season, the salinity level above 4 dS m^{-1} caused very high mortality of 50–100 % (average 91 %) with 100 % mortality in 54 sensitive genotypes, however, 29 genotypes survived with more than 5 % plant without any seed formation till maturity. But at the salinity level 3–4 dS m^{-1}, during *kharif* season, the plant mortality was 0–88 % (average 30 %) and a number of genotypes produced seed, was ideal for screening. There was a large genotypic variation in pod yield and related traits with 0–13 pods $plant^{-1}$ and 0–136 g m^{-2} seed yield and only 59 genotypes showed pod and seed bearing of which 20 genotypes had less than 10 % mortality. Overall the seed yield in a unit area (g m^{-2}) was the best criterion for selecting the salinity tolerant genotypes. Based on two seasons data, 11 genotypes NRCG 2588, 4659, 5513, 6131, 6450, 6820, 6919, 7206, TMV 2 NLM, TG 33, JNDS-2004-15 with high plant stand and more than 50 g m^{-2} seed yield were identified as salinity tolerant. 10 genotypes JNDS-2004-1, JNDS-2004-3, JNDS-2004-16, TG 28, TG 38C, TG 42, PBS 30031, PBS 30033, NRCG 6155, ICGV 86031 with more than 35 g m^{-2} seed yield were identified as moderately tolerant for their use in an area having salinity up to 3 dS m^{-1}.

Keywords*:* Field emergence, Groundnut (*Arachis hypogaea* L.) genotypes, plant mortality, pod and seed yield salinity tolerance.

Introduction

Groundnut (*Arachis hypogaea* L.) is an important crop grown in an area of about 26 million hectares (m ha) in more than 100 countries around the world (FAO, 2003) under different agro-climatic conditions for its nutritious oil rich kernel. However, India, China, Indonesia, the USA, Senegal, Nigeria, Brazil and Argentina are the major groundnut producing countries (FAO, 2003). In India, groundnut is one of the major oilseeds crops with its largest area in the world, but the area and production of this crop is fluctuating between 6.0 – 8.5 m ha and 6.0 – 9.5 million tonnes, respectively, mainly due to climatic variations, and biotic and abiotic stresses (Singh and Basu, 2004). 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 affecting the groundnut productivity. Also, in semi-arid region, where groundnut is main crop, the salinity area is increasing due to secondary salinisation by non-scientific use of poor quality ground water (Singh, 1992). But, so far neither any specific salinity management practice nor suitable groundnut genotypes have been recommended for these areas. The salinity decreases germination and seedling growth, dry matter production (Nautiyal et al., 1989; Singh et al., 1989; Janila et al., 1999) and induces Ca, K and Fe deficiencies in groundnut (Singh et al., 2004) causing yield losses (Hunshal et al., 1991). Saline and sodic soils limit groundnut cultivation as it is grouped under sensitive crop to

soil sodicity (Singh and Abrol, 1985) and soil salinity and could be grown with water having electrical conductivity (EC) up to 3.0 dS m^{-1} (Gupta and Yadav, 1986), although, enough genotypic variation exist for its tolerance (Singh et al., 2004; 2007). Thus, developing management practices and saline tolerant varieties to alleviate salinity stress are of utmost importance to bring more area under groundnut cultivation to increase production. The groundnut genotypes have been identified for their tolerance of iron chlorosis in calcareous and alkaline soils (Singh and Chaudhari, 1993) and soil acidity (Singh et al., 2004); however, information on tolerance of salinity is meager. Some efforts have been made to screen the groundnut genotypes by recording germination and plant growth till vegetative phase (Nautiyal et al., 1989; Joshi et al., 1990; Patel et al., 1992) and in field with limited genotypes without much variations (Mensah et al., 2006; Singh et al., 1989; Hunshal et al., 1991; Janila et al., 1999; Nautiyal et al., 2000), but there is hardly any study on *in situ* field screening of large number of groundnut genotypes till maturity to identify few tolerant ones. Recently an attempt is made for developing screening protocoal (Vadez et al., 2005). Thus, with an objective to provide groundnut genotypes that can grow and tolerate salinity with reasonably good yield, a systematic field study was undertaken by screening high yielding advanced breeding and germplasm lines and nutrient efficient genotypes.

Materials and Methods

Experimental details, groundnut genotypes and their cultivation

Screening of groundnut genotypes for tolerance of salinity stress was undertaken for two seasons at the experimental farm of Fruit Research Station, Junagadh Agricultural University, Mangrol (21° 07' N and 70° 07' E, 10.5 m above MSL), Junagadh, Gujarat. The soil of the experimental plot was loamy and calcareous (8-12 % $CaCO_3$) with medium fertility, having fast drainage capacity, pH 7.6, EC 1.6 dS m^{-1}, organic carbon 0.8 %, total N 0.019 %, available P 10 ppm (Olsen P), exchangeable K 224 ppm (Jackson, 1967) and DTPA extractable Fe, Mn, Zn and Cu 6.5, 20, 3.5, 0.8 mg kg^{-1}, respectively (Lindsay and Norvell, 1978). The land was prepared to a fine tilth by ploughing twice using a cultivator, leveled using a planker and 40 kg ha^{-1} N as urea and diammonium phosphate (DAP), 50 kg ha^{-1} P as DAP and 50 kg ha^{-1} K as muriate of potash were applied and mixed before sowing.

One hundred and twenty-seven groundnut genotypes with 120-130 days crop duration, comprising of nutrient efficient, advanced breeding and germplasm lines from National Research Centre for Groundnut, Junagadh; Bhabha Atomic Research Centre (BARC), Mumbai and Main Oilseeds Research Station, JAU, Junagadh were grown during summer (January-May) and *kharif* (June-October) seasons of 2004. The field was prepared and furrows were opened at a distance of 45 cm. The experiment was conducted in randomized block design (RBD) with two replications. Each genotype was sown in single row plots of 3 m length, seeds spaced at 10 cm with inter-row spacing of 45 cm. The crop was raised following recommended agronomic practices, and data on field emergence and plant stand at various crop stages were recorded. At maturity, the crop was harvested, dried in the sun and pod and seed yield, shelling outturn, 100-seed mass (HSM) and harvest index (HI) recorded. Five-plants were randomly selected from each genotype and number of pods, pod and seed yield per plant were recorded. All these data were statistically analyzed.

The meteorological data of the experimental site, during cropping season, was recorded (Table 1). The total rainfall received during the year was 1,067 mm all during June-August of *kharif* season and no rain during summer season. The station being situated on the seashore, no drastic fluctation in the temperature was noticed. The ground water of the farm was highly saline with 11-12 dS m^{-1} EC, hence water with low EC was mixed before irrigation (Table 2). There were 10 irrigations during summer season and no irrigation during *kharif* season.

Salinity treatment and screening procedures

The screening was undertaken for two consecutive seasons, first by imposing the salinity treatment as irrigation with saline water during summer season and then on residual salinity during *kharif* season (Table 2). The experimental soil showed 1.6 dS m^{-1} EC initially which increased to 4 dS m^{-1} by first irrigation with saline water (EC 11.7 dS m^{-1}) immediately after sowing, and hence to ensure maximum germination the second irrigation was given after five days with water of EC 1.4 dS m^{-1}. The subsequent irrigations were given at an interval of 10-15 days by saline water of EC around 6-7 dS m^{-1}, and the salinity build up and pH of the experimental plot was measured at regular intervals during the cropping season (Table 2). The EC of the soil at various crop stages ranged from 4.0-8.0 dS m^{-1}. There was no rain during the summer season. As there was severe plant death due to salinity build up upto 8 dS m^{-1} at the end of cropping season during summer, the screening of second crop during *kharif* season was done in the same field on residual salinity without further increasing the salinity. However, as the salinity level of 8.0 dS m^{-1} was quiet high for groundnut, next crop was planted only after heavy rainfall when soil salinity was reduced below 5.0 dS m^{-1}.

Table 1. Weather data of the Experimental Farm during 2004 Figures in parentheses indicates the number of rainy days

Months	Mean temperature (°C)		RH (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum			
January	30.3	13.6	70.6	-	2.8
February	32.9	15.3	74.3	-	3.8
March	36.7	19.3	76.4	-	4.9
April	34.3	24.4	82.2	-	4.9
May	34.1	27.5	81.0	-	5.1
June	33.9	27.7	80.1	386 (4)	4.1
July	31.4	26.6	84.1	127 (9)	3.2
August	29.9	25.6	89.4	554 (11)	2.0
September	32.7	25.0	83.8	-	3.1
October	35.2	21.7	69.0	-	3.3
November	35.6	19.6	64.8	-	3.1
December	32.5	16.2	67.5	-	2.6

Table 2. Electrical conductivity of water and soil during experimentation (DAS: Days after sowing)

Electrical conductivity and pH of saline water used for irrigation during summer, 2004				Electical conductivity and pH of soil during experimentation					
				Summer 2004			*Kharif* 2004		
Irrigation treatment	DAS	EC (dS m^{-1})	pH	DAS	EC (dS m^{-1})	pH	DAS	EC (dS m^{-1})	pH
1^{st}	0	11.7	7.0	0	1.60	7.60	0	4.5	7.5
2^{nd}	5	1.4	7.5	1	4.0	7.6	15	3.5	7.54
3^{rd}	21	1.4	7.5	21	6.20	7.70	45	3.3	7.6
4^{th}	37	7.4	6.9	41	6.70	7.73	80	3.0	7.7
5^{th}	48	6.4	6.9	77	6.8	7.69	118	2.51	7.9
6^{th}	62	6.3	7.4	91	6.8	7.70			
7^{th}	78	7.2	7.4	98	7.2	7.5			
8^{th}	88	6.8	7.1	112	8.0	7.5			
9^{th}	98	7.1	7.2	126	8.0	7.5			
10^{th}	112	1.4	7.5						

During summer season, the observations on field emergence and subsequent plant stand were recorded at 21, 41, 77, 91 and 112 days after sowing (DAS). The final plant survival and mortality were noted at the end (126 DAS). The plant mortality was calculated as reduction in plant stand at that stage over the initial plant stand at field emergence and expressed in percentage. As there was severe mortality and was hardly any pod and seed formation during this season, the genotypes were ranked based on mortality and high plant stand at 91, 112 and 126 DAS and grouped under different degrees of tolerance. The genotypes showing lesser mortality and better plant stand were grouped as tolerant and the ones showing higher mortality and lesser plant stand as sensitive.

During *kharif* season, the first shower was received on 15^{th} June 2004 followed by subsequent rains that brought down the salinity level of the upper surface (0-15 cm) of the field to 4.5 dS m^{-1} EC after 8 days, and then crop was sown in the same field for its screening on this residual salinity. The subsequent rain during the cropping season further reduced the soil salinity to 3.5 at 15 DAS, 3.0 at 80 DAS and 2.5 at maturity. Data on field emergence was recorded at 15 DAS and plant stand at 45 DAS and at harvest.

Hierarchical cluster analysis of 127 groundnut genotypes using SPSS software was carried out taking initial plant stand, final plant stand and mortality following salt stress during both summer and kharif seasons. The between-groups linkage method of clustering was adopted using eulcidean distances. Also, the groundnut genotypes were arranged for their plant stand and seed yield in descending order and mortality in ascending order and ranked. The genotypes were grouped under different degree of salinity tolerance based upon their ranking for higher plant stand and lesser mortality during summer season , and these

Table 3. Criteria for categorization of groundnut genotypes for their tolerance of soil salinity

		Categories of Salinity tolerance		
Season	Parameters	Tolerant	Moderately Tolerant	Sensitive
Summer 2004	Rank in plant survival at 91, 112 and 126 DAS (in descending order)	First 60 genotypes	First 60 genotypes	Last 50 genotypes
Kharif 2004	Rank in plant survival at harvest (in descending order)	First 60 genotypes	First 60 genotypes	Last 50 genotypes
	Rank in seed yield (in descending order)	Less than 20	Less than 30	Last 50 genotypes
	Seed yield (g m^{-2})	More than 50	More than 35	Less than 20

parameters along with agronomic performance during *kharif* season following the criteria given in Table 3.

Results and Discussion

Two seasons' data, on 127 groundnut genotypes, indicated that salinity delayed germination, reduced field emergence, plant growth and subsequent plant stand, and pod and seed yields with large genotypic variations providing a basis for selecting the salinity tolerant genotypes. The season-wise observations and final conclusions are described in the following sections.

Summer season

Salinity affected seedling emergence and mortality causing reduction and delay (3-10 days) in emergenece. Salinity cause accumulation of salt in the root zone and at the soil surface and hence its effect started with imbibition of seed as soon as it came in contact with saline water. As a result the groundnut, which takes only 8-10 days for emergence during summer season, showed low emergence in majority of the genotypes even after 13 DAS. At 21 DAS, the average plant stand was 28 % and range 1- 66 % with 13 genotypes showing more than 50 % emergence. At 41 DAS, though in majority of the genotypes the plant stand was lower than that at 21 DAS, in a few genotypes it increased due to late emergence.

The plant mortality increased with the advancement of the crop stages, however the mortality varied with genotypes with a clearcut demarcation between salinity tolerant and sensitive genotypes at 91 DAS and onwards indicating this as the best stage for screening. The average (of all the genotypes) plant stands were only 23, 16, 5 and 3 %, at 77, 91, 112 and 126 DAS, respectively with some of the genotypes showing very high mortality. At 91 DAS, 50 genotypes with 10 % or less plant stand were categorized as sensitive to salinity, of these 31 genotypes died by 112 DAS. On the other hand, 60 genotypes showed more than 15 % plant stand at 91 DAS indicating their better tolerance to salinity than others. At 112 DAS, 43 genotypes showed more than 5 % plant stand of which 21 had more than 10 % plant stand. Decrease in germination and seedling growth due to increasing salinity levels is well documented (Nautiyal et al., 1989; Singh et al., 1989; Patel et al., 1992; Janila et al., 1999; Mensah et al., 2006). At 126 DAS, the mortality was 50-100 % with 54 genotypes exhibiting complete mortality; however, 29 genotypes still showed more than 5 % plant alive indicating their tolerance of salinity. The salinity caused severe reduction in plant stature; as a result the plant height was less than 10 cm, with majority of genotypes less than 5 cm plant height.

The 120-130 days groundnut crop requires 9-11 irrigations during summer season and only one or two protective irrigations during *kharif* season. Thus, salinity build up is more during summer season than during *kharif*. In this study, the summer season groundnut genotypes faced salinity of 4 dS m^{-1} at sowing, 6-7 dS m^{-1} during 21-98 DAS and 8 dS m^{-1} afterwards till maturity (Table 2), which resulted in severe plant death. The mean maximum temperature was 34–36.7 °C during March, April and May and evaporation rate ranged from 4.9–5.1 mm day^{-1} (Table 1), which probably were responsible for higher salt accumulation at the soil surface and its uptake by plant that resulted in higher mortality. Thus, majority of the genotypes had shown only gynophores without pod formation. Though a few genotypes showed pod, it did not bear seed and hence no pod and seed yield could be recorded in any of the genotypes during summer season.

The clustering of genotypes based on plant stand at 21 and 91 DAS, mortality and plant height gave a large number of clusters. The genotypes with medium plant stand and very high mortality at maturity grouped together at the top of the dendrogram whereas those with low initial plant stand and low mortality at maturity grouped at the bottom. Genotypes with high plant stand but with low levels of mortality were placed in middle. Due to very high variation for these traits among the genotypes, the clustering was not very infoermative. Thus, all the 127 genotypes were

Table 4. Performance of groundnut genotypes bearing pods under salinity stress, during *kharif* 2004, [59 genotypes arranged in decending order of their seed yield (g m^{-2})]

Sl.No.	Groundnut genotypes	Plant stand (%)			Mortality at harvest (%)	Pods/ plant	Pod yield/ plant (g)	Seed yield/ plant (g)	Shelling (%)	100-seed mass (g)	HI (%)	Seed yield (g m^{-2})
		15 DAS	46 DAS	118 DAS								
1	NRCG 6450	64	67	58	14	12	10.4	7.1	73	41	35	137
2	NRCG 7206	63	61	60	4	10	7.0	4.9	68	31	34	99
3	NRCG 2588	58	64	60	6	11	6.8	4.5	67	31	36	90
4	JNDS-2004-16	68	90	68	25	7	4.6	3.1	63	31	23	70
5	NRCG 6919	68	72	67	7	6	4.2	3.0	71	33	38	66
6	TG 28	91	87	37	59	6	7.4	5.3	63	50	33	66
7	NRCG 5513	54	53	53	1	8	6.8	3.7	59	26	25	66
8	NRCG 6820	59	71	58	19	8	4.6	3.3	76	28	35	64
9	NRCG 7453	94	83	60	36	10	4.5	3.0	67	24	24	59
10	TMV 2 NLM	91	88	85	6	5	3.5	2.1	60	36	18	58
11	JNDS-2004-1	48	47	37	24	10	6.6	4.6	62	39	19	56
12	NRCG 4659	50	53	37	32	7	7.4	4.5	58	46	26	55
13	JNDS-2004-11	70	72	60	16	7	4.3	2.7	64	37	16	53
14	NRCG 6131	60	73	61	16	5	3.8	2.6	70	33	25	53
15	TG 33	55	52	52	6	4	4.3	3.0	74	35	26	52
16	JNDS-2004-15	72	73	60	18	8	4.1	2.6	62	29	19	52
17	TG 38C	83	76	40	52	11	6.3	3.6	58	32	30	48
18	PBS 21063	80	74	60	25	3	4.0	2.3	60	52	13	47
19	JNDS-2004-3	67	68	55	20	5	3.8	2.5	69	37	14	45
20	PBS 30031	77	70	66	15	5	3.2	2.0	62	39	14	44
21	TG 38A	70	60	30	57	13	7.1	4.3	63	35	40	43
22	TG 39	78	72	51	35	5	4.2	2.4	57	48	22	40
23	NRCG 6155	60	53	34	43	5	5.2	3.5	67	47	36	40
24	ICGV 86031	60	53	41	31	7	5.1	2.7	56	33	18	38
25	TG 42	69	58	37	47	6	5.0	3.0	63	48	28	37
26	PBS 30079	63	61	54	14	4	3.0	2.0	70	51	22	37
27	JNDS-2004-2	47	53	40	25	7	4.7	2.8	59	34	17	37
28	PBS 30033	68	65	61	9	5	3.3	1.8	63	33	20	36
29	PBS 30036	59	76	76	0	5	2.4	1.3	56	26	15	32
30	PBS 30104	81	77	70	14	3	2.4	1.3	57	39	17	30
31	TG 36B	61	66	26	60	5	4.1	3.0	66	36	29	26
32	PBS 19012	51	41	39	25	2	2.9	2.0	57	51	16	26
33	JNDS-2004-18	68	77	65	15	3	1.6	1.1	65	34	7	24
34	PBS 18045	77	66	63	19	2	1.6	1.0	69	40	13	22
35	JNDS-2004-25	73	77	52	33	3	2.1	1.2	66	44	13	22
36	NRCG 168	87	77	70	20	4	1.9	0.9	51	17	10	21
37	JNDS-2004-13	60	73	45	39	3	2.0	1.4	70	32	22	21
38	PBS 30044	67	64	61	9	3	1.7	1.0	62	42	10	21
39	TG 40	56	61	23	62	8	5.0	2.4	51	38	28	19
40	TG 27	65	53	43	33	5	2.4	1.3	56	34	13	18
41	PBS 30016	59	53	37	37	3	2.1	1.4	69	40	20	18
42	PBS 12175	70	59	51	27	2	1.6	1.0	70	43	11	17
43	JNDS-2004-20	64	78	51	34	3	1.5	0.8	55	26	13	14
44	TG 34	53	52	15	72	12	5.2	2.6	55	38	44	13
45	PBS 13003	66	64	40	39	2	1.5	0.9	69	43	11	12
46	PBS 11072	54	63	49	23	3	1.3	0.8	59	45	7	12
47	JNDS-2004-40	53	60	45	25	3	1.3	0.8	57	34	9	11
48	PBS 14010	70	53	41	41	2	1.4	0.8	63	38	17	11
49	PBS 30041	64	59	44	31	2	1.2	0.7	57	41	8	11
50	JNDS-2004-39	72	70	60	16	2	0.9	0.5	53	37	7	10
51	PBS 30012	57	57	27	52	3	1.8	1.1	65	27	14	10
52	TG 32	70	62	28	60	3	1.8	1.1	65	41	29	10
53	PBS 12169	69	60	47	31	1	1.0	0.6	70	39	7	9
54	PBS 30073	71	64	59	18	1	0.7	0.5	65	46	9	9
55	PBS 11070	66	63	50	24	1	0.7	0.5	65	39	9	8
56	JNDS-2004-48	72	58	37	49	2	1.0	0.5	44	35	9	6
57	PBS 18064	61	56	41	33	1	0.8	0.4	53	34	9	5
58	TG 29	55	58	23	60	2	1.0	0.5	57	39	14	4
59	TG 30	80	73	17	79	2	1.0	0.7	70	38	16	4
	Mean	66	65	49	30	5	3.5	2.1	63	37	20	35
	S.E.	4.6	4.9	5.7	3.0	1.2	0.9	0.7	3.4	4.2	3.2	3.1

Table 5. Performance of salinity tolerant and moderately tolerant groundnut genotypes under saline conditions during summer and *kharif* seasons of 2004

Groundnut genotypes	Summer season			*Kharif* season							
	(%) Plant stand at 91 DAS	At harvest		(%) Plant stand at 118 DAS	At harvest						
		Plant height (cm)	(%) Mortality		(%) Mortality	Pod yield/ plant (g)	Seed yield/ plant (g)	Shelling (%)	100-seed mass (g)	HI (%)	Seed yield (g m^{-2})
A. Tolerant											
NRCG 6450	16	3.5	89	58	14	10.4	7.1	73	41	35	137
NRCG 7206	17	4.9	84	60	4	7.0	4.9	68	31	34	99
NRCG 2588	30	2.6	91	60	6	6.8	4.5	67	31	36	90
NRCG 6919	47	10.0	100	67	7	4.2	3.0	71	33	38	66
NRCG 5513	14	6.5	80	53	1	6.8	3.7	59	26	25	66
NRCG 6820	23	7.2	81	58	19	4.6	3.3	76	28	35	64
TMV 2 NLM	16	11.0	62	85	6	3.5	2.1	60	36	18	58
NRCG 4659	44	3.6	77	37	32	7.4	4.5	58	46	26	55
NRCG 6131	26	3.4	68	61	16	3.8	2.6	70	33	25	53
TG 33	10	3.9	71	52	6	4.3	3.0	74	35	26	52
JNDS-2004-15	30	3.3	97	60	18	4.1	2.6	62	29	19	52
B. Moderately tolerant											
JNDS-2004-16	9	0.0	100	68	25	4.6	3.1	63	31	23	70
TG 28	4	3.8	89	37	59	7.4	5.3	63	50	33	66
JNDS-2004-1	29	0.0	100	37	24	6.6	4.6	62	39	19	56
TG 38C	4	3.6	83	40	52	6.3	3.6	58	32	30	48
JNDS-2004-3	4	5.1	93	55	20	3.8	2.5	69	37	14	45
PBS 30031	3	4.0	93	66	15	3.2	2.0	62	39	14	44
NRCG 6155	24	3.3	96	34	43	5.2	3.5	67	47	36	40
ICGV 86031	46	11.0	92	41	31	5.1	2.7	56	33	18	38
TG 42	14	4.4	69	37	47	5.0	3.0	63	48	28	37
PBS 30033	7	6.0	94	61	9	3.3	1.8	63	33	20	36
Range	0-47	0-11.1	0-100	15-85	0-79	0.7-10.4	0.4-7.1	44-76	17-52	7-44	4-137
Mean	16	2.7	91	49	30	3.5	2.1	63	37	20	35
S.E.	3.1	1.0	2.5	5.7	3.0	0.9	0.7	3.4	4.2	3.2	3.1

ranked based upon plant stand at 91, 112 and 126 DAS and mortality at harvest, the first 60 genotypes with lesser mortality and better plant stand, was shortlisted as tolerant to moderately tolerant and last 50 genotypes showing higher mortality and lesser plant stand as sensitive to salinity.

Kharif season

During *kharif* season the field emergence, in these genotypes, was 36-100 % (average 66 %) at 15 DAS with 15 genotypes showing more than 80 % emergence. The subsequent plant stand, at 45 DAS, ranged 33-90 % (mean 65 %) where 42 genotypes showed more than 70 % plant stand. The mortality increased with the days passed and at harvest it ranged from 0 to 88 % among genotypes with plant stand varying from less than 10 % to as high as 85 %. The average (of 127 genotypes) plant stand at harvest was 46 % with pod bearing in limited genotypes only. Interestingly, 22 genotypes showed more than 60 % plant stand of which 20 showed less than 10 % mortality.

At the end of cropping during summer season, there was salinity buildup upto 8 dS m^{-1} in the field which is very high for groundnut and hence the screening of next crop of *kharif* season in the same field, was undertaken only after receiving the showers that brought down the salinity level of the

field to 4.5 dS m^{-1}. As a result the germination during *kharif* season was higher than that recorded during summer season. However, there was still a delay of 2-7 days in many of the genotypes as evident from slight increase in the plant stand at 45 DAS in comparison to the initial emergence. With advancement of crop stages and due to rain, the salinity of the field further decreased to 3.0 dS m^{-1} at 80 DAS and 2.5 dS m^{-1} at harvest during *kharif* season (Table 2). But large genotypic variation in plant stand, mortality and yield clearly indicated that there was an ideal salinity condition during cropping season for screening and identification of salinity tolerant and sensitive genotypes.

The clustering of genotypes based on plant stand at 15 and 118 DAS and mortality, during kharif season, gave a dendrogram with very large number of clusters where genotypes with poor final plant stand and high mortality (highly sensitive to salinity) were grouped together at the bottom of the dendrogram, and genotypes with high initial plant stand and moderate levels of mortality (moderately tolerant) clustered together at the top. Other genotypes were dispersed in different clusters throughout the dendrogram.

As individual seasons clustering was not very useful, the hierarchial cluster analysis, based on the intial and final plant stand and mortality during both the seasons was attended which grouped the genotypes into more than 10 clusters with some having more number of genotypes while other had only 2-3 genotypes (Fig. 1). Here, interestingly, the genotypes with low plant stand and high mortality clusetered together and that with high to medium plant stand and low mortality clusetered together, but in 2-3 groups. The sensitive genotypes with low to medium plant stand and high mortality appeared on the top (in 3-4 groups) and that of low to medium plant stand and low mortality at the bottom (in 4-5 groups). The genotypes with high plant stand and low mortality (tolerant to moderately tolerant) one appeared in middle of the dendrogram, but in 4-5 groups, middle two for tolerant one (NRCG 6131 7206, 6820 5513 4659, 6919 2588) and surrounding two for moderately tolerant one (PBS 3033, 30044, 30031, JND 2004-16, JND 2004-3, JND 2004-21). However, large variation in plant stand and very high mortality during summer compared to *kharif* season, some genotypes grouped very differently. As yield data were available for only one season this was not used as criteria in clustering as a result decision on tolerance or susceptibility of the genotypes could not be taken only by clustering pattern.

The pod yield and related traits in various genotypes also showed extreme variations with 0-13 pods $plant^{-1}$, and 0-7 g seed yield $plant^{-1}$. Of the 127 groundnut genotypes, there was pod and seed bearing in 59 genotypes only which showed 1.0-10.4 g pods $plant^{-1}$ and 0.7-7.1 g seed $plant^{-1}$ with an average of 3.5 g pod and 2.1 g seed $plant^{-1}$ and shelling outturn varying in between 44 to 76 % (Table 4). The harvest index showed much variation mainly due to variation in pod bearing. The seed yield per unit area ranged from 3.8 to 136 g m^{-2} with a mean of 35 g m^{-2}. When the genotypes were arranged in descending order of their seed yield, 28 genotypes showed more than 35 g m^{-2} and 16 more than 50 g m^{-2} seed yields (Table 4).

There was plant mortality as well as pod bearing depending upon the salinity levels and season with large genotypic variations. The high salinity during summer season resulted in very high mortality and no seed formation, this necessitated considering only the plant stands as the criteria for selecting comparatively tolerant genotypes. The plant survival along with seed yield was considered during *kharif* season. Thus the seed yield in a unit area (g m^{-2}), a resultant of plant survival and yield parameters, earlier identified as the best criterion for selecting the salinity tolerant genotypes (Singh et al., 2007), here also was found best. Large variations in seed yield were mainly due to genetic variations for yielding ability of the genotypes coupled with tolerance of salinity.

Based on the data of the two seasons for plant stand, and seed yield data of *kharif* season, 11 genotypes (NRCG 2588, 4659, 5513, 6131, 6450, 6820, 6919, 7206, TMV 2 NLM, TG 33, JNDS-2004-15) showing high plant stand and more than 50 g m^{-2} seed yield were identified as salinity tolerant and 10 genotypes (JNDS-2004-1, JNDS-2004-3, JNDS-2004-16, TG 28, TG 38C, TG 42, PBS 30031, PBS 30033, NRCG 6155, ICGV 86031) with more than 35 g m^{-2} as moderately tolerant (Table 5). However, 50 genotypes with very high mortality and less than one-gram seed $plant^{-1}$ (20 g m^{-2}) were categorized as sensitive to salinity.

The tolerance is a relative term depending mainly upon the intensity of salinity and relative performance of genotypes. The groundnut genotypes with high field emergence followed by high plant stand and low mortality under saline conditions could be considered as tolerant of salinity stress. However, data on yielding ability is more vital for arriving at meaningful conclusion, as increasing salinity decrease pod yield (Hunshal *et al*., 1991; Singh et al., 2007). In a recent field screening of more than 200 groundnut genotypes for their tolerance of salinity stress at 3.0 dS m^{-1} EC, Singh et al. (2007) ranked genotypes based upon lesser mortality and better yield and top 10 genotypes were grouped as tolerant (NRCG 10874, NRCG 420, NRCG 13831, NRCG 9052, NRCG 12750, NRCG 9189, NRCG 894, NRCG 13787, NRCG 13791, NRCG 9038). Joshi et al. (1990), in a pot study, reported that the vegetative growth was impaired at salt concentrations of 8 dS m^{-1} EC and genotypes NRCG 168, 609, 3665 and 7453 were

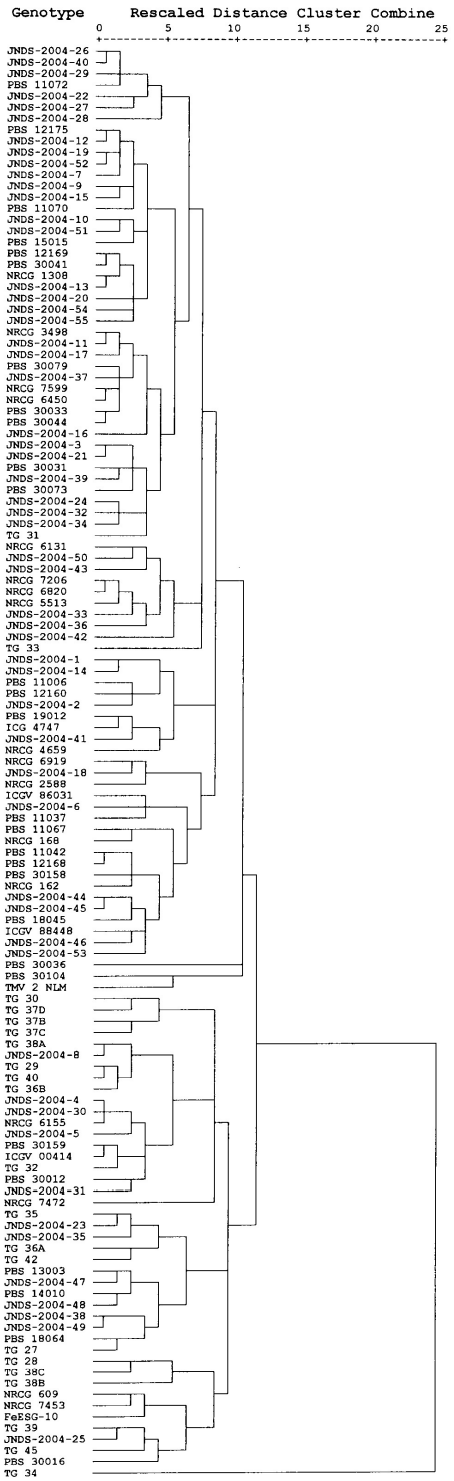

Fig 1. Hierarchical cluster analysis of groundnut genotypes using plant stand and mortality during both the seasons following salt stress

able to survive this level of salinity. However, the present study clearly demonstrated that groundnut genotypes must be tested till 90 DAS to judge their tolerance of salinity, where none of the three genotypes NRCG 168, 609 and 7453 was found tolerant. This further emphasizes the need of field evaluation for salinity tolerance.

The study clearly demonstrated that there are a few high yielding genotypes that can endure the salinity stress and also yield satisfactorily. Interestingly, some of these salinity tolerant genotypes (NRCG 2588, 4659, 5513, 6131, 6450, 6820, 6919 and 6155) also are tolerant of iron-chlorosis in alkaline and calcareous soils (Singh and Chaudhari, 1993) making them more fit for alkaline as well as saline soils. These salinity tolerant genotypes hold immense promise as these can be grown in the coastal saline areas with salinity upto 3 dS m^{-1}, and also can find their way into future breeding programmes.

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