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IDENTIFICATION OF GROUNDNUT (*ARACHIS HYPOGAEA* L.) CULTIVARS TOLERANT OF SOIL SALINITY

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IDENTIFICATION OF GROUNDNUT (*ARACHIS HYPOGAEA* L.) CULTIVARS TOLERANT OF SOIL SALINITY

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□ *Field screening of 83 groundnut cultivars was undertaken for two seasons to assess their tolerance of salinity based on plant mortality and yield attributes. During the dry season, soil salinity of 4 dS m^{-1} at sowing and 6–7 dS m^{-1} 21–98 days after sowing (DAS) caused high mortality without seed formation in any cultivars, however, at salinity 4.5 dS m^{-1} during sowing and 3.5–3.0 dS m^{-1} 15–80 DAS during wet season, 61 cultivars produced seed. The cultivars 'VRI 3', 'UF 70–103', 'TKG 19A', 'S 206', 'Tirupati 4', 'M 522', 'Punjab 1', 'BG 3', 'Somnath' and 'ICGV 86590', with high plant stand during both the seasons and over 75 g m^{-2} seed yield during wet season, were identified salinity tolerant. However, 15 cultivars with more than 50 g m^{-2} seed yield were moderately tolerant and 28 cultivars with less than 25 g m^{-2} seed yield were sensitive to salinity.*

Keywords: groundnut (*Arachis hypogaea* L.) cultivars, nutrient contents, plant mortality, pod and seed yield, salinity tolerance

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important legume crop grown world-wide in about 26 million hectares (m ha) area (FAO, 2003). India has the largest groundnut area in the world, but in recent years it is fluctuating between 6.0–8.5 m ha mainly due to climatic variations, and biotic and abiotic stresses. Salinity development due to non-scientific use of poor quality ground water is one of the major abiotic factors causing reduction in the area and productivity of groundnut in the coastal belt and, in semi-arid region (Singh et al., 2004). Also, there is an increasing pressure to make use of saline land through its management to bring more area under groundnut cultivation. But so far neither any specific salinity management practice nor suitable groundnut cultivars have been recommended for these

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areas. This calls for the attention by groundnut researchers to develop various management practices to salinity stress to increase the productivity and bring more area under cultivation. Development of saline tolerant cultivars, which can grow in and tolerate the salinity, is the most important option.

In India, groundnut is grown as a wet season crop during June–October as well as dry season crop during January–May. In the coastal areas, the groundnuts flourish well during wet season, but need one or two protective irrigation due to end season drought. The electrical conductivity (EC) of these soils ranges 1.0–2.0 dS m^{-1}, but water of the wells of this area contains 6–12 dS m^{-1} EC due to ingress of sea water and not fit for irrigation. As a result, farmers of these areas generally have to depend on rainfed cultivation during rainy (wet) season (June–September). Irrigation with well-water during October–May, causes the soil salinity build up up to 6.0–7.0 dS m^{-1} EC making the field unfit for the next season's crop. The heavy downpour during June though brings down this salinity to 4.5–5.0 dS m^{-1} EC, the groundnut production is seriously hampered. This is a common situation in the coastal parts of India leading to decrease in groundnut area and hence require immediate measure. Identification of groundnut cultivars that can grow and tolerate salinity to a certain level is the most important option. The groundnut genotypes have been identified for their tolerance of iron chlorosis for calcareous and alkaline soils (Singh and Chaudhari, 1993), but not for soil salinity. Gupta and Yadav (1986) reported that groundnut could be grown with water having EC up to 3.0 dS m^{-1}, but our recent study shows that groundnut plant starts facing salinity stress above 2.0 dS m^{-1} and EC above 4.5 dS m^{-1} kills the plants, however, as enough genotypic variation exists, the salinity level in between 3–4 dS m^{-1} during most of the cropping period was ideal for screening for salinity tolerance (Singh et al., 2007, 2008).

Some efforts have been made to study the performance of a few groundnut cultivars by recording germination and studying plant till vegetative phase in pots (Nautiyal et al., 1989; Patel et al., 1992; Vadez et al., 2005) and in field (Janila et al., 1999) and very few till maturity in field (Mensah et al., 2006; Hunshal et al., 1991; Hebbara et al., 1992; Nautiyal et al., 2000). Also, recently attempts were made for developing screening protocol using rate of survival under sodium chloride (NaCl) treatment in glass house (Vadez et al., 2005) as well as *in vitro* regenerated shoots grown on media (Mungala et al., 2008) as a measure of their tolerance to salinity. However, there are hardly any reports with systematic effort to screen a large number of groundnut cultivars till maturity in the field at the hot spot, and categorize them for salinity tolerance. Thus, an effort was made to screen the groundnut cultivars under natural saline conditions, and categorize them for their tolerance of salinity stress.

MATERIALS AND METHODS

Experimental Details and Groundnut Cultivation

In situ field screening of groundnut cultivars, for tolerance of salinity stress, was undertaken at the experimental farm of Fruit Research Station, Junagadh Agricultural University, Mangrol, (21° 07′ N and 70° 07′ E, 10 m above MSL) Junagadh, during dry (January–May) and wet (June–October) seasons of 2004. The soil of the experimental plot was loamy, calcareous [8–12% calcium carbonate ($CaCO_3$)], having pH 7.6, hydraulic conductivity 1.25 cm h^{-1}, electrical conductivity (EC) 1.6 dS m^{-1}, organic carbon 0.8%, total nitrogen (N) 0.019%, available phosphorus (P) 10 ppm (Olsen P), exchangeable potassium (K) 224 ppm and available [diethylenetriaminepentaacetic acid (DTPA) extractable] iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) 6.5, 20, 3.5, 0.8 ppm, respectively (Lindsay and Norvell, 1978). The ground water of the well at the farm was saline with EC 11–12 dS m^{-1}, which was not suitable for irrigation to groundnut crop, and hence normal water of low EC was mixed before irrigation during dry season. The land was prepared by plowing and leveling, 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 as basal and mixed at the time of sowing.

Eighty-three groundnut cultivars, released in India, were used for screening their tolerance of salinity stress during both dry and wet seasons. The experiment was laid out in a randomized block design (RBD) with three replications. After field preparation, 10–12 cm deep furrows were opened at 45 cm distance and divided into three strips of 3 m wide each. Each cultivar was sown in single row plots, 3 m in length and seeds spaced at 10 cm in the furrow at 45 cm. The recommended agronomic practices were followed and data on field emergence and plant stand at various crop stages were recorded. The crop was harvested at maturity, dried in the sun and pod and seed yield, shelling outturn, 100-seed mass (HSM) and harvest index (HI) were recorded. Five-plants were randomly selected from each cultivar and number of pods, pod and seed yields were recorded. All these data were analyzed statistically.

The weather data of the experimental site are given in Table 1. The experimental site being situated near seashore, no drastic fluctuation in the temperature was noticed.

Salinity Treatment and Screening Procedures

At the start of the experiment, during dry season, the initial EC of the experimental soil was 1.6 dS m^{-1} which increased to 4.0 with first irrigation of saline water (EC_{iw} 11.7 dS m^{-1} and pH 7.0) immediately after sowing. The second irrigation was given after five days with normal water (EC 1.4 dS m^{-1} and pH 7.5) to ensure maximum germination. The subsequent irrigations

TABLE 1 Weather data of the Experimental Farm during 2004

Month	Mean temperature (°C)		RH (%)	Rainfall (mm)	Number of rainy days	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

were given at an interval of 10–15 days by saline water of EC around 6–7 dS m^{-1} (Table 2). As there was no rain during dry season, altogether 10 irrigations were given. The soil of the experimental plot, from upper 15 cm depth at five places, was collected at regular intervals during cropping season and the salinity build up, as EC_e of saturated extract, was measured in triplicates at various stages (Table 2).

The observations on field emergence and subsequent plant stand at 21, 41, 77, 91, and 112 days after sowing (DAS) were recorded during dry season as the crop attains maturity in 120–130 days. 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

TABLE 2 Electrical conductivity (EC) and pH of water and soil during experimentation

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

DAS: Days after sowing.

stand at field emergence and expressed in percentage. As there was severe mortality and hardly any pod and seed formation during this season, the genotypes were ranked based on mortality and plant stand at 91, 112, and 126 DAS and grouped under different categories of salinity 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.

As there was severe plant death at maturity during dry season due to salinity build up upto 8 dS m^{-1} EC_e, the screening during wet season was repeated in the same field on residual salinity without further increasing the salinity level. However, as the salinity level of 8.0 dS m^{-1} was quite high for groundnut, next crop was planted only after heavy rainfall when soil salinity was reduced below 5.0 dS m^{-1}. The continuous rainfall for a week starting from 15 June 2004, during wet season, brought down the salinity level, of the upper 15 cm surface of the field, to 4.5 dS m^{-1} EC after eight days, and then all the groundnut cultivars were 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 (Table 2). The crop was raised following all recommended agronomic practices. Data on field emergence was recorded at 15 DAS and plant stand was recorded at 45 DAS and at maturity.

At 90 DAS, when there was visible differences in the tolerant and sensitive cultivars, the leaves of these groundnut cultivars were sampled, dried and analyzed for sodium (Na), K, calcium (Ca), magnesium (Mg), Fe, Mn, Zn, and Cu content using atomic absorption spectrophotometer and P by colorimetry and sulfur (S) by turbidity methods (Jones et al., 1991). The Na, Ca, and K content in leaves and Na/Ca and Na/K ratio of tolerant and sensitive cultivars were compared. The crop was harvested, at maturity, dried in the sun and pod and fodder yields, shelling outturn, 100-seed mass (HSM) and harvest index (HI) were recorded.

All the groundnut cultivars were arranged in descending order of plant stand and seed yield and in ascending order for mortality and grouped under various degree of salinity tolerance based upon the ranking of plant stand as well as agronomic performance following the criteria given in Table 3. As the experiment was conducted for two seasons, the groundnut cultivars falling in the same category during both the seasons only were finally considered.

RESULTS AND DISCUSSION

Dry Season

The salinity delayed seedling emergence for 3–10 days, reduced plant growth and caused plant mortality, however, large variations were observed among groundnut cultivars (Table 4). Generally groundnut takes 8–10 days

TABLE 3 Criteria used for categorization of groundnut cultivars for salinity tolerance

Season	Criterion	Tolerant	Moderately Tolerant	Intermediate	Sensitive
Dry 2004	Rank in plant survival at 91, 114 and 126 DAS (in descending order)	Less than 30	Less than 30	Less than 40	Last 40
Wet 2004	Rank in plant survival at harvest	Less than 30	Less than 30	—	Last 40
	Rank in seed yield (g m^{-2}) at harvest	Less than 20	Less than 30	—	—
	Seed yield (g m^{-2})	More than 75 g m^{-2}	More than 50 g m^{-2}	More than 25 g m^{-2}	Less than 25 g m^{-2}

TABLE 4 Plant stand, height and mortality of groundnut cultivars affected by soil salinity during dry season 2004

Sl. No.	Groundnut cultivar	Plant stand (%) at days after sowing (DAS)						At harvest	
		21	41	77	91	112	126	Plant height (cm)	Mortality (%)
1	'TG 22'	13	11	9	9	6	6	4.2	56
2	'LGN 2'	64	67	61	56	36	24	8.2	64
3	'Tirupati 4'	19	10	6	6	3	6	4.2	69
4	'ICGS 76'	27	26	20	10	9	7	5.0	74
5	'TG 26'	23	21	9	7	6	6	3.8	75
6	'BAU 19'	26	34	27	24	9	9	10.4	75
7	'SP 250A'	36	39	37	36	10	7	4.9	81
8	'Chitra'	29	37	20	10	7	7	5.3	81
9	'UF 70–103'	33	23	26	24	6	6	5.7	83
10	'ICGV 86590'	50	46	39	31	16	9	6.9	83
11	'CSMG 84–1'	27	26	9	7	6	4	4.5	84
12	'TG 17'	19	19	17	16	3	3	4.6	85
13	'TAG 24'	10	10	7	3	1	1	4.6	86
14	'S 206'	30	29	26	16	4	4	3.8	86
15	'DRG 17'	46	50	49	43	17	7	3.6	86
16	'ALR 2'	49	50	41	26	7	7	8.2	86
17	'ICG (FDRS)-4'	33	30	24	17	6	4	8.0	87
18	'BG 3'	33	33	30	23	6	4	3.9	87
19	'ICGS 37'	26	33	19	9	6	4	5.0	87
20	'RS 138'	20	21	20	16	4	3	7.7	87
21	'M 522'	41	56	49	37	21	7	3.9	87
22	'Punjab 1'	47	44	40	31	14	6	4.8	88
23	'M 197'	24	23	13	10	4	3	4.0	88
24	'TKG 19A'	46	50	49	36	17	6	3.7	89
25	'Co-1'	23	27	21	16	4	3	5.9	89
26	'RG 141'	20	26	24	19	4	3	4.6	89
27	'JL 24'	29	30	24	7	3	3	6.6	90
28	'Tirupati 2'	29	24	21	20	3	3	3.9	90
29	'DRG 101'	44	44	44	39	10	4	3.5	90
30	'R 9251'	46	37	41	33	11	4	4.0	91
31	'Somnath'	16	13	14	14	4	1	3.8	91
32	'DSG 1'	16	16	6	1	1	1	6.6	91
33	'M 13'	30	33	13	13	10	3	5.4	91
34	'M 335'	31	34	34	21	9	3	4.1	92
35	'Kadiri 4'	36	27	27	17	4	3	5.0	92
36	'Sp.Improved'	39	36	33	13	6	3	4.5	93
37	'MH 1'	21	23	16	14	1	1	2.8	94
38	'DRG 12'	49	46	46	39	10	3	4.0	94
39	'ICGS 5'	24	31	26	14	4	1	6.3	95
40	'MH 4'	57	50	37	21	3	3	2.3	95
41	'VRI 3'	57	57	50	33	13	3	5.0	95
42	'Jawan'	31	29	19	11	1	1	4.8	95
43	'GG 2'	36	40	36	27	3	1	3.8	96
44	'VRI 2'	29	34	16	13	4	1	5.5	96
45	'Kisan'	37	39	39	24	3	1	4.5	96
46	'HNG 10'	43	46	24	10	1	1	4.6	97
47	'JSP 19'	43	44	46	29	3	1	4.6	97
48	'Co-2'	44	46	36	21	6	1	5.0	97

(Continued)

TABLE 4 Plant stand, height and mortality of groundnut cultivars affected by soil salinity during dry season 2004 *(Continued)*

Sl. No.	Groundnut cultivar	Plant stand (%) at days after sowing (DAS)						At harvest	
		21	41	77	91	112	126	Plant height (cm)	Mortality (%)
49	'R 8808'	50	46	41	21	1	1	4.6	97
50	'RS 1'	61	61	51	37	6	1	4.3	98
51	'TG 3'	14	23	13	4	0	0	0.0	100
52	'TG 37A'	16	16	14	11	1	0	0.0	100
53	'TPG 41'	11	17	14	11	0	0	0.0	100
54	'Chico'	19	20	14	9	0	0	0.0	100
55	'SB XI'	24	26	21	9	0	0	0.0	100
56	'Girnar 1'	17	24	6	3	0	0	0.0	100
57	'Jyothi'	34	36	13	3	0	0	0.0	100
58	'SG 84'	43	36	20	6	0	0	0.0	100
59	'TNAU 256'	37	36	20	9	1	0	0.0	100
60	'TMV 2'	53	59	56	37	1	0	0.0	100
61	'KRG 1'	36	33	33	23	0	0	0.0	100
62	'S 230'	20	20	20	9	0	0	0.0	100
63	'Karad 4–11'	21	27	23	9	3	0	0.0	100
64	'Tirupati 3'	14	16	11	10	0	0	0.0	100
65	'Kadiri 2'	24	13	7	4	0	0	0.0	100
66	'Kadiri 3'	33	27	31	20	0	0	0.0	100
67	'ICGS 44'	33	26	17	6	0	0	0.0	100
68	'CSMG 884'	17	16	10	3	0	0	0.0	100
69	'ICGS 11'	34	34	26	14	1	0	0.0	100
70	'ICGS 1'	40	40	37	29	1	0	0.0	100
71	'ICGV 86325'	34	37	33	29	7	0	0.0	100
72	'B 95'	44	51	44	41	10	0	0.0	100
73	'ICG (FDRS)-10'	29	29	26	19	1	0	0.0	100
74	'ALR 1'	27	33	29	9	0	0	0.0	100
75	'ALR 3'	47	47	46	21	6	0	0.0	100
76	'BAU 13'	40	50	49	27	1	0	0.0	100
77	'MH 2'	61	63	44	21	3	0	0.0	100
78	'DH 8'	40	39	27	14	0	0	0.0	100
79	'JL 220'	13	13	3	0	0	0	0.0	100
80	'K 134'	20	20	14	7	0	0	0.0	100
81	'AK 12–24'	39	37	16	17	0	0	0.0	100
82	'Gangapuri'	34	40	19	11	0	0	0.0	100
83	'M 145'	17	19	14	7	1	0	0.0	100
	Mean	32	33	27	18	5	3	3	93
	SEm	11.0	11.7	11.0	9.1	6.1	3.6	3.4	—

for germination during dry season, but here even after 13 DAS, the germination was very poor in majority of the cultivars mainly because of initial irrigation with saline water of 11.7 dS m^{-1} that resulted in 4 dS m^{-1} soil EC_e. The plant stand at 21 DAS, in various groundnut cultivars, ranged from 10–64% and out of 83 cultivars, only 25 cultivars showed more than 40% emergence. At 41 DAS, in majority of the cultivars, the plant stand was lower than that of 21 DAS clearly indicating the effect of salinity. The crop faced

salinity stress of 4 dS m^{-1} at sowing and germination, and 6–7 dS m^{-1} during 21–98 DAS (Table 2). The plant mortality increased as the days passed and also increase of salinity in the subsequent observations. The average plant stand of all the cultivars were 32, 33, 27, 18, 5, and 3%, at 21, 41, 77, 91, 112, and 126 DAS, respectively indicating severe mortality at later stages. At 77 DAS, the plant stand among the cultivars ranged from 2.9–61% with 31 cultivars showing more than 30% plant stand, and in contrast 9 cultivars showing less than 10% plant stand.

The plant stand at 91 DAS was very critical for groundnut, and at this stage 29 cultivars showed less than 10% plant stand indicating their high sensitivity to salinity. On the other hand, 33 cultivars with more than 20% plant stand indicated their better tolerance to salinity. As clearcut demarcation was noticed, this stage (91 DAS) was found best for screening the cultivars. At 112 DAS, 20 cultivars showed complete mortality, with rest of the cultivars recording drastic drop in plant stand. Here also 31 cultivars showed more than 5% plant stand and 14 showed more than 10% plant stand. The harvesting of the crop was made at 126 DAS, where 33 cultivars were completely dried up, 35 showed some plant stand, but 15 showed more than 5% plant stand clearly indicating their better tolerance to salinity than the other cultivars. Decreases 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). The vegetative growth is impaired at salt concentration of 8 dS m^{-1} EC, as a result only a few genotypes were able to survive at this level of salinity in the present study.

The salinity caused severe reduction in plant stature; as a result the plant height (ranged from 2.3 cm to 10.4 cm) was less than 11 cm, with majority of cultivars less than 5 cm plant height with some cultivars having small immature pods. However, due to salinity, there was no seed formation in any of the cultivars. The plant mortality at harvest was very high (56–100%). When the cultivars were ranked based upon the mortality and plant stand at 91, 112, and 126 DAS, the first 30 cultivars showing lesser mortality and better plant stand were grouped as tolerant and last 40 cultivars showing higher mortality and lesser plant stand as sensitive. Present study clearly demonstrated that groundnut cultivars must be tested till 90 DAS to judge their tolerance of salinity under field conditions.

Wet Season

During wet season, when all the 83 cultivars were grown in the same field, salinity caused low germination and reduction in plant stand (Table 5). The field emergence, among cultivars, ranged from 45–98% with 24 cultivars showing more than 75% emergence at 15 DAS. Due to rains and subsequent leaching, the crop faced salinity stress of 4.5 dS m^{-1} at sowing and

TABLE 5 Performance of groundnut cultivars under salinity stress during wet season 2004

Sl. No.	Groundnut Cultivar	Plant stand (%) 15 DAS	45 DAS	118 DAS	Mortality at harvest (%)	Pods/ plant	Pod yield/ plant (g)	Seed yield/ plant (g)	Shelling (%)	100-seed mass (g)	HI (%)	Seed yield (g m^{-2})
1	'BG 3'	69	76	73	4	10	9.3	6.1	69	38	32	149
2	'UF 70–103'	72	64	57	21	11	10.3	6.8	68	40	34	130
3	'KRG 1'	81	79	76	7	8	6.5	4.6	71	34	35	117
4	'M 522'	80	79	69	15	6	8.3	5.0	63	53	33	115
5	'VRI 3'	75	67	62	17	12	7.7	5.4	70	28	36	112
6	'S 206'	98	79	75	24	10	6.1	4.3	71	25	30	108
7	'Tirupati 4'	55	65	56	14	11	8.8	5.8	67	42	43	107
8	'SG 84'	74	64	50	33	17	9.7	6.0	63	29	26	99
9	'ALR 3'	78	67	51	34	12	8.8	5.7	68	35	37	97
10	'Somnath'	65	70	45	36	18	12.8	6.4	48	41	28	96
11	'TKG 19A'	72	79	57	27	8	8.4	4.8	60	55	31	92
12	'Punjab 1'	64	68	60	12	8	6.8	4.5	69	40	28	91
13	'MH 2'	59	63	55	12	7	6.7	4.7	72	46	43	86
14	'Kadiri 3'	47	57	57	0	6	6.5	4.2	62	41	28	80
15	'HNG 10'	53	65	56	14	13	7.9	4.2	65	34	38	79
16	'GG 2'	68	63	50	27	12	7.0	4.7	69	35	31	78
17	'TMV 2'	63	74	67	10	7	5.1	3.5	73	35	28	77
18	'JL 24'	75	75	73	2	6	5.1	3.1	64	36	20	76
19	'MH 1'	88	79	83	6	6	4.4	2.8	67	37	28	76
20	'ICGV 86590'	77	74	74	3	5	5.1	3.0	60	39	23	75
21	'ICG (FDRS)-10'	80	69	62	22	9	5.9	3.6	64	34	28	75
22	'Sp.Improved'	43	58	56	2	8	5.6	3.8	70	38	32	72
23	'Co-1'	77	65	62	19	6	5.1	3.4	65	39	21	70
24	'ICGS 76'	57	70	53	25	10	5.9	3.8	65	32	21	67
25	'TNAU 256'	75	64	53	29	6	5.1	3.8	75	38	29	66
26	'ICGS 5'	56	57	56	3	8	5.0	3.5	72	31	32	65
27	'Tirupati 3'	67	70	68	4	7	5.9	2.9	57	32	20	65
28	'ICGV 86325'	75	68	49	34	6	5.4	3.7	74	43	25	61
29	'CSMG 884'	60	61	59	2	4	5.1	3.1	61	56	24	61
30	'Chico'	80	61	53	34	11	5.0	3.4	70	26	28	60
31	'RS 138'	61	70	69	2	4	4.0	2.5	63	36	18	57
32	'M 197'	74	78	75	4	4	3.6	2.3	68	41	28	57
33	'BAU 19'	69	77	76	1	7	3.7	2.2	63	26	15	56
34	'Gangapuri'	57	67	55	17	5	3.9	2.8	70	32	22	51
35	'DRG 17'	66	58	43	36	8	6.7	3.3	53	36	37	48
36	'Jyothi'	73	67	59	20	9	3.9	2.4	63	26	23	47
37	'DH 8'	54	60	55	9	7	4.2	2.6	64	32	27	47
38	'ICGS 37'	89	87	83	7	7	3.5	1.7	48	23	25	46
39	'Tirupati 2'	75	85	84	2	7	3.2	1.7	59	30	25	46
40	'AK 12–24'	57	63	48	24	7	4.3	2.8	70	31	24	45
41	'B 95'	81	76	42	48	4	4.4	3.1	68	51	26	44
42	'ICG (FDRS)-4'	77	66	58	25	5	3.9	2.3	62	30	18	44
43	'S 230'	71	58	55	23	4	3.7	2.4	66	38	19	43
44	'VRI 2'	56	51	41	27	4	4.4	3.1	70	43	23	42
45	'R 9251'	70	76	48	36	10	4.3	2.5	60	36	35	40
46	'JL 220'	49	62	56	9	5	3.8	2.1	57	43	19	40
47	'Jawan'	58	51	48	17	5	4.0	2.5	64	39	28	39
48	'Karad 4–11'	62	68	68	0	5	3.5	1.7	50	20	11	38
49	'Kisan'	79	72	51	36	5	3.3	2.2	68	29	26	37
50	'TPG 41'	89	91	30	67	7	6.4	3.7	66	43	42	37
51	'Kadiri 4'	43	57	53	7	8	3.4	2.1	64	28	21	36

(Continued)

TABLE 5 Performance of groundnut cultivars under salinity stress during wet season 2004 *(Continued)*

Sl. No.	Groundnut Cultivar	Plant stand (%) 15 DAS	45 DAS	118 DAS	Mortality at harvest (%)	Pods/ plant	Pod yield/ plant (g)	Seed yield/ plant (g)	Shelling (%)	100-seed mass (g)	HI (%)	Seed yield (g m^{-2})
52	'LGN 2'	76	73	49	35	5	3.5	2.1	60	28	24	35
53	'K 134'	42	52	52	0	11	4.2	1.9	51	17	12	33
54	'ICGS 1'	76	78	63	20	4	2.4	1.5	64	25	24	32
55	'ICGS 44'	62	67	61	9	7	4.0	1.4	56	29	24	28
56	'ICGS 11'	72	71	64	11	3	1.6	1.1	66	28	12	23
57	'TG 22'	85	73	63	26	2	1.8	1.0	62	45	12	22
58	'TG 26'	70	87	62	29	10	2.5	1.0	44	29	14	20
59	'TG 17'	60	63	47	26	3	2.4	1.2	47	50	11	18
60	'TG 3'	63	72	47	35	3	1.7	0.9	55	29	11	14
61	'R 8808'	64	62	35	45	5	2.0	0.9	53	23	14	11
	Mean	68	69	58	13	7	5.2	3.2	63	35	26	62
	SEm	12.2	7.8	9.1	25.4	2.2	1.9	1.3	5.2	5.5	5.5	—
	CD (0.05)	34.4	22.1	25.7	—	6.1	5.5	3.5	14.8	15.5	15.6	—

germination, 3.5–3.3 dS m^{-1} during 15–45 DAS, and 3.3–3.0 dS m^{-1} afterwards (Table 2). Here also the germination was delayed for 3–6 days due to salinity that resulted in slight increase in the plant stand at 45 DAS in nearly 50% of the cultivars tested. But in rest of the cultivars, there was significant reduction in plant stand. At 45 DAS, the plant stand, among cultivars, ranged from 45–91%, with 17 cultivars had more than 75% plant stand. At harvest, in 22 cultivars there was no mortality, clearly showing their tolerance to salinity, on the other hand, several cultivars showed more than 30% mortality indicating their sensitivity to salinity.

There was pod bearing with seed only in 61 cultivars out of 83 cultivars, which were arranged in the descending order of their seed yield (Table 5). The pod yield ranged from less than 2 g $plant^{-1}$ to as high as 12.8 g $plant^{-1}$ and seed yield ranged from less than 1 g $plant^{-1}$ to 6.8 g $plant^{-1}$ (Table 5). As there was plant mortality as well as pod bearing in groundnut cultivars during wet season, the seed yield in a unit area (g m^{-2}) was the best criterion for selecting the salinity tolerant cultivars as salinity stress hampers the development of seeds. The seed yield in various cultivars ranged from 11–149 g m^{-2} with 21 cultivars showing more than 75 g m^{-2} seed yield, 34 showing more than 50 g m^{-2} and 27 showing less than 50 g m^{-2} seed yield. Shelling outturn of 70% or above was recorded in nine cultivars that had pod yield in the range of 5–7 g $plant^{-1}$. Five cultivars ('TKG 19A', 'CSMG 884', 'M 522', 'B 95', 'TG 17') had HSM above 50 g and in three ('MH 2', 'Tirupati 4', and 'TPG 41') the harvest index was above 40%.

The data of the two seasons for plant stand and seed yield when compared for individual cultivars, 10 groundnut cultivars 'VRI 3', 'UF 70–103', 'TKG 19A', 'S 206', 'Tirupati 4', 'M 522', 'Punjab 1', 'BG 3', 'Somnath', and 'ICGV 86590' having high rank in plant stand and more than 75 g m^{-2} seed yield

were categorized as salinity tolerant and 15 cultivars with high plant stand and more than 50 g m^{-2} seed yield were categorized as moderately tolerant (Tables 5 and 6). On the other hand 28 cultivars with lesser plant stand and less than 25 g m^{-2} seed yield were categorized as sensitive to salinity, and rest 30 cultivars were of intermediate type (Tables 4–6).

Information on tolerance of groundnut to salinity till maturity is meager. Hunshal et al. (1991) reported decrease in pod yield by 22.2% and 48.5% at 4 and 6 dS m^{-1}, respectively. Based on the germination and seedling emergence, some of the tolerant cultivars reported earlier, from India, are 'GG 2' (Nautiyal et al., 1989), 'ICGS 11' and 'KRG 1' (Hunshal et al., 1991), 'JL 24', 'Robut' and 'GG 11' (Patel et al., 1992), 'Dh 39' and 'ICGS 11' (Hebbara et al., 1992), 'Dh 3–30' and 'ICGS 11' (Uma et al., 1995). In a preliminary study, under saline water (EC 3.5 dS m^{-1} and pH 7.2) irrigation, Nautiyal et al. (2000) found high yield in groundnut cultivars 'Karad 4–11', 'T 28', 'RSB 87', 'Punjab 1' and 'Kadiri 2'. Hebbara et al. (1992) reported that cultivars 'R 8806' and 'R 9021' showed tolerance to higher levels of salinity but with low yield potential. The *in vitro* study showed that, at 2.5% sodium chloride, the genotypes 'ICGS 76', 'MA 16', 'S 206', 'TG 17', 'GG 20', 'JL 24', 'Punjab 1', 'TMV12', 'MH 2', 'M 522', 'Tirupati 3', 'Dh 3–30', 'TMV 2' and 'GG 2' had less mortality of regenerated shoot and hence could be considered as tolerant to salinity (Mungala et al., 2008). In this study, after comparing 83 groundnut cultivars for their plant mortality and yield under field condition, the salinity tolerant and moderately tolerant cultivars were identified. The cultivars 'Punjab 1', 'S 206',and 'M 522'were categorized as tolerant, and cultivars 'GG 2', 'JL 24', 'KRG 1', 'TMV 2', and 'ICGS 76' as moderately tolerant to salinity, however 'ICGS 11' and 'Kadiri 2' were salinity sensitive cultivars. A total of 28 cultivars with high mortality and low yield were grouped as salinity sensitive (Table 6).

Salinity tolerance is a relative term depending mainly upon its intensity and relative performance of cultivars. The groundnut cultivars 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 as increasing salinity decreases pod yield (Hunshal et al., 1991; Singh et al., 2007, 2008). In a recent field screening of groundnut genotypes for their tolerance of salinity stress, Singh et al. (2007) ranked tolerant genotypes based upon lesser mortality and better yield.

Mineral Concentrations in Leaves

A clearcut difference in the mineral concentrations in leaves of tolerant and sensitive cultivars, at 90 DAS, was observed (Table 7). The leaves of salinity tolerant cultivars showed an average concentration of 0.19% Na and P, 1.65% K, 5.38% Ca, 0.32% S, and 1.07% Mg. On the other hand the salinity sensitive cultivars showed an average concentration of 0.38% Na, 0.20%

TABLE 6 Categorization of groundnut cultivars for their salinity tolerance

Tolerant	Moderately tolerant	Intermediate	Sensitive
'VRI 3', 'UF 70–103', 'TKG 19A', 'S 206', 'Tirupati 4', 'M 522', 'Punjab 1', 'BG 3', 'Somnath', 'ICGV 86590'	'ALR 3', 'ICGS 76', 'M 197', 'MH 2', 'Kadiri 3', 'KRG 1', 'ICG (FDRS)-10', 'JL 24', 'SG 84', 'RS 138', 'Sp.Improved', 'GG 2', 'HNG 10', 'TMV 2', 'Co-1'	'Kisan', 'Tirupati 3', 'R 9251', 'TG 22', 'BAU 19', 'AK 12–24', 'ICGS 37', 'S 230', 'Chico', 'CSMG 884', 'LGN 2', 'Jyothi', 'JL 220', 'ICGV 86325', 'B 95', 'MH 1', 'ICG (FDRS)-4', 'TPG 41', 'Jawan', 'TNAU 256', 'Karad 4–11', 'K 134', 'Kadiri 4', 'DRG 17', 'Tirupati 2', 'DH 8', 'Gangapuri', 'ICGS 5', 'SP 250A', 'VRI 2'	'ALR 1', 'ALR 2', 'BAU 13', 'Chitra', 'Co-2', 'CSMG 84–1', 'DRG 101', 'DRG 12', 'DSG 1', 'Girnar 1', 'ICGS 1', 'ICGS 11', 'ICGS 44', 'JSP 19', 'Kadiri 2', 'M 13', 'M 145', 'M 335', 'MH 4', 'R 8808', 'RG 141', 'RS 1', 'SB XI', 'TAG 24', 'TG 17', 'TG 26', 'TG 3', 'TG 37A'

TABLE 7 Nutrient concentration in groundnut cultivars grown under salinity stress during wet season

	Percent (%)						ppm				Ratio of	
Groundnut genotype	P	S	Na	Ca	Mg	K	Fe	Mn	Zn	Cu	Na/K	Na/Ca
Tolerant												
'VRI 3'	0.18	0.30	0.20	5.96	0.95	1.63	856	104	66	16	0.120	0.033
'TKG 19A'	0.20	0.33	0.17	5.88	1.02	1.10	1413	92	58	15	0.155	0.029
'S 206'	0.15	0.30	0.17	6.61	1.15	1.00	796	111	100	16	0.171	0.026
'Tirupati 4'	0.24	0.48	0.22	3.97	1.08	1.85	1055	108	58	22	0.116	0.054
'M 522'	0.17	0.35	0.16	4.67	1.18	2.00	882	146	77	13	0.080	0.034
'Somnath'	0.24	0.32	0.18	5.34	1.13	1.07	1227	120	73	16	0.169	0.034
'UF 70—103'	0.18	0.25	0.22	4.82	1.00	1.53	1083	92	52	16	0.146	0.046
'Punjab 1'	0.19	0.34	0.20	5.39	1.01	2.42	1083	116	77	16	0.083	0.037
'BG 3'	0.17	0.22	0.19	5.80	1.11	2.28	831	114	78	22	0.082	0.032
Mean	0.19	0.32	0.19	5.38	1.07	1.65	1025	111	71	17	0.114	0.035
Moderately tolerant												
'ALR 3'	0.18	0.35	0.20	6.16	1.12	2.03	1352	111	62	20	0.099	0.032
'M 197'	0.22	0.30	0.25	4.04	0.96	1.36	897	107	74	15	0.184	0.062
'MH 2'	0.24	0.21	0.26	5.08	0.95	2.52	1739	100	91	24	0.103	0.051
'Kadiri 3'	0.20	0.34	0.26	5.29	1.08	2.50	647	80	62	16	0.104	0.049
'JL 24'	0.08	0.18	0.16	4.69	1.05	1.32	855	150	55	15	0.121	0.034
'RS 138'	0.24	0.38	0.24	5.17	1.03	2.29	1013	86	77	14	0.106	0.047
'Sp. Improved'	0.14	0.30	0.18	6.81	1.01	1.22	1167	100	45	10	0.148	0.026
'HNG 10'	0.14	0.38	0.17	6.45	1.15	2.27	645	109	47	12	0.075	0.026
'TMV 2'	0.24	0.26	0.19	5.72	1.14	1.14	912	80	87	14	0.167	0.033
'ICGS 76'	0.24	0.36	0.24	4.06	0.99	1.87	779	88	63	20	0.128	0.059
'GG 2'	0.17	0.37	0.24	7.53	1.25	1.14	1231	116	83	15	0.212	0.032
Mean	0.19	0.31	0.22	5.55	1.07	1.79	1021	102	68	16	0.122	0.039
Sensitive*	0.20	0.32	0.38	5.31	1.03	1.83	1027	104	77	15	0.210	0.072
CD (0.05)	0.02	0.07	0.08	0.50	0.03	0.17	60	13	8	1	0.030	0.011

*Mean of 22 genotypes.

P, 1.83% K, 5.31% Ca, 0.32% S, and 1.03% Mg in their leaf tissues. This has clearly demonstrated that there was selective absorption of minerals by salinity tolerant cultivars under saline conditions. Salinity causes accumulation of Na^+ and Cl^- ions in seedling roots, shoots, and leaves (Srivastava and Sharma, 1998). The NaCl and Na_2SO_4 salinities suppressed Ca and K uptake, but increased Na, P, Fe, and Mn in plant tissues of groundnut cv. 'TMV-10' (Chavan and Karadge, 1980). In sodic soil, increase in exchangeable sodium percentage increased Na and decreased K, Ca, and N contents in groundnut (Singh and Abrol, 1985). Malakondaiah and Rajeswararao (1979) reported that Na accumulated while P, K, and Ca were lowered in groundnut cv. 'TMV-2' due to salinity.

The salinity caused accumulation of Na in leaves and to compensate that and maintain proper ratio of various nutrients there was accumulation of Ca and K content however, salinity tolerant cultivars showed comparatively less Na and K accumulation in their leaves than that of sensitive cultivars. This was clearer in the ratio of Na/K and Na/Ca, which were 0.114 and 0.035,

respectively in salinity tolerant cultivars and 0.210 and 0.072, respectively, in salinity sensitive cultivars.

CONCLUSIONS

The study clearly indicates that there are a few groundnut cultivars that can endure the salinity stress and also yield satisfactorily. These salinity tolerant cultivars, as such, can be grown in the saline areas and coastal regions with mild salinity upto 3 dS m^{-1} and also can find their way in future breeding programs. Further testing of these cultivars at different regimes of salinity may be useful to grow groundnut at higher level of salinity.

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