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ORIGINAL ARTICLE

Differential nutrients absorption an important tool for screening and identification of soil salinity tolerant peanut genotypes

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Abstract Field screening of 210 high yielding peanut germplasm accessions was undertaken to identify salinity tolerant genotypes based on plant mortality, seed yield and nutrient absorption. The salinity (4.5 dS m^{-1} at sowing and 3.5–3 dS m^{-1} 15–80 days after sowing), reduced plant stand, yield and yield attributes in peanuts with 0–70 % plant mortality and 9–78 % plant stand (average 51 %) at maturity, and out of 210 genotypes, only 134 showed pods setting. The seed yield of peanut genotypes, under saline condition, ranged from 0 to 203 g m^{-2}, and out of these ten genotypes NRCG 10874, 420, 13831, 9052, 12750, 9189, 894, 13787, 13791 and 9038 with more than 150 g m^{-2} seed yield were categorized as tolerant and 21 genotypes with 100–149 g m^{-2} seed yield as moderately tolerant to salinity. However, more than 100 genotypes with high mortality and less than 30 g m^{-2} seed yield were grouped as sensitive to salinity. The mineral analyses, of the tolerant, moderately tolerant and sensitive peanut genotypes, reveals selective absorption of minerals in the leaves with marked differences. The salinity tolerant genotypes showed less than 0.25 % Na, 0.20 Na/K ratio and 0.05 Na/Ca ratio, however, the salinity sensitive genotypes showed more than 0.4 % Na, 0.25 Na/K and 0.06 Na/Ca ratio in their leaves which are proposed as marker for selecting the salinity tolerance peanut genotypes.

Keywords Differential mineral concentrations · Mortality · Peanut · Salinity tolerance · Seed yield

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Introduction

India has the largest peanut area in the world. However, the area and production of this crop has been fluctuating between 5.5 and 8.5 m ha and 5.0–9.5 million tonnes, respectively, mainly due to biotic and abiotic stresses including salinity (Singh 2011; Singh et al. 2013, 2014; Chakraborty et al. 2013). Soil salinity (Gupta and Yadav 1986) and sodicity (Singh and Abrol 1985) limit peanut cultivation in India. Soil salinity has been increasing due to non-scientific use of poor quality ground water in coastal and saline areas and salt accumulation in excessively irrigated areas (Singh 1992). However, there is an increasing pressure to make use of saline land through its management to bring more area under peanut cultivation. But, unfortunately no specific salinity management practices for peanut has been recommended for saline areas.

In the peanut growing coastal areas of India, though EC of soils ranges from 1.5 to 3.0 dS m^{-1}, the EC of "well-water" ranges from 6 to 12 dS m^{-1} due to ingress of sea water, and in case the crop is irrigated with well-water during late rainy season (Sept–Oct) due to early withdrawal of mansoon and following summer crop (Jan–May), the soil EC increases up to 6.0–7.0 dS m^{-1} by the end of growing season, making the soil unfit for growing the next season crop (Singh et al. 2010). As a result, farmers of this area generally have to depend on rainfed cultivation during rainy season (June–Sept). This is a common situation in the coastal parts of India leading to decrease in both area and production of peanut. However, heavy down pour during June brings down this salinity to 4.5–5.0 EC and provides good scope for screening and selection of salinity tolerant genotypes. Though, Gupta and Yadav (1986) reported that peanut could be grown with water having EC up to 3.0 dS m^{-1}, our recent study showed that peanut starts facing salinity stress above 2.0 dS m^{-1} and EC above 4.5 dS m^{-1} kills the plants, however, salinity levels in between 3 and 4 dS m^{-1} during most of the cropping period are ideal for screening for salinity tolerance (Singh et al. 2004, 2008, 2010).

Screening and development of peanut genotypes that can grow and tolerate salinity to a certain level is the most important option, as a number of high yielding germplasm accessions are available in India (Singh et al. 2004; Singh 2011). As peanut is grown on all soil types, the germplasm accessions and cultivars have been identified for their tolerance of iron chlorosis (Singh and Chaudhari 1993) and soil acidity (Singh et al. 2004). Some efforts have also been made to screen the peanut genotypes for soil salinity by recording germination and plant growth till vegetative phase in pots (Nautiyal et al. 1989; Patel et al. 1992) and with limited genotypes in field (Hunshal et al. 1991; Hebbara et al. 1992; Janila et al. 1999; Nautiyal et al. 2000). But, the concerted efforts on in situ screening of peanut genotypes till maturity at the hot spot, started late and by now several advanced breeding lines (Singh et al. 2008) and cultivars (Singh et al. 2010) have been screened for salinity tolerance. There is need to screen entire germplasm and identify genotypes that can tolerant soil salinity of more than 3.0 EC throughout the cropping season to facilitate more area under cultivation. In the present study an effort was made to screen the high yielding peanut germplasm accessions, and to evaluate the nutrient absorption pattern in salinity tolerant and sensitive genotypes.

Materials and methods

Two hundred and ten high yielding peanut germplasm accessions, having yield potential of more than 1500 kg ha^{-1} pod were screened for their tolerance of salinity during wet season at the experimental farm of Fruit Research Station, Junagadh Agricultural University, Mangrol, Junagadh, Gujarat. The experiment was laid out in a randomized block design with two replications. The soil was loamy, inceptisol, having hydraulic conductivity 1.25 cm h^{-1}, electrical conductivity (EC) 4.5 dS m^{-1}, pH 7.5, organic carbon 0.68 %, total nitrogen (N) 0.039 %, available phosphorus (P) 9 ppm, exchangeable potassium (K) 200 ppm, and diethylene triamine pentacetic acid (DTPA) extractable Fe, Mn, Zn and Cu 6, 12, 3.5 and 6 mg kg^{-1} soil, respectively.

The salinity of the experimental soil was developed by irrigation with saline water of (6–12 dS m^{-1} EC) the previous summer season. After heavy shower during second fortnight of June, when the EC value of field came down to 4.5 dS m^{-1}, the field was prepared and a basal dose of 50 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 (Singh and Basu 2005). A total of 210 germplasm accessions each in single row plots, 3 m in length and seeds spaced at 10 cm with inter-row spacing of 45 cm were sown during the last week of June. The crop was raised following recommended agronomic practices and harvested at maturity.

The meteorological data and the EC of the experimental site are given in the Table 1. Data on field emergence at 15 days after sowing (DAS) and plant stand at 45 DAS and at harvest was recorded. At 90 DAS, when there was visible differences in the tolerant and sensitive genotypes, the leaf of a few tolerant and 62 sensitive genotypes were sampled, dried and analysed for sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) content using atomic absorption spectrophotometer (Hitachi, Z-6100, Japan), phosphorus (P) by colorimetry (Hitachi-U3010, Japan), and sulphur (S) by turbidity methods. At maturity, the crop was harvested, dried in the sun for a week and pod and seed yields, shelling percent, 100-seed mass and harvest index were recorded. Five plants were randomly selected from each genotype and number of pods and seeds, pod and seed yield per plant were recorded.

All the peanut accessions were arranged in descending order of plant stand and seed yield and in ascending order for mortality, Na content in leaves, and Na/K and Na/Ca ratios, and ranked. Acsessions were further grouped under various categories of salinity tolerance based upon their ranking for higher plant stand and lesser mortality as well as agronomic performance using the criteria mentioned in Table 2 and finally the genotypes falling in the same category, for most of the parameters, were considered in various categories.

Results and discussions

Field emergence and mortality

Salinity delayed germination, reduced field emergence, plant growth and subsequent plant stand, and pod and seed yields of peanut with large variations among genotypes (Table 3). Normally peanut takes 6–8 days for germination, but the initial salinity (4.5 dS m^{-1}) delayed it by 3–7 days, as a result it took 9–15 days for field emergence depending upon the genotypes. The plant stand among various accessions, ranged from 13 to 85 % with an average of 46 % (average of 210 accessions). However, at 45 DAS, the plant stand ranged 9–93 % with an average of 61 %, clearly indicating that plant mortality in a few accessions as well as slightly higher plant stand due to late germination in some other accessions. The plant mortality

Table 1 Weather data and electrical conductivity of the field during experimentation

Months	Mean temperature (°C)		RH (%)	Rainfall (mm)	Evaporation (mm day^{-1})	Electrical conductivity and pH of soil during experimentation		
	Maximum	Minimum				Days after sowing	EC (dS m^{-1})	pH
June	33.9	27.7	80.1	386 (4)	4.1	0	4.5	7.5
July	31.4	26.6	84.1	127 (9)	3.2	15	3.5	7.5
August	29.9	25.6	89.4	554 (11)	2.0	45	3.3	7.6
September	32.7	25.0	83.8	–	3.1	80	3.0	7.7
October	35.2	21.7	69.0	–	3.3	118	3.0	7.9

Figures in parentheses indicate the number of rainy days

Table 2 Criteria for categorization of peanut genotypes for their tolerance of soil salinity

Parameters	Categories of salinity tolerance			
	Tolerant	Moderately tolerant	Intermediate	Sensitive
Rank in plant survival at harvest (in descending order)	First 60 genotypes	First 60 genotypes	Less than 135	Last 100 genotypes
Rank in seed yield (in descending order)	Less than 30	Less than 30	Less than 100	Last 110 genotypes
Seed yield (g m$^{-2)}$	More than 150	More than 100	More than 30	Less than 30

continued with the advancement of crop growth stages and only a few genotypes were able to withstand the salinity till maturity with good plant stand and yield. The final plant stand at maturity was in between 9 and 78 % with an average of 51 % and out of 210 accessions, 82 showed 50 % or above plant stand. At maturity, the plant mortality ranged from zero to 70 % with an average of 17 %. The suppression of germination and seedling vigour by salinity is well known in peanut (Nautiyal et al. 1989; Patel et al. 1992; Janila et al. 1999).

Yield and yield attributes

Large variations in pod and seed yields, number of pods, shelling percentage, 100-seed mass and harvest index were observed in the peanut accessions. Out of 210, only 134 accessions showed pod setting, while 76 did not bear pods. Among the 134 genotypes that bore pods, the average and range of pods plant^{-1} were 6 and 1–24 pods, respectively, while the average and range of pod yield plant^{-1} were 5.8 and 0.6–15.2 g plant^{-1}, respectively. The average seed yield of these accessions was 3.6 g plant^{-1} (0.3–10.2 g plant^{-1}). The shelling percent ranged from 36.8 to 75.6 % with an average of 63 % and the 100-seed mass 17.5–64.7 g (average of 37.4 g). The harvest index varied from 4.4 to 41.9 % with an average of 19 %, which clearly demonstrated the effect of salinity on these yield attributes.

As there was plant mortality as well as pod bearing in peanut genotypes under saline condition, and the shelling out'turn varied with accessions, the seed yield in a unit area (g m^{-2}), was chosen as the best criterion for selecting the salinity tolerant genotypes. Accordingly, 134 peanut accessions showing pod bearing were arranged in descending order of their seed yield along with their mean performance of other agronomic characters (Table 3). The seed yield among these accessions varied from 2 to 203 g m^{-2} with an average of 67 g m^{-2}. Interestingly, 31 accessions showed more than 100 g m^{-2} seed yield. Out of 210 accessions, 106 showed more than 30 g m^{-2} seed yield and remaining 104 below 30 g m^{-2}.

Tolerance is a relative term, depends mainly upon the intensity of salinity and reaction of peanut genotypes. After comparing various parameters, the peanut genotypes that recorded high field emergence, followed by high plant stand and low mortality during cropping season was considered as tolerant to salinity stress. However, data on yielding ability is more vital for arriving at meaningful conclusion, as high plant stand alone would not suffice in breeding for salinity tolerance. After comparing 210 accessions for their plant mortality and yield, 31 genotypes showing more than 100 g m^{-2} seed yield were shortlisted. Of these, ten accessions NRCG 10874, 420, 13831, 9052, 12750, 9189, 894, 13787, 13791 and 9038 that had more than 150 g m^{-2} seed yield and also 54 % or above plant stand at maturity were categorized as salinity tolerant and 21 accessions NRCG 421, 442, 888, 889, 900, 5558, 5566, 9044, 9045, 9065, 9507, 10495, 12048, 12749, 12765, 13080, 13087, 13110, 13596, 13788 and 13792, with 42 % or above plant stand at maturity and more than 100 g m^{-2} seed yield as moderately tolerant. However, genotypes with very high mortality and less than 30 g m^{-2} seed yield were categorized as sensitive to salinity.

Table 3 Performance of peanut germplasm accessions to salinity stress during kharif season

S.no	Peanut germplasm accessions	Plant stand (%)			Mortality at harvest (%)	Pods plant^{-1}	Pod yield (g plant^{-1})	Seed yield (g plant^{-1})	Shelling (%)	100-Seed mass (g)	Harvest index (%)	Seed yield (g m^{-2})
		15 DAS	45 DAS	118 DAS								
1	NRCG 10874	55	80	66	18	11.7	12.8	9.3	73.3	49.1	34.4	203
2	NRCG 420	56	85	69	19	10.5	11.7	8.7	74.8	49.3	36.1	201
3	NRCG 13831	78	86	70	19	14.0	12.7	8.4	67.4	39.2	23.6	196
4	NRCG 9052	52	69	62	11	12.4	14.7	9.4	65.8	50.5	28.8	194
5	NRCG 12750	53	63	65	0	12.0	12.8	8.9	70.0	43.0	33.7	191
6	NRCG 9189	41	60	54	10	23.8	14.9	10.2	70.0	29.5	41.9	184
7	NRCG 894	38	65	61	6	13.4	15.2	8.7	56.4	38.6	26.4	177
8	NRCG 13787	57	73	75	0	9.0	9.2	6.5	72.5	44.3	30.8	163
9	NRCG 13791	47	66	54	17	14.0	14.3	9.0	70.3	46.8	32.3	162
10	NRCG 9038	48	75	71	5	6.9	10.3	6.4	63.8	60.0	29.0	153
11	NRCG 12749	73	92	75	18	7.6	7.8	5.9	73.8	47.4	24.0	147
12	NRCG 12765	66	86	71	17	9.1	8.9	5.7	65.6	38.9	24.2	137
13	NRCG 9065	46	79	63	20	7.2	12.0	6.4	54.3	64.7	27.7	136
14	NRCG 13110	37	72	62	14	7.6	9.3	6.3	66.6	50.2	26.4	130
15	NRCG 5566	54	86	75	12	8.4	7.8	5.1	65.7	55.1	27.1	128
16	NRCG 13788	46	74	68	8	8.3	8.0	5.6	70.9	39.0	36.0	128
17	NRCG 12048	45	78	60	23	8.3	11.0	6.3	60.4	63.6	33.4	126
18	NRCG 13087	38	51	44	13	14.3	13.8	8.6	66.2	44.6	35.9	126
19	NRCG 5558	51	63	66	0	10.6	8.9	5.4	63.3	35.2	32.3	119
20	NRCG 9044	48	70	60	14	6.4	9.8	6.0	62.9	53.2	25.0	119
21	NRCG 900	40	60	52	13	11.0	13.2	6.7	52.5	50.0	30.6	116
22	NRCG 421	42	68	53	21	9.3	9.3	6.3	68.6	43.1	31.4	112
23	NRCG 889	45	53	43	19	12.1	11.4	7.6	67.4	43.6	33.2	110
24	NRCG 888	47	77	65	15	6.8	8.0	5.0	66.4	49.5	22.4	109
25	NRCG 10495	59	70	51	27	17.8	9.9	6.4	63.2	28.3	20.8	108
26	NRCG 13792	50	67	56	17	9.7	8.4	5.7	69.4	36.6	25.1	107
27	NRCG 13596	68	92	78	16	9.2	6.8	4.1	60.8	31.8	16.5	107
28	NRCG 9507	60	73	65	11	6.6	7.2	4.9	64.8	40.6	16.3	106
29	NRCG 442	44	60	42	30	11.6	11.0	7.6	70.7	42.9	32.8	106
30	NRCG 13080	44	64	52	18	9.5	10.0	6.0	60.4	44.4	20.2	104
31	NRCG 9045	37	75	68	9	9.1	7.5	4.4	60.2	41.1	20.0	101
32	NRCG 12463	59	73	70	4	12.4	6.4	4.3	60.9	26.9	27.5	99
33	NRCG 4282	57	75	56	25	7.1	7.8	5.1	68.7	54.1	35.3	96
34	NRCG 840	46	64	59	7	7.3	8.3	4.8	60.4	43.3	19.6	94
35	NRCG 5615	72	76	73	5	7.7	5.5	3.8	65.3	29.7	18.9	92
36	NRCG 13686	65	77	69	11	7.3	6.0	3.8	64.8	36.5	17.2	86
37	NRCG 417	46	56	50	11	7.1	7.5	5.1	70.2	46.2	25.8	85

Table 3 continued

S.no	Peanut germplasm accessions	Plant stand (%)			Mortality at harvest (%)	Pods $plant^{-1}$	Pod yield (g $plant^{-1}$)	Seed yield (g $plant^{-1}$)	Shelling (%)	100-Seed mass (g)	Harvest index (%)	Seed yield (g m^{-2})
		15 DAS	45 DAS	118 DAS								
38	NRCG 13826	57	76	59	23	6.8	6.6	4.4	70.7	41.2	25.0	85
39	NRCG 897	54	71	67	6	7.7	6.0	3.8	63.3	31.6	18.8	84
40	NRCG 13802	46	64	59	9	8.5	6.6	4.2	65.2	31.5	19.5	82
41	NRCG 12767	58	72	61	15	4.9	5.7	3.8	68.7	37.4	13.9	78
42	NRCG 13095	52	63	46	27	6.9	8.5	4.9	59.8	48.7	18.8	76
43	NRCG 4367	56	73	62	15	8.1	7.0	3.7	57.0	31.4	18.9	75
44	NRCG 1951	44	64	49	23	5.6	7.2	4.6	65.7	52.8	17.5	75
45	NRCG 12971	46	72	65	9	5.3	4.8	3.4	70.8	35.3	15.0	75
46	NRCG 13838	47	50	47	7	9.8	7.7	4.7	62.9	34.6	18.5	74
47	NRCG 5373	33	61	61	0	8.2	7.7	3.5	49.9	42.7	26.4	72
48	NRCG 13102	56	70	57	18	5.5	5.8	3.6	62.7	48.4	25.8	69
49	NRCG 13082	33	39	33	14	9.1	10.3	6.2	64.5	51.3	32.7	69
50	NRCG 13830	53	64	51	21	7.4	6.8	4.0	60.3	38.6	19.7	68
51	NRCG 13828	70	73	58	21	4.4	4.8	3.5	72.8	44.4	18.2	67
52	NRCG 13598	38	58	42	27	8.3	7.2	4.7	60.6	29.7	18.4	66
53	NRCG 2833	63	70	61	12	6.6	5.7	3.2	57.6	36.3	18.5	64
54	NRCG 12933	66	86	69	20	7.3	4.6	2.7	62.0	27.4	13.7	63
55	NRCG 13798	49	56	50	10	7.4	6.7	3.7	60.6	34.7	18.5	61
56	NRCG 12466	60	79	71	9	4.4	4.0	2.6	65.3	34.0	15.6	61
57	NRCG 13096	50	75	71	6	7.4	5.2	2.5	56.0	29.7	8.9	58
58	NRCG 13846	46	58	56	3	5.3	4.5	3.1	66.5	36.9	25.1	58
59	NRCG 13847	45	63	63	0	6.4	4.3	2.8	63.7	23.8	12.9	57
60	NRCG 882	50	77	64	16	4.2	4.9	2.6	57.2	43.1	23.1	57
61	NRCG 6673	42	50	43	13	6.6	7.9	3.9	52.4	50.5	25.8	56
62	NRCG 5518	56	65	37	44	5.6	7.7	4.6	62.0	41.1	22.4	56
63	NRCG 10433	22	30	28	6	10.4	10.1	5.9	61.3	31.6	14.4	56
64	NRCG 8125	37	45	42	7	7.3	6.0	3.9	66.6	27.5	21.4	55
65	NRCG 13844	62	82	54	34	5.0	4.5	3.0	69.6	35.7	23.5	55
66	NRCG 13140	38	62	58	7	5.0	4.4	2.7	61.0	39.2	16.0	52
67	NRCG 12782	63	73	59	20	3.9	3.8	2.6	71.5	38.4	20.2	51
68	NRCG 13083	32	48	48	0	5.6	6.1	3.2	56.7	41.2	15.8	51
69	NRCG 5541	56	73	57	22	3.4	3.9	2.7	69.1	53.2	17.3	51
70	NRCG 17	54	63	50	20	4.5	4.5	3.0	69.2	33.5	17.3	50
71	NRCG 450	50	58	54	7	6.4	4.7	2.8	58.3	29.9	14.2	50
72	NRCG 13081	41	78	72	9	5.5	3.6	2.0	61.8	24.5	13.3	49
73	NRCG 5953	39	52	41	21	6.2	5.7	3.5	63.4	39.6	17.6	48
74	NRCG 4366	33	55	45	18	7.7	6.3	3.2	53.2	27.9	19.9	48

Table 3 continued

S.no	Peanut germplasm accessions	Plant stand (%)			Mortality at harvest (%)	Pods $plant^{-1}$	Pod yield (g $plant^{-1}$)	Seed yield (g $plant^{-1}$)	Shelling (%)	100-Seed mass (g)	Harvest index (%)	Seed yield (g m^{-2})
		15 DAS	45 DAS	118 DAS								
75	NRCG 12775	37	50	41	17	5.3	5.2	3.5	69.9	39.6	18.2	48
76	NRCG 13114	44	69	56	18	7.4	4.6	2.6	54.9	31.0	13.7	48
77	NRCG 12776	32	54	44	19	5.3	4.5	3.2	65.8	31.9	15.2	47
78	NRCG 13833	61	76	50	34	5.2	4.4	2.8	65.5	29.8	16.6	47
79	NRCG 13835	48	56	50	11	5.5	4.5	2.7	61.1	31.7	12.8	44
80	NRCG 5550	56	68	61	10	3.5	3.3	2.2	67.4	29.7	15.4	44
81	NRCG 13814	33	40	38	5	4.9	5.1	3.5	70.3	46.3	24.0	44
82	NRCG 10121	54	76	54	29	4.3	3.8	2.4	64.7	35.4	16.1	44
83	NRCG 13	64	64	64	0	4.5	3.0	2.0	66.4	25.5	13.6	43
84	NRCG 1997	30	58	52	11	6.8	4.3	2.5	58.4	29.5	12.7	42
85	NRCG 12764	47	53	49	8	3.5	3.9	2.6	66.8	40.3	16.0	42
86	NRCG 9040	52	83	47	43	4.8	4.4	2.6	60.1	41.7	28.8	41
87	NRCG 5542	73	91	76	17	3.2	2.5	1.6	67.0	32.4	14.1	41
88	NRCG 13165	39	63	44	30	5.3	4.3	2.7	61.3	35.3	25.0	39
89	NRCG 13816	43	54	47	13	4.2	4.1	2.5	61.3	30.6	12.8	38
90	NRCG 12761	48	60	43	29	3.7	3.7	2.7	69.2	39.8	14.8	38
91	NRCG 13794	33	50	49	3	5.2	3.5	2.3	68.2	29.9	13.5	38
92	NRCG 10293	22	36	35	5	12.8	5.4	3.2	63.0	22.2	21.5	37
93	NRCG 4478	40	47	32	32	9.8	5.4	3.5	67.0	28.7	13.2	37
94	NRCG 13821	64	75	45	40	2.9	3.2	2.4	75.6	50.6	23.6	36
95	NRCG 13072	23	50	42	15	4.9	4.0	2.5	60.2	37.7	20.8	35
96	NRCG 13822	45	59	51	12	2.5	2.6	2.0	73.3	41.7	16.6	34
97	NRCG 13799	34	41	29	30	5.5	5.1	3.5	69.9	37.9	18.0	33
98	NRCG 5560	40	60	58	3	3.7	2.8	1.7	63.0	29.1	16.2	33
99	NRCG 13834	44	51	49	6	4.2	3.0	2.0	69.9	32.6	12.6	33
100	NRCG 9033	43	57	47	18	5.3	4.2	2.1	57.2	32.2	16.9	33
101	NRCG 5543	67	86	69	20	2.6	2.5	1.4	64.8	46.8	15.6	32
102	NRCG 13825	45	60	58	3	2.9	2.6	1.7	69.2	32.3	15.8	32
103	NRCG 8989	67	89	61	31	3.0	2.8	1.6	60.1	28.2	18.3	32
104	NRCG 5547	57	68	48	30	2.6	2.9	2.0	70.2	45.5	16.0	31
105	NRCG 13827	66	84	66	22	2.5	2.4	1.4	58.1	34.5	9.6	31
106	NRCG 13795	24	37	31	15	7.4	5.0	2.8	55.9	32.0	14.4	30
107	NRCG 11628	50	76	54	29	3.1	2.6	1.6	64.0	41.1	14.8	29
108	NRCG 13600	43	67	53	20	3.8	3.1	1.6	53.9	30.6	8.3	29
109	NRCG 1022	30	64	48	25	4.9	4.0	1.8	49.5	30.5	14.4	29
110	NRCG 13832	41	50	39	23	4.7	3.2	2.2	69.1	30.7	19.5	28
111	NRCG 10450	39	61	45	26	3.1	3.2	1.8	60.2	42.0	7.1	27

Table 3 continued

S.no	Peanut germplasm accessions	Plant stand (%)			Mortality at harvest (%)	Pods $plant^{-1}$	Pod yield (g $plant^{-1}$)	Seed yield (g $plant^{-1}$)	Shelling (%)	100-Seed mass (g)	Harvest index (%)	Seed yield (g m^{-2})
		15 DAS	45 DAS	118 DAS								
112	NRCG 10135	54	66	46	30	4.5	3.1	1.8	54.1	20.7	6.7	27
113	NRCG 10	47	62	50	19	2.2	2.2	1.4	62.9	35.0	9.1	23
114	NRCG 9020	30	53	45	16	3.0	2.8	1.5	56.7	31.6	12.2	23
115	NRCG 12758	19	27	30	0	4.1	3.7	2.1	56.2	24.7	10.7	21
116	NRCG 13812	32	42	40	5	3.6	2.7	1.6	58.6	32.9	12.5	21
117	NRCG 13823	62	64	58	9	1.5	1.7	1.1	63.5	44.2	7.7	20
118	NRCG 9048	36	50	44	12	4.0	2.4	1.4	62.5	25.8	11.9	20
119	NRCG 13805	36	57	49	15	2.9	1.8	1.1	67.3	27.8	7.8	18
120	NRCG 13820	55	65	43	33	3.2	2.0	1.2	63.0	31.3	7.0	18
121	NRCG 13818	36	37	36	4	4.4	2.5	1.5	59.5	26.1	9.3	18
122	PBS 29058	51	69	51	25	1.3	1.9	1.0	58.3	36.6	10.1	17
123	NRCG 13099	30	35	30	14	4.0	3.8	1.6	44.1	36.2	9.8	16
124	NRCG 13594	39	48	46	4	2.8	2.0	1.0	59.7	28.6	6.1	15
125	NRCG 1613	22	58	50	14	4.2	2.1	0.9	45.1	28.9	9.7	14
126	NRCG 13811	37	60	43	28	2.6	1.4	0.9	65.3	26.3	6.1	13
127	NRCG 4371	39	35	33	6	3.0	2.0	1.1	58.7	31.2	6.5	13
128	NRCG 9039	55	66	36	45	4.8	2.1	1.0	48.9	17.5	16.8	12
129	NRCG 13829	62	83	56	33	1.5	1.2	0.7	59.4	31.9	10.8	12
130	NRCG 12756	33	43	43	0	2.0	1.3	0.8	59.7	30.7	8.9	12
131	NRCG 11629	50	60	50	17	1.1	0.8	0.6	70.5	33.6	7.0	10
132	NRCG 9036	31	65	50	23	1.9	1.4	0.5	36.8	38.2	7.4	9
133	PBS 29021	49	47	30	36	1.6	1.5	0.7	46.1	36.2	13.5	7
134	PBS 29030	50	51	26	50	1.2	0.6	0.3	45.3	35.3	4.4	2
Mean		47	64	53	16	6.4	5.8	3.6	63	37.4	18.9	66.5
SEM ± (133 *df*)		11.6	10.8	9.8		2.3	2.4	1.6	4.3	6.2	4.8	–
LSD ($p \leq 0.05$)		32.2	30.2	27.4		6.4	6.8	4.6	12.1	17.3	13.5	–

Identification of peanut genotypes that can grow and tolerate salinity to a certain level is essential component of the integrated approaches combining soil management practices and peanut varieties for salinity management. Earlier screening efforts of peanut genotypes for tolerance to salinity were mainly based on germination, seedling growth and dry matter production in pots (Nautiyal et al. 1989; Patel et al. 1992) and in field using a few genotypes (Hebbara et al. 1992; Nautiyal et al. 2000). However, Singh et al. (2008, 2010) standardized the screening procedure of peanut under field condition based on plant mortality and seed yield, and identified the seed yield in a unit area (g m^{-2}) as the best criterion for selecting the salinity tolerant genotypes as it takes care of all the parameters. In the present study, the peanut genotypes faced salinity level in the range of 3–4 dS m^{-1} during most of the cropping period (4.5 dS m^{-1} at sowing and 3.5–3.0 dS m^{-1} during 15–80 DAS), where more than 60 % genotypes produced seeds besides plant mortality, and hence was easy to identify tolerant genotypes. The large variations in plant mortality and yield, due to genetic variations, under salinity stress, provided better scope for distinguishing tolerant and sensitive genotypes and identify peanut genotypes that can grow and tolerate salinity with reasonable yield in saline soils. There was severe iron chlorosis in salinity sensitive peanut accessions and interestingly, the salinity tolerant genotypes identified here showed tolerance of iron-chlorosis also making them more fit for alkaline as well as saline soils.

Mineral contents and their ratio in leaves

The mineral concentrations in leaves at 90 DAS showed marked differences in the sensitive and tolerant peanut genotypes (Table 4). The salinity caused accumulation of Na in leaves and to compensate that and maintain proper ratio of various nutrients there was accumulation of Ca, K and S, but lowered the P content. Interestingly, the salinity tolerant genotypes showed comparatively less Na, K and Ca accumulation in their leaves than that of sensitive genotypes as a result there were clear distinction in the ratio of Na/K and Na/Ca. On an average, the mineral content of leaves of tolerant genotypes was 0.21 % Na, 1.34 % K, 4.35 % Ca and 0.23 % S, and in moderately tolerant genotypes 0.17 % Na, 1.48 % K, 4.13 % Ca and 0.23 % S. However, the salinity sensitive genotypes, showed on an average (average of 62 genotypes) concentration of 0.50 % Na, 1.84 % K, 6.25 % Ca and 0.36 % S in their leaf tissues, clearly indicating the differences in mineral contents. As a result the tolerant, moderately tolerant and sensitive peanut genotypes showed an average ratio of 0.162, 0.120 and 0.280 respectively for Na/K, and 0.049, 0.040 and 0.080, respectively for Na/Ca.

Table 4 Nutrient concentrations in leaves of various peanut genotypes at 90 days after sowing, grown under salinity stress during kharif season

Peanut genotypes	Percent (%)						ppm				Ratio of	
	P	S	Na	Ca	Mg	K	Fe	Mn	Zn	Cu	Na/K	Na/Ca
Tolerant												
NRCG 9189	0.18	0.30	0.14	4.22	1.25	0.86	462	227	36	16	0.163	0.033
NRCG 13831	0.16	0.22	0.18	3.68	1.08	1.61	788	161	46	19	0.112	0.049
NRCG 10874	0.15	0.20	0.19	3.34	0.89	0.99	640	135	76	18	0.192	0.060
NRCG 12750	0.16	0.25	0.24	5.42	1.18	1.64	617	125	61	17	0.177	0.054
NRCG 13787	0.18	0.20	0.22	5.22	1.01	1.54	914	170	69	16	0.143	0.042
NRCG 13791	0.14	0.19	0.24	4.20	1.00	1.48	995	114	42	22	0.162	0.057
Mean	0.16	0.23	0.20	4.35	1.07	1.35	736	155	55	18	0.162	0.049
Moderately Tolerant												
NRCG 900	0.14	0.25	0.07	3.38	1.08	1.31	543	149	48	19	0.053	0.021
NRCG 442	0.20	0.27	0.13	3.80	1.03	1.62	863	183	47	21	0.08	0.034
NRCG 12765	0.14	0.21	0.22	3.37	0.98	1.81	408	150	59	19	0.122	0.065
NRCG 10495	0.16	0.25	0.19	5.92	1.17	0.96	405	156	52	11	0.198	0.032
NRCG 421	0.16	0.23	0.24	3.34	1.04	1.43	852	92	97	13	0.175	0.075
NRCG 5566	0.18	0.20	0.24	3.45	0.92	1.57	749	116	133	18	0.153	0.070
NRCG 12749	0.12	0.21	0.16	5.32	1.22	1.60	851	152	83	14	0.10	0.030
NRCG 9065	0.16	0.23	0.11	4.42	1.17	1.50	486	146	98	14	0.073	0.025
Mean	0.16	0.23	0.17	4.13	1.08	1.46	645	143	77	16	0.12	0.04
Sensitive[a]	0.19	0.36	0.50	6.25	1.10	1.84	1264	115	67	16	0.28	0.08
LSD ($p \leq 0.05$)	0.03	0.08	0.13	0.40	0.02	0.20	55	15	6	1	0.08	0.02

[a] Mean of 62 genotypes

Salt exposure lead to accumulation of Na^+ and Cl^- ions in seedlings roots, shoot and leaves (Srivastava and Sharma 1998). Chavan and Karadge (1980) reported that NaCl and Na_2SO_4 salinities suppressed growth and Ca and K uptake, but increased accumulation of Na, P, Fe and Mn in plant tissues of peanut cv. TMV 10. In a field experiment on sodic soil, increase in exchangeable sodium percentage (ESP) from 8 to 35, delayed germination and flowering, decreased dry matter, grain yields and protein and oil percent in kernel with increased Na and decreased K, Ca and N contents, but had no effect on the Mg, P, S, Fe, Mn, Zn and Cu contents of the peanut plant (Singh and Abrol 1985). Malakondaiah and Rajeswararao (1979) reported that salinity caused accumulation of Na, and lowered P, K and Ca in peanut cv. TMV 2, and the foliar spray of P decreased Na and increased P, K and Ca contents.

This study clearly demonstrated that there was selective absorption of minerals in the salinity tolerant genotypes, which resulted in a clear differences between salinity tolerant and sensitive peanut genotypes. Because of this differential nutrient absorptions the salinity tolerant genotypes showed less than 0.25 % Na, 0.20 Na/K ratio and 0.05 Na/Ca ratio, however, the salinity sensitive genotypes showed more than 0.4 % Na, 0.25 Na/K and 0.06 Na/Ca ratio in their leaves. Thus Na content and Na/K and Na/Ca ratios can serve as probable marker for selecting the salinity tolerant genotypes, and also provide a new area of research for peanut that bear underground pods and requires high Ca for pod filling.

Conclusions

The present study holds immense promise, as a number of salinity tolerant germplasm accessions were identified that can endure the salinity stress and also yield satisfactorily in the coastal saline areas with salinity up to 3 dS m^{-1}, which can be used in future studies on salinity mechanism and developing cultivars. The salinity and iron-chlorosis tolerant genotypes are fit for alkaline as well as saline soils. The information generated on differential nutrient absorptions by tolerant and sensitive genotypes can further add to the understanding of salinity tolerance mechanism and in designing strategies for amelioration and enhancement of salt tolerance in peanut.

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