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Research Paper

Effects of potassium application on growth of peanut (*Arachis hypogaea*) and ionic alteration under saline irrigation

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ABSTRACT

A field experiment was conducted during the summer seasons, of 2011 and 2012 at Junagadh, Gujarat, to evaluate the ameliorative effect of potassium in salinity tolerance of peanut (*Arachis hypogaea* L.). Treatments included 2 differentially salt-responsive cultivars ('GG 2' and 'TG 37A') and 3 levels of salinity (control, 2.0 dS/m, 4.0 dS/m) along with 2 levels of potassium fertilizer (0 and 30 kg K_2O/ha). Supplementary application of potassium resulted in improved salinity tolerance in terms of growth (plant height, branches, root length and weight); yield attributes (100-pod and kernel weight and shelling %); yields (pod, kernel and haulm yield) and Na^+: K^+ ionic ratio in (shoot, root, leaf and kernel). Cultivar 'GG 2' showed better salt tolerance by excluding sodium from uptake although cultivar 'TG 37A' allowed more sodium to accumulate in all the peanut parts (root, shoot, leaf and kernel), hence showed more susceptibility to salinity stress. Further about 3–4 times higher sodium was accumulated in root over shoot, leaf and kernel. External application of potassium resulted in nullifying the harmful effect of salinity stress with slightly better response in the susceptible cultivar 'TG 37A' as compared to cultivar 'GG 2'.

***Key words* :** Amelioration, Na^+: K^+ ratio, Peanut, Saline irrigation, Yield

Peanut is one of the important grain legumes which is mainly cultivated on marginal and sub-marginal lands with low inputs. Grain legumes are more significant as they provide large amounts of high quality proteins which contain relatively more of the essential amino acids. Despite of an oilseed, peanut harbours *Rhizobium* bacteria in root nodules; which enable to fix about 180–200 kg atmospheric nitrogen/ha in every crop season. It is now being increasingly realized that peanut is much more than a mere oilseed crop, rather a multi-purpose crop and hence it should rightly be described as a confectionary, food, and fodder crop particularly in the Indian context.

Soil salinity is a serious worldwide problem for agriculture and covers around 6.7 million ha area in India and 1,200 million ha in world. Salinity can inhibit plant growth by a range of mechanisms, including low external water potential, ion toxicity and interference with the uptake of nutrients. Plants growing in arid or semi-arid region, may exhibit more tolerance to salt stress, because of the accumulation of osmo-protectants in their tissues (Le Rudulier, 2005). Significant research in the past has put emphasis on the osmotic effects of salinity. However, specific ion effects are also equally important to cause salinity-induced reduction in growth and yield of the crop. The knowledge for ion-specific effects induced by salinity like ion toxicities and nutritional disorders are increasingly emphasized for salinity management. For example, adequate level of potassium is essential for plant survival in saline habitats (Hauser and Horie, 2010) which lowered down the osmotic potential in the stele of roots, essentially required for turgour-pressure-driven solute transport in xylem and the water balance of the plants. The main feature of the relatively salt-tolerant plants is higher accumulation of Na^+ in leaves and an apparent capacity for K^+ redistribution to younger leaves. Approximately 13–36% of the Na^+ and K^+ ions imported in to leaves through xylem were exported by the phloem (Lohaus *et al.*, 2000). Though little information is available showing effects of potassium application in sodium-dominated soils like reduced uptake and translocation of sodium by plants, increasing K^+: Na^+ within the plant (Ashraf and Ahmad, 2000), improved plant growth and yield (Grattan and Grieve, 1999) etc. it is not certain that the potassium application reduces the deleterious effects of salinity (Cerda *et al.*, 1995). Further, calcareous soils are mostly alkaline, base saturated and dominated by calcium cation which directly or indirectly affected the

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chemistry and availability of soil nutrients (Obreza *et al.*, 1993). Thus in this study we studied how the beneficial effect of application of potassium contributes to overall salt tolerance in peanut cultivars.

MATERIALS AND METHODS

The field experiment was conducted at research farm, ICAR-Directorate of Groundnut Research, Junagadh, Gujarat (70.36° E and 21.31° N; 60 m above mean sea-level). The climate of this area is semi-arid with an average rainfall of 650 mm. The soil under study was medium black calcareous Vertisols and developed on weathered hard monolithic limestone parent materials. The soil depth within the root zone was shallow, very dark grey in colour and clayey. Soils are alkaline (*p*H 7.5–8.0), low in available nitrogen (<140 N kg/ha) and phosphorus (8–15 P_2O_5 kg/ha) and medium in available potassium (160–250 K_2O kg/ha). The soils are rich in calcium carbonate (>5%) having cation-exchange capacity (CEC) ranged from 45 to 55 cmol (+)/kg soil which is dominated by Ca^{+2} (65–75%) and Mg^{+2} (15–20%) cations. Soil organic carbon was 0.5–0.75% in the root zone.

The field experiment was conducted for 2 summer seasons during 2011 and 2012. These were laid out in split-split plot design, consisting of 3 different treatments as NaCl irrigation water of 3 salinity levels [5.6 mm (control), 22 mm and 44 mm] to main plots, 2 spanish cultivars of peanut ('TG 37A' and 'GG 2') in subplots and 2 levels of potassium (0 and 30 kg K_2O/ha) in sub-subplots. Potassium fertilizer (muriate of potash) was applied basal at the time of sowing. All the treatments were replicated 3 times. The gross plot size of main plot was 42 m^2 (7 m × 6 m) and each salinity block was separated by placing a 250-micron polythene sheet up to 60 cm soil depth in different channels surrounding the plots. Bunds were also raised around each block (30 cm wide and 30 cm height) to avoid lateral movement of saline water among different salinity blocks. The extent of rainfall and its distribution along with other weather parameters were presented (Table 1). The peanut crop was sown in the first fortnight of February in each year at 30 cm spacing after applying recommended fertilizers (25 kg N and 22 kg P/ha) as basal dose. The freshwater source used for irrigation purpose has the electrical conductivity of 0.5 dS/m and treated as the control. However, the saline waters of different levels were prepared using sodium chloride salts which were achieved using 22 mm (2.6 kg in 2000 *l* water) and 44 mm (5.2 kg in 2,000 *l* water) NaCl solutions using freshwater for 2 dS/m and 4 dS/m respectively. The NaCl salt used for application of total 8 saline water irrigation during cropping period for 22 mM was 20.8 kg and for 44 mm salinity level it was 41.6 kg/plot. Four sintex drums of 2,000 *l* capacity each were used for application of different saline water irrigation under field conditions.

The crop was raised using the fresh irrigation water source in all the plots at germination stage (up to 10–15 days after sowing; DAS); however at later stage irrigations were used as per the treatments in main plots. In totality about 10 irrigations were used including 8 irrigations as NaCl water irrigations as per the treatments throughout the crop season in both the years. The crop was harvested in the first week of June (110–115 DAS) during both the years of experimentation. Individual plots were harvested manually and the peanut pods were air-dried for final yield and other observations. The growth and yield-attributing characters were recorded in peanut crop at harvest.

Soil samples were collected from 0–30 cm soil depth periodically (30 days interval) during the crop-growing period, to monitor the build-up of soil salinity using soil auger during the crop season. The electrical conductivity and *p*H of the soil were measured using 1:2.5 soil and deionized water suspension. The suspension was shaken and allowed to stand overnight and then measured using Hanna make portable combined *p*H-EC-TDS meter (*model HI 991301*). All observations were taken by mean values of 5 random plants during harvesting. Plants were carefully dig out from the upper 20 cm soil layer with undisturbed root-system; the loose soil adhered to the roots was cleaned. Root length was measured, using the line-intercept method as per Tennant (1975). Principle of this method is that root length can be estimated by counting the number of intersections between roots and sample lines. In this method, roots were spread out with random orientation in a thin layer of water on a glass plate (about 25 cm × 25 cm) marked in grid lines. All intersections of roots with gird lines (taking the upper or left boundary of the line as criterion in case of doubt) are counted. Results for horizontal (H) and vertical (V) grid lines are added to number N. If the grid size was D (mm), root length L (mm), then the equation stands:

$$L = \frac{\pi ND}{4}$$

Different plant parts collected were ground in the pestle and mortal before extracting the elements. The grinded plant samples were digested using tri-acid mixture and diluted up to 100 ml. From each digested plant part K and Na contents were directly estimated by Flame photometer.

Analysis of variance was carried out using MS-Excel based software where least significant difference was computed to test the significant differences between treatment means at 5% probability (P=0.05).

RESULTS AND DISCUSSION

Root zone soil salinity

Imposition of salinity stress resulted in significant changes in electrical conductivity (Fig. 1). The electrical conductivity of saturated soil extract was increased from 1.16 to 4.37 and 2.62 to 5.53 dS/m at harvesting under different water salinity levels during 2011 and 2012, respectively. This may be due to no rainfall during the crop-growth period and also due to supplemental irrigation of saline water which resulted in accumulation of salt during the summer 2011 and 2012 seasons. Irrespective to water salinity levels, the application of potassium fertilizers significantly reduced the electrical conductivity of saturated soil extract (5%) as compared to no potassium fertilization. The soil salinity again gets reduced in the rainy season before sowing in coming year (2012). This might be due to leaching of soluble salts from the root zone as during the rainy season approximately more than 900 mm rainfall received during July–September 2011 (Table 1). The soil salinity at the time of sowing of peanut in February 2012 was 2.04–2.55 dS/m which significantly increased to a level of 2.62–5.52 dS/m at the time of harvesting of peanut in June 2012.

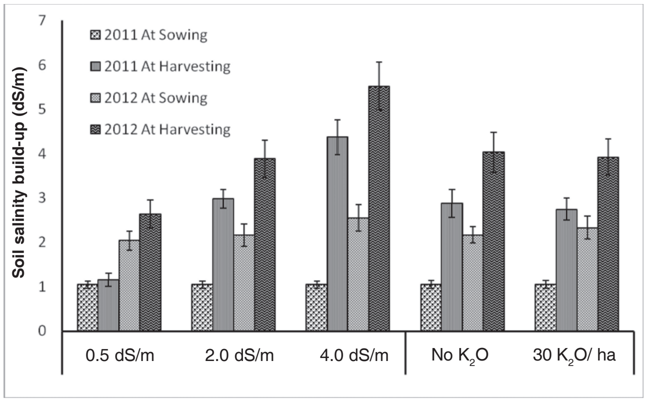

Fig. 1. Build-up of soil salinity due to application of NaCl saline irrigation water in peanut during summer season (2011 and 2012)

Effect of salinity on growth and yield of peanut

Application of saline irrigation and potassium fertilizer affected growth; yields and yield-attributing characters (Table 2). The yield of pod, kernel and haulm was significantly affected by saline irrigation and soil salinity. The reduction in pod, kernel and haulm yield was 5.1 and 34%; 5.5 and 37.8%, and 5.6 and 27.3% at 22 and 44 mm over application of freshwater (control) respectively. However, 100-pod and kernel weight and shelling percentage were also significantly differed by use of saline irrigation water above 22 mm. Similar significant decrease in plant height and root length was also observed, but number of branches and root weight showed non-significant difference with different salinity levels. The peanut cultivar 'TG 37A' performed better than to 'GG 2' under different levels of water salinity and the increase in yield was 31.8, 33.1 and 9.2% higher for pod, kernel and haulm yield respectively. However, the plant height of 'GG 2' was 12% higher than that of 'TG 37A'. Differences in the yield among the genotypes might be due to higher shelling percentage (2.4), 100-kernel (10.3%), 100-pod (17.6%) weight and number of branches (7.7%) of the 'TG 37A' than 'GG 2'. The pod, kernel and haulm yields of peanut were also significantly affected with application of K fertilization and significantly higher yields was found with 30 kg/ha K as com-

Table 1. Weather parameters during crop growth and post-crop-growth seasons in 2011 and 2012

Months	Temperature (°C)				Relative Humidity (%)		Rainfall (mm)		Wind speed (km/hr)		Evaporation (mm)	
	2011		2012									
	Max.	Min.	Max.	Min.	2011	2012	2011	2012	2011	2012	2011	2012
During crop-growth season												
February	30.7	14.6	31.2	13.3	52	36	0.0	0.0	4.4	5.5	5.2	6.8
March	36.6	18.5	36.0	17.7	40	37	0.0	0.0	5.1	5.5	8.0	8.5
April	39.1	23.0	39.3	23.2	42	47	0.0	0.0	6.3	6.3	9.6	9.7
May	37.9	25.9	38.3	25.4	59	57	0.0	0.0	9.5	8.5	9.0	9.5
June	36.3	26.9	36.5	27.0	66	64	37.5	84.2	11.3	11.9	6.8	7.8
During post-crop growth season												
July	32.0	25.2	33.7	26.2	82	75	341.7	67.6	7.4	10.0	3.4	4.5
August	30.3	25.1	32.0	25.0	88	80	341.7	79.5	6.5	8.6	2.3	3.4
September	30.9	24.2	32.0	24.5	81	78	241.8	193.7	5.7	5.2	3.0	3.4
October	35.4	23.0	37.0	21.5	53	48	0.0	0.0	3.7	3.1	5.2	6.0
November	34.7	20.0	33.8	15.3	49	42	0.0	0.0	3.3	2.7	5.1	5.0
December	31.1	13.7	32.1	15.7	47	43	0.0	0.0	4.1	4.0	4.8	5.2
January	28.6	11.4	28.1	11.6	50	45	0.0	0.0	4.0	4.0	4.3	4.3
Total	404	252	410	246	708	653	963	425	71	75	67	74

pared to without potassium fertilization. The per cent increases in pod, kernel and haulm yield of peanut were 5.1, 7.5 and 11.7 higher with the application of 30 kg/ha K as compared to without potassium fertilization. This might be due to ameliorative effect of potassium on salinity stress.

Salinity stress generally deters plants growth primarily due to its osmotic effect and after that because of more injurious specific ion toxicity effect. Thus under the initial stage of soil salinity plants started to show altered plant water status without much effect on cell turgour (Munns, 1993). It is well evident that salinity reduces the growth of the plants by upsetting water and nutritional balance (Meena *et al*., 2012, 2014, 2016) and loss of photosynthesis capacity (Rajesh *et al.*, 1998). In fact the water movement through stomata and its subsequent metabolic assimilation rate during transpiration and photosynthesis processes is strongly affected by salinity. Lobato *et al.* (2008), reported the reduced stomatal conductance for water loss to the atmosphere under soil and water salinity.

Salinity levels and nutrients accumulation in various plant parts

Application of NaCl irrigation water increased sodium content in different parts of the peanut which increased with successive increase in the salinity levels (Table 3). Although a significant difference in sodium accumulation with salinity levels was recorded in leaf and kernels. However, shoot and root showed non-significant difference under different saline irrigation levels. The sodium content increased in root, shoot, leaf and kernel by 25.9 and 75.6%, 41.3 and 59.4%, 38.0 and 100%, and 51.4 and 93.8% at 22 mm and 44 mm, respectively, as compared to fresh irrigation water (control). Irrespective of salinity levels, Na^+ concentration was found to be in the order of root > shoot > leaf > kernel (Table 3).Overall, Na^+ accumulation was higher in the root than shoot, leaves and kernel of peanut (Fig. 2). The accumulation of Na^+ was observed higher in 'TG 37A' over 'GG 2' in all the parts of peanut. Application of potassium fertilization with 30 kg/ha resulted in lowering down Na^+ uptake by adjusting the ionic balance in different parts of peanut. Different workers reported that, increasing salt levels were increased Na concentrations in different plant species (Tuncturk, 2011). They also reported that high Na content generally disrupts the nutrient balance and thereby causing specific ion toxicity despite disturbing osmotic regulation (Grattan and Grieve, 1999).

Unlike Na^+ content, the K^+ content showed an opposite trend that K^+ uptake was decreased in all the parts with the increasing level of salinity. The results showed that accumulation of potassium (K^+) in different plant parts was significantly affected except in roots (Table 3). Differential accumulation of K^+ was observed under salinity stress in different plant parts and the concentration was found in the order of kernel > leaf > shoot > root (Fig. 2).The potassium content decreased in root, shoot, leaf and kernel by 7.1 and 21.4%, 2.3 and 11.9%, 26.0 and 34.0% and 7.8 and 9.8% at 22 mm 44 mm respectively and as compared to fresh irrigation water (control). The K^+ accumulation in kernel was about 45.1, 44.7 and 52.2% higher than that in

Table 2. Growth, yield and yield attributing characters of peanut during summer season (average of 2 seasons)

Treatment	Growth and yield-attributing characters							Yield (kg/ha)		
	Plant height (cm)	Branches per plant	Root length (cm)	Root weight (g)	100-pod weight (g)	100-kernel weight (g)	Shelling (%)	Pod	Kernel	Haulm
Water salinity (S, dS/m)										
0.5	33.27	4.82	10.25	0.58	76.36	40.46	69.53	2,446	1,694	3,505
2	29.71	4.66	10.13	0.56	74.78	39.52	68.77	2,321	1,600	3,308
4	25.28	4.64	8.7	0.52	70.15	36.55	64.82	1,614	1,053	2,549
SEm±	0.78	0.10	0.22	0.04	1.07	0.61	0.68	30	25	61
CD (P=0.05)	2.23	NS	0.63	NS	3.04	1.74	1.93	84	72	173
Peanut cultivars (V)										
'TG 37 A'	27.74	4.88	9.694	0.55	80.89	40.96	68.52	2,529	1,736	3,271
'GG 2'	31.09	4.53	9.694	0.56	66.64	36.73	66.89	1,725	1,161	2,970
SEm±	0.64	0.08	0.179	0.08	7.96	1.11	0.55	24	21	50
CD (P=0.05)	1.82	0.23	NS	NS	NS	NS	1.57	69	59	142
Potassium levels (K, kg/ha)										
0	29.35	4.58	9.667	0.54	72.49	37.64	66.91	2,072	1,393	2,927
30	29.48	4.83	9.722	0.57	75.04	40.04	68.51	2,182	1,505	3,314
SEm±	0.64	0.08	0.179	0.03	0.87	0.50	0.55	24	21	50
CD (P=0.05)	NS	0.23	NS	NS	2.49	1.42	1.57	69	59	142

roots under different NaCl irrigation water levels. The accumulation of K^+ was higher in ‘GG 2’ than ‘TG 37A’ in all the parts but significant difference was observed in root and leaf of peanut. Application of potassium fertilization with 30 kg/ha significantly increased K^+ uptake in different parts. These results clearly indicate the differential behaviour of Na^+ and K^+ ions towards their acquisition and assimilation by the peanut plants. Salinity causes not only high Na^+ and Cl^- accumulation in plants, but it can also influence the uptake of essential nutrients such as K^+ and Ca^{2+} due to the effect of ion selectivity (Meena *et al.*, 2015).

The highest Na^+:K^+ ratio in shoot, root, leaves and kernel peanut were observed in saline irrigation using NaCl water of 4.0 dS/m (Table 3). The highest Na^+:K^+ accumulation ratio was obtained in roots followed by that in leaves then in shoots and the least in kernels. The Na^+:K^+ accumulation ratio in roots was almost 6 times higher than the aerial parts of the peanut which indicated the accumulation of Na^+ ions in the root cells and also signified the restricted translocation to the aerial part of the peanut under saline stress. The accumulation of Na^+:K^+ was higher in ‘TG 37A’ than ‘GG 2’ in all the parts of peanut. In contrast, the absorption and translocation of K^+ ions were higher in aerial parts of the peanut than roots which were significantly reduced with the increased salinity levels, while Na^+:K^+ ratio significantly increased with increased salinity levels. Similar results was also reported by (Cerda *et al.*, 1995) where they advocated that the reduced potassium content would be caused by Na^+ ion accumulation in roots which would likely to be the result of competitive intracellular influx of both ions. It also implies that competition between Na^+ and K^+ absorption in peanut plants resulting in a mass action competition (Taffouo *et al.*, 2010; Meena *et al.*, 2015).Due to similar physic-chemical properties of K^+ and Na^+ in the growing environment, plants often face K^+ deficiency under saline condition (Shabala and Cuin, 2008). Earlier studies indicated reduction in tissue K^+ content in plants grown under saline condition for prolonged period (Chakraborty *et al.*, 2012a). Thus, maintaining a high cytosolic K^+:Na^+ ratio in metabolically active tissues are critical for plant growth and salt tolerance (Wang *et al.*, 2013).

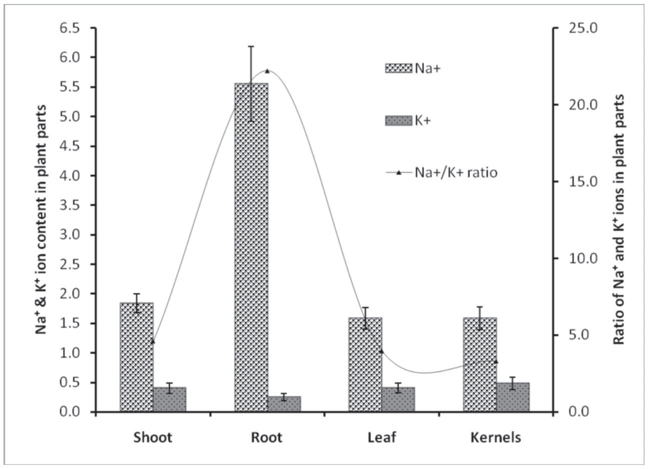

Fig. 2. Accumulation of Na^+ and K^+ ions in different plant parts of the peanut (bars) and Na^+:K^+ ratio (line) under NaCl irrigation water (average of 3 water salinity levels)

Application of potassium not only increased significantly the concentration of K in plant parts but also significantly decreased the accumulation of Na ions as well as Na:K ratio in different plant parts under salinity (Fig. 2).

Table 3. Nutrient content in different plant parts of peanut cultivars having different irrigation water salinity and potassium levels

Treatment	Shoot (g/kg)			Root (g/kg)			Leaf (g/kg)			Kernel (g/kg)		
	Na^+	K^+	Na^+:K^+	Na^+	K^+	Na^+:K^+	Na^+	K^+	Na^+:K^+	Na^+	K^+	Na^+:K^+
Water salinity (S, dS/m)												
0.5	13.8	4.2	3.28	46.4	2.8	16.57	10.8	5.0	2.16	10.7	5.1	2.09
2	19.5	4.1	4.75	58.4	2.6	22.41	14.9	3.7	4.02	16.2	4.7	3.44
4	22.0	3.7	5.94	81.5	2.2	37.04	21.6	3.3	6.54	20.7	4.6	4.50
SEm±	2	0.1	0.26	8.2	0.2	7.26	0.8	0.1	0.25	0.3	0.1	0.06
CD (P=0.05)	NS	0.4	0.73	NS	NS	NS	2.4	0.3	0.72	0.9	0.2	0.17
Peanut cultivars (V)												
TG 37 A’	18.9	3.7	5.10	67.3	2.2	30.50	16.2	3.4	4.76	16.2	4.8	3.20
‘GG 2’	18.0	4.2	4.28	56.9	2.8	20.30	15.3	4.6	3.32	15.4	4.8	3.37
SEm±	0.6	0.3	0.43	1.6	0.2	2.29	0.7	0.1	0.21	0.2	0.1	0.05
CD (P=0.05)	NS	NS	NS	4.6	0.4	6.52	NS	0.3	0.59	0.7	NS	NS
Potassium levels (K, kg/ha)												
0	19.5	3.7	5.27	64.7	2.2	29.40	17.2	3.8	4.52	16.3	4.7	3.27
30	17.3	4.2	4.11	59.5	2.9	20.50	14.3	4.2	3.40	15.2	4.9	3.30
SEm±	0.6	0.1	0.21	1.6	0.2	2.29	0.7	0.1	0.21	0.2	0.1	0.05
CD (P=0.05)	1.8	0.3	0.60	4.6	0.5	6.52	2	0.3	0.59	0.7	0.1	NS

The increased magnitude of K content was 11.9, 24.1, 9.5 and 4.1% and Na content decreased by 11.2, 8.0, 16.9 and 4.9% in shoot, root, leaves and kernel respectively. Consequently, the Na to K accumulation ratio also decreased by 22.0, 30.2, 24.7 and 0.89 in shoot, root, leaves and kernels, respectively. Previous studies indicated under saline condition maintenance of cytosolic K^+ concentration at a constant level is important for plant metabolism, while vacuolar K^+ concentrations may vary greatly (Shabala and Cuin, 2008;Wu *et al.,* 2014). Under K^+-deficient situation especially due to reduced uptake of K^+ under salinity stress results in constant consumption of vacuolar K^+ in order to maintain a uniform cytosolic K^+ concentration (Wang *et al.,* 2013). It is well established that various transporters were involved in K^+ transport in the plant system which are differentially regulated in various plant parts or tissues depending on the plant age (Su *et al.,* 2001). Although at whole plant level, the basis of cellular K^+ versus Na^+ ions discrimination is difcult to establish. Some studies have shown that K^+ concentration in plant tissues get reduced as Na^+ salinity or Na^+:Ca^{2+} ratio in the rooting media get increased (Subbarao *et al.,* 2003).

Interaction of salinity and potassium levels

Interaction of salinity and potassium levels were significantly altered the pod, haulm and kernel yield of peanut, but the effect of potassium was the highest at 0.5 dS/m salinity level. However, this was drastically reduced with increased levels of salinity especially in pod and kernel yield of peanut. It indicates that application of potassium with 30 kg/ha ameliorates the salinity developed by application of saline irrigation water up to 2 dS/m salinity level (Table 4). The highest application effect of potassium was observed on haulm yield (12%) followed by kernel (7%) and least on pod yield (5%) as compared to without application of potassium fertilizer.supplementary application of potassium resulted in compensating the salinity induced yield loss (Tables 4, 5) and the effect was quite higher in 'TG 37A' than 'GG 2', when external potassium was applied. This result advocated that, under potassium with 30 kg/ha condition higher availability of potassium (K^+) even in saline condition facilitated both the cultivars to retain better physiological status may be through higher uptake of potassium (K^+) or better withholding of potassium (K^+) as compared to without application of potassium condition. In salinity stress, the availability of nutrients to plants including that of potassium (K^+) is often hampered, hence sufficient availability of potassium (K^+) in growing environment is absolutely essential for plant growth. In earlier studies, supplementary application of potassium (K^+) promoted growth and biomass production in various crops (Meena *et al.,* 2015). It is possible that in the saline environment where there is presence of high salt concentrations, the amount of naturally occurring potassium (K^+) may suppress plant growth (Chen *et al.,* 2007). Increasing

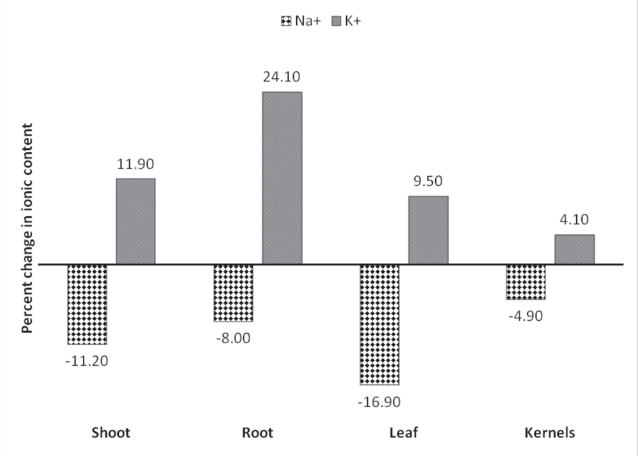

Fig. 3. Changes in Na^+ and K^+ content in different plant parts of the peanut as influenced by application of potassium

Table 4. Effect of NaCl irrigation water salinity and potassium levels on peanut productivity and ionic concentration and ionic ratio in different plant parts

Treatment	Pod (kg/ha)	Haulm (kg/ha)	Kernel (kg/ha)	Leaf K (%)	Leaf Na (%)	Leaf Na/K	Root Na (%)	Shoot Na:K
NaCl water salinity × potassium application								
S_0K_0	2,314	3,160	1,590	0.502	1.140	2.496	5.292	3.966
S_0K30	2,577	3,851	1,797	0.491	1.020	2.141	3.978	3.335
S_2K_0	2,287	3,255	1,543	0.304	1.432	4.720	6.088	5.385
S_2K_{30}	2,355	3,483	1,656	0.432	1.538	3.744	5.590	4.599
S_4K_0	1,614	2,608	1,044	0.327	2.598	8.320	8.023	7.607
S_4K_{30}	1,613	2,883	1,061	0.335	1.718	5.062	8.283	5.138
SEm±	41.891	85.937	35.70	0.017	0.012	0.36	0.28	0.36
CD (P=0.05)	119.482	245.11	101.82	0.049	0.034	1.02	0.79	1.04

S_0; NaCl irrigation water of 0.5 dS/m salinity, S_2; NaCl irrigation water of 2.0 dS/m salinity, S_3; NaCl irrigation water of 4.0 dS/m salinity, K_0; No potassium application, K_{30}; application of 30 kg K_2O/ha as murate of potash fertilizer potassium (K^+) concentration in growing medium in such situations may improve potassium (K^+) absorption and therefore counterbalance the adverse effect of salt stress (Zheng *et al.*, 2008).

The nutrient content of leaf for sodium and potassium and root for sodium significantly affected by salinity and potassium levels. Application of potassium enhanced the potassium content (10%) and reduced sodium content (21%) under different salinity levels as compared to without application of potassium fertilization. The sodium content of root was also decreased by (9%) with application of 30 kg/ha potassium as compared to without potassium application. The Na:K ratio considerably reduced in leaf (0.36 to 3.26) and shoot (0.63 to 2.47) by the application of potassium indicated that application of potassium considerably lower down the toxic effect of sodium on plant growth and nutrient balance. Potassium (K^+) is one of the major primary inorganic osmoticum in cellular osmotic adjustment whenever the plants face osmotic stress (Wang *et al.*, 2013). Due to similar physico-chemical properties of potassium (K^+) and sodium (Na^+) in the growing situation, plants often face potassium (K^+) deficiency under saline condition (Shabala and Cuin, 2008). Meena *et al.*, (2015) reported reduction in potassium (K^+) content in plants grown under saline condition for long period. Thus, maintaining a high cytosolic K^+:Na^+ ratio in metabolically active tissues are critical for plant growth and salt tolerance (Wang *et al.*, 2013). Previous studies suggested under saline condition maintenance of cytosolic potassium (K^+) concentration at a constant level is important for plant metabolism, while vacuolar potassium (K^+) concentrations may vary greatly (Shabala and Cuin, 2008). Under potassium (K^+)-deficient situation particularly due to reduced uptake of potassium (K^+) under salinity stress results in constant depletion of vacuolar potassium (K^+) in order to maintain a uniform cytosolic potassium (K^+) concentration (Wang *et al.*, 2013). Similarly, we also found reduced potassium (K^+) uptake under increasing salinity level and concomitant rise in sodium (Na^+) uptake and accumulation (Table 3).

Interaction between salinity levels and peanut cultivars

Haulm yield, shelling per cent, potassium content in leaf and kernels were significantly altered by salinity and cultivars (Table 5). Haulm yield and shelling percentage of 'TG 37A' was higher than 'GG 2' at all the levels of salinity. The potassium content (%) was also significantly higher in 'TG 37A' than 'GG 2' both in leaf and kernels at all the levels of NaCl water salinity. This might be due to the counter ion effect of potassium and sodium. Although, these effects were specific to salinity levels and needs to further study using wide range of salinity levels and genotypes.

Interaction between potassium levels and peanut cultivars

The interaction effect of potassium and peanut cultivars significantly altered the sodium content (%) of root, leaf and Na:K ratio of leaf (Table 5). Application of potassium drastically reduce the sodium content (1.9 to 1.3%) and Na:K ratio (6.36 to 3.79) in leaf of cultivar TG 37A whereas this difference was recorded very less in 'GG 2', indicating that the effect of potassium to counteract the irrigation water salinity was specific to genotypes. Therefore, this study indicated that peanut genotypes may vary in their choice for specific ion movement in different plant parts. Similarly, sodium content of roots was considerably reduced in cultivar 'GG 2' by application of potassium

Table 5. Interaction effect of NaCl irrigation water salinity and peanut cultivars as well as potassium fertilization and peanut cultivars on different plant parameters during summer season

Treatment	Shelling (%)	Haulm yield (kg/ha)	Kernel K (%)	Leaf K (%)	Treatment	Root Na (%)	Leaf Na (%)	Leaf Na:K
	NaCl salinity levels × peanut cultivars				*Potassium application × peanut cultivars*			
S_0V_1	70.14	3676	0.521	0.616	K_0V_1	6.671	1.904	6.358
S_0V_2	68.93	3335	0.488	0.502	$K_{30}V_1$	6.792	1.326	3.787
S_2V_1	70.15	3360	0.491	0.410	K_0V_2	6.264	1.542	3.999
S_2V_2	67.39	3255	0.453	0.304	$K_{30}V_2$	5.108	1.526	3.512
S_4V_1	66.48	2883	0.499	0.360				
S_4V_2	63.15	2214	0.424	0.327				
SEm±	0.96	85.94	0.009	0.017	SEm±	0.23	0.010	0.29
CD (P=0.05)	2.72	245.11	0.024	0.049	CD (P=0.05)	0.64	0.028	0.83

S_0; NaCl irrigation water of 0.5 dS/m salinity, S_2; NaCl irrigation water of 2.0 dS/m salinity, S_3; NaCl irrigation water of 4.0 dS/m salinity, K_0; No potassium application, K_{30}; application of 30 kg K_2O/ha as murate of potash fertilizer fertilizers. However 'TG 37A' showed slight increase in sodium content by the application of potassium. Also the variations in Na:K ratio in different plant parts of cultivar indicated the differential behaviour of peanut cultivars for accumulation of specific ions.

The interactions of NaCl irrigation water salinity, peanut cultivars and application of potassium significantly altered the sodium content of leaf, potassium content of leaf and kernel and Na:K ratio for leaf and kernels (data not shown). Although, no consistent trend was observed for interaction effect of these three factors on specific parameter and whatever the effects as reported has been already described in above interactions for salinity levels and peanut cultivars as well as for potassium levels and peanut cultivars.

From the results, we conclude that application of potassium fertilizer proved the ameliorative effect of the potassium on salinity stress conditions and counteract the specific ion effects of the sodium on absorption and translocation of other counter-ions of sodium chloride enriched irrigation water for peanut cultivation in calcareous vertisols. The cultivar 'GG 2' had basic salt tolerance character, which was evident from its capacity to exclude sodium from uptake and lesser accumulation particularly in metabolically active mesophyll tissue. On the other hand, 'TG 37A' allowed more accumulation of sodium. Application of potassium seemed to abolish the negative effect of salinity in both the cultivars, but the effect was better in 'TG 37A'. The higher accumulation of Na^+ in roots and K^+ ions in aerial parts of the peanut plants not only indicates the selective ion absorption and translocation mechanisms and their interactions but also signifies the physiological and metabolic effects of Na^+ ions on peanut growth and nutrition under salinity stress. Thus higher Na^+ concentration disrupted the nutrient balance in the plant parts and thereby causing ion deficient and/or toxicity in the plants.

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