J. Indian Soc. Coastal Agric. Res. 40(2): 69-78 (2022) https://doi.org/10.54894/JISCAR.40.2.2022.121059

Influence of Salinity on Micronutrient Availability in Soil and Plant in Cowpea-Groundnut Cropping System

DEBARATI BHADURI[1]*, H.N. MEENA and P.K. BHALODIA

ICAR-Directorate of Groundnut Research, Junagadh - 362 001, Gujarat, India

Received: 03.02.2022 Accepted: 14.12.2022

An experiment on cowpea-groundnut rotation was conducted to study the effect of saline irrigation water on the availability of micronutrient cations (Fe, Zn, Cu and Mn) in soil and in plants with the effect of a gradual imposition of irrigation salinity (EC_{iw}). Three saline treatments (S_1: 2.0 dS m^{-1}, S_2: 4.0 dS m^{-1}, S_3: 6.0 dS m^{-1} with a control S_0) were maintained in long-term field trials. In summer (cowpea) the soil EC_e was raised to 6.01 dS m^{-1} while in *kharif* (groundnut) the EC_e was 2.21 with S_3. A noticeable increase in soil pH (from S_0 to S_3) was also observed in cowpea (0.48 unit) and groundnut (0.97 unit) seasons. The four available micronutrients in soil did not show any significant trend in both seasons. The concentration of both shoot Fe and Zn increased from control (S_0) to highest salinity (S_3) to the tune of 19% and 74%, respectively in groundnut. The accumulation of root Fe and Zn in groundnut declined to the tune of 53% and 40% respectively with the increasing salinity from S_0 to S_3. For cowpea, only Zn content showed a decreasing trend among the other micronutrients. Genotypic variation of groundnut did not affect the accumulation of micronutrients as observed by testing eight groundnut genotypes in the present study. A significant drop in yield was noticed for both crops due to saline irrigation, and the groundnut yield varied between 1.6 t ha^{-1} (in S_0) to 0.14 t ha^{-1} (in S_3). This study marks a relevance where very less information is available on micronutrient availability in plant tissues and soil under changing salinity, especially for groundnut, which is considered an important oilseed crop from the national perspective.

(***Key words:*** *Cropping system, Groundnut, Micronutrients, Saline irrigation, Yield*)

Soil and water salinity has been a major problem in the semi-arid agro-ecosystem for a long past. Farmers face severe scarcity of freshwater while irrigating their crops in *rabi*-summer season. They have to cope-up with the situation by applying saline irrigation water year after year. Almost 100 countries of the world suffer due to salinity as it is a very serious constraint to crop plant growth (Munns, 2002) by a range of mechanisms: low external water potential, ion toxicity, and interference with the uptake of nutrients (Munns *et al.*, 1995; Taffouo *et al.*, 2008). Some tolerant or semi-tolerant crops bear the stress of salt with maintaining optimum production while others proved incompetent. Their inherent genetic characters determine this potentiality. Groundnut (*Arachis hypogea*) is an important leguminous oilseed crop, and their yield potentiality and yield attributing characters dropped gradually after crossing the threshold water salinity (Meena *et al.*, 2012). Groundnut is a moderately salt-tolerant crop which survives upto 2.0 dS m^{-1} EC and sometimes up to 4.0 dS m^{-1} EC for some good salt-tolerant varieties. In contrast, cowpea is considered to be a moderately sensitive crop to salinity (West and Francois, 1982).

The pH and EC of soil solution play a major role in the availability of most micronutrients along with the nature of binding sites on organic and inorganic particle surfaces. In saline and sodic soils, the solubility of micronutrients (e.g., Cu, Fe, Mn, Mo and Zn) remains low, and thus plants grown in these soils may face deficiencies of such elements (Page *et al.*, 1990). Although reports are available to describe the complex nature of the micronutrient availability in saline soil. Salinity often improves the available concentration of micronutrients due to a decrease in soil pH that inturn increases the solubility of the nutrient ions (Hassan *et al.*, 1970).

Unlike other plants, groundnut nutrition is unique

**Corresponding author:* E-mail: debarati.ssiari@gmail.com
[1]Present address: ICAR-National Rice Research Institute, Cuttack - 753 006, Odisha, India

as the pod develops under the soil and most of the seed nutrition is directly through pods rather than those transported from the root, shoot and back to the seed (Singh *et al.*, 2004). However, plant behaves differently in terms of their micronutrient accumulation in tissues with varying availability of the same in soil under a saline environment. The application of 60 mM NaCl significantly and negatively impacted the micronutrient uptake of wheat (Asik *et al.*, 2009). A significant decrease in the concentration of Zn, Cu, Mn and Fe in leaves, stems, tap roots and lateral root tissues of *Acacia senegal* was observed in response to an increase in salt stress (Hardikar and Pandey, 2008). A positive relationship was obtained between soil salinity and concentration of Zn, Cu, Mn and Fe in tissues of salt-tolerant species *Cassia montana* (Patel and Pandey, 2007). The application of 20mM NaCl increased the dry weight, and Fe, Cu, and Mn content of corn, but the amounts decreased with the application of 60 mM NaCl (Khaled and Fawy, 2011). A study reported that Mn, Fe and Zn concentration of wheat under saline conditions depends upon the availability of macronutrients and plant parts under observation (Hu and Schmidhalter, 2001).

Inherent soil salinity may not be very common in the Saurashtra region of Gujarat (except the coastal areas) but irrigation through saline water is often practised by the farmers of the region, thus the problem of secondary salinisation continues year after year. Our main purpose for conducting the study was to observe whether salinity (up to 6.0 dS m^{-1}) has any impact on soil and plant micronutrient (Fe, Mn, Zn, Cu) availability. Both the experimental crops, groundnut and cowpea, are popularly cultivated in Gujarat, especially in the Saurashtra region. This type of study has special relevance when we discuss the effect of salinity on plant nutritional aspects and if there is any role in the decrement of micronutrient availability which may be further detrimental to crop growth and yield. In the present context, we have chosen to study the soil micronutrient availability, micronutrient accumulation in various parts of plant tissues, and any genotypic variation (among the eight tested cultivars) if existing under varying salinity. Alongside, this might have caused a further impact on pod yield of summer cowpea - *kharif* groundnut rotation with four distinct salinity levels imposed by irrigation (control or zero salinity, 2.0 dS m^{-1}, 4.0 dS m^{-1} and 6.0 dS m^{-1} EC_{iw}) from the long-term salinity trials. This kind of study is not frequently reported especially targeting the micronutrients where crops have been raised under different salinity gradients, and artificially maintained under field conditions.

MATERIALS AND METHODS

Field experimentation and treatment imposition

The study was conducted at the farm of the Directorate of Groundnut Research, Junagadh, Gujarat (21º31′ N latitude, 70º36′ E longitude) under summer (dry season, February-May) cowpea - *kharif* (wet season, June-October) groundnut crop rotation during 2011 in calcareous saline black clay soils. Different saline water levels were maintained on a permanent fixed site on long-term basis since 2003 under groundnut-based crop rotation. The experimental soil, classified under *Vertic Ustochrept,* was characterized by shallow depth (15-20 cm), blackish to greyish in colour, clay texture, calcareous in nature (21-22% $CaCO_3$), weathered or hard miliolitic limestone underlying, alkaline pH (7.8), non - saline (0.32 dS m^{-1}), low organic carbon (4.8 g kg^{-1}), low available N (110 kg ha^{-1}), low available P (9.8 kg ha^{-1}) and medium available K (258.3 kg ha^{-1}).

To prepare saline irrigation water, 1.3, 2.6 and 3.9 kg of commercially available NaCl salt was dissolved per 1000 L of best available (non-saline) groundwater to make 2, 4 and 6 dS m^{-1} EC_{iw}, respectively. Different salinity level plots were separated from each other by putting a 250 µm polythene sheet up to 60 cm soil depth in different channels surrounding the treated plots. Bunds were raised to a 30 cm height and 30 cm width aiming to absorb maximum rainwater in the plot during *kharif* season. These artificially created saline plots were maintained since 2002 (Meena *et al.*, 2012; Bhaduri *et al.,* 2016). The gross plot area was 20 m^2.The cowpea (var. Gujarat 2) was irrigated five times in the summer season and the groundnut was irrigated twice with saline water as per the requirement of the crop and considering the amount of rainfall received during the crop growth. The cowpea was grown in a randomized block design with three replications under different salinity levels of irrigation water [0.5 (control), 2.0 (S_1), 4.0 (S_2) and 6.0 (S_3) dS m^{-1}]. After cowpea, *kharif* groundnut was sown in the last week of June, 2011 as a succeeding crop with the same four salinity levels. Eight Spanish genotypes (TPG 41, GG 6, GG 8, SG 99, GG 7, TG 37A, R 2001-3 and Girnar 3) of groundnut allotted to subplots, were laid out in a split-plot design with three replications. The fertilizers were applied at recommended doses for groundnut (12.5 kg N + 40 kg P_2O_5 ha^{-1}) and cowpea (20 kg N + 50 kg P_2O_5 ha^{-1}).

Sampling and nutrient analyses

Soil available Zn, Fe, Cu, and Mn were determined by using the 0.5 M DTPA (at pH 7.3) micronutrient extraction method developed by Lindsay and Norvell (1978) from the samples collected from two depths (0-15 cm, 15-30 cm) during harvesting of both the crops (groundnut and cowpea). The micronutrient concentrations in the DTPA extract were measured by using an atomic absorption spectrophotometer (Perkin Elmer make). Mineral analyses were performed on leaves, stems and root tissues. Mature plant parts grown in soil at the same level of salinity were collected separately before harvesting. Plant samples were prepared by finely grinding using a mortar and pestle. Three subsamples of plant tissues were analyzed. Concentrations of Zn, Fe, Mn and Cu were determined by atomic absorption spectroscopy (AAS) after tri-acid (HNO_3: H_2SO_4: $HClO_4$ in the ratio of 10:1:4) digestion. All other relevant soil parameters (soil pH, soil organic carbon, available P and K) were analyzed using standard analytical procedures (Jackson, 1973).

Statistical analysis

All the variables (yield, micronutrients and other salinity associated soil factors) were subjected to analysis of variance (ANOVA) to examine treatment effects and were statistically analyzed season-wise using MS-Excel based statistical programme. The ANOVA was performed for every variable according to the split-plot design. Fisher's least significant difference (LSD) was employed to test the significance of the differences among means at 95% probability ($P < 0.05$).

RESULTS AND DISCUSSION

Build-up of soil salinity

The changes in the soil salinity build-up in the summer cowpea-*kharif* groundnut cropping system was monitored. The salinity which was 0.8 to 3.4 dS m^{-1} at the time of sowing of summer cowpea during February was significantly increased to a level of 0.9 to 6.2 dS m^{-1} at the time of harvest of the crop (last week of May). The abrupt rise in salinity in different treatments was also noticed in summer cowpea (0.56 to 6.01 dS m^{-1} from S_0 to S_3), whereas for *kharif* groundnut season the increase was gradual and less abrupt (0.47 to 2.21 dS m^{-1} from S_0 to S_3) as compared to the summer season (Fig. 1). In groundnut season, statistically at par EC values were recorded with S_1 and S_2 while the significant changes were observed with S_3. This may have happened due to supplemental irrigation of saline water resulting in the accumulation of salt in the dry/summer season, but that partially leached out in the following *kharif* season as a result of ample rainfall. A similar increase in soil EC values in long-term salinity trials with groundnut was earlier reported (Bhaduri *et al.,* 2016; Bhaduri *et al.,* 2020). Saline vertisols, dominated by salinization and sodification processes, occupying a large share of salt-affected area (2.22 M ha) are present in Gujarat and productivity of these soils was found to be poor even at low salinity due to the typical physico-chemical characteristics (Chinchmalatpure *et al.*, 2018).

Salinity effects on soil fertility

Besides soil salinity other soil fertility parameters also changed due to the treatments in both cropping seasons. Significant changes in soil pH were noticed from S_0 and S_1 (which were statistically at par) to S_2 and S_3 in both cowpea summer and groundnut *kharif* seasons, reflecting the impact of higher salinity on high pH (8.68 and 8.42, respectively). Soil organic carbon did not vary significantly among the treatments in both crops. For soil available P content, the increase at the highest salinity *i.e.,* S_3 was visible at the harvest of groundnut (12.72 kg ha^{-1}), while there were no changes among the other treatments. This is perhaps caused by the impact of long-term salinity dissolving the non-exchangeable pool of Ca-bound phosphate, such as in calcareous soil (like in the present study) by replacing Ca^{2+} with ample Na^+ ions, thus the P concentration in soil solution is mostly governed by sorption processes otherwise resulting in low solubility of Ca-P minerals (Sharpley *et al.,* 1992). Soil available K content only differed significantly for cowpea with the observed highest value (206.5 kg ha^{-1}) with S_3, while at the harvest of groundnut, it remained

Table 1. *Soil properties in two crop seasons (summer cowpea followed by kharif groundnut) under the influence of saline irrigation water*

EC_{iw} (dS m^{-1})	Cowpea				Groundnut			
	pH	OC (%)	P (kg ha^{-1})	K (kg ha^{-1})	pH	OC (%)	P (kg ha^{-1})	K (kg ha^{-1})
S_0	8.20	1.03	15.30	154.93	7.45	1.10	10.37	253.87
S_1	8.19	1.05	15.96	174.72	7.78	1.03	9.83	247.15
S_2	8.36	1.04	24.48	174.35	8.23	0.98	10.87	237.07
S_3	8.68	1.07	20.06	206.45	8.42	0.94	12.72	266.93
S.E.(m±)	0.11	0.04	3.78	7.44	0.16	0.0382	0.233	10.89
CD (p=0.05)	0.36	NS	NS	25.77	0.56	NS	0.81	NS
C.V. %	2.18	6.37	34.57	7.26	3.52	6.55	3.69	7.51

NS - Non significant

Table 2. *Soil micronutrient content with different salinity levels at two soil depths after kharif groundnut*

Treatments	Soil micronutrients (mg kg^{-1} soil)			
	Fe	Zn	Cu	Mn
Main effect (salinity)				
S_0	13.78	2.54	2.27	9.17
S_1	14.09	2.99	2.22	8.78
S_2	14.92	2.91	2.33	9.73
S_3	15.26	3.03	2.47	9.49
S.E. (m±)	0.81	0.24	0.094	0.43
CD (p=0.05)	NS	NS	NS	NS
C.V. %	13.72	20.74	10.01	11.31
Sub-effect (depth of soil)				
D_1	14.05	3.04	2.34	9.44
D_2	14.97	2.69	2.30	9.15
S.E. (m±)	0.408	0.229	0.038	0.092
CD (p=0.05)	NS	NS	NS	NS
C.V. %	9.74	27.66	5.76	3.44
Interaction effect				
S.E. (m±)	7.59	7.59	7.59	7.59
CD (p=0.05)	NS	NS	NS	NS

statistically at par among the treatments (Table 1).

Changes in soil available micronutrients

The present experiment showed that salinity treatment could not bring any significant variation in the soil available micronutrients (Fe, Zn, Cu, Mn) for both the seasons of cowpea and groundnut grown soils. Though an increasing trend of available micronutrient content in soil was observed for Fe, Zn and Cu in groundnut grown soil from S_0 to S_3 (Table 2). The depth-wise (0-15, 15-30 cm) soil samples in both cropping seasons also followed a similar trend and no significant differences were observed (Tables 2 and 3). Previously available micronutrients (Mn, Cu, Fe and Zn) were found to increase with FYM (20 t ha^{-1}) and gypsum (100% neutralization of RSC) applications under sodic water irrigation cultivated with vegetable crops (Rathi *et al.,* 2020).

Micronutrient accumulation in plant parts

Salinity treatments significantly influenced Fe and Zn contents in shoot and root parts of groundnut; while Cu and Mn did not vary significantly with the treatments. Shoot Fe and Zn both increased with imposed salinity treatments (EC_{iw}) and enhanced content to the tune of

19% and 74% were observed from control (S_0) to highest salinity (S_3). For both elements, differences in content between S_0 to S_1 were non-significant, indicating that up to 2 dS m^{-1}, the micronutrient content did not vary for groundnut; however sharp changes were noticed beyond that. Achakzai *et al.* (2010) also reported that shoots of sunflower plants grown under the highest level of salinity have an increased accumulation of Fe, Mn, Zn and Cu, which is in accordance with the present finding. There may be two factors behind this: (1) Solubility of soil micronutrient cations, especially Fe^{3+} and Zn^{2+} ions had no negative influence so it might not have hindered micronutrient accumulation in the shoot of groundnut; Table 2 can support this information, where non-significant variation but an increasing trend of these cations in soil was noticed; (2) Soil pH exhibited an increasing trend from S_0 to S_3 by 0.48 unit and 0.97 unit in cowpea and groundnut seasons, respectively, which could also govern higher soil availability of micronutrients and increased accumulation *per se*; (3) Reduced plant biomass at higher salinity may have resulted in high contents of Fe^{3+} and Zn^{2+} (non-dilution effect) over the lower salinity. Root Fe and Zn contents declined with increasing salinity from S_0 to S_3. The decrement in root Fe content was 53% while for root Zn the rate of decrease was 40% with increasing salinity from S_0 to S_3. There are already some reports where reduced uptake and accumulation of micronutrients were noticed in oilseed crops under Inceptisol and Vertisol. Reduced accumulation of Fe, Mn and Zn was observed in root at the flowering and post-flowering stages of *Brassica* (Chakraborty *et al.,* 2016). However, the genotypic differences did not create any significant variation in the micronutrient contents of the shoot and root of groundnut (Table 4). The plant analysis of cowpea revealed that except Zn, no other micronutrient showed any significant variation, though a declining trend in values of accumulation for other micronutrients was observed with increasing salinity from S_0 to S_3 (Table 5). Over the years the studies related to the availability of micronutrients in saline soils showed a wide variability and contrasting results, which mainly depends on the factors like micronutrients' solubility, nature of the binding sites on the organic/inorganic particle surfaces, pH and pE of soil solution and this further impact on the differential accumulation of micronutrient cations in the

Table 3. *Soil micronutrient content with different salinity levels at two soil depthsaftersummer cowpea*

Treatments	Soil micronutrients (mg kg^{-1} soil)			
	Fe	Zn	Cu	Mn
Main effect (salinity)				
S_0	11.86	1.04	2.64	10.13
S_1	11.19	0.84	2.69	8.63
S_2	11.82	1.00	2.78	9.38
S_3	11.70	0.96	2.90	9.22
S.E.(m±)	0.29	0.05	0.08	0.64
CD (p=0.05)	NS	NS	NS	NS
C.V. %	6.05	13.66	7.61	16.72
Sub-effect (depth of soil)				
D_1	11.56	0.91	2.62	9.61
D_2	11.68	1.01	2.79	9.16
S.E.(m±)	0.24	0.09	0.05	0.59
CD (p=0.05)	NS	NS	NS	NS
C.V. %	6.18	29.81	6.09	18.92
Interaction effect				
S.E.(m±)	10.92	10.92	10.92	10.92
CD (p=0.05)	NS	NS	NS	NS

NS - Non significant

Table 4. *Micronutrient content in plant parts of groundnut with different salinity and cultivars*

Micronutrient concentration (mg kg^{-1} dry weight)								
Treatments	Shoot Fe	Shoot Zn	Shoot Cu	Shoot Mn	Root Fe	Root Zn	Root Cu	Root Mn
Main effect (salinity)								
S_0	1053.3	30.7	46.0	53.9	1457.4	42.5	39.8	153.4
S_1	1094.2	34.3	47.7	77.9	1294.5	37.2	33.3	145.4
S_2	1216.8	46.3	48.8	115.0	1216.5	33.8	26.5	135.5
S_3	1250.4	53.6	50.3	157.1	951.2	30.4	23.5	134.5
S.E.(m±)	20.8	1.9	3.1	21.8	70.9	2.2	6.6	17.4
CD (p=0.05)	71.9	6.6	NS	NS	245.5	7.5	NS	NS
C.V. %	8.83	22.58	31.43	105.59	28.26	29.39	104.53	60.06
Sub-effect (cultivars)								
TPG 41	1160.4	41.6	48.1	97.4	1206.4	32.1	22.7	133.9
GG 6	1145.7	41.9	45.9	99.6	1228.1	37.1	27.5	154.5
Girnar 3	1203.1	42.3	48.5	114.2	1243.4	30.8	23.8	137.7
GG 8	1141.5	41.3	46.8	104.9	1220.2	36.6	30.1	143.7
SG 99	1186.4	38.7	46.1	101.3	1221.4	36.3	35.3	131.8
TG 37 A	1148.8	41.8	47.4	96.7	1261.4	37.3	24.0	132.5
GG 7	1097.8	41.9	56.7	89.6	1242.0	35.3	29.1	152.9
R 2001-3	1145.7	40.5	46.2	104.3	1216.3	42.1	53.7	150.8
S.E.(m±)	44.8	1.9	3.2	9.3	60.5	4.5	10.4	11.8
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %	13.45	15.56	22.82	32.01	17.03	43.83	117.33	28.72
Interaction effect								
S.Em.±	2.2025	2.2025	2.2025	2.2025	2.2025	2.2025	2.2025	2.2025
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS - Non significant

Table 5. *Micronutrient content in cowpea with different salinity*

Treatments	Micronutrient concentration in cowpea (mg kg^{-1} dry weight)			
	Fe	Zn	Cu	Mn
S_1	907.20	43.77	31.33	100.03
S_2	873.07	38.27	28.33	92.33
S_3	801.57	35.97	27.33	86.50
S_4	709.83	32.03	27.33	79.20
S.E.(m±)	93.25	1.62	2.33	12.57
CD (p=0.05)	NS	5.62	NS	NS
C.V. %	19.63	7.5	14.1	24.32

NS - Non significant

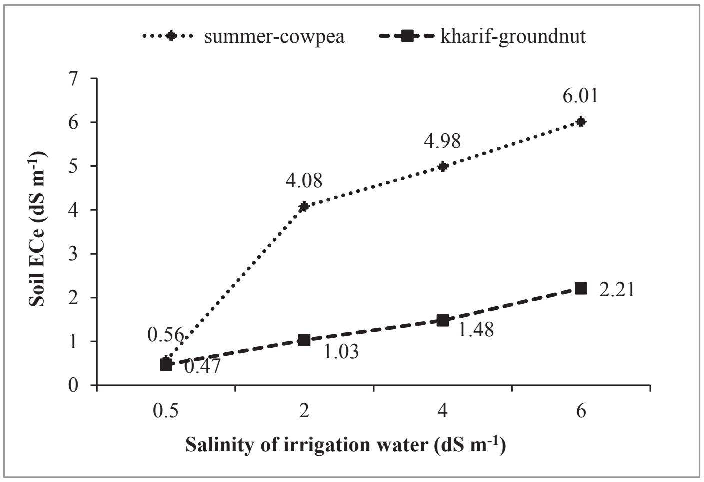
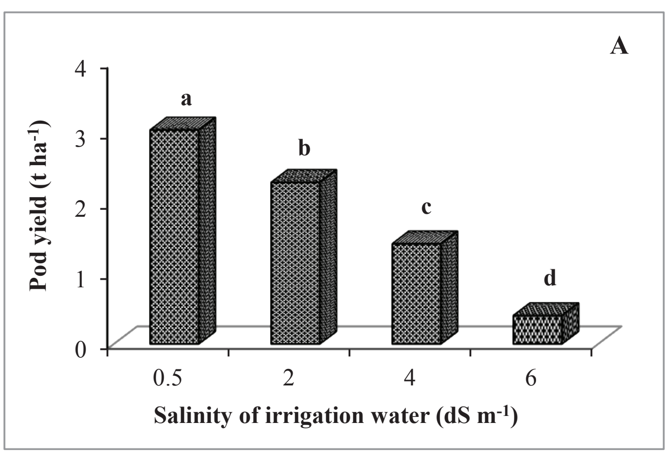


Fig. 1. *Soil salinity developed (electrical conductivity, EC_e) with imposition of different levels of saline irrigation water. Data points presented were significantly different with an observed CD (at 5% probability) values of 2.02 (cowpea) and 0.53 (groundnut) and with the respective SE (m±) values of 0.58 and 0.15*

plant tissues, depending upon the crop species and the salinity level (Oertli,1991; Hu and Schmidhalter, 2005).

Salinity effect on crop yield

The salinity build-up in the root zone drastically affected the yield of cowpea, as it is very sensitive and cannot tolerate even up to 2 dS m^{-1} saline irrigation water. In the present study, the observed yield reduction from S_0 to S_1 was 32%, which further declined to a tune of 114% from S_0 to S_2 and finally resulted in a minimum yield of 0.40 t ha^{-1} at S_3, showing the strong detrimental effect on cowpea yield (Fig. 2A). The results were in similarity to previous studies which also opined that pod yield of cowpea declined with increasing irrigation salinity (Taffouo *et al.,* 2009; Düzdemir *et al.,* 2009). The increase in soil salinity at the root zone affects water absorption which resulted in stunted plant growth, which further reduced the yield significantly. The plant height decreased to a tune of 34% from S_0 to S_3 reflecting the impact of salinity on important plant growth parameters (Fig. 2B).



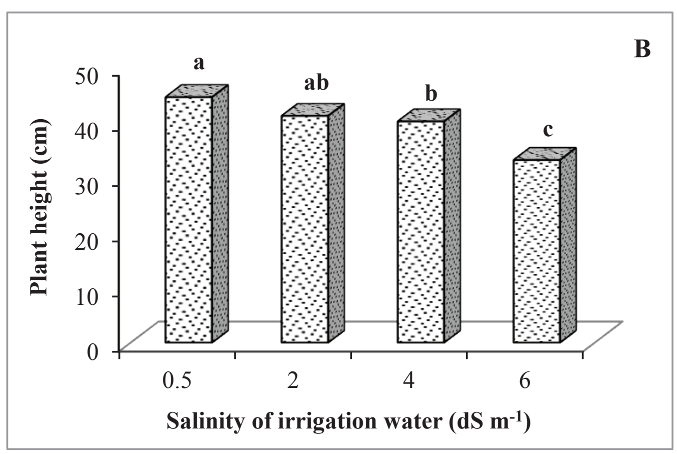


Fig. 2. ***A.*** *Fresh pod yield and* ***B.*** *plant height of cowpea crop grown under imposition of different levels of saline irrigation water. Data bars presented were significantly different with an observed CD (at 5% probability) values of 0.34 (yield) and 4.2 (height). The small letter above each bar defines if the values are statistically different or not*

Table 6. *Effect of salinity on groundnut yield of different cultivars*

Salinity (Main plot)	Pod yield ($t\ ha^{-1}$)	Genotypes (Sub-plot)	Pod yield ($t\ ha^{-1}$)
S_0 - 0.5 dS m^{-1}	1.58	TPG 41	1.13
S_1 - 2.0 dS m^{-1}	1.47	GG 6	0.94
S_2 - 4.0 dS m^{-1}	0.69	Girnar 3	0.88
S_3 - 6.0 dS m^{-1}	0.14	GG 8	1.03
		SG 99	0.85
		TG 37A	0.99
		GG 7	0.86
		R 2001-3	1.08
S.E.(m±)	0.03	S.E.(m±)	0.04
CD $_{(p=0.05)}$	0.11	CD $_{(p=0.05)}$	0.11
C.V. %	0.02	C.V. %	0.01
Interaction effect			
S.E.(m±)	0.002		
CD $_{(p=0.05)}$	0.219		

For groundnut, a sharp and concomitant decline in pod yield was observed, and the yield varied between 1.58 t ha^{-1} (in S_0 as control) to 0.14 t ha^{-1} (in S_3 as highest salinity). The yield drop between S_0 to S_1 was found gradual and recorded at only 8%, but a sharp drop was noticed beyond that (130% at S_2). Among the tested groundnut genotypes, TPG 41, R 2001-3 and GG 8 were under the high yielding group across the salinity treatments and yielded over 1.0 t ha^{-1} while the yield of SG 99 was observed to be the lowest (0.85 t ha^{-1}). The yield difference from the less sensitive genotype (TPG 41) to the more sensitive genotype (SG 99) varied to a tune of 33% (Table 6). Increasing salt stress was reported to decrease all growth parameters and shoot/root ratio of the two groundnut genotypes (Abdelraouf and Abdelaziz, 2020). Due to elevated root zone salinity groundnut could sustain its agronomic efficiency up to EC_{iw} 2.0 dS m^{-1} and showed a declining trend of pod and fodder yields beyond this level (Meena *et al.,* 2017). For other *kharif* crops like cotton and pearl millet, yield decline ranged from 9 to 36% due to saline irrigation water as compared to good quality water, whereas wheat yield could be sustained with saline irrigation water of $EC_{iw} \leq 4$ dS m^{-1} (Sharma and Minhas, 2004).

Induced salinity through saline irrigation water is a common problem in the Saurashtra region of Gujarat. Farmers often apply low to moderate levels of saline water to sustain their field crops under a shortage of sufficient fresh non-saline water. This study concluded that salinity does not always demonstrate harmful effects on nutrient availability in contrast to conventional thought. As a matter of fact, nutrient availability and salinity depend on localized factors like soil type, pH, level of salinity, the types of crop grown and plant parts under observation. In the present study, although the accumulation of root Fe and Zn declined with salinity, shoot Fe and Zn showed an opposite trend for groundnut. For a highly calcareous soil, the release of Ca-bound micronutrients might have played a great role in plant nutrition which may have been further influenced by the increase in soil pH. However, eight genotypes of groundnut did not show any variability of micronutrient concentration in plant tissues. Yield dropped gradually with increasing salinity for both cowpea and groundnut crops. Salinity is a localized problem but it has a global impact on understanding the changing relationship between soil EC, pH and soil nutrient availability. In a larger scenario, it has an impact on agricultural production. It thus amplifies the importance of pursuing such a kind of study, which is less frequent and needs further validation among a wide range of crops and soils.

CONFLICTS OF INTEREST

The authors declare that there is no competing interest.

ACKNOWLEDGEMENT

The authors acknowledge the Director, ICAR-DGR for all necessary support for conducting the study under an institute-funded project, Mrs. Vidya Chaudhari (Technical Officer) for providing the required assistance during the AAS analysis, and Mr. Hanif Habib (Supporting skilled staff) for his tireless effort in maintenance of field experiment.

REFERENCES

Abdelraouf, E.A. and Abdelaziz, S.M. (2020). Response of groundnut (*Arachis hypogaea* L.) genotypes to irrigation with magnetized saline water. *Alexandria Science Exchange Journal* **41**:409-418.

Achakzai, A.K.K., Kayani, S.A. and Hanif, A. (2010). Effect of salinity on uptake of micronutrients in sunflower at early vegetative stage. *Pakistan Journal of Botany* **42**: 129-139.

Asık, B.B., Turan, M.A., Celik, H. and Katkat, A.V. (2009). Effects of humic substances on plant growth and mineraluptake of wheat (*Triticum durum* cv. Salihli) under conditions of salinity. *Asian Journal of Crop Science* **1**: 87-95.

Bhaduri, D., Meena, H.N. and Chakraborty, K. (2016). Variation in phosphorus accumulation in groundnut cultivars under influence of water salinity. *Legume Research* **39**: 215-220.

Bhaduri, D., Meena, H.N., Saha, A., Yadav, R.S., Chakraborty, K., Jain, N.K. and Desai, D. (2020). Potassium and mulching ameliorants sustained soil enzyme activities in peanut crop facing salinity stress. *Indian Journal of Agricultural Sciences* **90**: 1830-1836.

Chakraborty, K., Sairam, R.K. and Bhaduri, D. (2016). Effects of different levels of soil salinity on yield attributes, accumulation of nitrogen, and micronutrients in *Brassica* spp. *Journal of Plant Nutrition* **39**: 1026-1037.

Chinchmalatpure, A.R., Kumar, S., Rao, G.G., Nikam, V., Prasad, I., Camus, D., and Sharma, D.K. (2018). Impact of irrigation on soil characteristics in saline Vertisols of Bara tract under Sardar Sarovar canal command of Gujarat. *Journal of the Indian Society of Soil Science* **66**: 381-385.

Düzdemir, O., Ünlükara, A. and Kurunç, A. (2009). Response of cowpea (*Vigna unguiculata*) to salinity and irrigation regimes. *New Zealand Journal of Crop and Horticultural Science* **37**: 271-280.

Hardikar, S.A. and Pandey, A.N. (2008). Growth, water status and nutrient accumulation of seedlings of *Acacia senegal* (L.) Willd. in response to soil salinity. *Anales de Biología* **30**: 17-28.

Hassan, N.A.K., Jackson, W.A., Drew, J.V., Knudsen, D. and Olson, R.A. (1970). Influence of soil salinity on production of dry matter and uptake and distribution of nutrients in barley and corn. 1. Barley (*Hordeum vulgare* L.). *Agronomy Journal* **62**: 43-45.

Hu, Y. and Schmidhalter, U. (2001). Effects of salinity and macronutrient levels on micronutrients in wheat. *Journal of Plant Nutrition* **24**: 273-281.

Hu, Y. and Schmidhalter, U. (2005). Drought and salinity: A comparison of their effects on mineral nutrition of plants. *Journal of Plant Nutrition and Soil Science* **168**: 541-549.

Jackson, M.L. (1973). *Soil Chemical Analysis,* Prentice Hall of India Pvt. Ltd., New Delhi, India.

Khaled, H. and Fawy, H.A. (2011). Effect of different levels of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. *Soil and Water Research* **6**: 21-29.

Lindsay, W.L. and Norvell, W. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Science Society of America Journal* **42**: 421-428.

Meena, H.N., Bhaduri, D., Yadav, R.S., Jain, N.K. and Meena, M.D. (2017). Agronomic performance and nutrient accumulation behaviour in groundnut-cluster bean cropping system as influenced by irrigation water salinity. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* **87**: 31-37.

Meena, H.N., Bhalodia, P.K., Jat, R.S. and Vekaria, L.C. (2012). Prospects of using saline irrigation water for irrigation in groundnut (*Arachis hypogaea*)-

pearl millet (*Pennisetum glaucum*) cropping system in saline black clay soils of Saurashtra. *Indian Journal of Agronomy* **57**: 122-126.

Munns, R. (2002). Comparative physiology of salt and water stress. *Plant Cell and Environment* **25**: 239-250.

Munns, R., Schachtman, D.P., and Condon, A.G. (1995). The significance of a two-phase growth response to salinity in wheat and barley. *Functional Plant Biology* **22**: 561-569.

Oertli, J.J. (1991).Nutrient management under water and salinity stress, Proceeding Symposium on *Nutrient management for sustained productivity*. Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab, India. pp 138-165.

Page, A.L., Chang, A.C. and Adriano, D.C. (1990). Deficiencies and toxicities of trace elements. In *Agricultural Salinity Assessment and Management*. ASCE Manuals and Reports on Engineering Practice No. 71, ASCE, Reston, VA, USA. pp 138-160.

Patel, A.D. and Pandey, A.N. (2007). Effect of soil salinity on growth, water status and nutrient accumulation in seedlings of *Cassia montana* (Fabaceae). *Journal of Arid Environments* **70**: 174-182.

Rathi, D., Antil, R.S., Sharma, M.K. and Sheoran, S. (2020). Effect of FYM and gypsum on distribution of micronutrient in soil under sodic water irrigation: A long-term study. *Journal of the Indian Society of Soil Science* **68**: 100-106.

Sharma, D.R. and Minhas, P.S. (2004). Soil properties and yields of upland crops as influenced by the long-term use of waters having variable residual alkalinity, salinity and sodicity. *Journal of the Indian Society of Soil Science* **52**: 100-104.

Sharpley, A.N., Meisinger, J.J., Power, J.F. and Suarez, D.L. (1992). Root extraction of nutrients associated with long-term soil management. In: *Advances in Soil Science,* B. Steward (ed.), Springer-Verlag, Berlin. pp 151–217.

Singh. A.L., Basu, M.S. and Singh, N.B. (2004). *Mineral Disorders of Groundnut*. ICAR-Directorate of Groundnut Research (formerly National Research Centre for Groundnut), Junagarh, Gujarat, India.

Taffouo, V.D., Djiotie, N.L., Kenné, M., Din, N., Priso, R.J., Dibong, D. and Amougou, A. (2008). Effects of salt stress on physiological and agronomic characteristics of three tropical cucurbit species. *Journal of Applied Biosciences* **10**: 434-441.

Taffouo, V.D., Kouamou, J.K., Ngalangue, L.M.T., Ndjeudji, B.A.N. and Akoa, A. (2009). Effects of salinity stress on growth, ions partitioning and yield of some cowpea (*Vigna unguiculata* L. Walp.) cultivars. *International Journal of Botany* **5**:135-143.

West, D.W. and Francois, L.E. (1982). Effects of salinity on germination, growth and yield of cowpea. *Irrigation Science* **3**: 169-175.