International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2022; 10(5): 38-45

Received: 04-06-2022
Accepted: 09-08-2022

Sonali Patel
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, SOA (Deemed to be University), Odisha, India

Rahaf Alomar
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, SOA (Deemed to be University), Odisha, India

Dr. Dinabandhu Jena
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, SOA (Deemed to be University), Odisha, India

Jatiprasad Barala
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, SOA (Deemed to be University), Odisha, India

Corresponding Author:
Sonali Patel
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, SOA (Deemed to be University), Odisha, India

Effect of irrigation water salinity, potassium and soil amendments on maize crop in coastal saline soil

Sonali Patel, Rahaf Alomar, Dr. Dinabandhu Jena and Jatiprasad Barala

Abstract
A pot experiment was conducted to study the effects of irrigation water salinity, FYM, gypsum and potassium on biomass yield and nutrient accumulation of maize in coastal saline soil. Application of saline water up to 12 dS m^{-1} significantly increased the biomass yield (7-12%) over control but, decreased by 11% at 16 dS m^{-1}. Combined application of recommended dose of fertilizer (RDF) + FYM, RDF + gypsum or RDF + K was found beneficial for maize by increasing the biomass yield (2-43%), K accumulation (15-29%), K uptake (22-63%) and K^+ / Na^+ ratio as compared to RDF alone. The adverse effect of Na decreased due to irrigation water salinity was reduced with amendments by decreasing the Na content (27-38%) and uptake (19-27%) over RDF alone. It is concluded that saline water up to 12 dS m^{-1} along with amendments can be used for maize in coastal saline areas.

Keywords: Salinity, maize, potassium, gypsum, K^+/Na^+ ratio

Introduction
Salinity is an agro-environmental problem in arid and semi-arid regions of the world and has a significant impact on crop productivity. Human-induced salinity, combined with the natural, limits food production in most semi-arid regions of the world (Rengasamy, 2010) [21]. The majority of the world's water is salty containing 30 g of sodium chloride per liter. The availability of saline water is greater than fresh water (Flower, 2004) [7]. Safe use of saline water in agriculture through soil management techniques will be beneficial to improve food security in developing countries. Salinity affects plants in different ways such as osmotic stress, specific-ion toxicity, and nutritional disorders (Lauchli and Epstein, 1990) [14]. Osmotic stress is linked to ion accumulation in the soil solution whereas, nutritional imbalance and specific ion toxicity are connected to ion build-up, mainly sodium and chloride to toxic levels which interferes with the availability of other essential elements such as calcium and potassium (Munns *et al*., 2006) [17], (Hussain *et al.*, 2013) [10]. Ionic imbalance and ion toxicity lead to the substitution of potassium with sodium resulting reduction in the K^+ /Na^+ ratio in plants. Toxic levels of sodium in plant organs reduce plant growth and affect photosynthesis, respiration, starch metabolism, and nitrogen fixation leading to losses in crop yield (Quintero *et al*., 2007) [20].

Coastal saline soils are recognized by high plant mobility, uneven and stunted plant growth and yield reduction. Generally, the coastal saline soils are mono cropped with rice during kharif season and the yield reduced drastically due to inundation of land during high tide with sea water. Underground water table is shallow and is enriched with high salt content. During *rabi* season, most of the land remained fallow due to accumulation of toxic amounts of salt on soil surface and lack of good quality irrigation water (Jena, 1991) [13]. Several studies indicated that brackish water can be used as an alternate source of irrigation for some crops with soil amendments during *rabi* season.

Among the cereals, maize (*Zea mays* L.) is the third most important cereal crop, cultivated in165 million hectares of land producing 850 million tons of grain with an average grain yield of 5200 kg ha^{-1} (FAO, 2016) [6]. Maize is typically classified as a moderately salt-sensitive crop showing signs of stress including wilting even when there is adequate soil moisture (Maas and Hoffman, 1977) [15]. Seed germination and early seedling growth stages are more sensitive to salinity than later developmental stages (Tayyaba *et al*., 2010) [23]. Hyper-osmotic stress and toxic effects of sodium and chloride ions may delay or inhibit germination, reduce plant growth, and leads to severe nutritional imbalances in maize.

Along with other mineral nutrients, potassium is very important for maintaining turgor and membrane potential, balancing osmotic potential, controlling stomatal movement, and activating enzymes (Cheel, 2004) [5]. The stress mitigating role of potassium in plants under drought, salinity, and pathogenic infection was reported by (Cakmak, 2005) [4].

The deficiency systems of calcium developed in the growing regions of plants under saline environment with high Na^+/Ca^{2+} ratio. As the salt concentration in the root zone increases, plant requirement for calcium also increases. Maintaining an adequate supply of calcium in saline soil solution is an important factor in controlling severity of ion toxicities in crops which are susceptible to sodium and chloride injury. Application of gypsum reduces sodium toxicity by replacing it with calcium at the cation exchange site and increase clay particle flocculation near soil surface.

Successful crop production in salt-affected soil depends on soil, water and plant managements practices. Application of amendments such as FYM, vermicompost improved physical properties of soil and increase nutrient availability.

Keeping in view the scarcity of good quality irrigation during *rabi* season, we attempted to use saline water as irrigation water. Further, we tried to test the possible impact of different amendments in reducing toxic effect of Na in coastal saline soil. With this hypothesis a pot culture experiment was undertaken: to study the interaction effects of irrigation water salinity, potassium, gypsum and FYM on maize biomass yield, nutrient accumulation, and uptake.

Materials and Methods

Experimental Site

The interaction effects of saline water, potassium and soil amendments on biomass yield, nutrient acquisition, and uptake of the maize crop were studied through a pot experiment. The experiment was conducted in the greenhouse of the Institute of Agriculture Science (IAS), SOA Deemed to be University, Bhubaneswar, Odisha during November 2019.

Experimental Design and Treatments

The experiment was conducted in a 2-factorial completely randomized design with three replications. These were 16 treatment combinations consisting of four amendments (T1-RDF,T2-RDF+FYM @20 t ha^{-1}, T3-RDF + gypsum @2.5 q ha^{-1}, T4-RDF + 100%excess K) and four levels of irrigation water salinity (SW0- normal water EC-0.5 dS m^{-1}, SW1-saline water irrigation EC-8dS m^{-1}, SW2- EC-12 dS m^{-1}, and SW3- EC-16 dS m^{-1}). The RDF for maize was 100 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare. The sandy loam saline soil used in the pot culture study was collected from Brahmagiri village in Puri district during October 2019. The field was mono-cropped with rice during the Kharif season and remained fallow during *rabi* season because of high salinity and non availability of good quality water for irrigation. The surface soil (0-15 cm depth) in bulk was collected from the field after harvest of rice crop and brought to the laboratory, air dried, processed, and used for pot study. The characteristics of soil are presented in table-1.

The saline water used in the study was brought from the Bay of Bengal at Puri seashore. The EC of sea water was 34.56 dS m^{-1} which was diluted to 8, 12, 16 dS m^{-1} for use as irrigation water in the study. The pH of sea water was 8.0.

The polythene-lined earthen pots were rinsed in 0.1N HCl followed by deionized water. Six kg of air-dried soil was transferred into each pot. Each pot received a common dose of N @ 100 kg ha^{-1} (on a weight basis) through DAP and granular urea. The nitrogen fertilizer was applied in three splits as 25% (basal), 50% at (knee high stage) and 25% at tasseling stage. A common dose of phosphorous @ 50 kg ha^{-1} (on a weight basis) through DAP and potassium @ 50 kg ha^{-1} was applied at seeding stage. In T4 extra 50 Kg of K applied at knee high stage. FYM was thoroughly mixed with soil before sowing. All the fertilizers and gypsum were applied through solution. All the pots were saturated with normal water up to field capacity and 4 hybrid sweet corn seeds (CV.4226) of 90 days duration were sown. The crop received seven no of saline water irrigation at 8,10,42,50, 57 65 and 72 days after seedling emergence (DASE).

Depending on the requirement, the crop was irrigated with normal water having EC of 0.5 dS m^{-1} and plant protection measures were taken as and when required. The crop was harvested at tasseling stage (80 days after germination). Soil, plant and root samples were collected after harvest, processed and analysed following standard procedures.

Soil and Plant Analysis

The soil was analyzed in the laboratory following standard procedures. Particle size was determined by the Bouyoucos hydrometer as given by (Piper, 1950) [19], pH by glass electrode with calomel as standard (Jackson, 1973) [12]. Electrical conductivity (EC) of soil was determined in 1:2 soil-water suspension by a conductivity meter (ELICOCM 180 conductivity meter) as suggested by (Maas and Hoffman, 1977) [15]. The bulk density, particle density, and porosity were determined as per the methods outlined by (Black, 1965) [3]. The organic carbon content of the soil was estimated by the wet digestion method (Walkley and Black, 1934) [24]. Available N in soil was determined by the modified alkaline permanganate method (Subbiah and Asija, 1956) [22] and available P by Olsen's method (Olsen, 1954) [18]. Water soluble K and Na were determined in a 1:5 (soil: water) ratio. The available K and Na which include water-soluble and exchangeable forms was extracted with neutral normal ammonium acetate and estimated with a flame photometer (Model: Systonic128) (Hanway and Heidal, 1952) [8]. The sodium and potassium content in the maize plant was estimated as per the method outlined by (Jackson, 1973) [12].

Statistical analysis

Statistical differences between treatments were determined by Duncan Multiple Range (DMRT) test using MSTATC software. The critical difference (C.D) and standard error of means (SEM) (SPSS and OPSTAT software) were used to express the analysed data.

Results and Discussions

Effects of saline water irrigation on P and Zn deficiency in maize plant

The plot experiment was under taken with an objective to study the effect of saline water irrigation and amendments on biomass yield of maize. The seeds were sown on 30th November 2019 and full germination was recorded after 8 days of germination.

The crop received 7 number of saline water irrigation and 25 number of normal water irrigation over 80 days of growing period. After 18 days of germination, the maize plants showed phosphorus deficiency in RDF, RDF + Gypsum and RDF+K treatments when the crop was irrigated with saline water of 8, 12, or 16 dS m^{-1} level. However, normal plant growth was observed in RDF+FYM treatment. The phosphorus deficiency was marked as appearance of brown colour starting from leaf margin, spread towards midrib and thereafter entire leaf became brownish colour (Plate 1). The older leaves showed the P deficiency symptoms whereas, the young leaves remained green. For correcting phosphorus deficiency, DAP @ 1.2 gm pot^{-1} was applied to all pots in solution form and crop recovered within 7 days (Plate 2).

After 55 days of germination, zinc deficiency was recorded in some plants irrespective of the treatments (Plate 3). Zinc sulphate was sprayed @ 0.5% to all treatments to overcome Zn deficiency.

Over ground biomass yield

In salt affected environment the plant growth is influenced by the availability and transport of essential elements from root to shoot. Under saline condition plants absorb the essential nutrients from a diluted source in the presence of highly concentrated sodium. This requires extra energy and plants some times are unable to fulfill these nutritional requirements which affect plant growth and yield.

The over ground biomass yield of maize was influenced by irrigation water salinity. The mean biomass yield in SW0 treatment was 38.97 g pot^{-1} and increased by 7% in SW1 (8 dS m^{-1}) and 12% in SW2 (12 dS m^{-1}) but, decreased by 11% when the salinity level increased to 16 dS m^{-1}. This showed that, the biomass yield of maize was severely affected when the level of saline water irrigation increased to 16 dS m^{-1}.

Effect of balance dose of fertilizer on biomass yield

Application of RDF was found effective to combat the adverse effect of saline water irrigation on maize crop. The biomass yield of maize in RDF was significantly increased by 25% in SW1 and 17% in SW2 over SW0. However, there was reduction in yield by 29% in SW3 treatment over SW0.

Application of recommended dose of P @ 50 kg ha^{-1} could not satisfy the P requirement of maize crop under saline environment with initial low P status (3.7 Kg ha^{-1}) by which the crop showed P deficiency symptoms after 18 days of germination. The phosphate availability is reduced in saline soils because of ionic strength effects that reduced the activity of phosphate. However, the P deficiency was corrected with application of additional P fertilizer (@12.5kg ha^{-1}).

Effect of gypsum on biomass yield

Application of gypsum can reduce sodium toxicity in saline soil by replacing it with Ca at the cation exchange site resulting clay particle flocculation near the surface of soil. The beneficial effect of gypsum application was observed when the saline water irrigation level was increased to 16 dS m^{-1}. The yield in RDF+gypsum treatment was lower than RDF alone in SW0, SW1 and SW2 treatments but increased over RDF when maize was irrigated with higher level of salinity (SW3). This might have happened due to beneficial effects of gypsum on soil physical properties and increase in calcium concentration in the root zone. Similar findings were reported by (Zhang *et al*., 2019) [25], they found that application of gypsum increased O.C content and Ca content in soil, lowered soil pH and Na content in plant. Accumulation of P, N, K, Mg and Ca content in maize plant increased and Na content decreased with gypsum application. Ibrahim and Dongli (2018) [11] reported that the Ca in gypsum reacts with bicarbonate to precipitate Ca CO_3 and release protons which helps to decrease soil pH in saline soil.

Effects of excess dose of potassium on biomass yield

Potassium in saline soil controls the solute transport and water balance in plants by reducing toxic effect of Sodium. Hence, sufficient amount of potassium in the root rhizosphere is necessary for metabolic process, regulation of ion transport and osmotic adjustment.

Data in table 2 showed that recommended dose of K was found optimum at lower level of salinity (SW0, SW1 and SW2 treatments) since the yield in RDF was higher than RDF+K. However, the yield in RDF+K treatment was increased over RDF when EC of irrigation water was increased to $16dSm^{-1}$ (SW3). This showed that higher dose of potassium was beneficial for maize under severe saline condition because of antagonistic relation between potassium and sodium. Similar results were reported by several researches (Mohapatra, 2020 [16], Alomar *et al*. 2022 [2], Abbasi *et.al*. 2015 [1], Hussain *et.al*. 2015 [9]). Comparing the effect of gypsum and potassium under saline environment, biomass yield in RDF + K treatment was higher than RDF + gypsum at 8 dS m^{-1} salinity level, but as 12 and 16 dS m^{-1}, the effect of gypsum was better than potassium.

Effect of FYM on biomass yield

Use of organic amendments is proved as an effective strategy for saline soil amelioration. Organic amendments improve soil physical, chemical and biological properties and alleviate adverse effects of sodium.

The results presented in table 2 showed that among all amendments RDF + FYM treatments significantly increased the biomass yield at all levels of irrigation water salinity. The yield in SW_0 treatment was 46.3 g pot^{-1} and increased by 9.3 and 28.3% at 8 and 12 dS m^{-1}, respectively. There after the yield was decreased at 16 dS m^{-1} salinity level. Further, the yield in RDF+FYM treatment was significantly higher over RDF+K and RDF+ gypsum treatments at all levels of salinity. Considering the effect of saline water stress on biomass yield, the treatments were arranged in the order of: Irrigation water salinity effect- SW2 > SW1 > SW0 > SW3 and amendment effect- RDF+ FYM > RDF+K > RDF+GYPSUM > RDF.

Effects of salt stress on K and Na content in maize plant

The data presented in table 2 shows that the potassium content in SW0 treatment was 449.3 mM kg dry $weight^{-1}$ and decreased significantly by 12% at 8 dSm^{-1}, 16% at 12 dS m^{-1} and 22% at 16 dS m^{-1} salinity level.

Application of amendments significantly increased K content in maize by reducing the deleterious effects of sodium. The K content in RDF treatment was 337.8 mM kg^{-1} and increased significantly by 15%, 21% and 29% in RDF + FYM, RDF+ gypsum and RDF+K treatments, respectively. At each level of irrigation water salinity, the K content in RDF+K treatment was higher than other amendment treatments.

The Na content in maize plant increased with increasing the level of salinity (Table 4). It was 14.7 mM kg^{-1} in SW0 treatment and significantly increased by 58, 117 and 185% when the salinity level increased to 8, 12, and 16 dS m^{-1}, respectively.

Application of amendments reduced the toxic effect of sodium. Among the amendments, highest Na accumulation was recorded in RDF treatment at each level of salinity and lowest in RDF + gypsum treatment. Averaged over the salinity levels, highest Na content in maize plant (37.4 mM kg^{-1}) was recorded in RDF treatment and significantly decreased by 27% in RDF+FYM, 38% in RDF + gypsum and 35% in RDF + K treatment.

Potassium and Na uptake by maize plant

Potassium and sodium uptake by maize plants were calculated by multiplying the biomass yield and nutrient concentration

(Table 5). The potassium uptake in SW0 treatment was 681.0 mg pot^{-1} and significantly decreased by 7% in SW1, 9% in SW2 and 32% in SW3 treatment. On the other hand application of different amendments had beneficial effect on K uptake. It was 462.1 mg pot^{-1} in RDF treatment and increased significantly by 22% in RDF + Gypsum treatment, 35% in RDF+K treatment and 63% in RDF+FYM treatment. At each levels of salinity, higher K uptake was recorded in RDF+FYM treatment might be due to higher biomass yield.

Salinity increased the sodium uptake by maize plant. Lowest Na uptake was obtained in sw_0 treatment (13.3 mg pot^{-1}) and increased by 65% at salinity level of 8 dS m^{-1}, 134% at 12 dS m^{-1} and 114% at 16 dS m^{-1} (Table 6).

On the other hand application of the amendments reduced Na uptake at each level of salinity. It was 26 mg pot^{-1} in RDF treatment and significantly decreased by 19 and 27% when the crop received excess dose of K and gypsum in addition to RDF, respectively. The Na uptakes in RDF+FYM treatment, was at par with RDF treatment.

K^+/Na^+ ratio in maize plant

Under saline environment, higher concentration of Na in root medium regulates the availability and transport of several other elements. Especially the uptake of K is affected because of toxic concentration of Na in the root rhizosphere.

The data presented in table 7 indicated that the K^+/Na^+ ratio in maize plant decreased with increasing the level of salinity. The K^+/Na^+ ratio in SW0 treatment was 26.2 and significantly decreased by 34% in 8 dS m^{-1}, 51% in 12 dS m^{-1} and 64% in 16 dS m^{-1} salinity level.

Application of amendments with saline water irrigation resulted in higher K^+/Na^+ ratio in plant. The K^+/Na^+ ratio in RDF treatment was 13.3 and increased by 29% in RDF+FYM, 33% in RDF + gypsum and 32% in RDF + K treatment but, statistically all treatments were at par. Although the RDF + FYM treatment recorded higher biomass yield and K uptake values, but the K^+/Na^+ ratio was lower as compared to RDF + K and RDF + gypsum treatments indicating that the chemical amendments influences the nutrient availability whereas, organic amendment like FYM improves the physical properties of soil and plant growth.

Correlation studies

The correlation studies between different soil and plant parameters were carried out. The negative linear relationship between ECe versus K content in plant (R^2- 0.96) showed that accumulation of K decreased with increasing in soil salinity (Figure 1). However, a reverse was reflected when ECe was correlated with Na content in plant. The positive linear relationship between ECe versus Na content in plant (R^2- 0.998) indicated that the Na accumulation was increased with increasing ECe (Figure 2). Similar relationship exists between K^+/Na^+ ratio versus K content (R^2- 0.99) or Na content in plant (R^2- 0.93) (Figure 3 and 4). These relationships confirmed that besides ECe, the K^+/Na^+ ratio in plant can be considered as a viable indicator to evaluate crop performances in saline environment.

Table 1: Physio-chemical properties of soil used in pot culture experiment

Parameter	Value
pH	6.46
ECe (dS m^{-1})	1.20
Sand (%)	55
Silt (%)	20
Clay (%)	25
Texture	Sandy loam
BD (gm cm^{-3})	1.25
PD (gm cm^{-3})	
Porosity (%)	41
OC (%)	0.94
Available N (kg ha^{-1})	350
Available P (kg ha^{-1})	3.7
Available K (kg ha^{-1})	0.230
Exch.K (mg kg^{-1})	0.217
Water soluble. K (mg kg^{-1})	0.013
Available Na (mg kg^{-1})	0.50
Water soluble Na (mg kg^{-1})	0.22
Exch Na (mg kg^{-1})	0.28

Table 2: Effect of salt stress and amendments on over ground biomass yield (gm pot^{-1}) of maize plant

Treatments	RDF	RDF+FYM	RDF+GYPSUM	RDF+K	Mean	% Increase over SW0
SW_0	32.70	46.30	33.50	43.40	38.97^b	
SW_1	43.40	51.60	33.70	38.10	41.70^{ab}	7.00
SW_2	39.60	59.40	39.10	36.70	43.70^a	12.13
SW_3	25.30	44.30	37.50	31.30	34.60^c	-11.21
Mean	35.25^B	50.40^A	35.95^B	37.37^B		
% Increase over RDF		42.97	1.98	6.01		

Factors	C.D	SE(d)	SE(m)
S	3.073	1.502	1.062
T	3.073	1.502	1.062
S*T	6.146	3.003	2.124

Each value is an average of 3 replications. Figures not showing the same letter(s) in the column differ significantly at a 5% probability level according to Duncan's Multiple Range Test.

Table 3: Effect of salinity and amendments on potassium content in maize plant (mM kg dry weight^{-1})

Treatments	RDF	RDF+FYM	RDF+GYPSUM	RDF+K	Mean	% Increase over SW0
SW_0	433.33	441.03	453.83	469.20	449.35^a	
SW_1	320.50	379.47	423.03	461.50	396.13^b	-11.84
SW_2	320.50	371.77	392.30	423.07	376.91^c	-16.12
SW_3	276.90	361.53	370.93	385.47	348.71^d	-22.39
Mean	337.81^D	388.45^C	410.03^B	434.81^A		
% Increase over RDF		14.99	21.37	28.71		

Factors	C.D	SE(d)	SE(m)
S	3.076	1.503	1.063
T	3.076	1.503	1.063
S*T	6.152	3.007	2.126

Each value is an average of 3 replications. Figures not showing the same letter(s) in the column differ significantly at a 5% probability level according to Duncan's Multiple Range Test.

Table 4: Effect of salinity and amendments on sodium content in maize plant (mM kg dry weight^{-1})

Treatments	RDF	RDF+FYM	RDF+GYPSUM	RDF+K	Mean	% Increase over SW0
SW_0	433.33	441.03	453.83	469.20	449.35^a	
SW_1	320.50	379.47	423.03	461.50	396.13^b	-11.84
SW_2	320.50	371.77	392.30	423.07	376.91^c	-16.12
SW_3	276.90	361.53	370.93	385.47	348.71^d	-22.39
Mean	337.81^D	388.45^C	410.03^B	434.81^A		
% Increase over RDF		14.99	21.37	28.71		

Factors	C.D	SE(d)	SE(m)
S	0.149	0.073	0.052
T	0.149	0.073	0.052
S*T	N/A	0.146	0.103

Each value is an average of 3 replications. Figures not showing the same letter(s) in the column differ significantly at a 5% probability level according to Duncan's Multiple Range Test.

Table 5: Effect of salinity and amendments on K uptake (mg pot^{-1}) by maize

Treatments	RDF	RDF+FYM	RDF+GYPSUM	RDF+K	Mean	% Increase over SW0
SW_0	555.90	787.10	603.00	781.20	681.00^a	
SW_1	564.20	774.00	539.20	658.80	634.05^b	-7.00
SW_2	475.20	831.60	586.50	587.20	620.13^b	-9.04
SW_3	253.00	620.20	525.00	469.50	466.93^c	-31.51
Mean	462.08^D	753.23^A	563.43^C	624.18^B		
% Increase over RDF		63.00	21.93	35.08		

Factors	C.D	SE(d)	SE(m)
S	14.016	6.850	4.843
T	14.016	6.850	4.843
S*T	28.031	13.699	9.687

Each value is an average of 3 replications. Figures not showing the same letter(s) in the column differ significantly at a 5% probability level according to Duncan's Multiple Range Test.

Table 6: Effects of salinity and amendments on sodium uptake (mg pot^{-1}) by maize

Treatments	RDF	RDF+FYM	RDF+GYPSUM	RDF+K	Mean	% Increase over SW0
SW_0	13.08	9.26	13.40	17.36	13.28^c	
SW_1	26.04	25.80	16.85	19.05	21.94^b	65.23
SW_2	39.60	35.64	23.46	25.69	31.10^a	134.25
SW_3	25.30	44.30	22.50	21.91	28.50^a	114.71
Mean	26.01^A	28.75^A	19.05^B	21.01^B		
% Increase over RDF		10.55	-26.73	-19.23		

Factors	C.D	SE(d)	SE(m)
S	0.566	0.276	0.195
T	N/A	0.214	0.151
S*T	N/A	0.477	0.338

Each value is an average of 3 replications. Figures not showing the same letter(s) in the column differ significantly at a 5% probability level according to Duncan's Multiple Range Test.

Table 7: Effect of salinity and amendments on K^+/Na^+ ratio in maize plant

Treatments	RDF	RDF+FYM	RDF+GYPSUM	RDF+K	Mean	% Increase over SW0
SW_0	29.73	30.13	23.77	21.23	26.22^a	
SW_1	12.33	16.83	18.43	21.27	17.22^{ab}	-34.32
SW_2	6.70	14.33	15.27	14.77	12.77^b	-51.32
SW_3	4.30	7.27	13.33	13.13	9.51^b	-63.73
Mean	13.27^A	17.14^A	17.70^A	17.60^A		
% Increase over RDF		29.20	33.41	32.65		

Factors	C.D	SE(d)	SE(m)
S	4.774	2.333	1.650
T	N/A	2.333	1.650
S*T	N/A	4.666	3.299

Each value is an average of 3 replications. Figures not showing the same letter(s) in the column differ significantly at a 5% probability level according to Duncan's Multiple Range Test.

Plate 1: Phosphorous deficiency in maize

Plate 2: Correction of P deficiency in maize through P application

Plate 3: Acute Zinc deficiency in maize

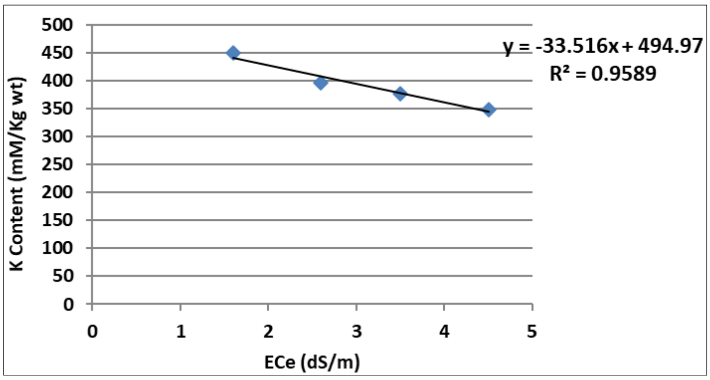

Fig 1: Correlation between ECe versus K content in plant

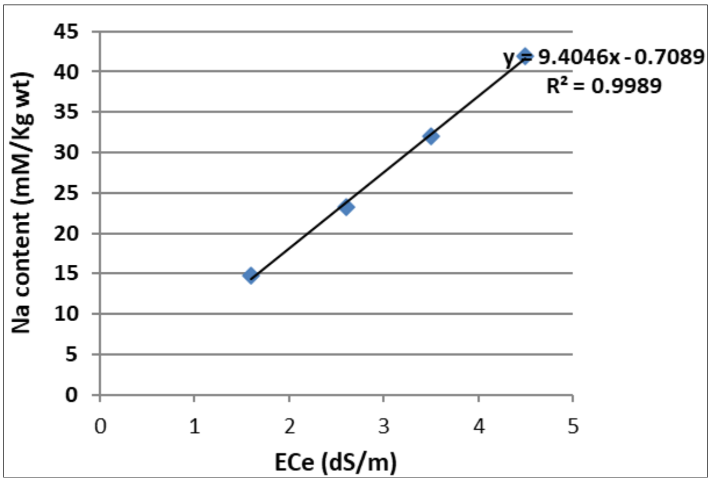

Fig 2: Correlation between ECe versus Na content in plant

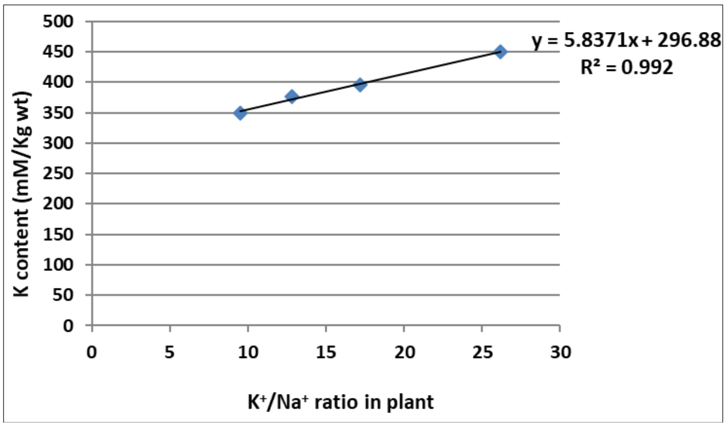

Fig 3: Correlation between K^+/Na^+ ratio in plant versus K content in plant

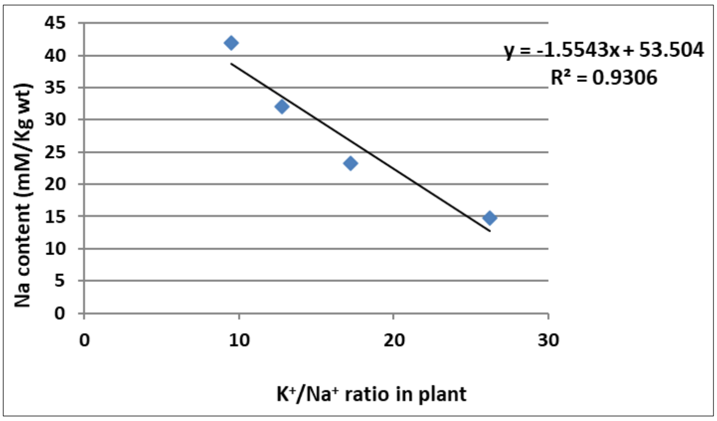

Fig 4: Correlation between K^+/Na^+ ratio in plant versus Na content in plant

Conclusion
In a pot experiment where leaching and seepage are allowed, the biomass yield of maize was increased by 12% when the crop was irrigated with saline water @ 12 dS m^{-1}. Saline water application beyond 12 dS m^{-1} reduced the biomass yield by 11%. Among the amendments tested, application of RDF+FYM treatment significantly increased the biomass yield but, RDF+K or RDF+ gypsum resulted in higher accumulation and uptake of potassium. Based on these findings, it is recommended that the farmers in coastal saline areas can use saline water up to 12 dSm^{-1} along with amendments for growing crops during *rabi* season when there is scarcity of good quality irrigation water.

Acknowledgement
We wish to express our sincere gratitude to Siksha ‘O’ Anusandhan University, Bhubaneswar for providing all the necessary facilities to carry out the present research work.

Competing interests
Authors have declared that no competing interests exist.

References
1. Abbasi GH, Akhtar J, Ahmad R, Jamil M, Anwar-ul-Haq M, Ali S, *et al*. Potassium application mitigates salt stress differentially at different growth stages in tolerant and sensitive maize hybrids. Plant Growth Regulation. 2015;76(1):111-125.
2. Alomar R, Jena D. Interactive effect of salinity and potassium on maize yield. IJPSS. 2022;34(5):37-52.
3. Black CA. Methods of soil analysis. Part I. American Society of Agronomy, Madison, Wisconsin, USA. 1572:1965.
4. Cakmak I. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. Journal of Plant Nutrition and Soil Science. 2005;168(4):521-530.
5. Cheel L. Regulating of K+ channel activities in plants: from physiological to molecular aspects. J. Exp. Bot. 2004;55(396):337-35.
6. FAO. 2016. Available: http://www.fao.org/statistics/en/
7. Flower TJ. Improving crop salt tolerance. J. Exp. Bot. 2004;55:307-319.
8. Hanway JJ, Heidal H. Soil analysis, as used in lowa State College, Soil Testing Laboratory, lowa State College Bulletin. 1952;57:1-31.
9. Hussain A, Arshad M, Ahmad Z, Ahmad HT, Afzal M, Ahmad M. Potassium fertilization influences growth, physiology and nutrients uptake of maize (*Zea maize* L.). Cercetări Agronomiceîn Moldova. 2015;12(2):161-168.
10. Hussain M, Park HW, Farooq M, Jabran H, Lee DJ. Morphological and physiological basis of salt resistance in different rice genotypes. Int J Agric Biol. 2013;15(1):113-118.
11. Ibrahim M, Dongili S. Effect of effective microorganism and gypsum amendments on nutrient leaching, pH, electrical conductivity and okra growth parameters under coastal saline soil. Communication in Soil science and plant analysis. 2018;49(18):2327-2337. https://doi.org/10.1080/00103624.2018.1499767
12. Jackson ML. Soil Chemical Analysis. Prentice Hall of India, Pvt. Ltd., New Delhi, 1973.
13. Jena D. Soil related constraints in costal saline of Orissa, J. Indian Soc. Coastal Agric. Res. 1991;9(182):183-186.
14. Lauchli A, Epstein E. Plant responses to saline and sodic conditions, in Agricultural salinity assessment and management KK. Tanji, ed. ASCE Manuals and Reports

on Engineering Practice No. 71, ASCE, Reston, Va, 1990;71:113-137.
15. Maas EV, Hoffman GJ. Crop salt tolerance—current assessment. J Irrig Drain Div ASCE. 1977;103(2):115-134.
16. Mohapatra A, Jena D, Pradhan PP, Pattnaik D, Pal AK, Pattnaik MR. Interactive effects of potassium and saline water on yield, nutrient accumulation and uptake by rice. IJCS. 2020;9(1):2936-2943.
17. Munns R, James RA, Läuchli A. Approaches to increasing the salt tolerance of wheat and other cereals. J Exp Bot. 2006;57(5):1025-1043. DOI:10.1093/jxb/erj100.
18. Olsen S, Cole C, Watanabe F, Dean L. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, USDA Circular Nr 939, US Gov. Print. Office, Washington, D.C. 1954;(939):19.
19. Piper C. Soil and Plant Analysis. International Public Inc., New York; c1950.
20. Quintero JM, Fournier JM, Benlloch M. Na+ accumulation in shoot is related to water transport in K+-starved sunflower plants but not in plants with a normal K+ status. J Plant Physiol. 2007;164(1):60-67. DOI:10.1016/j.jplph.2005.10.010
21. Rengasamy P. Soil processes affecting crop production in salt affected soils. Fun Plant Biol. 2010;37(7):255-263.
22. Subbiah BV, Asija GL. A rapid procedure for the determination of available nitrogen in soil. Curr. Sci. 1956;25:259-260.
23. Tayyaba K, Khalid H, Abdul M, Khalid N, Nisar NM. Morphological Variations in Maize (*Zea mays* L.) Under Different Levels of Nacl at Germinating Stage. World Applied Sciences Journal. 2010;8(10):1294-1297.
24. Walkley AJ, Black IA. Estimation of soil organic carbon by the chromic acid titration method. Soil Sci. 1934;37:29-38.
25. Zhang J, Jiang X, Xue Y, Li Z, Yu B, Xu L, *et al*. Closing Yield Gaps through Soil Improvement for Maize Production in Coastal Saline Soil, Agronomy. 2019;9(10):573.