Journal of Pharmacognosy and Phytochemistry 2022; 11(5): 195-201

Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2022; 11(5): 195-201
Received: 13-07-2022
Accepted: 17-08-2022

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Effects of potassium and saline water irrigation on growth of maize plant

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DOI: https://doi.org/10.22271/phyto.2022.v11.i5c.14495

Abstract
A pot culture experiment was carried out during 2019-20 to evaluate the interactive effects of saline water irrigation and potassium on growth and nutrients accumulation of maize crop. The experiment was conducted in CRD with three replications. The treatments consist of 5 levels of saline water-0, 8, 12, 16 and 20 dSm^{-1} and three levels of amendments-FYM, K and FYM + K. The results indicated that cumulative application of saline water @ 8, 12, 16 and 20 dSm^{-1} decreased the shoot length (10-30%), root length (5-35%), shoot dry mass (50-65%), root weight (60-89%) and k uptake (52-69%) as compared to control. The Na content was increased by 25-107% at same level of salinity. Application of FYM + K reduced the adverse effect of Na at all levels of salinity. The K^+/Na^+ ratio in maize plant and ECe of soil significantly correlated with several plant parameters. The K^+/Na^+ ratio in soil failed to correlate well with biomass yield and nutrient accumulation. It is concluded that the K^+/Na^+ ratio in plant can be considered as a best indicator in evaluating crop performance in saline soils.

Keywords: potassium, saline water, irrigation, growth, maize, FYM

Introduction

Plants are affected by several abiotic stresses, among them salinity stress being the major cause of reduced crop growth and production (Jalil and Ansari 2019) [16]. High salinisation restricts agricultural productivity through destructive influences on seed germination, seedling growth, root development, flowering, and fruit setting (Chakdar *et al*. 2019) [8]. In addition, the adverse impact of salt stress on plant growth may be contributed with specific ion effect, osmotic effect, induction of oxidative stress, or nutritional imbalance (Sharma *et al*. 2019) [25].
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.
Potassium plays a vital role and stimulates biological process in plant including enzyme activity, photosynthesis and water balance in leaves and regulate stomatal opening. The selective uptake of potassium as compared to sodium is considered to be one of the important physiological mechanisms contributing to salt tolerance in many crops (Benda *et al.* 2015) [6].
Thus, under saline condition, potassium may be considered as an important management strategy because of potassium competition with sodium in plants. Considering all these factors, the objective of the present study were to (i)evaluate the salt stress response of maize to different levels of salinity and potassium in early growth stages.(ii)study the interaction between salinity and potassium on biomass yield, nutrients accumulation and uptake of maize.

Materials and Methods

A pot culture experiment was carried out during November,2019 in the green house of institute of Agricultural Science, SOA Deemed to be University, Bhubaneswar to study the interaction effect of saline water irrigation, potassium and FYM growth, nutrient accumulation and uptake by maize (CV.4226).
The experiment was conducted in a completely randomized design with three replications. There were altogether fifteen treatments consist of five levels of salinity, designated as: SW_0 - good water, SW_1-saline water 8 dS m^{-1}, SW_2-saline water 12 dS m^{-1}, SW_3-saline water 16 dS m^{-1} -SW_4-saline water 20 dS m^{-1} and three amendments designated as:T_1 -FYM @ 20t/ha (wt. basis), T_2 - K @ 180 kg/ha and T_3 -FYM + K Each treatment received uniform dose of N @ 120kg/ha) and P_2O_5 @ 60 kg/ha) on weight basis. There were three replications. Potassium @180 kg/ha was applied as per the treatment. Two hundred (200) grams of air dried saline soil was taken in small plastic pots.

The soil was mixed with FYM and fertilizers as per the treatments and soaked with normal water to its field capacity. Four numbers of bold maize seeds (CV 4226) were sown in each pot.

Full germination was observed on 2nd day and emergence of shoot recorded on 3rd day of seeding. The maize plant received six no of saline water irrigation (as per treatments) on 5th, 7th, 9th, 12th, 16th and 19th day of seedling emergences. Irrigation was applied up to field capacity with saline water as per the treatments. The saline water used in the study was brought from Bay of Bengal as Puri sea beach. The saline water was EC of 34.56 dS/m and diluted as per the treatments. The chlorophyll contents of maize leaves were recorded on 12th day of seedling emergences. The symptoms of salinity *viz*. leaf curling, leaf tip burning were observed after 17 days of seedling.

The maize plants were harvested after 25 days of seedling emergences. The seedlings were washed with tap water, dried with paper towels. Shoot length and root length were measured. Then the samples were kept in oven at 70^0C for 48 hours and the shoot and root dry weights were recorded. The samples were grinded and kept for analysis. Soil samples were air dried, processed and kept for analysis.

Results and discussion

The saline soil collected from surface layer (0-15 cm depth) of rice – follow field had pH 7.65 with electrical conductivity of saturated paste 3.2 dSm^{-1}. The soil texture was loamy sand with clay content 4%. The soil had B.D of 1.2 gm cm^{-3}, P.D 2.46 gm cm^{-3}, porosity 42.5% and moisture content at saturation 27%. The soil was low in organic carbon (0.67%), available N (200 kg ha^{-1}) and Olsen's P (8.15 kg ha^{-1}). The exchangeable and water soluble potassium content was 0.60 and 0.08 c mol (+) kg^{-1} soil, respectively, indicating low status. The soil was rich in sodium having exchangeable and water soluble sodium content of 0.8 and 2.0 c mol (+) kg^{-1} soil, respectively.

The saline water used for the study was alkaline in reaction (pH 7.99) having EC of 34.56 dSm^{-1}. The content of soluble Na, K, Ca and Mg was 5.1, 0.20, 0.19 and 0.56 gm L^{-1}, respectively.

Effect of salt stress on shoot length

Salinity reduced shoot growth by suppressing leaf initiation and expansion as well as internodes growth. Being a salt sensitive crop, the shoot growth in maize is strongly inhibited in the first phase of salt stress (EI Sayed, 2011) [9].

The shoot length decreased significantly with increasing the level of salinity (Table1). It was 48.1 cm in control treatment and decreased significantly by 10.4, 14.1, 25.4 and 27.9 percent when the crop received saline water irrigation @ 8, 12, 16 and20 dSm^{-1}, respectively. Saline toxicity leading water uptake limitation resulted in reduction of cell enlargement and seedling development. Cumulative application of saline water irrigation @8-20 dS/m in this study significantly the shoot length as in the study significantly decreased the shoot length as compared to normal water irrigation.

Table 1: Interactive effect of salinity, FYM and potassium on shoot length (cm)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	41.67	50.50	52.00	48.06^a	
SW_1	39.87	41.37	48.00	43.08^b	-10.4
SW_2	39.17	41.73	43.00	41.30^b	-14.1
SW_3	34.30	36.30	37.20	35.93^c	-25.4
SW_4	32.80	34.97	36.20	34.65^c	-27.9
Mean	37.56^B	40.97^{AB}	43.28^A		
% Increase		9.0	15.2		

Means followed by the same letter are not significantly different with in levels of salinity and amendments according to Duncan's test (p<0.05).

The unfavorable effect of water stress resulted in 28% shoot length reduction at 20 dSm^{-1} salinity level as compared to control. The rate of shoot length reduction was lower at the lower salinity levels (8, 12, 16 dSm^{-1}) as compared to 20 dSm^{-1}. The deleterious effect of soil salinity was reduced by application of FYM and potassium. Averaged over the salinity levels, shoot length in FYM treatment (T_1) was 37.6 cm and increased by 9% when the crop fertilized with potassium @180 kg/ha. Combined application of FYM +K (T_3) further increased the shoot length by 15% over FYM.

Effects of salts stress on root length

Under saline condition, the roots are less sensitive to salt stress than shoots although the root is the first organ exposed to salt stress. The length of root is an important characteristic for stress conditions owing to absorption of water and nutrients from soil environment (Khodarahmpour *et al.*, 2012) [21]. The length of roots decreased significantly with increase in the level of salinity (Table2). Longest root (26.7 cm) was measured in saline control treatment (normal water) and shortest in the highest salinity (20 dSm^{-1}). As the salinity level increased from control to8 dSm^{-1}, the root length tended to decrease significantly by 5% over control. It was further deceased by 13, 34 and 36% when the salinity level of increased to 12, 16 and 20 dSm^{-1} respectively. Increasing the salinity level from 12 to20 dSm^{-1} caused much reduction in root length.

The beneficial effects of FYM and potassium applied alone or in combination were reflected on root length. Averaged over the salinity levels, the root length increased over FYM treatment (21.4 cm) by 3.3% with potassium and 5.17% with combined application of FYM+K. The adverse effect of salinity can be reduced by application of amendments.

Table 2: Interactive effect of salinity, FYM and potassium on root length (cm)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	26.43	26.70	26.90	26.68^a	
SW_1	24.29	25.80	25.90	25.33^{ab}	-5.05
SW_2	22.60	23.20	23.70	23.17^b	-13.16
SW_3	16.80	17.50	18.40	17.57^c	-34.15
SW_4	16.90	17.33	17.60	17.28^c	-35.23
Mean	21.40^A	22.11^A	22.50^A		
% Increase		3.31	5.14		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test (p< 0.05).

Salt stress effects on dry shoot weight

Salt stress reduced plant growth at vegetative stage and there by significantly decreased shoot weight. The data presented in table 3 showed that the highest shoot weight was obtained in saline control treatment (7.3 g/pot) and lowest in 20 dSm^{-1} salinity (2.6 g/pot) level. With increasing the salinity level, the shoot weight decreased significantly over control by 50, 58, 62 and 64%, as 8, 12, 16, and 20dSm^{-1} respectively. On the other hand, application of amendments significantly reduced the adverse impact of soil salinity. Averaged over the salinity levels, application of potassium alone or in combination with FYM increased shoot weight by 15 and 24%, respectively in comparison to FYM.

In consistence with this results, Hussein *et al.* (2007) [13] and Carpici *et al.* (2009) [7] confirmed that significant decreased in vegetative growth of maize was observed as the salinity levels increased.

Salt stress impacts on dry root weight

The effect of salinity stress was greatly marked on root weight. The parameters like root length, root number, root density contribute towards root mass. The data presented in table 4 indicated that root weight decreased significantly as the level of salinity increased from 0 to20 dSm^{-1}. The highest root weight of 3.7 gm/pot was recorded in SW_0 (normal water) and decreased over control by 60% at 8 dSm^{-1}, 83% at 12 dSm^{-1}, 84% at 16 dSm^{-1} and 86% at 20 dSm^{-1}. The results further showed that the maize root activity is affected when the salinity was increased beyond 8dSm^{-1}. However, considering the salinity levels, application of potassium alone or with FYM increased the root weight by 50% over FYM alone although all were at par.

Salt tolerance index (STI)

Salt tolerance index (STI) is a function of both germination rate and total dry weights; therefore it is a more useful selection criterion. Highest STI values show the highest salinity tolerance of crops or genotypes (Jaradat *et al*., 2004) [18]. Management practices including amendments also greatly influence the STI

Table 3: Interactive effects of salinity, FYM and potassium on shoot weight (gm/pot)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	6.20	7.43	8.40	7.34^a	
SW_1	3.50	3.57	3.93	3.67^b	-50.06
SW_2	2.80	3.23	3.20	3.08^b	-58.08
SW_3	2.33	2.77	3.00	2.70^b	-62.23
SW_4	2.37	2.70	2.73	2.60^b	-64.59
Mean	3.44^B	3.94^B	4.25^A		
% Increase		14.53	23.63		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test(p< 0.05).

Table 4: Interactive effects of salinity, FYM and potassium on root weight (gm/pot)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	3.40	3.57	4.03	3.67^a	
SW_1	0.60	2.70	1.13	1.48^b	-59.69
SW_2	0.40	0.53	0.97	0.63^b	-82.73
SW_3	0.33	0.40	0.80	0.51^b	-86.06
SW_4	0.23	0.37	0.63	0.41^b	-88.79
Mean	0.99^A	1.51^A	1.51^A		
% Increase		52.36	52.36		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test (p< 0.05).

The Salt tolerance indexes were generally higher in the lower salinity levels while lower in higher salinity levels. While considering the salinity level, the STI was 100% in FYM treatment (taken as control) and increased by 19 and 36% with K and K+ FYM application when the crop was irrigation with normal water (Table 5).

However the STI values reduced by 50% when the salinity was increased from 0 to 8 dSm^{-1} and by 64% at highest level of salinity (20 dSm^{-1}). This indicated that the maize is severely affected when the salinity level was increased beyond 8dSm^{-1}. The STI values significantly increased with application of amendments. Averaged over the salinity levels, the STI was 55.5% in FYM treatment and increased by15 and 23% with application of K and K + FYM, respectively.

Chlorophyll content

Chlorophyll is a pigment that gives plants to their green colour and it helps plants to create their own energy through photosynthesis. The amount of chlorophyll in leaf tissues is influenced by nutrient availability and environmental stress such as drought, salinity, cold and heat. Salinity decreases the chlorophyll content in leaves because of water stress and decreased in iron and phosphorous content in soil.

The results showed that higher chlorophyll content (SPAD Index-29.7) was observed in SW_0 treatment (normal water) and lowest (SPAD index-25.1) in highest salinity level (20 dSm^{-1} table 6). The chlorophyll content significantly decreased with increasing the level of salinity. The rate of reduction in chlorophyll contents in comparison to control was about 3% at 12 dSm^{-1}, 13% at 16 dSm^{-1} and 16% at 20 dS m^{-1}. The chlorophyll content in maize at 8dSm^{-1} was at par with control treatment without much reduction.

On the other hand, application of potassium recorded significantly higher SPAD values (7%) than FYM. Combined application of potassium and FYM further increased the chlorophyll content by 12% over FYM.

Table 5: Interactive effects of salinity, FYM and potassium on salt tolerance index

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	100	119.4	135.5	118.3^a	
SW_1	56.5	58.1	62.9	59.2^b	-50.6
SW_2	45.2	51.6	51.6	49.5^b	-58.2
SW_3	37.1	45.2	48.4	43.6^b	-63.0
SW_4	38.7	43.5	43.5	41.9^b	-64.6
Mean	55.5^C	63.6^B	68.4^A		
% Increase		14.6	23.2		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan`s test (p< 0.05).

Table 6: Effect of salinity, potassium and FYM on chlorophyll content of maize leaf (SPAD Index value)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	28.43	29.93	31.63	30.00^a	
SW_1	28.77	29.83	30.70	29.77^a	-0.77
SW_2	28.27	28.93	29.70	28.97^{ab}	-3.44
SW_3	23.43	26.80	27.90	26.04^{bc}	-13.18
SW_4	22.50	25.77	27.10	25.12^c	-16.26
Mean	26.28^B	28.25^A	29.41^A		
% Increase		7.50	11.89		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan`s test (p< 0.05).

Salt stress effects on potassium and sodium content in maize

In saline soils, excessive build up of sodium and chloride ions in the root rhizosphere leads to severe nutritional imbalances in maize due to strong interference of these ions with other essential mineral elements such as K, Ca, N, P, Mg, Mn, Cu, Fe and Zn (Turan *et al*., 2010) [27]. Generally the salt stress reduces the uptake of N, K, Ca, Mg and Fe. For maize, sodium is the principal toxic ion interfering with potassium uptake and transport, leading to disturbance in stomatal modulations and causing water loss and necrosis. Competition between potassium and sodium under salt stress severely reduces potassium content in both leaves and roots of maize and reduces potassium content by up to 64% in the symplast of expanding tissues (Kaya *et al*., 2010) [20]. Moreover, salt stress not only reduces potassium uptake rates but to a greater extent, disturbs potassium translocation from root to shoot tissues in maize, leading to lower potassium shoot contents than root contents.

The results of the present study indicated that significantly higher potassium accumulation in maize (593.7 mM /kg dry weight) was recorded in SW_0 treatment (normal water) and lowest potassium accumulation (522.89 mM /kg dry weight) in highest level of salinity (20 dSm^{-1}) (Table7). The potassium content decreased with increased the level of salinity. The rate of reduction in potassium content in comparison to control was about 5% at 8-12 dSm^{-1} and 11-12% at 16-20 dSm^{-1} salinity level. Averaged over the salinity levels, combined application of potassium and FYM behaved in similar pattern to that of FYM treatment.

Content of sodium in maize significantly increased with increasing the level of salinity (Table 8). Lowest Na content (16.4 mM /kg dry weight) was recorded in SW_0 (normal water) and highest (35.5 mM/kg dry weight) in highest level of salinity (20 dSm^{-1}). With increasing the level of salinity from 0 to 8 dS m^{-1}, the Na content was increased by 25%. Further, with increasing the salinity level to 12, 16 and 20 dSm^{-1}, the Na content in maize plant increased by 61%, 76% and 107%, respectively over the control treatment.

On the other hand, the Na accumulation in maize plant decreased with application of potassium because of antagonistic interaction between sodium and potassium. Averaged over the salinity levels, the sodium content in maize plant decreased by 17% and 33% when potassium was applied alone or in combination with FMY, respectively.

Table 7: Effects of salinity and Potassium on potassium content in maize (mM K/kg dry wt)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	589.71	575.76	615.49	593.65^a	
SW_1	563.87	534.30	583.28	560.48^b	-5.58
SW_2	563.13	588.70	538.74	563.52^b	-5.07
SW_3	538.39	512.07	538.90	529.79^c	-10.75
SW_4	538.49	520.55	509.62	522.89^d	-11.91
Mean	558.72^A	546.28^B	557.21^A		
% Increase		-2.22	-0.27		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan`s test (p< 0.05).

Table 8: Effect of salinity, potassium and FYM on sodium content in maize (mM Na/ kg dry wt)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	17.80	17.10	16.40	17.10^e	
SW_1	27.60	18.90	17.50	21.33^d	24.75
SW_2	35.80	29.00	18.00	27.60^c	61.40
SW_3	36.70	30.33	23.40	30.14^b	76.28
SW_4	39.80	35.90	30.70	35.47^a	107.40
Mean	31.54^A	26.25^B	21.20^C		
% Increase		-16.78	-32.78		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test ($p< 0.05$).

Effects of salt stress on K^+/Na^+ ratio in maize plant

In salt affected soils, crop growth may be adversely affected by salinity induced nutritional disorder. These disorders may result from the effect of salinity on nutrient availability, competitive uptake and transport within the plant. High concentration of Na^+ and Cl^- in saline soils may depress nutrient ion activities and produce extreme ratios of Na^+/Ca^{++}, Na^+/Ka^+, $Ca^{2+}/Mg2^+$ and Cl^- /NO_3^-. As a result, the plant becomes susceptible to osmotic and specific ion injury as well as to nutritional disorders that may result in reduced yield or quality.

The data presented in table 9 revealed that the K^+/Na^+ ratio in maize plant was adversely affected due to soil salinity. Highest K^+/Na^+ ratio (34.8) in maize plant was recorded in SW_0 treatment (normal water) and lowest (14.88) K^+/Na^+ ratio at highest level of salinity (20 dSm^{-1}). The K^+/Na^+ ratio decreased significantly by 21% with increasing the level of salinity from 0 to8 dSm^{-1}. Further, the K^+/Na^+ ratio reduced by 37% at 12 dSm^{-1}, 48% at 16 dSm^{-1} and 57% at 20 dSm^{-1}. Reduction in K^+/Na^+ ratio in plant disturb the plant metabolism, plant growth and yields of maize.

The K^+/Na^+ ratio in maize was improved by application of soil amendments. Application of potassium increased the K^+/Na^+ ratio by 16% over FYM (19.50). Combined application of potassium and FYM was found most effective management practice which increased the K^+/Na^+ ratio by 44% over FYM alone. Similar finding were reported by Shahzad *et al*., (2012) [25].

Potassium and sodium uptake by maize plant

The uptake of potassium and sodium depends on biomass yield and sodium or potassium content in maize plant. Highest potassium uptake (171.5 kg/pot) was recorded in SW_0 (normal water) treatment and decreased significantly by 52% at 8 dSm^{-1}, 61% at 12 dSm^{-1}, 67% at 16 dSm^{-1} and 69% at 20 dSm^{-1} salinity level (Table10).

However, application of potassium alone or with FYM resulted in 14 and 25% higher K accumulation over FYM treatment (76 mg pot^{-1}).

Maximum Na uptake (2.9 gm pot^{-1}) in SW_0 treatment (normal water) was recorded might be due to higher biomass yield in spite of lower Na accumulation (Table 11). Although, the Na content in saline treatments was higher, but its uptake decreased because of lower in biomass yield.

Similar trend was observed in amendment treatments. Averaged over the saline treatments, Na uptake in FYM treatment was 2.2 mg pot^{-1} and decreased by 4 and 8% when the crop received K or FYM+K, respectively. Lower Na uptake in K or FYM+ treatment was possible due to lower Na accumulation in maize plant

Table 9: Effects of salinity, potassium and FYM on K^+ /Na^+ ratio in maize plant

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	33.13	33.67	37.53	34.78^a	
SW_1	20.43	28.27	33.33	27.34^b	-21.37
SW_2	15.73	20.30	29.93	21.99^c	-36.77
SW_3	14.67	16.90	23.03	18.20^d	-47.66
SW_4	13.53	14.50	16.60	14.88^e	-57.22
Mean	19.50^C	22.73^B	28.09^A		
% Increase		16.54	44.03		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test ($p< 0.05$).

Table 10: Effect of salt stress on K uptake by maize (mg/pot)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	142.60	170.20	201.60	171.47^a	
SW_1	77.00	79.20	89.70	81.97^b	-52.19
SW_2	61.60	73.60	67.20	67.47^c	-60.65
SW_3	48.30	56.00	63.00	55.77^{cd}	-67.47
SW_4	50.40	54.00	54.00	52.80^d	-69.20
Mean	75.98^C	86.60^B	95.10^A		
% Increase		13.97	25.16		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test ($p< 0.05$).

Table 11: Effect of salt stress on Na uptake by maize (mg/pot)

Treatments	FYM	K	FYM+K	Mean	% Increase
SW_0	2.48	2.96	3.36	2.93^a	
SW_1	2.10	1.44	1.56	1.70^b	-42.03
SW_2	2.24	1.92	1.60	1.92^{ab}	-34.53
SW_3	1.84	1.96	1.50	1.77^b	-39.75
SW_4	2.16	2.16	1.89	2.07^{ab}	-29.42
Mean	2.16^A	2.09^A	1.98^A		
% Increase		-3.51	-8.41		

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test ($p < 0.05$).

Post harvest soil properties

The data presented in table 12 showed that the ECe of soil in saline control treatment (SW_0) at harvest was lower (1.33 dSm^{-1}) than the initial value (3.3 dSm^{-1}) might be due to application of good quality irrigation water as well as Na uptake by maize plant. On the other hand, the ECe values significantly increased with increasing level of saline water irrigation. The values were 15.77 at 8 dSm^{-1}, 24.53 at 12 dS/m, and 27.98 at 16 dS/m and 35.24 at 20 dS/m saline water irrigation. Similar results were reported by Fard *et al*., (2007), Ragab *et al*., (2008) [23]. There was significant effect of amendments on soil salinity. Application of K alone or with FYM significantly decreased the ECe as compared FYM treatment.

Available, exchangeable and water soluble K in all treatments were increased as compared to initial value might be due to application of FYM and K. Higher values of exchangeable K at higher salinity level indicated that, Na depressed the uptake of K by plant leaving more K in soil. Application of saline water greatly influenced the Na content in soil. In all saline water treatments, the exchangeable and water soluble Na was higher than the initial value (Table13).

The K^+/Na^+ ratio in soil at beginning was 0.24 and increased to 0.43 to 0.47 under SW_0 (good quality water) might be due to high exchangeable K in soil. The values decreased in saline water treatments, might be due to higher sodium content in soil. In all saline water treatments, the K^+/Na^+ ratio increased with increasing the level of potassium.

Table 12: Effect of salinity, potassiumm and FYM on ECe (dSm^{-1}) of post harvested soil

Treatments	FYM	K	FYM+K	Mean
SW_0	1.833	1.533	1.333	1.567^d
SW_1	17.667	16.900	12.733	15.767^c
SW_2	25.633	23.667	24.300	24.533^b
SW_3	30.667	28.167	25.100	27.978^b
SW_4	37.467	35.300	32.967	35.244^a
Mean	22.653^A	21.113^{AB}	19.287^B	

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test ($p < 0.05$).

Table 13: Available, water soluble, exchangeable sodium and potassium content and K^+/Na^+ ratio in post-harvest soil

Treatments		Sodium (c mol p^+ kg^{-1})			Potassium (c mol p^+ kg^{-1})			K^+/Na^+
		Av.	Exch.	W.S.	Av.	Exch.	W.S.	
SW_0	T_1	1.8	1.6	0.20	0.78	0.71	0.07	0.43
	T_2	1.9	1.7	0.20	0.81	0.73	0.08	0.43
	T_3	1.8	1.6	0.20	0.85	0.77	0.08	0.47
SW_1	T_1	9.7	7.8	1.9	0.77	0.71	0.06	0.08
	T_2	9.7	7.8	1.9	0.81	0.73	0.08	0.08
	T_3	9.7	7.8	1.9	0.81	0.73	0.08	0.08
SW_2	T_1	10.6	7.8	2.8	0.87	0.78	0.09	0.08
	T_2	11.0	7.2	3.8	0.91	0.82	0.09	0.08
	T_3	11.4	7.9	3.5	1.00	0.90	0.10	0.09
SW_3	T_1	12.8	8.5	4.3	0.88	0.79	0.09	0.07
	T_2	11.4	7.4	4.0	1.13	1.0	0.13	0.10
	T_3	13.2	8.2	5.0	1.39	1.26	0.13	0.11
SW_4	T_1	13.6	8.6	5.0	1.09	0.98	0.11	0.08
	T_2	13.6	8.0	5.6	1.27	1.13	0.14	0.09
	T_3	13.8	8.0	5.8	1.59	1.44	0.15	0.12
Initial		2.8	0.8	2.8	0.68	0.60	0.08	0.24

Means followed by the same letter are not significantly different with the levels of salinity and amendments according to Duncan's test ($p < 0.05$).

Conclusion

Cumulative application of saline water @ 8-20 dSm^{-1} increased the soil ECe above critical limit. Cumulative application of saline water significantly reduced the dry shoot weight (50-65%), root weight (60-89%), shoot length (10-28%), root length (5-35%) and leaf chlorophyll content (1-16%). The potassium accumulation (6-12%) and uptake decreased significantly where as sodium content (25-107%) and uptake increased significantly. Application of potassium alone or with FYM decreased the adverse effect salinity by increasing all the plant parameters. Addition of higher dose of potassium alone or with FYM increased the salt tolerance index by 15-23%. The K^+/ Na^+ ratio in plant decreased with salinity but, increased with potassium application. The ECe of soil at harvest and K^+/Na^+ ratio in plant significantly correlated with all plant parameters. It is concluded that the K^+/Na^+ ratio in plant as a best indicator in evaluation of crop performances in saline soils.

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