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# Effect of saline water and integrated approach based treatments on chemical properties of water and soil and growth and development of black gram

**RAJAGOPAL V*, P SANTHY, K NAGARAJAN, T. KALAISELVI AND N CHANDR SOKARAN**

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore -641003

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## ABSTRACT

*The twelve treatments comprised in series of physical, cultural and biological methods were imposed on 2, 4 and 6.0 dS $m^{-1}$saline water (SW)for assessing water EC and ions concentrations. Of which, two treatments viz.SW exposure to 0.44 T MFs (6 min) + incubation with Amla stem powder @ 6 g 6 hrs $L^{-1}$ + five days incubation with $C_{10}$ bacterial culture (BC)@ 4 ml $L^{-1}$,and SW exposure to 0.44 T MFs (6 min) + incubation with Muringa seed powder @ 6 g 6 hrs $L^{-1}$ + five days incubation with $C_{10}$BC solution @ 4 ml $L^{-1}$were carried out for assessing the treated SW effect on soil properties and growth and development of black gram (Vigna mungo) grown in saline and non-saline soils. The treatment efficiency decreased with increased salt content. The treatments of cultural and saline bacterial combinations, and integration of all approaches were equally effective.The integrated approach treatment reduced on an average 30.3 % EC, and 64.3% $Ca^{2+}$, 51.6 % $Mg^{2+}$, 24.9 % $Na^{+}$, 26.5 % $SO_4^{2-}$ and 18 % $Cl^{-}$ions concentration. The salt accumulation from saline water lowered for treatments and both the treatments were equally effective. As a whole, it reduced nearly 50-56 % salt accumulation, and >57% $Ca^{2+}$, >44 % $Mg^{2+}$, >36% $Na^{+}$, >22 % $SO_4^{2-}$ and >13 % $Cl^{-}$ in both the soils. Improvement of plant growth parameters and eventually 13.4 % yield increase were achieved.*

**Key words:** Saline water treatments, black gram, soil salinity, growth parameters, yield

## INTRODUCTION

Studies have reported that more than 50 % of cultivated area is going to remain as rainfed area at the same time water demand is increasing with time deposited accounting more than 70 % of available water in agriculture. Under this situation, farmers are using widelypoor quality saline water that dominantly prevails as underground water resource in arid and semi-arid regions. Besides, huge amount of wastewater generated from different industries can also bea potential irrigation source for agriculture. It contains lot of organic and inorganic pollution that need to be abated before the use. In this regard, reverse osmosis, membrane filters and ionic polymers are some of organic and inorganic pollutants removal techniques of industrial wastewater in practice, but they are costlier and have so far not commercialised for irrigation purpose (Holkar *et al.* 2016). After understanding saline water behaviour in soils, guidelines have been devised for saline water management in agriculture for achieving higher yield with saline water EC up to 6 dS $m^{-1}$ (Kim *et al.,* 2016). Regarding eco-friendly and cheaper techniques for saline water amelioration, studies have recently reported that the saline water exposure to physical radiation can increase growth and development of crops (Surendran*et al.* 2016). In support of this, some farmers use magnetic devices for treating the irrigation water yet the scientific mechanism has not been elucidated. Studies have also reported the possible use of some plant residues could remove ions from saline water through adsorption process and change the properties of potable water (Apte *et al.* 2011). Besides these, halobacteria survives under salinity situation adapting different mechanism such as salt accumulation, and exopolysaccharide production and precipitation of salts can be used for improving saline water quality (Sasaki *et al.*2017). The individual effect of magnetic field under physical approach, indigenous materials under cultural methods and saline bacteria under biological approach on saline water quality has already been published (Rajagopal *et al.* 2021a,b). This manuscript narrates how different treatments of integrated approach affect the saline water quality, soil properties and growth and development of black gram.

*Scientist, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune-413115 Maharashtra
Corresponding author mail id: v.rajagopal@icar.gov.in

## MATERIALS AND METHODS

The study was conducted at Tamil Nadu Agricultural University during the period of 2017-20. Treatments were saline water (SW) exposure to 0.44 T MF for 6mins under south pole (MFs) + The same SW incubation with Amla Stem Powder (ASP) @ 6 g $L^{-1}$ 6 hrs ($T_1$), The SW exposure to 0.44 T MFs for 6 mins+ The SW incubation with Muringa Seed Powder (MSP) @ 6 g $L^{-1}$ 6 hrs ($T_2$), exposure to 0.44 T MFs for 6 mins ($T_3$) + The SW incubation for 5 days with $C_{10}$salt tolerant bacterial culture (BC) @ 4 ml $L^{-1}$, The SW exposure to 0.44 T MFs for 6 mins+ The SW incubation for 5 days with $C_{12}$BC @ 4 ml $L^{-1}$($T_4$), The SW incubation with ASP @ 6 g $L^{-1}$6 hrs + The SW incubation with $C_{10}$BC solution for 5 days @ 4 ml $L^{-1}$(T5), The SW incubation with ASP @ 6 g $L^{-1}$6 hrs + The SW incubation with $C_{12}$BC solution @ 4 m $L^{-1}$for 5 days ($T_6$),The SW incubation with MSP @ 6 g $L^{-1}$6 hrs+ The SW incubation with $C_{10}$BC solution for 5 days @ 4 ml $L^{-1}$ ($T_7$), The SW incubation with MSP @ 6 g $L^{-1}$6 hrs + The SW incubation with $C_{12}$ BC solution for 5 days @ 4 m $L^{-1}$, ($T_9$)The SW exposure to 0.44 T MFs for 6 mins+ The SW incubation with ASP @ 6 g $L^{-1}$6 hrs + The SW incubation with $C_{10}$ BC solution for 5 days @ 4ml $L^{-1}$, The SW exposure to 0.44 T MFs for 6 mins+ The SW incubation with MSP @ 6 g $L^{-1}$6 hrs + The SW incubation with $C_{10}$ BC solution for 5 days @ 4ml $L^{-1}$ ($T_{10}$), The SW exposure to 0.44 T MFs for 6 mins+ The SW incubation with ASP 6 g $L^{-1}$6 hrs + The SW incubation with $C_{12}$BC solution for 5days @ 4 ml $L^{-1}$($T_{11}$) , and ($T_{12}$) SW exposure to 0.44 T MFs for 6 mins+ The SW incubation with MSP @ 6 g $L^{-1}$ 6 hrs + The SW incubation with $C_{12}$ BC for 5 days @ 4 ml $L^{-1}$. The saline water is another factor with three levels: ($S_1$) 2.0 dS $m^{-1}$ saline water, ($S_2$) 4.0 dS $m^{-1}$ saline water and ($S_3$) 6.0 dS $m^{-1}$ saline water. As mentioned above, the treatments were imposed in series.

With best performing treatments identified from saline water incubation study, a pot culture experiment was conducted to assess the effect of treated saline water on soil properties, and growth and development of black gram with9different treatments. They were ($T_1$) 2.0 dS $m^{-1}$ SW, The 2.0 dS $m^{-1}$ SW exposed to 0.44 T MFs for 6 mins+ The SW incubation with ASP @ 6 g $L^{-1}$6 hrs + The SW incubation with $C_{10}$BC solution @ 4 ml $L^{-1}$ for 5 days ($T_2$), The 2.0 dS $m^{-1}$SW exposed to 0.44 T MFsfor 6 mins+ The SW incubation with MSP @ 6 g $L^{-1}$ for 6 hrs + The SW incubation with $C_{10}$BC solution @ 4 ml $L^{-1}$for 5 days ($T_3$), The 4.0 dS $m^{-1}$ SW ($T_4$), The 4.0 dS $m^{-1}$SW exposed to 0.44 T MFsfor6mins + The SW incubation with ASP @ 6 g $L^{-1}$ 6 hrs + The SW incubated with $C_{10}$BC solution @ 4 ml $L^{-1}$ for 5 days ($T_5$), The 4.0 dS $m^{-1}$SW exposed to 0.44 T MFsfor 6 mins+The SW incubation with MSP @ 6 g $L^{-1}$6 hrs + The SW incubation with $C_{10}$BC solution @ 4 ml $L^{-1}$ for 5 days ($T_6$), The 6.0 dS $m^{-1}$saline water ($T_7$), The 6.0 dS $m^{-1}$SW exposed to 0.44 T MFs for6 mins + The SW incubation with ASP @ 6 g $L^{-1}$ for 6 hrs + The SW incubation with $C_{10}$ BC solution @ 4 m $L^{-1}$ for 5 days ($T_8$), The 6.0 dS $m^{-1}$SW exposed to 0.44 T MFsfor 6 mins +The SW incubation with MSP @ 6 g $L^{-1}$6 hrs + The SW incubation with $C_{10}$BC solution for 5 days @ 4 ml $L^{-1}$($T_9$). Soil type was another factor taken with two levels of non-saline soil and saline soil.

The saline water representing different EC value was prepared following the procedure given by Hussain (1989). Accordingly, 2.009 g of sodium chloride, 2.996 g of sodium sulphate, 1.15 g of calcium chloride dehydrate and 0.961 g magnesium sulphate hepta hydrate were dissolved in 5000 ml of distilled water in order to have the solution conductivity value 2.0 dS $m^{-1}$. Similarly, saline water EC 4.0 and 6.0 dS $m^{-1}$ prepared using distilled water in the laboratory. The chemical properties of saline water are given in the Table 1. The chemical parameters of water such as electrical conductivity, calcium, magnesium, sodium, chloride and sulphate concentration and soil EC, and water-soluble fraction of cations and anions concentrations were analysed following standard procedures (Tandon, 2005). Besides this, plant growth parameters such as plant height, biomass

Table 1: Basic chemical characteristics of saline waters

| Kinds of saline water | pH | EC (dS $m^{-1}$) | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $Cl^{-}$ | $SO_4^{2-}$ |
|---|---|---|---|---|---|---|---|
| | | | (meq $L^{-1}$) | | | | |
| S2 (2.0 dS $m^{-1}$) | 7.7 | 1.82 | 1.85 | 1.35 | 13.6 | 9.7 | 5.2 |
| S3 (4.0 dS $m^{-1}$) | 7.7 | 4.1 | 3.71 | 2.71 | 27.18 | 19.4 | 10.4 |
| S4 (6.0 dS $m^{-1}$) | 7.7 | 5.9 | 5.55 | 4.05 | 40.8 | 29.1 | 15.6 |

production and seed yield were also recorded. The experiment conducted following factorial CRD and the experimental unit and observational units are saline water was highly heterogeneous nature. So the treatment effects were converted into efficiency data and used for ANOVA test. The SPSS.16 version software package used for data analysis

## RESULTS AND DISCUSSION

### Effect of integrated measures on chemical properties of saline water

**Electrical conductivity:** The electrical conductivity value representing salt content of water differed significantly among the treatments consisted of physical, cultural methods and microbiological techniques (Table 2). The rate of saline water EC change decreased with increased salt content of water and the largest change(41.6 %) was observed in 2.0 dS $m^{-1}$ saline water. The ions involved in electron conductance removed mostly through the process of adsorption on the surface of materials which are indigenous materials and polysaccharide produced by microbes. As the ions saturate completely the surface following adsorption theorem, the further removal from water decreases with increase of salt concentration (Apte *et al.*, 2011).

Table 2: Effect of integrated approaches of saline water treatments on reduction of (%) its electrical conductivity

| Treatments | S1 | S2 | S3 | Mean |
|---|---|---|---|---|
| $T_1$- 0.44 T MFs 6 mins+ ASP 6 g $L^{-1}$ 6 hrs incubation | 40.0 | 23.5 | 21.2 | 28.2 |
| $T_2$- 0.44 T MFs 6 mins + MSP 6 g $L^{-1}$ 6 hrs incubation | 39.0 | 22.0 | 20.3 | 27.1 |
| $T_3$- 0.44 T MFs 6 mins + $C_{12}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 38.5 | 21.8 | 20.2 | 26.8 |
| $T_4$- 0.44 T MFs 6 mins + $C_{10}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 36.5 | 21.0 | 18.8 | 25.4 |
| $T_5$-ASP 6 g $L^{-1}$ 6 hrs incubation + $C_{10}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 42.5 | 29.5 | 22.5 | 31.5 |
| $T_6$-ASP for 6 g $L^{-1}$ 6 hrs incubation + $C_{12}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 41.5 | 27.8 | 22.0 | 30.4 |
| $T_7$-MSP 6 g $L^{-1}$ 6 hrs incubation + $C_{12}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 41.5 | 27.5 | 21.8 | 30.3 |
| $T_8$- MSP 6 g $L^{-1}$ 6 hrs incubation + $C_{10}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 40.5 | 26.3 | 20.8 | 29.2 |
| $T_9$- 0.44 T MFs 6 mins + ASP for 6 g $L^{-1}$ 6 hrs incubation + $C_{10}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 46.5 | 33.0 | 25.2 | 34.9 |
| $T_{10}$- 0.44 T MFs 6 mins + MSP 6 g $L^{-1}$ 6 hrs incubation + C10 isolates 5 days incubation @ 4ml $L^{-11}$ | 45.5 | 31.8 | 24.2 | 33.8 |
| $T_{11}$- 0.44 T MFs 6 mins + ASP for 6 g $L^{-1}$ 6 hrs incubation + $C_{12}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 45.0 | 31.5 | 24.3 | 33.6 |
| $T_{12}$- 0.44 T MFs 6 mins + MSP 6 g $L^{-1}$ 6 hrs incubation + $C_{12}$ isolates 5 days incubation @ 4ml $L^{-11}$ | 42.0 | 30.3 | 23.3 | 31.9 |
| CD(0.05) | S 4.9 | T 5.2 | SXT 6.5 | |

The ions in saline water removed through adsorptive mechanism as treatments were imposed in sequence one after another which could explain why it has relatively higher effect in comparison to individual components (Lestari *et al.*, 2018:).They were in the order of physical, cultural and microbiological methods. The treatments, $T_9$, $T_{11}$, $T_{12}$, $T_7$, $T_6$, and $T_5$ were equally effective at more than 30 % reduction of saline water EC value. The treatments effect varied significantly with salt content of water as all the treatments effect were significantly higher for 2.0 dS $m^{-1}$ saline water, but these$T_1$, $T_2$, $T_3$, $T_4$, $T_6$, $T_7$ and $T_8$ treatments equally effective in both 4.0 and 6.0 saline water and the remaining treatments effect were significantly higher for 4.0 dS $m^{-1}$ in comparison to other 2.0 and6.0 saline water (Table 2).

**Ionic concentration of saline water:** Treatments made up with all three approaches namely, $T_9$, $T_{10}$, $T_{11}$ and $T_{12}$ were almost equal in lowering of cationic and anionic concentrations of saline water whose EC value ranged between 2.0 and 6.0 dS $m^{-1}$ (Fig 1). Further, the decline ions concentration for integrated approach was decreased with increased salt content. The highest decline was nearly 78.0 % calcium, 62.7 % magnesium, 32.5 % sodium, 20.6 % chloride and 26.8 % sulphate ions concentrations from saline water of 2.0 dS $m^{-1}$(Fig 2). In total, this approach could reduce 64 % calcium, 51.6 %

magnesium, 24.8 % sodium, 20.5 % sulphate and 15.3% chloride concentrations. The ions removal from saline water followed in the series of calcium, magnesium, sodium, sulphate and chloride implies that the ion adsorption from saline water could be based on valence and size of the ions (Dishon*et al.*2011). Thus, treatments $T_9$ and $T_{10}$ can be carried forward to assess treated water impact on soil and growth and development ofplants

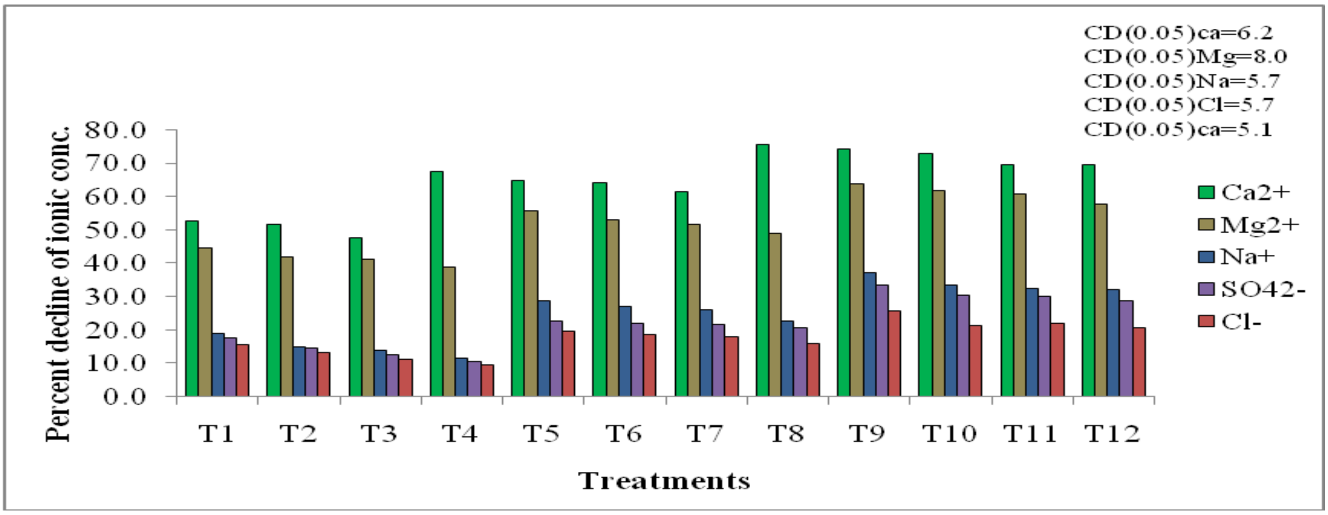


Fig 1: Effect of integrated approach on saline water ionic concentrations

**Effect of integrated approach based saline water treatment on soil properties**

**Soil electrical conductivity:**The soil EC differed significantly for use of treated saline water, which varied significantly with soil types as a relatively very steep decline in comparison to untreated saline water was observed in the saline soil. Moreover, both treatments, namely saline water treated in series to the 0.44 T MFs (6 min) + incubation with ASP (6 g 6 hrs $L^{-1}$) and C10 saline bacterial cultural solution @ 4 ml $L^{-1}$ for 5 days and the treatment of saline water exposure to 0.44 T MFs (6 min) + incubation with MSP @ 6 g 6 hrs $L^{-1}$and $C_{10}$BC solution @ 4 ml $L^{-1}$ for 5 days were equally effective in lowering soil EC (about 42 %) over the control plots irrigated with untreated water (Table 3).

Table 3: Effect of integrated approach based saline water treatments on soil properties

| Treatments | EC ($dSm^{-1}$) | | $Ca^{2+}$ (meq $L^{-1}$) | | $Mg^{2+}$(meq $L^{-1}$) | | $Na^{+}$(meq $L^{-1}$) | | $SO_4^{2-}$ (meq $L^{-1}$) | | $Cl^{-}$ (meq $L^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NS | SS | NS | SS | NS | SS | NS | SS | NS | SS | NS | SS |
| $T_1$ | 1.9 | 3.0 | 1.2 | 4.0 | 3.6 | 4.3 | 9.6 | 15.6 | 3.7 | 6.7 | 7.0 | 11.0 |
| $T_2$ | 1.3 | 2.2 | 0.5 | 2.1 | 2.5 | 3.0 | 4.5 | 7.5 | 2.9 | 4.5 | 6.5 | 8.1 |
| $T_3$ | 1.4 | 2.6 | 0.5 | 2.2 | 2.7 | 3.7 | 4.6 | 7.8 | 3.0 | 4.8 | 6.6 | 8.3 |
| $T_4$ | 3.9 | 4.3 | 3.1 | 5.8 | 8.1 | 9.2 | 15.1 | 22.9 | 9.6 | 10.5 | 16.1 | 22.3 |
| $T_5$ | 2.8 | 3.1 | 0.8 | 2.6 | 4.4 | 4.8 | 10.2 | 15.6 | 5.8 | 8.2 | 14.2 | 17.5 |
| $T_6$ | 2.9 | 3.6 | 0.8 | 2.6 | 4.3 | 6.3 | 10.6 | 16.0 | 6.0 | 8.1 | 14.1 | 17.1 |
| $T_7$ | 5.9 | 7.1 | 5.2 | 6.6 | 11.6 | 14.5 | 31.5 | 41.6 | 15.2 | 16.6 | 22.2 | 30.2 |
| $T_8$ | 4.6 | 5.1 | 1.3 | 3.2 | 7.5 | 9.9 | 20.1 | 26.3 | 6.9 | 9.6 | 20.1 | 24.1 |
| $T_9$ | 4.8 | 5.2 | 1.4 | 3.4 | 8.5 | 10.6 | 20.5 | 27.1 | 7.0 | 10.0 | 20.2 | 24.3 |
| Mean | 3.0 | 3.9 | 1.9 | 3.0 | 1.6 | 2.5 | 15.3 | 19.7 | 6.8 | 8.2 | 16.6 | 20.9 |
| Initial value | 0.6 | 4.8 | 0.9 | 7.0 | 0.7 | 6.7 | 2.8 | 19.0 | 2.2 | 8.8 | 3.8 | 26.4 |
| SEd | 0.3 | 0.4 | 0.3 | 0.4 | 0.3 | 0.4 | 0.9 | 1.2 | 0.4 | 0.6 | 0.3 | 0.6 |
| CD(0.05) | 0.6 | 0.8 | 0.6 | 0.8 | 0.5 | 0.7 | 1.8 | 2.3 | 0.8 | 1.2 | 0.6 | 1.2 |

*$T_1$- The untreated 2.0 dS $m^{-1}$SW, $T_2$- The 2.0 dS $m^{-1}$ SW exposure to 0.44 T MFs (6 min) + The SW incubation with ASP @ 6 g 6 hrs $L^{-1}$ and incubation with $C_{10}$ BC @ 4 ml $L^{-1}$ for 5 days, $T_3$- The 2.0 dS $m^{-1}$ SW exposure to 0.44 T MFs (6 min) + The SW incubation with MSP @ 6 g 6 hrs $L^{-1}$ and incubation with $C_{10}$ BC @ 4 ml $L^{-1}$ for 5 days, $T_4$- The untreated 4.0 dS $m^{-1}$ SW, $T_5$- The 4.0 dS $m^{-1}$ SW exposure to 0.44 T MFs (6 min) + The SW incubation with ASP @ 6 g 6 hrs $L^{-1}$ and incubation with $C_{10}$ BC @ 4 ml $L^{-1}$ for 5 days, $T_6$- The 4.0 dS $m^{-1}$ SW exposure to 0.44 T MFs (6 min) + The SW incubation with MSP @ 6 g 6 hrs $L^{-1}$ and incubation with $C_{10}$ BC @ 4 ml $L^{-1}$ for 5 days, T7- The 6.0 dS $m^{-1}$untreated SW, $T_8$- The 6.0 dS $m^{-1}$SW exposure to 0.44 T MFs (6 min) + The SW incubation with ASP @ 6 g 6 hrs $L^{-1}$ and incubation with $C_{10}$ BC @ 4 ml $L^{-1}$ for 5 days, $T_9$- The 6.0 dS $m^{-1}$ SW exposure to 0.44 T MFs (6 min) + The SW incubation with MSP @ 6 g 6 hrs $L^{-1}$ and incubation with $C_{10}$ BC @ 4 ml $L^{-1}$ for 5 days,*

**Water-soluble ionic concentrations:** All the saline water used for irrigation enriched the water-soluble fraction of calcium, magnesium and sodium ion concentrations and they were in the order of sodium>magnesium>calcium in non-saline soil. The calcium concentration increased about 0.4, 2.2 and 4.3 meq $L^{-1}$, respectively in the 2.0, 4.0 and 6.0 dS $m^{-1}$ saline water. Similarly, the 2.0, 4.0 and 6.0 dS $m^{-1}$ saline water increased respectively the magnesium concentration 1.2, 1.5 and 2.9 meq $L^{-1}$ and the sodium concentrations 6.8, 12.3 and 28.7 meq $L^{-1}$ (Table 3). As the calcium and magnesium ions are subjected to positive adsorption on colloidal complex when their concentrations in soil solution increase due to valence and ionic size (Dishon*et al.* 2011). Further, the ionic concentrations of the saline water are relatively low compared to sodium. Moreover, the sodium is more prone for negative adsorption (Holkar*et al.*2016). The saline water treatments, exposure to 0.44 T MF for 6 minutes duration under south pole, incubating the same saline water under ASP @ 6 g 6 hrs $L^{-1}$, and then incubating to $C_{10}$BC solution for 5 days and The treatment of SW exposure to 0.44 T MFs for 6 mins, incubating the same SW with MSP @ 6 g 6 hrs $L^{-1}$, and then to C10 BC solution @ 4 ml $L^{-1}$ for 5 days were equally effective in amelioration of ionic concentrations of saline water , which reported to reduce the soluble fraction of calcium and magnesium ions concentrations nearly about 58 and 43.5 % under the treatment of 2.0 dS $m^{-1}$ saline water, 73.0 and 50.0 % under 4.0 dS $m^{-1}$ saline water and 54 and 40.3 % under 6.0 dS $m^{-1}$ saline water. Similarly, the soil sodium concentrations were reduced about 52.4, 31.2 and 35.5 % in 2.0, 4.0 and 6.0 dS $m^{-1}$ saline water, respectively.On average, the treatment could bring down about 62 % calcium accumulation, 44.6 % magnesium accumulation and 39.7 % sodium accumulation from non-saline soil for use of sodium enriched saline water whose EC value varied between 2 and 6.0 dS $m^{-1}$.

Similar to water-soluble fractions of cations, the anions concentrations of non-saline soils differed significantly for use of saline water and water treatment. The chloride and sulphate concentrations increased with increased concentration of saline water and the chloride content increase was relatively very high and it was 4.2, 12.3 and 18.4 meq $L^{-1}$ increase in 2.0, 4.0 and 6.0 dS $m^{-1}$ saline water and 2.6, 7.4 and 13 meq $L^{-1}$ the sulphate concentration increase. The both treatments were equally effective for anions also and the effects were 18.1, 11.9 and 9.2 % reduction of chloride concentrations in the respective 2.0, 4.0 and 6.0 dS $m^{-1}$ saline water and 38.3, 30.6 and 30.9 % reduction for the sulphate (Charles*et al.* 2016).

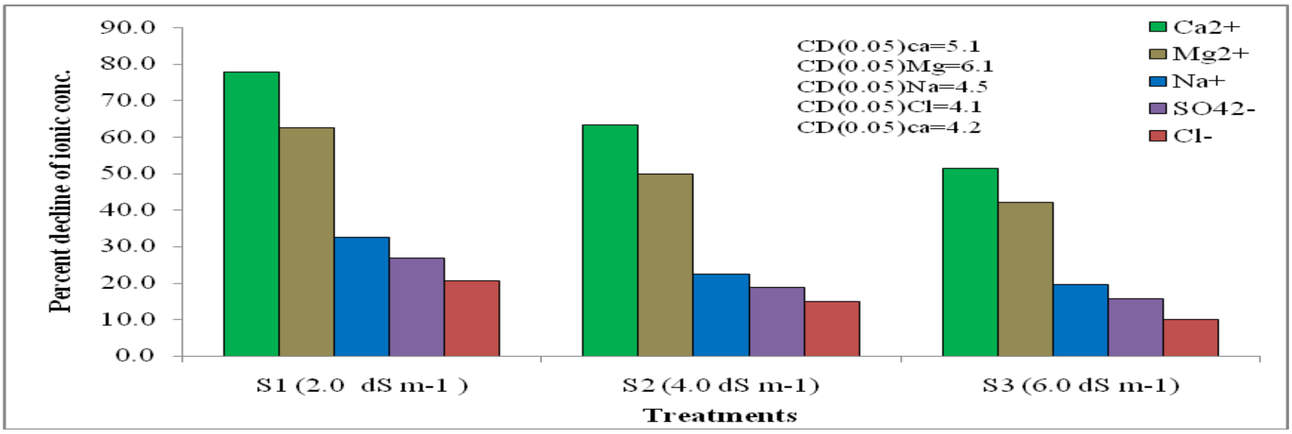


Fig 2: Effect of integrated approach on ionic concentrations for different kinds of saline water

Under the saline soil, the saline water decreased the concentrations of calcium and magnesium, which decreased with increase of salt concentrations. On an average, it was the decline of nearly 20 % calcium and 28 % magnesium concentrations. In contrast to these ions, the sodium ion concentration decreased under the 2.0 dS $m^{-1}$saline water (3.4 meq $L^{-1}$) but accumulated from the 4.0 (5.0 meq $L^{-1}$) and 6.0 dS $m^{-1}$ (15.6 meq $L^{-1}$) saline water treatments. Both the treatments had almost the same effect, which increased with increase of ions concentration, on average, 57.2 % reduction of calcium, 47.2 % reduction of magnesium and 36.9% sodium concentrations were observed due to saline water treatments. In contrast to cations concentrations change in saline soil, the chloride concentrations decreased by 11.9 and 3.1 meq $L^{-1}$under 2.0 and 4.0 dS $m^{-1}$ saline water and the decrease was 3.0 meq $L^{-1}$ for sulphate concentration under 2.0 dS $m^{-1}$saline water. Whereas, the 6.0 dS $m^{-1}$ saline water increased the soil chloride and sulphate concentrations by 3.8 and 2.8 meq $L^{-1}$ and the 0.8 meq $L^{-1}$ sulphate content increase from the 4.0 dS $m^{-1}$ saline water. It was more than 22 % reduction of anions concentrations in saline soil.

**Effect of ameliorated saline water on growth and development of black gram**

The plant height of black gram was not sensitive up to the saline water 2.0 dS $m^{-1}$but significant reduction of 12.9 % under the treatment 4.0 dS $m^{-1}$ saline water and 33.7% under the treatment of 6.0 dS $m^{-1}$ saline water were recorded in the non-saline soil. Similarly, the height reduced about 19 % under 2.0 dS $m^{-1}$ saline water and 40.2 % under 4.0 dS $m^{-1}$saline water in the saline soil (Rengasamy, 2010). The treatment effects on plant height were 5.5 and 9.0 % increase under the treatments of 4.0 and 6.0 dS $m^{-1}$ saline water of non-saline soil and the 7.9 and 15.0 % more height was from the saline soil (Table 4). The above and belowground biomass production of black gram was not affected significantly with use of saline water up to 2.0 dS $m^{-1}$. The impact of reduced biomass got increase with increase of saline water and the highest was recorded under the treatment of 6.0 dS $m^{-1}$ saline water in both the soil types. It was 22.3 % and 31.7% decrease of above ground biomass production in the respective 2.0 and 4.0 dS $m^{-1}$ saline water treatments of non-saline soils. Similarly, 25.4 % and 35.4 % reduction of below ground biomass observed in the respective of 4.0 and 6.0 dS $m^{-1}$ saline water of saline soil. Both the treatments of saline water were reported to increase above ground biomass production nearly 11 % under 2.0 dS $m^{-1}$ saline water and 18.4 % under the 4.0 dS $m^{-1}$ saline water in the non-saline soils and it was 13.8 % under the 2.0 dS $m^{-1}$ saline water and 21.0 % increase under 4.0 dS $m^{-1}$ saline water in the saline soil (Table 4). The dry matter production was also affected significantly for use of saline water and the 4.0 and 6.0 saline water treatments recorded the effect of 17.6 and 22.9 % reduction in the non- saline soils and 23.1 and 33.3 % the reduction of biomass in the 4.0 and 6.0 dS $m^{-1}$ saline water in the saline soil (Alvarez *et al.* 2012). The low dry matter production indicates the salinity interference on plant photosynthesis process and reduced accumulation of dry matter (Paranychianakis *et al.* 2005).Both the treatments of saline water amelioration increased the DMP of black gram and the effect were significant only the 6.0 dS $m^{-1}$ saline water which increased the DMP about 12.4 % in the non-saline soil and 18.8 % in the saline soil.

For the saline water treatment effect on nutrients uptake, it was no difference between control and treated 2.0 dS $m^{-l}$ saline water but there was statically high uptake of 2.5% and

Table 4: Effect of integrated approach based saline water treatments on growth and development and nutrient uptake of black gram

| Treatments | Plant height (cm) | | AGB (g $p^{-1}$) | | BGB (g $p^{-1}$) | | DMP (g $p^{-1}$) | | Yield (g $p^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NS | SS | NS | SS | NS | SS | NS | SS | NS | SS |
| T1 | 25.4 | 24.2 | 4.9 | 4.5 | 3.1 | 2.9 | 3.0 | 2.6 | 32.3 | 25.6 |
| T2 | 26.0 | 25.5 | 5.2 | 4.0 | 3.2 | 3.1 | 3.2 | 2.7 | 33.2 | 29.0 |
| T3 | 26.0 | 25.5 | 5.1 | 4.8 | 3.2 | 3.0 | 3.0 | 2.8 | 33.1 | 28.3 |
| T4 | 23.0 | 20.3 | 4.0 | 2.9 | 2.5 | 2.2 | 2.6 | 2.2 | 24.5 | 20.4 |
| T5 | 24.0 | 22.0 | 4.5 | 3.5 | 2.7 | 2.4 | 2.8 | 2.4 | 26.2 | 24.4 |
| T6 | 24.2 | 21.9 | 4.5 | 3.4 | 2.8 | 2.3 | 2.7 | 2.4 | 25.8 | 24.4 |
| T7 | 17.0 | 15.0 | 2.4 | 1.9 | 2.2 | 1.8 | 2.4 | 2.0 | 17.1 | 14.1 |
| T8 | 19.0 | 17.4 | 3.0 | 2.6 | 2.3 | 2.0 | 2.8 | 2.4 | 21.3 | 18.2 |
| T9 | 19.0 | 17.1 | 3.0 | 2.6 | 2.4 | 2.1 | 2.7 | 2.3 | 21.0 | 17.9 |
| Mean | 23.0 | 21.4 | 4.2 | 3.6 | 0.2 | 0.3 | 0.1 | 0.2 | 27.5 | 24.5 |
| Sed | 0.6 | 0.9 | 0.1 | 0.6 | 0.4 | 0.6 | 0.2 | 0.3 | 0.4 | 0.8 |
| CD(0.05) | 1.1 | 1.7 | 0.2 | 0.3 | 3.4 | 3.3 | 3.1 | 2.9 | 0.8 | 1.4 |

3.4% in the treated 4.0 and 6.0 dS $m^{-1}$ over the respective untreated saline water in the normal soil.However, the nutrient uptake for saline water treatment was significantly higher in all the saline water over the respective untreated saline water in the saline soil. It was 1.1 % increase under treated 2.0 dS $m^{-1}$ saline water, 2.8 % increase under treated 4.0 dS $m^{-1}$ saline water and 4.9 % increase under treated 6.0 dS $m^{-1}$ saline water(Table 4). The black gram is sensitive to water salinity that significant yield reduction of 6.4 % under non-saline soil and 14.8 % reduction under saline soil from 2.0 dS$m^{-1}$ saline water were observed**.** As the salinity of water increased, the yield was also reduced and the highest yield reductions were 42.4 % in the non-saline soil and 50.6 % in the saline soil from 6.0 dS $m^{-1}$ saline water (Shanti *et al.* 2014). Further, the treated saline water reduced the water salinity impact on seed yield and the treatment effect increased with increase of salt content and the highest effect were 16.8 % and 24.5 % yield increase over the same untreated saline water. Over all, the seed yield increase for integrated based treated saline water whose EC value between 2 and 6.0 dS $m^{-1}$ were 10.3 % in non-saline soil and 16.5 % in saline soil (Table 4).

In conclusion, saline water exposed in series to the integrated approach based saline water treatments results in improved saline water quality and is more efficient over any of the individual approach. Moreover, either of treatments, the saline water exposure to 0.44 T MFs for 6 mins + incubation with Amla Stem Powder@ 6 g $L^{-1}$6 hrs + The SW incubation with C10 BC solution @ 4 ml $L^{-1}$for 5 days, and the saline water exposure to 0.44 T MFs for 6 mins + Muringaseed powder at the rate of 6 g $L^{-1}$ 6 hours + The SW incubation with $C_{10}$BC solution @ 4 ml $L^{-1}$for 5 days can be recommended for saline water treatments as it improves saline water quality for adsorptive removal of salts and reduces salt accumulation in soil. The improvement in yield were10.3 % in non-saline soil and 16.5 % in saline soil when 2.0 to 6.0 dS $m^{-1}$ saline water was used for irrigation. Still, one-time treatment of saline water at critical stage of crop when other techniques are not feasible economically it would save the crop and improve livelihood of farmers under water scarce situation.

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