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Influence of INM on Soil Soluble Ions in Pearl Millet-Wheat Cropping System in Semi-Arid Region

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ABSTRACT

The major salts in saline soils are chloride and sulphates of sodium, calcium, magnesium and potassium and these salts directly and indirectly interfere with various biological processes in the soil. The present study was conducted to know the effect of these salts on soil properties at soil science research farm, CCS Haryana Agricultural University, Hisar-125004 (Haryana) India. The study included twelve treatments viz. T_1 *(75 % RDF),* T_2 *(recommended dose of fertilizers, RDF),* T_3 *[75% RDF +ST-3 (Azotobacter chroococcum)],* T_4 *(RDF +ST-3),* T_5 *[75% RDF+ 2.5 t/ha Biogas slurry (BGS) + ST-3],* T_6 *(RDF+ 2.5 t/ha BGS+ ST-3),* T_7 *[75% RDF+ 2.5 t/ha Vermicompost (VC)+ ST-3],* T_8 *(RDF+ 2.5 t/ha VC+ ST-3),* T_9 *[75% RDF+ 10 t/ha farm yard manure (FYM) + Biomix],* T_{10} *(RDF+ 10 t/ha FYM+ Biomix),* T_{11} *(75% RDF+ 2.5 t/ha VC+ Biomix) and* T_{12} *(RDF+ 2.5 t/ha VC+ Biomix). The lowest mean total cations as well as anions has been found under treatment* T_{10} *viz. 15.87 and 16.63; and highest was observed under treatment* T_1 *viz. 19.11 and 20.59 meq* l^{-1}*, after harvest of pearl millet and wheat, respectively.*

Keywords: *Integrated nutrient management, Saline soil, Cropping system, Vermicompost, Biogas slurry*

INTRODUCTION

As people are struggling for natural resources and climate change to meet the growing food demand (Zhang et al., 2022), it is essential to reduce the crop losses occurring due to soil degradation. The inevitable use of saline water resulted in increased concentration of salts, especially, sodium ions which have dispersing effect on soil aggregates that deteriorates the soil structure which interfere with better crop production and overall soil health. The process of irrigation induced soil salinity is a major concern for agricultural sustainability and economical growth of nation in arid and semi-arid regions where good quality irrigation water is not available for crop production. It affects the soil fertility status and plant growth (Elmeknassi et al., 2024).

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The saline soils are characterized by pH less than 8.5; EC is above 40 mM NaCl, which creates an osmotic pressure of 0.2 MPa at 25°C. Most of the crops experiences yield reduction at this electrical conductivity of the saturation extracts (Munns, 2005 and Jamil et al., 2011).The major salts in saline soils are chloride and sulphates of sodium, calcium, magnesium and potassium (Sharma et al., 2015) and these salts directly and indirectly interfere with various biological processes in the soil. Higher content of chlorides, sulphates, carbonates and bicarbonates deteriorates the soil physical properties (such as permeability and soil aeration) due to swelling and dispersion of clay particles, increase in soil pH, electrical conductivity and exchangeable sodium percentage (Minhas et al., 2019); and development of salinity not only reduces choice of crop but also limits choice of crop (Meena et al., 2018). About 69% of the total wheat production is adversely affected by high salinity (Isayenkov, 2012) among cereal crops. The high concentration of salts can inhibit the seed germination and seedling growth due to combined effect of osmotic potential and specific ion toxicity. Under higher salt concentration, the applied nutrients will also leach down due to poor physical properties and reduced nutrient retention leads to nutrient deficiency in soil causing reduction in crop production. The irrigation water of hot and dry climates should not contain soluble salts in amount that can adversely affect the crop production and soil properties, however good quality water is usually not available in sufficient quantity to satisfy the need of water requirement for all crops grown. Farmers are obliged to use water with higher content of dissolved salts under these conditions that eventually results in crop yield reduction. The sole application of inorganic fertilizers is not sufficient in maintaining sustainability of soil health and productivity. Under such conditions, the organic amendments works as soil conditioners that has the capability to improve soil structure, water holding capacity, soil aggregation and microbial activities. Integrated nutrient management (INM) is one of the most important tools for better utilization of resources for getting more crop production with less expenditure. INM is important practice that can be adopted to overcome the problems of saline-water irrigation. The management practices like INM and cropping systems that ensure greater amount of crop residues returned to the soil are expected to cause a net buildup of SOC stock (Benbi, 2015). Conjunctive use of all available resources i.e. organic, inorganic and bio-fertilizers based on economic consideration to sustain soil fertility and productivity are perhaps the best way to maintain soil fertility in our climatic condition. The INM plays important role in reducing negative impact of dissolved ions on soil.

Therefore, the present study was conducted to evaluate Influence of INM on soil soluble ions under saline water irrigation in pearl millet-wheat cropping system in semi-arid region.

MATERIALS AND METHODS

Site description

The present investigation was carried out at Soil Research Farms of Chaudhary Charan Singh (CCS) Haryana Agriculture University, Hisar (Haryana), during Kharif and Rabi seasons of 2022-23 and 2023-24. The site is characterised by a semi-arid climate with maximum temperature ranges between 43 to 48 °C during summer in May and June, while temperatures below the freezing point accompanied by frost occur during December and January. The mean annual rainfall of the area is about 450 mm. The texture of the soil at the experimental site was sandy loam.

Treatment details

The experiment consisted of twelve treatments i.e. T_1 (75 % recommended dose of fertilizers (RDF)), T_2 (100 % RDF), T_3 [75 % RDF + ST-3 (*Azotobacter chroococcum*)], T_4 (100 % RDF + ST-3), T_5 [75 % RDF + 2.5 t ha^{-1} biogas slurry (BGS) + ST-3], T_6 (100 % RDF + 2.5 t ha^{-1} BGS + ST-3), T_7 [75 % RDF + 2.5 t ha^{-1} vermicompost (VC) + ST-3], T_8 (100 % RDF + 2.5 t ha^{-1} VC + ST-3), T_9 [75 % RDF +

10 t ha^{-1} farm yard manure (FYM) + biomix (*Azotobacter* + *Azospirillum* + phosphate solubilizing bacteria (PSB))], T_{10} (100 % RDF + 10 t ha^{-1} FYM + biomix), T_{11} (75 % RDF + 2.5 t ha^{-1} VC + biomix) and T_{12} (100 % RDF + 2.5 t ha^{-1} VC + biomix) and was laid out in factorial randomized block design (RBD) with three replications. The FYM, VC and BGS were used as organic sources and urea, single super phosphate and murate of potash were used as chemical fertilizers. The chemical composition of organic manures used in the experiment has been presented in Table 1 and organic manures were applied during both Kharif and Rabi seasons. Pearl millet variety HHB 299 and wheat variety HD 3086 were used for the experiment. Saline water having an EC of 7.5 - 8.0 dS m^{-1} was used for irrigation. The soluble cations and anions (Richards, 1954) in irrigation water were: Na^+ (54.49 meq L^{-1}), K^+ (0.32 meq L^{-1}), Ca^{2+} (8.63 meq L^{-1}), Mg^{2+} (15.28 meq L^{-1}), HCO_3^- (1.83 meq L^{-1}), Cl^- (61.03 meq L^{-1}) and SO_4^{2-} (17.12 meq L^{-1}).

Soil parameters

Carbonates and bicarbonates in aliquot were determined by titrating it with standard H_2SO_4 using phenolphthalein and methyl red indicators, respectively (Richard, 1954). Chlorides in the aliquot were determined by titrating it with $AgNO_3$ solution using potassium dichromate as an indicator (Richard, 1954). Sulphate in aliquot was determined by Chesnin and Yien (1950) method by using barium chloride using gum acacia solution. Sodium and potassium in aliquot were determined by using flame photometer (Richard, 1954). Calcium and magnesium in aliquot was determined by versenate titration using Eriochrome black- T indicator in the presence of buffer (Richard, 1954). The chemical analysis of soil properties of the experimental site was performed using established protocols as given in Table 2.

Statistical analysis

Statistical significance was tested at the 5 % probability level using the F-test. The difference between treatments was calculated using the critical difference (CD) worked out by OPSTAT software developed by the Department of Statistics, CCS Haryana Agricultural University (Sheoran et al., 1998).

Table 1: Chemical composition of organic manures used in investigation

Chemical properties	**FYM**	**VC**	**BGS**	**Method**
pH	7.41	7.40	7.53	pH meter (Jackson, 1973)
EC (dS m^{-1})	1.27	1.30	1.42	Conductivity meter (Richards, 1954)
Total nitrogen (%)	0.75	1.59	1.63	Nesslers' reagent (Snell and Snell, 1950)
Total phosphorus (%)	0.61	0.57	1.02	Vanadomolybdate phosphoric acid yellow colour method (Jackson, 1967)
Total potassium (%)	1.12	1.09	1.46	Flame photometer (Jackson, 1967)
Iron (mg kg^{-1})	2.50	2.10	2.30	DTPA extractable method (Lindsay and Norvell 1978)
Manganese (mg kg^{-1})	286	271	277	
Zinc (mg kg^{-1})	224	216	219	
Copper (mg kg^{-1})	25.0	26.1	25.2	

Table 2: Initial soil properties of the experimental site

Soil property	Value	Analytical method
pH	8.10	Glass electrode pH meter (Jackson, 1973)
EC (dS m^{-1}, 25 °C)	0.87	Conductivity meter (Richards, 1954)
Texture	Sandy loam	International pipette method (Piper, 1944)
Organic carbon (%)	0.45	Wet digestion method (Walkley and Black, 1934)
Available N (Kg ha^{-1})	122	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P (Kg ha^{-1})	16.3	Sodium bicarbonate extractable P method (Olsen, 1954)
Available K (kg ha^{-1})	290	Ammonium acetate extractable K method (Richards, 1954)

RESULTS AND DISCUSSION

Soil pH

The data pertaining to soil pH is presented in table 3 revealed that it varied non-significantly by addition of organic manures along with inorganic fertilizers under saline water irrigation. The soil pH varied from 7.71 to 8.10 before sowing of Kharif crop in 2022; 8.62 to 8.09, 7.47 to 8.07 after harvest of pearl millet during 2022-23 and 2023-24; and 7.55 to 8.05 and 7.42 to 8.02 after harvest of wheat during 2022-23 and 2023-24, respectively. However, comparatively higher reduction in soil pH was observed in plots receiving organic manures along with RDF as compared to sole application of inorganic fertilizers under saline water irrigation. The lowest mean value of soil pH was found in treatment T_{10} viz. 7.55 and 7.49 after harvest of pearl millet and wheat, respectively. The soil pH reduced by 6.62 and 6.90 % in treatment T_{10} as compared to 75% RDF, while reduction in treatment T_{12} was 4.83 and 5.04 % after harvest of pearl millet and wheat, respectively. The mean reduction in soil pH with treatment T_3 and T_4 was found 0.31 and 0.62 % after pearl millet and wheat harvest, respectively which was comparatively higher than 75% RDF. The treatments T_{10} was found non-significantly superior over T_{12} and T_6 with maximum percentage reduction in soil pH in both pearl millet and wheat crop.

Electrical conductivity, EC_e

The data related to electrical conductivity of saturation extract of soil (EC_e) has been presented in table 4. The EC_e increased significantly with addition of various organic manures in combination with inorganic fertilizers during both years of experimentation under saline water irrigation. The lowest mean value of EC_e was recorded under treatment T_{10} viz. 7.36 and 7.72 dS m^{-1}, which was being at par with treatment T_{12} viz. 7.45 and 7.87 dS m^{-1}, T_8 viz. 7.51 and 7.97 dS m^{-1} and T_6 viz. 7.64 and 8.05 dS m^{-1}, after harvest of pearl millet and wheat, respectively. However, significantly higher value of EC_e was observed under treatment T_1 viz. 8.87 and 9.55 dS m^{-1} and T_2 viz. 8.59 and 9.19 dS m^{-1} after harvest of pearl millet and wheat, respectively after two year of experimentation as compared to other treatments. The EC_e was 17 and 19.2 % lower under treatment T_{10}; and 16 and 17.7 % lower with treatment T_{12} as compared to treatment T_1 after pearl millet and wheat harvest, respectively. The treatment T_1, T_2, T_3 and T_4 varied non significantly with each other and treatment T_4 recorded lowest EC_e (8.41 and 8.93 dS m^{-1}) after harvest of both pearl millet and wheat, respectively.

Soluble cations and anions

The results related to soluble cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}) has been presented in table 5, 6, 7, and 8 revealed that soluble cations and anions increased non-significantly with various treatments during both years of cropping season under saline water irrigation. The mean soluble cations viz. Na^+, K^+, Ca^{2+} and Mg^{2+} in soil solution varied from 5.10 to 7.19, 1.48 to 1.83, 9.29 to 10.09 meq l^{-1}, respectively after harvest of pearl millet and 7.28 to 8.32, 7.96 to 10.35 and 1.39 to 1.92 meq l^{-1}, respectively after harvest of wheat under saline water irrigation. The mean soluble anions viz. HCO_3, Cl^-, SO_4^{2-} varied from 0.72 to 1.08, 10.34 to 12.60 and 4.80 to 5.44 meq l^{-1}, respectively after harvest of pearl millet and from 0.79 to 1.15, 10.52 to 13.28 and 5.32 to 6.17 meq l^{-1}, respectively after harvest of wheat under saline water irrigation. The data revealed that carbonate was absent in the soil solution. The lowest mean total cations as well as anions has been found under treatment T_{10} viz. 15.87 and 16.63; and highest was observed under treatment T_1 viz. 19.11 and 20.59 meq l^{-1}, after harvest of pearl millet and wheat, respectively.

Table 3: Effect of INM on soluble cations - Na^+, K^+, $Ca^{2+} + Mg^{2+}$ (meq l^{-1}) of soil under saline water irrigation after harvest of pearl millet

		Na^+			K^+			$Ca^{2+} + Mg^{2+}$		
Sr. No.	**Treatments**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**
T_1	**75% RDF**	7.04	7.34	7.19	1.77	1.89	1.83	9.99	10.19	10.09
T_2	**RDF**	6.69	7.09	6.89	1.68	1.84	1.76	9.83	9.86	9.85
T_3	**75%RDF + ST-3**	6.97	7.29	7.13	1.71	1.84	1.78	9.98	10.12	10.05
T_4	**RDF +ST-3**	6.52	6.78	6.65	1.63	1.81	1.72	9.67	9.82	9.75
T_5	**75% RDF+ BGS+ ST-3**	5.85	6.03	5.94	1.61	1.78	1.70	9.59	9.75	9.67
T_6	**RDF + BGS + ST-3**	5.30	5.35	5.33	1.51	1.59	1.55	9.51	9.65	9.58
T_7	**75% RDF+VC + ST-3**	5.58	5.73	5.66	1.61	1.74	1.68	9.53	9.71	9.62
T_8	**RDF+ VC+ ST-3**	5.18	5.31	5.25	1.48	1.58	1.53	9.35	9.47	9.41
T_9	**75% RDF+FYM+Biomix**	5.36	5.44	5.40	1.51	1.63	1.57	9.51	9.68	9.60
T_{10}	**RDF + FYM+ Biomix**	5.04	5.15	5.10	1.40	1.55	1.48	9.27	9.31	9.29
T_{11}	**75% RDF+ VC+ Biomix**	5.55	5.56	5.56	1.54	1.68	1.61	9.52	9.70	9.61
T_{12}	**RDF+ VC+Biomix**	5.15	5.26	5.21	1.42	1.56	1.49	9.31	9.39	9.35
	C.D. (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4: Effect of INM on soluble cations -Na^+, K^+, $Ca^{2+} + Mg^{2+}$ (meq l^{-1}) of soil under saline water irrigation after harvest of wheat

		Na^+			$Ca^{2+} + Mg^{2+}$			K^+		
Sr. No.	**Treatments**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**
T_1	**75% RDF**	8.12	8.52	8.32	9.67	11.03	10.35	1.90	1.94	1.92
T_2	**RDF**	7.96	8.24	8.10	9.23	10.47	9.85	1.80	1.89	1.85
T_3	**75%RDF + ST-3**	8.07	8.45	8.26	9.61	10.85	10.23	1.85	1.91	1.88
T_4	**RDF +ST-3**	7.84	8.21	8.03	8.97	9.92	9.45	1.69	1.87	1.78
T_5	**75% RDF+ BGS+ ST-3**	7.69	8.18	7.94	8.27	8.90	8.59	1.65	1.86	1.76
T_6	**RDF + BGS + ST-3**	7.49	7.91	7.70	7.94	8.26	8.10	1.45	1.65	1.55
T_7	**75% RDF+VC + ST-3**	7.63	8.16	7.90	8.12	8.64	8.38	1.60	1.82	1.71
T_8	**RDF+ VC+ ST-3**	7.44	7.74	7.59	7.89	8.25	8.07	1.42	1.62	1.52
T_9	**75% RDF+FYM+Biomix**	7.51	7.95	7.73	7.95	8.28	8.12	1.48	1.77	1.63
T_{10}	**RDF + FYM+ Biomix**	7.25	7.31	7.28	7.72	8.19	7.96	1.32	1.46	1.39
T_{11}	**75% RDF+ VC+ Biomix**	7.54	8.06	7.80	7.99	8.34	8.17	1.52	1.79	1.66
T_{12}	**RDF+ VC+Biomix**	7.35	7.59	7.47	7.82	8.24	8.03	1.38	1.52	1.45
	C.D. (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 5: Effect of INM on soluble anions - CO_3^{2-} , HCO_3^-, Cl^- and SO_4^{2-} (meq l^{-1}) of soil under saline water irrigation after harvest of pearl millet

		CO_3^{2-}		HCO_3^-			Cl^-			SO_4^{2-}		
Sr. No.	Treatments	2022-23	2023-24	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
T_1	75% RDF	Nil	Nil	1.04	1.11	1.08	12.37	12.82	12.60	5.49	5.39	5.44
T_2	RDF	Nil	Nil	1.02	1.04	1.03	11.87	12.31	12.09	5.44	5.31	5.38
T_3	75%RDF + ST-3	Nil	Nil	1.02	1.09	1.06	12.30	12.68	12.49	5.48	5.34	5.41
T_4	RDF +ST-3	Nil	Nil	0.97	0.99	0.98	11.63	11.99	11.81	5.43	5.23	5.33
T_5	75% RDF+ BGS+ ST-3	Nil	Nil	0.94	0.97	0.96	11.03	11.24	11.14	5.35	5.08	5.22
T_6	RDF + BGS + ST-3	Nil	Nil	0.81	0.92	0.86	10.51	10.61	10.56	5.07	4.99	5.03
T_7	75% RDF+VC + ST-3	Nil	Nil	0.93	0.96	0.95	10.76	11.01	10.89	5.21	5.03	5.12
T_8	RDF+ VC+ ST-3	Nil	Nil	0.72	0.82	0.77	10.48	10.58	10.53	4.96	4.81	4.89
T_9	75% RDF+FYM+Biomix	Nil	Nil	0.84	0.95	0.89	10.53	10.68	10.61	5.12	5.01	5.07
T_{10}	RDF + FYM+ Biomix	Nil	Nil	0.69	0.75	0.72	10.27	10.41	10.34	4.85	4.75	4.80
T_{11}	75% RDF+ VC+ Biomix	Nil	Nil	0.91	0.96	0.94	10.70	10.82	10.76	5.16	5.01	5.09
T_{12}	RDF+ VC+Biomix	Nil	Nil	0.71	0.76	0.74	10.38	10.54	10.46	4.90	4.79	4.85
	C.D. (p=0.05)	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6: Effect of INM on soluble anions - CO_3^{2-} , HCO_3^-, Cl^- and SO_4^{2-} (meq l^{-1}) of soil under saline water irrigation after harvest of wheat

		CO_3^{2-}		HCO_3^-			Cl^-			SO_4^{2-}		
Sr. No.	Treatments	2022-23	2023-24	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
T_1	75% RDF	Nil	Nil	1.13	1.17	1.15	12.45	14.10	13.28	6.11	6.22	6.17
T_2	RDF	Nil	Nil	1.08	1.09	1.09	11.87	13.34	12.61	6.04	6.17	6.11
T_3	75%RDF + ST-3	Nil	Nil	1.11	1.14	1.13	12.37	13.88	13.13	6.05	6.19	6.12
T_4	RDF +ST-3	Nil	Nil	1.06	1.09	1.08	11.45	12.68	12.07	5.99	6.23	6.11
T_5	75% RDF+ BGS+ ST-3	Nil	Nil	1.05	1.07	1.06	10.78	11.98	11.38	5.78	5.89	5.84
T_6	RDF + BGS + ST-3	Nil	Nil	0.91	0.93	0.92	10.46	11.33	10.90	5.51	5.56	5.54
T_7	75% RDF+VC + ST-3	Nil	Nil	0.96	0.98	0.97	10.75	11.81	11.28	5.64	5.83	5.74
T_8	RDF+ VC+ ST-3	Nil	Nil	0.87	0.90	0.89	10.41	11.19	10.80	5.47	5.52	5.50
T_9	75%RDF+FYM+Biomix	Nil	Nil	0.93	0.95	0.94	10.48	11.42	10.95	5.52	5.63	5.58
T_{10}	RDF + FYM+ Biomix	Nil	Nil	0.77	0.81	0.79	10.29	10.74	10.52	5.23	5.41	5.32
T_{11}	75% RDF+ VC+ Biomix	Nil	Nil	0.94	0.96	0.95	10.52	11.45	10.99	5.59	5.78	5.69
T_{12}	RDF+ VC+Biomix	Nil	Nil	0.81	0.87	0.84	10.40	11.03	10.72	5.34	5.45	5.40
	C.D. (p=0.05)	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS

DISCUSSION

Soil pH and EC_e

The perusal of data regarding soil pH and EC_e (table 3 and 4) revealed that soil pH was decreased non-significantly with various treatments under saline water irrigation and the maximum reduction was observed with INM as compared to sole application of inorganic fertilizers. The treatment T_{10} (RDF+ FYM+ Biomix) recorded maximum reduction in soil pH and lowest was recorded with treatment T_1 (75% RDF) under increasing salinity level from year 2022-23 to 2023-24. The integration with FYM recorded lower soil pH compared to vermicompost and biogas slurry. The decrease in soil pH under increasing salinity might be due to the fact that the salinity leads to increased electrolyte concentration in soil solution which expand the diffuse double layer of the clay surface and the H^+ ions are free to move in soil and reduced the soil pH (Aechra et al., 2017 and Ankush et al., 2021). The soil electrical conductivity increased after two years of experimentation under saline water irrigation in pearl millet-wheat cropping system. However the percent increase in soil EC_e was lower with T_{10}, followed by T_{12}, T_8 and T_6. The lower electrical conductivity under integrated application of organic manures and inorganic fertilizers might be due to the fact that organic manures act as chelated complex and will bind the soluble salts with it and thus reduced their concentration in soil solution (Meena et al., 2016). The highest increase in electrical conductivity of soil was found with treatment T_1, followed by T_3 and T_4. The continuous application of saline water leads to increase in salt concentration of soil and thus electrical conductivity of soil. Significantly higher electrical conductivity was observed during Rabi 2022-23 and 2023-24 as compared to Kharif 2022-23 and 2023-24 which were due to higher rainfall occurrence during Kharif season that leach down the salts from upper soil layer. Our results are in accordance with the findings of Ragab et al. (2008), Ghuman et al. (2010), Salih and Kia (2013). The variation in soil pH and EC with among different organic manures depends on the initial EC and pH of manures used in the experiment and also on site-specific factors of saline soils (Regar et al., 2005). The reduced soil pH with addition of organic manures might be due to the release of various organic acids during decomposition of organic matter that resulted in lower soil pH.

Soluble cations and anions

The soluble cations and anions as presented in table 5 to 8 revealed that cations and anions varied non-significantly among various treatments under saline water irrigation. The cations and anions increased linearly with increasing salinity level after two years of experimentation. The increase in concentration of soluble cations and anions might be due to longer use of saline water to irrigate field that will increase the distribution and concentration of salts in the soil solution. However comparatively lower accumulation of cations and anions were recorded with addition of organic manures as compared to inorganic fertilizers. Meena *et* al. (2016) also reported that addition of organic manures reduced the soil EC and, thus salt concentration in soil solution. Our results are in comformity with findings of Ragab et al. (2008), Salih and Kia (2013) and Ankush et al. (2022). Exo-polysaccharide production by PGPR strains also helps in binding cations, including Na, and thus could decrease Na available for plant uptake and help alleviate salt stress (Haj-Amor et al., 2018).

CONCLUSION

The continuous use of saline water for irrigation in sandy loam textured soil resulted in increased salt concentration in the soil from 2022-23 to 2023-24. The treatment T_{10} (RDF+ FYM+ Biomix) was found superior over others with maximum reduction in soil pH and also less percentage increase in electrical conductivity and soluble cations and anions. The difference among various organic manures, i.e. FYM, VC and BGS, might be due to their chemical composition, decomposition rate and release pattern of nutrients for plant growth. The study is very helpful for farmers to save unnecessary cost on chemical fertilizers.

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