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Research Article

Effect of Organic Amendments on Physico-chemical Properties of Sandy Loam Soils of Haryana under Saline Water Irrigation

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ABSTRACT

Non-availability of good quality irrigation water in arid and semi-arid regions is an emerging concern for better crop production and obtaining higher returns from farm produce. The higher evaporation rate in these areas resulted in the development of saline soils, which interfere with crop production and sustainability in agriculture. To overcome such problems, the present investigation was conducted at a soil science research farm, CCS Haryana Agricultural University, Hisar, Haryana, India, to know the effects of various organic amendments on physico-chemical properties of soil, viz. bulk density, water holding capacity, electrical conductivity and pH of soil. 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 soil texture was sandy loam. The highest water holding capacity and lowest bulk density was obtained with treatment* T_{10} *(RDF + FYM@ 10t/ha+ Biomix) which was at par with treatment* T_9*,* T_{12}*,* T_8 *and* T_6*. The lowest water holding capacity was found under 75% RDF, followed by RDF. The soil pH is reduced under integrated nutrient management with increasing salinity levels. The electrical conductivity of soil increased after two years of study under all the treatments. The study suggests sustainable saline irrigation water management and improved soil physico-chemical properties by adopting integrated nutrient management.*

Keywords: *Biogas slurry, Bulk density, Farmyard manure, Saline soil, vermicompost.*

INTRODUCTION

The continuous use of poor-quality water for irrigation in arid and semi-arid regions leads to the development of soil salinity and sodicity, which are major problems nowadays in agricultural soils that affect plant growth in the short term and soil health in the long term (Kramer & Mau, 2023). The reduced availability of freshwater worldwide favours the development of alternative and secondary quality sources of water for irrigation in agricultural use.

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The inevitable use of saline water resulted in the increased concentration of sodium ions, which have a dispersing effect on soil aggregates (Yu et al., 2010) and can deteriorate the soil structure, which interferes with better crop production and overall soil health. The sandy soils, which have peculiar soil constraints, *viz.* deficiency of macro- and micronutrients, coarse texture, low water holding capacity and nutrient retention power, and less organic carbon content, pose greater challenges to the sustainable crop production in these soils. Moreover, the mineral composition, uptake and crop yield have been affected by the continuous use of poor-quality irrigation water without organic amendments under most soil conditions (Ayer & Westcot, 1985). About 84 per cent of the cultivated area in Haryana is under irrigated conditions; out of this, 45.3 per cent is through canals and 54.2 per cent by tube wells, but 62 per cent area is irrigated with poor-quality water (Grewal et al., 2021). As soil is essential for the nation's food supply (Khotabaei et al., 2013), so proper management practices should be adopted for its quality conservation. The use of organic amendments under saline-sodic soils is the most suitable method for reclamation of soil which contributes towards increased soil productivity (Melero et al., 2007). In recent years, the use of organic manures on agricultural lands by farmers has been increased. However, the beneficial effects of various manures, *viz*. farmyard manure, vermicompost and biogas slurry, depend upon the soil texture, moisture availability and decomposition rate (Drozd, 2003). The present study has been conducted to know the effect of organic manures, namely, farmyard manure, vermicompost and biogas slurry, on the physical and chemical properties of soil under saline water irrigation in sandy loam soils of Haryana.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out for two years (2022-23 and 2023-24) at Soil Science Research Farm, CCS Haryana Agricultural University, Hisar (125004), Haryana (India) during *Kharif* and *Rabi* seasons following pearl millet-wheat cropping system. Geographically the experimental site is situated at $29^0$15´N latitude and $75^0$68´ E longitude at an elevation of 215.2 meters above mean sea level. The climate of the site is semi-arid and sub-tropical with mean annual rainfall of about 450 mm. The soil of the site is sandy loam in texture with low nutrient status and water-holding capacity.

Treatment details

The study comprised of twelve treatments with varying nutrient combinations. The first treatment (T_1) was the application of 75% of the recommended dose of fertilizers (75 % RDF*), second (T_2) is RDF, third (T_3) was 75% RDF along with the application of ST-3 (salinity tolerant strain of *Azotobacter chroococcum*) and fourth (T_4) was RDF with ST-3 strain. The treatment 5 (T_5) and treatment 6 (T_6) are similar to T_3 and T_4 along with the integrated application of biogas slurry @ 2.5 t/ha respectively. Similarly, treatment 7 (T_7) and treatment 8 (T_8) were identical to T_3 and T_4 with additional application of vermicompost @ 2.5 t/ha, respectively. Treatment 9 (T_9) and treatment 10 (T_{10}) include the integrated application of FYM @ 10 t/ha and seed treatment with Biomix (*Azotobacter* + *Azospirillum* + *Phosphate solubilizing bacteria*) with 75 % RDF and RDF, respectively. Treatment 11 (T_{11}) and treatment 12 (T_{12}) comprised of combined application of vermicompost @ 2.5 t/ha and Biomix with 75 % RDF and RDF, respectively. The RDF for pearl millet was 156.25 kg/ha nitrogen and 62.5 kg/ha phosphorus; for wheat, the RDF was 150, 60 and 30 kg/ha nitrogen, phosphorus and potassium, respectively. The Irrigation water of electrical conductivity 7.5-8.0 dS/m was used for irrigation. The experiment was laid out in randomized block design (RBD) with three replicates each with a plot size of 6.0 m × 4.5 m.

Collection of organic manures: Vermicompost (VC) and farmyard manure (FYM) were collected from an Agronomy research farm, and biogas slurry was collected from an organic farm of the Department of Microbiology, CCS Haryana Agricultural University, Hisar. The organic manures were also analyzed in a soil science laboratory to determine their nutrient content.

Soil sampling

The initial soil samples were collected at 0-15 cm depth from each plot for laboratory analysis. The bulk density was estimated with the help of the core sampler method before the start of the experiment. Another set of soil samples was drawn from each plot at the start of the experiment from 0-15 cm soil depth and air dried, crushed and sieved (< 2 mm) to determine the soil pH, EC and water holding capacity.

Soil analysis

The soil samples were collected in cylinders of known volume and dried at 105^0C in an oven. The bulk density of the soil was calculated from its oven-dried mass and volume relationship (Blake & Hartage, 1986). The water holding capacity was determined using the Keen Rackzowski Box Method (Jackson, 1973). Soil pH and electrical conductivity (EC) were measured using a 1:2 soil-water suspension with the help of a glass electrode pH meter and electrical conductivity (Jackson, 1973).

Statistical analysis

The data were subjected to statistical analysis with randomized block design (RBD) using OPSTAT software developed by CCS Haryana Agricultural University, Hisar. The statistical significance between the treatments was computed using critical difference (CD) values at 5% level of significance (Panse & Sukhatme, 1985).

RESULTS AND DISCUSSION

Bulk Density (g/cm^3)

The data pertaining to bulk density has been shown in Table 1. The bulk density varied significantly among various treatments. However, the variation among the first four treatments was non-significant. During both years of experimentation (2022-23 and 2023-24), a decrease in bulk density was observed with the integrated application of organic manures along with inorganic fertilizers as compared to the sole application of inorganic fertilizers in pearl millet- wheat cropping system under saline water irrigation. The maximum reduction in bulk density was found under treatment T_{10} (RDF+ FYM + Biomix) *viz.* 6.54 % which was followed by T_9 (75% RDF+ FYM + Biomix) and T_{12} (RDF + VC + Biomix)*viz.* 5.88 % with respect to sole application of 75% RDF (T_1). As compared to initial values, the percent reduction was also higher under treatment T_{10} *i.e.*, 2.05 %, while an increase in the bulk density was observed under treatment T_1, T_2 and T_3 under saline water irrigation. The lowest bulk density was recorded under treatment T_{10} (1.44 g/cm^3), followed by T_9 (1.45 g/cm^3) and T_{12} (1.45 g/cm^3). The highest bulk density was recorded under treatment T_1 (1.53 g/cm^3) and T_3 (1.53 g/cm^3). The bulk density was found 3.92, 3.92 and 4.58 % lower in treatment T_5, T_7, T_{11} as compared to application of 75 % RDF alone.

The decrease in bulk density after two years of experimentation with integrated application of organic manures (farmyard manure, vermicompost and biogas slurry) along with inorganic fertilizers was due to increased organic matter content of the soil, which enhances the microbial activities and thus the release of various plant available nutrients which enhance the root biomass in the soil. This increased root biomass leads to better soil aeration and improvement in soil mechanical composition (Malik & Singh, 2016). Similar results were also reported by Hussain et al. (2001) and Bajpai et al. (2006).

The lowest value of bulk density was recorded under farmyard manure treated plots as compared to vermicompost and biogas slurry under saline water irrigation. Pal et al. (2006) also recorded the lowest value of bulk density under FYM-treated plots. The higher percentage reduction in bulk density under organic manure treated plots under saline water irrigation might be due to the fact that organic manures will bind the soluble salts in the soil and make chelated-complex with these salts and reduced their concentration in soil solution, lowering the salt stress in the soil, thus improved the soil physical condition. This also resulted in better aggregation which led to lower bulk density as compared to the sole application of inorganic fertilizers under saline conditions. Kiranbe (2018) also reported similar results under salt affected soils of Gujarat.

Water Holding Capacity (%)

The results of water holding capacity has been described in Table 2. The results revealed that the water holding capacity differs significantly in treatments receiving integrated application of organic manures *viz.* farmyard manure, vermicompost and biogas slurry along with inorganic fertilizer, while the variation among treatments receiving sole application of inorganic fertilizers *viz.* T_1 (75% RDF) and T_2 (RDF), and T_3 (75% RDF + seed treatment with salinity tolerant strain, ST-3 of *Azotobacter chroococcum*) and T_4 (RDF + ST-3) was non-significant. The maximum water holding capacity was observed with application of recommended dose of fertilizers (RDF) along with farmyard manure @10 t/ha and seed treatment with biomix (*Azotobacter* + *Azospirillum* + PSB) *i.e.*, under treatment T_{10} (44.93 %) followed by treatment T_9 (75% RDF + FYM + Biomix) *viz*. 44.04 %, T_{12} (RDF + VC+ Biomix) *viz*. 43.98 %and T_8 (RDF + VC+ ST-3) *viz.* 43.62%. The mean water holding capacity was also recorded higher *viz*. 4.9, 6.5, 8.5 and 11.8 % under treatment T_5 (75 % RDF + BGS+ ST-3), T_6 (RDF + BGS+ ST-3), T_7 (75% RDF + VC+ ST-3) and T_{11} (75% RDF+ VC+ Biomix), respectively as compared to treatment T_1(75% RDF). The lowest water holding capacity was recorded under treatment T_1 (75 % RDF) *viz.* 38.75 % followed by T_3 (75% RDF + ST-3) *viz.* 38.77 %, T_4 (RDF + ST-3) *viz.* 38.83 % and T_2 (RDF) *viz.* 38.99 %. After two years of experimentation, a significant increase in water holding capacity was observed with integrated nutrient management under saline water irrigation.

The increase in WHC of soil after two years of experimentation might be due to improved aggregate stability due to the addition of organic manures, which enhanced the macro- and micropores in the soil system and thus increased the free movement of water in the soil, which resulted in increased water holding capacity of the soil. Similar results were also reported by Chaudhary et al. (2008), Walia et al. (2010), Tedesse et al. (2013). The highest water holding capacity was found under FYM-treated plots as compared to vermicompost and biogas slurry, which might be due to more bulky nature of farmyard manure and higher organic matter content compared to vermicompost and biogas slurry, which resulted in higher aeration and higher porosity in these plots that ultimately improves the water movement and thus leads to higher percentage increase in WHC compared to vermicompost and biogas slurry. Pal et al. (2006) also reported a percentage increase in water-holding capacity under farmyard-treated plots. Kiranbe (2018) also reported higher water-holding capacity in plots receiving the integrated application of organic manures as compared to sole application of nitrogenous fertilizers in salt-affected soils, specifically under FYM-treated plots as compared to vermicompost and castor cake treatments.

Table 1:Effect of various treatments on bulk density (g/cm^3) of soil under saline water irrigation

Sr.No.	Treatments	Initial	2022-23	2023-24	Mean
T_1	75% RDF	1.52	1.52	1.53	1.53
T_2	RDF	1.51	1.51	1.52	1.52
T_3	75%RDF + ST-3	1.52	1.53	1.53	1.53
T_4	RDF +ST-3	1.52	1.52	1.51	1.52
T_5	75% RDF+ BGS+ ST-3	1.48	1.48	1.47	1.48
T_6	RDF + BGS + ST-3	1.49	1.48	1.46	1.47
T_7	75% RDF+VC + ST-3	1.49	1.47	1.47	1.47
T_8	RDF+ VC+ ST-3	1.47	1.46	1.45	1.46
T_9	75% RDF +FYM+ Biomix	1.47	1.46	1.44	1.45
T_{10}	RDF + FYM+ Biomix	1.46	1.45	1.45	1.45
T_{11}	75% RDF+ VC+ Biomix	1.47	1.47	1.46	1.47
T_{12}	RDF+ VC+ Biomix	1.46	1.46	1.44	1.45
	C.D (p=0.05)	NS	0.013	0.112	**0.028**

Table 2: Effect of various treatments on water holding capacity (%) of soil under saline water irrigation

Sr.No.	Treatments	Initial	2022-23	2023-24	Mean
T_1	75% RDF	38.87	38.77	38.73	38.75
T_2	RDF	39.32	39.17	38.81	38.99
T_3	75%RDF + ST-3	38.91	38.82	38.71	38.77
T_4	RDF +ST-3	39.01	38.92	38.73	38.83
T_5	75% RDF+ BGS+ ST-3	40.10	40.48	40.80	40.64
T_6	RDF + BGS + ST-3	40.65	41.06	41.44	41.25
T_7	75% RDF+VC + ST-3	41.37	41.82	42.23	42.03
T_8	RDF+ VC+ ST-3	43.15	43.05	44.18	43.62
T_9	75% RDF +FYM+ Biomix	43.18	43.77	44.30	44.04
T_{10}	RDF + FYM+ Biomix	44.02	44.65	45.21	44.93
T_{11}	75% RDF+ VC+ Biomix	42.78	43.14	43.54	43.34
T_{12}	RDF+ VC+ Biomix	43.46	43.75	44.21	43.98
	C.D (p=0.05)	**0.48**	**0.71**	**0.52**	**0.64**

Soil pH

The data pertaining to soil pH is presented in Table 3, which revealed that the soil pH varied non-significantly with the 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 2022-23; 8.62 to 8.09, 7.47 to 8.07 after the 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, a comparatively higher reduction in soil pH was observed in plots receiving organic manures along with RDF as compared to the sole application of inorganic fertilizers under saline water irrigation. Sebastian et al., 2009 also observed reduction in soil pH that could be ascribed to the acidifying effect due to organic acids produced during the course of decomposition of organic amendments and green manure (Dhaincha- *Sesbania aculeata*). Acid forming amendments will also increase the availability of Ca^{2+} in irrigation water by neutralizing HCO_3^- and CO_3^{2-} that otherwise tie up some of the Ca^{2+} to form lime precipitates. Since, these amendments form acids during different soil reaction, thus, can reduce the soil pH if applied in sufficient quantity.

The lowest mean value of soil pH was found in treatment T_{10}, *viz*. 7.55 and 7.49, after the harvest of pearl millet and wheat, respectively. The soil pH was reduced by 6.62 and 6.90 % in treatment T_{10} as compared to 75% RDF, while the reduction in treatment T_{12} was 4.83 and 5.04 % after the 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.

The integration of inorganic fertilizers 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 salinity leads to increased electrolyte concentration in soil solution, which compresses the diffuse double layer of the clay surface. The H^+ ions are free to move in the soil and reduce the soil pH (Aechra et al., 2017 and Ankush et al., 2021).

Table 3: Effect of INM on soil pH (1:2 soil-water suspension) under saline water irrigation after harvest of pearl millet and wheat

			Pearl millet			Wheat		
Sr. No.	Treatments	Initial	2022-23	2023-24	Mean	2022-23	2023-24	Mean
T_1	**75% RDF**	8.10	8.09	8.07	8.08	8.05	8.02	8.04
T_2	**RDF**	8.09	8.07	8.05	8.06	8.02	7.98	8.00
T_3	**75%RDF + ST-3**	8.08	8.07	8.07	8.07	8.04	7.99	8.02
T_4	**RDF +ST-3**	8.08	8.06	8.05	8.06	8.00	7.98	7.99
T_5	**75% RDF+ BGS+ ST-3**	8.11	8.05	7.92	7.99	7.97	7.85	7.91
T_6	**RDF + BGS + ST-3**	7.92	7.88	7.75	7.82	7.80	7.67	7.74
T_7	**75% RDF+VC + ST-3**	7.92	7.87	7.72	7.80	7.80	7.70	7.75
T_8	**RDF+ VC+ ST-3**	7.91	7.83	7.69	7.76	7.74	7.67	7.71
T_9	**75% RDF+FYM+ Biomix**	7.89	7.85	7.71	7.78	7.77	7.66	7.72
T_{10}	**RDF + FYM+ Biomix**	7.71	7.62	7.47	7.55	7.55	7.42	7.49
T_{11}	**75% RDF+ VC+ Biomix**	8.00	7.97	7.90	7.94	7.92	7.81	7.87
T_{12}	**RDF+ VC+ Biomix**	7.85	7.76	7.62	7.69	7.70	7.57	7.64
	C.D. (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Electrical conductivity, EC_e

The data related to the 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 recorded *at par* with treatment T_{12}*viz*. 7.45 and 7.87 dS m^{-1} after harvest of pearl millet and wheat, respectively. However, a significantly higher value of EC_e was observed under treatment T_1 (75% RDF) *viz*. 8.87 and 9.55 dS m^{-1} and T_2 (RDF) *viz*. 8.59 and 9.19 dS m^{-1} after harvest of pearl millet and wheat, respectively after two years 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 treatments T_1, T_2, T_3 and T_4 varied non-significantly with each other and treatment T_4 recorded the lowest EC_e (8.41 and 8.93 dS m^{-1}) after the harvest of both pearl millet and wheat, respectively.

Table 4: Effect of INM on electrical conductivity, EC_e (of saturation extract of soil, dS m^{-1}) under saline water irrigation after harvest of pearl millet and wheat

			Pearl millet			Wheat		
Sr. No.	Treatments	Initial	2022-23	2023-24	Mean	2022-23	2023-24	Mean
T_1	75% RDF	8.34	8.73	9.01	8.87	9.14	9.97	9.55
T_2	RDF	8.11	8.46	8.72	8.59	8.81	9.56	9.19
T_3	75%RDF + ST-3	8.29	8.66	8.93	8.80	9.06	9.84	9.45
T_4	RDF +ST-3	7.95	8.27	8.54	8.41	8.58	9.28	8.93
T_5	75% RDF+ BGS+ ST-3	7.62	7.91	8.15	8.03	8.17	8.79	8.48
T_6	RDF + BGS + ST-3	7.33	7.57	7.70	7.64	7.83	8.27	8.05
T_7	75% RDF+VC + ST-3	7.51	7.76	7.97	7.87	8.05	8.64	8.34
T_8	RDF+ VC+ ST-3	7.25	7.43	7.59	7.51	7.77	8.17	7.97
T_9	75% RDF+FYM+Biomix	7.35	7.60	7.77	7.69	7.86	8.35	8.11
T_{10}	RDF + FYM+ Biomix	7.14	7.29	7.43	7.36	7.56	7.87	7.72
T_{11}	75% RDF+ VC+ Biomix	7.43	7.71	7.86	7.79	7.91	8.44	8.18
T_{12}	RDF+ VC+Biomix	7.21	7.37	7.52	7.45	7.68	8.05	7.87
	C.D. (p=0.05)	**0.37**	**0.41**	**0.33**	**0.10**	**0.30**	**0.37**	**0.28**

The continuous application of saline water leads to an increase in the salt concentration of soil and, thus, the 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 *the Kharif* season that leach down the salts from the upper soil layer. 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 complexes and will bind the soluble salts and thus reduce their concentration in soil solution (Meena et al., 2016). The decrease in EC with addition of organic manures might be due to production of organic and inorganic acids during decomposition, which was responsible for leaching of salts (Sebastian et al., 2009). During this decomposition of organic materials acidification will occur and encourage base cation uptake (by plants and microbes), which again leading to leaching of bases with carbonic, organic or nitric acids and humus formation (Ragab et al., 2008; Ghuman et al., 2010; & Salih & Kia, 2013).

CONCLUSION

The continuous use of saline water for irrigation led to increased soil pH as well as electrical conductivity of the soil. The higher reduction in soil bulk density and greater increment in water holding capacity was observed in organic manure treated plots as compared to sole application of inorganic fertilizers *viz*. 75% RDF and RDF. The treatment T_{10} (RDF + FYM @ 10t/ha + Biomix) was found superior over other treatments during two years of experimentation. The bulky nature and higher organic matter content of farmyard manure made it superior over other treatments. The seed inoculation with biofertilizers *i.e.*,biomix (*Azotobacter* + *Azospirillum* + PSB) and ST-3 (*Azotobacter chroococcum*) along with application of organic manures showed positive relation with soil properties like improved soil pH, EC, bulk density and water holding capacity as compared to sole application of 75% RDF and RDF (recommended dose of fertilizers) under saline conditions. The adoption of integrated nutrient management (INM) significantly improved the soil's physical and chemical conditions and, thus, better soil health under saline water irrigation.

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Author Contribution
All authors have participated in critically revising of the entire manuscript and approval of the final manuscript.

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