



Effect of integrated nutrient management in pearl millet (*Pennisetum glaucum*)-wheat (*Triticum aestivum*) system under water saline irrigation

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ABSTRACT

Salinity predominates in the arid and semi-arid regions which negatively affects the crops yield, nutrient availability, and microbes present in the soil. The present study was carried out during 2019–2021 at Chaudhary Charan Singh Haryana Agriculture University, Hisar, Haryana to access the effect of saline irrigation water on performance of pearl millet [*Pennisetum glaucum* (L.) R. Br.]-wheat (*Triticum aestivum* L.) cropping system while using organic manures. The varieties HHB226 and WH 1105 of pearl millet and wheat were taken for the experiment, respectively. The experiment was conducted in a randomized block design (RBD) comprised of 12 treatments, viz. 75% RDF (T₁); 100% RDF (T₂); 75% RDF + salinity strain (ST3) (T₃); 100% RDF + ST3 (T₄); 75% RDF + 2.5 t/ha biogas slurry (BS) + ST3 (T₅); 100% RDF + 2.5 t/ha biogas slurry (BS) + ST3 (T₆); 75% RDF + 2.5 t/ha vermicompost + ST3 (T₇); 100% RDF + 2.5 t/ha vermicompost + ST3 (T₈); 75% RDF + 10 t/ha FYM + biomix (T₉); 100% RDF + 10 t/ha FYM + biomix (T₁₀); 75% RDF + 2.5 t/ha vermicompost + biomix (T₁₁); 100% RDF + 2.5 t/ha vermicompost + biomix (T₁₂). The results revealed that the crop responded better to salt stress where organic manures were incorporated. The highest grain and straw yields of both crops were attained with treatment T₁₀ (100% RDF + 10 t/ha FYM + biomix) being at par with treatments T₁₂, T₈ and T₆. The soil properties were found improved in term of NPK availability and other microbiological parameter under manurial treatments compared to control and solely applied chemical fertilizers. Salinity stress was considerably decreased when organic manures were used either alone or in conjunction with mineral fertilizers.

Keywords: Integrated nutrient management, Manures, Pearl millet, Salinity, Soil properties, Wheat, Yield

Soil salinity poses a significant challenge to agricultural productivity, especially in arid and semi-arid regions, which account for just 15% of global arable land but contribute over 40% of the world's food production (Mukhopadhyay *et al.* 2021). Salinization, resulting in abnormal ion concentrations in soil and water, disrupts ion uptake balance and leads to physiological disorders in plants (Majeed and Muhammad 2019, Ankush *et al.* 2021a). Furthermore, desertification and salinization, driven by intensive land use, improper irrigation practices, and high evapotranspiration rates threaten conventional agricultural practices in these areas (Kumar and Sharma 2020). Agricultural land is increasingly becoming saline, resulting in reduced or zero productivity, and limited water availability for irrigation further constrains crop production in arid and semi-arid regions. With the reduction in the share of agriculture sector

by 2050, there is no alternative but to use poor quality water to meet irrigation needs (FAO 2023). As a result, it is necessary to search for crop/genotype alternatives and develop sustainable and economically sound production systems that can withstand drought and use poor quality water. The negative effects of saline soils are further intensified by the low levels of organic matter, affecting nutrient dynamics and soil microbe activity (Haj-Amor *et al.* 2022). The use of organic manures is an effective way to reduce the adverse effects of salinity stress on crops. Organic manures not only provide essential nutrients to the crops but also improve soil fertility, water-holding capacity, and soil structure. A number of organic manures such as animal manures, rice straw compost, sewage sludge and plant residues are being used as soil amendments for improving the saline soil quality (Murtaza *et al.* 2020, Ankush *et al.* 2020, Foronda and Colinet 2022). Therefore, present study was planned to access the effect of saline irrigation water on performance of pearl millet [*Pennisetum glaucum* (L.) R.Br.]-wheat (*Triticum aestivum* L.) cropping system while using organic manures, viz. FYM, vermicompost and biogas slurry as manures to supplement nutrient and also act as an ameliorant under saline condition.

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MATERIALS AND METHODS

The present study was carried out during 2019–2021 at the Chaudhary Charan Singh Haryana Agriculture University, Hisar (29°10'N, 75°46'E and 215.2 m altitude), Haryana. The initial characteristics of the soil were as, pH, 8.10; EC, 1.85 dS/m; organic carbon, 0.34%; available NPK, 141.32 kg/ha, 15.20 kg/ha, and 195.25 kg/ha; iron, 1.90 ppm; manganese, 5.24 ppm; zinc, 0.99 ppm; and copper 0.72 ppm.

The experiment consisted of 12 treatments, viz. 75% RDF (T₁); 100% RDF (T₂); 75% RDF + salinity strain (ST3) (T₃); 100% RDF + ST3 (T₄); 75% RDF + 2.5 t/ha biogas slurry (BS) + ST3 (T₅); 100% RDF + 2.5 t/ha biogas slurry (BS) + ST3 (T₆); 75% RDF + 2.5 t/ha vermicompost + ST3 (T₇); 100% RDF + 2.5 t/ha vermicompost + ST3 (T₈); 75% RDF + 10 t/ha FYM + biomix (T₉); 100% RDF + 10 t/ha FYM + biomix (T₁₀); 75% RDF + 2.5 t/ha vermicompost + biomix (T₁₁); 100% RDF + 2.5 t/ha vermicompost + biomix (T₁₂). The experiment was laid out in a randomized block design (RBD) with three replications. The recommended doses of fertilizers were used as per package practice adopted in Haryana, i.e. 62.5: 25 kg N: P₂O₅/acre for pearl millet and 60: 24: 12 kg N: P₂O₅: K₂O/acre for wheat crop. The varieties HHB226 and WH 1105 of pearl millet and wheat crops were taken for the experiment, respectively. *Azotobacter chroococcum* (ST-3) was used as the salinity strain, and the biomix mixtures contained *Azotobacter chroococcum* (Mac27) + *Azospirillum* + PSB. Organic manures were applied in the *rabi* season, specifically 20 days before sowing. The composition of organic manures is presented in Table 1.

Saline water with an electrical conductivity (EC_{iw}) of 7 dS/m was used for irrigation throughout the cropping season. The on-farm saline water was prepared by mixing borewell's saline water (~25 EC dS/m) with canal water (~0.30 EC dS/m) to achieve the desired electrical conductivity of the saline irrigation water. The ionic composition of the irrigation water was determined using standard methods (Richards 1954) and consisted of pH (7.00), EC (7.86 dS/m), Ca²⁺+Mg²⁺ (23.71 me/l), Na⁺ (43.52 me/l), K⁺ (1.49 me/l), HCO₃⁻ (1.51 me/l), Cl⁻ (52.24 me/l) and SO₄²⁻ (15.12 me/l). The grain and stover/straw yields of the crops were recorded after harvest of the crop. Soil samples were taken at the depth of 0–15 cm during the final harvest and analysed for chemical and biological properties using appropriate

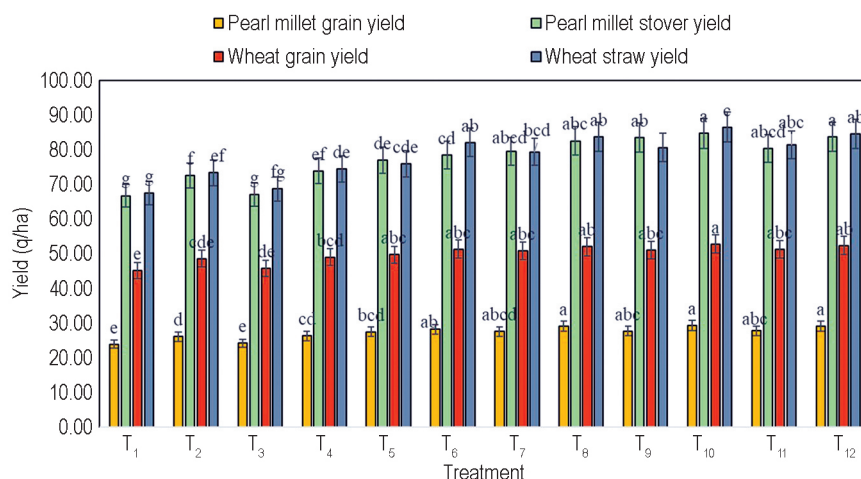


Fig. 1 Effect of integrated nutrient management practices on yields of pearl millet-wheat cropping sequence under saline water irrigation [Pooled data of 2 years (2019–2021)]. Treatment details are given under Materials and Methods.

methods outlined by Antil *et al.* (2002).

Statistical analysis: The data was statistically analysed using EXCEL and the OPSTAT statistical software package developed by the Department of Statistics, CCS Haryana Agricultural University (Sheoran *et al.* 1998), with a significance level of $P=0.05$.

RESULTS AND DISCUSSION

Yield: The grain and stover/straw yields of pearl millet and wheat crops are illustrated in Fig. 1. The pooled study showed that the highest yield responses were observed in both the crops when organic and inorganic fertilizers were integrated compared to inorganic fertilizer alone. The treatment T₁₀ which received recommended dose of fertilizer (RDF) in combination with FYM and biomix yielded the highest grain and stover/straw of both pearl millet and wheat crops compared to 100% RDF + ST3 (T₄), 100% RDF (T₂), 75% RDF (T₃) and 75% RDF + ST3 (T₁), respectively. However, the per cent increase in grain and stover yield of pearl millet with T₁₀ was 11.2, 12.1, 21.0, 22.5 and 14.6, 16.8, 26.3, 26.9% with treatments T₄, T₂, T₃, and T₁, respectively. Likewise, in case of wheat grain and straw yields this per cent increase with T₁₀ was 7.8, 8.8, 15.3, 17.0 and 16.2, 18.1, 26.0, 28.1% with treatments T₄, T₂, T₃, and T₁, respectively. While the application of salinity strain (ST3) had a non-significant impact, the use of organic manures, particularly FYM, resulted in significantly improved crop yields. The prolonged use of saline water for irrigation caused build-up of salts in the soil (Table 2). The lowest yields under 75% RDF (T₁) could be attributed due to presence of salts which might have affected nutrient recycling in the soil, and reduced nutrients availability in the soil. But at the same time in saline conditions, the deficiency and poor availability of nutrients are overcome by combined application of organic and inorganic fertilizers, which supply essential elements that encourage plant growth and balanced microbial activity in the soil (Ankush *et al.* 2020, Foronda and Colinet 2022). Adequate nutrient supply

Table 1 Chemical composition of organic manures

Nutrients (%)	Biogas slurry	FYM	Vermicompost
N	1.72	0.75	1.66
P	1.16	0.50	0.86
K	1.67	1.08	1.10

Table 2 Effect of integrated nutrient management practices on soil chemical properties

Treatment	pH	EC (dS/m)	Organic carbon (%)	Available nutrients (kg/ha)		
				Nitrogen	Phosphorus	Potassium
T ₁	8.18a	7.15a	0.16e	137.67f	12.69d	188.60i
T ₂	8.09a	7.01a	0.22ef	151.15de	16.63bcd	200.27h
T ₃	8.12a	7.13a	0.18ef	142.06e	15.44cd	195.62hi
T ₄	8.10a	6.64ab	0.25de	157.89cde	17.90abc	210.10g
T ₅	7.84b	6.35abc	0.34bc	174.70abc	19.72abc	235.85de
T ₆	7.82b	5.94abc	0.39ab	180.36ab	21.13ab	246.15c
T ₇	7.79b	6.24abc	0.30cd	165.37bcd	19.05abc	226.96f
T ₈	7.75b	5.13c	0.40ab	184.43ab	22.02a	250.21bc
T ₉	7.73b	6.14abc	0.36bc	178.63abc	20.09abc	243.16cd
T ₁₀	7.77b	5.07c	0.43a	189.63a	22.27a	259.99a
T ₁₁	7.78b	5.47bc	0.31cd	171.62abcd	19.62abc	230.06ef
T ₁₂	7.75b	5.09c	0.41ab	186.37ab	22.16a	255.25ab

Treatment details are given under Materials and Methods.

is essential for maintaining optimum growth and yield under salinity stress. This increase in crops yield with integrated application might be due to enhanced microbial activities and better nutrient recycling (Ankush *et al.* 2021a). Differences in nutritional composition, application amounts, and nutrient release patterns likely contributed to the varying effects of organic manures (Rani *et al.* 2020). Organic manures, rich in organic matter effectively absorb and reduce the concentration of salts in the soil. Moreover, they enhance soil structure by increasing porosity and water retention capacity, thus preventing waterlogging and ensuring a well-aerated root zone (Ahmed *et al.* 2010). Furthermore, these manures serve as a nutrient reservoir, providing essential elements that might otherwise be restricted due to salt interference with nutrient uptake. Additionally, organic manures reintroduce beneficial microorganisms into saline soils, revitalizing microbial activity, improving nutrient cycling, and bolstering overall soil health (Chen *et al.* 2021). Overall, it was seen that an integrated application of organic manures and inorganic fertilizers provided a thorough solution to the problems caused by saline conditions.

Soil properties: The final harvest data indicates improvements in soil chemical properties with the use of organic manures such as FYM, vermicompost, and biogas slurry (Table 2). The following soil properties are explained below:

pH, EC, OC: The application of organic manures led to a decrease in soil pH, likely due to the release of organic acids during decomposition (Ankush *et al.* 2020). Soil electrical conductivity (ECe) increased under all treatments compared to initial values due to the continuous use of saline irrigation water. However, the increase was lower in plots treated with organic manures, indicating improved soil structure and enhanced microbial activities. Fluctuations in soil EC and pH due to organic fertilization may be influenced by the

characteristics of the organic manures used and site-specific parameters of the saline soils (Jadhao *et al.* 2021). Organic carbon content improved with the application of both organic and inorganic fertilizers. The significantly highest organic carbon was obtained with T₁₀ due to promoted microbial proliferation and activity and boosted root growth (Eid *et al.* 2019), may have contributed to the rise in organic carbon by increasing the production of biomass, crop stubble, and residues. Organic manures when applied to saline soils, they introduced a valuable source of organic matter. Also, the diverse microbial community within organic manures is integrated into the soil, where it thrives on the provided organic matter. As these microorganisms decompose organic materials, they generate microbial biomass that contains carbon-rich compounds, augmenting the soil organic carbon pool. Saline soils typically hinder microbial activity and the decomposition of organic matter, which can result in the release of carbon dioxide into the atmosphere. However, the persistent supply of organic matter from organic manures counteracts this inhibition, promoting organic carbon retention in the soil (Ankush *et al.* 2020).

Available NPK and micronutrients: Despite the interference of salinity with nutrient availability and microbial activities, the study demonstrated that fertilization helped maintain soil fertility under saline water irrigation. The significant build-up of nutrient (NPK) was recorded with T₁₀ compared to RDF alone, however it was statistically at par with T₁₂, T₈ and T₆ (Table 2). Improved mineralization of manures in the presence of inorganic fertilizers likely contributed to the enrichment of nutrients in the soil's native pool, gradually releasing them and enhancing nutrient efficiency (Sharma and Dhaliwal 2019, Rani *et al.* 2020). The INM enhanced mobilization of nutrients more efficiently and improved their availability during the critical crop growth stages. These findings align with the

results obtained by Darjee *et al.* (2023) in their research on INM applied in irrigated wheat crop. The observed increase in available nitrogen can be attributed to the enhanced microbial population responsible for converting organically bound N into its inorganic form (Jadhao *et al.* 2021). Additionally, the application of organic manures has been found to facilitate the solubilization of previously insoluble organic phosphorus fractions in the soil. This solubilization process occurs through the release of various organic acids upon the decomposition of manures, resulting in a noteworthy improvement in the soil's P status, as noted in a study by Ankush *et al.* (2020). Furthermore, the build-up of available soil potassium with organic manure application can be attributed to a reduction in potassium fixation and the release of potassium from the association of organic

matter with clay particles. In context of micronutrient the effects of various fertilizer treatments on iron (Fe) were non-significant, but treatment T₁₀ resulted in significantly higher concentrations of manganese (Mn), zinc (Zn), and copper (Cu) compared to RDF alone, similar to treatments T₁₂, T₈ and T₆ (Fig. 2). The utilization of organic manures not only enhances fertilizer use efficiency but also serves as an alternative nutrient source. Additionally, the application of INM ensures a consistent nutrient supply, mitigates nutrient losses, and ultimately promotes more efficient nutrient utilization. The results are in corroboration with the findings of Jadhao *et al.* (2021). These findings collectively suggest that the integrated use of organic and inorganic fertilizers is more effective in enhancing nutrient availability in the soil compared to using inorganic fertilizer alone.

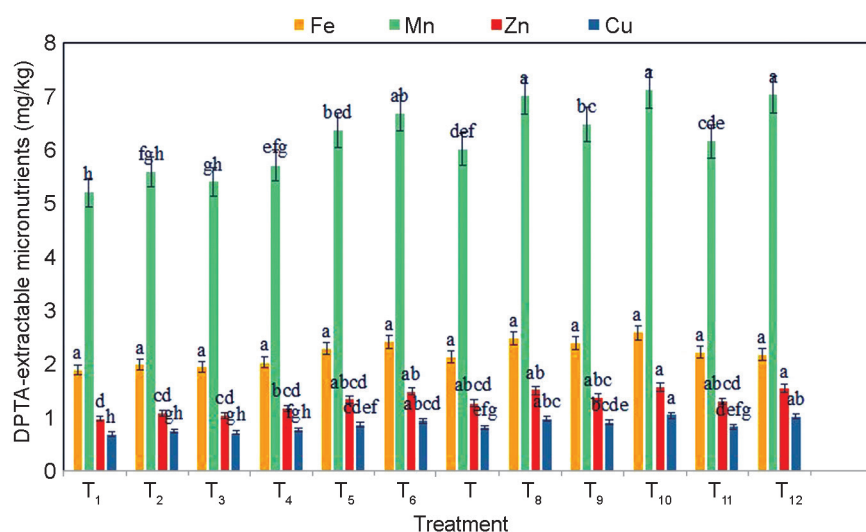


Fig. 2 Effect of integrated nutrient management practices on micronutrient concentration in soil.

Treatment details are given under Materials and Methods.

Biological properties: Organic manures have a profound impact on soil microbial activities in saline conditions. In saline soils, high salt concentrations can inhibit microbial populations and their metabolic processes. However, the application of organic manures introduces a rich source of organic matter and nutrients into the soil. The soil bacterial counts and enzymatic activities were found to improve under manures added plots compared to chemically fertilizer plots (Fig. 3). The application of RDF + 10 t/ha FYM + biomix (T₁₀) recorded significantly highest total bacterial count (6.76), free living N-fixer (6.59), dehydrogenase (33.78 µg TPF/g/24 h), alkaline phosphatase (75.68 µg PNP/kg/h) and urease activities (44.86 µg

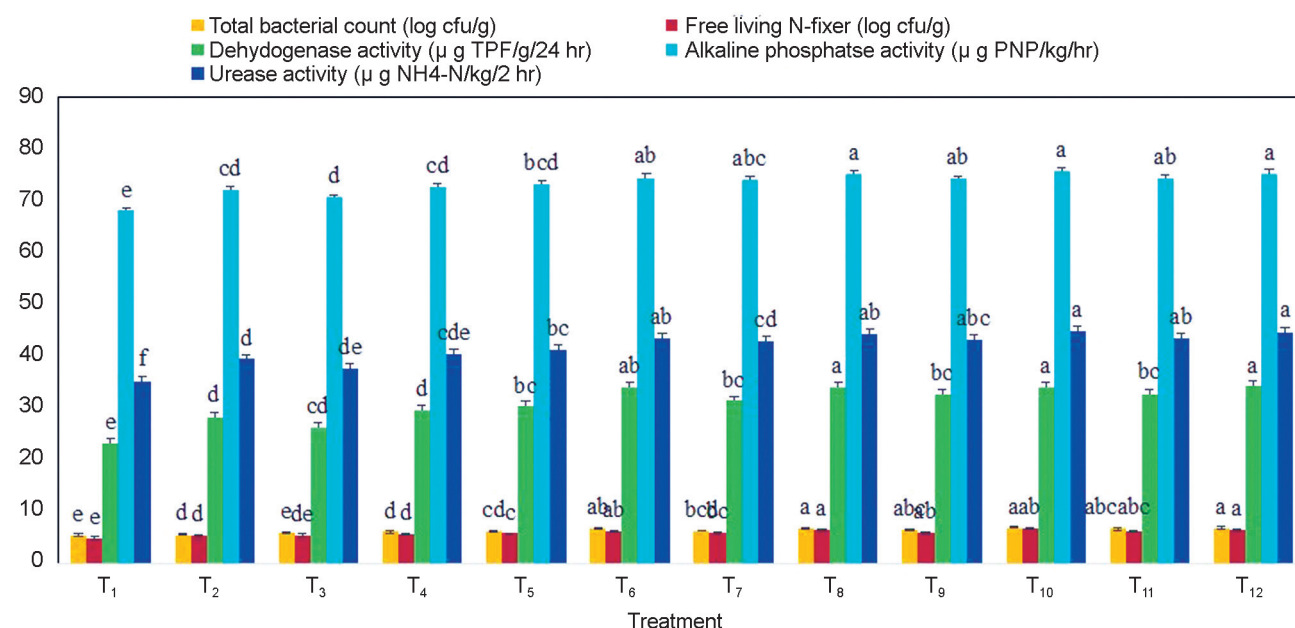


Fig. 3 Effect of integrated nutrient management practices on soil biological properties.

Treatment details are given under Materials and Methods.

NH₄-N/kg/2 h) being statistically at par manure added treatments. The treatments receiving ST-3 and biomix inoculation (T₃ and T₄) had more bacterial count, N-fixer and enzymatic activities in the soil compared to uninoculated treatments (T₁ and T₂). The improvement in soil biological properties can be attributed to the increased microbial growth resulting from the addition of organic substrate. Conversely, the use of chemical fertilizers without any organic input led to the lowest microbial activities, likely due to the prolonged absence of any organic input. The organic matter present in manures serves to protect enzymatic activities from degradation (Bai *et al.* 2020). This organic material serves as a substrate for microorganisms, providing them with the necessary energy and nutrients to thrive even in the presence of salinity stress. As a result, microbial populations begin to flourish, and their activities, such as decomposition of organic matter, nutrient cycling, and the production of beneficial enzymes, become more pronounced. Organic manures act as a microbial "rescue" by alleviating the stressful conditions in saline soils, fostering a more conducive environment for microbial growth and function (Duan *et al.* 2021). As a result, the application of both organic and inorganic inputs helps maintain the soil's biological properties intact. This confirms the earlier findings of Rani *et al.* (2020), Ankush *et al.* (2020) and Jadhao *et al.* (2021).

The addition of organic manures not only provides essential nutrients to the crops but also improves soil health and reduces the accumulation of salts in the soil. The results indicated that integrated nutrient management by combining organic and inorganic fertilizers along with biological sources, significantly enhanced crop yields compared to relying solely on inorganic fertilizers. Specifically, the treatment that received the recommended dose of fertilizer (RDF) in combination with farmyard manure (FYM) and biomix (T₁₀) showed the highest grain and stover yields for both pearl millet and wheat crops. This integrated approach led to substantial yield increases, highlighting its effectiveness in mitigating the negative effects of salinity on crop productivity. Therefore, the use of organic manures should be promoted as an effective way to reduce salinity stress in crops, especially in arid and semi-arid regions. These findings underscore the importance of considering integrated nutrient management strategies to maximize productivity and soil health under saline condition.

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