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Impact of integrated nutrient management on micronutrients uptake in pearl millet-wheat cropping system under saline water irrigation

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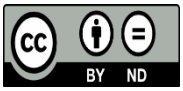
ABSTRACT

The combination of organic manures and fertilizers played a crucial role in improvement of soil physico-chemical properties, transformation and distribution of macro and micro-nutrients under various cropping system. The non-availability of good quality water for irrigation especially in arid and semi-arid regions of Haryana led to development of soil salinity that interferes with sustainable crop production. The study was conducted with the aim to explore the appropriate combination of manures and fertilizers under such conditions in pearl millet-wheat cropping system on sandy loam soils of Haryana (India). The use of organic manures along with fertilizers and bio-fertilizers resulted in improved nutrient status of soil enhancing both micro and macro nutrient pools in soil. The combination of fertilizers with organic manures reduced the soil pH up to greater extent over sole application of inorganic fertilizers under salt stress conditions. The INM reduced the bulk density, increased the water holding capacity and improved the overall soil health. This resulted in increased transformation of micro and macro nutrients in soil, thus enhancing their uptake by plants giving higher crop production.



1. Introduction

The adoption of intensive cropping system to obtain higher production resulted in depletion of macro and micro nutrients in soil. In addition to this the increased use of chemical fertilizers which are free of micro nutrients, and fertilizer responsive high yielding varieties continuously depleted a large amount of micronutrients from soil [16]. In India, 12–15, 3–8, 44–49, and 5–6% of soil samples collected from different states were found to be deficient with respect to Fe, Cu, Zn, and Mn, respectively [23]. The quantity of micronutrients required by plants for proper growth is very little compared to that of macronutrients, however the crop productivity is heavily dependent on the supply of these micronutrients in appropriated amount [22]. Micronutrient deficiencies cause reduced immunity, nyctalopia, anemia, and slow growth in human beings and livestock [6]. Several micronutrient deficiencies in plants expose them to biotic and abiotic stress leading to deterioration of quality of economic product and decline in the yield [19]. Due to increasing cost of

micronutrient fertilizers the use of alternate sources like organic manures has been promoting for sustainable soil health. The fractions (chemical pools) which supply the micronutrients to plants for uptake are remarkably influenced by the soil chemical properties like pH, electrical conductivity and organic carbon content. The addition of organic matter ameliorates these soil by improving these properties marked by increased microbial activity, enhanced cation exchange and water holding capacity, and lower bulk density [4].

In South-Western Haryana, pearl millet-wheat cropping system is widely adopted in irrigated conditions and the poor-quality irrigation water is major constraint in these regions of Haryana. About 84 percent of cultivated area in Haryana is under irrigated conditions, out of this, 45.3 percent by canals, and 54.2 percent by tube wells but 62 percent area is laid under poor-quality water [8]. Although pearl millet and wheat are moderate salinity tolerant crop but their productivity is affected by salinity up to greater extent. In this situation, the integrated nutrient management proved a durable and viable option for long-term sustainable crop production. As people are struggling for natural resources and climate change to meet the growing food demand [25], 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 major salts in saline soils are chloride and sulphates of sodium, calcium, magnesium and potassium [20] and these salts directly and indirectly interfere with various biological processes in the soil. To overcome the problem of salinity, addition of organic manures such as farm yard manure (FYM) and vermicompost which plays a crucial role in improvement of the soil fertility and productivity through its positive effects on soil physico-chemical and biological properties, and in balanced plant nutrition [12]. Biogas slurry proves to be good quality organic manure that improves physical and biological quality of soil by adding organic matter to the soil [7]. The present investigation was conducted to know the impact of INM on micronutrient content and uptake in pearl millet-wheat cropping system (which is the most prominent cropping system in arid and semi-arid regions of Haryana) on light textured soils which are highly prone to micronutrient deficiency.

2. Materials and Methods

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

The experiment consisted of twelve treatments *i.e.* 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^{-1} Biogas slurry (BGS) + ST-3], T_6 (RDF+ 2.5 t ha^{-1} BGS+ ST-3), T_7 [75% RDF+ 2.5 t ha^{-1} Vermicompost (VC)+ ST-3], T_8 (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)], T_{10} (RDF+ 10 t ha^{-1} FYM+ Biomix), T_{11} (75% RDF+ 2.5 t ha^{-1} VC+ Biomix) and T_{12} (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. Pearl millet variety HHB 299 and wheat variety HD 3086 were used for the experiment. Saline water having EC of 7.5 - 8.0 dS m^{-1} was used for irrigation.

Table 1: Chemical composition of organic manures used in investigation

S.No.	Chemical properties	FYM	VC	BGS	Method	Reference
1	**pH**	7.41	7.40	7.53	1:2 soil water suspension	[10]
2	**EC (dS m^{-1})**	1.27	1.30	1.42	1:2 soil water suspension	[18]
3	**Total N (%)**	0.75	1.59	1.63	Nessler's reagent	[24]
4	**Total P (%)**	0.61	0.57	1.02	Vanadomolybdate phosphoric acid yellow colour method	[11]
5	**Total K (%)**	1.12	1.09	1.46	Flame photometer	[11]
6	**Fe (mg kg^{-1})**	2.50	2.10	2.30	DTPA extractable method	[14]
7	**Mn (mg kg^{-1})**	286	271	277		
8	**Zn (mg kg^{-1})**	224	216	219		
9	**Cu (mg kg^{-1})**	25.0	26.1	25.2		

Total micronutrients (Fe, Cu, Mn and Zn) in aliquot were determined using Atomic Absorption Spectrophotometer (AAS) as proposed by [5]. Uptake of micronutrients (Mn, Fe, Cu and Zn) were computed from the data of Mn, Fe, Cu and Zn content in grain of pearl millet and wheat crop by using the following formula:

Nutrient uptake in grain or straw (kg ha^{-1}) = [Nutrient content (%) in grain or straw/100] x grain or straw yield (kg ha^{-1}).

Statistical analysis

The test of significance was carried out at 5 % level of significance by alluding to "F" table values. The difference between treatments was calculated using critical difference (C.D.) worked out by OPSTAT software developed by Department of Statistics, CCS Haryana Agricultural University [21].

3. Results

Micronutrients (Fe, Mn, Zn and Cu) content in grain of pearl millet and wheat

The data pertaining to micronutrients (Fe, Mn, Zn and Cu) content in pearl millet and wheat grain has been presented in table 2 and 3. The micronutrients content in pearl millet as well as in wheat grain varied significantly among various treatments under saline water irrigation. The Fe, Mn, Zn and Cu content varied from 53.95 to 93.60, 63.40 to 87.75, 55.8 to 66.5 and 3.83 to 7.33 mg kg^{-1} in pearl millet grain and 92.73 to 185.49, 53.09 to 109.94, 68.37 to 77.45 and 2.65 to 8.66 mg kg^{-1} in wheat grain, respectively under saline water irrigation. The mean highest Fe, Mn, Zn and Cu content was observed under treatment T_{10} (RDF+ FYM+ Biomix) which was significantly at par with treatment T_9, T_6, T_5 and T_{12}. The micronutrient content decreased non-significantly under treatment T_1, T_2, T_3 and T_4 under increasing salinity level in both pearl millet and wheat grain, however the micronutrient content was decreased with lesser percentage in treatment T_3 (75% RDF+ ST-3) and T_4 (RDF + ST-3) as compared to treatment T_1 and T_2, respectively under saline water irrigation. The Zn content varied non-significantly among treatment T_1, T_2, T_3 and T_4.

Micronutrients- Fe, Mn, Zn and Cu uptake by pearl millet grain

The perusal of data presented in table 4 revealed that Fe, Mn, Zn and Cu uptake varied significantly among various INM treatments. The Fe, Mn, Zn and Cu uptake varied from 0.10 to 0.26, 0.12 to 0.24, 0.11 to 0.18 and 0.007 to 0.02 kg ha^{-1}, respectively by pearl millet grain under saline water irrigation. The highest Fe, Mn, Zn and Cu uptake was found with treatment T_{10} (RDF+ FYM + Biomix) viz. 0.26, 0.24, 0.18 and 0.02 kg ha^{-1}, respectively by pearl millet grain which was at par with treatment T_6 (RDF+ BGS+ ST-3), T_5 (75% RDF+

BGS+ ST-3), T_{12} (RDF+ VC+ Biomix) and T_8 (RDF+ VC+ ST-3). The micronutrients uptake decreased with increasing salinity from 2022-23 to 2023-24 under sole application of inorganic fertilizers viz. T_1 (75% RDF) and T_2 (RDF).

Micronutrients- Fe, Mn, Zn and Cu uptake (kg ha^{-1}) by wheat grain

The data related to micronutrient uptake by wheat grain has been presented in table 5 which varied significantly among various INM treatments under saline water irrigation. The Fe, Mn, Zn and Cu uptake varied from 0.36 to 0.93, 0.21 to 0.55, 0.26 to 0.39 and 0.010 to 0.044 kg ha^{-1}, respectively by wheat grain. The highest uptake by wheat grain was found with treatment T_{10} (RDF+ FYM+ Biomix), followed by treatment T_9 (75% RDF+ FYM+ Biomix), T_6 (RDF+ BGS+ ST-3) and T_5 (75% RDF+ BGS+ ST-3).

4. Discussion

The critical perusal of data regarding micronutrient content (table 2 and 3) and their uptake as presented in table 4 and 5 revealed that micronutrient content and uptake varied significantly with various treatments under saline water irrigation. The micronutrients (Fe, Mn, Zn and Cu) content and uptake decreased with increase in salinity level from 2022-23 to 2023-24 under both pearl millet and wheat crop with sole application of inorganic fertilizers. The restricted supply of water under salt stress to roots and other plant parts might have contributed to the reduction in micronutrient contents [2]. The concentration of Fe, Mn and Cu in wheat depends on the concentration of macronutrients [9]. The non-linear relation between micronutrient and salt concentration makes it difficult to understand the mechanism of micronutrient concentration in plants under saline conditions [13], [17]. Copper is present in the soil in solution form, on adsorbed sites, in occluded form, and in the structure of primary and secondary minerals. The availability and mobility of in soil is enhanced by the formation of Cu containing inner-sphere complexes at high affinity sites and the sites having low-binding energy during its uptake in soil [3]. The combined use of chemical fertilizers and organic manures increased the content of Zn in all fractions in comparison to 75% and 100% RDF. This might be due to the reason that the application of chemical fertilizers increased the crop yield which left a large amount of crop residues and root mass in the soil, thereby, increased the organic matter content in the soil. The micronutrient content in grain and stover/straw of pearl millet and wheat increased significantly with integrated application of organic manures and inorganic fertilizers. The higher micronutrient concentration was recorded under treatment T_{10} (RDF+ FYM+ Biomix), followed by T_9 (75% RDF+ FYM+ Biomix). The application of organic manures resulted in increased concentration of available micronutrients by forming soluble chelated complexes which will increase uptake and concentration of micronutrients in plants [1], [15]. The higher concentration and uptake of micronutrients with FYM might be due to higher concentration of micronutrients in FYM compared to vermicompost and biogas slurry and also the ease of decomposability of farm yard manure.

Table 2: Influence of INM on micronutrients- Fe, Mn, Zn and Cu (mg kg^{-1}) content of pearl millet grain under saline water irrigation

		Fe			Mn			Zn			Cu		
Sr. No.	**Treatments**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**
T_1	**75% RDF**	54.30	52.78	53.95	66.2	60.6	63.40	56.30	55.20	55.80	4.02	3.64	3.83
T_2	**RDF**	68.40	66.80	67.60	72.5	71.6	72.05	57.60	56.10	56.85	4.91	4.83	4.87
T_3	**75%RDF + ST-3**	60.10	58.70	59.40	71.3	69.7	70.50	57.00	56.40	56.70	4.40	4.23	4.32
T_4	**RDF +ST-3**	73.20	73.00	73.10	74.5	75.3	74.90	58.00	57.20	57.60	5.18	5.11	5.15

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T_5	**75% RDF+ BGS+ ST-3**	88.30	87.20	87.75	81.6	84.3	82.95	62.50	63.90	63.20	6.17	6.51	6.34
T_6	**RDF + BGS + ST-3**	89.40	90.30	89.85	83.3	86.1	84.70	62.10	64.60	63.40	6.74	6.89	6.82
T_7	**75% RDF+VC + ST-3**	76.20	77.30	76.75	75.9	76.8	76.35	58.40	59.60	59.00	5.12	5.32	5.22
T_8	**RDF+ VC+ ST-3**	78.70	79.20	78.95	77.3	78.6	77.95	60.00	60.70	60.40	5.89	6.04	5.97
T_9	**75% RDF+FYM+Biomix**	90.80	91.80	91.30	83.9	86.3	85.10	63.20	64.50	63.85	7.02	7.36	7.19
T_{10}	**RDF + FYM+ Biomix**	92.50	94.70	93.60	86.4	89.1	87.75	65.40	67.60	66.50	7.12	7.53	7.33
T_{11}	**75% RDF+ VC+ Biomix**	81.50	83.10	82.30	79.6	83.2	81.40	59.20	60.30	59.75	5.87	6.12	6.00
T_{12}	**RDF+ VC+Biomix**	85.60	88.40	87.00	80.7	82.5	81.60	61.90	63.20	62.55	5.92	6.11	6.02
	C.D. (p=0.05)	**1.14**	**3.01**	**2.38**	**4.87**	**3.77**	**4.04**	**1.21**	**2.3**	**2.07**	**0.89**	**1.01**	**0.37**

Table 3: Influence of INM on micronutrients- Fe, Mn, Zn and Cu (mg kg^{-1}) content of wheat grain under saline water irrigation

		Fe			**Mn**			**Zn**			**Cu**		
Sr. No.	**Treatments**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**
T_1	**75% RDF**	96.10	89.36	92.73	55.17	51.02	53.09	68.47	68.26	68.37	3.26	2.04	2.65
T_2	**RDF**	87.25	81.27	84.26	69.63	68.44	69.03	70.21	69.97	70.09	3.68	3.22	3.45
T_3	**75%RDF + ST-3**	90.41	93.31	91.86	63.53	62.14	62.83	69.36	68.17	68.77	4.02	3.01	3.52
T_4	**RDF +ST-3**	97.29	95.78	96.54	70.94	71.52	71.23	70.74	68.49	69.62	4.11	3.88	4.00
T_5	**75% RDF+ BGS+ ST-3**	168.47	173.56	171.02	91.52	96.15	93.84	72.85	75.26	74.06	6.25	6.62	6.44
T_6	**RDF + BGS + ST-3**	170.19	178.29	174.24	94.87	99.23	97.05	73.91	76.33	75.12	6.39	7.16	6.78
T_7	**75% RDF+VC + ST-3**	154.84	163.41	159.13	78.25	80.25	79.25	71.23	73.36	72.30	4.57	4.71	4.64
T_8	**RDF+ VC+ ST-3**	159.58	168.23	163.91	87.26	91.41	89.34	71.89	73.91	72.90	5.61	5.72	5.67
T_9	**75% RDF+FYM+Biomix**	177.26	181.46	179.36	100.36	110.67	105.52	74.87	77.19	76.03	7.89	8.62	8.26
T_{10}	**RDF + FYM+ Biomix**	183.36	187.62	185.49	106.60	113.27	109.94	75.27	79.63	77.45	8.14	9.17	8.66
T_{11}	**75% RDF+ VC+ Biomix**	166.43	172.38	169.41	90.16	93.64	91.90	72.45	75.19	73.82	5.87	6.12	6.00
T_{12}	**RDF+ VC+Biomix**	160.58	169.39	164.99	88.23	92.38	90.31	72.66	74.67	73.67	6.04	6.34	6.19
	C.D. (p=0.05)	**6.14**	**7.22**	**8.65**	**8.26**	**7.11**	**6.17**	**2.05**	**3.46**	**3.00**	**1.02**	**0.73**	**1.09**

Table 4: Influence of INM on micronutrients- Fe, Mn, Zn and Cu uptake (kg ha^{-1}) by pearl millet grain under saline water irrigation

		Fe			Mn			Zn			Cu		
Sr. No.	**Treatments**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**
T_1	**75% RDF**	0.11	0.10	0.10	0.13	0.11	0.12	0.11	0.10	0.11	0.008	0.007	0.007
T_2	**RDF**	0.15	0.14	0.14	0.15	0.15	0.15	0.12	0.12	0.12	0.010	0.010	0.010
T_3	**75%RDF + ST-3**	0.12	0.12	0.12	0.15	0.14	0.15	0.12	0.12	0.12	0.009	0.009	0.009
T_4	**RDF +ST-3**	0.16	0.17	0.16	0.16	0.17	0.17	0.13	0.13	0.13	0.011	0.012	0.012
T_5	**75% RDF+ BGS+ ST-3**	0.21	0.21	0.21	0.19	0.21	0.20	0.15	0.16	0.15	0.015	0.016	0.015
T_6	**RDF + BGS + ST-3**	0.23	0.24	0.23	0.21	0.23	0.22	0.16	0.17	0.16	0.017	0.018	0.018
T_7	**75% RDF+VC + ST-3**	0.19	0.19	0.19	0.18	0.19	0.19	0.14	0.15	0.14	0.012	0.013	0.013
T_8	**RDF+ VC+ ST-3**	0.21	0.22	0.21	0.20	0.21	0.21	0.16	0.17	0.16	0.016	0.016	0.016
T_9	**75% RDF+FYM+Biomix**	0.23	0.24	0.23	0.21	0.23	0.22	0.16	0.17	0.16	0.018	0.019	0.018
T_{10}	**RDF + FYM+ Biomix**	0.25	0.27	0.26	0.23	0.25	0.24	0.18	0.19	0.18	0.019	0.021	0.020
T_{11}	**75% RDF+ VC+ Biomix**	0.20	0.21	0.20	0.19	0.21	0.20	0.14	0.15	0.15	0.014	0.015	0.015
T_{12}	**RDF+ VC+Biomix**	0.23	0.25	0.24	0.22	0.23	0.02	0.17	0.18	0.17	0.016	0.017	0.016
	C.D. (p=0.05)	**0.02**	**0.01**	**0.02**	**0.03**	**0.04**	**0.02**	**0.01**	**0.02**	**0.01**	**NS**	**NS**	**NS**

Table 5: Influence of INM on micronutrients- Fe, Mn, Zn and Cu uptake (kg ha^{-1}) by wheat grain under saline water irrigation

		Fe			Mn			Zn			Cu		
Sr. No.	**Treatments**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**
T_1	**75% RDF**	0.39	0.33	0.36	0.22	0.19	0.21	0.28	0.25	0.26	0.013	0.008	0.010
T_2	**RDF**	0.37	0.33	0.35	0.30	0.28	0.29	0.30	0.29	0.29	0.016	0.013	0.014
T_3	**75%RDF + ST-3**	0.37	0.39	0.38	0.26	0.26	0.26	0.29	0.29	0.29	0.017	0.013	0.015
T_4	**RDF +ST-3**	0.43	0.43	0.43	0.31	0.32	0.32	0.31	0.31	0.31	0.018	0.017	0.018
T_5	**75% RDF+ BGS+ ST-3**	0.77	0.81	0.79	0.42	0.45	0.43	0.33	0.35	0.34	0.029	0.031	0.030
T_6	**RDF + BGS + ST-3**	0.82	0.88	0.85	0.46	0.49	0.47	0.36	0.38	0.37	0.031	0.035	0.033
T_7	**75% RDF+VC + ST-3**	0.72	0.77	0.75	0.36	0.38	0.37	0.33	0.35	0.34	0.021	0.022	0.022
T_8	**RDF+ VC+ ST-3**	0.77	0.84	0.80	0.42	0.46	0.44	0.35	0.37	0.36	0.027	0.028	0.028
T_9	**75% RDF+FYM+Biomix**	0.85	0.89	0.87	0.48	0.54	0.51	0.36	0.38	0.37	0.038	0.042	0.040
T_{10}	**RDF + FYM+**	0.90	0.96	0.93	0.53	0.58	0.55	0.37	0.41	0.39	0.040	0.047	0.044

	Biomix												
T_{11}	**75% RDF+ VC+ Biomix**	0.78	0.83	0.81	0.42	0.45	0.44	0.34	0.36	0.35	0.028	0.029	0.029
T_{12}	**RDF+ VC+Biomix**	0.79	0.86	0.82	0.43	0.47	0.45	0.36	0.38	0.37	0.030	0.032	0.031
	C.D. (p=0.05)	**0.07**	**0.04**	**0.06**	**0.03**	**0.07**	**0.04**	**0.04**	**0.01**	**0.03**	**0.01**	**0.02**	**0.01**

5. Conclusion

The addition of organic manures along with fertilizers and bio-fertilizers showed the build-up of different forms of micronutrients in soils especially the plant available forms. The micronutrients (Fe, Mn, Zn and Cu) content and uptake increased significantly with integrated nutrient management as compared to sole application of inorganic fertilizers under saline water irrigation. The highest micronutrients content and uptake was recorded with treatment T_{10} (RDF+ FYM+ Biomix) and lowest being recorded with treatment T_1 (75% RDF) in both pearl millet and wheat under saline water irrigation.

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