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An assessment of domestic sewage sludge in pearl millet-wheat system under saline irrigation

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ABSTRACT

The present two-year experiment (2017-19) evaluated the impact of domestic sewage sludge (SS) on yield parameters and soil nutrient status under the pearl millet-wheat system using saline irrigation. The field study consisted of three irrigation treatments [canal water (0.35 dS/m); saline water (8 and 10 dS/m)], and five fertilizer treatments [control, SS (5 t/ha), SS (5 t/ha)+50% recommended dose of fertilizers (RDF), SS (5 t/ha)+75% RDF and 100% RDF]. The results revealed a significant reduction in the biological yield and yield attributes, and protein content of both crops with increasing salinity levels of irrigation water during both the years. However, all these parameters recorded significantly highest values under 100% RDF which was statistically at par with SS (5 t/ha) + 75% RDF treatment. The soil available sulphur (S) was significantly increased with 8 and 10 dS/m EC of saline water over canal water (0.35 dS/m) irrigation. But, SS (5 t/ha) + 75% RDF obtained 36.7 and 22.3% higher available S over control and 100% RDF, respectively. No significant effects were made in DTPA-extractable micronutrients (Fe, Mn, and Cu) with saline irrigation except Zn, which was reduced under saline environment. SS added treatments obtained higher micronutrient concentration over control. Hence, SS incorporation has proven useful in sustainable crop production and improved micronutrient availability in the soil.

Keywords: Domestic sewage sludge, Micronutrient, Pearl millet, Salinity, Wheat, yield

The limited availability of freshwater is increasingly in demand for competing uses and creates the need to use marginal quality water in agriculture. The saline groundwater arises through primary (natural) and secondary (anthropogenic) salinization (Amor *et al*. 2013). Irrigation water has a wide range of salt concentration mainly depends on the characteristics of the soil and water (Ragab *et al*. 2008). Salinity has an adverse effect on soil micronutrient availability (Sharma *et al*. 2009) and plant systems, such as root growth, cell division, leaf elongation, a rate of evapotranspiration, absorption of nutrient and water (Singh *et al*. 2018), and ultimately reduced yield might be due to due to a shift in osmotic potential of soil-water phase (Vanlalruati *et al*. 2019). Furthermore, to encourage sustainability by preventing or mitigating the negative impacts of saline irrigation water on agricultural lands, proper management has become necessary.

Sewage sludge is a likely by-product of the operations of wastewater treatment plants (Ankush *et al*. 2021), and its rapidly increasing production is a key issue in many developing countries. Furthermore, it can be utilized as a source of fertilizer (Roy *et al*. 2019, Sharma and Dhaliwal 2019). Field application of sewage sludge would be the best alternative, as the economic and environmental costs for landfilling, spreading, and incineration are very high. It also offers the chance to recover high organic carbon and essential plant nutrients in the soil (Ankush *et al*. 2020). The use of sewage sludge as an organic fertilizer has therefore proven beneficial for various field crops (Roy *et al*. 2013, Biswas *et al*. 2017, Kumar *et al*. 2020). Pearl millet-wheat cropping system is however the second most prominent system after rice- wheat system in the Northern plains of Haryana. Being an intensive system, it is very exhaustive and requires balanced nutrition, which can't be achieved by the alone application of either inorganic fertilizer or organic manure. However, considering the above facts, this study was undertaken to evaluate the results of domestic sludge application on yield and yield attributes, protein content and, soil nutrient status using saline irrigation under the pearl millet-wheat system.

MATERIALS AND METHODS

The present study (2017–19) was carried out in sandy loam textured soil of Hisar, (Haryana) with three replications in a factorial randomized block design (RBD). The initial

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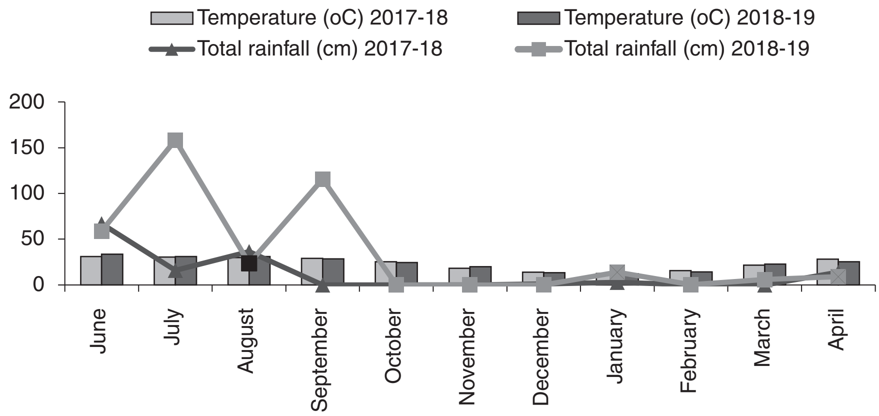

Fig 1 Average monthly meteorological data during both years of experimentation.

soil samples were analyzed for various chemical properties i.e. pH 8.25, EC (0.37 dS/m), soil organic carbon (0.31%), available nitrogen (110 kg/ha), phosphorus (16 kg/ha), potassium (290 kg/ha), sulphur (102 ppm) and DTPA-extractable micronutrients (Fe, Mn, Zn and Cu), viz. 2.31, 4.40, 1.37 and 0.83 mg/kg, respectively. The field experiment was conducted with three irrigation treatments [canal water (0.35 dS/m); saline water (8 and 10 dS/m)], and five fertilizer treatments [control, SS (5 t/ha), SS (5 t/ha) + 50% recommended dose of fertilizers (RDF), SS (5 t/ha)+75% RDF and 100% RDF]. Sewage sludge was applied only in *rabi* season. However, it was slightly alkaline in nature (*p*H 7.84) and having low EC (1.45 dS/m). The organic carbon, total N, P, K, S and micronutrient's concentration (Fe, Mn, Zn and Cu) of SS were 25.4%, 1.36%, 0.87%, 1.40%, 0.79%; 256, 103, 49 and 11 mg/kg, respectively. The experimental site has a semi-arid climate and mean monthly meteorological data during the cropping season (2017–19) (Fig 1).

The number of irrigations applied in crops according to their package of practices adopted in the Haryana state of India and the desired level of EC was prepared by the blending of borewell (saline) water with canal water. However, the safer limits for making use of water for irrigation purpose is EC < 2 dS/m as per the guidelines of HAU, Hisar. Irrigation water samples were taken at the time of irrigations and standard methods were adopted to calculate their ionic composition (Richard 1954). Water used to irrigate the crops was chloride dominated. However soil soluble cation and anion order in canal (0.35 dS/m), 8 and 10 dS/m EC saline water was: Na^+ (0.71, 53.80 and 69.15 me/l) > Mg^{2+} (1.65, 18.50 and 24.04 me/l) > Ca^{2+} (0.98, 7.50 and 8.45 me/l) > K^+ (0.09, 0.35 and 0.40 me/l) and Cl^- (1.35, 59.60 and 72.80 me/l) > SO_4^{2-} (1.20, 19.23 and 25.27 me/l) > HCO_3^- (0.80, 1.60 and 2.40 me/l), respectively.

During the years, biological yields and yield attributes i.e. length of earhead/spike, number of effective tillers, plant height, and test weight were recorded at harvesting time. The protein content was calculated by multiplying % N in the grain of crops by a factor of 6.25 and protein yield by multiplying % protein content with grain yield of crops (Yamaguchi 1992). The soil samples (0-15 cm depth) were collected initially before pearl millet sowing (2017) and then at the completion of the cropping system each year from the respective treated plot. The chemical parameters of soil and sewage sludge were determined by standard methods as outlined by Antil *et al*. (2002). The data was statistically analyzed by using EXCEL, OPSTAT statistical software package developed by the Department of Statistics, CCS Haryana Agricultural University (Sheoran *et al*. 1998) at the probability (P= 0.05) to drive ANOVA.

RESULTS AND DISCUSSIONS

Biological yield: Among irrigation treatments, the significantly highest biological yield of pearl millet (91.46 and 85.33 q/ha) and wheat (92.68 and 94.83 q/ha) was recorded with canal irrigation (0.35 dS/m) during 2017–18 and 2018–19, respectively (Table 1). However, irrigation through saline irrigation (8 and 10 dS/m EC) reduced biological yield in pearl millet i.e. 23.6, 31.2; 24.3, 31.9% and in wheat i.e. 23.7, 32.5; 24.4, 32.8% in the year 2017–18 and 2018–19 as compared to canal irrigation, respectively. Similar results were reported by Ragab *et al*. (2008), Kalhoro *et al*. (2016). The osmotic pressure of the soil solution rises due to higher concentrations in the soil/root zone and plants face difficulties with the extraction of water and nutrients (Singh *et al*. 2018). Among fertilizer treatments, the significant highest biological yield of pearl millet (89.21 and 83.94 q/ha) and wheat (94.61 and 97.09 q/ha) was recorded with 100% RDF being statistically at par with of SS (5 t/ha) + 75% RDF whereas minimum biological yields of pearl millet (57.34, 51.65 q/ha) and wheat (51.73 and 49.63 q/ha) crops were recorded in control during 2017–18 and 2018–19, respectively. The highest yield with 100% RDF may be due to the easily availability of nutrients compared to manures. However, integrated use of SS and mineral fertilizers might have improved soil physico-chemical and biological properties with the beneficial effect of organic matter present along with macronutrients and micronutrients in sewage sludge (Meena *et al*. 2013, Latare *et al*. 2014) thus it increased yield over rest of the treatments being statistically similar with 100% RDF.

Yield attributes: The data revealed that yield attributing characters of pearl millet and wheat (Table 1) crops were significantly affected with the application of sewage sludge and saline water irrigation during both the years of experimentation. The yield attributes, viz. earhead/spike length, number of effective tillers, plant height and test weight of pearl millet (20.98 and 21.62 cm; 12.07 and 12.27; 217.40 and 219.42 cm; 8.89 and 9.03 g) and wheat (12.69 and 12.88 cm; 50.69 and 51.80; 93.85 and 94.91;

Table 1 Effect of sewage sludge application on yield parameter and grain quality of pearl millet- wheat cropping system under saline water irrigation

Treatments	Pearl millet														Wheat													
	Biological yield (q/ha)		Protein content (%)		Protein yield (kg/ha)		Earhead length (cm)		Number of effective tillers/m row length		Plant height (cm)		Test weight (g)		Biological yield (q/ha)		Protein content (%)		Protein yield (kg/ha)		Spike length (cm)		Number of effective tillers/m row length		Plant height (cm)		Test weight (g)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation treatment																												
Canal (0.35 dS/m)	91.46	85.33	10.14	10.18	304.63	292.43	20.98	21.62	12.07	12.27	217.40	219.42	8.89	9.03	92.68	94.83	10.13	10.16	397.62	411.55	12.69	12.88	50.69	51.80	93.85	94.91	43.06	43.51
8 dS/m	69.81	64.52	9.14	9.13	211.77	200.04	16.94	16.46	9.60	9.00	165.32	164.45	6.94	6.98	70.68	71.66	9.23	9.30	276.55	283.19	10.13	10.17	40.09	40.08	71.02	71.22	32.85	32.95
10 dS/m	62.92	58.11	8.62	8.56	178.93	168.13	15.52	14.78	8.40	8.33	151.48	150.72	6.47	6.46	62.53	63.71	8.70	8.71	231.53	237.69	9.25	9.35	35.07	35.01	64.73	64.91	31.40	31.43
CD (P= 0.05)	6.45	6.25	0.78	0.80	40.52	43.31	0.32	0.50	0.29	0.24	3.45	2.89	0.08	0.09	6.37	6.46	0.78	0.89	51.77	43.39	0.28	0.31	1.00	0.97	1.52	1.82	0.51	0.47
Fertilizer treatment																												
Control	57.34	51.65	7.67	6.96	153.18	127.84	13.95	13.37	8.00	8.00	164.19	162.27	6.73	6.80	51.73	49.63	7.31	7.02	165.57	151.79	8.71	8.55	36.46	35.64	67.14	66.27	29.16	28.94
SS (5 t/ha)	66.56	61.55	8.68	8.78	196.46	185.80	16.34	15.69	9.11	9.22	170.04	170.26	6.95	7.07	62.13	64.62	8.82	8.89	233.93	243.55	9.58	9.78	38.91	39.43	71.09	71.38	32.78	32.95
SS (5 t/ha)+ 50% RDF	75.50	69.66	9.23	9.38	229.15	215.88	18.28	18.19	9.78	9.56	175.04	175.83	7.50	7.55	79.41	81.26	9.40	9.48	312.78	321.53	10.57	10.76	41.72	42.20	76.08	76.55	37.09	37.17
SS (5 t/ha)+ 75% RDF	85.04	79.80	10.23	10.46	279.78	275.24	19.76	20.21	11.11	10.89	187.95	188.49	7.86	7.90	88.60	91.07	10.46	10.56	381.50	398.48	11.81	11.90	45.10	45.86	82.41	83.74	39.12	39.80
100% RDF	89.21	83.94	10.70	10.87	300.32	296.23	20.73	20.65	12.11	11.67	192.99	194.13	8.13	8.11	94.61	97.09	10.76	11.00	415.72	438.69	12.77	13.02	47.57	48.37	85.95	87.14	40.69	40.94
CD (P= 0.05)	8.32	8.07	1.01	1.03	52.31	55.91	0.41	0.64	0.38	0.31	4.45	3.72	0.11	0.12	8.22	8.34	1.01	1.15	66.83	56.01	0.36	0.40	1.28	1.25	1.97	2.35	0.65	0.61

43.06 and 43.51 g) crop were obtained with canal irrigation respectively, and a significant reduction was recorded with saline irrigation. The stunting growth of plants is a clear consequence of salinity stress. Restricted plant growth and decreased leaf area thus affect the plant metabolic activities of nutrient uptake and normal plant growth which may results in an excessive accumulation of Na^+ and Cl^- in plant tissue (Saqib *et al*. 2005) and ultimately results in a reduction in crop yields. Salinity stress at the grain filling stage can cause a decrease in photosynthates mobilization to grains and thereby decreasing test weight (Sadeghipour 2008). However, the significantly highest yield attributes were recorded with 100% RDF which was statistically at par with SS (5 t/ha) + 75% RDF. It has been demonstrated that sewage sludge application in pearl millet-wheat cropping system could supplement 25% of the recommended dose of fertilizers though yields were at par with 100% RDF. An increase in yield could be due to improved nutrient supply along with a conductive physical environment for better root activity and greater nutrient absorption (Sharma and Dhaliwal 2019).

Protein content: Application of sewage sludge and saline water irrigation significantly influenced the protein content and protein yield of pearl millet and wheat crops during both years (Table 1). The significantly highest protein content and protein yield of pearl millet (10.14 and 10.18%, 304.63 and 292.43 kg/ha) and wheat (10.13 and 10.16%, 397.62 and 411.55 kg/ha) were recorded with canal irrigation (0.35 dS/m), during 2017–18 and 2018–19, respectively whereas the lowest was recorded under plots irrigated with saline water (EC 8 and 10 dS/m). The higher concentration of Na^+ in soil solution interferes with N absorption resulting in lower protein content in the grains (Makarana *et al*. 2017). Among fertilizer treatments, the significant highest protein content and yield of pearl millet (10.70 and 10.87%, 300.32 and 296.23 kg/ha) and wheat (10.76 and 11.00%, 415.72 and 438.69 kg/ha) was recorded with 100% RDF being statistically at par with of SS (5 t/ha) + 75% RDF. The lowest protein content and protein yield of crops were recorded in control. These results are in agreement with those reported by Meena *et al*. (2013).

Available sulphur: The data (Fig 2) showed that highest available S was obtained with saline water irrigation (EC 10 dS/m) i.e. 138.38 and 141.90 ppm followed by 8 dS/m EC of saline water irrigation (127.14 and 129.13 ppm) after 1st and 2nd year of experimentation, respectively. This increase in available S content may be due to the addition of S through irrigation water. A similar result was reported by Weggler *et al*. (2004). The soil available S was significantly increased with sewage sludge application, and significantly higher values were obtained with SS (5 t/ha) + 75% RDF i.e. 133.83 and 137.60 ppm being at par with SS (5 t/ha) + 50% and SS (5 t/ha) after Ist and IInd year harvest, respectively. Sole application of sewage sludge significantly increased soil available S over RDF and control during both years. A significant increase in available S content in the soil might be due to the sewage sludge application that furnish as a source of nutrients and increased the availability of available sulphur in soil (Latare *et al*. 2014).

DTPA-extractable micronutrients: At post-harvest, the micronutrient's availability in soil was remained unaffected by the saline irrigation water except for Zn which was decreased significantly (Table 2). Similar result was reported by Talukdar *et al*. (2009). However, the reduction of micronutrients under saline conditions might be due to precipitation as hydroxides or carbonates resulting of higher *p*H (Malik *et al*. 2017). DTPA-extractable micronutrient availability is negatively correlated with high salinity (Sharma *et al*. 2009). It was observed that the application of the sewage sludge significantly increased micronutrient availability in soil. The maximum concentration of Fe, Mn, Zn, and Cu i.e. 3.50 and 4.48; 5.97 and 6.77; 1.79 and 2.24; 1.07 and 1.40 mg/kg were obtained with SS (5t/ha) being at par with SS (5 t/ha) +50% RDF and SS (5 t/ha) + 75% RDF during 1st and 2nd year, respectively. As sewage sludge contains high concentration of micronutrient which upon slow decomposition, further added micronutrient pool in soil. Our study is in line of agreement with the findings of Roy *et al*. (2013), Singh *et al*. (2015), Sharma and Dhaliwal (2019).

Salinity exerted an adverse effect on yield attributes, and grain quality of cereals. The available S in soil was significantly increased with increasing salinity levels of

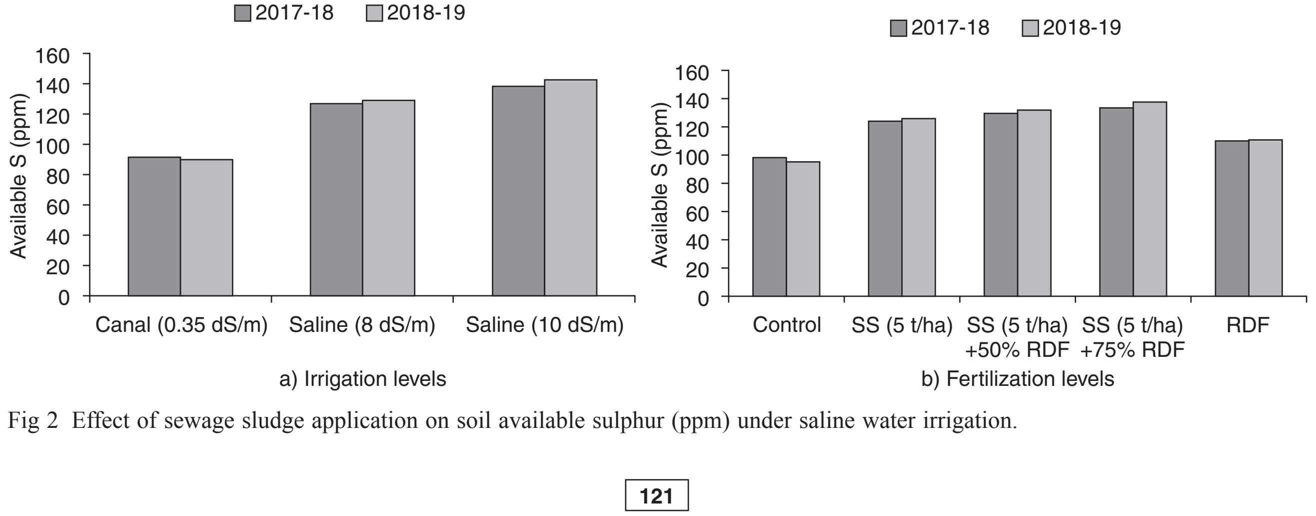

Fig 2 Effect of sewage sludge application on soil available sulphur (ppm) under saline water irrigation.

Table 2 Effect of sewage sludge application on DTPA-extractable micronutrients (mg/kg) at post-harvest soil under saline water irrigation

Treatments	Fe		Mn		Zn		Cu	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation treatment								
Canal (0.35 dS/m)	3.26	3.71	5.45	5.98	1.75	1.99	0.97	1.11
8 dS/m	2.77	3.28	4.91	5.51	1.52	1.70	0.93	1.05
10 dS/m	2.64	3.09	4.77	5.19	1.42	1.56	0.87	0.96
CD (P=0.05)	NS	NS	NS	NS	0.26	0.30	NS	NS
Fertilizer treatment								
Control	2.25	2.16	4.37	4.02	1.23	1.19	0.79	0.69
SS (5 t/ha)	3.50	4.43	5.97	6.77	1.79	2.24	1.07	1.40
SS (5 t/ha)+ 50% RDF	3.32	4.23	5.46	6.59	1.73	2.12	1.03	1.31
SS (5 t/ha)+ 75% RDF	3.18	3.97	5.21	6.50	1.67	1.92	1.00	1.24
100% RDF	2.19	2.01	4.20	3.92	1.40	1.29	0.72	0.57
CD (P=0.05)	0.67	0.71	0.89	1.06	0.33	0.38	0.17	0.21

irrigation water, while micronutrient's availability (Fe, Mn, and Cu) remained unaffected except Zn, which was reduced under saline conditions. However, 100% RDF significantly enhanced yields and quality of both crops but it was statistically at par with SS (5 t/ha) + 75% RDF. This implies that the use of SS could save 25% RDF. Also, SS addition enhanced nutrient availability in the soil. Hence, the use of SS can be appropriate in agricultural crop production, and farmers can use it as gold instead of thinking it a waste material.

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