Indian Journal of Traditional Knowledge
Vol 21(2), April 2022, pp 450-457

Influence of sewage sludge and saline water irrigation on soil soluble ions and nutrient uptake under Pearl millet-Wheat cropping system in semi-arid region

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Received 30 January 2020; revised 17 October 2021

Salinity is the most common problem in arid and semi-arid regions hindering nutrient accumulation in plants. A field trial (2017-18) was carried out to study the effect of sewage sludge (SS) and saline water irrigation on nutrient uptake under the pearl millet-wheat system and soluble ions in the soil. The experiment consisted of three irrigation levels (canal water, 8 and 10 dS/m EC_{iw} saline water) and five fertilizer treatments i.e., control, sewage sludge (SS)- 5 t/ha, SS (5 t/ha) + 50% recommended dose of fertilizer (RDF), SS (5 t/ha) + 75% RDF and 100% RDF where sewage sludge was applied in *rabi* season only. The results indicated that the saline water irrigation significantly increased the concentrations of soluble ions (Na^+, K^+, Ca^{2+}+Mg^{2+}, HCO_3^-, SO_4^{2-} and Cl^-) in the soil, and also the increase was non-significant under sewage sludge application. Na^+ and Cl^- ions were dominated under saline conditions among the soluble ions in the soil. The nutrient (N, P and K) uptake by grain and stover/straw of pearl millet and wheat crops were significantly reduced under saline environment. However, the maximum uptake in both crops was obtained under canal water irrigation (0.35 dS/m). Among fertilizer treatments, the maximum uptake (NPK) in both crops was attained under RDF being at par with SS (5 t/ha) + 75 RDF except K uptake in pearl millet crop, where the highest K uptake was obtained with SS (5 t/ha) + 75 RDF which was remained statistically at par with RDF treatment. The interactive effect was however non-significant. It is concluded that incorporating SS would enhance nutrient uptake in crops under saline conditions besides solving its dumping problem.

Keywords: Nutrient uptake, Pearl millet, Saline irrigation, Sewage sludge, Soluble ions, Wheat

IPC Code: Int Cl.[22]: A01G 25/00, C02F 11/00

The production of sewage sludge is increasing worldwide as due to the fast-growing population, urbanization and industrialization. It is the semi-solid by-product obtained during sewage treatment of municipal wastewater[1]. To reduce the negative effects of their application or disposal, it becomes very important to properly treat and manage the sewage sludge. There are two main strategies for managing sewage sludge: reuse, including the agricultural purpose or the final disposal. The use of sewage sludge as a fertilizer source in agricultural production might be a good option[2], but it brings a serious concern: the heavy metals accumulation in soil/plants if applied in larger quantities[3]. Though the occurrence of heavy metals in sewage sludge mainly depends on the source from where it was collected[4].

Besides heavy metals, it is a rich source of organic matter, macronutrients, and micronutrients[5,6] if applied in the right amount and at the right time, and it also helps in improving soil physico-chemical and biological properties[1]. Arpali *et al.*,[7] recorded 99% higher yield over control, and with the increasing rate of sewage sludge, other yield attributes also increased and obtained highest with the treatment @ 30 t/ha application of sewage sludge. Nutrient uptake (NPK) by wheat crop was significantly increased where sewage sludge was used in a conjoint application with inorganic fertilizers[8]. The application of organic manures into agricultural land is a traditional practice since ancient times, but at current, dumping of sewage sludge is an emerging issue. So, agricultural use of sewage sludge is highly appreciable due to its nutritious value. However, it is very beneficial to use sewage sludge as a supplement

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Abbreviation: SS- Sewage sludge, EC_{iw}- electrical conductivity of irrigation water, RDF- recommended dose of fertilizers; Na^+- sodium, K^+- potassium, Ca^{2+}+Mg^{2+}- calcium and magnesium, HCO_3^-- bicarbonate, SO_4^{2-}- sulphate, Cl^- - chloride, N- nitrogen, P- phosphorus and K- potassium of fertilizers or in an integrated manner with mineral fertilizers in cereals production[9,10].

Further, the availability of good quality water is a major concern nowadays and the availability of irrigation water in Haryana is poor due to salinity/sodicity problems. In past years, farmers used to irrigate their fields traditionally by canal or well water. Nevertheless, due to over-exploitation, problems of salinity and water-logging has arisen. The farmers are forced to use such water for crop production. In the present time, lack of good quality water is a limiting factor in crop production. Salinity predominates in arid and semi-arid regions due to the accumulation of soluble salts, limiting plant growth, yield and inhibiting water and nutrient flow in the soil-plant system[11]. Husaain *et al.*,[12] reported decreased nitrogen, phosphorus and potassium uptake in wheat crop by 36, 56 and 42%, respectively, under salinity stress. The decreased nutrient uptake under saline conditions might be attributed to the building of salts concentration in soil that creates a situation of osmotic effects, specific ion effect and ions imbalance in the soil-plant system and hinders the absorption and transportation of nutrients from the soil to plant roots and further from roots to the upper plant parts[13].

Salts also get accumulated with sewage sludge application because of their composition, but organic matter might chelate them and reduce their concentration in the soil. Minimal efforts have been made to study the use of sewage sludge under saline conditions. With keeping in view, the above points, an experiment was planned to evaluate the effect of sewage sludge and saline water irrigation on soluble cations and anions in the soil and nutrient uptake by grains and straws of pearl millet-wheat cropping system in the semi-arid region of Haryana.

Materials and Methods

Experimental site

To assess the sewage sludge as a source of fertilizer in pearl millet-wheat crop rotation irrigated with saline irrigation, an experiment (part of a long-term experiment) was conducted at Soil Research Farm, CCS Haryana Agricultural University, Hisar during 2017-18. The location is situated in semi-arid, sub-tropics. A factorial randomly block design was chosen with three repetitions.

Treatments details

The experiment involved three irrigation levels i.e., canal water, 8 and 10 dS/m EC_{iw} of saline water and five fertilizer treatments i.e., control, SS (5 t/ha), SS (5 t/ha)+50% RDF, SS (5 t/ha)+ 75% RDF and RDF. Sewage sludge was applied as basal dose in *Rabi* season only.

Collection and characterization of soil and sewage sludge

Initial composite soil sample was taken before pearl millet sowing and the final was taken at completion of crop rotation. The experimental soil was sandy loam in texture. Initially the soil was low in organic carbon (0.31%) and having available nitrogen (110 kg/ha); medium in available phosphorus (16.1 kg/ha) and available potassium (290 kg/ha). The soil was alkaline in reaction (pH 8.25) and had soil EC of 0.37 dS/m. The soil sample had varying concentrations of soluble ions i.e., Na^+ (1.82 me/l), K^+ (0.31 me/l), Ca^{2+}+Mg^{2+} (1.55 me/l), HCO_3^- (0.24 me/l), SO_4^{2-} (1.35 me/l) and Cl^- (2.05 me/l). Sewage sludge used in the experiment was collected from municipal solid waste treatment located at university farm. Sewage sludge had pH (7.84), EC (1.45 dS/m), organic carbon (25.4%), total nitrogen (1.36%), total phosphorus (0.87%), total potassium (1.40%).

Agronomic practices

The portions of nitrogen, phosphorus and potassium nutrients were applied through urea, di-ammonium phosphate (DAP) and muriate of potash (MOP), respectively. Half dose of the nitrogen (N) and full portion of phosphorus (P) and potassium (K) was incorporated at the sowing time of crops and remaining N dose was applied after 1st irrigation and recommended dose of zinc through zinc sulphate ($ZnSO_4$) was applied at sowing time in wheat season only. Varieties HHB 226 and WH 1105 of pearl millet and wheat were undertaken for the experimentation, respectively. Sowing was done manually with the help of hand held plough. The remaining practices were done according to package practice adopted in Haryana.

Irrigation

Irrigations were applied in both crops according to their package practice adopted in Haryana. In pearl millet three irrigations and in wheat five irrigations were done. Canal water was directly applied in required plots and the desired level of EC_{iw} (8 and 10 dS/m) was prepared by mixing of saline water with canal water. Water samples were taken at the time of irrigation and standard methods were adopted to calculate ionic composition in it. Carbonates and bicarbonates in irrigation water were determined by titrating it with standard H_2SO_4 using phenopthalin and methyl red indicators, respectively[14]. Chloride in water was determined by titrating it with $AgNO_3$ solution using potassium dichromate as an indicator[14]. Sulphate in water was determined by Chesnin and Yien[15] method by using barium chloride using gum acacia solution. Sodium and potassium in water was determined by using flame photometer[14] and magnesium in water were determined by versenate titration using Eriochrome black-T (EBT) indicator in the presence of buffer[14]. The chemical composition of irrigation water is expressed in Table 1.

Soil, sewage sludge and plant analysis

The soil $pH_{(1:2)}$ and $EC_{(1:2)}$ were determined by using pH and conductivity meter[14]. The suspension left out after EC analysis was stored for further analysis of soluble ions in soil. The methods adopted for analysis of soil soluble ions are as same as mentioned above for irrigation water analysis. Sewage sludge sample was air-dried, ground and pass through a 2 mm sieve. The ratio of sewage sludge and water suspension was 1:5 in case of sewage sludge analysis for pH and EC. Soil texture was determined by the hydrometer method[16]. Organic carbon content in soil and sewage sludge was determined by the wet digestion method[17]. The available soil nitrogen was determined with the help of alkaline potassium permanganate ($KMnO_4$)[18]. For available soil phosphorus[19] and potassium[20], soil sample was extracted with 0.5 M $NaHCO_3$ and 1 M NH_4 OAC, respectively. Digestion is the main step in the plant and sewage sludge analysis thereafter standard methods adopted. The total nitrogen (N) content in sewage sludge was determined by using Nessler's reagent[21] and total phosphorus with the help of vandomolybdate phosphoric acid yellow color method[20]. Potassium in sewage sludge was determined with the help of flame photometer[14]. For plant analysis, dried plant samples were chopped down with the help of chopper machine and then methods adopted were same as above described for sewage sludge analysis. Nutrient uptake was calculated by multiplying their nutrient content with corresponding grain and biomass yields.

Statistical analysis

For final conclusions, the data on plants were statistically analyzed by adopting the method as explained by Fischer[22].

Results and Discussion

N uptake

The data related to mean N uptake by pearl millet and wheat crops are being expressed in Table 2 and Table 3.

Effect of salinity

A critical perusal of data presented in Table 2 showed that N uptake by pearl millet and wheat grain was significantly reduced under a saline environment. The significantly higher N uptake by pearl millet grain (48.74 kg/ha) as well as by wheat grain (63.62 kg/ha) was recorded with canal water irrigation followed by 8 dS/m EC_{iw} which was statistically at par with 10 dS/m EC_{iw} of saline water. Application of 8 and 10 dS/m EC of saline water irrigation significantly reduced 30.5, 41.3% N uptake in pearl millet grain and 30.4, 41.8% in wheat grain as compared to canal water irrigation, respectively. It was noticed that N uptake by pearl millet stover and wheat straw (Table 3) was also significantly reduced with increasing salinity levels of irrigation water. The significantly higher N uptake by pearl millet stover (51.31 kg/ha) as well as by wheat straw (50.32 kg/ha) was recorded with canal water irrigation (0.35 dS/m). Application of 8 and 10 dS/m EC_{iw} of saline water irrigation had shown a significant reduction of 34.5, 45.1% respective N uptake in pearl millet stover and 37.2, 49.6% in wheat straw in comparison of canal water irrigation, respectively. Salinity affects nutrient availability mainly by three reasons; modifying the retention, fixation and transformation of nutrients in soil, interfering uptake/adsorption of nutrients due to ionic competition and disturbing the metabolism of nutrients in plant mainly through water stress[23]. Ionic and nutritional imbalances are particularly linked with salinity stress in plants and occur due to competition of salts ions with nutrients present in the soil[24,25]. Reduction in N uptake in both crops might be due to decreased rate of nitrification of ammonium ions due to salinity and

Table 1 — Chemical composition of irrigation water

Treatment	pH	EC (dS/m)	Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	SAR
			(me/l)								
Canal	7.10	0.35	0.71	0.09	0.98	1.65	Nil	0.80	1.35	1.20	0.62
8 dS/m	7.66	8.17	53.80	0.35	7.50	18.50	Nil	1.60	59.60	19.23	14.90
10 dS/m	7.83	10.09	69.15	0.40	8.45	24.04	Nil	2.40	72.80	25.27	17.15

Table 2 — Effect of sewage sludge application on NPK uptake (kg/ha) by pearl millet and wheat grain under saline water irrigation

Treatments	N				P				K			
	Canal	8dS/m	10 dS/m	Mean	Canal	8dS/m	10 dS/m	Mean	Canal	8dS/m	10 dS/m	Mean
Pearl millet												
Control	30.99	22.45	20.09	24.51	14.65	9.46	8.04	10.71	9.37	5.69	4.38	6.48
SS (5 t/ha)	42.03	27.85	24.42	31.43	21.43	12.38	10.25	14.69	14.43	8.05	5.59	9.36
SS (5 t/ha) + 50% RDF	48.67	33.37	27.95	36.66	25.78	15.65	12.74	18.06	19.14	11.27	7.83	12.75
SS (5 t/ha) + 75% RDF	59.04	41.23	34.02	44.76	32.32	20.11	16.33	22.92	23.74	14.01	10.51	16.09
RDF	62.97	44.51	36.67	48.05	35.34	22.39	18.33	25.35	22.69	12.88	9.44	15.01
Mean	48.74	33.88	28.63		25.90	16.00	13.14		17.87	10.38	7.55	
C.D. (p= 0.05)	Irrigation- 6.48 Treatment- 8.37 Irrigation x Treatment- NS				Irrigation- 3.33 Treatment- 4.30 Irrigation x Treatment- NS				Irrigation- 2.39 Treatment- 3.09 Irrigation x Treatment- NS			
Wheat												
Control	33.85	24.31	21.31	26.49	16.25	10.15	8.64	11.68	9.48	5.71	4.61	6.60
SS (5 t/ha)	50.46	33.56	28.26	37.43	28.00	15.81	13.38	19.06	21.81	11.67	9.28	14.25
SS (5 t/ha) + 50% RDF	66.89	45.94	37.31	50.05	38.98	23.12	18.79	26.97	32.42	17.57	13.96	21.32
SS (5 t/ha) + 75% RDF	80.78	56.27	46.07	61.04	47.31	28.30	23.63	33.08	39.27	21.90	17.65	26.28
RDF	86.11	61.16	52.28	66.52	51.84	32.02	26.95	36.94	42.49	25.18	20.46	29.37
Mean	63.62	44.25	37.04		36.48	21.88	18.28		29.09	16.41	13.19	
C.D. (p= 0.05)	Irrigation- 8.28 Treatment- 10.69 Irrigation x Treatment- NS				Irrigation- 4.47 Treatment- 5.77 Irrigation x Treatment- NS				Irrigation- 3.45 Treatment- 4.46 Irrigation x Treatment- NS			

Irrigation water quality

Table 3 — Effect of sewage sludge application on NPK uptake (kg/ha) by pearl millet stover and wheat straw under saline water irrigation

Treatments	N				P				K			
	Canal	8dS/m	10 dS/m	Mean	Canal	8dS/m	10 dS/m	Mean	Canal	8dS/m	10 dS/m	Mean
Pearl millet												
Control	24.01	16.42	14.03	18.15	9.97	6.78	5.22	7.32	50.92	32.14	24.77	35.94
SS (5 t/ha)	36.39	22.42	18.70	25.84	14.89	9.13	6.36	10.13	72.66	42.34	35.52	50.17
SS (5 t/ha) + 50% RDF	49.99	32.10	26.13	36.07	18.98	11.05	8.13	12.72	93.01	54.15	45.35	64.17
SS (5 t/ha) + 75% RDF	68.64	44.13	37.24	50.00	24.57	14.80	11.81	17.06	114.87	68.68	58.70	80.75
RDF	77.55	53.00	44.82	58.45	27.23	17.47	13.71	19.47	113.82	71.50	56.46	80.59
Mean	51.31	33.61	28.18		19.13	11.85	9.04		89.06	53.76	44.16	
C.D. (p= 0.05)	Irrigation- 7.25 Treatment- 9.36 Irrigation x Treatment- NS				Irrigation- 2.29 Treatment- 2.96 Irrigation x Treatment- NS				Irrigation- 9.56 Treatment- 12.34 Irrigation x Treatment- NS			
Wheat												
Control	18.12	12.14	9.92	13.39	7.25	5.08	3.56	5.30	39.15	24.57	18.81	27.51
SS (5 t/ha)	34.03	19.41	15.25	22.89	14.52	8.51	5.98	9.67	68.96	41.20	30.49	46.88
SS (5 t/ha) + 50% RDF	51.76	31.33	23.66	35.58	22.68	13.92	9.54	15.38	94.80	57.53	43.11	65.15
SS (5 t/ha) + 75% RDF	69.09	43.02	33.25	48.45	28.29	17.92	12.25	19.49	117.12	72.29	55.13	81.51
RDF	78.62	52.16	44.81	58.53	31.16	19.90	15.69	22.25	132.82	81.73	65.87	93.47
Mean	50.32	31.61	25.38		20.78	13.07	9.40		90.57	55.46	42.68	
C.D. (p= 0.05)	Irrigation- 7.19 Treatment- 9.29 Irrigation x Treatment- NS				Irrigation- 3.49 Treatment- 4.50 Irrigation x Treatment- NS				Irrigation- 10.57 Treatment- 13.65 Irrigation x Treatment- NS			

Irrigation water quality

direct effect of Cl^- on bacterial activity in the soil. High Cl^- content showed an antagonistic affect with NO_3^- thus causing reduction in its uptake[26,27].

Effect of fertilizer treatments

Among treatments, it was observed from the Table 2 that N uptake by pearl millet and wheat crops were significantly increased under sewage sludge application. The N uptake was ranged from 24.51 to 48.05 kg/ha in pearl millet grain and 26.49 to 66.52 kg/ha in wheat grain. However, the maximum N uptake by pearl millet grain (48.05 kg/ha) as well as by wheat grain (66.52 kg/ha) was recorded with RDF being at par with SS (5 t/ha) + 75% RDF and followed by SS (5 t/ha) + 50% RDF, SS (5 t/ha) and control. Similar results have been reported by Ramprakash *et al.*,[9]. The sewage sludge upon decomposition released nitrogen relatively slow and reduced N losses in the soil, which further enhanced N uptake by the crop. The increase in nutrient uptake in the treatment receiving organic fertilizers might be because sewage sludge contains various macro and micro nutrients and improved soil physical and biological properties. A reduction of 6.8 and 8.2% in the pearl millet and wheat grain was recorded with SS (5 t/ha) + 75% RDF compared to RDF, respectively. In context of straws (Table 3), the N uptake was ranged from 18.15 to 58.45 kg/ha in pearl millet stover and 13.39 to 58.53 kg/ha in wheat straw. However, the maximum N uptake in pearl millet stover and wheat straw was observed with RDF treatment being significantly at par with SS (5 t/ha) + 75% RDF. This might be probably due to easy availability of nutrients in the soil through RDF supply compared to sewage sludge. Sole application of sewage sludge was significantly increased N uptake by wheat crop compared to control, but in pearl millet crop, these treatments were at par with others. The lower uptake in control plots was due to the continuous exploitation of nutrients without any supplement fertilizers. Integrated application of sewage sludge and mineral fertilizers increased nitrogen uptake by crops in the canal and saline water irrigated plots. However, the interactive effect of sewage sludge and saline water irrigation was non-significant.

P uptake

The data regarding mean P uptake by pearl millet and wheat crops is presented in Table 2 and 3.

Effect of salinity

It was observed (Table 2) that P uptake by pearl millet and wheat crops was significantly reduced with salinity levels of irrigation water, whereas significantly higher P uptake by pearl millet grain (25.90 kg/ha) and by wheat grain (36.48 kg/ha) was recorded with canal irrigation. A significant reduction of 38.2, 49.3% P uptake in pearl millet grain and 40.0, 49.9% in wheat grain was observed under saline water irrigation (EC_{iw} 8 and 10 dS/m) in comparison to canal irrigation, respectively. In case of straws, the significantly higher P uptake by pearl millet stover (19.13 kg/ha) as well as by wheat straw (20.78 kg/ha) was recorded with canal irrigation. Application of 8 and 10 dS/m EC_{iw} of saline water irrigation had resulted into significantly reduction of 38.1, 52.7% P uptake in pearl millet stover and 37.1, 54.8% in wheat straw as compared to canal water irrigation, respectively. Under saline conditions, plant faces difficulties in absorbing water and nutrients along with it mainly due to osmotic effects. The decreasing trend might be attributed to the fact that increasing Cl^- concentration due to prolonged use of saline irrigation prompted salt stress in plants[28].

Effect of fertilizer treatments

Application of sewage sludge significantly enhanced P uptake in pearl millet and wheat grains (Table 2). P uptake was ranged from 10.71 to 25.35 kg/ha in pearl millet grain and 11.68 to 36.94 kg/ha in wheat grain and the maximum N uptake in pearl millet grain (25.35 kg/ha) and in wheat grain (36.94 kg/ha) was obtained with RDF being statistically at par with SS (5 t/ha) + 75% RDF treatment. However, sole application of sewage sludge increased 27.1 and 38.7% P uptake in pearl millet and wheat grain over control, respectively. The higher uptake in fertilized plots could be attributed to increased nutrient availability in soil. An integrated application of sewage sludge and mineral fertilizer showed higher P uptake over sole application of sewage sludge was due to increased nutrient availability[29]. It was observed that P uptake was ranged from 7.32 to 19.47 kg/ha in pearl millet stover and 5.30 to 22.25 kg/ha in wheat. The maximum P uptake (Table 3) by pearl millet stover (19.47 kg/ha) and by wheat straw (22.25 kg/ha) was recorded with RDF being statistically at par with SS (5 t/ha) + 75% RDF and followed by SS (5 t/ha) + 50% RDF, SS (5 t/ha) and control treatments. Arpali *et al.*,[8] reported highest grain P uptake with mineral fertilizers and effects of sewage sludge were significant on P concentration as compared to control. Similar result has been reported by Yagmur *et al.*,[11]. Moreover, conjunctive use of sewage sludge and inorganic fertilizers might have increased P sorption in soil and formation of phosphor-humic complex which could be easily assimilated by plants[30]. The interaction effect of sewage sludge and saline water irrigation was however non-significant.

K uptake

The data on mean K uptake by pearl millet and wheat crops is expressed in Table 2 and Table 3.

Effect of salinity

The data presented in Table 2 revealed that K uptake by pearl millet and wheat grains was significantly reduced under saline conditions and significantly higher mean K uptake by pearl millet grain (17.87 kg/ha) and by wheat grain (29.09 kg/ha) was recorded with canal water irrigation. However, A significantly reduction of 41.9 and 57.8% K uptake in pearl millet grain and 43.6and 54.7% in K uptake in wheat grain was recorded with application of 8 and 10 dS/m EC_{iw} of saline water irrigation in comparison to canal irrigation, respectively. A critical perusal of data presented in Table 3 revealed that significantly higher K uptake by pearl millet stover (89.06 kg/ha) as well as by wheat straw (90.57 kg/ha) was recorded with canal irrigation. Also, the application of 8 and 10 dS/m EC of saline water irrigation significantly reduced K uptake in pearl millet stover by 39.6, 50.4% and K uptake in wheat straw by 38.8, 52.9% as compared to canal water irrigation, respectively. Due to continuous use of saline irrigation, the build-up of salts in soil reduced nutrient uptake by plants. Similar results have also been reported by Ragab *et al.*,[31]. Under excessive concentrations of Na^+ ion in soil and plant, there is an antagonism or competition with K^+ion for binding sites in root cells which ultimately retards translocation and transportation of nutrient from the soil and within the plants[32] or the inhibition of uptake process[33].

Effect of fertilizer treatments

It was noticed that sewage sludge application significantly increased K uptake in pearl millet and wheat grains (Table 2). The potassium uptake was ranged between 6.48-16.09 kg/ha in pearl millet grain and 6.60-29.37 kg/ha in wheat grain and the maximum K uptake by pearl millet grain (16.09 kg/ha) was recorded with SS (5 t/ha) + 75% RDF and being at par with RDF, while in wheat grain, the maximum mean uptake (29.37 kg/ha) was observed under RDF which was statistically at par with SS (5 t/ha) + 75% RDF. The reason might be due to fast decomposition of sewage sludge in presence of inorganic fertilizers results in significant build-up of N, P and K in plant[34]. Sewage sludge application significantly enhanced K uptake in pearl millet and wheat stover/straw (Table 3). The maximum K uptake by pearl millet stover (80.75 kg/ha) was recorded with SS (5 t/ha) + 75% RDF which was statistically similar with RDF, whereas, in wheat straw, the maximum K uptake (93.47 kg/ha) was recorded with RDF being statistically at par with SS (5 t/ha) + 75% RDF because potassium source fertilizer was applied only during wheat season so its residual effect decreases in pearl millet after wheat harvest. The addition of sewage sludge and mineral fertilizers might have affected soil properties that enhanced root development in demand for nutrient absorption. However, several workers concluded that application of mineral fertilizers or manures did not influence K in plant[8,35].

Soluble ions in soil

Soluble cations

Application of saline water irrigation significantly affected mean soluble cations whereas sewage sludge effect was non-significant (Table 4). The interaction effect of sewage sludge and saline water irrigation was also non-significant. The soluble cations (Na^+, K^+ and Ca^{2+}+Mg^{2+}) were significantly increased with the increasing salinity levels. The maximum contents of Na^+, K^+ and Ca^{2+}+Mg^{2+} i.e., 9.14, 1.67 and 7.61 me/l, respectively were recorded with 10 dS/m EC_{iw} followed by 8 dS/m EC of saline water (7.95, 1.50 and 7.02 me/l, respectively) and canal water irrigation (1.65, 0.41 and 2.03 me/l, respectively).

Soluble anions

The data on soluble anions (me/l) in soils depicted in Table 4 revealed that saline irrigation water significantly affected mean soluble anions (HCO_3^-,

Table 4 — Effect of sewage sludge application on mean soluble ions (meq/l) at the crop harvest under saline water irrigation

Treatments	Na^+	K^+	Ca^{2+}+Mg^{2+}	HCO_3^-	SO_4^{2-}	Cl^-
			Irrigation levels			
Canal	1.65	0.41	2.03	0.29	1.50	2.18
8 dS/m	7.95	1.50	7.02	0.65	5.80	9.94
10 dS/m	9.14	1.67	7.61	0.83	5.97	11.43
C.D. (0.05)	0.76	0.13	0.54	0.13	0.36	0.77
			Fertilizer levels			
Control	5.60	1.08	5.11	0.43	4.05	7.14
SS (5 t/ha)	6.82	1.29	5.87	0.68	4.60	8.51
SS (5 t/ha) + 50% RDF	6.51	1.26	5.76	0.65	4.58	8.19
SS (5 t/ha) + 75 % RDF	6.23	1.21	5.64	0.61	4.54	7.87
100% RDF	6.08	1.12	5.38	0.56	4.36	7.54
C.D. (0.05)	NS	NS	NS	NS	NS	NS

SO_4^{2-} and Cl^-) in soil but remains unaffected with sewage sludge application. The interaction effect of sewage sludge and saline water irrigation was non-significant. The carbonate was absent in soil solution and remaining soluble anions (HCO_3^-, SO_4^{2-} and Cl^-) were significantly increased with saline water irrigation. The maximum HCO_3^- and Cl^- concentrations i.e., 0.83 and 11.43 me/l, respectively were recorded with 10 dS/m EC_{iw} saline water followed by 8 dS/m EC_{iw} saline water (0.65 and 9.94 me/l, respectively) and canal water irrigation (0.29 and 2.18 me/l, respectively). The sulphate content was obtained significantly highest (5.97 me/l) with 10 dS/m EC of saline water being at par with 8 dS/m EC saline water (5.80 meq/l) and lowest (1.50 meq/l) was recorded with canal irrigation.

Soluble ions in soil (Na^+, K^+, Ca^{2+}+Mg^{2+}, HCO_3^-, SO_4^{2-} and Cl^-) were increased linearly with increasing salinity levels. This may be due to the longer use of saline water to irrigate the field which increased the distribution and concentration of salts in the soil[36]. Our study is in line of agreement with those obtained by Abd El-Nour[37] who found that the significant increases in soil EC was proportional to the concentration of salts in the irrigation water. Similar results have also been reported by several research workers[13,30,38].

Conclusions

It is concluded from the present study that the continuous use of saline irrigation has led to build up of salts in soil that further decreased nutrient (NPK) uptake in pearl millet and wheat crops. Furthermore, addition of sewage sludge increased NPK uptake in the canal as well as saline water irrigated plots. However, treatments SS (5 t/ha) + 75% RDF and RDF attained comparable NPK uptake in crops. It is be concluded that the conjoint application of sewage sludge with mineral fertilizers resulted into significant build-up of N, P and K in crops. From the present study, farmers are encouraged to use sewage sludge in agriculture.

Acknowledgment

The authors are thankful to Soil Science Department, CCS HAU, Hisar, Haryana for their technical and financial help.

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions

Ankush and RP designed the experiment; Ankush conducted the field experiment and data analysis; Ankush wrote the article; AK, VS and SK provided the initial draft feedback and all the authors revised it.

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