Indian Journal of Agricultural Sciences **91** (2): 296–9, February 2021/Article
https://doi.org/ 10.56093/ijas.v91i2.111642

Salt ratios respond to saline irrigation and sewage sludge application in pearl millet-wheat rotation

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Received: 09 September 2020; Accepted: 05 October 2020

ABSTRACT

Salinity is a limiting factor for crop production in irrigated areas. A field experiment was conducted for two consecutive years (2017–19) using three irrigation treatments, viz. canal water (0.35 dS/m) and saline water (8 and 10 dS/m); and five fertilizer treatments, viz. control, sewage sludge (SS)-5 t/ha, SS (5 t/ha)+50% recommended dose of fertilizers (RDF), SS (5 t/ha)+75% RDF and 100% RDF, to evaluate the effect of saline water irrigation, organic and inorganic fertilization on salt ratios in pearl millet and wheat crops. However, SS was applied in the *Rabi* only. As the salinity of irrigation water increased, the salt ratios (Na^+/K^+ and Cl^-/SO_4^{2}) in pearl millet and wheat crops were increased markedly during both years. However, SS (5 t/ha) + 75% RDF recorded the lowest Na^+/K^+ ratio in pearl millet crop over control, but it was statistically at par with 100% RDF, while in wheat crop, the ratio was decreased considerably under 100% RDF treatment followed by sewage sludge amended treatments. Also, the ratio (Cl^-/SO_4^{2-}) in both crops was significantly decreased with sewage sludge incorporation, and the lowest was recorded with SS (5 t/ha) + 75% RDF. From the present study, it is concluded that the SS and inorganic fertilizer application helps in gaining potential of cereals against salt stress by reducing Na^+ and Cl^- besides increasing potassium and sulphate contents in plants.

Keywords: Cl^-/SO_4^{2-}, Na^+/K^+, Pearl millet, Saline water irrigation, Sewage sludge, Wheat

About 62% area of Haryana state is restrained with poor quality water (Anonymous 2019), due to which problems of soil salinity, crashing soil health (Ankush *et al*. 2020a), and reducing crop productivity have arisen. To overcome water scarcity, many countries have adopted the use of marginal water for irrigation. Besides using saline water irrigation, it has been noted that salinity inhibited water and nutrient uptake by plants due to osmotic and ion-specific effect which may result in higher accumulation of Na^+ and Cl^- in plant tissue (Ankush *et al*. 2020b) and increased reactive oxygen species generation in plants (Khan *et al*. 2012). However, plant species differ in their sensitivity or tolerance of salt stress. Pearl millet and wheat crop are reasonably tolerant to salinity (Krishnamurthy *et al*. 2007) and, also both the crops are very nutrient-exhaustive. Therefore, there is a need to apply a balanced amount of nutrients through chemical fertilizers integrating with organic sources on a regular basis to have better production.

Some researchers have conducted field trials to evaluate if certain nutrients have any curative effects on salt tolerance (El-Sidding and Ludders 1994). In the modern agriculture system, more focus is being given to sustainable agriculture development. Some studies showed that the application of inorganic fertilizers and organic manures in saline soils might result in increased, decreased, or unchanged plant salt tolerance. In other words, plant response to fertilizers mainly relies on the extremity of salt stress in the root zone (Faiza and Amin 2009). Sewage sludge is the by-product of the municipal solid waste treatment plant, and the use of this in field conditions might help solve problems of dumping wastes. It contains various amounts of nutrients, microorganisms and metals. The application of sewage sludge helps recycle nutrients in the soil and improve soil physico-chemical and biological properties (Meena and Patel 2018, Ankush *et al*. 2020a). There is barely any research carried out related to the use of sewage sludge to mitigate salinity effects, so the present research aimed to assess the effect of sewage sludge application and saline water irrigation on Na^+/K^+ and Cl^-/SO_4^{2-} ratio in pearl millet and wheat crops.

MATERIALS AND METHODS

The experiment was conducted at the Soil Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar, during 2017–19. The location is situated in semi-arid, sub-tropics at 29º 8´N latitude, 75º 70´E longitude at an elevation of 215.2 meters (amsl). The experimental soil was sandy loam in texture and was low

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in organic carbon (0.31%) and available nitrogen (110 kg/ha); medium in available phosphorus (16.1 kg/ha), and high in soil potassium (290 kg/ha) and sulphur (102 ppm). The soil was alkaline in reaction (*p*H 8.25) and had EC of 0.37 dS/m. The experiment was laid out in factorial randomized block design (FRBD) with three replications. The experiment consisted of three levels of irrigation i.e. canal water (0.35 dS/m), 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 100% RDF where sewage sludge was applied as basal dose before the last plough in *Rabi* only. Sewage sludge had alkaline *p*H (7.84), lower EC (1.45 dS/m), organic carbon (25.4%) and total NPKS (1.36, 0.87, 1.40 and 0.79 %, respectively). HHB 226 and WH 1105 varieties of pearl millet and wheat were taken for experimenting, respectively. Sowing of crops was done with the help of manual plough. Irrigation was applied in both crops according to their package of practice adopted in Haryana and the desired level of EC was prepared by the blending of saline water with canal water (Table 1).

The chemical parameters of soil and sewage sludge were determined by standard methods outlined by Antil *et al*. (2002). For plant analysis, dried plant samples were chopped with the help of a chopping machine. Digestion is the main step in the plant analysis; thereafter, standard methods were adopted. Potassium and sodium in the plant samples were determined with the help of flame photometer (Richards 1954). The procedure outlined by Chesnin and Yien (1950) was used to determine sulphate content. Chloride was analyzed with silver nitrate titration using potassium dichromate as an indicator (Richards 1954).

The data were statistically analyzed by using the EXCEL sheet and OPSTAT statistical software package developed by the Department of Statistics, CCS Haryana Agricultural University (Sheoran *et al*. 1998) to drive ANOVA (P=0.05).

Table 1 Chemical composition of irrigation water

Treatment	*p*H	EC (dS/m)	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}
			(me/l)					
Canal	7.10	0.35	0.71	0.09	0.98	1.65	1.35	1.20
8 dS/m	7.66	8.17	53.80	0.35	7.50	18.50	59.60	19.23
10 dS/m	7.83	10.09	69.15	0.40	8.45	24.04	72.80	25.27

RESULTS AND DISCUSSION

Na^+/K^+ ratio in grain: The saline water irrigation application significantly increased the Na^+/K^+ ratio in pearl millet and wheat grains (Table 2). The lowest ratio in pearl millet grain (0.14 and 0.24) and in wheat grain (0.17 and 0.21) was obtained under canal water irrigation compared to saline irrigation during the 1st and 2nd years of experimentation, respectively. The results are in line of accordance with the findings of several research workers (Ragab *et al*. 2008, Kalhoro *et al*. 2016). Among fertilizer treatments, it was observed that sewage sludge application significantly reduced the Na^+/K^+ ratio in wheat grain, but it was affected non-significantly in pearl millet grain. However, in wheat grain, the lowest Na^+/K^+ ratio i.e. 0.23 and 0.25 were obtained with 100% RDF, which was statistically at par with SS (5 t/ha) + 75% RDF (0.28 and 0.30) during Ist and IInd years of experimentation, respectively. Na^+/K^+ ratio plays an vital role in the tolerance of crops against salinity. Generally, a lower ratio favors the tolerance power of plant because potassium (K) is the third essential element after nitrogen (N) and phosphorus (P) required for physiological and metabolic activities (Fageria 2016) that help the plant in attaining power against stress by maintaining ion homeostasis and osmotic balance. Merwad (2016) reported that the application of K could have a positive effect on *B. vulgaris*

Table 2 Effect of sewage sludge application on Na^+/K^+ ratio in pearl millet-wheat cropping system under saline water irrigation

Treatment	Pearl millet				Wheat			
	Grain		Stover		Grain		Straw	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation levels								
Canal	0.14	0.24	0.60	0.64	0.17	0.21	0.55	0.56
8 dS/m	0.27	0.39	1.27	1.32	0.31	0.37	1.14	1.17
10 dS/m	0.41	0.67	1.46	1.53	0.43	0.54	1.37	1.42
CD.(P=0.05)	0.06	0.09	0.09	0.05	0.06	0.05	0.08	0.06
Fertlizer levels								
Control	0.26	0.50	1.21	1.37	0.38	0.61	1.26	1.42
SS (5 t/ha)	0.31	0.51	1.18	1.24	0.32	0.39	1.06	1.05
SS (5 t/ha) + 50% RDF	0.27	0.41	1.09	1.10	0.29	0.32	1.00	1.00
SS (5 t/ha) + 75 % RDF	0.25	0.37	1.02	1.02	0.28	0.30	0.94	0.96
100% RDF	0.26	0.39	1.04	1.08	0.23	0.25	0.84	0.83
CD (P=0.05)	NS	NS	0.12	0.07	0.08	0.07	0.10	0.07

Where; SS= sewage sludge; RDF= recommended dose of fertilizers.

Table 3 Effect of sewage sludge application on Cl^-/SO_4^{2-} ratio in pearl millet-wheat cropping system under saline water irrigation

Treatments	Pearl millet				Wheat			
	Grain		Stover		Grain		Straw	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation levels								
Canal	3.53	5.01	8.87	9.28	4.32	4.17	8.76	8.57
8 dS/m	9.19	12.67	28.11	33.02	11.07	11.45	29.13	34.59
10 dS/m	11.55	16.69	33.24	44.19	14.25	14.94	40.35	43.60
CD (P=0.05)	1.93	3.95	2.45	4.11	3.57	3.53	6.20	4.50
Fertilizer levels								
Control	7.18	11.53	25.13	33.95	9.22	10.57	27.23	35.91
SS (5 t/ha)	7.51	10.26	22.64	28.10	9.02	9.17	25.01	26.50
SS (5 t/ha) + 50% RDF	7.68	10.19	20.53	25.89	8.61	8.16	23.70	23.99
SS (5 t/ha) + 75 % RDF	7.65	9.34	20.49	22.93	8.19	7.15	21.15	21.56
100% RDF	10.42	15.96	28.24	33.30	14.34	15.88	33.31	36.66
CD (P=0.05)	NS	NS	3.16	5.31	NS	4.56	8.00	5.81

Where; SS= sewage sludge; RDF= recommended dose of fertilizers.

cultivars under stress. Similar results regarding decreased Na^+/K^+ ratio with fertilizer application were also reported in *H. vulgare* (Fayez and Bazaid 2014).

Na^+/K^+ ratio in stover/straw: The data (Table 2) revealed that the salt ratio (Na^+/K^+) in both crops was significantly increased under a saline environment. Under saline conditions, plants accumulate more sodium (Sairam *et al*. 2002), resulting in ionic imbalance, specific-ion effects, and nutritional deficiency symptoms. Salinity prompted an increase in sodium and a decrease in potassium, thus resulted in an increased ratio with salinity levels (Kalhoro *et al*. 2016). The application of sewage sludge however, lowered the salt ratio in pearl millet and wheat stover/straw. In pearl millet stover, a significantly lower Na^+/K^+ ratio was however obtained with SS (5 t/ha) + 75% RDF being at par with 100% RDF whereas in the case of wheat straw, lowest Na^+/K^+ ratio i.e. 0.84 and 0.83, was obtained with 100% RDF being statistically at par with SS (5 t/ha) + 75% RDF during 1st and 2nd year, respectively. It has been implied that the plant's tolerance level response is characterized by a markedly sodium/potassium ratio, which may be used to envision tolerance/sensitivity in wheat varieties (Joshi *et al*. 1979) and pearl millet (Venkata *et al*. 2012).

Cl^-/SO_4^{2-} ratio in grain: During the 1st and 2nd year, the salt ratio (Cl^-/SO_4^{2-}) in pearl millet and wheat grain was increased markedly with the application of saline water irrigation compared to canal irrigation (Table 3). Alike Na^+/K^+, Cl^-/SO_4^{2-} ratio plays a vital role in the tolerance of crops against salt stress. It has been reported earlier that salinity resulted in increased chloride content and decreased sulphate content in plants (Yadav *et al*. 2015). However, the addition of sewage sludge significantly reduced the Cl^-/SO_4^{2-} ratio in wheat grain during 2018-19 only, but the ratio was remained decreased non-significantly in pearl millet grain during both years. The higher ratio in both crops was recorded with 100% RDF treatment due to faster plant growth and it might be due to the exclusion of sulphate source fertilizers in the package practice.

Cl^-/SO_4^{2-} ratio in stover/straw: The data on Cl^-/SO_4^{2-} ratio in stover/straw of pearl millet and wheat as influenced by the application of sewage sludge and saline water irrigation (Table 3). The lowest ratio in pearl millet stover (8.87 and 9.28) and wheat straw (8.76 and 8.57) was obtained with canal water irrigation (EC 0.35 dS/m) as compared to saline water irrigation during 1st and 2nd year, respectively. As water used to irrigate the crops was chloride dominated, so decreased Cl^-/SO_4^{2-} ratio in our experiment might be due to competition between Cl^- and SO_4^{2-} ions where an excess of chloride ions inhibited the sulphate uptake by plants (Yadav *et al*. 2015). Comparing fertilizer treatments, the application of sewage sludge reduced the Cl^-/SO_4^{2-} ratio in pearl millet and wheat stover/straw. The significantly lowest Cl^-/SO_4^{2-} ratio i.e. 20.49 and 22.93 in pearl millet stover and in wheat straw (21.15 and 21.56), was obtained with SS (5 t/ha) + 75% RDF treatment during the first and second year, respectively. The decreased Cl^-/SO_4^{2-} ratio in crops with the addition of sewage sludge might be due to the sewage sludge composition. It is contemplated that transition of S metabolism in plants would help in pacifying adverse effects of salinity as its metabolites control various plant processes (Khan *et al*. 2014), but a federated approach on salinity through sulphur metabolism is not available. Similar results were reported by Khan *et al*. (2013) and Nocito *et al*. (2007).

It was observed that salt ratios (Na^+/K^+ and Cl^-/SO_4^{2-}) in pearl millet and wheat crops were increased markedly by applying saline water irrigation. However, among fertilizer treatments, integrated sewage sludge and mineral fertilizers application recorded significantly lower salt ratios. Thus, based on results, it may be concluded that organic and inorganic fertilization help in alleviating salinity stress in both crops.

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