Annals of Plant and Soil Research 24(2):245-249 (2022)
https://doi.org/10.47815/apsr.2022.10156

Effect of long term use of manures and fertilizers on soluble salts in soil and mineral composition of wheat (*Triticum aestivum*)

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Received: September, 2021; Revised accepted: November, 2021

ABSTRACT

A long-term field experiment started in 1995 on coarse loamy soil at CCS Haryana Agricultural University, Hisar (India) was selected to examine the impact of organic manures and fertilizers on soluble salts content in soil and mineral composition of wheat (Triticum aestivum). The results revealed that continuous application of organic manures (FYM, poultry manure and pressmud) alone or in combination with fertilizers significantly increased the content of soluble ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^- and CO_3^{2-}) in soil. Water soluble CO_3^{2-} content showed irregular trend among various treatments. The amounts of soluble ions were found highest in FYM treated plots as compared to poultry manures and pressmud which resulted in higher soil EC of these plots. Increased availability of these soluble ions in soil also increased the plant uptake and accumulated in plant tissues. The Na, Ca, Mg and Cl contents in wheat grain and straw were higher when organic manures were applied alone, while K and S contents were found higher in the plots receiving combined application of manures and fertilizers.

Keywords: Long term, manures, soluble ions, plant composition, wheat

INTRODUCTION

Organic manures after addition in soil undergo continuous decomposition process mediated by microbes and release the mineral nutrients in soil. Thus, their continuous application can increase the level of N, P, K, Ca, Mg, Na and other soluble ions in soils and create a nutrients reservoir in soil. However, repeated or elevated application rates of animal manures or compost having relatively higher salt contents could not be sustainable for soil health and quality depending on soil and environmental conditions (He *et al.* 2008). It may elevate the potential risk of secondary soil salinization/sodification even in soils receiving recommended dose of these manures (Watts *et al.* 2010). Although, this type of secondary soil salinization most frequently occurs in arid and semi-arid regions, but potential risk of secondary soil salinization even in the humid region with continuous application of animal manure was reported by Li-Xian *et al.* (2007). The sodium adsorption ratio (SAR) and potassium adsorption ratio (PAR) of the soil solution are important indicators in evaluating the impact of livestock manure on soil salinization. The increased availability of soluble salts in soil also increased the uptake of these salts by plant tissues and may affect the quality of food grains if accumulated in excess concentration (Ojeniyi *et al.* 2013). These complex problems of soil fertility management can be monitored by conducting long-term field experiments as it provides sufficient time for crop, crop rotation, fertilizers and manures to have a measurable effect on soil fertility. However, relatively limited information is available concerning these chemical changes under long-term manorial field experiments of arid and semi-arid regions. Considering the above facts, the present study was carried out with the objective to assess and compare the impact of long- term application of different manures and fertilizers on soluble ions content in soil and mineral composition of wheat under semi arid environment of North India.

MATERIALS AND METHODS

A long-term field experiment with pearl millet-wheat cropping system was initiated in 1995 on a coarse loamy, *Typic Ustochrept* soil at CCS Haryana Agricultural University, Hisar, India. The experimental site is located at 29°16'N latitude and 75°7'E longitude in north-west part of the country. The climate of the site is semi-arid with 443 mm mean annual precipitation and mean annual temperature is around 24.8°C. The

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water table of experimental site fluctuates between 1 meter (in rainy season) to 4 meter in summer season. The physico-chemical properties of surface soil (0–15 cm) analyzed at the start of experiment (1995) were : pH 8.1, EC 0.36 dSm^{-1}, OC 0.3.9g kg^{-1}, available N P K 196, 25.2, 434 kg ha^{-1}, respectively. Since 1995, following 10 treatments with three replications were maintained on the permanent plots in a randomized block design: T_1 : 75 kg N + 30 kg P_2O_5 ha^{-1}, T_2 : 150 kg N + 60 kg P_2O_5 ha^{-1}, T_3 : 15 Mg FYM ha^{-1}, T_4 : 15 Mg FYM + 150 kg N ha^{-1}, T_5 : 15 Mg FYM + 150 kg N + 30 kg P_2O_5 ha^{-1}, T_6 : 5 Mg poultry manure ha^{-1}, T_7 : 5 Mg poultry manure + 150 kg N + 30 kg P_2O_5 ha^{-1}, T_8 : 7.5 Mg pressmud ha^{-1}, T_9 : 7.5 Mg pressmud + 75 kg N +30 kg P_2O_5 ha^{-1}, T_{10} : 7.5 Mg pressmud + 150 kg N + 30 kg P_2O_5 ha^{-1}. The plots size was of 24 x 5 m^2 area. The manures were applied once in a year at the time of wheat sowing, while fertilizers N and P were applied in both the crops through urea and di-ammonium phosphate, respectively. The average nutrient composition of manures (FYM, poultry manure and pressmud) used in this experiment were also analysed (Table 1).

Table 1: Nutrient composition of various organic manures used in the experiment

Parameter	FYM	Poultry manure	Pressmud
Organic carbon (%)	38.10	25.20	49.60
N (%)	1.20	2.51	3.23
P (%)	0.97	1.82	1.10
K (%)	1.87	1.72	0.86
C:N	31.75	10.04	15.40
Na (%)	0.68	0.35	0.11
Ca (%)	1.25	3.30	3.10
Mg (%)	7.0	9.6	5.8
S (%)	0.36	0.26	0.52

The surface soil samples (0-15 cm depth) collected after the harvest of wheat crop were analysed for sodium (Na^+) and potassium (K^+) contents were measured using flame photometer. For calcium (Ca^{2+}) and magnesium (Mg^{2+}), the aliquot was titrated with EDTA solution in the presence of Calcon and Eriochrome Black T indicator. Carbonate and bicarbonate contents were analyzed by titrating the aliquot with sulfuric acid in the presence of phenolphthalein and methyl orange indicators. Chloride content was measured by titration with silver nitrate in presence of potassium chromate solution. Soluble sulfate (SO_4^{2-}) was estimated at 420 nm wave length of spectrophotometer. Grain and straw samples of wheat were collected at the harvest. and digested in di-acid mixture of HNO_3 and $HClO_4$ (4:1). The K and Na content in acid digest were determined using emission flame photometric method. Calcium and magnesium content in plant digest were determined by titration of the aliquot with standard solution of EDTA using Calcon and Erichrome Black-T indicator in presence of sodium hydroxide. Adequate amount of sodium cyanide and hydroxylamine hydrochloride were also used to remove the interference of heavy metals. Sulfur content was determined by turbidimetric method (Chesnin and Yien 1950). The chloride content was determined by following the standard procedure (Chhabra 1973). The experimental data was subjected to analysis of variance (ANOVA) using the program STATISTCA 6.0 Stat Soft, Inc. (2001). Within the STATISTCA 6.0, DUNCAN multiple range test is applied to compare significant differences within the treatments. The treatment means were compared at a significance level of 0.05.

RESULTS AND DISCUSSION

Soluble ions content in soil

Continuous application of manures for 19 years under pearl millet-wheat cropping system significantly increased the water soluble cations and anions in soil as compared to chemical fertilizers applied alone (Table 2). This might be due to the reason that manures contain considerable amount of soluble salts and their application increased soluble ions content in soil (Meena *et al.* 2013). This type of results is in conformity with the findings of (Ghulam *et al.* 2010 and Abbas *et al.* 2011). Under these conditions, soluble salts added through repeated application of manures can accumulate in the surface horizons. However, several workers concluded that application of organic manures did not increase the soil salinity and soil EC was stable (Bahadur *et al.* 2013, Meena *et al.* 2016). Among the manures, the highest salt content was observed in FYM treated plots. This might be due to higher amount of soluble salts present in FYM as compared to poultry manure and pressmud. Water soluble Na^+ and K^+ content in soil ranged from 0.81 to 2.60 and 0.16 to 1.11

meqL^{-1}, respectively (Table 2). Among different treatments, the highest and lowest Na^+ and K^+ contents were observed with the application of 15 Mg FYM ha^{-1} and NP fertilizers, respectively. The highest (2.80 meqL^{-1}) and lowest (1.79 meqL^{-1}) SO_4^{2-} content was observed in the treatment $FYM_{15}N_{150}P_{30}$ and $N_{75}P_{30}$, respectively. Application of organic manures increased soluble Na^+, K^+ and SO_4^{2-} content in soil as compared to chemical fertilizers. However, when organic manures were applied in combination with N or NP fertilizers, a significant decrease in Na^+, K^+ and SO_4^{2-} contents was recorded as compared to organic manures applied alone. With conjoint use of manures and fertilizers, balance nutrition having sufficient available N is supplied and under such condition more K^+ and SO_4^{2-} were absorbed by the crop and lesser content was left in the soil. Similarly, due to higher yield in INM treatment, more quantity of Na was removed by crop and less amount was left in soil. This was also confirmed by the data of mineral composition of wheat (Table 2). The another probable reason might be the synergistic effect of sulfate and phosphate. With combined application of manures and fertilizers, more sulphates were removed by crop with higher phosphate availability and uptake.

Table 2: Effect of long-term application of organic manures and fertilizers on soluble ions content in soil (meL^{-1})

Type of manure	Dose (Mg ha^{-1})	Fertilizer (kg ha^{-1})		Content (meL^{-1})							
		N	P	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^{-1}	SO_4^{2-}	CO_3^{2-}	HCO_3^-
No manure	0	75	30	0.81	0.17	1.10	1.01	0.22	1.79	0.065	0.200
	0	150	60	0.82	0.16	1.11	1.03	0.21	1.91	0.067	0.195
	15	0	0	2.60	1.11	1.47	1.43	0.39	2.70	0.075	0.250
FYM	15	150	0	1.74	0.92	1.60	1.53	0.40	2.50	0.077	0.226
	15	150	30	2.31	0.89	1.80	2.00	0.41	2.80	0.076	0.210
Poultry manure	5	0	0	1.35	0.39	1.17	0.93	0.32	2.62	0.070	0.245
	5	150	30	0.95	0.34	1.20	1.10	0.33	2.14	0.053	0.255
	7.5	0	0	1.05	0.28	1.23	1.16	0.24	2.55	0.070	0.240
Pressmud	7.5	75	30	1.00	0.19	1.34	1.20	0.27	2.09	0.066	0.235
	7.5	150	30	1.08	0.18	1.43	1.23	0.28	2.03	0.070	0.230
C.D.(p=0.05)				0.07	0.04	0.05	0.06	0.02	0.117	0.004	0.011

Water soluble Ca^{2+}, Mg^{2+} and Cl^{-1} content in soil ranged from 1.10 to1.80, 0.93 to 2.00 and 0.21 to 0.41 meqL^{-1}, respectively (Table 2). The highest Ca^{2+}, Mg^{2+} and Cl^{-1} contents in soil were observed in $FYM_{15}N_{150}P_{30}$ treatment and lowest with the application of $N_{75}P_{30}$, 5 Mg poultry manure ha^{-1} and $N_{150}P_{60}$, respectively. The water soluble Ca^{2+}, Mg^{2+} and Cl^{-1} content in soil was higher with combined application of manures and fertilizers as compared to sole application of manures. The antagonistic relationship of K with $Ca^{2+}$and Mg^{2+}, and SO_4^{2-} with Cl^- as indicated by mineral composition of plant also justified these results. The magnitude of increase in Ca^{2+}, Mg^{2+} and Cl^- content in soil with application of organic manures was more as compared to other ions. This reflects the extreme mobile nature of these ions in soil. Application of organic manures increased the water soluble CO_3^{2-} and HCO_3^- content in soil, however, significant increment was observed only in FYM treated plots (Table 2). Water soluble CO_3^{2-} content showed no definite trend among various treatments and the highest (0.077 meqL^{-1}) and lowest (0.065 meqL^{-1}) values were observed in the treatment $FYM_{15}N_{150}$ and $N_{60}P_{30}$, respectively. Increase in CO_3^{2-} and HCO_3^- content with application of manures alone or in combination with fertilizers may be due to decrease in soil pH because CO_3^{2-} and HCO_3^- solubility is pH dependent.

Mineral composition of wheat grain and straw

The total Na, K, Ca and Mg content in wheat grain ranged from 0.015 to 0.023, 0.21 to 0.30, 0.17 to 0.31 and 0.73 to 1.10 %, respectively (Table 3). The SO_4 and Cl content in wheat grain ranged from 0.101 to 0.133 and 0.63 to 1.06 %, respectively. Application of manures significantly increased the Ca, Mg, Na and Cl content in wheat grain as compared to chemical fertilizers. Along with improvement in soil properties, application of manures increased the available nutrient pool in soil through their microbial decomposition.

Table 3: Effect of long-term application of organic manures and fertilizers on mineral composition of wheat grain and straw

Manure	Manure Dose ($Mg\ ha^{-1}$)	Fertilizer Dose ($kg\ ha^{-1}$)		Concentration (%) in grain						Concentration (%) in straw					
		N	P	Na	K	Ca	Mg	SO_4	Cl	Na	K	Ca	Mg	SO_4	Cl
No manure	0	75	30	0.016	0.29	0.25	0.75	0.113	0.65	0.026	1.09	0.17	0.48	0.061	0.23
	0	150	60	0.018	0.28	0.21	0.73	0.101	0.63	0.027	1.12	0.18	0.49	0.072	0.22
	15	0	0	0.023	0.27	0.31	1.10	0.114	1.06	0.035	1.08	0.18	0.60	0.084	0.45
FYM	15	150	0	0.018	0.25	0.24	0.80	0.123	0.99	0.017	1.50	0.14	0.54	0.092	0.42
	15	150	30	0.020	0.30	0.26	1.00	0.133	0.97	0.031	1.60	0.15	0.55	0.094	0.40
Poultry	5	0	0	0.019	0.22	0.22	0.85	0.101	0.90	0.036	1.39	0.17	0.57	0.072	0.37
manure	5	150	30	0.016	0.26	0.19	0.81	0.122	0.84	0.033	2.00	0.17	0.53	0.083	0.31
	7.5	0	0	0.018	0.21	0.23	0.83	0.110	0.85	0.024	1.29	0.18	0.53	0.081	0.31
Pressmud	7.5	75	30	0.016	0.22	0.17	0.80	0.122	0.85	0.022	1.27	0.15	0.47	0.093	0.29
	7.5	150	30	0.015	0.25	0.20	0.77	0.131	0.81	0.022	1.70	0.14	0.43	0.094	0.27
C.D. (p=0.05)				0.002	0.03	0.03	0.04	0.011	0.11	0.002	0.02	0.01	0.02	0.008	0.09

Under higher availability of nutrients, the plants absorbed nutrients liberally without any hindrance resulting into higher nutrient content of grain and straw (Dogra and Jat 2017). However, the combined application of manures and fertilizers decreased the Ca, Mg, Na and Cl content as compared to sole application of manures. The K and SO_4 content showed the reverse trend to that of Ca, Mg and Na. The decrease in K content in grain and straw was influenced by increased Na saturation of soil accompanied by extensive depletion of K in plant. The high Na content in the root zone competed with K for binding sites in the roots as well as uptake and translocation from root to shoot (Tahir *et al.* 2011, Ashraf *et al.* 2017). This could be explained by the hypothesis that Na-K relationship might be synergistic or antagonistic depending upon their ratio. The decrease in K content in barley grain and straw due to increased Na was also reported in other studies (Mahmood 2011). The higher Na content in the soil also could decrease the mobility of SO_4 in soil. The highest Na, Ca, Mg and Cl content was observed with FYM_{15}, while the highest K and SO_4 content was noticed with the application of $FYM_{15}N_{150}P_{30}$. Among the manures, the highest nutrient content in wheat grain was observed in FYM treated plots as compared to poultry manure and pressmud. The higher content of soluble ions in wheat grain was also indicated by high EC of grain harvested from FYM treated plots (Sheoran *et al.* 2017). Total Na, K, Ca and Mg content in wheat straw ranged from 0.017 to 0.036, 1.07 to 2.00, 0.14 to 0.18 and 0.43 to 0.60 %, respectively (Table 3). The SO_4 and Cl content in wheat straw ranged from 0.061 to 0.094 and 0.22 to 0.45 %, respectively. Application of manures along with fertilizers significantly decreased the Ca, Mg, Na and Cl content of wheat straw as compared to manures applied alone. The K and SO_4 content followed the reverse trend and found higher under INM treatments. The lowest SO_4 and Cl content was observed with the sole application of chemical fertilizers. The highest Na, K content was observed in FYM treated plots, while Mg and Cl content was found higher in poultry manure treated plots. The higher Na, Ca, Mg and Cl content in wheat grain and straw with sole application of manures as compared to INM treatments might be due to the reason that when organic manures was applied alone, due to insufficiency of available nitrogen in soil highly mobile ions (Na, Ca, Mg and Cl) was absorbed by plants in higher quantities.

Continuous application of organic manures (FYM, poultry manure and pressmud) alone or in combination with fertilizers for 19 years deposited the soluble salts in soil. The increment of soluble salts content in soil was more with the application of FYM as compared to poultry manure and pressmud. Although the salt deposition in soil was below the threshold level of soil salinity but some indications of adverse effect on soil and seed quality were noticed. Under semi-arid environment, conjoint use of manures and NP fertilizers is a better nutrient management practice for sustainability the soil fertility as compared to their individual use. Periodical monitoring of soil quality is necessary for avoiding any adverse effect of long-time manure application. The potential increase in soil EC to the threshold level should be avoided by adopting proper management practices.

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