



Available nutrients and labile carbon fractions in soil irrigated with sodic water

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ABSTRACT

An ongoing long-term field experiment established in the year 1994 at Vegetable Science Research Farm, CCS HAU, Hisar, India under different vegetable cropping systems was selected to study the effects of sodic water irrigation, gypsum and farmyard manure on labile soil organic carbon fractions and available nutrients in soil. The present study was conducted after 20 years of experimentation during 2014-2015. The field was irrigated with high RSC (11.5 me/l) sodic water having three treatment levels each of gypsum, viz G_0 control, $G_1=50\%$ neutralization of RSC, $G_2=100\%$ neutralization of RSC, as well as FYM (F_0 = control, $F_1=10$ tons/ha, $F_2=20$ tons/ha) in a sandy loam *Typic Ustochrept*. Results showed that the pH of soil was very high under F_0G_0 , and it decreased with the use of FYM and gypsum as amendments, however a reverse trend was observed in electrical conductivity. There was an increase in different carbon fractions and available nutrients when FYM was applied over no FYM application. Application of gypsum increased microbial biomass carbon, light fraction carbon and available nutrients (N, P, S) content in the soil but dissolved organic carbon and available K content was found decreased. It can be concluded that application of FYM @20 t/ha along with gypsum @100% neutralization of RSC of irrigation water should be applied for maintaining soil quality and productivity.

Key words: Available nutrients, Dissolved organic carbon, Light carbon, Microbial biomass carbon

In arid and semi-arid regions, irrigation water plays a vital role in crop production, where scarcity of good quality water is a major problem. Groundwater surveys indicate that poor quality water is being utilized for irrigation purpose in different states of India ranges between 32-84% of the total groundwater development (Choudhary 2007). Furthermore, on an average 55% of ground water are brackish in nature in Haryana (Manchanda 1976). Soil organic carbon (SOC) is the key contributor to soil productivity directly or indirectly by regulating the soil physical, chemical and biological properties. The fractions of SOC are widely used as the surrogate measures for evaluating the soil fertility. The main difference among these fractions is related to degree of decomposition and turnover rate. Labile soil organic carbon pools, i.e. dissolved organic C, microbial biomass C, and particulate organic matter C are the fine indicators of soil quality which influence soil function in specific ways (e.g. immobilization–mineralization) and are much more sensitive to change in soil management practices (Xu *et al.* 2011). The continuous and indiscriminate use of sodic water for irrigation not only deteriorates all the

soil chemical characteristics but also modifies the quality of soil organic carbon and its biotic components such as microbial biomass (Rao *et al.* 2004). To offset the harmful effects of sodic irrigation water, application of gypsum as well as FYM is a commonly used practice (Kaur *et al.* 2008 and Sharma *et al.* 2016). Under such conditions, use of organic sources as amendments plays a dual role in not only increases the solubility (Singh *et al.* 2015, Sundhari *et al.* 2018, Millard and Angers 2013) of gypsum through the organic acids released during decomposition but also helps to improve the soil chemical properties. Therefore, this study was carried out to evaluate the changes under long-term application of sodic irrigation water in soil properties and how FYM and gypsum could lead to improvement in soil properties.

MATERIALS AND METHODS

The ongoing long term field experiment initiated in 1994 at Vegetable Research Farm, Department of Vegetable Crops of CCS Haryana Agricultural University, Hisar was selected for the present study after 20 years of experimentation (2014-15). It is situated at 29°10' North latitude and 75°46' longitude at mean elevation of 215.2 m. Study area has arid climate and normal annual rainfall is 330 mm. The soil of the experimental field was sandy loam, *Typic Ustochrept* having 19.6% clay and 9.3 C mol (+)/kg CEC in depth of 0-15 cm surface layer. The experimental treatments were laid out

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in randomized block design having 3 levels of FYM (0, 10 and 20 t/ha represented as F_0 , F_1 and F_2 respectively) and 3 doses of gypsum (0, 50 and 100% neutralization of RSC represented as G_0 , G_1 and G_2 , respectively). These treatments were replicated thrice. Total 27 plots were irrigated with sodic water from farm tube well having the average ionic composition dominated by HCO_3^- (13.3 me/l) of Na^+ (15.8 me/l) and having the values of EC, RSC and SAR of 2.4 dS/m, 11.5 me/l and 14 mmol/l $1/2$ respectively during past twenty years. The fertilizer in all plots was applied @ 125 kg N, 50 kg P_2O_5 and 100 kg K_2O /ha in the plots of sizes of 3.0 m $\times$ 3.0 m. Nutrient composition of FYM used in the experiment was organic carbon 38%, N 1.20%, P 0.97% and K 1.87 % and gypsum had 23.1% calcium and 18.6% sulphur. Soil samples (0-15 cm) were collected after 20 years of experimentation in the month of April from all the plots. Soil samples were air dried ground and passed through 2 mm sieve and kept for chemical analysis. The chemical properties and available nutrients were analysed by the methods as outlined by Jackson (1973). Organic carbon pools, viz. DOC, MBC and LFC was analysed by Ciavitta *et al.* (1989), Vance *et al.* (1987) and Janzen *et al.* (1992) respectively. The data obtained under various studies was subjected to statistical analysis for significance using OPSTAT software. Least square difference was used to compare the treatment effects at $P < 0.05$.

RESULTS AND DISCUSSION

Soil pH and electrical conductivity: In the present study, mean value of soil pH (9.4) was more in sodic water irrigated plots without addition of amendments. Addition of gypsum and FYM decreased the soil pH. This could be due to movement of Na^+ to lower depth owing to its replacement by Ca^{2+} . The higher soil pH observed where no gypsum and FYM was applied. This was attributed to the precipitation of calcite in presence of high concentration of carbonates and bicarbonates and build up of Na^+ in the soil. The soil pH in G_1 (7.9) and G_2 (7.7) treatment was significantly lower as compared to the G_0 (9.1). The replacement of exchangeable Na^+ during Na^+ - Ca^{2+} exchange and subsequent leaching lowers the soil pH. Lowest value of pH was found in G_2 treated plots because of 100% neutralisation of RSC of irrigation water. The pH decreased with increasing levels of FYM from 0 (8.5) to 20 t/ha (8.0). Decrease in pH with addition of organic material may be due to increase in microbial respiration and production of organic acid during decomposition of organic material and as a result of increased pCO_2 . These results are in agreement with those reported by Pareek and Yadav (2011), Chaudhary *et al.* (2013), Korai *et al.* (2015), Datta *et al.* (2015) and Singh and Singh (2014).

Lower values of electrical conductivity (EC) were observed in plots where only sodic water was applied (0.48 dS/m) as compared to amended plots. The EC was significantly higher in treatments G_2 (1.03 dS/m) and G_1 (0.84 dS/m) as compared to G_0 (0.67 dS/m) treatment and it could be simply because of Na^+ released from the soil

exchange complex by Ca^{2+} and salt released due to gypsum dissolution. Similar type result was reported by Kaur *et al.* (2008) and Pareek and Yadav (2011). The EC of soil increased with addition of FYM application and highest value was found in F_2 (1.18 dS/m) treated plots and it might be due to increase of ions in solution, which might have resulted from mineral dissolution which is caused by increase in partial pressure of carbon dioxide and organic acid. These results are in agreement with the findings of Wong *et al.* (2008).

Available nutrients: The available nitrogen was found lowest (140 kg/ha) in plots where no FYM and gypsum were applied (Table 1) and it may be due to the fact that the ammonium volatilisation losses are more in sodic water irrigation and at high pH, similar reports have been reported by Yaduvanshi *et al.* (2001). The increase in available N content from 153-174 kg/ha with the incorporation of FYM may be attributed to N mineralization. Similar findings were reported by Singh *et al.* (2009). The available N was found highest (177 kg/ha) in case of G_2 treatment because of addition of gypsum reduced the soil pH, and at lower pH more microbial activity leads to more nitrogen mineralisation and fixation of atmospheric nitrogen. A polynomial relationship ($R^2=0.50$) observed between SOC and available N (Fig 1).

Available phosphorus content of soil was enhanced significantly from 16.6-23.6 kg/ha with the application of gypsum over control (Table 1). This might be due to the fact that the decrease in soil pH resulted in more availability of native and applied P. Similar result was obtained by Singh (2009). There was increase in available P status of soil from 15.9-24.2 kg/ha with addition of FYM, and which might be attributed to decomposition of organic matter accompanied by the production of organic acids which played a dominant role in solubilisation of native and applied phosphorus in soil. Organic acids also formed a protective cover on sesquioxides and this facilitated reduction in phosphate fixing capacity of soil. Regression equation predicts (Fig 1) significant relationship between organic carbon and available phosphorus with $R^2=0.73$. With the increase in FYM level from F_0 to F_2 , the soil available potassium (K) was also increased from 198 to 299 kg/ha (Table 1). This build up of soil available K due to FYM application might be due to additional supply of K applied through it and the solubilising action of certain organic acids produced during FYM decomposition and its greater capacity to hold K in the available form. Available K content in soil decreased (280 to 237 kg/ha) with increasing level of gypsum which may be due to improvement in soil properties which enhanced the crop yield and potassium removal from soil.

The content of available sulphur (S) in soil was increased with increase in level of FYM from 0 to 20 t/ha in different plots (Table 1). It might be due to greater mobilization of native soil S and decomposition of organic matter accompanied by the release of abundant quantities of CO_2 . This CO_2 production played a dominant role in reducing the pH and enhanced the sulphur availability.

Table 1 Effect of FYM and gypsum on available nutrients in soil under long term sodic water irrigation condition

Available nitrogen (kg/ha)					Available phosphorus (kg/ha)				
Treatment	G0	G1	G2	Mean	Treatment	G0	G1	G2	Mean
F0	140	153	168	153	F0	13.2	15.5	19.0	15.9
F1	147	164	176	162	F1	17.2	21.0	23.2	20.5
F2	160	175	188	174	F2	19.5	24.5	28.6	24.2
Mean	149	164	177		Mean	16.6	20.4	23.6	
CD (P=0.05) FYM=3.99 Gypsum=3.99G × F=NA					CD (P=0.05) FYM=1.25 Gypsum=1.25 G × F=NA				
Available potassium (kg/ha)					Available sulphur (kg/ha)				
F0	217	200	178	198	F0	35	48	57	46
F1	298	272	261	277	F1	42	56	67	55
F2	327	298	273	299	F2	50	65	74	63
Mean	280	257	237		Mean	42	56	66	
CD (P = 0.05) FYM = 3.72 Gypsum = 3.72 G × F=6.45					CD (P = 0.05) FYM = 1.53 Gypsum = 1.53 G × F = NA				

Available S content of soil was significantly enhanced with gypsum application over control. The highest (66 kg/ha) and the lowest (46 kg/ha) values for available S were found in the G₂ and G₀ treated plots respectively. It might be due to the decrease in soil pH resulted in more availability of native and applied S.

Soil organic carbon and its fractions: Addition of FYM and gypsum significantly increased the organic carbon (SOC) content in soil from 4.5-8.2 and 6.4-6.9 g/kg soil, respectively. This is because under improved soil physical environment, carbon inputs was more in the forms of more root biomass and above ground small plant residue. Addition of gypsum also increased the aggregation stabilization from the formation of Ca-organic linkage in the form of clay particle-Ca-organic molecule (Baldock *et al.* 2000). The soil organic carbon content in soil increased 62 and 82% with application of FYM @10 and 20 t/ha, respectively over no FYM application. Similarly organic carbon content increased 4.6% and 7.8%, respectively with increasing neutralization

of RSC of water from 50-100% respectively over control for gypsum. Interaction of FYM and gypsum levels showed significant differences for SOC of soil.

The mean value of dissolved organic carbon (DOC) significantly increased from 0.30 to 0.68 g/kg with increasing level of FYM from 0 to 20 t/ha (Table 2). It might be due to addition of high C inputs in soil which liberate more DOC in soil and this DOC was not leached out properly from compact soil. Contrary to FYM, the gypsum application decreased the DOC content from 0.57-0.44 g/kg in soil, this might be due to the fact that without gypsum application in sodic condition, the oxidation of organic matter was more and thus quantity of DOC formed which remained in upper layer of soil due to reduction in leaching under compact soil condition. Although DOC represents only small parts (5.7-9.4%) of C pools, it is supposed to be most active and mobile form of organic matter in soil. A significant interaction between FYM and gypsum indicate that higher value of DOC was observed at higher FYM level with

Table 2 Effect of FYM and gypsum on total soil organic carbon and its fractions in soil under long term sodic water irrigation condition

Light fraction carbon (g/kg)					Microbial biomass carbon (mg/kg)				
Treatment	G0	G1	G2	Mean	Treatment	G0	G1	G2	Mean
F0	0.29	0.35	0.38	0.34	F0	145	200	215	187
F1	0.48	0.58	0.64	0.56	F1	340	359	375	358
F2	0.55	0.65	0.71	0.63	F2	435	450	468	451
Mean	0.44	0.52	0.57		Mean	307	336	353	
CD (P=0.05) FYM=0.029 Gypsum=0.029 G × F=0.051					CD (P=0.05) FYM=11.05 Gypsum=11.05 G × F=NS				
Dissolved organic carbon (g/kg)					Soil organic carbon (g/kg)				
F0	0.35	0.30	0.27	0.30	F0	4.2	4.5	4.7	4.5
F1	0.60	0.52	0.42	0.51	F1	7.0	7.3	7.5	7.3
F2	0.75	0.67	0.63	0.68	F2	8.0	8.2	8.5	8.2
Mean	0.57	0.49	0.44		Mean	6.4	6.7	6.9	
CD (P=0.05) FYM=0.014 Gypsum=0.014 G × F=0.025					CD (P=0.05) FYM=0.048 Gypsum=0.048 G × F=0.083				

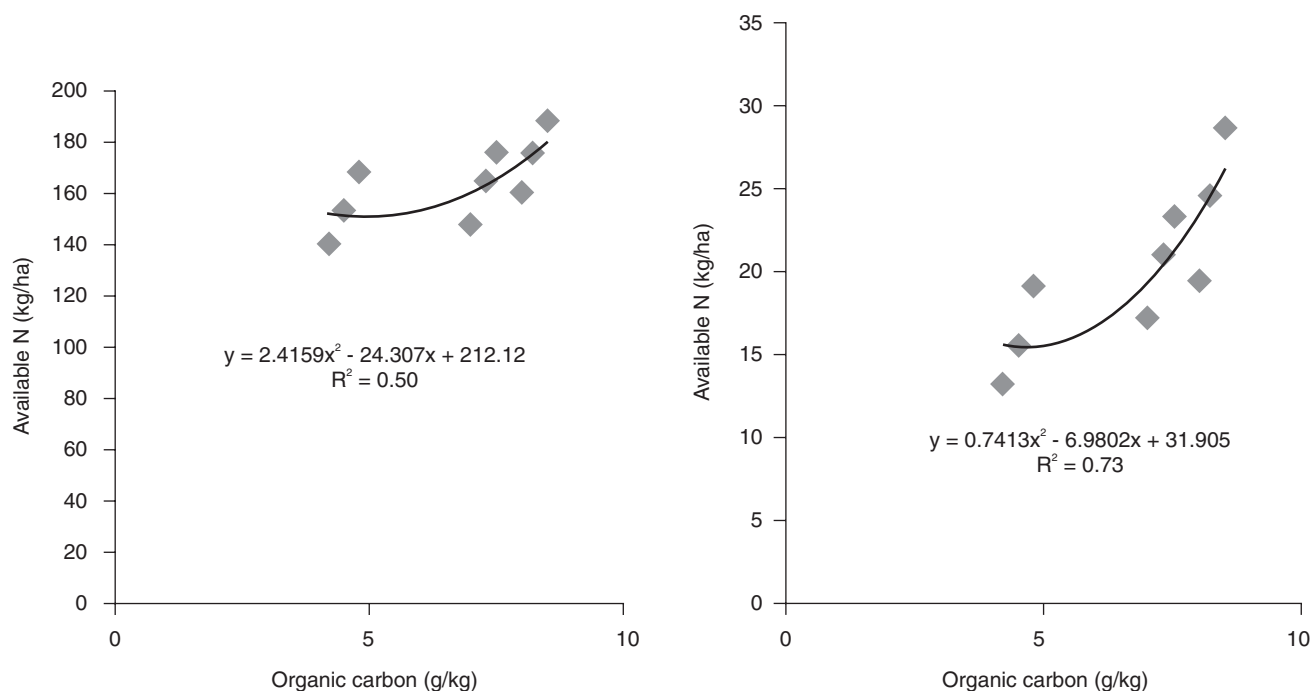


Fig 1 Relationship between soil organic carbon and available nitrogen and phosphorus content of soil.

lower dose of gypsum.

Addition of carbon to soil through FYM stimulates microbial activity which increased the microbial biomass carbon (MBC) content of soil and highest MBC (451 mg/kg) was recorded when FYM was applied @ 20 t/ha (Table 2). Similarly MBC significantly increased from 307-353 mg/kg with increasing dose of gypsum from 0-100% neutralization of RSC in soil. In the present study, MBC content varied between 3.5-5.5% of total organic carbon of soil. The improvement in soil properties upon application of gypsum and organic manures created a better soil environment for microbial activity that resulted an increase in MBC in soil (Kaur *et al.* 2008). The increase in light fraction carbon (LFC) was about 64 and 85% with the application of FYM @ 10 and 20 t/ha, respectively over no FYM application (Table 2). The LFC content also increased significantly with the increasing level of gypsum from 0-100% neutralization of RSC, but the magnitude of increase was less as compared to FYM application. The interactive effect of FYM and gypsum on LFC was significant. This increase in LFC may be due to addition of organic matter in the form of FYM and crop residue inputs due to higher crop yield achieved under improved soil environment. In the present study, the LFC content varied between 6.9-8.4% of total organic carbon of soil, which is lower than that reported by Kumara (2013) at same Research Farm under normal soil conditions. In presence of alkali salts, rate of mineralization of organic matter increased, which results in losses of carbon as dissolved organic matter (Nelson and Oades 1998).

Long term application of FYM and gypsum under sodic water irrigation for 20 years significantly influenced the soil properties and organic carbon fractions in soil. Soil pH was found decreased with the application of FYM and

gypsum over their no application, however reverse trends was observed in case of EC. Available N, P and S increased significantly with the addition of all levels of FYM and gypsum. Available K increased with the increasing level of FYM but reverse trends was observed with increasing level of gypsum. Similarly, soil organic carbon, LFC, and MBC content increased significantly with the increasing levels of FYM and gypsum. Dissolved organic carbon was found increased with increasing levels of FYM. However, its value decreased with increasing levels of gypsum. Distribution of organic carbon fractions such as MBC, DOC and LFC constituted about 3.5-5.5, 5.7-9.4, and 6.9-8.4% of total soil organic carbon present in soil. It can be concluded that application of FYM @20 t/ha along with gypsum @100% neutralization of RSC of irrigation water should be applied for maintaining soil quality and productivity.

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