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Study of ameliorants on crop growth and soil physicochemical properties in relation to salinity in an inceptisol of coastal soil

BY

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Abstract

We carried out an experiment in the ICAR-Central Soil Salinity Research Institute, Canning Town research farm to study the effect of different ameliorants on soil physico-chemical properties and crop growth. The experiment was carried out in a split-plot design where in the ameliorants were put in the main plot and their doses in the sub-plots. Soil samples were collected from 0-15 cm depth after two year of decomposition and were processed. Rice cv. Canning 7 was grown in winter (2020-21) for studying the effect of salinity and ameliorants on its growth. Saturated moisture content, bulk density, saturated hydraulic conductivity, and organic carbon were also determined. Soil bulk density decreased with increase in amount of doses, 1.28 Mgm^{-3} for 12 t/ha amendments. The value was 1.45 Mgm^{-3} for control. The saturated hydraulic conductivities were also dependent on the treatment and doses. The hydraulic conductivity values were little higher for F.Y.M. and poultry manure treatment (4.9-5.2 cmh^{-1}) than to green leaf manure and tank silt treatments (3.8-4.8 cmh^{-1}) for the soil. Leaf area index and NDVI values were slightly higher in F.Y.M. and poultry manure treatments (4.3-3.9 and 0.54-0.52, respectively) which were higher than green leaf and tank silt treatments (3.2-3.7, 0.50-0.51, respectively). Similarly, rice grain and straw weights were higher for F.Y.M. and poultry manure treatments (3.4, 4.2, and 3.3, 4.6 t/ha, respectively) than other treatments.

Introduction

Organic matter affects the soil's ability to provide nutrients for plants. In tropical regions, the reduced levels of soil organic matter are unavoidable. Organic materials as soil amendment have been widely used to improve the properties of the soil. A good indicator of the soil quality is soil aggregation as it relates to microbial and the carbon and nitrogen ratio (Jimenez *et al*., 2001; Demisie *et al*, 2014). It is also important to increase the soil's carbon and nitrogen, which is an indicator of soil fertility (Körschens *et al*., 2014). Busscher *et al*. (2011) showed an increase in organic carbon by the addition of organic soil amendments. Haynes and Naidu (1998) stated that the soil organic matter increase can improve soil pore structure. Muyassir *et al*. (2012) explained that the addition of organic materials can degrade the bulk density of 0.16 g cm^{-3}, increasing the aggregate's stability by 21.33%, and increasing the soil porosity of inceptisol by 13.67%. Some researchers reported that the traditional organic fertilizers (such as manure) have the positive effects potential for physical, chemical, and biological properties soil. The use of manure as a fertilizer is a common practice, it has been widely used as a natural amendment to improve soil fertility and increase crop yield (Kapkiyai *et al*., 1999).

The productivity of the soils in Coastal West Bengal is low. This is due to high soil salinity. Soil nitrogen content is low to medium, phosphorus content is low to medium, and Potassium content is medium to high. The soil salinity of the region becomes high, particularly in *rabi* season. It has been proposed that the water and nutrient holding capacity of these soils could be increased by the addition of organic amendments, thereby enhancing soil fertility. Soil amendment with organic materials and manures has been found to improve the physical and chemical properties of soil. Beneficial effects of organic soil amendments include decreased soil salinity, bulk density, and increased water holding capacity, aggregate stability, saturated hydraulic conductivity, water infiltration rate, and biochemical activity (Martens and Frankenberger, 1992; Turner *et al*., 1994). The reclamation of saline soils involves basically the removal of salts from the saline soil through the processes of leaching with water and drainage. Addition of organic manures like FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (Sunhemp, Dhaincha, Kolingi) and or green leaf manuring also counteracts the effects of salinity (Hake and Kerby, 2008).

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Materials and methods

The experiment was conducted in an Inceptisol of Central Soil Salinity Research Institute, Canning Town research farm. The soil is clayey (16% sand, 30% silt, and 54% clay). Four ameliorants namely poultry manure, farm yard manure (F.Y.M.), Green leaf (*Acacia auriculiformis),* and tank silt were used. The design of the experiment was split plot with three replications where the ameliorants were put in the main plots and doses in the subplots. The doses were 2, 4, 6, 8, 10, and 12t / ha (T_1, T_2, T_3, T_4, T_5 and T_6, respectively) on the basis of moist weight. The ameliorants were added in the plots and well mixed at 0-15 cm soil layer before onset of monsoon (February-March, 2020). The field was left undisturbed for near two year so that the ameliorants were well-decomposed. Soil samples were collected from 0-15 cm depth during Nov.-Dec., 2021 and were processed. Samples were collected with core samplers in three replicates without disturbing *in situ* soil conditions for determining bulk density. The saturated hydraulic conductivity was determined. The different particle sizes were determined using a Buoycous hydrometer. Diameters of soil particles at 10% cumulative weight (D_{10}) for different plots receiving various doses of amendments were calculated. Hydraulic conductivity of soil under different doses were also determined from Kozeny- Carman equation (Chapuis and Aubertin, 2003) and Shepherd's (Shepherd, 1989) equation as given below: (1) $K = \rho.g.\ C_k\ f_k\ n\ d_{10}{}^2 / (\mu)$ (Kozeny – Carman) where ρ is density, g is acceleration due to gravity, μ is dynamic viscosity, C_k is 8.3×10^{-3}, $f_k\ (n) = n^3/(1-n)^2$, n is porosity, d_{10} is 10% cumulative passing (geotechnical grain size distribution). (2) $K = a\ d^{\ b}$ (Shepherd) where K is saturated hydraulic conductivity (cm / s), d is grain diameter (mm), 'a' values range from 4.79×10^{-2} to 9.86 cm / s, 'b' (dimensionless) is 1.11 to 2.05. The content of soil organic carbon was estimated by modified Walkley-Black method. Soil EC and soil pH (1:2 soil: water suspension) were also determined. Rice cv. Canning 7 was grown for winter season of 2020-21 to study the effect of salinity and ameliorants on growth of the crop. Crop growth was judged through leaf area index (LAI) (Watson, 1952) and normalized difference vegetation index (NDVI).

Results and discussion

Soil bulk density was higher for the control, 1.45 Mgm^{-3} soil than for all other amendment treatments were applied, averages of 1.35 Mgm^{-3} (Table 1). Some differences in soil bulk density among amendment treatments were measured, for example, soil bulk density was higher for the green leaf manure treatment (1.40 Mgm^{-3}) than poultry manure treatment (1.26 Mgm^{-3}). There was a slight decrease in soil bulk density with the increase in amount of doses, 1.28 Mgm^{-3} for 12 t/ha amendments. Whereas, the value was 1.42 Mgm^{-3} for 2 t/ha amendment used. Changes in saturated hydraulic conductivity were also dependent on the treatment and doses (Table 1 and 2).

Table 1 Effect of different ameliorants on soil bulk density and hydraulic conductivity

Ameliorants*	B.D. (Mg/m3)	H.C. (cm/h)
M_1	1.37	4.9
M_2	1.40	3.8
M_3	1.37	4.8
M_4	1.26	5.2
C.D. (p=0.05)	ns	ns

*M_1 : F.Y.M., M_2: green leaf manure, M_3: tank silt and M_4: Poultry manure

Table 2. Effect of different ameliorant doses on soil bulk density and hydraulic conductivity

Dose	B.D. (Mg/m^3)	H.C. (cm/h)
T_1 (2 t/ha)	1.42	1.1
T_2 (4 t/ha)	1.40	2.0
T_3 (6 t/ha)	1.37	3.2
T_4 (8 t/ha)	1.34	4.5
T_5 (10 t/ha)	1.29	5.2
T_6 (12 t/ha)	1.28	5.4
C.D. (p=0.05)	0.14	1.24
Interaction ameliorant X dose	ns	s

ns-non-significant

Table 3. Effect of ameliorants and their doses on soil salinity and pH

Dose	EC_2 (dS /m)/pH			
	M_1	M_2	M_3	M_4
T_1 (2t/ha)	3.0/6.8	3.0/7.2	3.4/7.1	3.1/6.9
T_2 (4t/ha)	3.1/6.8	2.8/6.9	3.2/6.9	2.9/6.9
T_3(6t/ha)	3.0/6.7	2.9/6.8	3.0/6.8	2.6/6.8
T_4(8t/ha)	2.5/6.5	2.5/6.8	2.4/6.7	2.5/6.7
T_5(10t/ha)	2.4/6.4	2.4/6.4	2.2/6.7	2.3/6.4
T_6(12t/ha)	2.1/6.4	2.3/6.4	2.2/6.5	2.1/6.4

C.D. (p=0.05) (EC, pH) -- ns; Interaction ameliorants X doses (EC, pH) – ns

M_1 : F.Y.M., M_2: green leaf manure, M_3: tank silt and M_4: Poultry manure

Table 4. Effect of different ameliorants and their doses on crop growth parameters, grain, and straw yield

Ameliorants	LAI	NDVI	Grain weight (t/ha)	Straw weight (t/ha)
M1	4.3	0.54	3.4	4.2
M2	3.2	0.50	3.2	4.1

M3	3.7	0.51	3.1	4.2
M4	3.9	0.52	3.3	4.6

Dose	LAI	NDVI	Grain weight (t/ha)	Straw weight (t/ha)
T1 (2 t/ha)	3.1	0.50	3.1	4.1
T2 (4 t/ha)	3.4	0.51	3.0	4.2
T3 (6 t/ha)	3.3	0.51	3.1	4.1
T4 (8 t/ha)	3.7	0.52	3.2	4.3
T5 (10 t/ha)	3.8	0.53	3.3	4.3
T6 (12 t/ha)	3.6	0.54	3.4	4.5
CD (p=0.05)	-	-	0.13	0.18

*M_1: farm yard manure, M_2: green leaf manure, M_3: tank silt, M_4: poultry manure; LAI: leaf area index, NDVI: normalized difference vegetation index; T: treatment dose

Table 5. Percentage of soil pores in relation to ameliorants used

Ameliorants used	Organic matter (%)	Macropore (%)	Micropore (%)	Total pore (%)
M_1	1.6	0.23	0.43	0.66
M_2	1.1	0.21	0.42	0.63
M_3	1.1	0.20	0.41	0.61
M_4	1.3	0.24	0.43	0.67
C.D. (p=0.05)		ns	ns	ns

M_1 : F.Y.M., M_2: green leaf manure, M_3: tank silt and M_4: Poultry manure

Table 6. Percentage of soil pores in relation to ameliorant doses

Doses	Organic matter (%)	Macropore (%)	Micropore (%)	Total pore (%)
T_1 (2 t/ha)	1.30	0.16	0.43	0.59
T_2 (4 t/ha)	1.40	0.18	0.43	0.61
T_3 (6 t/ha)	1.40	0.21	0.44	0.65
T_4 (8 t/ha)	1.41	0.22	0.44	0.66
T_5 (10 t/ha)	1.44	0.24	0.44	0.68
T_6 (12 t/ha)	1.68	0.23	0.45	0.68
C.D. (p=0.05)	-	0.05	ns	0.06
C.D. (p=0.05)	-	0.05	ns	0.06

The hydraulic conductivity values were little higher for F.Y.M. and poultry manure treatment (4.9-5.2 cmh^{-1}) than to green leaf manure and tank silt treatments (3.8-4.8 cmh^{-1}) for the soil. The saturated hydraulic conductivity was increased from 1.1 to 5.4 cmh^{-1} when the amount of doses increased from 2 to 12 t / ha. The use of different ameliorants did not bring about significant change in soil parameters like bulk density (B.D.) (avg. 1.35 Mgm^{-3}) and saturated hydraulic conductivity (H.C.) (4.7 cmh^{-1}) (Table 1). However, saturated HC for different plots treated with different doses of ameliorants differ significantly (C.D. $t_{0.05}$= 1.24 for the treated soil) (Table 2). The interaction effects of ameliorants and doses were also significant in bringing significant change in saturated hydraulic conductivity of soil. Similar study was done by Pravin *et al*. (2013) who reported that the levels of soil organic matter determines the weight of the soil contents. The results of their study indicated that increased soil organic matter content can both reduce bulk density and increase in hydraulic conductivity. The EC (1:2 soil: water suspension) values of the soil varies from 3.0 to 2.1 dS/m in the 2 t/ha and 12 t/ha F.Y.M. treated plots, respectively where as the values varied from 3.0 to 2.3 dS/m in the 2 t/ha and 12 t/ha green leaf manure treated plots. The values were 3.1 dS / m to 2.1 dS / m for poultry manure treatments. The pH values were 6.8 to 6.4 for F.Y.M. and 6.9 to 6.4 for poultry manure treated plots. In general, with increase in ameliorant doses, there was a decrease in EC and pH values of soils but the differences were non-significant (Table 3). Leaf area index and NDVI values were slightly higher in F.Y.M. and poultry manure treatments (4.3-3.9 and 0.54-0.52, respectively) which were higher than green leaf and tank silt treatments (3.2-3.7, 0.50-0.51, respectively). Similarly, rice grain and straw weights were higher for F.Y.M. and poultry manure treatments (3.4, 4.2, and 3.3, 4.6 t/ha, respectively) than other treatments (Table 4). With increment in treatment doses from 2t/ha to 12 t/ha, in general there was an increase in LAI (3.1-3.6), NDVI (0.50-0.54), grain weight (3.1-3.4 t/ha) and straw weight (4.1-4.5 t/ha) of rice (Table 4). These findings are in agreement with those of Watson (1952).

The provision of soil amendment can increase the porosity of different types of soil (Widowati *et al*.,(2020). In the present

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study the soil amendment application increased soil porosity. Organic matter content was high for F.Y.M. and Poultry manure treatments (1.6 and 1.3 %, respectively than green leaf manure and tank silt treatments (1.1%) (Table 5). Total porosity varied from 0.61 to 0.67% in which macropores varied from 0.20-0.24%, but the difference was non-significant. With increase in ameliorant dose from 2 t/ha to 12 t/ha organic matter content of soil increased from 1.32-1.68% resulting in significant difference in pore spaces (Table 6). Widowati *et al*. (2020) found that increased soil porosity resulting in a three-fold increase in surface area of soil which leads to the increased water-holding capacity in inceptisol. Organic carbon percentage was positively correlated with hydraulic conductivity (r=+0.59) and negatively correlated with soil bulk density (r=-0.79). The relationship between measured and calculated hydraulic conductivities using Kozeny-Carman and Shepherd's equations were significant (r^2 =0.96, p<0.01; r^2=0.97, respectively) (Fig. 1).

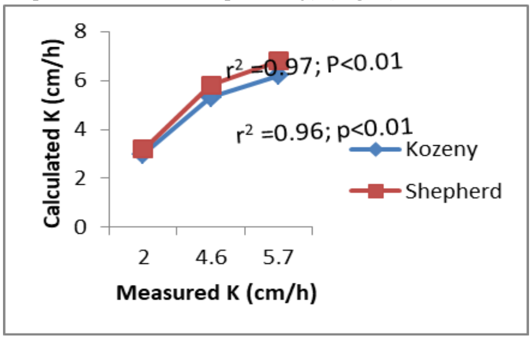

Fig.1. Relation between calculated and measured hydraulic conductivities

Conclusions

In the present study soil bulk density was higher for the green leaf manure treatment (1.40 Mgm^{-3}) than poultry manure treatment (1.26 Mgm^{-3}). There was a slight decrease in soil bulk density with the increase in amount of doses, 1.28 Mgm^{-3} for 12 t/ha amendments, and was 1.42 Mgm^{-3} for 2 t/ha amendment used. Changes in saturated hydraulic conductivity were also dependent on the treatment and doses. Leaf area index and NDVI values were slightly higher in F.Y.M. and poultry manure treatments (4.3-3.9 and 0.54-0.52, respectively) which were higher than green leaf and tank silt treatments (3.2-3.7, 0.50-0.51, respectively). Similarly, rice grain and straw weights were higher for F.Y.M. and poultry manure treatments (3.4, 4.2, and 3.3, 4.6 t/ha, respectively).

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