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EFFECTS OF ORGANIC AMENDMENTS ON PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF SALINE SOIL

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Abstract

Soil salinity is a great constraint for crop production in the coastal zone of Bangladesh. Soil amendment could be a good strategy to address salinity problem. An incubation experiment was undertaken with two saline soils representing Gopalpur and Ishurdi series under Khulna district. The study used two types of organic amendment - rice hull and sawdust, which were applied at a rate of 0, 3, 6, and 9 t ha^{-1}, designated as T_0, T_1, T_2, and T_3, respectively. Their effects were evaluated on soil physical properties (bulk density & porosity), chemical properties (organic carbon & available nitrogen content), biological properties (microbial biomass carbon and CO_2 emission). Results varied between the amendments as well as between the soils. It revealed that the rice hull amendment in Gopalpur soil significantly ($p \leq 0.05$) enhanced the organic carbon and nitrogen contents, which, in turn, catalyzed a significant increase in microbial biomass carbon and CO_2 emission while the physical properties of soil remained unaffected. Conversely, the application of sawdust to Ishurdi soil had significant positive effect on all soil properties except organic carbon content. Compared with unamended soil, soil treated with organic amendments showed favorable changes in Gopalpur soil as compared to Ishurdi soil. However, most of the soil properties were greatly improved with the amendments applied at the rate of 3 t ha^{-1}. Therefore, it is suggested to use rice hull and saw dust for crop production in saline soils.

Keywords: Incubation experiment, Microbial biomass, Organic carbon, Rice hull, Sawdust

1. Introduction

There are five fragile ecosystems in Bangladesh viz., haor, char land, hill, barind and coastal ecosystems where cropping intensity as well as crop yield is very low. Coastal areas exist in 19 southern districts, of which 11 districts are near the sea. Soil salinity reaches its peak during March - May. Approximately 1.056 million hectares of land is salt-affected (SRDI, 2010) because of seawater intrusion and saline water irrigation systems. Globally substantial amount of research has been carried out to solve the difficulties of crop production in the soils (Chen *et al.* 2020; Zhu *et al.* 2021) while in Bangladesh it is the minimum, the most works are concentrated on development of crop varieties. .

An effective approach could be using organic amendments to raise the amount of organic matter in the salt-affected soils. Different organic amendments, such as sewage sludge compost, animal manure, poultry manure, straw, and biochar have all been added to soils in an effort to influence soil properties (Luna *et al.,* 2018; Meena *et al.* 2019). Studies have shown that treating saline soils with organic amendments can enhance their cation exchange capacity (CEC), water-holding capacity, soil fertility, organic carbon levels and reduce the salt content, electrical conductivity (EC), and exchangeable sodium percentage (ESP) and microbial biomass carbon of soils (Trivedi *et al.,* 2017; Hossain *et al.,* 2019; Larsen *et al.,* 2024).

While selecting reclamation agents, it is important to consider their impact on the soil, as well as the cost and any environmental risks. Rice hull, which is the residue left after harvesting paddy, can serve as a significant agricultural resource for growing plants. Similarly, sawdust, a type of wood residue, is useful for recycling into land used for agriculture, maintaining soil fertility by enhancing the soil's nutrient status, and facilitating cultivation by enhancing the soil's physical and chemical qualities (Begum and Khan, 2014). By incorporating rice hull and sawdust into the soil, organic matter content is enhanced, leading to an increase nitrogen levels in both soil and plant tissue (Kaniz and Khan, 2013). Additionally, rice straw may release cellulose, hemicelluloses, and lignin entering the soil through mineralization processes, which renders them potentially accessible to subsequent crop growth (Byous *et al.,* 2004; Marzouk *et al.,* 2024). However, study of organic amendments, especially rice hull and sawdust, in saline soils is highly limited. Therefore, the present study was undertaken to evaluate the influence of organic amendments (rice hull and sawdust) on physical, chemical, and biological properties of saline soils of two different soil series. We hypothesized that such organic amendment would result favorable soil properties and thus reduce the adverse effect of soil salinity on crops.

2. Materials and Methods

The incubation study was carried out in the laboratory of the Soil, Water and Environment Discipline of Khulna University in room temperature condition 25ºC ± 1ºC. Soil moisture content was monitored and kept at field capacity (48%) by watering when required during the 6-month incubation period. The soils at 0-10 cm depth were collected from Chanderdanga, (Gopalpur series) and Kalyansri (Ishwardi series) of Khulna district. The samples were air-dried and sieved through a 2-mm sieve prior to the incubation experiment and soils analysis. Sub-samples of air-dry soils were used for determining the soil characteristics. The particle size distribution of soil was determined by the hydrometer method (Gee and Bauder, 1986), bulk density by core sampler method (Blake and Hartge, 1986) and soil porosity was by estimated by Brady and Weil (2017) method. Soil pH was measured at a soil: water ratio of 1: 2.5, as suggested by Jackson (1973). Electrical conductivity (EC) was determined in soil-paste extract (USDA, 2004). The organic carbon (OC) content was determined by Walkley and Black’s wet oxidation method (Jackson, 1973), organic matter was calculated by multiplying the percentage of OC with conventional Van-Bemmelen factor 1.724 (Piper, 1950). Available N content of soil was determined followed the method of Bremmer and Mulvaney (1982). Microbial biomass carbon was determined according to the method of Jenkinson and Ladd (1981) and soil respiration was measured following the procedure of Anderson (1982). The physico-chemical and biological properties of the two soils and amendments are shown in Table 1.

Table 1. Characteristics of the soils and amendments used

Parameter	Gopalpur Series	Ishwardi Series	Rice hull	Sawdust
Location (GIS)	N $22^0$40.700’ E $89^0$27.112’	N $22^0$40.915’ E $89^0$26.31’	--	--
Soil pH (H_2O)	7.32 ± 0.005	7.72 ± 0.15	7.46 ± 0.02	7.37 ± 0.01
EC (dSm^{-1})	13.94 ± 0.04	17.74 ± 0.03	0.09± 0.01	0.12± 0.03
CEC (Cmol kg^{-1})	22.90 ± 0.20	16.00 ± 0.03	--	--
Clay (%)		27.00 ± 1.65	13.00 ± 2.0	-- --
Silt (%)	61.00 ±2.61	73.00 ± 1.73	--	--
Sand (%)		12.00 ± 2.21	14.00 ± 5.19	-- --
Texture	Silty clay loam	Silt loam	--	--
OC (%)	0.95 ± 0.05	0.97 ± 0.04	29.21±0.69	27.47±1.10
OM (%)	1.18 ± 0.03	1.67 ± 0.10	--	--
Available N (mg kg^{-1}), KCl extractable	80.01 ± 2.92	89.31 ± 3.41	--	--
Available P (mg kg^{-1})	12.07 ± 0.13	3.16 ± 0.10	--	--
Total N (mg kg^{-1})	--	--	118.16±2.11	74.98±1.33
Total P (mg kg^{-1})	--	--	53.11±0.83	43.19±1.07
Total K (mg kg^{-1})	--	--	688.37±8.59	797.07±12.72
Bulk density (g cc^{-1})	1.48± 0.06	1.46± 0.03	--	--
Porosity (%)	38	39	--	--
Microbial biomass carbon (mg kg^{-1})	45.52± 0.36	35.22± 0.96	--	--
Soil respiration (mg CO_2 g^{-1} soil day^{-1})	144.21± 2.06	140.47± 3.16	--	--

Plastic pots were arranged in a completely randomized design (CRD) with two amendments and four rates for each soil, each replicated thrice. Rice hull and sawdust as organic amendment were added to soil at the rates of 0 (control), 3, 6, and 9 t ha^{-1}, designated as T_0, T_1, T_2, and T_3, respectively. Rice hull (RH) and sawdust (SD) at a specified rate were well-mixed with eight kg of each soil. The soils were equilibrated with the respective amendments at field capacity for three days and observation on soil parameters was made at the expiry of six-month period. The level of significance for the different treatment means was calculated by Duncan's new multiple range test (DMRT) (Zaman et al., 1982).

3. Results

3.1 Effects of organic amendments on physical properties of soil

Both organic amendments showed a tendency to lower the soil bulk density (Fig. 1a and 1b). In Goplapur soil, rice hull and sawdust reduced bulk density BD to a value of 1.44 g cc^{-1} and 1.43 g cc^{-1}, respectively as compared to the control (1.46 g cc^{-1}) whereas in Ishwardi soil, bulk density was reduced to a value of 1.38 g cc^{-1} and 1.37 g cc^{-1} respectively against the control (1.45 g cc^{-1}). The maximum reduction in BD was found with the highest rate (9 t ha^{-1}) of rice hull and sawdust in both soils. The results demonstrated a significant reduction in BD for the case Ishurdi soil while for Goplapur soil the reduction was not significant.

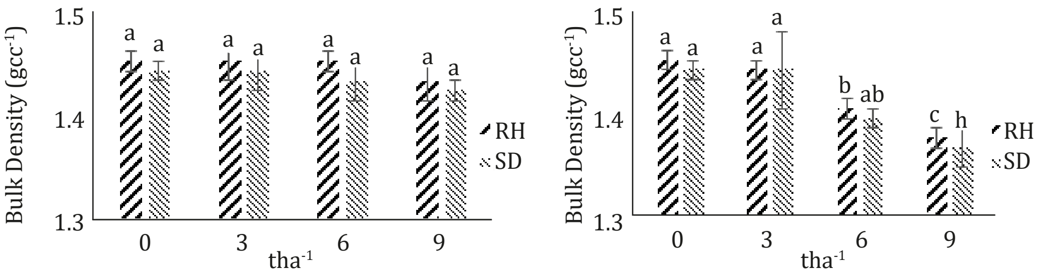

Fig. 1 *Effects of organic amendments on the changes in soil BD in Gopalpur (a) and Ishurdi (b) soils*

The soil porosity results (Fig. 2a and 2b) demonstrate that both amendments increased soil porosity at the maximum application level. In Gopalpur soil, the highest porosity (46%) was found with sawdust amendment that significantly differed from that with control (38%) and for rice hull, the highest porosity value was 44% which was comparable with the value noted for the control treatment (39%). In Ishwardi soil, there was a significant increase in porosity as 45% found in sawdust and 44% in rice hull treated soil as compared to control.

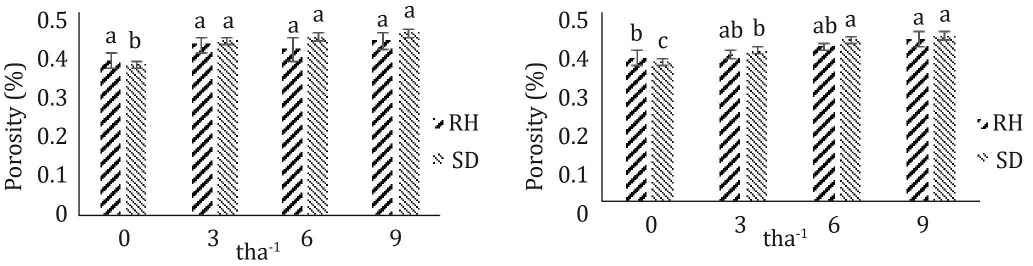

Fig. 2 *Effects of organic amendments on the changes in soil porosity in Gopalpur (a) and Ishurdi (b) soils*

3.2 Effects of organic amendments on chemical properties of soil

Changes in organic carbon content in response to organic amendments is depicted in Fig. 3. The result showed that application of both amendments (rice hull and sawdust) increased the carbon content in Gopalpur soil significantly and the increment was greater for rice hull (1.19%) than that of sawdust (1.08%). On the contrary, in Ishurdi soil the changes in carbon content were not significant for both treatments.

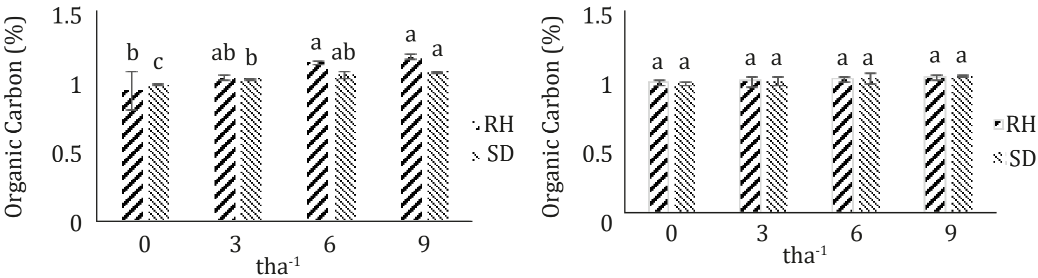

Fig. 3 *Effects of organic amendments on the changes in soil organic carbon in Gopalpur (a) and Ishurdi (b) soils*

Application of rice hull and sawdust (Fig. 4a and 4b) significantly increased the available N content in soils. The highest values of N content that noted for the highest rate (9 t ha^{-1}) of rice hull and sawdust application were 112 and 108 mg kg^{-1}, respectively in Gopalpur soil and in Ishwardi soil the values were 133 and 130 mg kg^{-1}, respectively.

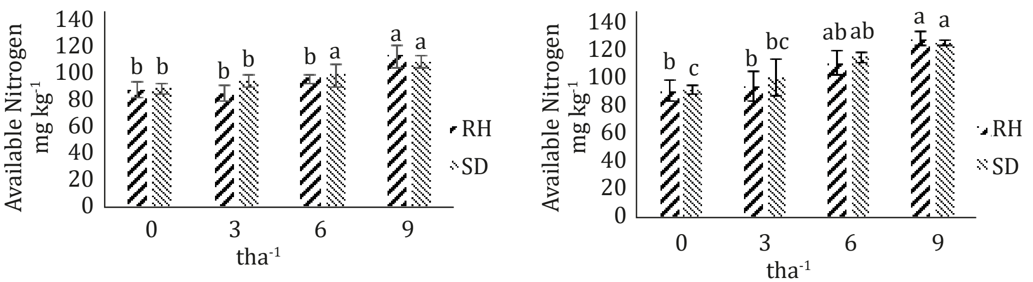

Fig. 4 *Effects of organic amendments on the changes in soil available nitrogen in Gopalpur (a) and Ishurdi (b) soils*

3.3 Effects of organic amendments on biological properties of soil

The results for MBC due to two amendments over two soils were not consistent. The highest MBC (129 mg kg^{-1}) was recorded with 9 t ha^{-1} sawdust treatment in Gopalpur soil (Fig. 5a) which was 84.2 mg kg^{-1} for rice hull amendment at 6 t ha^{-1} rate of application (Fig. 5b). In Gopalpur soil increments in MBC were 22.5% for rice hull and 61.8% for sawdust. In Ishurdi soil, the highest value (89.9 mg kg^{-1}) was observed with 9 t ha^{-1} rate of rice hull and in sawdust treated (6 t ha^{-1}) soil the highest value was 81.2 mg kg^{-1}.

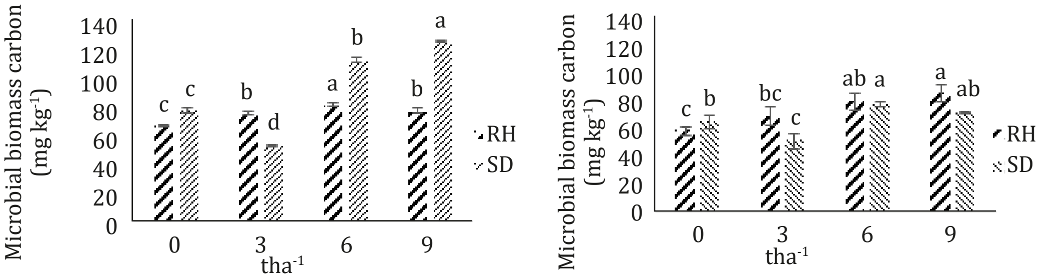

Fig. 5 *Effects of organic amendments on the changes in soil MBC in Gopalpur (a) and Ishurdi (b) soils*

The soil respiration rate in terms of CO_2 evolution increased with the rates of rice hull and sawdust application in both Gopalpur and Ishwardi soils amended (Fig. 6a and 6b). In Gopalpur soil, the maximum value was that recorded with rice hull at 9 t ha^{-1} addition was 173 mg CO_2 g^{-1} soil day^{-1} and with sawdust it was 170 mg CO_2 g^{-1} soil day^{-1}. As observed in Ishwardi soil the maximum value for sawdust treatment was 167 mg CO_2 g^{-1} soil day^{-1} and for rice hull it was 163 mg CO_2 g^{-1} soil day^{-1}. In Gopalpur soil, exclusively the sawdust treatment significantly increased the soil respiration rate while in Ishurdi soil the CO_2 evolution increased significantly for both types of amendment.

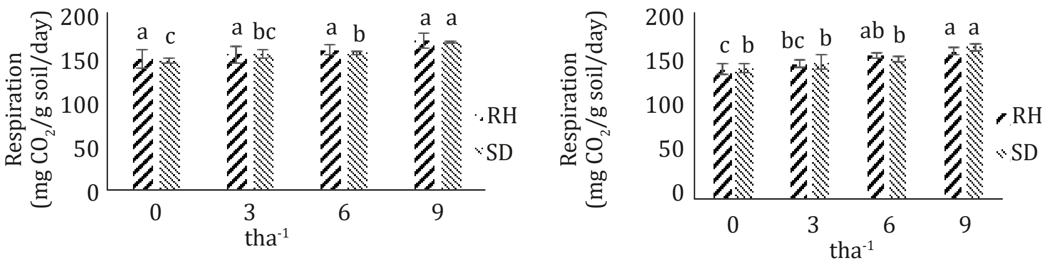

Fig. 6 *Effects of organic amendments on the changes in soil respiration in Gopalpur (a) and Ishurdi (b) soils*

4. Discussion

In both Gopalpur and Ishwardi soils, the lowest organic carbon content was observed with control (0.99%) and the highest carbon was with the highest rate (9 t ha^{-1}) of rice hull or sawdust application . Between the two soils the result was higher for Gopalpur soil than for Ishurdi which could be attributed to higher clay content, 27% of the former soil compared to the later soil, 13% clay (Fig. 1, Table 1). The higher clay content might be a cause to adsorb more carbonaceous material in Gopalpur soil compared to Ishurdi soil. In general, the concentration of soil organic carbon is typically higher in soils with high clay content due to the enhanced soil aggregation and organic matter protection provided by clay minerals.

Mon *et al.* (2024) and Linam *et al.* (2023) found a positive correlation between the addition of compost and soil organic carbon content. Addition of both rice hull and sawdust resulted in increased available N content in both soils. In Gopalpur soil it accounted 28.6% and 22.2% increment for rice hull and sawdust, respectively over the unamended (control) soil whereas in Ishurdi soil the increments were 41.9% and 37.4%, respectively. Rice hull contained more N (118 mg kg^{-1}) than sawdust did (75 mg kg^{-1}) which value (Table 1) could explain the result difference between the two soils. Rice hull and sawdust significantly increased soil MBC showing 47.6% and 19.3, respectively in Ishurdi soil. The C:N ratio controls the activities of soil microbes. When C:N ratio is high microbial growth becomes high and much carbon is immobilized by soil microbes, principally bacteria. It becomes stable when C:N ratio comes down to 10:1 – 12:1. In the present study, total status of soil N was not measured. Because the research observed the changes in available nitrogen content due to the addition of organic amendments in saline soi. That's why research didn't conduct total N determination.

The result suggests that the organic matter from sawdust was more biodegradable than that from the rice hull possibly due to higher C:N ratio in sawdust. Compared to the 100% chemical nitrogen (CN) treatment, the use of organic amendments significantly stimulated microbial growth and increased the activity of most carbon-degrading enzymes (Luan *et al.,* 2020). According to Lamptey *et al.* (2019), soil respiration increased by an average of 12% with amendment treatments compared to no amendments.

The decreased bulk density in soils might be due to increase in soil volume for addition of organics having low density (could be 0.5 g cc^{-1}). The study of Aytenew and Bore (2020) showed application of organic amendments lower soil bulk density values by more than 5% versus sole urea fertilized soil and for each 1% increase inorganic matter, soil water holding capacity increased by up to 3.7%. Their study also stated that organic amendments play a positive role in chemical characteristics of the soil including increase in organic carbon, organic nitrogen, microbial biomass and increased enzymatic activity. The increase in soil porosity is related to decrease in soil bulk density. Dong *et al.* (2022) observed that the organic amendments increased soil porosity and available water amount and decreased bulk density y of soil.

5. Conclusions

The result of the present study indicated that rice hull and sawdust varied in their effectiveness on the soil characteristics. Rice hull and sawdust significantly improved most of the soil parameters (except bulk density) in Gopalpur soil whereas in Ishwardi soil the organic carbon content remained unaffected after rice hull and sawdust application. Field experiment with crops is necessary to evaluate the effectiveness of organic amendments on improvement of saline soil for successful crop production.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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