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Amelioration of Saline Soil by the Application of Gypsum, Calcium Chloride, Rice Husk and Cow Dung

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Abstract

A pot experiment was conducted to investigate the effect of cow dung, rice husks, calcium chloride and gypsum on soil reclamation and compare the effect of organic and inorganic amendments on soil reclamation during the period of 5th March to 20th April, 2017. The experiment was laid to fit a completely randomized design (CRD) with seven treatments [Reference soil (T_0), Cow dung (T_1), Rice husk (T_2), Gypsum (T_3), Calcium chloride (T_4), Cow dung + Rice husk (T_5) and Gypsum + Calcium chloride (T_6)] each having three replications for this experiment. After incubation (45 days), the laboratory investigation was carried out in the Soil, Water and Environment Discipline, Khulna University, Khulna, Bangladesh. Results indicate that the individual or combined effect of gypsum (T_3) was more effective in changing EC and SAR. Gypsum application in combination with calcium chloride (T_6) improved the soil chemical properties by reducing the EC. Among the treatment, calcium chloride (T_4) had a remarkable effect in reducing sodium adsorption ratio and gypsum had a remarkable effect in reducing pH. Cow dung (T_1), rice husk (T_2), combination of cow dung and rice husk (T_5) were less effective to reduce EC, pH and SAR. It's measured for soils of different soil amendments varied significantly ($P < 0.05$) and also with the reference soil.

Keywords

Amelioration, Saline Soil, Cow dung, Rice Husk, Gypsum, Calcium Chloride, C/N Ratio

1. Introduction

Salinization of land is one of the most important problems in South and

South-West coastal parts of Bangladesh. The total area of Bangladesh is 147,570 km^2. The coastal area covers about 20% of the country. Over 30% of the net cultivable area in Bangladesh is on the coast [1]. Out of the 2.85 million hectares (mha) of coastal and off-shore area (30% of net cultivable area), about 0.83 mha arable land were affected by varying degrees of soil salinity during 1966-1975 which has increased to 1.02 mha in 2000 [2]. The coastal soil salinity has undergone rapid changes in recent years. Such changes occur due to conversion and encroachment of agricultural land to shrimp farming. Transformation of rice fields into shrimp farms has changed the land use because the rain-water cannot wash out the salt water now rather it stored in "Gher". So, salinity increases day by day and form salt crust in sub-surface.

Bangladesh, a low-lying deltaic land, is particularly vulnerable to climate change and its associated hazards [3]. The coastal areas of Bangladesh, with its near flat topography and location at the tip of "funnel shaped" Bay of Bengal, are susceptible to a number of natural hazards: cyclones and tidal surges, salinity intrusion, riverbank erosion, shoreline recession etc. [4]. Although all hazards are detrimental to agriculture, however sea level rise is likely to put the gravest threat by land submersion and salinity intrusion [5] [6]. Irrigated water demand is highly affected by salinity intrusion in surface water [7] and salt accumulation in the root zone of soil affects plant growth in coastal soil [8]. Besides constraining agricultural production, salinity limits the fresh water availability for drinking purpose and industrial production. Coastal area of Bangladesh has already been experiencing erosion. It has been found that the sea level rise of 0.5 m over the last 100 years has eroded approximately 162 km^2 of Kutubdia, 147 km^2 of Bhola and 117 km^2 of Sandwip [9]. Based on 22 years data, SAARC Meteorological Research Council (SMRC) found that the sea level rise in Hiron point, Char Ganga and Cox's Bazar, three tidal stations of Bangladesh, was 4.0 mm/year, 6.0 mm/year and 7.8 mm/year, respectively [10]. If the trend continues, sea water may intrude much longer distance in inland extending towards interior coast in low-laying areas of Bangladesh [11]. Being an agrarian country, 60% people of Bangladesh are directly or indirectly dependent on agriculture for their livelihood, with the contribution of 20% to its GDP [12]. The dominant land use in coastal Bangladesh is also agriculture. Even though gross and net-cropped areas in the coastal zone of Bangladesh are 144,085 and 83,416 hectors, respectively [13], but net-cropped area of coastal zone has been showing a decreasing trend over the years due to a combination of factors. Gowing *et al.* [14] argued that coastal Agri-lands often suffered from saline intrusion that prevented crop production in dry season. CCC study identified salinity intrusion as the most pressing problem for yield reduction in coastal agriculture. The study found that 830,000 million hectares of land at coastal Bangladesh were affected by soil salinity at different degrees. It is estimated that a net reduction of 0.5 million MT of rice production would take place due to a 0.3 m sea level rise in coastal areas of Bangladesh [15].

There are many different methods of reclamation of saline soils such as physical amelioration (deep ploughing, sub-soiling, sanding, profile inversion), chemical amelioration (amending of soil with various reagents e.g., gypsum, calcium chloride, limestone, sulphuric acid, sulphur, iron sulphate), electro-reclamation (treatment with electric current) [16]. Though the amelioration of saline soils with chemical amendments is an established technology [17] [18], the chemical strategies, however, have become costly for subsistence farmers in the developing countries during the last two decades because of the increased use by industry and reductions in government subsidy to farmers for their purchase [19]. Organic manures not only increase soil fertility, but enhance soil chemical and physical properties [20]. The biological amelioration methods using living or dead organic matter such as crops, stems, straw, green manure, barnyard manure, compost, sewage sludge have two principal beneficial effects on reclamation of saline and alkaline soils: improvement of soil structure and permeability thus enhancing salt leaching, reducing surface evaporation and inhibition of salt accumulation in surface soils, and release of carbon dioxide during respiration and decomposition [21]. Therefore, the main objectives of this research were to investigate the effect of cow dung, rice husks, calcium chloride and gypsum on soil reclamation and compare the effect of organic and inorganic amendments on soil reclamation.

2. Methods and Materials

A pot experiment was conducted in the net house at the premises of the Soil, Water and Environment Discipline, Khulna University, Khulna, Bangladesh during the Kharif season from 5th March to 20th April, 2018 to investigate the effect of cow dung, rice husks, calcium chloride and gypsum on soil reclamation and compare the effect of organic and inorganic amendments on soil reclamation. The net house experiment, collection and preparation of soil samples and analytical methods adopted during the course of investigation were presented in this chapter.

Soil sample collection and preparation

Soil samples were collected at a depth of 0 - 15 cm from a square area of 1 km^2 under Bagerhat district (GPS: 22˚40.542'N and 89˚31.406'E) in Bangladesh. Then sample were mixed together to form a composite sample. After air drying, the larger aggregates were broken gently by crushing it in a wooden hammer, and passed through a 2 mm sieve. The sieved soils were preserved in plastic bag for pot experiment and also preserved in plastic pot for determining their various physical and chemical properties and both are labeled properly. General information of the experimental soil was shown in **Table 1**.

Experimental design and treatments

A pot experiment was carried out in net house of Soil, Water and Environment Discipline at Khulna University. The study was arranged in a completely randomized design (CRD) [22] using seven treatments replicated three times (**Table 2**). Each pot containing 3 kg of air-dried soil with different combinations

Table 1. General information about sampling sites.

	General information
Location	Village: Harikhali; Upazilla: Bagerhat; District: Bagerhat
GPS	22˚40.542'N and 89˚31.406'E
EC	8.30 $dS \cdot m^{-1}$
pH	8.45
SAR	2.01
CEC	20.4 Cmolc (+) kg^{-1}
%OC	0.78%
%OM	1.35%
%N	0.14%
C:N	5.6
Calcareousness	Calcareous
Textural class	Silty clay

Table 2. Treatment of the experiment.

Treatment	Description
T_0	Reference soil (Indigenous soil)
T_1	Cow dung
T_2	Rice husk
T_3	Gypsum
T_4	Calcium chloride
T_5	Cow dung + Rice husk
T_6	Gypsum + Calcium chloride

of the amendments were prepared as follows.

The application rate of amendments for T_1, T_2, T_3 and T_4 was 3000 kg per hectare. For T_5 half of cow dung + half of rice husk (3000 kg cow dung per ha + 3000 kg rice husk per ha) and for T_6 half of gypsum + half of calcium chloride (3000 kg gypsum per ha + 3000 kg calcium chloride per ha) were applied. These pots were incubated in net house of Soil, Water and Environment Discipline at Khulna University for 45 days under 25˚C temperature. Field condition was maintained by the addition of water in weekly intervals during the period of incubation.

Analytical procedure

Different physical and chemical parameters of soil were analyzed by following procedures. Electrical conductivity (EC) of soil was estimated by EC meter maintaining the ratio of soil to water of 1:5 and then the result was converted to the ratio of 1:1 (soil:water) as suggested by USDA [23]. The pH value of soil samples was measured by using pH meter maintaining the ratio of soil to water of 1:2.5 as suggested by Jackson [24]. Organic Carbon of soil samples was determined by Walkley Black's Wet Oxidation method as outlined by Jackson [25]. Organic matter was calculated by multiplying the percent value of organic carbon with the conventional Van-Bemmelene's factor of 1.724 [26]. The CEC of the soils was determined by extracting the soil with neutral ammonium acetate solution (NH_4OAc, pH-7) by the replacing the ammonium in the exchange complex by 1N KCl solution and the result recorded by flame photometric method [24]. The total Nitrogen of the soil was determined by Micro-Kjeldahl's method following H_2SO_4 acid digestion as suggested by Jackson [25]. Available Ca^{2+} and Mg^{2+} was extracted with 1 N NH_4OAc solution (pH 7.0) as described by Piper [26] and Jackson [27] and measured by atomic adsorption spectrophotometer. Sodium (Na^+) content in soil samples was determined separately by Flame emission spectrophotometer (Model: Jenway, PEP-7) using Sodium filter, as outlined by Jackson [27]. Sodium adsorption ratio was calculated by the equation: $SAR = [Na^+]/[Ca^{2+} + Mg^{2+}]^{1/2}$ [28].

Statistical analysis

The ANOVA and Duncan Multiple Range Test (DMRT) were done for completely randomized design by using the SAS 6.12 software package [29].

3. Results and Discussions

This experiment was to investigate the effect of cow dung, rice husks, calcium chloride and gypsum on soil reclamation and compare the effect of organic and inorganic amendments on soil reclamation. The results pertaining to the investigations are presented in this chapter.

Effect of different soil amendments on electrical conductivity (EC) in soil

The electrical conductivity measured for soils of different soil amendments varied significantly ($P < 0.05$) and also with the reference soil and the Electrical Conductivity (EC) measured for the soils varied from 5.14 to 8.30 $dS \cdot m^{-1}$ as presented in **Appendix I** and **Figure 1**. The highest EC (7.67 $dS \cdot m^{-1}$) was measured at rice husk treated soil. The magnitude of the differences is at the order of $T_2 > T_5 > T_1 > T_4 > T_3 > T_6$. So, among the treatment's gypsum + $CaCl_2$ treatment significantly ($P < 0.05$) decreased the EC (5.14 $dS \cdot m^{-1}$) of the soil presented the

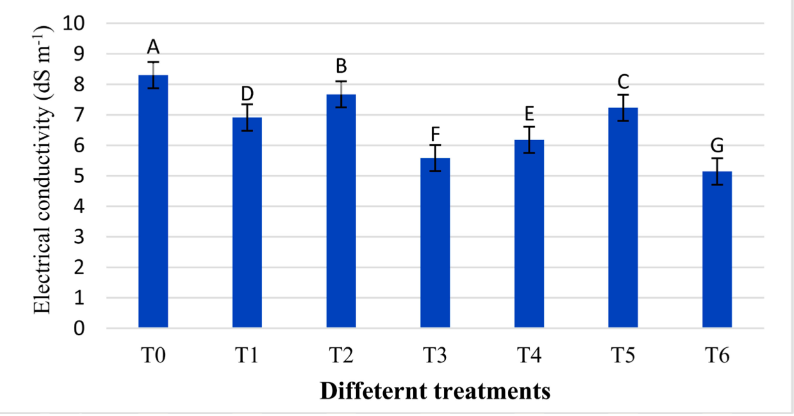

Figure 1. Effects of different soil amendments on Electrical Conductivity (EC) in soil.

in **Figure 1**. $CaCl_2$ proved less effective as compared to gypsum for soil amelioration. Sharma *et al.* [30] reported decrease in EC as a result of gypsum application. Organic amendments (cow dung and rice husk) also decreased EC and the numerical value of rice husk significantly ($P < 0.05$) lower than that of reference soil. The decreasing trend of EC might be due to leaching followed by the addition of organic amendments for releasing organic acids during decomposition, which was responsible for leaching of salts. Rehman *et al.* [31] achieved a substantially decreased EC of saline-sodic soils with the addition of different organic amendments. Decreased EC was the result of organic matter triggered leaching of excessive ions by improving the physical properties of soil.

Effect of different soil amendments on pH in soil

The pH measured for soils of different soil amendments varied significantly ($P < 0.05$) with the reference soil and the pH measured for the soils varied from 8.20 to 8.32 as presented in **Appendix I** and **Figure 2**. The highest pH (8.32) was measured at cow dung treated soil. The magnitude of the differences is at the order of $T_1 > T_5 > T_6 > T_4 > T_2 > T_3$. The pH was found 8.2 for gypsum, 8.226 for rice husk; 8.27 for both $CaCl_2$ and $CaCl_2$ + gypsum; 8.32 for rice husk + cow dung combination and 8.32 for cow dung are presented in the **Figure 2**. Differences between treatments to control were significant ($P < 0.05$). Lowest value recorded for gypsum treated soil. This might be due to water promoted gypsum dissolution, expediting the reclamation reactions and due to improvement of soil [32]. Organic amendments only showed a slight decrease in the pH of 8.326 for cow dung, and 8.226 for rice husk in comparison to the control. This may due to acidifying effect of organic acids produced during the course of decomposition of organic amendments. Guidi and Hall [33] observed that the application of various organic materials decreased the pH values due to organic and inorganic acids formed when organic matter decomposition takes place. There was no significant ($P < 0.05$) difference between cow dung treated soil and cow dung + rice husk treated soil and also between gypsum + $CaCl_2$ treated soil and $CaCl_2$ treated soil; also, between Rice husk treated soil and gypsum treated soil at 5% level of significance.

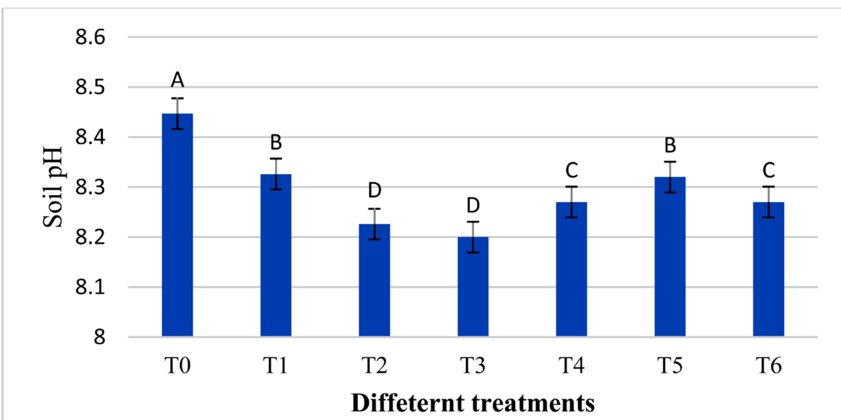

Figure 2. Effects of different soil amendments on pH in soil.

Effect of different soil amendments on sodium adsorption ratio (SAR) in soil

The sodium adsorption ratio (SAR) measured for soils of different soil amendments varied significantly ($P < 0.05$) compared to reference soil and the sodium adsorption ratio measured for the soils varied from 1.01 to 1.45 as presented in **Appendix I** and **Figure 3**. The highest SAR (1.45) was measured at cow dung treated soil. The magnitude of the differences is at the order of $T_1 > T_5 > T_2 > T_6 > T_3 > T_4$. A clear decrease of SAR was observed for amended soils presented in the **Figure 3**. The decrease in SAR due to either increase in divalent cations (Ca^{2+} and Mg^{2+}), or decrease in monovalent cation (Na^+). The measured values of cations indicated that Na^+ decreased while Ca^{2+} increased in the exchangeable complex after the application of organic and inorganic amendments followed by leaching. The relatively high mobility and leachability of Na^+ from soil due to the applied amendments as compared with Ca^{2+} resulted in lower values of SAR, hence, the SAR values of the treated soil were sharply decreased. Effect of ameliorant and its combinations were significantly different at 5% significant level compare to reference soil. Gypsum only or combination with inorganic amendments proved superior to organic amendments only for treatments in reducing SAR. A decrease in SAR with simple leaching in control was likely due to mineral weathering and leaching out from the soil [34]. Chorom and Rengasamy [35] reported that gypsum applied to the soil was more effective in reducing the SAR than an equivalent amount of $CaCl_2$.

Effect of amendments on cation exchange capacity (CEC) in soil

The Cation Exchange Capacity (CEC) measured for soils of different soil amendments varied significantly ($P < 0.05$) compared to reference soil and the CEC measured for the soils varied from 19.73 to 27.72 Cmolc (+) kg^{-1} as presented in **Appendix I** and **Figure 4**. Among seven treatments except $CaCl_2$, CEC was increased significantly compared to reference soil presented in the **Figure 4**. The CEC was decreased in $CaCl_2$ treated soil (19.73 Cmolc (+) kg^{-1}) compared to reference soil (20.40 Cmolc (+) kg^{-1}). But there was no significant difference between these treatments at 5% level of significance. The highest (27.72 Cmolc (+) kg^{-1}) CEC was observed in gypsum + $CaCl_2$ treated soil. The CEC of Cow dung + Rice husk treated soil was 21.73 Cmolc (+) kg^{-1}. So, there was a

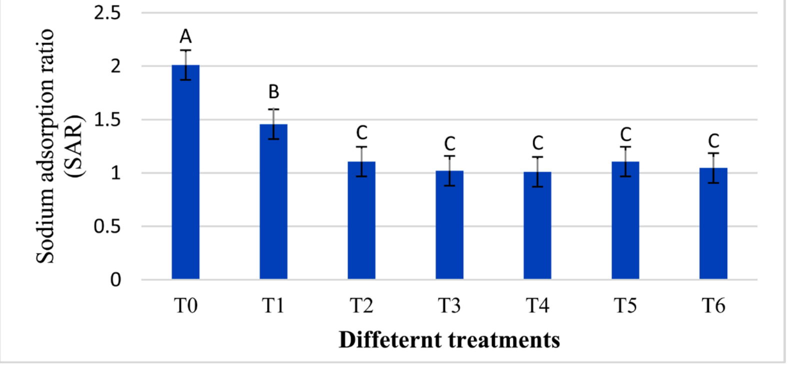

Figure 3. Effects of different soil amendments on sodium adsorption ratio (SAR) in soil.

significant difference between combined applications of organic and inorganic treatment at 5% level of significance. The CEC of rice husk treated soil was 25.05 Cmolc (+) kg^{-1}. There was no significant difference among cow dung treated soil; cow dung + rice husk treated soil and gypsum treated soil at 5% level of significance.

Effect of different soil amendments on organic carbon (%) in soil

The %OC measured for soils of different soil amendments varied significantly ($P < 0.05$) compared to reference soil and the %OC measured for the soils varied from 0.57 to 0.95 as presented in **Appendix I** and **Figure 5**. The effect of amendments on %OC in saline soil were significantly different compared to control as presented in **Figure 5**. The %OC was reduced to 0.57% compared to control 0.78%. The highest %OC was observed in cow dung + rice husk treated soil (0.95%). The %OC of cow dung treated soil and rice husk treated soil 0.89% and 0.87% respectively but there was no significant difference between these treatments at 5% level of significance. The %OC of $CaCl_2$ treated soil and gypsum treated soil were 0.74% and 0.70% respectively and there was significant difference at 5% level of significance. So, the %OC was increased with the application of organic amendments and decreased with the application of inorganic amendments as compared to reference soil.

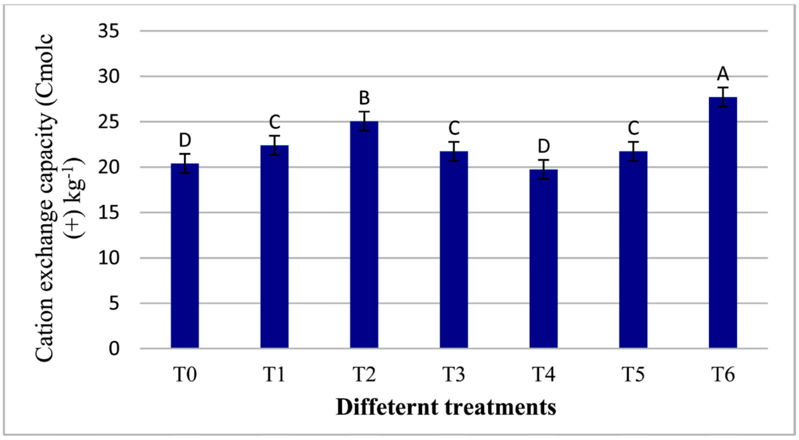

Figure 4. Effects of different soil amendments on cation exchange capacity (CEC) in soil.

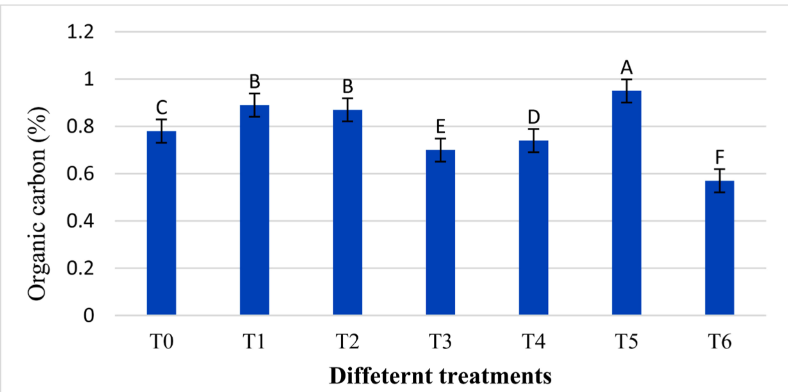

Figure 5. Effects of different soil amendments on organic carbon (%) in soil.

Effect of different soil amendments on organic matter (%) in soil

The %OM measured for soils of different soil amendments varied significantly ($P < 0.05$) compared to reference soil and the %OM measured for the soils varied from 0.98% to 1.63% as presented in **Appendix I** and **Figure 6**. The effect of amendments on %OM in saline soil was significantly different compared to reference soil as presented in **Figure 6**. The %OM was reduced to 0.98% compared to reference soil (1.34%). The highest %OM was observed in cow dung + rice husk treated soil (1.63%). The %OM of cow dung treated soil and rice husk treated soil were 1.53% and 1.49% respectively but there was no significant difference between these treatments at 5% level of significance. The %OM of $CaCl_2$ treated soil and gypsum treated soil were 1.27% and 1.20% respectively and there was significant difference between these treatments at 5% level of significance. So, the %OM was increased with the application of organic amendments and decreased with the application of inorganic amendments as compared to reference soil.

Effect of different soil amendments on nitrogen (%) in soil

The %N measured for soils of different soil amendments varied significantly ($P < 0.05$) compared to reference soil and the %N measured for the soils varied from 0.04% to 0.21% as presented in **Appendix I** and **Figure 7**. The %N was reduced to 0.04% compared to control 0.14%. The highest %N was observed in

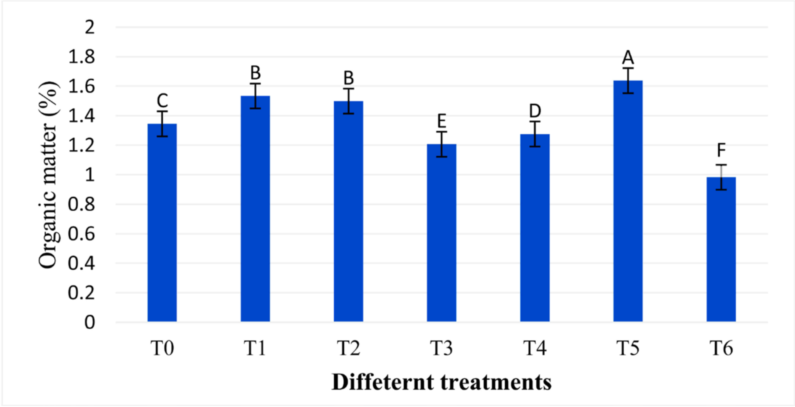

Figure 6. Effects of different soil amendments on organic matter (%) in soil.

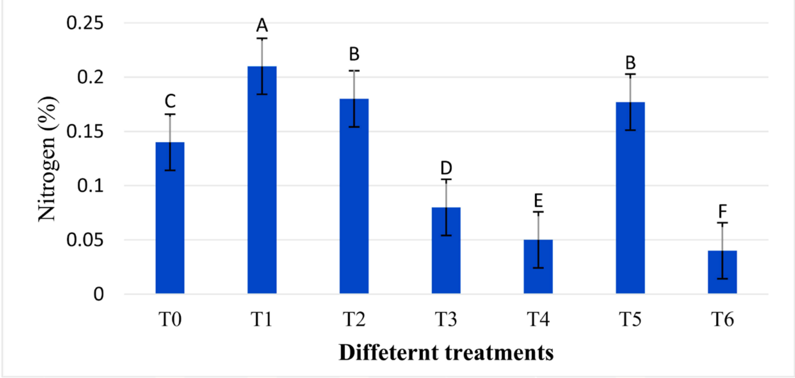

Figure 7. Effects of different soil amendments on nitrogen (%) in soil.

cow dung treated soil (0.21%). The nitrogen (%) of cow dung + rice husk treated soil and rice husk treated soil were 0.17% and 0.18% respectively but there was no significant difference between these treatments at 5% level of significance. The %N of $CaCl_2$ treated soil and gypsum treated soil were 0.05% and 0.08% respectively and there was significant difference at 5% level of significance. So, the %N was increased with the application of organic amendments and decreased with the application of inorganic amendments as compared to reference soil.

Effect of different soil amendments on carbon/nitrogen ratio (C/N) in soil

The effect of amendments on C/N ratio in saline soil were significantly ($P < 0.05$) different compared to reference soil and inorganic treatments presented in **Appendix I** and Figure 8. The C/N ratio were reduced to 4.24 for Cow dung treated soil; reduced to 4.84 for Rice husk treated soil and reduced to 5.38 for cow dung + rice husk treated soil as compared to reference soil (5.59). The highest C/N ratio was observed in gypsum treated soil (14.24) and the C/N ratio of gypsum + $CaCl_2$ treated soil was 13.26 but there was no significant difference between these treatments at 5% level of significance. The C/N ratio of $CaCl_2$ treated soil was 8.84 and there was significant difference among other two inorganic amendments at 5% level of significance. So, the C/N ratio was increased with the application of inorganic amendments and decreased with the application of organic amendments as compared to reference soil.

4. Conclusion

The study revealed that the addition of cow dung, rice husk, gypsum and calcium chloride acted as ameliorants to saline soil. In this study, individual or combined effect of gypsum (T_3) was more effective in changing EC and SAR. Gypsum application in combination with calcium chloride (T_6) improved the soil chemical properties by reducing the EC. Among the treatment, calcium chloride (T_4) had a remarkable effect in reducing sodium adsorption ratio and gypsum had a remarkable effect in reducing pH. Cow dung (T_1), rice husk (T_2), combination of

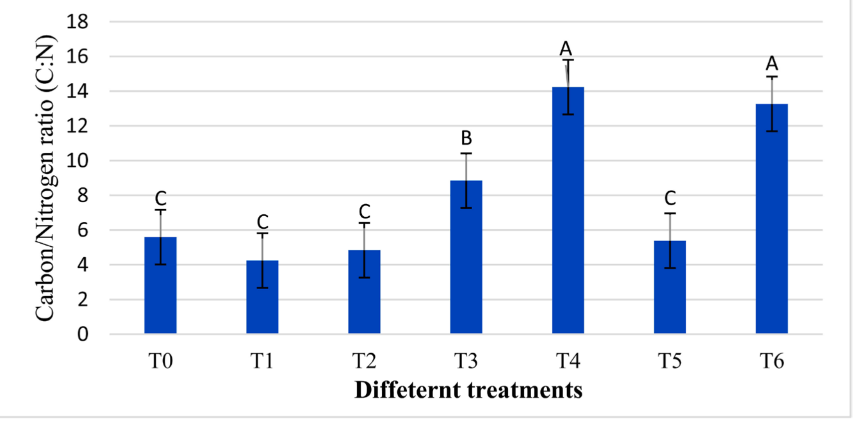

Figure 8. Effects of different soil amendments on Carbon/Nitrogen ratio (C/N) ratio in soil.

cow dung and rice husk (T_5) were less effective to reduce EC, pH and SAR. So, inorganic amendments were superior to organic amendments to reduce salinity. On the other hand, the combined effect of cow dung and rice husk (T_5) was more effective to increase organic carbon and organic matter. Individual effect of cow dung (T_1) and rice husk (T_2) also had remarkable effect in increasing organic carbon and organic matter. Among the treatments, the combined application of gypsum and calcium chloride (T_6) had remarkable effect in reducing organic carbon as well as organic matter. Individual application of gypsum (T_3) and calcium chloride (T_4) also decreased organic carbon and organic matter. Individual effect of cow dung (T_1) had remarkable effect in increasing nitrogen. Rice husk (T_2) also increased the nitrogen percentage slightly. So, organic amendments are superior to inorganic amendments to increase organic carbon, organic matter and nitrogen percentage. Though the inorganic amendments are better than organic to ameliorate soil, the use of organic amendments is sustainable to soil health.

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Conflicts of Interest

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

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Appendix

Appendix I. Mean Value of Soil Parameters after 45 Days of Incubation Compare to Reference Soil

Treatments	EC ($ds \cdot m^{-1}$)	pH	SAR	CEC (Cmolc (+) kg^{-1})	Organic carbon (%)	Organic matter (%)	Total nitrogen (%)	C:N ratio
T_0	8.30a	8.44a	2.01a	20.40d	0.78c	1.34c	0.14c	5.59c
T_1	6.91d	8.32b	1.45b	22.39c	0.89b	1.53b	0.21a	4.24c
T_2	7.67b	8.22d	1.10c	25.05b	0.87b	1.49b	0.18b	4.84c
T_3	5.58f	8.20d	1.02c	21.73c	0.7e	1.20e	0.08d	8.84b
T_4	6.18e	8.27c	1.01c	19.73d	0.74d	1.27d	0.05e	14.24a
T_5	7.23c	8.32b	1.10c	21.73c	0.95a	1.63a	0.177b	5.38c
T_6	5.14g	8.27c	1.04c	27.72a	0.57f	0.98f	0.04f	13.26a