



Management of Saline Soil Using Organic Manure and Gypsum Fertilizer for Growing Sweet Gourd in Coastal Region of Bangladesh

Mohammad Asadul Haque✉

Department of Soil Science, Patuakhali Science and Technology University, Patuakhali 8602, Bangladesh

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Correspondence

Mohammad Asadul Haque

✉: masadulh@yahoo.com



ABSTRACT

Salinity is a major threat for growing cucurbit vegetables in the coastal zone of Bangladesh. A consecutive two year experiment was conducted during Rabi season 2019 and 2020 at Taltali and Amtali upazila, respectively of Barguna district Bangladesh to find out whether organic manure amendment and gypsum fertilizer can reduce salinity related degradation of soil and increase sweet gourd yield in coastal region of Bangladesh. There were six treatments having control (no amendment), gypsum fertilizer, cowdung, poultry manure and the combination of gypsum fertilizer with cowdung and poultry manure. The design of the experiment was randomized complete block design with four replications. Every plot received recommended rate of nitrogen, phosphorus and potash fertilizer. The text crop was sweet gourd. Organic amendment significantly increase fruit yield of sweet gourd in saline soil. The performance of poultry manure was better than cowdung. The poultry manure, and poultry manure plus gypsum fertilizer produced fruit yield of 29.1 and 38.1 t ha⁻¹, which is 67 and 119% higher over control treatment, respectively. The gypsum application had positive effect on fruit yield when it is applied with poultry manure. Application of organic manure increase soil moisture content, and reduce soil pH and electrical conductivity. Organic amendment with poultry manure is therefore recommended for sustainable yield of sweet gourd in saline soil, and reduces salinity related land degradation in coastal region of Bangladesh.

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Introduction

Among the environmental stresses soil salinity is the most devastating (Shahbaz and Ashraf, 2013) which not only limits plant growth and metabolism but also poses a foremost intimidation to sustainable agricultural production (Tayyab *et al.*, 2016). Salt-affected soils are widely distributed throughout the world, and more than 400 million hectares of the total geographical area of the world are affected by high concentration of the soluble salts (Sana *et al.*, 2016). In Bangladesh there are 2.86 million hectares of coastal and offshore lands of which about 1.056 million hectares are affected by varying degrees of salinity (SRDI, 2010). The high concentration of salts reduces the osmotic potential of the soil solution. Salinity produces imbalance in plant nutrients, including deficiencies of several nutrients or excessive levels of Na⁺ (Kaya *et al.*, 2001). Reclaiming these salt-affected soils will require new amelioration methods and improved management practices (Qadir *et al.*, 2000).

Leaching with water, chemical amendment, and phytoremediation are among the methods used to ameliorate saline soils (Qadir *et al.*, 2000). The use of

gypsum, calcite, calcium chloride, and other chemical agents that provide Ca, which tends to replace exchangeable Na, is effective for saline soil amelioration (Hanay *et al.*, 2004). Another important practice is the application of organic manure, which can both ameliorate and increase the fertility of saline soils (Melero *et al.*, 2007).

Salt-affected soils generally exhibit poor structural stability due to low organic matter content. Many researchers have suggested that the structural stability of soil can be improved by the addition of organic materials (e.g. green manures, farmyard and poultry manures, compost, and food processing wastes) (Tejada *et al.*, 2006; Oo *et al.*, 2013). Barzegar *et al.* (1997) found that the application of organic matter to saline soils can accelerate Na⁺ leaching, increase the percentage of water-stable aggregates, and decrease the exchangeable sodium percentage (ESP), electrical conductivity (EC) and soil salinity. Even though there are many studies dealing with organic amendments as degraded soil conditioners, very little is known about their effects on coastal saline soil. In view of the above, two organic materials

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(cowdung and poultry manure) and gypsum fertilizer were applied in this study. Due to salt sensitivity cucurbit vegetable production in the coastal region of Bangladesh is very poor, therefore a large amount of vegetables are imported from other regions of the country.

The aim of the work was to evaluate the effects of different organic amendments on soil salinity and yield of sweet gourd in the coastal region of Bangladesh. The information obtained from this study will help provide guideline on selection of organic matters in ameliorating coastal saline soils.

Materials and Methods

The experiment was conducted in consecutive two years; at Taltali upazila in 2019 and Amtali upazila in 2020 of Barguna district, Barishal division, Bangladesh. The average annual temperature is 25.9°C and the average rainfall is 2647 mm. April–May is susceptible to storm surges. Winter starts on November and ends on February. The winter is short, excessively dry and rainfall less than 75 mm which is lower than the evaporation. Plants enjoy severe drought in the dry (December–May) season, therefore, most of the lands remain fallow due to severe soil salinity.

The experiment was laid out in a single factor randomized complete block design with four replications. There were six amendment treatments having control (no amendment), gypsum fertilizer (56 kg ha⁻¹), cowdung (5 t ha⁻¹), poultry manure (3 t ha⁻¹), and the combination of gypsum fertilizer with cowdung and poultry manure. The test crop was sweet gourd. The whole land was prepared by ploughing followed by laddering three times. For planting of seedlings one meter diameter circle area was further deep ploughed by a spade to make soil powdery structure. Seedlings were raised in polybag. The 10 cm length polybag was filled with soil. One sprouted seed was sown in each polybag. The seedlings in the polybag were watered whenever necessary. Twenty day old healthy seedlings were used for transplanting. Seedlings were transplanted on 20 December 2018 at Taltali upazila and 21 December 2019 at Amtali upazila, respectively. Plant spacing was 2 m × 2 m. Granular insecticide (Furadan 5 g) was given in the field during final land preparation to control soil born insects.

Experimental field was fertilized with a blanket dose of N, P and K @ 70, 35 and 50 kg ha⁻¹, respectively. The source of N, P and K were urea, triple super phosphate (TSP) and muriate of potash (MoP), respectively. In all the experimental plots TSP and MoP, and treatment wise gypsum, cowdung and poultry manure were applied during final land preparation. Urea was applied in three

equal splits at 10, 25 and 45 days after transplanting. Same amount of irrigation water was given in each plant so that all the plants enjoy same environment. An amount of 1000 mL irrigation water twice in a week was given in root zone area of each plant. In the coastal region farmers generally harvest rain water in the pond during monsoon. In the experiment irrigation was made using this pond water.

Soil temperature was measured using celcius thermometer from 2 to 4 cm soil depth on 06 March 2019 at 1.00 pm and 17 March 2020 at 12.00 pm. To determine the treatment effect on soil properties the soil samples were collected in the same date from the root zone of the plant (within 50 cm radius) and analyzed for determination of pH in 1:2.5 soil water suspension (Jackson, 1968), electrical conductivity in 1:5 soil water suspension (Petersen and Shireen, 2001), and gravimetric soil moisture content. To measure soil moisture content by the gravimetric method a subsample of a fresh sieved composite sample or a fresh soil core is weighed, oven dried there is no further mass lose, and then re-weighed. The moisture content is expressed as mass of water per mass of dry soil (Reynolds, 1970). The equation was as follows:

$$MC (\%) = \frac{\text{Wt. of moist soil} - \text{Wt. of dry soil}}{\text{Wt. of dry soil}} \times 100$$

Where, MC = Gravimetric soil moisture content.

In addition, a central position of the experimental field was selected from where soil samples were collected periodically with 15 days interval. The periodic soil samples were analysed for electrical conductivity (1:5 soil water suspension) and gravimetric soil moisture content of soil. The sweet gourd fruits were harvest on maturity at 01 April 2019 in first year and 05 April 2020 in second year. The yield data were expressed as fresh weight basis. The chemical analysis of soil samples was done in the laboratory of the Department of Soil Science, Patuakhali Science and Technology University, Bangladesh. Data recorded on soil and crop characters were subjected to statistical analysis through computer based statistical program STAR (Statistical Tool for Agricultural Research) following basic principles as outlined by Gomez and Gomez, 1984).

Results and Discussion

Initial soil physico-chemical properties

Experimental field was a medium high land under the AEZ 13, Ganges Tidal Flood Plain Soil. Texturally Taltali upazila soil was silty clay loam having 32% clay, 65% silt and only 3% sand. The initial soil had 4.78 pH, 0.95 dS m⁻¹ electrical conductivity (EC_{1:5}), 0.075% total N, 4.25

ppm available P and 141.4 ppm available S contents. Regarding Amtali upazila texturally soil was again silty clay loam having 38% clay, 60% silt and only 2% sand. The initial soil had 4.54 pH, 0.71 dSm⁻¹ EC_{1:5}, 0.050% total N, 2.83 ppm available P and 157.1 ppm available S contents.

Growth parameters

Stem length was significantly influenced by organic manures and gypsum treatments. Lowest of 3.87m stem length was found in control treatment which was statistically similar and very closer to gypsum treatment. Highest of 4.67m stem length was found in cowdung plus gypsum treatment that was statistically similar with poultry manure plus gypsum treatment. The sole cowdung and sole poultry manure treatment produced statistically similar and very closer stem length of 4.25 and 4.26m, respectively.

The number of leaves per primary stem was also significantly influenced by different treatments. The cowdung plus gypsum treatment had highest of 36.3 leaves per stem which was at par with poultry manure plus gypsum treatment (36.0). The single cowdung and poultry manure treatments had 33 and 32 leaves per primary stem, respectively. The control treatment and sole gypsum treatment had statistically similar number of leaves per primary stem.

The number of branches per plant was significantly influenced by different treatments, and significantly highest branching was found in poultry manure plus gypsum treatment. The both sole cowdung and cowdung plus gypsum treatments had 4.8 branching which indicates that addition of gypsum fertilizer with cowdung had no positive effect on this parameter. However, addition of gypsum with poultry manure had positive effect to produce the number of branches per plant. If we consider the sole effect of gypsum to produce number of branching per plant it was found that addition of gypsum had no positive effect compared to control treatment. The positive effect of organic manure amendments was also described by some other scientists. For example, Wang *et al.* (2014) reported that compared to a non-amended control (CK), the amendments, which were applied at 4.5 kg organic matter m⁻³, dramatically promoted plant growth; improved soil structure; increased the organic carbon, and available nutrients; and reduced the salt content. Andrade *et al.* (2018) reported that elemental sulphur applied @ 1.39 t ha⁻¹ promoted the best growth of sorghum.

Fruit yield

Fruit yield of sweet gourd was significantly influenced by different manures and gypsum treatments both in 2019 and 2020, and their pooled yield. In 2019, fruit yield

ranged from 19.4 to 41.6 t ha⁻¹ over the treatments. The lowest fruit yield was observed in control treatment. If gypsum fertilizer is added to the soil fruit yield increased to 21.3 t ha⁻¹, this yield was statistically similar with the yield of cowdung treatment (21.6 t ha⁻¹). When gypsum fertilizer was added with cowdung the fruit yield increased to 26.6 t ha⁻¹, in 2019. The poultry manure treatment gave fruit yield of 28.3 t ha⁻¹, and poultry manure plus gypsum treatment recorded highest of 41.6 t ha⁻¹ fruit yield.

In 2020, the fruit yield varied from 15.5 to 34.5 t ha⁻¹ over the treatments. The control treatment obviously produced the lowest yield of 15.5 t ha⁻¹. The gypsum treatment produced only 16.5 t ha⁻¹ fruit which is statistically similar with control treatment. All the organic manure treatments had significantly higher fruit yield over control. In 2020, the cowdung, and cowdung plus gypsum treatments produced fruit yield of 23.6 and 23.1 t ha⁻¹, respectively and both are statistically similar. The results indicated that the gypsum treatment had no additional benefit when applied with cowdung. However, gypsum application had a positive effect when it applied with poultry manure; as the poultry manure, and poultry manure plus gypsum treatment produced fruit yield of 29.9 and 34.5 t ha⁻¹, respectively.

The mean value of two year (2019 and 2020) fruit yield data were calculated and presented in Table 2. The mean fruit yield of sweet gourd was varied from 17.4 t ha⁻¹ in control treatments to 38.1 t ha⁻¹ in poultry manure plus gypsum treatments. The sole gypsum treatments had no significant effect on fruit yield as it was statistically at par with control treatment. All the manure treatments had significant effect on fruit yield. The cowdung treatment, and cowdung plus gypsum treatment had statistically similar fruit yield of 22.6 and 24.9 t ha⁻¹, respectively. Both these treatments had 30 and 43% higher yield over control treatment. The poultry manure, and poultry manure plus gypsum treatment produced mean fruit yield of 29.1 and 38.1 t ha⁻¹, which is 67 and 119% higher over control treatment, respectively. Based on the grain yield it is consistently showed that the gypsum application had positive effect on fruit yield when it is applied with poultry manure. Among the manures poultry manures had outstanding performance.

Walker and Bernal (2008) described the mechanism by which organic amendment helps to improve crop yield in salt affected soils. The application of poultry manure and compost to soil can increase both the CEC and the soluble and exchangeable-K⁺, which is a competitor of Na⁺ under saline-sodic conditions, thus, limiting the entry of Na⁺ into the exchange complex. Dutta *et al.* (2015) reported that organic amendments (poultry manure, cowdung and green manure) helped to

ameliorate salinity stress compared to those without organic amendments in rice. Ahmed *et al.* (2016) showed that varying levels of sulfur and gypsum significantly improved soil properties and rice-wheat yield than control.

Economic analysis

The economic analysis was done to find out the marginal benefit-cost ratio (MBCR) against different manure and fertilizer treatments. The summary result is shown in Table 3. Marginal benefit-cost ratio (MBCR) is the ratio of marginal or added benefits and costs. To compare different treatments with control treatment the following formula was used.

$$\text{MBCR (over control)} = \frac{\text{Gross return (T}_i\text{)} - \text{Gross return (T}_1\text{)}}{\text{VC (T}_i\text{)} - \text{VC (T}_1\text{)}} \\ = \frac{\text{Added benefit (over control)}}{\text{Added cost (over control)}}$$

Where, $T_i = T_2, T_3, \dots, T_6$ treatments, $T_1 =$ control treatment; VC = Variable cost (manure and fertilizer costs); Gross return = Yield \times price.

The economic analysis was done using two year mean fruit yield data. The cowdung and poultry manure used in the experiment was collected from the farmer's own farm; therefore, there were no expenditure on input purpose. But for calculation of input price, market price of the manures was used. The benefit cost ratio (BCR) ranged from 81 to 340. The highest BCR (340) was obtained from gypsum fertilizer treatment; which was due to use of very lower amount of gypsum fertilizer compare to manures. Second highest BCR (107) was obtained from poultry manure plus gypsum treatments. The marginal benefit cost ratio (MBCR) was varied from 20-58. The highest MBCR (58) was found in poultry manure plus gypsum treatment. The second highest MBCR (38) was achieved in sole poultry manure treatments. The cowdung, cowdung plus gypsum and sole gypsum treatment had comparable MBCR of 20, 24 and 27, respectively. The experiment was conducted in coastal saline soils of Bangladesh. In saline soils without any management practice crop production is very difficult. In the experiment application of poultry manure in the soils probably creates favorable soil environment for which yield was very high, and concomitantly MBCR was highest in poultry manure receiving treatments.

Soil moisture content

In the experiment gravimetric soil moisture content was determined both in 2019 and 2020. In 2019, control treatment and gypsum fertilizer treatment had identical soil moisture content of 10.6%. The cowdung plus gypsum fertilizer treatment had highest of 14.6%

moisture content which in sole cowdung treatment was 12.3%. The sole poultry manure and poultry manure plus gypsum treatments had 11.6 and 11.1% gravimetric soil moisture content, respectively. The results clearly evidenced that cowdung had better performance to preserve soil moisture content. In 2020, similar trend was observed where control and gypsum fertilizer treatments had identical soil moisture content (10.3%).

Organic manures increased soil moisture content. Among cowdung and poultry manure the cowdung had better performance than poultry manure. The better performance of cowdung was probably due to use of higher rates (5 t ha^{-1}) than poultry manure (3 t ha^{-1}). Due to higher moisture content in organic amended soil, there is ample scope to dilute salinity in the soil. Oo *et al.* (2013) reported that combinations of organic amendments resulted in substantial flocculation and in the formation of a large number of soil aggregates. As a consequence of aggregate stability, soil porosity, water infiltration, and water-holding capacity of soil are improved, thus minimizing the impact of drought.

Soil temperature was significantly influenced by the treatments in 2020 but not in 2019. Over the treatments soil temperature varied from 35 to 37°C in 2019 and 29.2 to 30.5°C in 2020. Generally application of manures and gypsum fertilizer was found to be increase soil temperature to some extent.

Soil pH

Soil pH is the measure of the extent of acidity of soil. Generally pH value closer to 7.0 is the best for nutrient availability and better soil health, and better crop yield. In the experiment control treatments had pH value of 4.95. The gypsum fertilizer treatment had pH value of 4.94 which had a tendency to make the soil more acidic in nature. All the organic manure treatments significantly increased the pH of soil. Among the manures poultry manure (5.45) had higher pH than cowdung (5.27). When gypsum fertilizer is added then pH value is reduced to their sole application. The results indicate that in coastal region application of gypsum fertilizer reduced pH value and increase acidity of soil. Application of cowdung (5 t ha^{-1}) and poultry manure (3 t ha^{-1}) increased soil pH by 6.5 and 10.1% over control; however, the increment was insignificant. The insignificant effect of gypsum on soil pH is also described by Stamford *et al.* (2015). Ahmed *et al.* (2016) and Andrade *et al.* (2018) reported that increasing sulphur levels promoted reduction in soil pH and electrical conductivity of the saturation extract of soil. Gypsum, when slowly mixed with water, releases calcium ions, which replace sodium ions from the soil into the downward moving water (Machado and Serralheiro, 2017).

Table 1. Growth parameters of sweet gourd as influenced by different manure and gypsum treatments at coastal saline soil of Bangladesh

Treatments	Stem length (m)	No. of leaves primary stem ⁻¹	No. of branches plant ⁻¹
T ₁ : Control	3.87 b	27.5 c	3.7 b
T ₂ : Gypsum	3.88 b	28.5 bc	3.8 ab
T ₃ : Cowdung	4.25 ab	33.0 ab	4.8 ab
T ₄ : Poultry manure	4.26 ab	32.0 abc	4.5 ab
T ₅ : Cowdung + Gypsum	4.67 a	36.3 a	4.8 ab
T ₆ : Poultry manure + Gypsum	4.50 ab	36.0 a	5.3 a
% CV	7.14	7.37	15.64
Pr (> F)	0.0105	0.0003	0.0467

Similar letters in a column are not significantly different at 5% level by DMRT

Table 2. Fruit yield of sweet gourd as influenced by different manure and fertilizer treatments at coastal saline soil of Bangladesh

Treatment	Fruit yield of sweet gourd (t ha ⁻¹)		
	2019	2020	Mean
T ₁ : Control	19.4 d	15.5 c	17.4 e
T ₂ : Gypsum	21.3 cd	16.5 c	18.9 de
T ₃ : Cowdung	21.6 cd	23.6 b	22.6 cd
T ₄ : Poultry manure	28.3 b	29.9 a	29.1 b
T ₅ : Cowdung + Gypsum	26.6 bc	23.1 b	24.9 c
T ₆ : Poultry manure + Gypsum	41.6 a	34.5 a	38.1 a
% CV	8.89	9.21	6.66
Pr (> F)	0.0000	0.0000	0.0000

Similar letters in a column are not significantly different at 5% level by DMRT

Table 3. Economic analysis for different manure and fertilizer treatments for growing sweet gourd in coastal saline soil of Bangladesh

Treatments	Gross return	Added benefit	Added cost	BCR	MBCR
T ₁ : Control	4154				
T ₂ : Gypsum	4502	348	13	346	27
T ₃ : Cowdung	5377	1223	60	90	20
T ₄ : Poultry manure	6921	2767	72	96	38
T ₅ : Cowdung + Gypsum	5920	1766	73	81	24
T ₆ : Poultry manure + Gypsum	9068	4914	85	107	58

Values generated through calculation therefore, statistical analysis was not performed; Price: Sweet gourd- 238.1 US dollar t⁻¹, CD- 11.9 US dollar t⁻¹, PIM-23.8 US dollar t⁻¹, Gypsum-238.1 US dollar t⁻¹

Table 4. Soil moisture content and soil temperature of snake gourd field as influenced by different manure and fertilizer treatments at coastal saline soils of Bangladesh

Treatments	Soil moisture content (%)		Soil temperature (°C)	
	2019	2020	2019	2020
T ₁ : Control	10.6 b	10.3 b	35.0	29.2 b
T ₂ : Gypsum	10.6 b	10.3 b	35.5	30.2 ab
T ₃ : Cowdung	12.3 b	12.3 ab	36.5	29.5 ab
T ₄ : Poultry manure	11.6 b	10.8 b	37.0	30.3 ab
T ₅ : Cowdung + Gypsum	14.6 a	13.6 a	35.8	29.5 ab
T ₆ : Poultry manure + Gypsum	11.1 b	12.2 ab	36.0	30.5 a
% CV	7.44	7.51	2.90	2.02
Pr (> F)	0.0001	0.0004	0.1578	0.0473

Similar letters in a column are not significantly different at 5% level by DMRT

Table 5. Soil pH and EC_{1:5} of snake gourd field as influenced by different manure and fertilizer treatments at coastal saline soil of Bangladesh in 2020

Treatments	Soil pH	Soil EC _{1:5} (dS m ⁻¹)
T ₁ : Control	4.95	1.79 a
T ₂ : Gypsum	4.94	1.78 a
T ₃ : Cowdung	5.27	1.35 b
T ₄ : Poultry manure	5.45	1.42 ab
T ₅ : Cowdung + Gypsum	4.97	1.37 b
T ₆ : Poultry manure + Gypsum	5.30	1.41 ab
% CV	6.08	11.59
Pr (> F)	0.1397	0.0041

Similar letters in a column are not significantly different at 5% level by DMRT

Electrical conductivity of soil

Electrical conductivity (EC) of soil indicates the extent of salinity in soil. Higher the EC value indicates the higher salinity of soil and lower crop growth. In the experiment EC value was determined in 1:5 soil water suspension. The salinity threshold (E_c) of the majority of vegetable crops is low (ranging from 1 to 2.5 dS m⁻¹ in saturated soil extracts). Generally, the EC of saturated soil extract is at least five times than determined in 1:5 soil water suspension. In the experiment periodic soil samples were collected from a central point of the study experiment and analysed for determination of electrical conductivity in 1:5 soil water suspension and gravimetric soil moisture content. The results are presented in Figure 1. There was found a big range of EC_{1:5} of soil having 0.29 to 2.38 dS/m over the study period. The EC_{1:5} value found only 0.29 dS/m in 1st December and it progressively increased with the passes of time. February to April the soil was strongly affected by salinity then it further declined with the onset of monsoon rain. Due to very high level of soil salinity in February to April most of the farmers keep their land fallow in rabi season at coastal region of Bangladesh. Regarding soil moisture content March to April the soil was found extremely dry (Fig. 1). The effects of different treatments on EC_{1:5} of soil was significant. Over the treatments highest EC_{1:5} of 1.79 was found in control treatment.

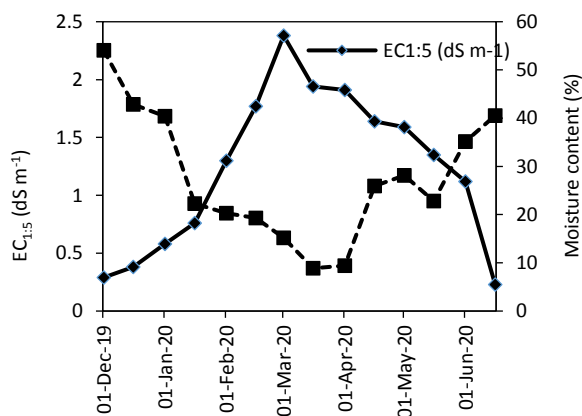


Figure 1. Temporal variability of soil electrical conductivity (EC_{1:5}) and soil moisture content (%) in the study field

The application of gypsum fertilizer very slightly reduced the EC_{1:5} to 1.78 dS m⁻¹ (Table 5). Application of cowdung and poultry manure significantly reduced the EC_{1:5} of soil. In poultry manure and poultry manure plus gypsum fertilizer treatment the EC_{1:5} was 1.42 and 1.41 dS m⁻¹, respectively. Similarly, EC_{1:5} in cowdung and cowdung plus gypsum treatments were 1.35 and 1.37 dS m⁻¹, respectively. The sole application of cowdung and poultry manure reduced EC_{1:5} of soil by 24.6 and 20.7%, respectively compared to control treatment. The positive effect of manure amendment on EC of soil was also described by some other researchers; for example, Khatun *et al.* (2019) reported that organic amendment with cowdung significantly reduce the soil EC (from 10.6 dS/m to 3.4 dS/m) in maize. Wang *et al.* (2014) found that a mixture of organic wastes decreased EC of soil by 87%. Ahmed *et al.* (2016) reported that gypsum appreciably lowered the E_c by 44.09%. Abdelhamid *et al.* (2013) reported that values of soil EC and pH was reduced by about 10.3%, 3.2%; comparing S treated plot relative to the control plot.

Conclusion

Soil salinity is the most devastating among all the environmental stresses. Without any management practice there is little scope to produce vegetable crops in saline soils, especially in the coastal salt affected soils of Bangladesh. Amendment of saline soil with cowdung and poultry manure was found very promising as they reduce salinity of soil and increase crop yield. Among the manures poultry manure was better than cowdung. Gypsum fertilizer application along with poultry manure also had a positive effect on sweet gourd yield in saline soils of Bangladesh.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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