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Effects of Different Reclaimed Saline Soil on the Growth and Yield Response of Water Spinach (*Ipomoea aquatica*)

Sudipta Mandal[1], Md. Zulfikar Khan[1, 3, *], Sharmin Sultana[1], Sushmita Dey[1], Sushmita Mondal[1], Shaikh Motasim Billah[1], Rameswer Mondal[2]

[1]Soil, Water and Environment Discipline, Khulna University, Khulna, Bangladesh
[2]Department of Soil, Water and Environment, University of Dhaka, Dhaka, Bangladesh
[3]Instituto Superior de Agronomia, University of Lisbon, Lisbon, Portugal

Email address

zulfikar.ku11@gmail.com (Md. Z. Khan)

[*]Corresponding author

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Abstract: A pot experiment was conducted to investigate the Effect of different reclaimed saline soil on the growth and yield response of water spinach (*Ipomoea aquatica*) during the period of 22th May to 23th June, 2017. Soil samples were collected at a depth of 0-15cm from a square area of $1km^2$ from Harikhali, under Bagerhat district in Bangladesh. The location of sampling area was 22°40.542′N and 89°31.406′E. Soils mainly dark calcareous. Textural class is Clay loam and Physiography of the soil is Ganges tidal floodplain. The experiment was laid to fit a completely randomized design (CRD) with seven treatments T_0 (Reference soil); T_1 (Cow dung); T_2 (Rice hulls); T_3 (Gypsum); T_4 ($CaCl_2$); T_5 (Rice hulls + Cow dung) and T_6 (Gypsum + $CaCl_2$). After plant harvesting, the laboratory investigation was carried out in the Soil, Water and Environment Discipline, Khulna University, Khulna, Bangladesh. Yield contributing characters like number of leaves, fresh weight and dry weight were significantly ($P<0.05$) influenced by different treatments. The study revealed that addition of cow dung, rice husk, gypsum and calcium chloride acted as ameliorant to saline soils and effective in increasing number of leaves per plant, root length per plant (cm), shoot length per plant (cm), fresh weight per plant (gm) and dry weight per plant (gm) compared to reference soil.

Keywords: Effects, Reclaimed Saline Soil, Growth, Yield Response, Moisture Content, *Ipomoea aquatic*

1. Introduction

Salinity is one of the major environmental factors that leads to a deterioration of agricultural land and reduction in crop productivity worldwide [1, 2]. It is estimated that about one-third of the world's cultivated land is affected by salinity [3]. The National Academy of Sciences of the USA includes salinization of soils and waters as one of the leading processes contributing to a possible worldwide catastrophe [4]. The increasing world population, especially in arid and semi-arid regions, food shortages, and land scarcity are compelling the use of lands not utilized because of salinity and other soil stresses. Salinity and sodicity problems are characterized by an excess of inorganic salts and are common in the arid and semi-arid lands (ASAL) where they have been naturally formed under the prevailing climatic conditions and due to the high rates of evapotranspiration and lack of leaching water [5].

The ability of vegetation to survive under higher salinity conditions is important for the distribution of plants and agriculture around the world. Enhancing the salt tolerance of plants is an important breeding objective in areas, which are affected by soil salinity [6]. A plant's ability to acclimate to salt stress includes alterations at the leaf level, associated with morphological, physiological and biochemical characteristics whereby many plants adjust to high salinity and the consequent low soil water availability [1, 7].

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) [8]. Though the amelioration of saline soils with chemical amendments is an established technology [9], 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 [10]. Organic manures not only increase soil fertility, but enhance soil chemical and physical properties [11]. 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 [12].

Water spinach (*Ipomoea aquatica*), a leafy vegetable is commonly known as Kalmi shak, is widely cultivated in Bangladesh and meets the nourishment here, especially in the rural areas. The plant has creeping, hollow, water-filled stems and shiny green leaves, and large purple or white 2-5cm long funnel-shaped flowers. Therefore, the main objective of this research was to observe the effect of different reclaimed saline soil on the growth and yield response of water spinach (*Ipomoea aquatica).*

2. Materials and Methods

A study was conducted to observe the growth and yield of water spinach (*Ipomoea aquatica*) on different reclaimed saline soils. The purpose of this chapter is to summarize the information about the soils, analytical methods and statistical analysis used in the experiment.

2.1. Collection and Preparation of Soil Samples

Soil samples were collected at a depth of 0-15cm from a square area of 1km^2 from Harikhali, under Bagerhat district. The location of sampling area was 22°40.542′N and 89°31.406′E. They have dark calcareous. Textural class is Clay loam and Physiography of the soil is Ganges tidal floodplain. Then samples 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 2mm sieve. The sieved soils were preserved in plastic bag for pot experiment.

2.2. Experimental Design and Treatments

The experiment was laid to fit a completely randomized design (CRD) [13] with six treatments, each having three replications (Table 1). Three (3) kg supplied soil sample was used in each earthen pot (15.5cm × 9.5cm) for this experiment. Composition of reference and different reclaimed soils used in the experiment shows in the table 2.

Table 1. *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

Table 2. *Composition of reference and different reclaimed soils used in the experiment [14].*

Treatments	EC (ds\m)	pH	SAR	CEC {cmol (+) kg^{-1}}	%OC	%OM	%N	C\N
T_0	8.3	8.44	2.01	20.40	0.78	1.34	0.14	5.59
T_1	6.91	8.32	1.45	22.39	0.89	1.53	0.21	4.24
T_2	7.67	8.22	1.10	25.05	0.87	1.49	0.18	4.84
T_3	5.58	8.20	1.02	21.73	0.7	1.20	0.08	8.84
T_4	6.18	8.27	1.01	19.73	0.74	1.27	0.05	14.24
T_5	7.23	8.32	1.10	21.73	0.95	1.63	0.17	5.38
T_6	5.14	8.27	1.04	27.72	0.57	0.98	0.04	13.26

2.3. Test Crops Used in the Experiment

The effect of salinity in the environment and its impact on the growth and yield of a selected leafy vegetable Kalmi Shak/water spinach *(Ipomoea aquatica)* was used as the test crop for the experiment. This particular variety has gained popularity among the farmers of the study area for their high yielding potential and can be grown throughout the year and harvested in a short time (one month).

2.4. Sowing of Seeds

The seeds were sown on 22th May, 2017. The seeds were sown thoroughly as it was possible to keep uniformity and then the seeds were covered by soils. After germination on the sixth day five plants/pot were maintained for the experiment until harvest.

2.5. General Observations

The pots under experiment were frequently observed to note any change in the crop growth and other characteristics. The crop growth was very luxuriant in some treatments and lower in some treatments.

2.6. Collection of Plant Samples

The plants were uprooted after 31 days (23th June, 2017) of germination and the whole plants were washed with distilled water. The parts of the plants were separated by using a scissor to cut larger parts of the plant in to smaller size. The samples were kept in paper bags and date, location of the sampling, treatment number was written on the paper bags. Plants of the same treatment of three replicated pots were kept in separate packets. Plant samples were processed for laboratory analysis as per standard methods.

2.7. Preparation of Plant Samples

The Paper bags were put in an oven at 65°C for 48 hours until a constant dry weight was obtained. After completion of the drying the dry weight was measured.

2.8. Data Collection of Different Attributes of the Test Crops

Different growth and yield parameters were recorded and their mean values were calculated from the sample plants during experiment. The number of leaves of five plants of each pot was counted and average value was considered. Root length per plant of each pot was measured with the help of scale and average value was considered. Shoot length per plant of each pot was measured with the help of scale and average value was considered. At harvest of five plants from each pot, fresh weight of whole plant was taken by an electrical balance and their mean value was calculated as fresh weight expressed in gm/plant.

2.9. Dry Weight Per Plant (g/Plant)

Five plants of each pot were collected and oven dried at 65°C for 48 hours, weighed in gm/plant by an electrical balance and average value was recorded.

2.10. Moisture Content (%)

Percent moisture content was calculated by using the formula:

$$\text{Moisture content (\%)} = \frac{\text{Wf} - \text{Wo}}{\text{Wf}} \times 100$$

Where, Wf = Fresh weight of the plant sample.

Wo = Oven dry weight of the plant sample.

Analysis of variance (ANOVA) was calculated by using Minitab (17.0) to observe the growth and yield of water spinach (*Ipomoea aquatica*) on different reclaimed saline soils and graphs were drawn by using Microsoft Excel 10.0.

3. Results and Discussion

The results of the study, Effect of different reclaimed saline soil on the growth and yield response of water spinach (*Ipomoea aquatica)* are presented and possible interpretations are made in this chapter.

3.1. Effect of Different Reclaimed Saline Soils on the Number of Leaves Per Plant

Effect of different reclaimed saline soils on the number of leaves per plant is presented in Figure 1. The result confirmed that the number of leaves per plant changes between 8.20 to 13.87 (Appendices). The highest number of leaves per plant (13.87) was observed for treatment T_5 (Cow dung + Rice husk treated soil) and the lowest number of leaves per plant (8.2) was recorded for reference soil (T_0).

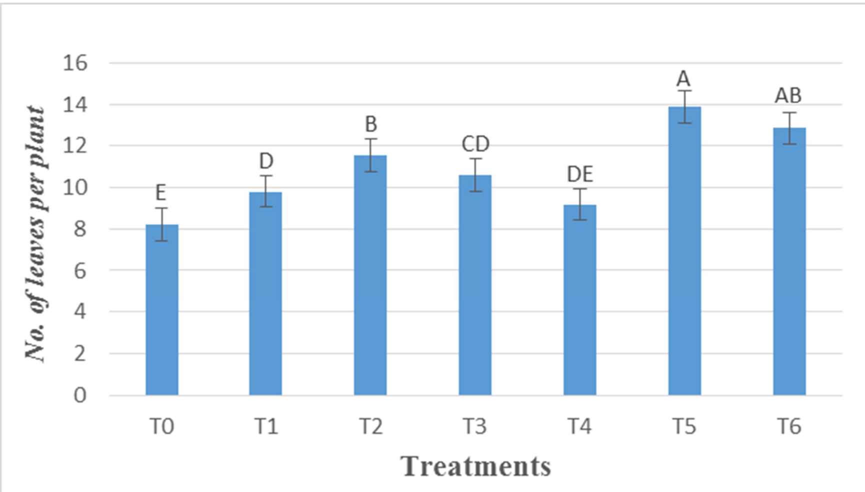

Figure 1. *Effect of different reclaimed saline soils on the number of leaves per plant. Different letters on bars indicate the significant difference (p<0.05). Error bars represent the standard error.*

From the statistical point of view the significant difference was observed between treatments and reference soil but insignificant difference was observed between treatment T_5 and T_6, treatment T_6 and T_2, treatment T_1 and T_3, treatment T_1 and T_4 and treatment T_4 and reference soil (T_0) (Figure 1). Because of having higher amount of EC (8.3dS/m) value, the reference soil contains lower number of leaves. Salinity lowers the total photosynthetic capacity of the plant through decreased leaf growth and inhibited photosynthesis, limiting its ability to grow [15]. The number of leaves is significantly varied between treatments and reference soil at 5% level of significance Visual symptoms of salt injury in plant growth appear progressively.

The first signs of salt stress are wilting, yellowed leaves, and stunted growth. In a second phase the damage manifests as chlorosis of green parts, leaf tip burning, and necrosis of leaves, and the oldest leaves display scorching [16].

3.2. Effect of Different Reclaimed Saline Soils on the Root Length Per Plant

Effect of different reclaimed saline soils on the root length per plant is presented in (Figure 2). The result ascertained that the root length per plant changes between 5.98cm to 6.99cm (Appendices). Treatment T_6 (gypsum + $CaCl_2$ treated soil) contains higher amount of root length per plant (cm) among six treatments because the supplemental Ca alleviates the inhibitory effect of salt on root growth. Individual application of gypsum had a remarkable effect in increasing root length. Combined effect of cow dung and rice husk (treatment T_5) was more effective to increase root length. The root growth of reference soil was poor because of salinity.

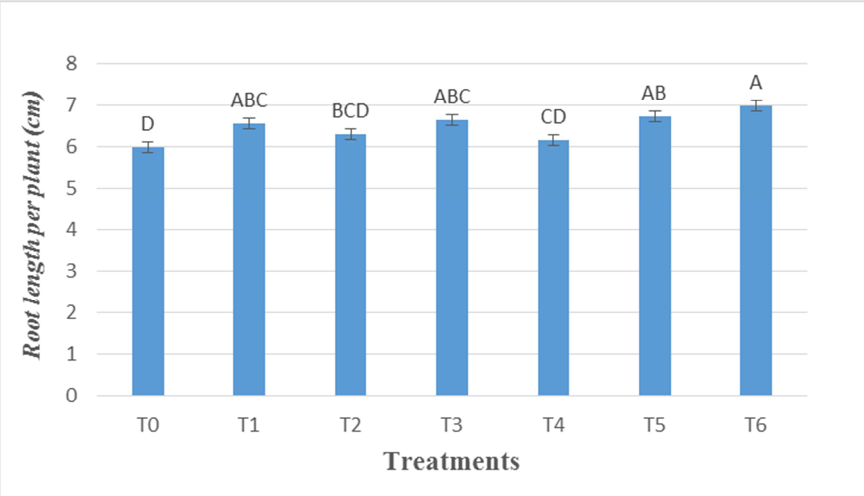

Figure 2. *Effect of different reclaimed saline soils on the root length per plant. Different letters on bars indicate the significant difference (p<0.05). Error bars represent the standard error.*

From the above graph, the significant difference was observed between treatments and reference soil (Figure 2). Treatment T_1 and T_3 values were similar and it is significantly varied with reference soil (T_0) but insignificant difference was observed between treatment T_1 and T_3 (Figure 2). Insignificant difference was observed between treatments T_2 and T_4 with compare to reference soil (T_0). The reduction in seedling and root development may be due to toxic effects of the NaCl used as well as unbalanced nutrient uptake by the seedlings. The ability of the root system to control entry of ions to the shoot is of crucial importance to plant survival in the presence of NaCl [17]. In addition, high salinity may inhibit seedling and root elongation by slowing down the water uptake by the plant [18]. The plant root length is significantly varied between treatments and reference soil at 5% level of significance.

3.3. Effect of Different Reclaimed Saline Soils on the Shoot Length Per Plant

Effect of different reclaimed saline soils on the shoot length per plant is presented in (Figure 3). The result ascertained that the shoot length per plant changes between 17.81cm to 41.64cm (Appendices). Treatment T_5 (Cow dung + Rice husk treated soil) contains higher amount of shoot length per plant (cm), among six treatments (Figure 3). The use of cow dung + rice husk reduced salinity and increase organic matter and nitrogen which are helpful for shoot and vegetative growth of plants. Combined application gypsum and calcium chloride also had remarkable effect in increasing shoot length per plant (cm) per plant. Individual effect of calcium chloride was less effective in increasing shoot length per plant (cm). The shoot growth of reference soil was poor because of salinity. Reduction in shoot growth due to salinity is commonly expressed by a reduced leaf area and stunted shoots. It is well known that salinity with an adequate supply of calcium reduces shoot growth, particularly leaf area, more than root growth [19].

From the statistical point of view the significant difference was observed among treatments and reference soil (Figure 3). The significant difference was observed between treatment T_5 and reference soil (T_0). Treatments (T_6, T_1 and T_2) value were similar and it is significantly varied with reference soil but insignificant difference was observed among treatments T_6, T_1 and T_2 (Figure 3). Insignificant difference was observed between treatments T_3 and T_4 with compare to reference soil (T_0). The plant shoot length is significantly varied between treatments and reference soil at 5% level of significance.

3.4. Effect of Different Reclaimed Saline Soils on the Fresh Weight Per Plant (gm)

The result confirmed that the fresh weight per plant changes between 1.02gm to 2.16gm (Appendices). From the statistical point of view the significant difference was observed between treatments and reference soil (Figure 4). Fresh weight of plant of treatment T_5 was greater than others treatment and reference soil (T_0) because the number of leaves was greater. The lowest fresh weight (1.02gm) per plant recorded for reference soil (T_0) due to higher amount of salinity. Treatment T_5, T_6 and T_1 is significantly varied with reference soil (T_0) but treatment T_2, T_3 and T_4 is insignificantly varied with reference soil (T_0). Insignificant difference was observed between treatment T_1 and T_2, treatment T_2 and T_3, treatment T_3 and T_4 and treatment T_4 and reference soil (T_0). The fresh weight of plant is significantly varied between treatments and reference soil at 5% level of significance.

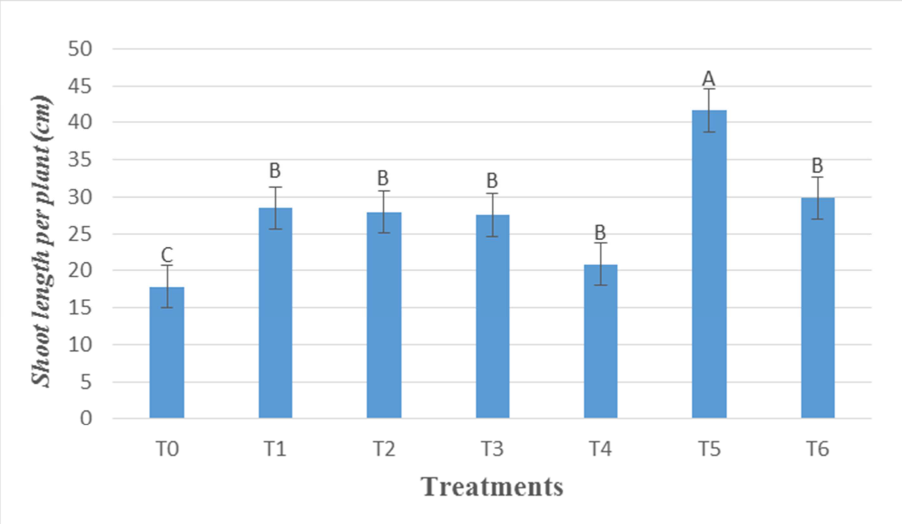

Figure 3. *Effect of different reclaimed saline soils on the shoot length per plant. Different letters on bars indicate the significant difference (p<0.05). Error bars represent the standard error.*

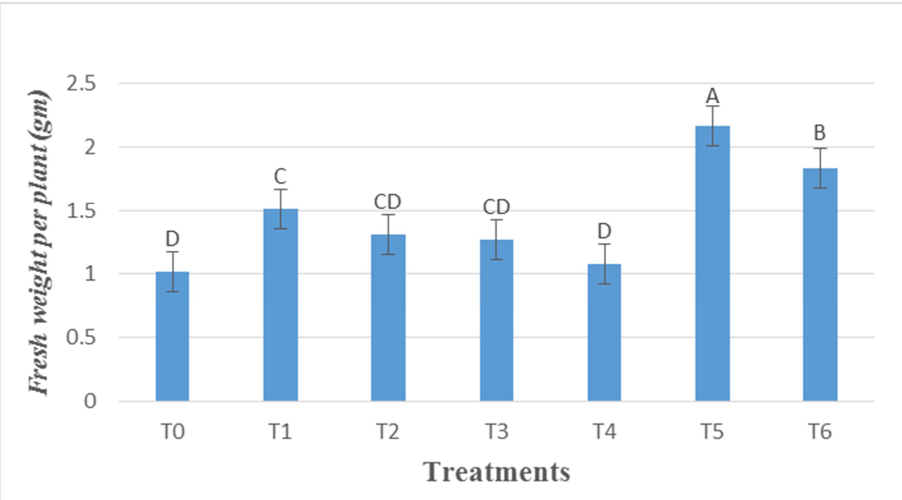

Figure 4. *Effect of different reclaimed saline soils on the fresh weight per plant. Different letters on bars indicate the significant difference (p<0.05). Error bars represent the standard error.*

3.5. Effect of Different Reclaimed Saline Soils on the Dry Weight Per Plant (gm)

The result ascertained that the dry weight per plant changes between 0.09gm to 0.2gm (Appendices). From the statistical point of view the significant difference was observed between treatments and reference soil (Figure 5). Dry weight (0.2gm) per plant of treatment T_5 was greater than others treatment and reference soil (T_0) because fresh weight was greater. The lowest dry weight (0.09gm) per plant recorded for reference soil (T_0) due to high salinity. Treatment T_5 and T_6 is significantly varied but treatment T_6 and T_1, treatment T_1 and T_2, treatment T_2 and T_3, treatment T_3 and T_4 and treatment T_4 and reference soil (T_0) are insignificantly varied. The weight of treatment T_2 and T_3 are similar but insignificant difference was observed between treatment T_2 and T_3 (Figure 5). The fresh weight of plant is significantly varied between treatments and reference soil at 5% level of significance.

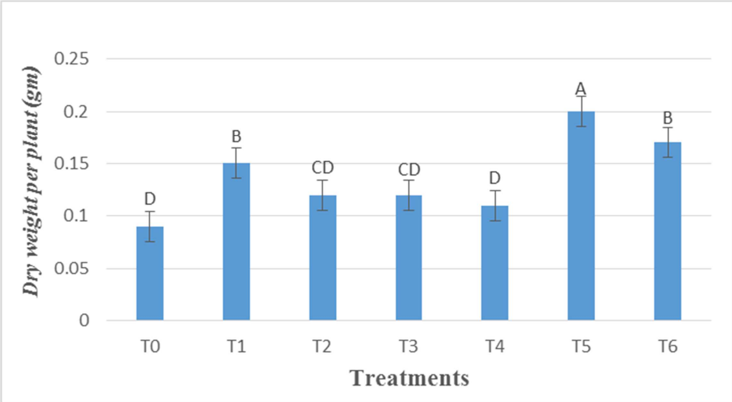

Figure 5. *Effect of different reclaimed saline soils on the dry weight per plant. Different letters on bars indicate the significant difference (p<0.05). Error bars represent the standard error.*

3.6. Effect of Different Reclaimed Saline Soils on the Percent Moisture Content

The result confirmed that the percent moisture content changes between 89.44% to 91.46% (Appendices). From the statistical point of view the insignificant difference was observed between treatments and reference soil (Figure 6). But from eye observation of the graph (Figure 6) and from (Appendices) it is clear that percent moisture content has a reduced trend for the application of different amendments such as cow dung, rice husk, gypsum, $CaCl_2$ (Figure 6) The percent moisture content is higher (91.46%) for reference soil (T_0) and lower (89.44%) for treatment T_4 as compare to other treatments. There is insignificant relationship among the treatments and reference soil at 5% level of significance.

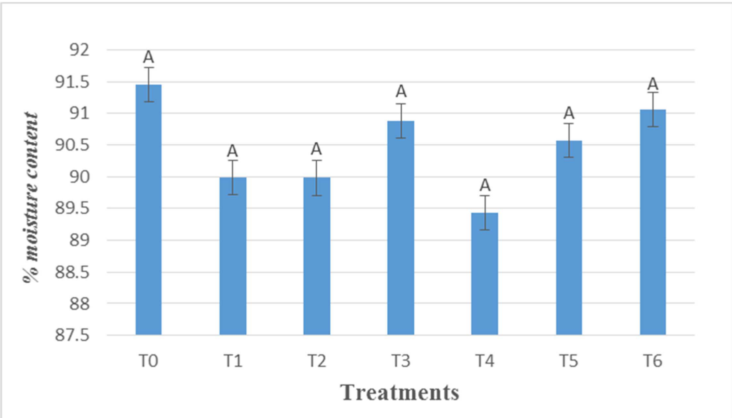

Figure 6. *Effect of different reclaimed saline soils on the percent moisture content. Different letters on bars indicate the significant difference (p<0.05). Error bars represent the standard error.*

4. Conclusion

The study revealed that addition of cow dung, rice husk, gypsum and calcium chloride acted as ameliorant to saline soils and effective in increasing number of leaves per plant, root length per plant (cm), shoot length per plant (cm), fresh weight per plant (gm) and dry weight per plant (gm) compared to reference soil. Treatment T_6 (gypsum + $CaCl_2$ treated soil) contains higher amount of root length per plant (cm) among six treatments. Treatment T_5 (Cow dung + Rice husk treated soil) contains higher amount of number of leaves, shoot length per plant (cm), fresh weight per plant (gm) and dry weight per plant (gm) among six treatments. For percent moisture content, the insignificant difference was observed between treatments and reference soil. But from eye observation of the graph and from Table A1, it is clear that percent moisture content has a reduced trend for the application of different amendments such as cow dung, rice husk, gypsum and $CaCl_2$. Though the inorganic amendments (gypsum and calcium chloride) are superior to reduce salinity, organic amendments (cow dung and rice husk) are effective for plant growth. Though chemical amendments have great influence in soil reclamation as well as plant growth but organic amendments and organic plus inorganic amendments have also positive effect on plant growth.

Conflicts of Interest

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

Appendix

Effect of different reclaimed saline soils on the growth and yield of water spinach (*Ipomoea aquatica*).

Table A1. *Effect of different reclaimed saline soils on the growth and yield of water spinach (Ipomoea aquatica).*

Treatment	No. of leaves per plant	Root length per plant (cm)	Shoot length per plant (cm)	Fresh weight per plant (gm)	Dry weight per plant (gm)	Percent moisture content
T_0	8.20E	5.98D	17.81C	1.02D	0.09D	91.46A
T_1	9.80D	6.56ABC	28.53B	1.51C	0.15B	89.99A
T_2	11.55B	6.30BCD	27.92B	1.31CD	0.12CD	89.98A
T_3	10.60CD	6.63ABC	27.53B	1.27CD	0.12CD	90.89A
T_4	9.18DE	6.15CD	20.85B	1.08D	0.11D	89.44A
T_5	13.87A	6.72AB	41.64A	2.16A	0.20A	90.58A
T_6	12.85AB	6.99A	29.83B	1.83B	0.17B	91.07A

Means followed by different letters in each column are significantly different ($P<0.05$) according to Duncan Multiple Range Test.

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