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Research Paper

Organic amendments can alleviate the adverse effects of soil salinity on the performance of tomato plant

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Abstract. This research aims to explore the potential of various organic materials as soil salinity improvement tools to increase crop yields. A pot experiment was conducted to investigate the effects of organic amendments plus or either soil test based (STB) chemical fertilizer (seven-treatment combinations as: T_1 = untreated saline soil, T_2 = STB, T_3 = biochar 2 t ha^{-1} +STB, T_4 = poultry manure 3 t ha^{-1} +STB, T_5 = vermicompost 3 t ha^{-1} +STB, T_6 = cow dung 3 t ha^{-1} +STB, T_7 = cow dung bio-slurry 3 t ha^{-1} +STB) on growth and yield of tomatoes grown in saline soil. Furthermore, the study also determined the mechanism of organic amendments to solve the salt stress of tomato plants. The results showed that untreated reference saline soil adversely affected vegetative growth and tomato yield attributes and ultimately significantly affected tomato yield. Organic amendments plus STB increased vegetative growth, yield, and quality parameters of tomato plants grown in saline soil and ameliorated the salt stress on crop growth. Among the amending substances, vermicompost and biochar along with STB fertilizer showed better-alleviating effects on salt stress and providing the maximum total biomass and fruit yield of tomato. The organic amendments can effectively enrich the physiological and osmotic adjustment characteristics such as proline and relative water content of tomato leaves, and reduce leaf electrolyte leakage as alleviating mechanisms of salt stress and thereby protecting the mechanism of photosynthesis and plant development. However, it is necessary to clarify the mechanisms and justify the effectiveness of the organic amendments through field trials in saline-prone areas.

Keywords: Saline soil, organic amendments, tomato, growth, yield.

INTRODUCTION

Soil degradation caused by salt is the main obstacle to the optimal use of land resources (Oo *et al*., 2015). Soils affected by salt are spread all over the world. Globally, about 800 × 10^6 million hectares of land are affected by salt, which is growing at a rate of about 1 to 2% per year (Munns and Tester, 2008). Salinity affects about 20% of the world's arable land and nearly half of the irrigated land (Mali *et al.*, 2012). Among the 2.85 million hectares of coastal and offshore areas of Bangladesh, approximately one million hectares of land in 64 sub-areas in 13 districts are affected by varying degrees of salinization, accounting for 30% of cropland area (Haque, 2006; Uddin *et al*., 2011). Currently, Bangladesh's agriculture is facing a huge challenge in sustainable crop production due to the increased risk of soil salinity caused by climate change. Land degradation caused by salinization is causing an annual economic loss of USD 27.2 billion in terms of crop loss in irrigated agriculture

(Qadir *et al*., 2014).

Salt stress has a negative impact on crop growth and productivity (Bidabadi *et al*., 2017). Due to its negative effects on microbial activity, nutrient availability and soil physical properties, soil salinity poses a major threat to the soil productivity of cultivated land (Lobell *et al.*, 2007). A large amount of salt entering the soil and irrigation water will destroy all physiological and biochemical processes of plants (Hasanuzzaman *et al*., 2013). The reduction of the osmotic potential of the soil solution, the imbalance of nutrients and the effects of ionic toxicity are the consequences of salinity, which harms plant growth and ultimately accelerates the yield loss of crops (Munns and Tester, 2008; Akhtar *et al.*, 2015a; Sofy *et al.*, 2020). Generally, depending on the soil salt level, 30 to 50% yield loss will occur (Khatun *et al*., 2019). Therefore, it is necessary to increase crop yield through sustainable intensification of climate-vulnerable degradable land to ensure food security.

The application of organic amendments might be considered as a sustainable practice to mitigate the effects of salinity stress on crops, due to having both ameliorative effects and enhancing the fertility status of saline soils (Melero *et al.*, 2007). Several reports explained that organic matter could alleviate salt stress in soil by improving its physical, chemical and biological properties (Tejada *et al*., 2006; Walker and Bernal, 2008). Biochar is a carbon-rich material obtained from thermochemical conversion (slow, intermediate, and fast pyrolysis) of biomass in an oxygen-limited environment, acts as a key for agricultural sustainability due to its long-term C sequester capacity. Biochar has been described as a possible tool for soil fertility improvement, potential toxic element adsorption, and climate change mitigation (Stewart *et al*., 2013). Due to its fairly stable nature and high Na^+ adsorption potential, effectively reduces the plant's absorption of Na^+, and therefore may alleviate salt stress (Lashari *et al*., 2014; Akhtar *et al*., 2015a). Moreover, Biochar becomes an effective remediation technique in saline soil, because of its higher potential to add Ca^{2+} and Mg^{2+}, improved several physical properties such as bulk density, porosity, aggregate stability and saturated hydraulic conductivity of soil and thereby enhance Na+ leaching (Herath *et al.*, 2013). However, there is little information on the use of biochar as a potential soil amendment for saline soils.

Tomato (*Lycopersicon esculentum* L) belongs to the Solanaceae family, most of which grow in almost all regions of the world. It is listed as the second most important vegetable crop (Megahed *et al*., 2013). It is mainly grown in tropical and subtropical regions of the world (Nicola *et al*., 2009). Tomatoes play a crucial role in the human diet because of their taste and nutritional value. Tomato is the horticultural plant most susceptible to salt stress because of its wide range of leaves, high stomatal conductance, and shallow root system (Mohammed *et al.*, 2018). In Bangladesh, tomatoes are mainly grown during the dry season (October to March) of the year. To cope with climate change and transform a large number of saline soils under agricultural intensive conditions, it is necessary to understand the impact of salt stress and find ways to reduce its impact. However, there are few reports concerning the effect of salt stress on tomato plants as well as the economical and effective organic amendment technology for reducing the effect of salt. The purpose of this study is to determine the effect of organic amendments on tomato performance, growth and yield under salinity stress.

MATERIALS AND METHODS

Plant material and growth conditions

BARI Tomato-9 (Lalima) a high-yielding, prolific bearer, bacterial wilt tolerant and indeterminate type variety, developed by the Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, was chosen as the experimental crop. The potential yield of this variety is 90-95 t ha^{-1}. The saline soil (EC = 5.86 dSm^{-1}) used in the experiment was collected from the village of Hetalbunia, Batiaghata Union, Batiaghata, Khulna (22° 41´36.1˝N and 89° 31’56. 0˝E). The soil was silty clay loam classified as Bajoa series soil under the AEZ of Ganges Tidal Floodplain (AEZ 13). The experimental soil was slightly saline soil (between 4.1-8.0 dS m^{-1}) and slightly alkaline (pH 7.68) and having low organic carbon (0.68%), very low N (0.07%), low P and K (10.90 mg $kg^{-1}$and 0.18 Cmol kg^{-1}, respectively) and very high Ca, Mg and Na (7.46, 3.72 and 2.56 Cmol kg^{-1}, respectively) content. Table 1 lists some key properties of the studied soil. In the present study, five different organic substances i.e- cow dung, poultry manure, vermicompost, cow dung bio-slurry and rice husk biochar, were used for the correction of the saline soil. One-month-old decomposed poultry manure and cow dung were purchased from a local farm. The vermicompost and cow dung bio-slurry used in the research was collected from Soil Science Division, BARI. Rice husk biochar was prepared by the pyrolysis process at 400 to 500°C temperature in the absence of oxygen or insufficient oxygen with two modified chambers equipped with pyrolysis furnaces developed by the Department of Soil Science of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). Table 2 summarized the major components of used organic amendments.

Experimentation

The experiment was conducted in plastic pots laid out in Randomized Complete Block Design (RCBD) with three

Table 1. Physical and chemical characteristics of the experimental saline soil.

Composition (% (w/w))			Textural class	pH	EC	OC	OM	N	P	K	Ca	Mg	Na
Sand	Silt	Clay			dS m^{-1}	(%)	(%)	(%)	(mg kg^{-1})	(Cmol kg^{-1})	(Cmol kg^{-1})	(Cmol kg^{-1})	(Cmol kg^{-1})
18.1	45.3	36.6	Silty Clay loam	7.69	5.86	0.68	1.17	0.07	10.90	0.18	7.46	3.72	2.56

Table 2. Some physio-chemical compositions of used manure and biochar.

Organic matter	Moisture (%)	pH	OC (%)	Total N (%)	C/N ratio	P (%)	K (%)	Ca (%)	Mg (%)	Zn (mg kg^{-1})
Cow dung	37.60	7.28	22.94	1.13	20.30	0.35	0.80	0.97	0.54	142.10
Poultry manure	37.43	8.22	34.20	2.22	15.41	0.97	1.18	1.51	0.51	178.10
Vermicompost	36.40	7.11	17.9	1.52	11.58	1.18	0.82	1.02	0.52	153.50
Cow dung slurry	23.10	7.08	23.72	2.80	8.47	1.25	0.84	0.98	0.48	143.30
Biochar (Rice Husk)	-	7.65	42.03	3.46	12.15	0.13	0.84	1.68	0.49	240.10

replicates. Five different organic amendment treatments along with reference saline soil and sole chemical fertilization with soil test based (STB) fertilizer were evaluated i.e T_1 (control), T_2 (STB), T_3 (biochar 2 t h^{-1} +STB), T_4 (poultry manure 3 t h^{-1} +STB) T_5 (vermicompost 3 t h^{-1} +STB) T_6 (cow dung 3 t h^{-1} +STB) and T_7 (cow dung bio-slurry 3 t h^{-1} +STB). On 21st November 2018, plastic pots (length 24 cm and diameter 20 cm) were filled with a uniform weight of 5.5 kg air-dried saline soil along with a measured amount of organic amendment according to treatment. To avoid the leaching of salt from the abandoned saline soil the outlets of the pot were closed by a crock.

Four weeks old tomato seedlings obtained from the Department of Soil Science nursery, BSMRAU, Gazipur, were transplanted (29th November 2018) maintaining two seedlings in each pot. After establishment, the seedlings were thinned to leave one seedling per pot. All plants were raised in a vinyl house under semi-controlled conditions. During the growing period, the daily average maximum and minimum temperatures were 34.3 and 26.2°C, respectively, and relative humidity (95.1% and 67.3% respectively). The pots were irrigated twice a week using tap water. The crop was fertilized with STB-based fertilizer 320.78 kg ha^{-1} urea, 84.7 kg ha^{-1}, triple superphosphate (T.S.P) 21.86 kg ha^{-1}, muriate of potash (MoP) and 19.81 kg ha^{-1} Gypsum calculated according to Fertilizer Recommendation Guide (FRG, 2012). During pot preparation, all calculated amounts of phosphorus, potassium, sulphur and one-third of nitrogen were added. On the15th and 35th days after transplanting (DAT) the remaining nitrogen was applied in two equal splits. The cultural practices during the tomato growth periods were done according to the standard cultivation method in Bangladesh.

Measurement of tomato growth and yield attributes

Tomato morphological parameters such as plant height (cm), number of branches and number of leaves $plant^{-1}$ were measured at 70 (DAT) considering an active flowering stage. The number of flowers $cluster^{-1}$ was also measured at 70 DAT. All others measured yield attributes i.e number of flower cluster $plant^{-1}$ was counted up to the last fruit plucking. Tomato fruits were harvested from February 14 to March 21, 2019. The number of fruits $plant^{-1}$, fruit length and girth were measured and weighted immediately after each plucking to determine fruit weight (yield). After the fruit was finally picked, the plant in each pot was uprooted, washed with tap water, and then chopped with a sharp knife for portioning shoot and root, air-dried in the laboratory and finally oven-dried for 72 hours at 65°C. The sample was then allowed to cool at room temperature and weighted to calculate the total dry mass (TDM).

Measurement of pigments content

Total chlorophyll content (mg g^{-1} FW) was estimated from the fully expanded uppermost leaf samples at the flowering stage (71 DAT) using the method described by Lichtenthaler (1987). The fresh leaf samples of 20 mg were taken in small vials containing 20 ml of 80% acetone and covered with aluminium foil for chlorophyll extraction. The extracts were stored overnight at 4°C in the dark. After centrifugation, the absorbance was measured at 663 and 645 nm wavelengths by a visible spectrophotometer, and chlorophyll concentration was calculated using the given by MacKinney (1941).

Total Chlorophyll: [20.2(A645) + 8.02(A663)] × (V/1000 × W)
Chlorophyll a: [12.7(A663) – 2.69(A645)] × (V/1000 × W)
Chlorophyll b: [22.9(A645) – 4.68(A663)] × (V/1000 × W)

Where A is the absorbance of the extract of respective wavelength, V is final volume of chlorophyll extract in 80% acetone (ml) and W is fresh weight of tissue extract (g).

Measurement of leaf proline, electrolyte leakage and relative water content

Leaf proline content (mg g^{-1} FW) was measured according to the method described by Bates *et al.* (1973). Proline (at 71 DAT) was extracted from 0.5 g of each leaf sample by grinding in 10 ml 3% (v/v) sulphosalicylic acid and then the mixture was centrifuged at 10,000×g for 10 minutes. To a test-tube was added 2 ml of the supernatant, 2 ml of a freshly prepared acid-ninhydrin solution and 2 ml glacial acetic acid. The tubes were incubated in a water bath at 100°C for 30 min, and the reaction was stopped in an ice bath. The reaction mixture was extracted with 4 ml toluene and vortex mixed for 15 s. The tubes were allowed to stand for ≥ 20 min in the dark at room temperature to separate the toluene and aqueous phases. Then carefully collect each toluene phase into a clean test tube and read the absorbance at 520 nm. A standard curve prepared using analytical grade proline was used to determine the concentration of free proline in each sample and the calculation was based on the fresh weight.

The total inorganic ions leaked out in the leaves (at 71 DAT) were estimated by the method of Sullivan and Ross (1979). Twenty leaf discs were taken in a boiling tube containing 10 ml of deionized water for 10 min and electrical conductivity (EC) of the supernatant was measured denoted as EC_a. The supernatant was incubated in a water bath at 55°C for 30 min and EC was measured again and denoted as EC_b. After that, the supernatant was again incubated in a water bath at 100°C for 10 min and EC was again recorded and denoted as EC_c. The electrolyte leakage was calculated by using the formula: Electrolyte leakage (%) = $((EC_b - EC_a) / EC_e) \times 100$

The leaf relative water content (LRWC) was calculated according to the methods of Hayat *et al.* (2007). To measure the LRWC, four leaves samples (at 71 DAT) of each treatment were picked from the middle of branches and weighed the fresh mass (FM). To obtain the turgid mass (TM) the same leaves were soaked in distilled water inside a closed petri dish for 24 hours and then the water on the surface of the leaves was gently wiped with tissue paper and weighed. After the imbibition period, the leaf samples were placed in a pre-heated oven at 80°C for 48 hours, and the dry mass (DM) was taken. The leaf relative water was calculated by using the formula: LRWC (%) = [{(FM – DM)/(TM – DM)} × 100]

Statistical analysis

The experimentally recorded data were subjected to RCBD analysis of variance (ANOVA) by using Statistics Version 10.0 software to find out the significance of variation between treatments. The differences between the treatment means were judged by the least significant difference (LSD) test (Gomez and Gomez, 1984).

RESULTS

Photosynthetic pigment content

Table 3 showed that the combinations of organic modifiers and STB fertilizer or either chemical fertilizer treatment were significantly influenced the chlorophyll content in the tomato plant. The highest total chlorophyll and Chl "a" contents (1.86 and 1.37 mg g^{-1}FW, respectively) were found in T_5 treated plant and alike information noted in T_4 (1.80 and 1.21 mg g^{-1}FW, respectively) and T_3 (1.52 and 1.11 mg g^{-1} FW, respectively) treatment. Meanwhile, the maximum chlorophyll "b" content (0.58 mg g^{-1} FW) was found in T_4 treatment. The lowest value of total chlorophyll, Chl "a", and Chl "b" contents (0.66, 0.48 and 0.17 mg g^{-1} FW, respectively) was noted in T_1 treatment. Statistically, a similar response was noted in solely STB fertilizer treatment T_2.

Growth attributes of tomato

All of the organic amendments plus or sole STB fertilizer

Table 3. Effects of organic amendment on the chlorophyll content in leaf at 71 DAT of tomatoes grown in saline soil.

Treatments	**Chlorophyll** "a" (mg g^{-1} FW)	**Chlorophyll** "b" (mg g^{-1} FW)	**Total Chlorophyll** (mg g^{-1} FW)
T_1	0.48 ± 0.08^{d}	0.17 ± 0.03^{d}	0.66 ± 0.06^{d}
T_2	0.83 ± 0.12^{c}	0.21 ± 0.13^{c}	1.04 ± 0.31^{c}
T_3	1.12 ± 0.22^{ab}	0.40 ± 0.10^{ab}	1.52 ± 0.31^{a}
T_4	1.22 ± 0.07^{ab}	0.59 ± 0.17^{ab}	1.81 ± 0.15^{ab}
T_5	1.37 ± 0.25^{a}	0.48 ± 0.16^{a}	1.86 ± 0.20^{a}
T_6	1.13 ± 0.14^{ab}	0.31 ± 0.07^{b}	1.44 ± 0.09^{abc}
T_7	$1.01 \pm 0.\ 13^{bc}$	0.28 ± 0.04^{b}	1.28 ± 0.17^{bc}
CV (%)	0.11	0.09	0.43

Results are expressed as means ± SD (n =3). In each column, different letters indicate a significant difference among the different treatments in soil salinity stressed plant at *P < 0.05* (Least significant difference, LSD); similar letters indicates a non-significant difference; Treatment T_1 = un-treated saline soil; T_2 = soil test based fertilizer (STB); T_3 = biochar 2 t ha^{-1} + STB; T_4 = poultry manure @3 t ha^{-1} + STB; T_5 = vermicompost 3 t ha^{-1} + STB; T_6 = cow dung 3 t ha^{-1} +STB; T_7 = cow dung bio-slurry 3 t ha^{-1} + STB.

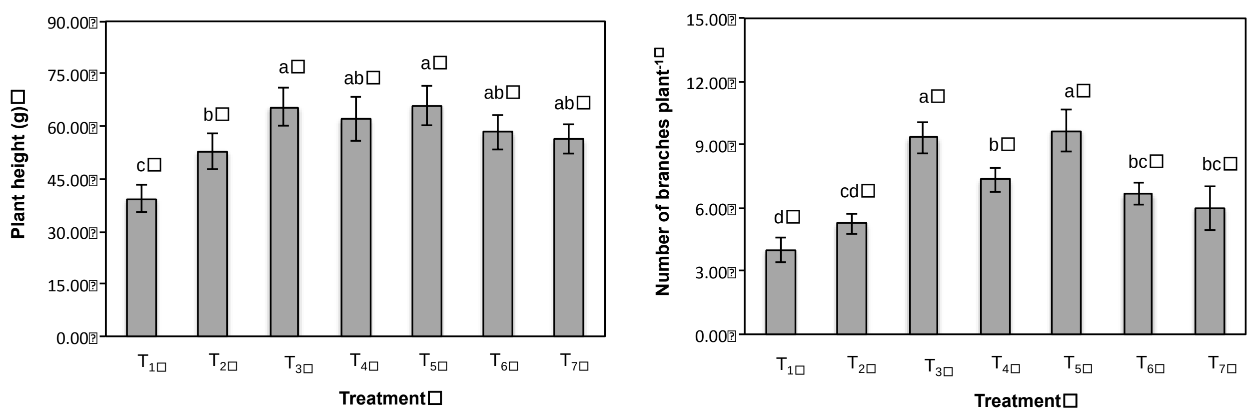

Figure 1. Effects of organic amendment on plant height and number of branches $plant^{-1}$ of tomato grown in saline soil. Results are expressed as means ± SD (n = 3). In each bar, different letters indicate a significant difference among the different treatments in soil salinity stressed plant at *P < 0.05* (Least significant difference, LSD); similar letters indicates a non-significant difference; Treatment T_1 = un-treated saline soil; T_2 = soil test based fertilizer (STB); T_3 = biochar 2 t ha^{-1} + STB; T_4 = poultry manure @3 t ha^{-1} + STB; T_5 = vermicompost 3 t ha^{-1} + STB; T_6 = cow dung 3 t ha^{-1} + STB; T_7 = cow dung bio-slurry 3 t ha^{-1} + STB.

significantly increased the plant height, number of branches $plant^{-1}$, number of leaves $plant^{-1}$ and leaf area in tomato plant (Figures 1 and 2). The tallest tomato plant (66.00 cm) was recorded in the T_5 (vermicompost 3 t h^{-1} + STB) treatment, while the shortest plants (39.30 cm) from the treatment T_1 (control). As compared to T_1 treatment the treatments T_2, T_3, T_4, T_6 and T_7 were 34.6, 66.7, 58.2, 48.3 and 43.4% higher plant height, respectively. The treatment T_5 showed the maximum number of branches $plant^{-1}$ (9.66), and a similar response in T_3 treatment (Figure 1). The untreated saline soil had the least number of branches $plant^{-1}$ (2.66).

Among the treatments, the highest leaf proliferation (44.00) was found in the T_3 treatment, while the lowest (21.33) counted in T_1 treatment (Figure 2). The addition of organic amendments positively influences the leaf area of the tomato plant (Figure 2). The significantly higher leaf area (110.6 cm^2) was found in plants treated with T_5, while the lowest leaf area (56.6 cm^2) was accounted for in T_1 treatment.

Yield and yield attributes of tomato

Tomatoes yield and yield parameters were measured in different treatments and presented in Table 4 and Figure 3). Different organic amendment and STB fertilizer together play a significant role in the number of flower

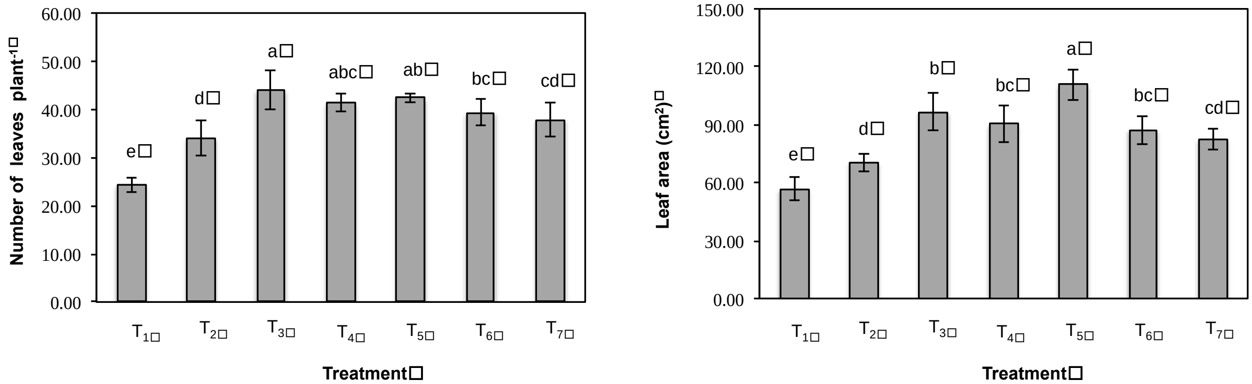

Figure 2. Effects of organic amendment on number of leaves plant^{-1} and leaf area of tomato grown in saline soil**.** Results are expressed as means ± SD (n = 3). In each bar, different letters indicate a significant difference among the different treatments in soil salinity stressed plant at $P < 0.05$ (Least significant difference, LSD); similar letters indicates a non-significant difference; Treatment T_1 = un-treated saline soil; T_2 = soil test based fertilizer (STB); T_3 = biochar 2 t ha^{-1} + STB; T_4 = poultry manure @3 t ha^{-1} +STB; T_5 = vermicompost 3 t ha^{-1} + STB; T_6 = cow dung 3 t ha^{-1} + STB; T_7 = cow dung bio-slurry 3 t ha^{-1} + STB.

Table 4. Effects of organic amendment on the yield attributes of tomato plant grown in saline soil.

Treatments	Number of flower cluster plant^{-1}	Number of fruit cluster^{-1}	Number of fruit plant^{-1}	Fruit length (cm)	Fruit girth (cm)
T_1	3.90 ± 1.15^{e}	2.75 ± 0.44^{c}	9.60 ± 0.85^{d}	4.63 ± 0.47^{b}	8.25 ± 1.18^{b}
T_2	4.66 ± 0.58^{e}	3.43 ± 0.26^{ab}	16.80 ± 0.78^{c}	6.26 ± 0.60^{a}	12.05 ± 1.96^{a}
T_3	7.33± 0.58^{ab}	3.93 ± 0.66^{a}	26.05 ± 3.07^{a}	6.83 ± 0.45^{a}	15.20 ± 2.53^{a}
T_4	6.66 ±0.55^{bc}	3.50 ± 0.37^{ab}	22.24 ± 0.89^{b}	6.70 ± 0.80^{a}	13.65 ± 1.85^{a}
T_5	7.66 ± 0.44^{a}	3.91± 0.39^{a}	26.88 ± 2.82^{a}	7.23 ± 0.74^{a}	15.36 ±1.73^{a}
T_6	6.33 ± 0.50^{cd}	3.19 ± 0.35^{bc}	21.12 ± 0.72^{b}	6.50 ± 0.66^{a}	14.06 ± 1.69^{a}
T_7	5.66 ± 0. 48^{d}	3.56 ± 0.06^{ab}	20.20 ± 2.23^{bc}	6.36 ± 0.64^{a}	12.73 ± 2.76^{a}
CV (%)	9.88	9.42	12.09	8.66	14.95

Results are expressed as means ± SD (n =3). In each column, different letters indicate a significant difference among the different treatments in soil salinity stressed plant at $P < 0.05$ (Least significant difference, LSD); similar letters indicates a non-significant difference; Treatment T_1 = un-treated saline soil; T_2 = soil test based fertilizer (STB); T_3 = biochar 2 t ha^{-1} +STB; T_4 = poultry manure @3 t ha^{-1} +STB; T_5 = vermicompost 3 t ha^{-1} +STB; T_6 = cow dung 3 t ha^{-1} +STB; T_7 = cow dung bio-slurry 3 t ha^{-1} +STB.

cluster/plant and number of fruit/cluster in tomatoes (Table 4). The maximum number of flower cluster plant^{-1} at 70 DAT (7.66) was recorded in T_5 treatment and statistically similar was found in the treatment T_2 (7.33) and T_4 (6.66). The minimum number of flower cluster plant^{-1} (3.90) was found in treatment T_1. Similarly, the highest number of fruit cluster^{-1} (3.93) was recorded in the treatment T_3 and the lowest number of fruit cluster^{-1} (2.75) noted in control.

The application of organic amendment plus STB fertilizer or sole chemical fertilizer had significant effects on the total fruit number (Table 3). The highest recorded fruits plant^{-1} (26.88) was found in T_5 treatment and the close proximity data noted in T_3 (26.05) treatment. The T_1 showed the minimum number of fruit plant^{-1} (9.60) (Table 3). The treatment applied with STB fertilizer either alone or in combination with organic amendment showed significantly increased tomato fruit length and girth grown in soil saline condition. The largest fruit length and girth (7.23 and 15.36 cm, respectively) of tomato was recorded in the T_5 treatment and the smallest (4.63 and 8.25 cm, respectively) found in control. There was no significant difference in fruit length and diameter among organically or chemical fertilizer treatments.

The influence of different organic improvers plus STB fertilizer or sole fertilizer on the weight of tomato single fruit and total fruit weight plant^{-1} are shown in Figure 3. A positive significant difference was observed in single fruit weight and total fruit weight plant^{-1} by the addition of different organic amendments and STB fertilizer in combination or sole fertilizer (Figure 3). The maximum single fruit weight (39.62 g) of tomato was recorded in the treatment T_5. Organic amendment plus STB fertilizer treatment T_3 (38.37 g), T_4 (36.12 g), T_6 (35.23 g) and T_7

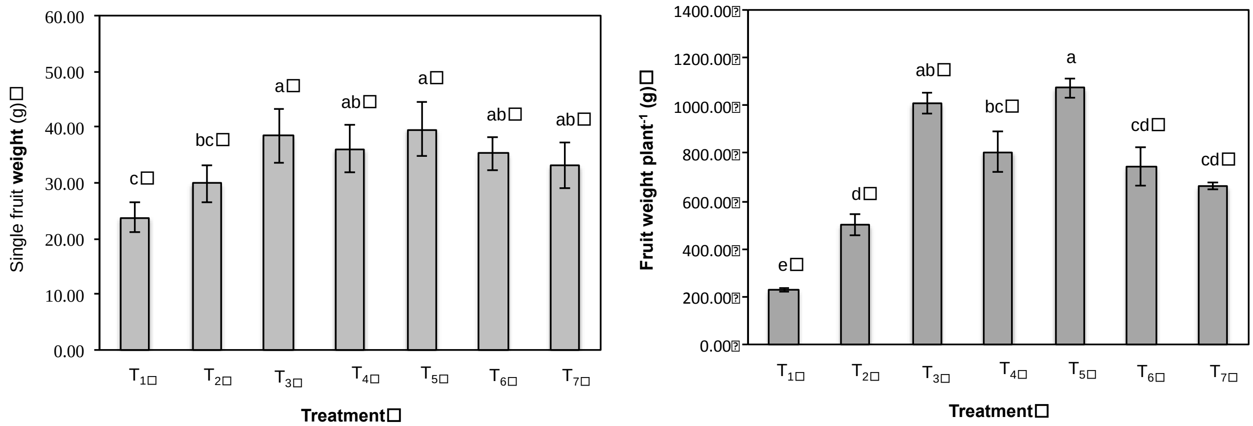

Figure 3. Effects of organic amendment on single fruit weight and total fruit weight plant^{-1} of tomato grown in saline soil. Results are expressed as means ± SD (n =3). In each bar, different letters indicate a significant difference among the different treatments in soil salinity stressed plant at $P < 0.05$ (Least significant difference, LSD); similar letters indicates a non-significant difference; Treatment T_1 = un-treated saline soil; T_2 = soil test based fertilizer (STB); T_3 = biochar 2 t ha^{-1} +STB; T_4 = poultry manure @3 t ha^{-1} +STB; T_5 = vermicompost 3 t ha^{-1} +STB; T_6 = cow dung 3 t ha^{-1} +STB; T_7 = cow dung bio-slurry 3 t ha^{-1} +STB.

Table 5. Effects of organic amendment on the biomass yield of tomato grown in saline soil.

Treatments	Dry above-ground biomass (g)	Dry below-ground biomass (g)	Total dry mass (g)
T_1	5.06 ± 0.55^{d}	1.33 ± 0.13^{d}	6.39 ± 0.56^{d}
T_2	7.81 ± 0.74^{c}	2.25 ± 0.17^{c}	10.06 ± 0.68^{c}
T_3	10.34 ± 0.79^{a}	2.67 ± 0.24^{ab}	13.01 ± 0.70^{a}
T_4	9.84 ± 0.65^{ab}	2.68 ± 0.11^{ab}	12.51 ± 0.54^{ab}
T_5	10.43 ± 0.37^{ab}	2.87 ± 0.09^{a}	13.30 ± 0.43^{a}
T_6	9.33 ± 1.29^{bc}	2.61 ± 0.08^{b}	11.94 ± 1.35^{abc}
T_7	8.95 ± 0. 73^{bc}	2.56 ± 0.10^{b}	11.51 ± 0.69^{bc}
CV (%)	0.67	0.11	0.64

Results are expressed as means ± SD (n =3). In each column, different letters indicate a significant difference among the different treatments in soil salinity stressed plant at $P < 0.05$ (Least significant difference, LSD); similar letters indicates a non-significant difference; Treatment T_1 = un-treated saline soil; T_2 = soil test based fertilizer (STB); T_3 = biochar 2 t ha^{-1} +STB; T_4 = poultry manure @3 t ha^{-1} +STB; T_5 = vermicompost 3 t ha^{-1} +STB; T_6 = cow dung 3 t ha^{-1} +STB; T_7 = cow dung bio-slurry 3 t ha^{-1} +STB.

(33.08 g) showed statistically similar responses on single fruit weight and total fruit weight plant^{-1}. At the same time, the highest recorded total fruits weight plant^{-1} (1073.75 g) was found in T_5 treatment and the close was found in the T_3 (1008.83 g) treatment. In addition to these, the remaining T_2, T_4, T_6 and T_7 provided 500.22, 804.45, 744.88 and 622.29 g, total fruits weight plant^{-1}, respectively. However, the untreated saline soil-grown plants showed the lowest single fruit weight and total fruit weight plant^{-1} (23.75 and 228.00 g, respectively).

Biomass yield of tomato

Data regarding dry above-ground biomass (DAGB), dry below-ground biomass (DBGB) and total dry mass (TDM) are presented in Table 4. The data reveals that different organic and/or inorganic amendments significantly increased the DAGB, DBGB and TDM of the tomato plants (Table 5). Among the organic amendment in combination with STB fertilizer or either sole fertilizer treatment the maximum DAGB, DBGB and TDM production (10.43, 2.87 and 13.30 g, respectively) of the tomato plant was observed in the T_5 treatment. Almost statistically similar DAGB, DBGB and TDM data were represented in T_3 (10.34, 2.67 and 13.01 g, respectively), T_4 (9.84, 2.68 and 12.51 g, respectively) and T_6 (9.33, 2.61 and 11.94 g, respectively) treatment. The lowest DAGB, DBGB and TDM production (5.06, 1.33 and 6.39 g, respectively) of tomato plants was attaining in the T_1 treatment. Meanwhile, compared to untreated saline soil plants, STB fertilizer treated one showed statistically least

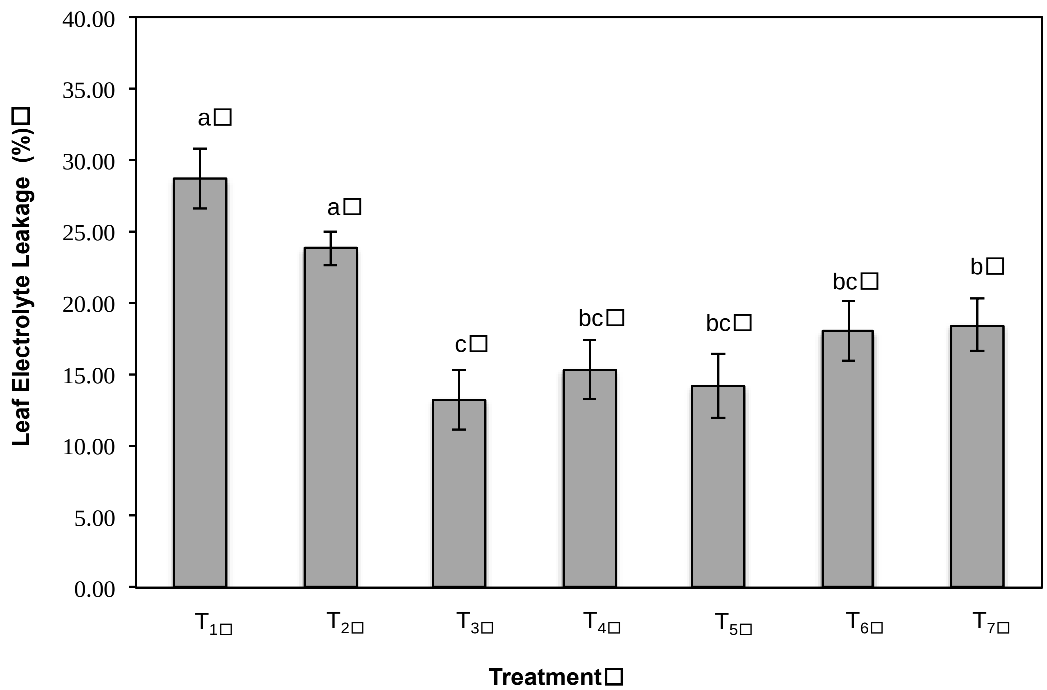

Figure 4. Effects of organic amendment on the electrolyte leakage of tomato leaf at 71 DAT grown in saline soil. Results are expressed as means ± SD (n = 3). In each bar, different letters indicate a significant difference among the amending substances application in soil salinity stressed plant at $P < 0.05$ (Least significant difference, LSD); similar letters indicates a non-significant difference; Treatment T_1 = un-treated saline soil; T_2 = soil test based fertilizer (STB); T_3 = biochar 2 t ha^{-1} + STB; T_4 = poultry manure @3 t ha^{-1} + STB; T_5 = vermicompost 3 t ha^{-1} + STB; T_6 = cow dung 3 t ha^{-1} + STB; T_7 = cow dung bio-slurry 3 t ha^{-1} + STB.

significant data.

Response in osmoregulatory physiological traits

Data in Figure 4 represents the osmotically active solutes such as proline and leaf relative water content in organic plus inorganic fertilizer or absolute fertilizer amended or non-amended tomato plant.

Different organic and inorganic amending substances in combinations or either STB fertilizer had a significant negative effect on the free proline content of leaves. The lowest value of proline content (20.33 mg g^{-1} fresh weight) was found in the untreated saline soil, while the highest proline content (33.10 mg g^{-1} fresh weight) was noted in the T_5 treatment. In contrast, the addition of different organic amendments plus STB fertilizer combinations or sole fertilizer had significant positive effects on the relative water content in leaves (Figure 4). Tomato plants that were grown in untreated saline soil (T_1) had the lowest average relative water content (66.59%). The present data showed that the maximum leaf relative water content of the tomato plant (90.04%) was found in the T_5 treatment and maintain statistically identical results in the treatment T_3 (88.47%), T_4 (85.71%) and T_6 (86.08%).

Electrolyte leakage in leaves of tomato

The combinations of different organic substances and STB fertilizer or either chemical fertilizer treatment were significantly lower the leaf electrolyte leakage in tomato plants (Figure 5). The highest electrolyte leakage (28.68%) was noted in untreated salinity stress plants in T_1 treatment. Significantly no variation in leaf electrolyte leakage was recorded by administered STB fertilizer treated saline soil as compared to un-treated T_1 treatment tomato plant. The lowest electrolyte leakage (13.18%) was calculated in the T_3 treatment that was statistically identical with the treatment T_4 (15.26%) and T_5 (14.11%) and T_6 (17.94%).

DISCUSSION

The untreated saline soil showed the lowest plant height and number of branches of tomato plants (Figure 1). This may be due to salinity that reduced the growth of roots, is affecting its morphology and physiology that in turn change the water and ion uptake, which led to a decrease in plant growth and production (Tejera *et al*., 2006) or reducing the absorption of water and the activity of metabolic processes (Mohamed *et al*., 2018). Organic amendment and/sole chemical fertilizer actively improved the plant height and number of branches of the tomato plant (Fig 1) as a result of overcoming the harmful effects of soil salinity. In the present study, comparatively higher plant height and branch development were found in the treatment T_5 (vermicompost 3 t h^{-1} + STB), which denoted its better salt stress reclamation efficiency. Adamipour *et al.* (2019) also described the application of vermicompost significantly alleviates the harmful effects of salinity and increases the morpho-physiological indices of marigold. The positive findings may be due to its effect on enhancing absorption and transportation of essential nutrients in plants, thereby increasing the photosynthetic area of plants, maximizing the photosynthesis, and ultimately increasing the plant height and branches development (Rahimi *et al*., 2013; Sofy *et al*., 2020).

Under untreated soil salinity, the number of leaves and leaf areas of the stressed tomato plants were the lowest (Figure 2), indicating that this variety is sensitive to salt-stress. The reduction in compound leaves and leaf area may be due to the salt-induced osmotic effect, which reduces the availability of water and nutrients to the roots, ultimately disrupts the plant tissues, resulting in decreased meristematic activity and cell expansion (Ullah *et al*., 2020). Meanwhile, the addition of organic amendments plus /or either chemical fertilizer significantly increased the number of compound leaves $plant^{-1}$ and leaf area of soil salinity stressed tomato plant, indicating its alleviating mechanisms of salt stress (Figure 2). Meanwhile, as compared to all amendments, T_5 (vermicompost 3 t h^{-1} + STB) treatment showed less salt injury. Akhzari *et al.* (2016) described Inline findings that the addition of vermicompost significantly mitigates the salt injury in *Medicago rigidula* L. The better leaf proliferation in amended saline soil tomato plant may be observed due to the better nutrient availability influence higher root development and physiological efficiency of nutrients that ultimately increases the number of cells, cell size, chloroplasts development, and synthesis of chlorophyll (Latif and Mohamed, 2016; She *et al*., 2018).

The vigorous physiological status of the stressed plants grown in saline soil applied with the organic amendments plus chemical fertilizer resulted in healthy plant growth, in terms of increased above-ground, below-ground and total dry mass (Table 5). Organic amendments that can stimulate plant growth regulators positively affect plant metabolism and ultimately improve plant growth (Rady, 2012). In this study, under saline soil conditions, organic amendment plus/ or chemical fertilizer had positive results on leaf proline, relative water content and chlorophll chlorophyll contents and negative results on leaf electrolytes leakage (Figures 4 and 5; Table 3). Such a result reflects alleviating mechanisms by adding organic substances to salt stress and ensures the better growth of tomato plants. By reducing plant exposure to stress or by enhancing plant stress resistance, organic amending substances can alleviate the adverse effects of abiotic stress (Buss *et al.*, 2012). Organic amendments may reduce the adverse effects of salinization on tomato plants by the following three main mechanisms: reducing transient N^+ by adsorption, releasing mineral nutrients, and decreasing osmotic stress by improving soil water availability (Akhtar *et al*., 2015a).

Plants produce osmotically active solutes (such as proline) under salt stress to balance the water potential (Szabados and Savoure, 2010). To defend abiotic stress from salinity, the content of free proline in plant protein is usually increased through protein biosynthesis or metabolism (Lashari *et al*., 2014). It has been shown that an increase in proline content reduces salinity-induced oxidative stress by eliminating certain harmful reactive oxygen species (ROS). Therefore, proline is a scavenger of hydroxyl and singlet oxygen, which effectively reduces the threat of ROS and electrolyte leakage in tomato leaves with excessive salt under salt stress (Rady, 2012). However, the interesting thing that emerged in the present study is that plants treated with the soil organic plus chemical fertilizer amendment enhanced the level of proline (Figure 4) under salt-stress conditions. Therefore, the maximum values were recorded in the plants grown in the saline soil amended with the T_5 (vermicompost 3 t h^{-1} + STB) treatment. Alike information also noted by Ruiz-lau *et al.* (2020) that the addition of vermicompost positively influenced the improvement of osmolyte but reduces electrolyte leakage under salinity stress conditions, ultimately helps to mitigate the salt injury. The present study suggests that increase the proline pool in the amended plant grown in saline soil may have accelerated their salt tolerance.

The increased tolerance to the salt stress was manifested in terms of improving growth and photosynthetic pigments (total chlorophyll) (Table 3) and the subsequent fruit yield and yield attributes (Table 4 and Figure 3). The present investigation also shows that soil salinity stress (untreated T_1 treatment) caused a significant reduction in the chlorophyll concentration (Table 3). The decrease in chlorophyll content may be attributed to increased activity of chlorophyll-degrading enzyme chlorophyllase, under stress conditions (Reddy and Vora, 1986) and may have the inhibition of its biosynthesis, which may disrupt the photo-assimilates accumulation mechanism. Organic amendment plus chemical fertilizer enables plants to overcome the adverse effects of salinity stress and consequently the increase in the content of total chlorophyll positively reflecting in the plant growth (Table 3). Similar data was also found in pomegranate by Bidabadi *et al.* (2017) that vermicompost effectively ameliorates the chlorophyll loss and reduced photosynthesis efficiency caused by salinity.

Current research shows that untreated reference soil salinity stressed plants exhibit disruption in numerous physiological mechanisms, which may lead to decrease the yield (single and total fruit weight plant $^{-1}$) and yield attributes (number of flower cluster plant^{-1}, fruit cluster^{-1}, fruit plant^{-1} and fruit size) of tomato (Table 3 and Figure 3). The decline in yield and yield attributes may be due to insufficient absorption of water and essential nutrient, and the unique toxicity impact of the salt ions (Ullah *et al.*, 2020). Fruit weight was significantly lowest in the plant grown in untreated saline soil (Figure 3). This effect may be because that salinity affects chlorophyll pigments and may reduce the rate of photosynthesis resulting in a decrease in photosynthetic products and ultimately reducing yield attributes (number of flower cluster plant^{-1}, fruit cluster^{-1}, fruit plant^{-1} and fruit size) of tomato and consequently the fruit weight (El-Beltagi *et al.*, 2020). The better yield performance of tomatoes in organically amended saline soil may be attributed to the positive influences of the organic amending substances. Compare to untreated saline soil or chemical fertilizer, all organic plus inorganic amending materials showed improved plant growth through its effects on ion transfer and increased absorptions of nutrients at the root system by activating the oxidation-reduction state of the plant growth medium. It also enhances the cell permeability, allowing nutrients to enter the root cells rapidly, leading to higher nutrient uptake by plants (Sayed *et al.*, 2007). Organic amendment alleviates the negative impacts of salt stress on fruit weight plant^{-1} (Figure 3). This may be due to their stimulating effects on photosynthetic pigments and biochemical activities in plants leading to an increase in photosynthates, which were closely interlinked with a positive increase of fruit yield attributes, and resulted in better fruit weight (El-Tantawy, 2009).

CONCLUSION

Our results have shown that combinations of different organic substances and STB fertilizer or either chemical fertilizer were significantly increased the growth and yield of salt-stressed tomato plants. The saline soil treated with Vermicompost 3 t h^{-1} plus STB fertilizer had afforded the maximum total biomass and fruit yield of tomato, and the adjacent higher data in biochar 2 t h^{-1} plus STB fertilizer treated pot. Organic amendments plus chemical fertilizer can enrich the total chlorophyll, proline and relative water content of tomato leaves, and reduce leaf electrolyte leakage. Thus, organic amendments can significantly alleviate salt damage on tomato plants by enriching their physiological and osmotic adjustment properties, thereby protected the photosynthetic machinery and plant growth. The study suggests that field trial is obligatory to clarify alleviating mechanisms and effectiveness of the organic amendments in saline agriculture.

Competing interests

The authors declare that they have no competing interests.

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