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The effect of different organic matters on plant growth regulation and nutritional components under salt stress in sweet sorghum [*Sorghum bicolor* (L.) Moench.]

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Abstract

Salinity is one of the major constraints of crop production, especially in the world's arid and semi-arid regions. Variations in the nutritional components of Gulseker sweet sorghum (local variety) and the effects of different organic matter on morphological and physiological changes under salt stress were examined herein. The response of sweet sorghum to applications of different organic matter [amino acid (AA), cow/farmyard manure (CM), biochar (BC), humic acid (HA), sheep manure (SM), worm casting (WC), poultry manure (PM), and bat guano (BG)], as well as water irrigation salinity at 150 mM NaCl were evaluated under greenhouse conditions using plastic pots containing 11 L of peat:perlite (2:1). Plants grown under different treatments were then classified as morphological (shoot fresh and dry weights, shoot diameter, shoot length, number of leaves and leaf area per plant) and physiological parameters (relative water content (RWC), chlorophyll (SPAD), malondialdehyde (MDA), Na^+, K^+, Ca^{++}, and Cl^- ion content. The results revealed that salt stress caused reduced growth parameters and chlorophyll, RWC, K^+ and Ca^{++} ion content, while MDA content, Na^+ and Cl^- accumulation showed an increase. The results showed that the organic matter treatments diminished the damaging effects caused by salt stress via a reduction in the uptake of Cl^- and Na^+, which enhanced K^+ and Ca^{++} uptake and reduced the MDA levels, presenting a favorable effect in reducing the oxidative stress that emerged from salt stress.

Introduction

Salinity is a significant abiotic stress factor that threatens agriculture in both arid and semiarid environments. It affects over 20% of irrigated land worldwide, and 40% of the food produced around the world is impacted by increased amounts of salt, as the amount of land affected by salinity is on the rise. It is also estimated that 50% of the cultivable land will effect due to salinity by 2050 (Hussein *et al*, 2019). Salt stress induces changes in biochemical, physiological, and morphological responses of a plant, which leads to reduced growth, yield, biomass, and quality of crop plants. Salinity's significant inhibitory impact on plant growth and yield was due to: (1) osmotic influence, (2) ion toxicity, and (3) nutritional deficiency leading to decreased photosynthetic efficacy and other physiological disorders (Almodares *et al*, 2008). Salinity causes excessive reactive oxygen species (ROS) accumulation, possibly resulting in enzyme inactivation, damage to DNA, lipid peroxidation, protein oxidation, and interaction with other essential plant cell components.

Two solutions can be chosen for sustainable agriculture in salt-soils: planting salt-crops or using salt-soil recovery methods. Various organic improvements such as garden compost, green manure, farmyard manure and urban solid waste compost have been applied to soil to increase soil quality and crop yields (Mbarki *et al*, 2020).

As chemical fertilizers are both expensive and have dangerous effects, the use of organic compound solutions is on the rise. Furthermore, nutrient supply and chemical fertilizer usage restriction in soils under salt stress are considerable issues that must be resolved using appropriate methods and effective management implementation. Organic fertilizers result in improved soil composition and increase availability of nutrients,

Table 1 - Effects of organic matter applications on growth parameters of broomcorn plants under salt stress condition

Tr [1]	Shoot fresh weight (g plant^{-1})	Shoot dry weight (g plant^{-1})	Root fresh weight (g plant^{-1})	Root dry weight (g plant^{-1})	Shoot length (cm plant^{-1})	Shoot diameter (mm plant^{-1})
C	291.44±16.44^{a}	87.20±3.05^{a}	54.33±3.71^{a}	15.53±1.18^{a}	96.33±8.33^{a}	20.61±0.20^{a}
S	42.73±3.89^{c}	11.74±1.46^{c}	12.83±1.01^{d}	3.83±0.75^{f}	40.00±3.12^{b}	12.99±1.46^{b}
AA	78.86±16.54^{bc}	23.89±2.81^{bc}	25.63±1.85^{b-d}	7.21±1.53^{d-f}	64.67±10.79^{ab}	18.06±1.64^{ab}
CM	123.37±8.18^{b}	50.12±2.85^{b}	41.01±2.24^{ab}	13.86±3.06^{ab}	67.67±2.08^{ab}	19.82±1.31^{a}
BC	91.83±15.52^{bc}	26.73±3.38^{bc}	27.35±3.04^{b-d}	8.10±1.07^{c-f}	63.33±3.58^{ab}	15.90±1.46^{ab}
HA	70.50±3.11^{bc}	19.23±1.56^{bc}	29.86±2.56^{bc}	10.15±0.67^{b-e}	54.33±5.51^{b}	17.61±0.93^{ab}
SM	121.75±19.66^{b}	44.32±2.16^{bc}	37.96±1.34^{a-c}	12.16±0.78^{a-c}	65.67±4.38^{ab}	19.05±1.83^{a}
WC	89.13±8.22^{bc}	30.90±4.16^{bc}	21.48±2.19^{cd}	6.42±0.66^{ef}	50.33±4.45^{b}	15.24±1.63^{ab}
PM	109.68±15.20^{bc}	35.77±3.93^{bc}	37.69±2.61^{bc}	11.34±0.82^{a-d}	63.33±3.58^{ab}	18.50±1.36^{ab}
BG	65.09±9.29^{bc}	19.52±1.26^{bc}	26.96±0.54^{b-d}	9.34±1.00^{b-e}	56.67±2.45^{b}	16.91±1.55^{ab}

*Each value represents the mean of three replicates. For each parameter of each different letters are significantly different at $p<0.05$ according to Tukey test.

which support quality and yield protection, and they are less expensive than synthetic ones (Bidabadi *et al*, 2017). Generally, biological, chemical, and physical properties of soil could be improved following the incorporation of organic manure. Adding organic waste to the soil, which reduces evaporation, while moderating the temperature of the soil, reduces stress to the roots of the plant and supplies nutrients, which in turn, results in productivity enhancement (Ahmed *et al*, 2010). Moreover, Leskovar and Othman (2018) reported that organic foods are significantly more nutritious than conventional foods and these had fewer pesticide residues and antibiotic-resistant bacteria. Organic manure has been reported to improve fruit and vegetable bioactive compound contents, such as beta-carotene, flavonoids, lycopene, and phenol, as well as antioxidant activity (Aina *et al*, 2019). The application of manure is well-known for its ability to improve and preserve the biological, chemical, and physical properties of soil, as well as provide various nutrients, such as N. As a soil enhancer and fertilizer, manure is a highly valuable resource (Irshad *et al*, 2002). Baddour *et al* (2017) suggested that organic manures could be the safest way to preserve soil fertility, sustainability and salt resistance. Various ecological improvements including farmyard manure (FYM), compost, poultry manure (PM) can be used to reinforce saline soils. Organic improvements enhance soil physical, mechanical, and biological properties under saline conditions. Biochar is characterized as a result of thermal degradation (pyrolysis, more than 250 °C) of organic materials in the absence of oxygen and privileged as a soil alteration from conventional charcoal). Regardless of environmental gains, biochars greatly impact soil physicochemical properties and fertility status (Verheijen *et al*, 2014). Studies have also shown that biochar can promote plant growth through its direct or indirect action mechanism. Direct growth promotion under biochar amendment related to mineral nutrient availability, *i.e.* Ca, Mg, P, K and S to the plant, though indirect process entails enhancing physical, chemical and biological characteristics of the soil (Farhangi-Abriz and Torabian, 2017). Humic acid (HA), a significant constituent in organic fertilizer, is the result of the biological and chemical breakdown of organic matter. It is one of the main constituents of organic soil material, and it improves crop growth and yield, as well as the chemical and physical characteristics of the soil, like aeration, aggregation, ion availability, and transportation via pH buffering, permeability, and capacity for holding water (Shaaban *et al*, 2013). Vermicomposts are formed via the compression of the organic waste of earthworms, and they comprise a form of nutrients that is easily absorbed by plants (Bidabadi *et al*, 2017). They also comprise regulators for plant growth, such as auxins, cytokinins, and other molecules that influence plant growth, like humates, which are produced by microorganisms and positively affect the growth and productivity of various crops. The fact that vermicompost is able to modulate the dangerous effects of salt stress on various crops has been reported in previous research (Bidabadi *et al*, 2017; Jabeen and Ahmad, 2017).

Sorghum is the world's fifth most valuable cereal crop and a staple for humans and other animals for milk, meat, fodder, and, additionally, is a source of fiber and

[1] C: Control/NaCl-free, S: Irrigation with solution contained 150 mM NaCl, AA: S+Amino acid, CM: S+Cow/farmyard manure, BC: S+Biochar, HA: S+Humic Acid, SM: S+Sheep manure, WC: S+worm casting, PM: S+poultry manure, BG: S+bat guano

Table 2 - Effects of organic matter applications on leaf parameters, chlorophyll, RWC, and MDA of broomcorn plants under salt stress condition

Tr	Leaf mumber (number plant^{-1})	Leaf area (cm^2 plant^{-1})	Chlorophyll (SPAD)	RWC (%)	MDA (µmol g^{-1} FW)
C	8.33±0.58^{a}	965.16±26.97^{a}	44.73±5.36^{a}	85.66±1.09^{a}	2.24±0.69^{e}
S	5.33±0.73^{e}	191.25±65.01^{b}	6.63±1.53^{d}	24.68±2.62^{c}	22.31±0.70^{a}
AA	7.00±0.75^{a-e}	582.08±67.15^{ab}	21.33±3.52^{b-d}	79.43±2.15^{a}	12.46±0.86^{c}
CM	8.00±1.00^{ab}	751.40±97.88^{ab}	35.90±5.77^{ab}	83.22±4.61^{a}	9.51±0.73^{d}
BC	5.67±0.45^{de}	561.95±71.82^{ab}	23.93±2.94^{bc}	80.75±2.18^{a}	15.94±0.77^{b}
HA	6.33±0.75^{b-e}	443.74±64.30^{ab}	22.05±2.67^{b-d}	70.80±3.39^{ab}	17.33±0.84^{b}
SM	7.67±0.58^{a-c}	644.91±73.08^{ab}	32.70±1.60^{a-c}	73.31±1.59^{a}	11.48±1.38^{cd}
WC	6.00±0.58^{c-e}	429.38±35.01^{ab}	17.41±2.49^{cd}	46.88±3.95^{bc}	16.68±0.76^{b}
PM	7.33±0.58^{a-d}	580.01±45.37^{ab}	32.65±2.59^{a-c}	75.62±4.36^{a}	12.20±0.60^{c}
BG	6.33±0.25^{b-e}	471.65±53.36^{ab}	33.27±2.01^{a-c}	74.65±3.45^{a}	16.37±1.39^{b}

*Each value represents the mean of three replicates. For each parameter of each different letters are significantly different at $p<0.05$ according to Tukey test.

fuel. Cultivating sweet sorghum is a desirable alternative to cope with the uncertainties of climate change that require adaptation to sustain successful production rates (Dalla Marta *et al*, 2014; Anami *et al*, 2015).

Although some cultural precautions can be applied to address and combat these issues, the previously mentioned applications are restricted, temporary, and their costs are actually high (Kusvuran, 2019). Therefore, resistant varieties to abiotic stress should be developed over the long-term. In this respect, while the development of varieties that are resistant to abiotic stress factors, such as salinity, is a more permanent measure in the long-term, it is of great importance to search for alternative solutions to increase the yield production in the short term, and to realize these alternatives within the framework of sustainable agriculture. Hence, in the present research, the following two hypotheses were investigated: 1) the effects of different organic fertilizers on salt tolerance in sweet sorghum, and 2) how these organic substances induce a change in ion regulation.

Material and methods

Greenhouse conditions

Experiments to identify the impact of different organic matter and salt-stress on various morphological and physiological characteristics of sweet sorghum were conducted under greenhouse conditions (natural daylight, relative air humidity of 65%, and day/night air temperature of 25±2 / 17±2 °C). The experimental plants were grown in plastic pots containing 11 L (57x16x12 cm) of peat: perlite (2:1). A salt solution was prepared using sodium chloride (NaCl) as a 150 mM dose. Plants in the control group were cultivated and grown under stress-free conditions for the same duration of time. Organic matter was mixed into the substrate before prior to the sweet sorghum being planted.

Eight different organic matters were used, as follows:

1- AA (Amino acid)

2- BC (Biochar)

3- CM (Cow/farmyard manure)

4- HA (Humic acid)

5- SM (Sheep manure)

6- WC (Worm casting)

7- PM (Poultry manure)

8- BG (Bat guano)

Experimental treatments

For each experiment, 10 treatments were performed, as follows:

1) control [C: NaCl-free],

2) salt treatment [S: irrigation with solution contained 150 mM NaCl],

3) salt treatment + AA [AA: irrigation with solution contained 150 mM NaCl + AA 4.5 g pot^{-1}],

4) salt treatment + CM [CM: irrigation with solution contained 150 mM NaCl + cow/farmyard manure 136 g pot^{-1}],

5) salt treatment + biochar [BC: irrigation with solution contained 150 mM NaCl + BC 18 g pot^{-1}],

6) salt treatment + HA [HA: irrigation with solution contained 150 mM NaCl + HA 4.5 g pot^{-1}],

7) salt treatment + SM [HA: irrigation with solution contained 150 mM NaCl + SM 136 g pot^{-1}],

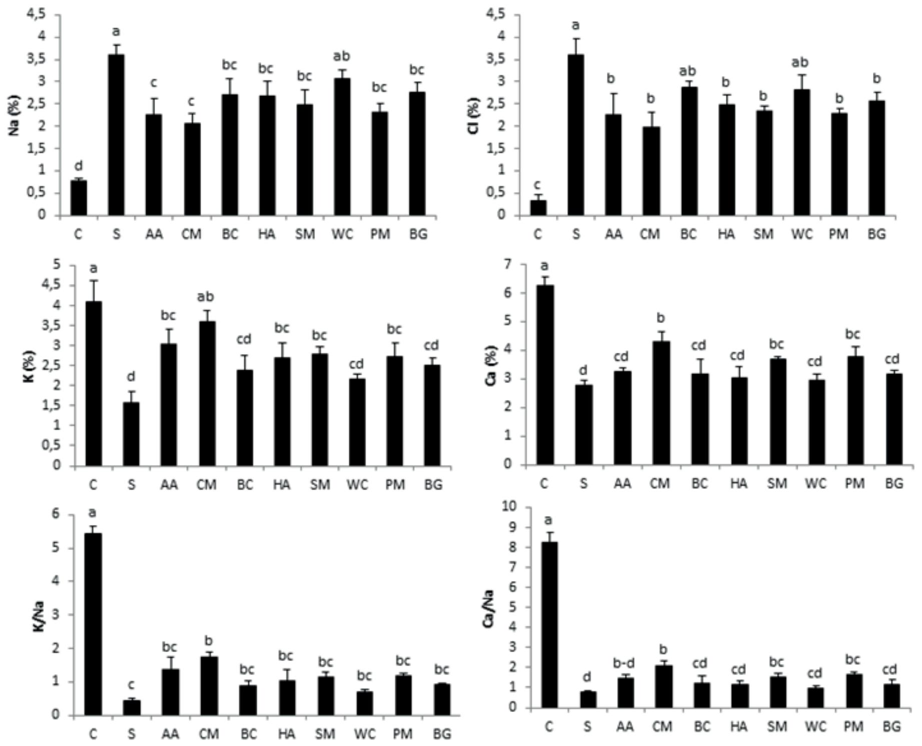

Fig. 1[i] - Effects of organic matter applications on ion contents of broomcorn plants under salt stress condition. Each value represents the mean of three replicates. For each parameter of each different letters are significantly different at p<0.05 according to Tukey test.

8) salt treatment + WC [WC: irrigation with solution contained 150 mM NaCl + WC 9 g pot^{-1}], 9) salt treatment + PM [PM: irrigation with solution contained 150 mM NaCl + PM 18 g pot^{-1}], and

10) salt treatment + BG [BG: irrigation with solution contained 150 mM NaCl + BG 9 g pot^{-1}].

Calculation of the volume of water used in the experiment was done in accordance with the drained water/applied water ratio (Schröder and Lieth, 2002), which was under the stress-free conditions of the control, around 30%. The monitored parameters were measured at the end of the experiment.

Chlorophyll measurement

A chlorophyll meter (SPAD-502 Plus, Minolta, Japan) used to calculate the chlorophyll value index. At the end of the experiment, plants were analyzed using certain plant morphology (shoot fresh and dried weights, shoot diameter, shoot length, and the number of leaves and leaf area per plant) and physiological parameters (relative water content, chlorophyll (SPAD), malondialdehyde (MDA), Na, K, Ca, and Cl ion value).

Ion leaf content analysis

For the determination of ion contents, sweet sorghum leaves were dried at 65 °C for 48 h. After drying, samples were grinded using a mill with a 2 mm mesh sieve. The leaf powder was turned to ash at 550 °C for about 6 h and the ash was dissolved in 3.3% HCl. The concentrations of Na^+, K^+ and Ca^{++} in leaves were determined by atomic absorption spectrometry (Jones, 2001). The Cl- concentration in tissue samples was determined using titrimetric analysis with silver nitrate (AgNO3) with the Mohr method (Dasgan *et al*., 2018)

Malondialdehyde content analysis

The amount of MDA ascertained via the thiobarbituric acid reaction was used to measure lipid peroxidation (Heath and Packer, 1968). The calculation of the MDA content was based on the MDA molar extinction coefficient; 155 mM^{-1} cm^{-1}.

Experimental plan and statistical analysis

The experimental plot design was randomized comprising three replications. A comparison of the parameter mean values was performed via the least significant difference test. Statistical significance was determined

[i] C: Control/NaCl-free, S: Irrigation with solution contained 150 mM NaCl, AA: S+Amino acid, CM: S+Cow/farmyard manure, BC: S+Biochar, HA: S+Humic Acid, SM: S+Sheep manure, WC: S+worm casting, PM: S+poultry manure, BG: S+bat guano

as $p<0.05$ using JMP statistical software, ver. 5.1 (SAS Institute Inc., USA). Data are presented as the mean ± standard deviation and in all figures, error bars are representing standard errors of the means.

Results

Growth characteristics

An improvement value in growth parameters of sweet sorghum plants grown under saline conditions using different organic ingredients is shown in Tables 1 and 2. Sweet sorghum plants were treated with water containing NaCl (150 mM) and eight different organic matters were added into each pot ranged from 31-86% compared to the control.

However, organic matter applications significantly enhanced the growth components such as shoot fresh and dry weight, shoot length, shoot diameter, and root fresh and dry weights, the number of leaves per plant, leaf area per plant under salt stress compared to the salt-stressed groups. The values of these growth parameters ranged from 28-191%. When compared to S, the maximum mean growth values and amelioration for growth were obtained in the CM, SM, and PM treatment groups, which were an increase of 56-292%, 18-326%, 18-204%, respectively.

Relative water content (RWC)

Sweet sorghum seedlings in the S treatment group demonstrated a decrease in the RWC at 71% when compared to the C group (Table 2). Compared to the S treatment group, significant improvement in RWC in the organic matter treatment group was observed at an increase of average 197%. The application of CM led to a greater effect on protecting RWC losses and resulting in increases in the RWC by 237% compared to S treatment. This application was followed by BC (227% increase) and PM (206% increase), respectively.

Chlorophyll content index (SPAD)

Under salt stress (150 mM NaCl) chlorophyll content index was reduced by 85% compared to control plants (Table 2). The application of organic matter mitigated the reduction of chlorophyll content index (SPAD) under salt stress (decreases of 19%-62%). The auxiliary addition of organic matter on the salt-stressed sweet sorghum plants induced a significant increase in SPAD by 221%, 441%, 260%, 232%, 393%, 162%, 392% and 401%, in the AA, CM, BC, HA, SM, WC, PM, and BG treatment groups, respectively when compared to the S treatment group.

Malondialdehyde (MDA) content

Often, MDA is used as an indicator for the assessment of damage resulting from abiotic stress. When compared to the control group, the MDA levels were observed to have increased in sweet sorghum (9.51-22.31 μmol g^{-1} FW). The highest MDA levels were determined in the S treatment group (895% increases). However, this increase was lower with the treatment of organic fertilizer in plants grown under salt stress (Table 2). In other words, MDA content was decreased by 22%-57% through the application of organic matter. Compared to the salt application, the most significant reduction in MDA content was determined 57% in the CM treatment group. The overall increase trend was visualized as: HA> WC> BG> BC> AA> PM> SM> SM. Salt stress results in the formation of free radicals in plants, which cause irreversible lipid and protein damage.

Ion contents (Na^+, Cl^-, K^+, and Ca^{++})

Nutrient content in leaves of sweet sorghum was measured to investigate the nutrient uptake by sweet sorghum (Figure 1). Na^+ and Cl^- contents significantly increased in salt stressed plant leaves as compared to their non-saline respective controls (373% and 987% increase, respectively). Under salinity stress, plants maintain ionic homeostasis by regulating K^+ and Ca^{++} levels. The plants subjected to salt stress showed a significant decrease in the K^+ and Ca^{++} accumulation and these reductions resulted in 61% and 56% compared to control plants, respectively. Application of organic manure showed a significant increase of K^+ and Ca^{++} contents under saline condition by 7-126% ratios as compared to the plants grown in non-saline conditions. In this study, K^+ and Ca^{++} concentrations were measured and then calculated the K^+/Na^+ and Ca^{++}/Na^+ ratios. The lowest K^+/Na^+ and Ca^{++}/Na^+ ratios were observed at 150 mM NaCl treatment (0.44 and 0.77). The CM application had the highest K^+/Na^+ ratio, followed by those treated with AA, SM, and PM. Similar results were obtained for the Ca^{++}/Na^+ ratio.

Discussion

Salt stress is a significant environmental component limiting crop plants from reaching their total genetic potential; thus, plant salt stress causes various growing limitations. Growth inhibition under saline conditions occurs from many physiological responses that could involve improvements in ion concentration, photosynthetic capacity, carbon storage and usage. Under the stress of water, plants produce more inorganic ions in the leaves and in the vacuoles compartmentalize these ions. These ions build up in the cytoplasm and prevent enzyme production, or can build up in cell walls resulting in cell dehydration (Jabeen and Ahmad, 2017). There are evidences that soil amendments with organic manures reduce the toxic effects of salinity in various plant species such as geranium (Leithy *et al*, 2010), wheat (Zaki and Radwan, 2011), alfalfa (Mbarki *et al*, 2020). Baddour *et al* (2017) reported that the increase in plant growth parameters with organic matter was mainly due to the reason of more concentrated nutrients or minerals were made readily available and easily absorbable by the receiving plants leading to faster growth and development.

In this study, the increase in fresh weight of shoots by 84% (AA), 188% (CM), 114% (BC), 64% (HA), 184% (SM), 108% (WC), 156% (PM) and 52% (BG) compared with salt treated plants, as well as dry weight of shoot by 103% (AA), 277% (CM), 127% (BC), 63% (HA), 326% (SM), 163% (WC), 204% (PM) and 64% (BG) (Table 1). Generally, all growth parameters effected positively with organic matter treatment under salt stress condition. The organic matter may affect plant growth as a source of growth promoters, auxin, vitamins, amino acids which act on the vegetative growth, yield and quality of the plant product (Abou El-Magd *et al*, 2008).

The dehydration due to lower water ability is mild under salt stress or irrigation deficiency induced by plants due to greater water absorption difficulties or lower substratum water rates. The most negative leaf water and stem water potential values were observed in plants subjected to water and salinity stress, because passive dehydration, as well as the accumulation of salt, plays a role in decreasing the water potential in leaves (Acosta-Motos *et al*. 2017).

In this study, concerning the effect of treatment sweet sorghum plants with organic matters, data in Table 2 showed clearly significant increments in RWC compared to untreated plants at 150 mM NaCl. While RWC values decreased under salt stress by 71% in saltyplants, the organic matter applications to RWC demonstrated an increase by 89-237% in the same conditions. The accumulation of osmolytes in cells aids in the preservation of turgor pressure in the cell and protects cell membranes, metabolic machinery, protein against cell dehydration (Venkataraman *et al*, 2013).

Growth inhibition in plants is the result of decreased chlorophyll content, possibly due to the ROS-induced chlorosis, photo-reduction, and triplet chlorophyll formation, which causes serious damage to photosystems I and II, and the formation of chlorophyll in plants (Singh *et al*, 2018). Even though the application of NaCl decreased the photosynthetic pigment contents of the seedlings, the application of organic matter limited those decreases. In this study, the favorable effects of the manure treatment were identified through the SPAD, which increased by 441% in the CM treatment group when compared to the S treatment group. Manure increased the photosynthesis efficiency of saline treatments when compared to those that were untreated and counterparts for sweet sorghum.

Dineshkumar *et al* (2018) reported that the increased chlorophyll accumulation in organic fertilizers, even at a decreased rate, could be the result of the cooperative effects of the consortium, which facilitates plant N, P, and K uptake better, resulting in increased chlorophyll accumulation. The application of manure increases soil fertility. Macro and micronutrients become more available, and the soil microorganism population becomes more abundant (Sutrisno and Yusnawan, 2018). Darini (2017) reported that organic fertilizer can increase the pigment of chlorophyll concentration in aloe vera. HA may cause an enhancement in the synthesis of the chlorophyll and/or delay chlorophyll degradation in plants (Nardi *et al*, 2002). The stimulatory effect that HA has on increasing the concentration of leaf chlorophyll was reported by Asghari *et al* (2018). Besides, vermicompost may play an important role in the alleviation of the damage induced by salt to chloroplasts via the reduction of chlorophyllase activity. Hosseinzadeh *et al* (2018) reported that applying organic matter such as vermicompost fertilizer improved physiological and photosynthetic responses under conditions of moderate stress and nonstress; however, no positive effect was observed under severe water stress.

Cell membrane integrity is destroyed by lipid peroxidation, eventually leading to cellular death (Dolatabadian *et al*, 2008). The lipid peroxidation increase is due to compounds like OH, H_2O_2, and O_2- in chloroplasts. MDA, which plays the role of a cellular toxicity bioindicator, is well-known oxidation that emerges from lipid peroxidation during oxidative stress (Singh *et al*, 2018). In this study, the lipid peroxidation of sweet sorghum increased with salt stress. At the same time, MDA organic matter contents, especially in the CM treatment group, were lower than the contents of seedlings in the other group and S treatment group. It was clear that because the seedlings which had been exposed to salt stress after treatment with the organic matter exhibited less defoliation and necrosis, the organic matter has positive effects on the improvement of plant growth quality. The results showed that the organic matter treatments reduced MDA levels, presenting a favorable effect in reducing the oxidative stress that emerged from salt stress.

Accumulation of Na^+ and Cl^- ions in stressed plants may play a major role in osmotic adjustment if effectively compartmentalized at the cell level. Modification of organic fertilizers has assisted in the reduction of sodium and chlorine content in leaves regardless of saline and non-saline water irrigation and balanced the sodium-induced toxicity (Jabeen and Ahmad, 2017). It is reported that the addition of organic fertilizer declined uptake of sodium and chlorine ion by enhancing the availability of other crucial ions *i.e.* potassium, nitrogen and phosphorus for the whole plant (Chamani *et al*, 2008; Abou El-Magd, 2008). The reduction in the potassium percentage in the leaves stems from the reverse relationships between it and sodium concentration and an increase of the sodium concentration in the soil solution by the irrigation with salty brings the removal of potassium from the absorption area in the roots, the deterioration in the balance of nutrition and reduction of its absorption (Burhan *et al*, 2018). Al-Taey *et al*., 2014 demonstrated that sodium accumulates rapidly in cells under saline conditions due to deactivation of the optional permeability mechanism for the plasma membrane.

The accumulation may also due to the fact that sodium is absorbed free of charge and without the consumption of energy and its properties by moving quickly within the plant to the leaves. Burhan *et al* (2018) mentioned that the addition of organic matter declines the sodium percentage because organic matter stores a part of sodium in the form of a Na-Organic compound. K^+/Na^+ or Ca^{++}/Na^+ ratios are also good indexes for assessing damage due to salinity, and these two ratios were strongly reduced compared to the control in sweet sorghum. The results from the present research indicating that treatment with high concentrations of NaCl caused lower K^+/Na^+ and Ca^{++}/Na^+ ratios is in accordance with previous findings (Xu *et al*, 2016). In rice, increased nutrient uptake and K^+/Na^+ ratios were observed due to application of organic manures (Chowdhury *et al*, 2019). Similarly, Mbarki *et al* (2020) conducted an experiment to study the soil amendments with organic matter such as farmyard and poultry manure significantly increased the growth, grain and straw yields, K^+/Na^+ ratio and nutrient uptake of rice cultivars under saline conditions leading to plant salt tolerance improvement.

Conclusion

Organic fertilizers are important for the environment and represent a favorable and renewable cheap source for agricultural practices. The application of organic matter under salt stress appeared to be favorable for the morphological and physiological processes of the sweet sorghum. From the results presented herein, it could be concluded that the application of organic fertilizer could effectively increase the growth parameters, chlorophyll, and K^+ and Ca^{++} accumulation, in addition to reduce MDA content, Na^+ and Cl- accumulations of sweet sorghum plants, under salt stress. Interestingly, in the current study, even though all of the organic matter components improved salt tolerance, the manure effect was more evident than that of the other organic manures under salt stress. Therefore, it could be recommended to use organic fertilizers that can effectively improve metabolic and physiological processes in sweet sorghum plants that might lead to increased salt stress tolerance.

Author Contributions

Conceived and designed the experiments: AK and SK. Performed the experiments: AK, SK, and MB. Analyzed the data: SK. Contributed reagents/materials/analysis tools: RIN and SK. Wrote the paper: AK, SK and MB. Revised the paper: AK and MB. All authors read and approved the final manuscript.

Compliance with Ethical Standards

Conflict of interest: The authors declare that they have no conflict of interest.

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