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ORIGINAL PAPER

Cottonseed meal soil application, nutrient uptake, biochemical attributes of cotton (*Gossypium hirsutum* L.) and activities of soil enzymes in saline soil

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Abstract

High salinity levels exert detrimental effects on plant growth and development by disturbing photosynthesis, water relations, and nutrient absorption. Different soil amendments are used to alleviate the adverse effects of soil salinity on plant growth and development. This study investigated the impact of cottonseed meal (CSM) application as soil amendment on soil enzymes, macro- and micro-nutrients, and phenol and sugar content in cotton plants grown on normal and saline soil. Three different CSM levels, i.e. 0 (CK), 40 and 80 Mg ha^{-1} were included in the study. Soil amendment with CSM significantly increased soil enzyme activities, organic carbon, and available nutrients, and improved soil structure. Soil amendment with 40 Mg ha^{-1} CSM improved dehydrogenase and urease enzyme activities by 15.38 and 40.51%, whereas amendment with 80 Mg ha^{-1} improved the activities of these enzymes by 15.29 and 21.47%, respectively. However, the activity of catalase enzyme was decreased by 32.18 and 48.28% under 40 and 80 Mg ha^{-1} CSM amendment, respectively. Soil amendment with 40 Mg ha^{-1} CSM to increased N, K, Ca, and Mg content by 65.90, 52.29, 5.71, 15.79%, and decreased Na content by 28.85%, whereas 80 Mg ha^{-1} increased these nutrients by 87.12, 53.63, 10.60, 40.63% and decreased Na content by 4.19%. Similarly, application of 40 Mg ha^{-1} CSM significantly increased B and Mn content in plants by 7.12, 8.6% on saline soil and by 1.13, and 10.09% on normal soil. Likewise, while 80 Mg ha^{-1} CSM application increased the B and Mn content by 1.84, and 9.46% on saline soil and 4.0, and 8.94% on normal soil. The application of 80 Mg ha^{-1} CSM improved total sugar content by 45.5% in saline soil and 3.97% in normal soil. The total phenol content of the plants was improved by 17.25% in saline soil and 2.9% in normal soil. It is concluded that CSM can be used alone or in combination with other organic amendments, such as compost and poultry manure, to alleviate the adverse effects of soil salinity on soil enzymes and nutrient uptake by plants.

Keywords: cotton, salinity, nutrient uptake, seed meal, soil enzymes

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INTRODUCTION

Ionic, osmotic, and oxidative stresses as well as nutritional imbalances in crop plants are the secondary stressors caused by soil salinity (Türkan, Demiral 2009). The maintenance of ion balance in plants is of utmost significance for the survival, growth, and development under salinity stress (Borsani et al. 2003). Crop plants have a reduced capacity to absorb water through their roots under elevated soil salinity, leading to an uptake of sodium (Na^+) and chloride (Cl^-) ions. Elevated Na^+ and Cl^- levels exert detrimental effects on plant development, photosynthetic activity, and metabolic activities (Sorkhi 2021). A high Na concentration and an imbalanced sodium--potassium (Na/K) ratio hinder some metabolic functions. Furthermore, an increased concentration of Na^+ inside the cytosol may lead to disturbed protein synthesis (Parvaiz, Satyawati 2008, Sorkhi 2021). Numerous studies have reported that salinity exerts an indirect negative impact on plant development by impeding the breakdown of organic matter and disrupting nutrient cycling in soil (Rath, Rousk 2015, Leogrande, Vitti 2019, Mahajan et al. 2021, Cevheri et al. 2022).

Several methods have been developed to enhance crop production and mitigate salt contents in saline soils. These methods include integrated nutrient management, improving soil integrity, and preservation of physicochemical soil structure (Mitran et al. 2021). Organic and inorganic fertilizers may be used to enhance the chemical and physical properties of saline soils and reduce the salt concentration (Mandal et al. 2019, Mahajan et al. 2021). Cottonseed meal (CSM) is rich in nutrients and contains significant amounts of organic matter; therefore, it can be used as a fertilizer. It is a byproduct of the cottonseed oil extraction process. The byproducts of cotton seed processing consist of 50% meal, 22% shell, 16% oil, and 7% linter (Hinze et al. 2015).

The use of CSM and similar fertilizers increases soil microbial activity and alters the activities of soil enzymes as well as metabolic reactions. The use of fertilizers and the integration of additional chemicals can enhance the nutritional value of crop plants and increase agricultural productivity (Spohn et al. 2016, Mahajan et al. 2021, Mitran et al. 2021). Soil enzymes, which constitute the whole of soil's biochemical composition, are essential components in the biochemical processes. These enzymes are the substrates used by soil microorganisms for food digestion (Rowell et al. 1973). Enzyme activities function as bioindicators of natural or anthropogenic degradation of soil, and they exhibit higher sensitivity than plants and animals (Hinojosa et al. 2004). Urease is classified as an extracellular enzyme that facilitates the catalytic breakdown of urea into ammonia and carbon dioxide. The process of ammonia oxidation plays a vital role in promoting agricultural and ecological sustainability (Hutchinson, Viets 1969). Dehydrogenase has considerable importance in soil ecosystems as it plays a crucial role in shaping soil biological activity and soil biomass (Pettit et al. 1976, Yuan, Yue 2012).

The enzyme catalase is found in almost all aerobic microorganisms, and the catalytic activity in plant cells is very high (Nicholls et al. 2000).

CSM has the potential to enhance soil enzyme activities and promote plant growth on saline soils by reducing soil salinity, increasing nutrient availability, and improving plant stress tolerance. Numerous enzymes, i.e., proteases, amylases, and cellulases, have been identified in CSM, and their activity is enhanced inside the soil. Increased activities of these enzymes can improve soil structure and fertility, release nutrients and expedite the decomposition of organic waste. All these processes significantly improve plant growth and development (Ma et al. 2021).

Although some studies have reported the positive impact of CSM on plant growth, there are few studies reporting the effects of CSM on the activities of soil enzymes, nutrient uptake and biochemical attributes of cotton plants grown on saline soil. Therefore, this study investigated the influence of CSM application on the activities of soil enzymes, nutrient uptake and biochemical attributes of cotton plants grown on saline soil. It was hypothesized that CSM application would improve the activities of soil enzymes, nutrient uptake and biochemical attributes of cotton plants grown on saline soil.

MATERIALS AND METHODS

Materials

The study was conducted in a controlled greenhouse environment at the Faculty of Agriculture, Harran University, Şanlıurfa Türkiye, and the soil samples used in the study were obtained from two distinct locations. The greenhouse was maintained with a 14:10 hours light-dark period and an average temp. of 27±1°C (30°C/26°C) – Reddy et al. (2004), Salvucci, Crafts-Brandner (2004). Sunlight and fluorescent light were used as the light source of plants. The pot experiment started on 10 May 2021, and ended on 5 July 2021, lasting 55 days. Saline soil samples were taken from the Asagi Beydes village, Şanlıurfa, whereas normal soil samples were collected from research fields of Osmanbey Campus, Harran University, Şanlıurfa, Türkiye. The collected samples were dried and sieved to exclude sizable pebbles and plant residue. The soil was then placed in pots. Two different cottonseed meal (CSM) levels, i.e., 40 and 80 Mg ha^{-1} were used in the study, while no CSM application was regarded as control. The chemical composition of CSM used in the study is given in Table 1.

Table 1

Physicochemical properties of the experimental soil

pH	Organic Matter	N	K	Ca	Mg	Fe	Mn	Zn	Cu
	(%)					(mg kg^{-1})			
6.5	61.7	2.1	0.99	0.65	0.32	511.4	22.8	27.1	8.5

METHODS

The pH and electrical conductivity (EC) of the soils used in the experiment were measured in soil water mixes in 1:2.5 and 1:5 ratios (Thomas 1996). The organic matter content of soils was assessed using the modified Walkley Black technique (Nelson, Sommers 1996), whereas Kjeldahl technique was used to assess the total nitrogen content of the plant samples (Kirk 1950). Dehydrogenase activity in soil samples was determined according to Tabatabai (2018). The soil samples were combined with 30 mg of glucose, 1 ml of a 3% solution of 2,3,5-triphenyltetrazoliumchloride (TTC), and 2.5 ml of distilled water. The mixture was then subjected to incubation for 24 h at a temp. of 25°C. The amount of triphenyl formazan (TPF) that was generated in the incubated soil samples was measured using a spectrophotometer set at a wavelength of 485 nm. The results were then expressed as grams of TPF per gram of soil (g TPF g^{-1}). Following a 1-hour incubation period at a temp. of 37°C, a spectrophotometric analysis was conducted to evaluate the amount of ammonium released.

The urease enzyme catalyses the decomposition of one mole of urea into two moles of ammonia and one mole of carbon dioxide. The ammonium concentration was determined on a spectrophotometer calibrated to a wavelength of 578 nm, as described by Tabatabai and Bremner (1972). The approach developed by Beck (1971) was used to monitor catalase activity. The soil samples, each consisting of five grams, were subjected to treatment using phosphate buffer solution with pH of 7. This treatment was accompanied by the addition of substrate solution containing 3% hydrogen peroxide, in a volume of 10 ml or 5 ml, respectively. Subsequently, the specimens were placed for 5 min in an incubation apparatus set at a temp of 20°C. The amount of oxygen released was determined, and the catalase activity was measured in millilitres of oxygen per gram of soil with no moisture.

Plant samples and CSM were analysed using the wet digestion technique devised by Jones and Case (2018) for the purpose of measuring Ca, Mg, Na, K, Fe, Zn, Cu, and Mn contents. The samples were prepared by using nitric acid (HNO_3) and hydrochloric acid ($HClO_4$), followed by filtration through blue filter paper. The concentrations of nutrients were assessed by using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) equipment. The phenol-sulfuric approach was used to ascertain the overall amount of soluble sugar, while the concentration was assessed on a spectrophotometer configured at a wavelength of 490 nm (Chandler, Dodds 1983).

Statistical analysis

The experimental design consisted of randomized complete blocks with split plot arrangements. Soil types composed main plots, whereas CSM application was randomized in sub-plots. A two-way analysis of variance (ANOVA) was made to assess the influence of different CSM treatments on measured traits (Steel et al. 1997). The least significant difference (LSD) test was used to compare the treatment means where ANOVA denoted significant differences among treatments. The statistical analysis was performed on JMP 13.2 software. The interactive effect of soil types and CSM dose was significant; therefore, interactive effects were presented and interpreted.

RESULTS AND DISCUSSION

Results

This study assessed the effects of CSM fertilizer application on various soil parameters, such as soil enzyme activities and the macro- and micronutrient content of cotton plants.

Dehydrogenase activity

Dehydrogenase enzyme (DHG) activity was significantly affected (p<0.01) by individual and interactive effects of soil types and CSM doses. The DHG activity was lower in saline soil (6.94 μg TPF g^{-1} dry soil 24 h^{-1}) and higher in non-saline soil (22.78 μg TPF g^{-1} dry soil 24 h^{-1}). The lowest DHG activity in soil type × CSM dose interaction was recorded with 40 Mg ha^{-1} CSM dose in both saline and non-saline soil. The increase in DHG activity was 15.38% in saline soil, compared to 85.41% in non-saline soil. The highest DHG activity was obtained in 80 Mg ha^{-1} CSM treatment, where the increase in DHG activity was 40.51% in saline soil and 105.82% in non-saline soil (Figure 1).

Urease activity

Urease enzyme activity was significantly altered by individual and interactive effects of soil types and CSM doses (p<0.01). The CSM application increased the urease enzyme activity in both saline and non-saline soils, but this increase was higher in saline soils. The lowest urease enzyme activity (10.63 μg N g^{-1} dry soil h^{-1}) was recorded in saline soil, while the highest activity was recorded in non-saline soil (48.60 μg N g^{-1} dry soil h^{-1}). The urease activity was increased by 15.29% in saline soil with 40 Mg ha^{-1} CSM application, while the increase in non-saline soil was 5.19%. The increase in urease activity induced by the 80 Mg ha^{-1} CSM dose was 21.47% in saline soil and 11.55% in non-saline soil (Figure 1).

Catalase activity

The individual and interactive effects of soil types and CSM doses on catalase enzyme activity were significant (p<0.01). Overall, higher catalase enzyme activity was recorded in saline soils than in non-saline soils.

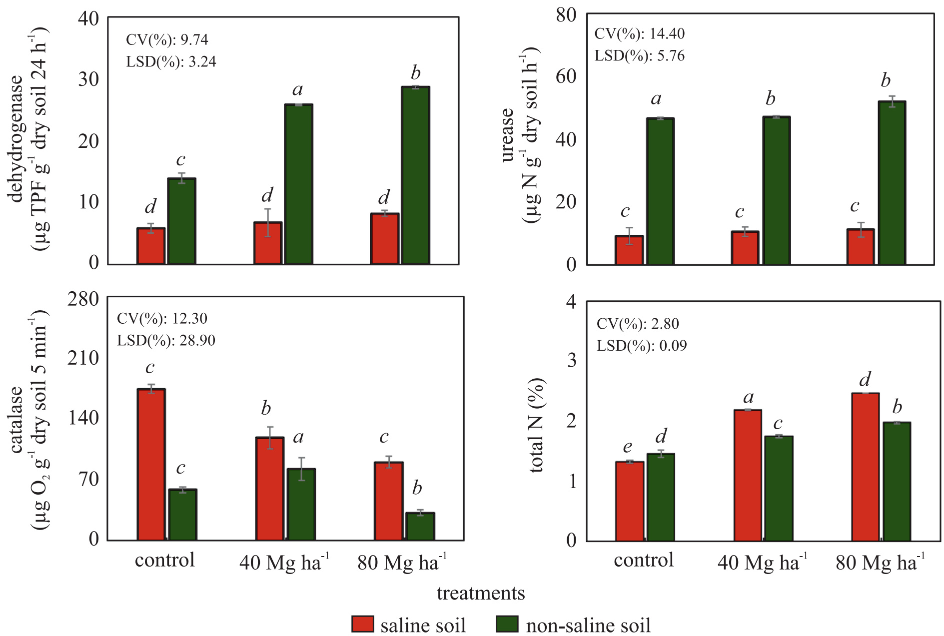

Fig. 1. The activities of soil enzymes and nitrogen uptake by cotton grown in saline and non-saline soil

The lowest catalase enzyme activity (57.44 ml O_2 g^{-1} dry soil 5 min^{-1}) was recorded in non-saline soil, and the highest activity was recorded in saline soil (127.33 ml O_2 g^{-1} dry soil 5 min^{-1}). Catalase enzyme decreased in saline soil by 32.18% in response to the 40 Mg ha^{-1} CSM application, and the corresponding increase in non-saline soil was 28%. The decrease in catalase activity due to the application of 80 Mg ha^{-1} CSM dose was 42.28% in non-saline soil and was 45.14% in saline soil (Figure 1).

Plant nutrients (%)

The total N content of cotton plants was significantly altered by individual and interactive effects of soil types and CSM doses ($p<0.01$). The CSM application increased total N content compared to the control. The lowest (1.65%) and the highest (1.99%) N content was recorded in plants from non-saline and saline soil, respectively. The application of 40 Mg ha^{-1} CSM to saline soil increased the N content by 65.9%, whereas the increase in non-saline soil was 19.86%. Similarly, 80 Mg ha^{-1} CSM application to saline soil increased the N content by 87.12% and by 35.62% in non-saline soil (Figure 1).

The plants supplemented with CSM displayed higher concentrations of K, Ca, Mg and Na compared to the control. The application of 80 Mg ha^{-1} CSM resulted in the highest plant nutrient concentrations. The increase in K, Ca, Mg, B and Mn concentrations with 80 Mg ha^{-1} CSM application into saline soil was 115.63, 10.60, 40.63 and 4.19%, whereas the increase on non-saline soil was 42.58, 9.54, 4.26, 10.07 and 10.45%, respectively (Figures 1 and 2).

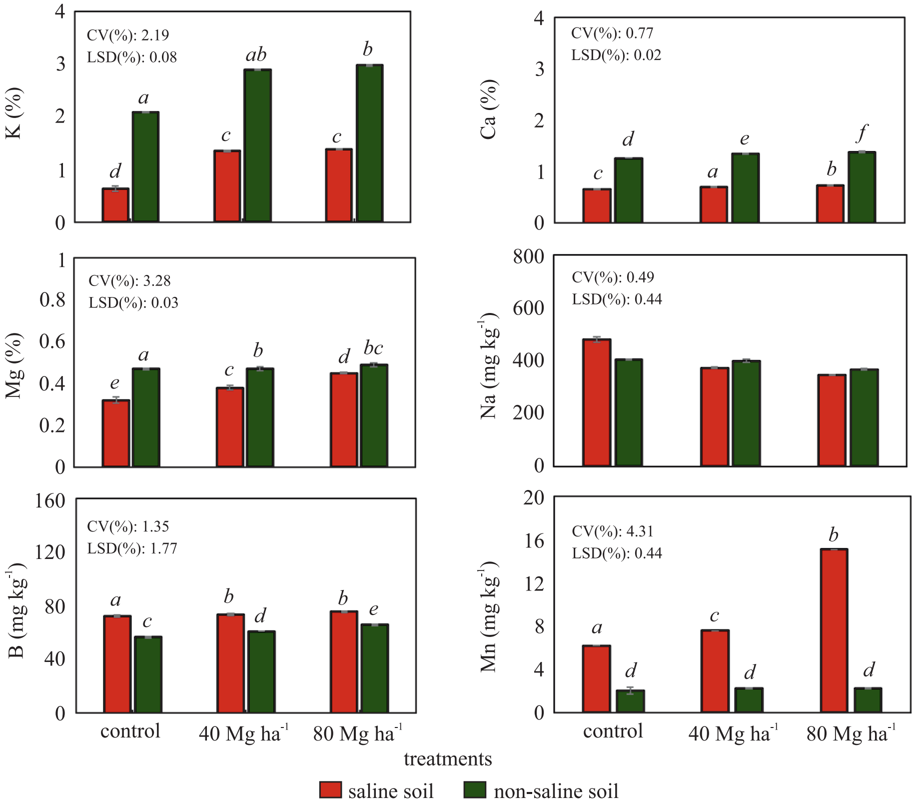

Fig. 2. Nutrient uptake of cotton plants grown in saline and non-saline soil

Total sugar and total phenol

Individual and interactive effects of soil types and CSM doses significantly modified total sugar and total phenol contents (p<0.01). The total soluble sugar content in non-saline soil was lower (12.61 mg g^{-1} DW) than in saline soil (21.03 mg g^{-1} DW). Like total sugar, the total phenol content in saline soil (4.66) was significantly higher than in non-saline soil (4.08). The application of 80 Mg ha^{-1} CSM to saline and non-saline soil increased the total sugar content by 45.5 and 3.97%, respectively. Similarly, the application of 80 Mg ha^{-1} CSM to saline and non-saline soil increased the total phenol content by 17.25 and 2.9%, respectively (Figure 3).

Plant height and root length (cm)

Individual effects of soil types and CSM doses significantly modified the plant height and root length (p<0.01), while their interactive effect remained

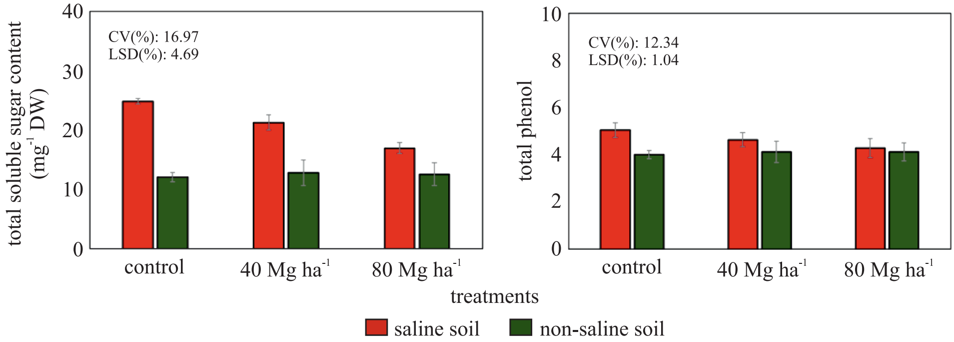

Fig. 3. Total sugar and phenol contents of cotton plants grown on saline and non-saline soil

non-significant in this regard. The root length was 34.11 and 30.0 cm in non-saline and saline soils, respectively. Similarly, higher plants (59.22 cm) grew in non-saline soils and lower ones (50.89 cm) in non-saline soil. The application of 80 Mg ha^{-1} CSM increased the root length by 29.5 and 22.34 cm in saline and non-saline soil, respectively. Likewise, 80 Mg ha^{-1} CSM application increased plant height by 23.20% and 26.44% in saline and non-saline soil, respectively (Figure 4).

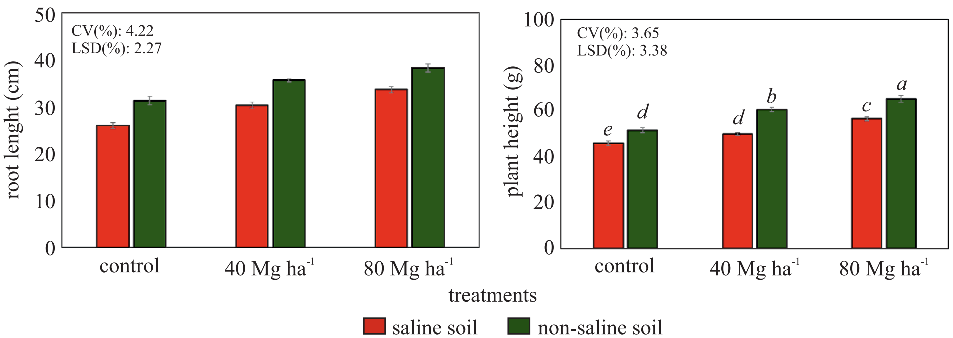

Fig. 4. Plant height and root length of cotton plants grown in saline and non-saline soil

DISCUSSION

The impact of CSM treatment on soil enzymes remained consistent, irrespective of the soil salinity level. Distinct microbial reactions led to significant differences in enzyme activities between saline and non-saline environments. Prior studies have delivered similar findings (Iqbal et al. 2016, Leogrande, Vitti 2019, Sakin et al. 2021, Cevheri et al. 2022). The addition of CSM resulted in an increase in enzyme activity in saline soil, as compared to regular soils. Despite the salinity of the soil, empirical tests have shown that the incorporation of organic fertilizers has significantly enhanced soil respiration (Sall et al. 2015, Iqbal et al. 2016, Sakin et al. 2021). Therefore, the use CSM may serve as a potential means to alleviate the detrimental impact of soil salinity on soil microorganisms and enzymes (Leogrande, Vitti 2019). The beneficial effect of CSM application may be attributed to the capacity of soil microorganisms to produce osmolytes, which counteract osmotic pressure under high salinity, as well as the presence of carbon-rich compounds in organic amendments. These factors facilitate metabolic processes involved in detoxification and cellular restoration (Wichern et al. 2006). Telesiński (2012) indicated that the decrease in soil enzyme activity under elevated salt levels might be attributed to alterations in the osmotic potential of enzymatic proteins caused by salinity. Alternatively, this decline may be linked to variations in the toxicity of certain ions within the soil.

The results of the current study evidenced that the application of CSM has a considerable positive impact on the quality of saline soils and the growth of plants. The capacity of CSM to enhance the soil's organic carbon content resulted in an increase in microbial activity, subsequently leading to better nutrient availability and soil physicochemical characteristics (Bhattacharya 2019). The application of CSM has been shown to enhance the biological and physicochemical characteristics of soil, leading to an increase in the carbon and nitrogen content of soil microbial biomass (Almaroai, Eissa 2020). The application of CSM to soil resulted in an increase in microbial activity in both non-saline and saline soil. Furthermore, it was shown that CSM had a mitigating effect on the adverse impact of salinity, specifically in saline soil. The results indicated that organic compounds are effective in reducing the adverse impact of soil salinity. Various studies have implicated using soil organic additions as a strategy to mitigate soil salinity (Gunarathne et al. 2020, Rekaby et al. 2020). Applying organic waste to alleviate the adverse impact of soil salinity on plant growth is an established agricultural technique, which is cost-effective, simple and ecologically compatible (Gunarathne et al. 2020). The effectiveness of CSM as an organic waste material in mitigating soil salinity in arid and semi-arid regions has been reported in various studies. Salinity significantly impedes enzymatic and microbiological activity in soil. Research findings indicated that soil salinity was the main factor that restricted soil enzyme activity (Haddad et al. 2017). The reduced microbial activity seen in saline soil may be attributed to the deleterious effects of salt on microorganisms (Rietz, Haynes 2003). The detrimental impact of salty water on plants results in a reduction in soil organic matter and microbial activity (Singh 2016). The results align with the meta-analysis conducted by Song et al. (2016). The response of soil organisms to various fertilizer treatments has shown significant variations due to changes in the physicochemical properties of organic amendments. The microbial and dehydrogenase enzyme activity of soil is influenced by soil hardness, concentration of cellulose and hemicellulose, and carbon (C) content. The variability in the activity of dehydrogenase enzymes in soils may be attributed to fluctuations in the soil's redox potential and the composition of the microbial community (Deng, Tabatabai 1997).

The potential link between optimal cotton-growing conditions and elevated urease enzyme activity in non-saline soils might be the breakdown of organic residues. The structural instability of salt-affected soils is attributed to the decreased concentration of organic matter. Multiple research investigations have shown that the inclusion of organic waste in soils leads to a significant improvement in their structural stability (Tejada et al. 2006, Sakin et al. 2021, Cevheri et al. 2022). The observed differences in urease activity between saline and non-saline soils may be due to the occlusion of some pores and the limited availability of oxygen in the soil. This phenomenon can be attributed to the high clay content and dispersion characteristics of the saline soil used in the experimental setup. The incorporation of CSM into saline soil effectively alleviated the adverse impacts of salinity on the soil microbial community and mineralization processes. The impact of organic materials on the activity of the urease enzyme has been shown to differ depending on the specific kind of organic material, the characteristics of the soil used, and the crops grown in the experimental setting (Tiwari et al. 1989). Nevertheless, Albiach et al. (2001) did not show any statistically significant differences between the experimental and control groups during a decade-long field trial examining urease activity. Zantua et al. (1977) observed that the introduction of different plant waste resulted in an increase in urease activity when compared to the control group. However, no significant association was reported between this increase in urease activity and the presence of organic waste. Deng and Tabatabai (1997) suggested a potential relationship between soil management practices and the observed levels of enzyme activity in the soil.

The enzyme dehydrogenase (DHG) plays a pivotal role in comprehending the microbial activity inside soil (Salazar et al. 2011, Yuan, Yue 2012). DHG activity is used for assessing the dynamic microbial activity in soils, and it has been shown to have a robust association with extracellular enzymes generated by microorganisms and subsequently bound to soil colloids. The strength of this link is influenced by several factors, including soil organic matter, soil colloids, clay content, and environmental variables (Frankenberger, Tabatabai 1991). The DHG activity serves as a reliable measure of biological activity, making it a valuable indicator of soil fertility. There is a significant correlation between DHG activity and soil fertility, wherein the former serves as an indicator of the biological activity within soils (Boguslawski et al. 1976). The DHG exhibits activity in a diverse range of oxidative reactions that are accountable for the dehydrogenation of organic substances (Włodarczyk et al. 2002). There is a strong positive association between the organic matter content in soils and the average activity of DHG (Camiña et al. 1998). The DHG activity has a strong association with the release of CO_2 from soil (Ross 1971).

Catalase is an enzymatic defence mechanism that facilitates the conversion of hydrogen peroxide into water and oxygen, so effectively neutralizing its potential to cause harm to cellular constituents. The catalytic activity of the catalyst enzyme is significantly relied upon many aerobic microorganisms, plant cells, and animal cells (Nicholls et al. 2000). The decreased catalase activity in saline soils may be attributed to reduced abundance of microorganisms within such environments. The increase in soil salinity leads to a reduction in microbial growth and activity due to the osmotic stress imposed on microorganisms, resulting in their dehydration (Oren 1999). Two stress reactions to increased soil salt levels include heightened catalase activity and decreased microbial activity. The findings of this study indicate that the enzyme activities examined were adversely affected by soil salinity. Garcia and Hernindez (1996) reported comparable findings as of current study.

The addition of organic compounds has the potential to enhance soil quality by increasing nutrient levels within the soil. The negative impact of saline soils has been mitigated with the improvement in soil quality. Almaroai and Eissa (2020) and Rekaby et al. (2020) observed that the introduction of organic matter into soil resulted in elevated levels of plant-accessible nutrients, enhanced soil microorganism and enzyme activity, and improved physicochemical properties of the soil. Consequently, these findings indicate a positive impact on soil quality. The use of CSM in the current study led to notable enhancements in enzyme activity and nutritional levels. The presence of a substantial amount of organic matter in CSM probably facilitated the proliferation of several beneficial bacterial species. Microorganisms are responsible for the production of several organic acid compounds, which fulfil crucial functions in the processes of nutrient cycling and plant growth (Singh et al. 2019, Cui et al. 2021). The extraction of nutrients from the soil during cultivation is significantly reduced in saline environments compared to non-saline conditions due to the inhibitory effects of salinity on plant growth. The presence of organic matter mineralization and limited nitrogen consumption in saline soils may potentially contribute to the elevated levels of N seen in such soils (Cevheri et al. 2022).

The positive impact of CSM on soil quality and plant growth in saline soil conditions was manifested by the increased levels K, Ca, Mg, B, and Mn. The observed effects on plant growth in the conducted experiment may be ascribed to the reduced Na content in the soil. The application of CSM resulted in an increase in the soil organic carbon content, which subsequently promoted the release of nutrients and improved the physicochemical properties of the soil. This enhancement ultimately led to an increase in microbial activity (Ding et al. 2020). The application of CSM has the potential to augment the nutritional composition of the soil, thus leading to an increase in the population of soil-dwelling organisms. An increase in microbial activity results in an increase in enzyme activity, hence enhancing plant growth via the facilitation of nutrient absorption (Sadegh-Zadeh et al. 2018, Rajput et al. 2019). The incorporation of cottonseed meal is expected to have improved the soil chemistry and structure. The incorporation of CSM resulted in a reduction of the adverse impact caused by salts and contributed to the alleviation of the negative outcomes associated with salinity. The introduction of organic matter into the soil resulted in an improvement of soil quality, as it led to an increase in the accessibility of essential nutrients within the soil (Eissa, Abeed 2019, Rekaby et al. 2020, Sakin et al. 2021, Cevheri et al. 2022).

The cotton plants grown in soil with high salinity had a higher total sugar content in comparison to their counterparts grown in non-saline soil. Prior studies have shown a positive correlation between elevated soil salt levels and an increase in the total sugar content of plants. The osmotic potential of plants may rise by as much as 50% when they are subjected to excessive salinity due to the accumulation of soluble carbohydrates (Parvaiz, Satyawati 2008). The sugar content of cotton plants might potentially be influenced by the decreased Ca concentration seen in saline soils. The phenomenon of carbohydrate increases in plants experiencing Ca deficiency was also seen and recorded by Whitenberg and Joham (1964). The findings of this investigation support the results obtained in the previously described study. Increased soil Ca levels resulted in a decrease in the total sugar content of cotton plants in the current study. The application of organic amendments to the soil may have served to alleviate the adverse impacts of salinity. This may be explained by considering the influence of Ca resulting from the decomposition of organic waste.

The presence of high levels of salts in the soil has been seen to have an impact on the concentration of phenol in the leaves of plants (Rezazadeh et al. 2012). Cotton plants cultivated on saline soils had a higher phenol content in comparison to those cultivated in non-saline soils. The problem of soil salinity in arid regions is a significant concern, notwithstanding the multitude of factors that impact plant phenolic compound levels (Smirnoff 2005). The phenol content of plants gradually decreased with the addition of organic residues (Formagio et al. 2015). Plants accumulate phenol chemicals in response to salinity stress. Numerous studies have shown that salt stress reduces the accumulation of antioxidants in plant tissues (Navarro et al. 2006, Ksouri et al. 2007). The application of CSM has been shown to potentially reduce the osmotic pressure inside the root zone, resulting in increased utilization of water and nutrients. The treatment of organic waste is also expected to have had a significant influence on mitigating the adverse effects of salt and alkalinity-inducing factors (such as soluble and exchangeable sodium, sodium adsorption ratio, and electrical conductivity) within the area around plant roots. The findings of the current study align with the outcomes of several prior examinations (Raychev et al. 2001, Mahdy 2011).

A favourable association has been observed between the application of fertilizer treatments and all growth indices. However, the interaction between soil and a fertilizer dose did not have a meaningful effect. Plants experience initial detriment in their root systems upon exposure to elevated quantities of salt. The root zone experiences excessive osmotic pressure, and therefore plants will be unable of effectively using the available plant nutrients and water, despite their presence in the soil solution. Nevertheless, the deleterious effects of salinity might potentially be alleviated by the enhancement of the soil's biochemical properties via the process of mineralization, wherein certain organic waste materials are incorporated into the soil. This phenomenon might perhaps be attributed to the potential benefits of fertilizing saline soils, which may contribute to the enhancement of the content of both organic and inorganic constituents of the soil. The results agree with the findings reported by Hossain and Sarkar (2021). The increased root and height growth seen in plants supplied with CSM may be attributed to its elevated available N concentration (Yadav et al. 2019, Hossain, Sarkar 2021, Sakpal et al. 2021). Zhang et al. (2020) indicated that the use of organic fertilizer treatments resulted in significant modifications to the root morphology and physiological characteristics of cotton plants. Additionally, the application of CSM has been shown to enhance the absorption of water and nutrients by reducing the osmotic pressure inside the root zone. The organic wastes have the potential to improve soil properties in the plant root zone by reducing salinity and alkalinity, as well as lowering the levels of soluble and exchangeable Na, sodium adsorption ratio and electrical conductivity (Raychev et al. 2001, Mahdy 2011).

CONCLUSIONS

The presence of salt in soil exerts detrimental effects on soil microorganisms and their activities. Nevertheless, an application of organic fertilizers, such CSM, might potentially mitigate this negative impact and promote microbial health. The incorporation of CSM in the soil enhanced the capacity of soil microorganisms to effectively cope with osmotic stress by supplying more energy required to sustain their metabolic functions. The results indicated that CSM has the potential to serve as alternatives or supplements to compost and chicken manure. Further research is needed to investigate the effects of organic residues, such as CSM, in both field and greenhouse environments. An additional investigation is necessary to ascertain the impact of organic additions on the microbial composition and enzyme activities in soil, considering the significant correlation between soil biological activities and soil quality.

Author contributions

V.B. – conceptualization, data curation, formal analysis, funding acquisition, investigation, C.I.C. – methodology, project administration, resources, E.R. – software, supervision, validation, S.C. – visualization, writing – original draft, E.S. – writing – review and editing. All authors have read and agreed to the published version of the manuscript.

Conflict of interests

The authors declare that there are no conflicts of interest related to this article.

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