T.R.
ONDOKUZ MAYIS UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF SOIL SCIENCE AND PLANT NUTRITION

IMPROVEMENT OF SOIL PROPERTIES USING BIOCHAR AND COMPOST UNDER SALT STRESS

Master's Thesis

Mahmuda BEGUM

Supervisor
Prof. Dr. Coşkun GÜLSER

II. Supervisor

Prof. Dr. Violina ANGELOVA

SAMSUN
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SAMSUN
2023

ACCEPTANCE AND APPROVAL OF THE THESIS

The study entitled **"IMPROVEMENT OF SOIL PROPERTIES USING BIOCHAR AND COMPOST UNDER SALT STRESS"** prepared by **Mahmuda**, and supervised by **Prof. Dr Coşkun GÜLSER and Prof. Dr. Andon ANDONOV** , was found successful and unanimously accepted by committee members as Master thesis, following the examination on the date 15.8.2023 .

	Title Name SURNAME **University** **Department/Art**	**Final Decision**
Chairman	Prof. Dr. Coskun GULSER Ondokuz Mayis University Department of Soil Science and Plant Nutrition	☒ Accept ☐ Reject
Member	Prof. Dr. Andon ANDONOV Agricultural University Plovdiv Department of Plant Physiology, Biochemistry and Genetics	☒ Accept ☐ Reject
Member	Prof. Dr. Ridvan KIZILKAYA Ondokuz Mayis University Department of Soil Science and Plant Nutrition	☒ Accept ☐ Reject

This thesis has been approved by the committee members that already stated above and determined by the Institute Executive Board.

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Prof. Dr. Ahmet TABAK
Head of Institute of Graduate Studies

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I hereby declare and undertake that I complied with scientific ethics and academic rules in all stages of my Master's Thesis , that I have referred to each quotation that I use directly or indirectly in the study and that the works I have used consist of those shown in the sources, that it was written in accordance with the institute writing guide and that the situations stated in the article 3, section 9 of the Regulation for TÜBİTAK Research and Publication Ethics Board were not violated.

Is Ethics Committee Necessary?

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No ☒

13/07/ 2023
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Thesis Title : IMPROVEMENT OF SOIL PROPERTIES USING BIOCHAR AND COMPOST UNDER SALT STRESS

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23 /08 / 2023
Prof. Dr. Coşkun GÜLSER

ÖZET

BİYOÇAR VE KOMPOST KULLANARAK TUZ STRESİ ALTINDAKİ TOPRAKLARIN ÖZELLİKLERİNİN İYİLEŞTİRİLMESİ

Mahmuda BEGUM
Ondokuz Mayıs Üniversitesi
Lisansüstü Eğitim Enstitüsü
Toprak Bilimi Ve Bitki Besleme Ana Bilim Dalı
Yüksek Lisans, Temmuz/2023
Danışman: Prof. Dr. Coşkun GÜLSER
II. Danışman: Prof. Dr. Violina ANGELOVA

Tuzluluk için toprak düzenleyicileri olarak biyoçar ve komposta artan ilgiye rağmen, bunların tuzlu ve sodik toprak üzerindeki etkilerine ilişkin hala bir bilgi eksikliği bulunmaktadır. Bu çalışmada, biyoçar ve kompostun toprağın iyileştirilmesinde rol oynayabileceğini ve bunun da ürün verimini artırabileceği hipotezi kabul edilmiştir. Bioçar ve kompostun toprak ve ürün verimi üzerindeki etkilerini kontrol etmek için test bitkisi olarak buğday kullanılarak iki aylık bir sera denemesi yapılmıştır. Tuzlu, tuzlu-alkali ve alkali olmak üzere üç tür toprak tipi hazırlanmış ve düzenleyiciler bioçar, kompost, bioçar + kompost olarak deneme kurulmuştur. Sera denemesi sonunda, bitkiler hasat edildi ve bitki verim parametreleri kaydedilirken, daha fazla laboratuvar toprak kimyasal analizi için toprak numuneleri alındı. Alkali toprağın, tuzlu toprağa kıyasla bitki biyokütlesini çok önemli düzeyyde etkilediği kaydedilmiştir. Toprağın kimyasal analizine yönelik bulgular, tüm toprak türleri (Tuzlu, Tuzlu-alkali, Alkali) ve tüm katkı maddeleri (biyoçar, kompost) için OC, Ca, Mg, K'nin artan bir trend gösterdiği ve EC ve Na'unn düşüş eğiliminde olduğu linear bir sonuç gösterdiği ve toprak için faydalı oldukları belirlenmiştir. Öte yandan, bitkiler için yapılan kimyasal analiz sonucu, Ca, Mg, K ve P için pozitif etki gösterirken, mikrobesinler (Cu, Zn, Fe, Mn), tuzlu toprak için gözle görülür bir gelişme göstermezken, tuzlu alkali için hafif ve orta derecede değişiklik göstermiştir. Biochar ve kompost, sodyum ve EC'yi azalttı ve toprak durumu için iyi olan besin kullanılabilirliğini artırdı. Sonuçlar, biochar, kompost ve kompost + bioçar'ın tuz stresi üzerinde dikkate değer bir etkiye sahip olduğunu göstermektedir.

Anahtar Sözcükler: Tuzluluk, Organik madde, toprak düzenleyicileri, alkalilik, bitki besin maddeleri

ABSTRACT

IMPROVEMENT OF SOIL PROPERTIES USING BIOCHAR AND COMPOAT UNDER SALT STRESS

Mahmuda BEGUM
Ondokuz Mayıs University
Institute of Graduate Studies
Department of Soil Science and Plant Nutrition
Master, July/2023
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There is still a lack of knowledge regarding their effects on saline and sodic soil despite the growing interest in biochar and compost as soil amendments for salinity. We hypothesized that biochar and compost can play a role in the betterment of soil in turn have improved crop yield. A two-month green-house experiment was conducted using wheat as an indicator plant to check the effects of biochar and compost on the soil and yield of the crop. Three kind of soil types were taken these are saline, saline-sodic, and sodic and amendments are biochar, compost, biochar + compost. Thereafter, plants were harvested, and plant yield parameters were recorded while soil samples were collected for further lab soil chemical analysis. It was noted that sodic soil influenced the plant biomass most compared to saline soil. Findings for chemical analysis of soil showed positive result that is OC, Ca, Mg, K has increasing trend where EC and Na had decreased trend for all soil type (Saline, Saline-sodic, Sodic) and all amendments (biochar, compost, compost + biochar) which means these are beneficial for soil. On the other hand Result of chemical analysis for plants showed positive effect for Ca, Mg, K and P where Micronutrients (Cu, Zn, Fe, Mn) exhibited no noticeable improvement for saline soil where it is slight change for saline sodic and moderate for sodic soil for every treatment. Biochar and compost decreased sodium and EC and increased nutrient availability which is good for soil condition. Results suggest biochar, compost, and compost + biochar had remarkable effect on salt-stress.

Keywords: Salinity, Organic matter, soil amendments, sodicity, plant nutrientents

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Mahmuda BEGUM

CONTENTS

SYMBOLS AND ABBREVIATIONS

pH	:Power of Hydrogen
EC	:Electrical Conductivity
K	:Control
B	:Biochar
C	:Compost
B + C	:Biochar + compost
SP	:Soil + Planting
S	:Saline
S-Na	:Saline-Sodic
Ca	:Calcium
Mg	:Magnesium
K	:Potassium
P	: Phosphorus
Fe	:Iron
Zn	:Zinc
Cu	:Copper
Mn	:Manganese
OC	:Organic Carbon
S	:Soil
SP	:Soil + Planting

FIGURES LEGENDS

TABLES LEGENDS

1. INTRODUCTION

The frightening threat posed by the world's population issue has caused an increase in crop production requirements. Improving agricultural production quality and quantity is required to fulfill the food needs of a rising population. The growth and development of plants are inhibited by abiotic stresses. Salt stress is one of the most serious restrictions to crop yield. Rhoades and Loveday 1990 report that high salt concentrations damage 7% of the world's land surface, 20% of cultivated land, and over half of irrigated land (Rhoades and Loveday, 1990). It is anticipated that the proportion of saline soil is increasing at a 10% annual growth rate, and that by 2050, more than 50% of global arable lands may be threatened to different extents by soil salinity (Jamil, Riaz et al. 2011). The osmotic pressure in the soil solution of roughly 0.2 MPa occurs when the electrical conductivity of the soil solution exceeds 4 dS m-1 (equivalent to 40 mM NaCl) (Munns and Tester 2008).

The buildup of much salts in the soil profile to the point that they impede plant development is known as soil salinization. Agriculture has been faced with this serious environment challenge since the beginning of time (Rengasamy 2006). The impacts of salt stress on soil's physical, chemical, and biological characteristics have a direct impact on plant development. The adverse effects of salinity might take the form of induced water stress, ion toxicity, or an imbalance of ions, or they can be a mix of all three. The annual cost to the world economy of crop failure in irrigated agriculture is estimated to be $27.2 billion owing to the deterioration of land caused by salt (Qadir, Quillérou et al. 2014).

There are several ways in which excessive soluble salts affect the soil's physicochemical and biological properties As soon as salt stress is detected, the root system reacts. By reducing water availability, salt stress causes osmotic stress, which slows plant growth in the short term. Eventually, salt stress inhibits plant growth by generating salt-induced ion toxicity, which results from a nutritional imbalance in the cytosol (Munns 2005).

Plants are unable to germinate seeds, grow, and develop, as well as flower and fruit when exposed to salt. (Quan, Lin et al., 2007). High sodium concentrations in saline soil inhibit a plant's ability to absorb water and nutrients [10]. (Gong 2021). The cumulative effect of salt stress is to cause a range of modifications at the physiological and molecular levels, to hinder plant development by stopping photosynthesis and, as

a result, reducing the amount of resources that are available, and to inhibit cell division and expansion (Van Zelm, Zhang et al. 2020)
(Rozelle and Huang, 1998) estimate that wheat is the third most widely cultivated cereal after rice and maize in the tropical and subtropical regions of the world. Wheat, like all grains, is high in proteins and carbohydrates, according to the Ministry of Food, Agriculture, and Livestock (2007). The human diet is primarily composed of proteins and carbohydrates. Wheat is an essential source of carbohydrates (55%), and it also provides 20% of food requirements (Bos, Juillet et al. 2005). According to McCance, Widdowson, and others in 1945, wheat, like all other grains, has an abundance of proteins and carbohydrates. Proteins and carbohydrates are generally regarded as the chief sources of energy in the human diet. (McCance, Widdowson et al. 1945). Because precipitation throughout the winter wheat developing season is usually inadequate to fulfill water demands for desired yields, the production of winter wheat is significantly reliant on supplementary irrigation in arid and semi-arid locations(Wang, Yang et al. 2015, Attia, Rajan et al. 2016, Tari 2016). This is because dry and semi-arid regions have a lower average annual precipitation. Due to increasing dry weather brought on by present-day climate change and greater competition for water consumption in urban and industrial sectors, the freshwater deficit is becoming the most significant barrier to the production of winter wheat in these locations (Zhang, Qin et al. 2017). Winter wheat production in these regions is being impacted by this shortage. Previous studies have shown that irrigating wheat with salty water at the phases of its growth when it is most susceptible to drought may result in a better grain yield than not irrigating at all. However, irrigation with salty water may make the risks of soil salinity and sodicity buildup worse, which can lead to problems with the structure of the soil, the surface crust, and infiltration.

In order to produce biochar with the desired physical and chemical qualities, the pyrolysis parameters and the kind of biomass materials used need to be determined (Qayyum, Abid et al. 2015). All biomass is a source of energy (Mazac 2016), including agricultural waste, bioenergy crops, forest leftovers, and kitchen trash. The accumulation of biochar to saline-sodic soil has the potential to assist in the restoration of the soil by adding Ca^{2+} and $Mg2^{+}$, as well as enhancing aggregate stability, hydraulic conductivity, and Na+, and perhaps accelerating leaching (Chaganti, Crohn et al. 2015). Biochar soil amendment benefits nutrient-poor soils more than fertile soils(Verheijen, Jeffery et al. 2017). Furthermore, it has been shown that biochar may boost plant biomass, nutrient absorption, agricultural yield components, and disease control (Liu, Zhang et al. 2013, Ma, Egamberdieva et al. 2019). These benefits can be attributed to biochar.

In addition, the addition of biochar to soil improves plant development by increasing the levels of organic carbon and nutrients, as well as the cation exchange capacity and hydraulic conductivity of the soil (Lu, Li et al. 2015) (Akhtar, Andersen et al. 2015, Lu, Li et al. 2015). Potassium ions are increased when biochar is incorporated into soils that have been impacted by salt. This, in turn, lessens the amount of salt stress that is experienced by the plants growing in such soils (Drake, Cavagnaro et al. 2016, Usman, Al-Wabel et al. 2016)

According to Tejada, Garcia et al. (2006), composting has the ability to change both the physical and chemical characteristics of soil, which results in an increase in the soil's potential to foster the development of plants. On salty soils, the use of composted straw or manure from the barnyard was shown in a number of earlier experiments to result in significant increases in crop yields (Tahir, Shahid et al. 1991, Gaffar, Ibrahim et al. 1992).

The objectives of this studies

a. To understand the remediation potential of biochar and compost in alleviating salt stress
b. To know the effect of biochar and compost wheat.
c. To compare individual affect of biochar, compost and combined application of biochar and compost in soil and plant.

2. LITERATURE REVIEW

2.1. Salt stress

The vast majority of cultivated crops that are planted for the purpose of providing sustenance for humans and animals are susceptible to abiotic stresses, and as a direct consequence of inadequate plant nutrition, their output has considerably dropped. According to Mwando, Angessa et al. (2020) research from 2020, salinity levels that are too high may lead to nutritional deficiencies as well as imbalances in the elements nitrogen, calcium, potassium, phosphorus, and zinc. Growing plants in soil, water, and environmental conditions can influence their capacity to withstand soluble salts in the root media. Plants may be able to cope with salt stress at different stages of growth and development. A recent study has demonstrated that cereal crops in their vegetative and early reproductive stages are more vulnerable to salt stress. A variety of crops must be measured throughout crucial development stages for the effect of salt stress on their yields (Maas 1993). According to Greenway and Munns (1980), the specific impacts of certain ions may induce direct toxicity, or ion insolubility or competitive absorption can upset the plant's nutritional balance. In contrast, there is an increase in proline and water-soluble carbohydrate (Shamsi and Kobraee 2013) when salt concentration is increased. Increased salt concentration decreases the number of grains per spike, the number of grains per spikelet, grain yield, and plant height; however, it increases the amount of grain yield and relative water content. According to Ben-Laouane, Baslam et al. (2020) research, an excessive amount of salt in soil solution disrupts all of the physiological and biochemical processes that plants engage in, including photosynthesis, respiration, nutritional imbalance, and osmotic adjustment.

Salt stress has a number of different effects on the physiological systems of plants, including an increased respiration rate and ion toxicity, changes in the development of plants, changes in the distribution of minerals, and membrane instability brought on by sodium dislodging calcium. (Marschner 1986),(Mwando, Angessa et al. 2020)

A plant's development and expansion are adversely affected by salt stress because of the inhibition of cell division and expansion. In maintaining the form and function of the cell, the cell wall protects it against the damaging effects of salt stress. The cell membrane is the second line of protection (Van Zelm, Zhang et al. 2020). Plants' cell walls are widely considered to be one of the earliest indicators of salt stress (Zhao, Zhang et al. 2021).

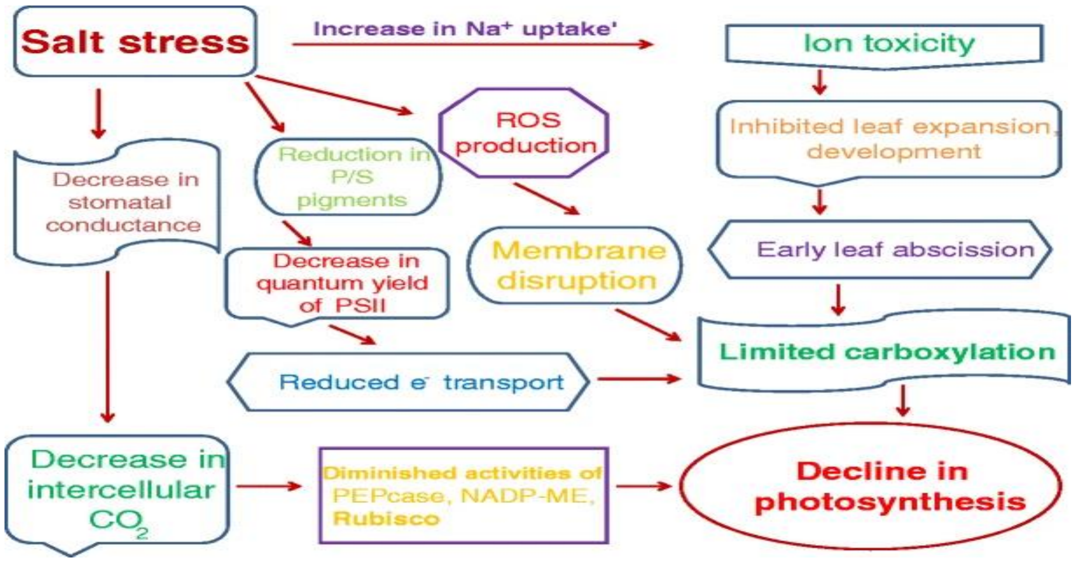

Figure 2.1: Effect of salt stress on plant growth

Source: (Farooq, Hussain et al. 2015)

Inhibition of growth is the predominant kind of damage that leads to additional symptoms, but programmed cell death may also take place under severe salt shock conditions. Adding salt to the soil increases the production of abscisic acid, which when delivered to guard cells closes stomata. Photosynthesis is reduced when stomata close, and oxidative stress and photoinhibition are also experienced. Potassium nourishment may be disrupted by excessive sodium ions at the root surface. With similar chemical structures, sodium inhibits potassium's absorption by roots because it inhibits the binding of potassium ions to sodium ions. A nonselective cation channel mediates sodium import, and calcium has been shown to directly inhibit that import. (Jouyban, n.d.). A study carried out by Jeffery, Verheijen et al. (2011) and Levi 1992 found salts retarded germination in seed tubers and potatoes seeds (Levy 1992).

It was discovered that the salt gradually reduced both the size of the marketable tubers and the quantity of tubers generated by each plant. Tubers of both sizes and quantities produced fit this pattern. In salt-treated plants, the reduced yield is likely due to a reduction in the number of marketable tubers they produce as well as a reduction in tuber weights (Ghosh, Asanuma et al.2001).

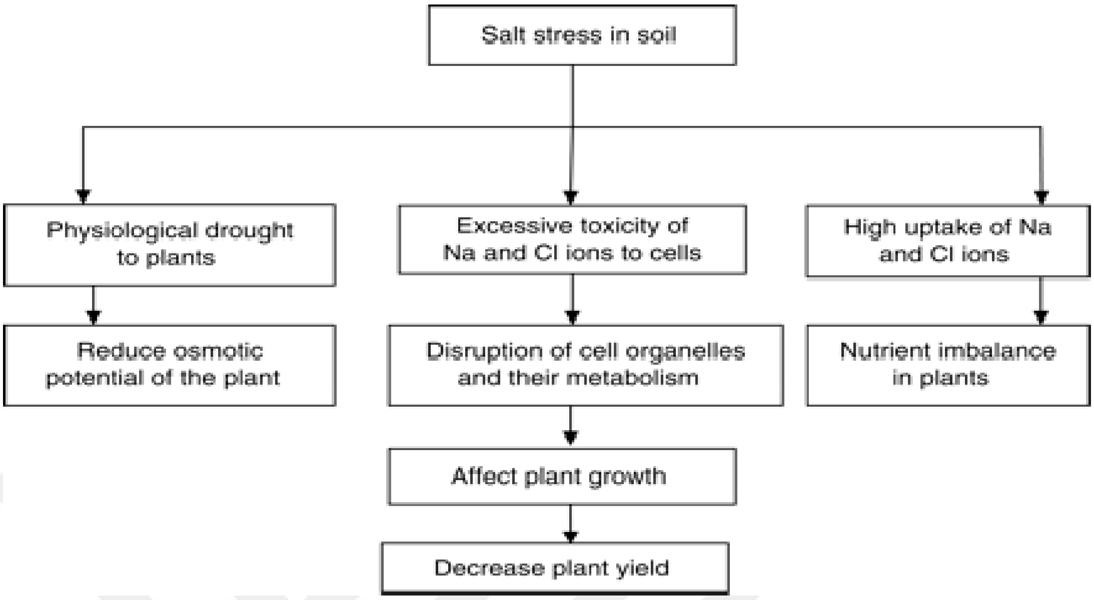

Figure 2.2: Impact of salt stress on plant

(Evelin, Kapoor et al. 2009)

In direct response, salt stress adversely affects a plant's growth and yield as well as a number of other aspects of its metabolism. If there is an excessive quantity of salt in the soil solution, it may restrict the osmotic absorption of water by the roots of the plant as well as cause specific ion effects, all of which can have a negative influence on the development of the plant (Yildirim, Taylor et al. 2006).

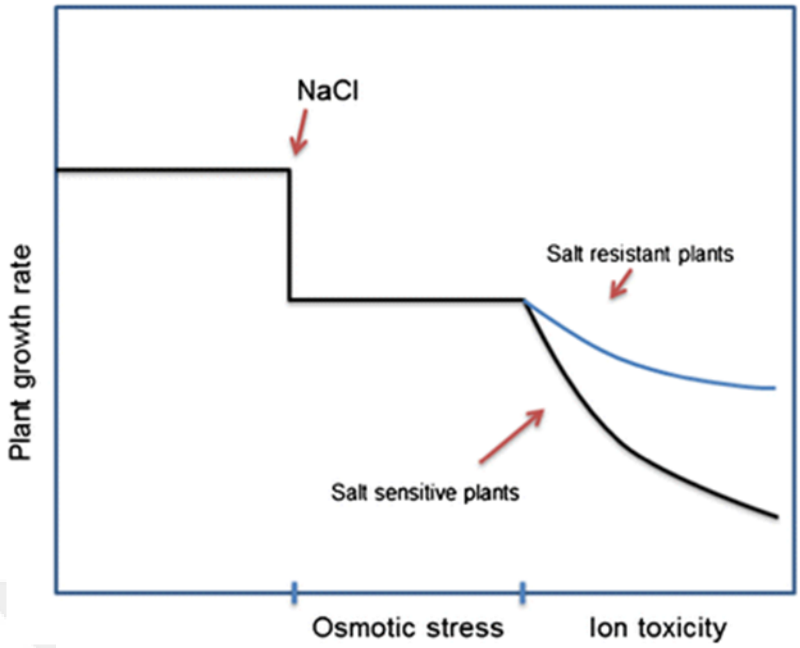

Figure 2.3: Effect of NaCl on plant growth

Source. (Farooq, Hussain et al. 2015)

2.2. Biochar and its effect on salt stress

Biochar is made through pyrolysis, the heating of biomass with oxygen-limited conditions. Temperatures of up to 1000 °C occur during pyrolysis, water evaporates, and biomass is transformed into char. This procedure utilizes carbon-rich biomass such as wood, manure, and crop residues. (Verheijen, Jeffery et al. 2010), there are many types of biochar that are produced from forestry, agriculture, and food processing biomass, such as wood chips, crop leftovers, sewage sludge, and dairy manure. In addition to improving soil quality, biochar can be used as a soil amendment.

In the pyrolysis process, organic chemicals are converted into biochar, a material similar to charcoal, by burning them. According to Akhtar, Andersen et al. (2015) research, the agricultural industry has shown a large level of interest in the process of recovering highly deteriorated or damaged soil in order to assure continuing crop production. Biochar is recognized not only as a kind of organic fertilizer but also as a form of activated carbon that may be used to amend soil. This is one of the items that will be changed in the amendment. According to Kanwal, Ilyas et al. (2018) research, biochar is hypothesized to have a high cation-exchange capacity and to have a naturally alkaline composition. According to the results of (Thomas, Frye et al. 2013), the inclusion of biochar into soil has the ability to alleviate or even reverse the adverse effects of salt on plant development. This is the conclusion drawn from the research conducted by Thomas, Frye et al. The fundamental impact that salinity has is to reduce the amount of carbon inputs, which in turn lowers the amount of biomass produced. According to (Ali, Rizwan et al. 2017), the application of biochar, which is a carbon-rich byproduct of the burning of biomass, improves carbon inputs, which in turn minimizes the detrimental effects of salt stress on plants. Biochar's ability to improve soil physical, chemical, and biological properties was demonstrated by Akhtar, Andersen et al. (2015) when applied to salt-affected soils.

According to Lehmann and Joseph (2015), biochar might be applied to salt-affected soil in the capacity of a soil amendment. Biochar has shown to be helpful in improving salt-damaged agricultural land (Lashari, Liu et al., 2013). A study by Kanwal, Ilyas et al. (2018) investigated biochar's impact on wheat seed germination and growth metrics under salt stress. Both amounts of biochar enhanced germination and growth in spite of the presence of salt (Kul, Arjumend et al. 2021). In research that was carried out in soils that were either saline (100 M) or non-saline (control), three different concentrations of biochar were applied: 0, 5, and 10% (v/v). The research indicated that while salt stress had a negative influence on plant development regardless of the concentration of biochar used, treatments consisting of 5% and 10% biochar improved plant performance in general. Akter et al. In a greenhouse with climatic control, a pot experiment was carried out to investigate the effects of salt stress on the development, physiology, and yield of potatoes. Biochar was used as the amendment. In addition, an adsorption examination was carried out with the purpose of determining the Na^+ adsorption capability of biochar. Using biochar, researchers found that salinity stress could be minimized by absorbing Na^+. A significant reduction in shoot biomass, root length and volume, tuber yield, photosynthetic rate (An), stomatal conductance (GS), and midday leaf water potential was found in this study when the salinity level was increased. However, abscisic acid concentration in leaf sap and xylem sap increased as a result. The ameliorative benefits of biochar on potato plants subjected to salt stress were proven by a decreased amount of sodium, a decreased ratio of sodium to potassium, and an increased amount of potassium content in the xylem.

It has also been suggested that adding biochar to salt-affected fields and increasing plant salt tolerance may be accomplished successfully via the use of an effective approach called amendment. It was found that increased water retention capacity of the soil, increased nutrient retention, enhanced enzyme activity of the soil, and increased microbial community diversity were a few of the results (Egamberdieva, Alaylar et al. 2022).

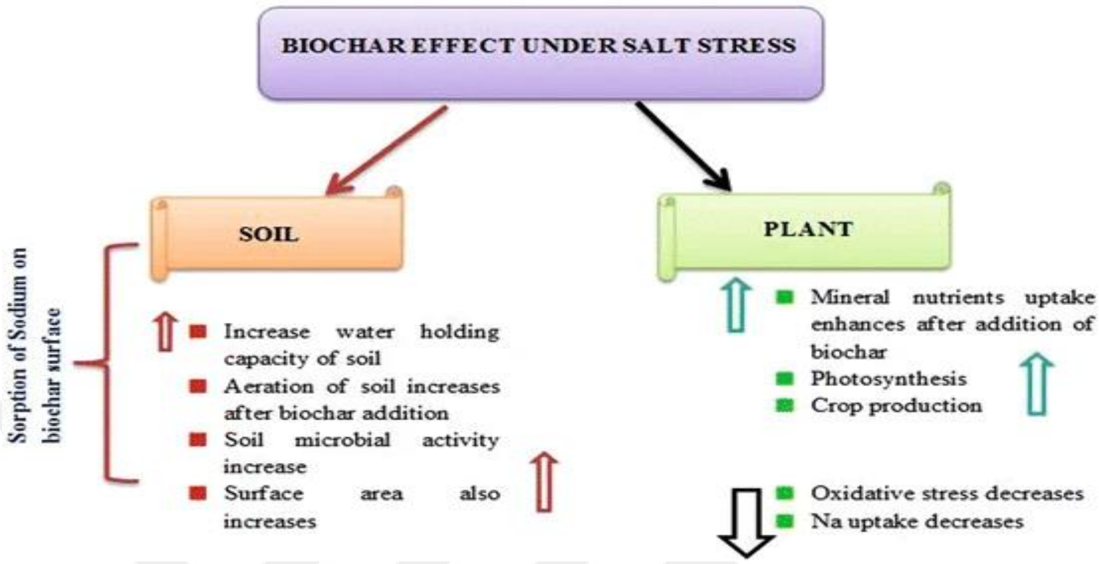

Figure 2.1: Effect of biochar on soil and plant under salt stress

Source: (Patel, Khare et al. 2017)

Adding biochar to plants reduced their ability to absorb sodium due to its high adsorption capacity. The soil solution was also enriched with mineral nutrients, including calcium, magnesium, and potassium, which reduced osmotic pressure by increasing soil moisture. When conditions with high levels of salt are present, adding biochar to wheat can improve its growth, physiology, and yield. In wheat that had been subjected to salt stress, it was discovered that biochar had a considerable residual impact on lowering the amount of sodium intake (Akhtar, Andersen et al. 2015).

2.3. Compost and its effect on salt stress

In areas that are affected by excessive salinity, the practice of adding organic fertilizers to soil has become quite common in recent decades and has expanded across the region. Particularly in arid and semi-arid environments, this method is seen as a possible environmentally friendly strategy for the regeneration of soil and the restoration of soil fertility (Scotti, Pane et al. 2016, Boutasknit, Ait-Rahou et al. 2021). The physiochemical properties of soil may be improved by the addition of compost, which is an organic substance that has through the decomposition process (Meena, Joshi et al. 2016). A significant amount of literature has been published in recent years on how compost can be used to reduce salt's negative effects (Ait-El-Mokhtar, Fakhech et al. 2022).The physiochemical properties of soil may be improved by the use of compost, which is an organic substance that has been broken down through the process of decomposition. Recent studies have focused a significant amount of emphasis on the use of compost as a way of minimizing the negative effects that are caused by salt. Compost can increase water infiltration, cation-exchange and water holding capacity, and aggregate stability in salt-affected soils by hastening the leaching of sodium ions (Na+), while lowering electrical conductivity and sodium exchange rates (Wang, Sun, et al. 2014). In addition, the introduction of organic materials into the soil has the potential to increase the soil's enzymatic activities, humic substances, minerals, and beneficial microbes. This, in turn, can improve the soil's nutrient availability, beneficial microorganism diversity, plant development, and tolerance to stress.

An absence of organic matter usually leads to physical, chemical, and biological problems in salinized and/or sodic soils. Water and nutrient storage skills have declined, soil aggregation is poor, cation exchangeable capacity is low, and microbial activity has decreased. A higher salt concentration is also typical for salinized and sodic soils (Xi 1998, Liang, Yang et al. 2003).

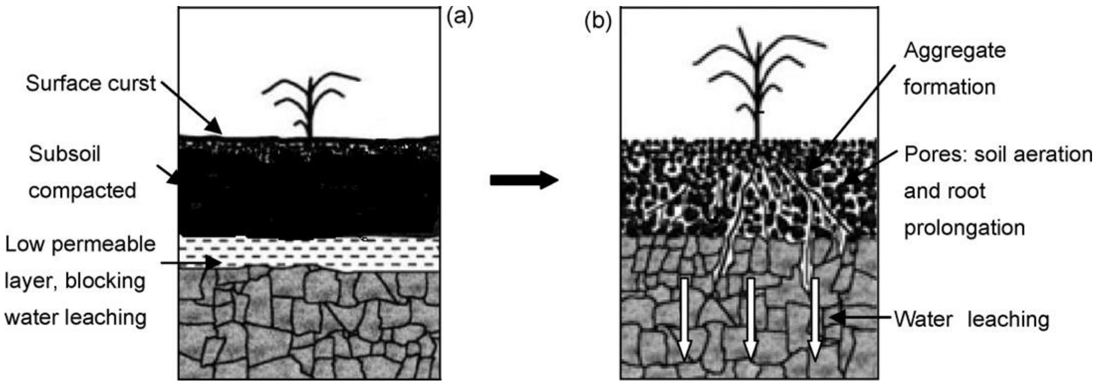

Figure 2.2: Before organic and after organic application

Source: (Lakhdar, Rabhi et al. 2009)

Soil fertility can be improved with compost, increase the crop's accessibility to nutrients, and promote healthy plant development while at the same time decreasing the detrimental effects that salt stress may have (Tejada and Gonzalez 2005, Çimrin, Türkmen et al. 2010). Additionally, according to Tejada and Gonzalez (2005), increasing the soil with the appropriate amount of organic matter (OM) causes an rise in soil bulk density, structural stability, and, as a result, soil microbial biomass in salty soils.

The plants that were cultivated in a salty environment had low values of growth qualities, whereas plants that had compost applied to them had higher values of these attributes (Ait-El-Mokhtar, Fakhech et al. 2022). The increasing salinity caused a rise in the concentration of sodium (Na+) and chlorine (Cl-) ions in plants, while at the same time causing a decrease in the absorption of phosphorus (P), nitrogen (N), potassium (K+), and calcium (Ca2+). The inclusion of compost helped to minimize these effects by increasing the concentrations of important components (P, K+, N, and Ca2+) in plant shoots and roots, as well as by reducing the toxicity caused by salt ions (Na+ and Cl-), which led to greater K/Na and Ca/Na ratios. According to the findings, the compost with an initial ratio of carbon to nitrogen is the kind of material that should be used as an amendment in order to reduce the level of soil salinity (Tejada and Gonzalez 2005).

3. MATERIALS AND METHODS

3.1. Setting up an experimental setup

During October and December 2022, the experiment was conducted at Ondokuz Mayis University in Samsun, Turkey, in a climate-controlled greenhouse. Pot experiment(size) and column study(size) were used for designing the experiment. The soil was collected from the agriculture experiment site of Ondokuz Mayis University. In the pot experiment, thirteen wheat seeds were planted in each pot, while three seeds were sown in each column containing 2 kg and 250g of soil. For the pot experiment, there are three replications with two types of containers, and for the column study, there are two replications. The soil was sieved through a 4 mm mesh. Biochar (2%), compost (2%), biochar + compost (2%) were used as amendments. None amended pots were served as controls. The climate conditions in the greenhouse were set at: humidity 80% or more, temperature 22℃

3.2. Collection and preparation of initial soil samples for chemical analysis

Soil samples were taken separately from the properly mixed soil before the experiment began. Soil samples were air dried on paper sheets. The air-dried soil was sieved with a 2-mm mesh. The processed samples were placed in polyethylene containers for storage Then, standard methods were used to analyze the soil samples for fundamental soil parameters such as pH, organic carbon, texture, EC, and nutrient status (available phosphorus, exchangeable potassium, calcium, magnesium, available sulphur, available zinc, available iron, and available manganese) as shown in Table 3.1.

Table 3.1: Analysis of soil parameters

Soil Parameter Analyzed	Methods of Analysis for Both Studies
Soil Texture	Hydrometer method (Bouyoucos, 1962).
Soil pH	Glass electrode pH meter method (Jackson, 1973)
Soil Organic Carbon (%)	Wet oxidation method (Walkley and Black 1934).
Electrical Conductivity (ds/m)	Ammonium acetate method (Jackson, 1973)
Calcium (meq/100g)	Ammonium acetate extraction
Magnesium (meq/100g)	Ammonium acetate extraction
Potassium (meq/100g)	Ammonium acetate extraction
Sodium (meq/100g)	Flame photometer

3.3. Data of initial analysis of soil

Table 3.2: Data from initial soil analysis

Soil Parameter	Salina soil	Saline sodic	Sodic
% sand	46.27	46.27	46.27
% silt	36.24	36.24	36.24
%clay	17.49	17.49	17.49
Texture	Loam	Loam	Loam
pH	7.3	7.45	7.89
Electricalconductivity (dS/m)	6.9	8.5	9.4
Organic carbon (%)	1.7	1.69	1.59
Exchangeable Ca (meq)	40.67	22.08	17.08
Exchangeable Mg (meq)	19.03	10.98	9.09
Exchangeable Na (meq)	2.9	6.02	10.01
Exchangeable K (meq)	1.2	0.9	1.3

3.4. Treatments

The experiment included 4 different treatment combinations, which are listed below:

T_0: Control (without any amendments)

T_1: Biochar

T_2: Compost

T_3: Biochar + Compost

The experiment was done with randomized complete block design. Biochar was from woodchip and compost was from tea waste. The soil was mixed with different salts artificially to different extents. The soil mixtures are a) Saline, b) Saline sodic, c) Sodic.

3.5. Irrigation and fertilization

Proper irrigation was done and taken data. Urea was applied two times throughout the experiment.

3.6. Harvesting

In both studies, the plants were harvested at heading stage. The plants were harvested on July 17, 2023. Harvested plants of each pot were placed in individual bags and labeled appropriately after taking yield data.

3.7. Collection and preparation of post-harvest soil

Soil samples were taken from each of the pots at the end of the experiments. In the laboratory of Soil Science, soil samples were spread out on paper sheets to air dry. The air-dried soil was ground and passed through a 2-mm sieve. Processed samples were kept in the small plastic container for further analyses.

3.8. Chemical analysis of post-harvest soil sample

The processed soil samples were analyzed for pH, OC, available P, exchangeable K, Ca, Mg, available Zn, available Fe and available Mn using standard methodology as presented earlier in table 1 .

3.9. Collection and preparation of plant sample

During the harvesting of the plants in both experiments, plant samples were collected. The wet samples were air-dried, whereas the dry samples were oven-dried for 72 hours sat 60 ± 2 ^{0}C temperature. Using a grinding machine, the samples were finely ground into powder. The samples were then placed in a desiccator for analysis.

3.10. Chemical analysis of plant sample

The amounts of Ca, Mg, P, K, Cu, Zn, Fe and Mn were quantitatively determined in the laboratory of OMU.

Table 3.3: Chemical analysis of plant parameter

Plant Parameter Analyzed	Methods of Analysis for Both Studies
Phosphorus (%)	dry-ashing procedure
Ca (%)	Atomic Absorption Spectrophotometry
Mg (%)	
Zn (ppm)	
Cu (ppm)	
Mn (ppm)	
Fe (ppm)	
K (ppm)	Flame photometer

3.11. Statistical analysis

The results of this experiment were evaluated statistically using the SPSS 17 program in a completely randomized plot design. The means of results were compared using the Duncan test at 0.01 and 0.05 levels.

4. RESULT AND DISCUSSION

4.1. Soil Analysis

4.1.1. Soil pH

The soil pH ranged from 7.30 to 7.89 (Fig. 4.1) Biochar consistently exhibited the highest significance level with pH values of 7.89, 7.87, and 7.72 in the different soil types.

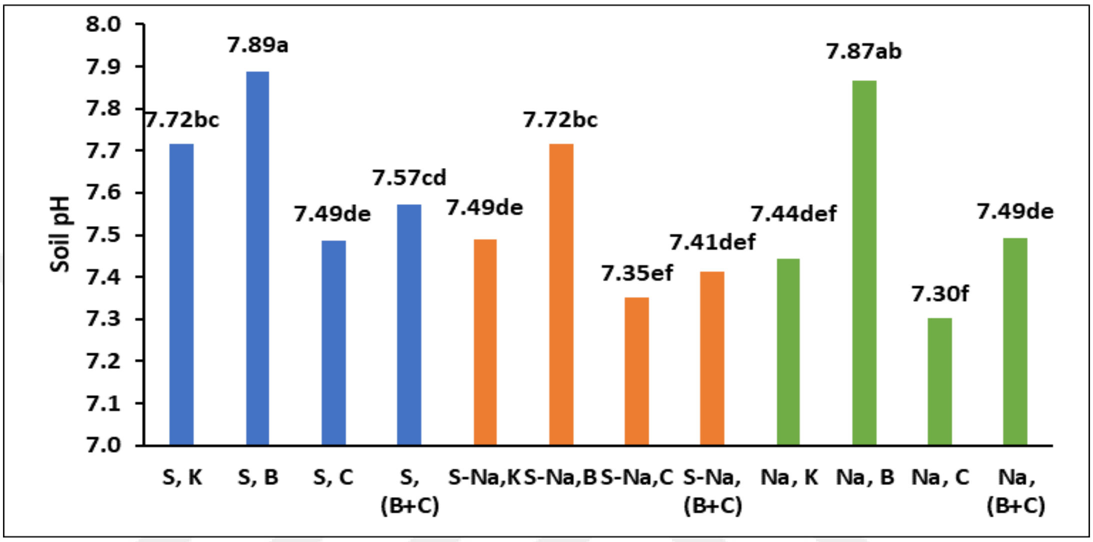

Figure 4.1: The amount of plant soil pH under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline,. Saline-sodic, Sodic) Lettering indicates significance level, Significance level 0.01

However, the addition of biochar and biochar + compost did not result in any significant differences compared to the control in any of the soil types. The higher pH values associated with biochar treatments indicate that biochar has an alkalizing effect on the soil. This is in line with previous research that suggests biochar can increase soil pH due to its alkaline nature and the release of basic cations during decomposition. The significance of these pH differences is important as soil pH plays a crucial role in nutrient availability and soil health. The observed significance in pH values with biochar treatments suggests that biochar has the potential to modify soil pH and impact nutrient availability and plant growth. According to Cooper, Greenberg et al. (2020) The soil pH rose proportionally to the increased amounts of compost and biochar. According to study of Phuong, Khoi et al. (2020) The application of compost resulted in the greatest increase in pH value that is aligned with or experiment. According to (Luo, Liu et al. 2017) In saline soils, composted biochar decreased the soil pH which is similar to our study.

4.1.2. Soil Electrical Conductivity (EC)

The application of amendments, specifically biochar combined with compost, resulted in a decrease in EC levels for all soil types (Fig. 4.2).

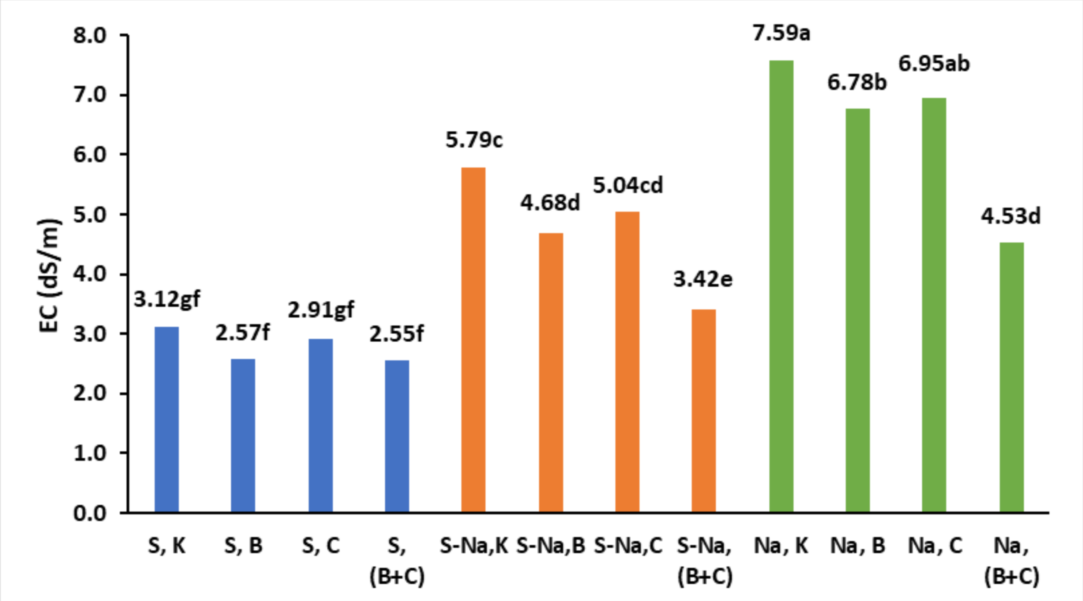

Figure 4.2: The amount of soil EC under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic)Letteringindicates significance level, Significance level 0.01

The EC values for biochar + compost was 2.55 dS/m, 3.42 dS/m, and 4.53 dS/m for the respective soil types. Additionally, biochar alone also contributed to lowering the EC levels, with values of 2.57 dS/m, 4.68 dS/m, and 6.78 dS/m for the respective soil types. Lowering the EC in soil is advantageous as it indicates a reduction in salt concentrations. High EC levels can negatively affect plant growth and restrict nutrient availability. By decreasing the EC, plants can better absorb water and nutrients, leading to improved growth and overall plant health. According to (Phuong, Khoi et al. 2020) EC increased significantly in compost treatment which does not align with our result. The reason might be the climate condition, species of crop, the intensity of amendments or the condition of soil.

4.1.3. Organic Carbon (OC)

The range of soil organic carbon observed in the study was from 1.48% to 3.64% (Fig. 4.3) Significant differences were found among the amendments and soil types. In saline soil, biochar, compost, and biochar + compost significantly increased organic carbon content. The values were 2.82%, 3.20%, and 3.11%, respectively.

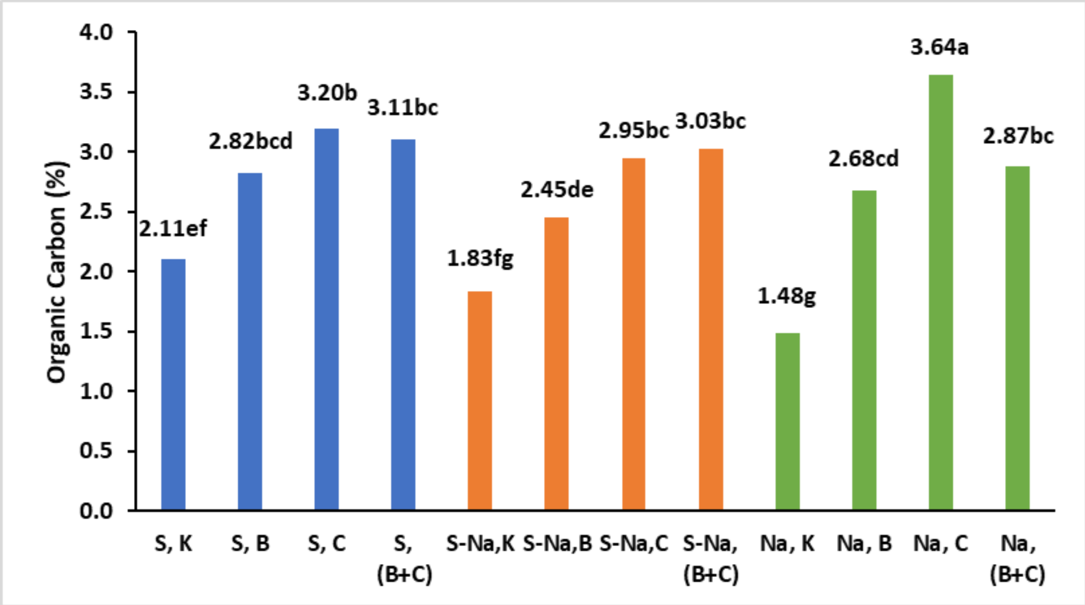

Figure 4.3: The amount of soil OM under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic) Lettering indicates significance level, Significance level 0.01

In saline sodic soil, all amendments showed significant increases in organic carbon content. The values were 2.45%, 2.95%, and 3.03% for biochar, compost, and biochar combined with compost, respectively. In sodic soil, all amendments significantly increased organic carbon content. The values were 2.68%, 3.64%, and 2.87% for biochar, compost, and biochar combined with compost, respectively. Increasing organic carbon in soil improves soil structure, water-holding capacity, and nutrient cycling. These results suggest that biochar, compost, and biochar + compost have the potential to enhance organic carbon content in saline, saline sodic, and sodic soils.
In saline soils, composted biochar improved the soil organic matter content (Luo, Liu et al. 2017). According to Cooper, Greenberg et al. (2020) Biochar and compost and biochchar+compost significantly increased organic carbon. These are completely go with our result.

4.1.4. Exchangeable Calcium

The soil calcium content ranged from 23.15 meq/100g to 54.75 meq/100g (Fig.4.4) In saline soil, all amendments significantly increased calcium content compared to the control, with values of 51.14 meq/100g, 50.87 meq/100g, and 54.75 meq/100g. In saline sodic and sodic soils, the amendments also had a small but significant effect on increasing calcium content, with values of 32.15 meq/100g, 30.26 meq/100g, 33.40 meq/100g and 29.73 meq/100g, 29.90 meq/100g, 32.80 meq/100g, respectively.

Increasing calcium content in the soil can positively impact soil fertility and plant health, as calcium is essential for plant growth and soil structure maintenance.

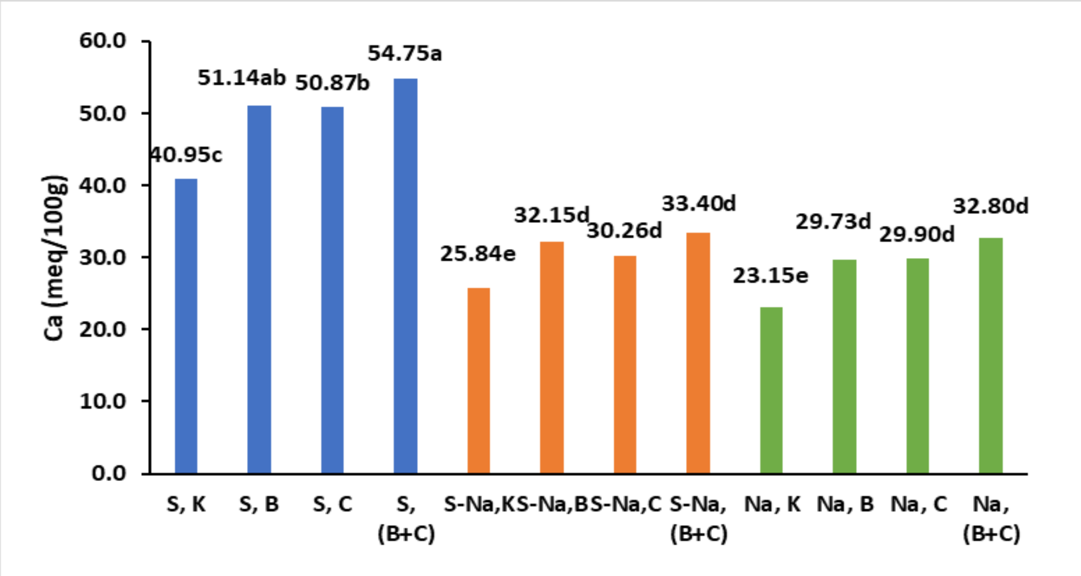

Figure 4.4: The amount of soil Ca under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic) Lettering indicates significance level, Significance level 0.01

In the soils with Ca^{2+} amendments, WSA was increased as the amount of Ca was increased (Kim, Kim et al. 2016) since the Ca^{2+} adsorption occurs on the negatively charged surface of the biochar (Antonangelo, Sun et al. 2021). The Ca^{2+} supplied from biochar can promote Na+ displacement from exchange sites (Lashari, Liu et al. 2013, Chaganti, Crohn et al. 2015, Dahlawi, Naeem et al. (2018)), which means Ca^{2+} availability increased. Biochar has been shown to reduce salt stress in saline soils due to its ability to release macronutrients such as calcium in soil, which prevent the negative effects of salt (Kim et al. 2, 2016, Haider et al. 2022.). Moreover, Biochar can be an excellent source of calcium and nutrients (Tsai, Liu et al. 2012). When compost and biochar are added to saline-sodic soils, they can significantly increase soil Ca^{2+} concentrations. (Chaganti, Crohn et al., 2015). These informations support our results.

4.1.5. Exchangeable Magnesium

The soil magnesium ranges from 15.85 meq/100gm to 32.05 meq/100 (Fig. 4.5). In saline soil, magnesium levels showed a significant increase with the application of amendments. The highest significance level was observed in biochar + compost, with a value of 32.05 meq/100gm.

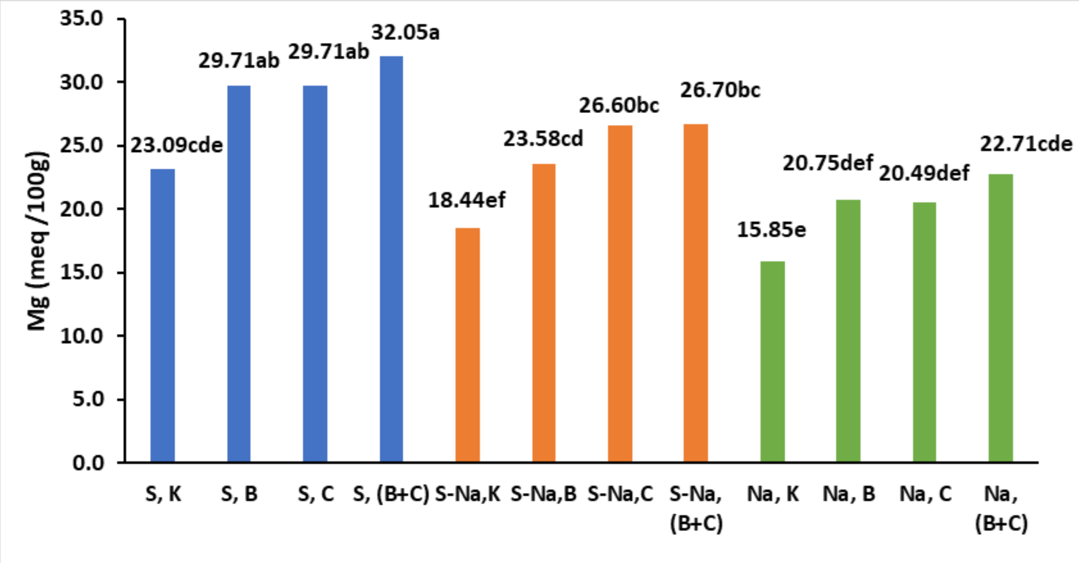

Figure 4.5: The amount of soil Mg under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

Biochar and compost also exhibited high significance levels of 29.71 meq/100gm. For saline sodic soil, similar trends were observed. The highest magnesium value was found in the biochar combined with compost treatment, measuring 26.70 meq/100gm. Biochar and compost individually also exhibited high significance levels of 23.58 meq/100gm and 26.70 meq/100gm, respectively. In sodic soil, there were significant differences in magnesium levels among the different amendments. The values were 20.75 meq/100gm for biochar, 20.49 meq/100gm for compost, and 22.72 meq/100gm for biochar combined with compost. These results suggest that the application of amendments, especially biochar combined with compost, can significantly increase magnesium levels in saline and saline sodic soils. Since biochar has high surface charge density and high surface area per unit mass, application of biochar increased soil CEC. (Atkinson, Fitzgerald et al. 2010), that means Mg^{2+} increase. Composts and biochar can significantly enhance soil Mg^{2+} .(Chaganti, Crohn et al. 2015). Our results completely align with all these information.

4.1.6. Potassium (K)

The range of soil potassium was from 1.00 meq/100 to 3.22 meq/100 (Fig. 4.6). In saline soil, all amendments showed highly significant differences compared to the control. The compost amendment had the highest significance level with a value of 3.22.

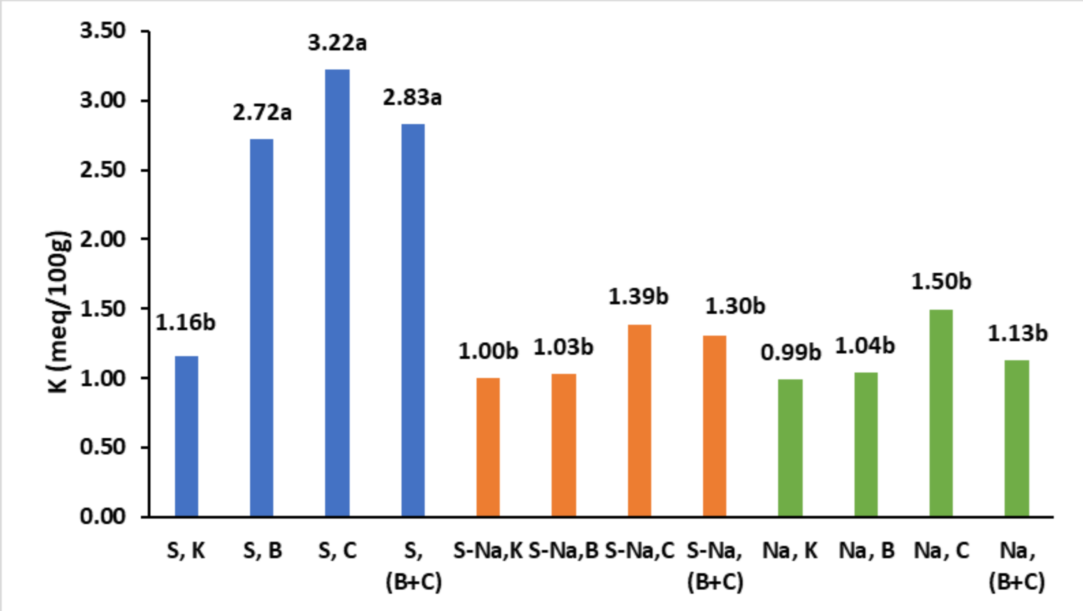

Figure 4.6: The amount of soil K under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

Biochar and biochar combined with compost also exhibited significant differences with values of 2.72 and 2.83, respectively. In saline sodic soil and sodic soil, the compost and biochar + compost amendments showed slight significance differences compared to the control. The values were 1.39 and 1.30 for saline sodic soil, and 1.50 and 1.13 for sodic soil, respectively. In saline soil found that the release of macronutrients such as potassium in soil helped to prevent the negative effects of salts by reducing salt stress and increasing plant growth (Kim, Kim et al. 2016, Haider, Coulter et al. 2022). Moreover, the biochar contained more K+ than the original soil. Therefore, the addition of biochar mechanically increased K+, which resulted in higher soluble and exchangeable K+. (Phuong, Khoi et al. 2020)

4.1.7. Sodium (Na)

In the saline soil and sodic soil, there were no significant differences observed in sodium (Na) levels among the amendments compared to the control.

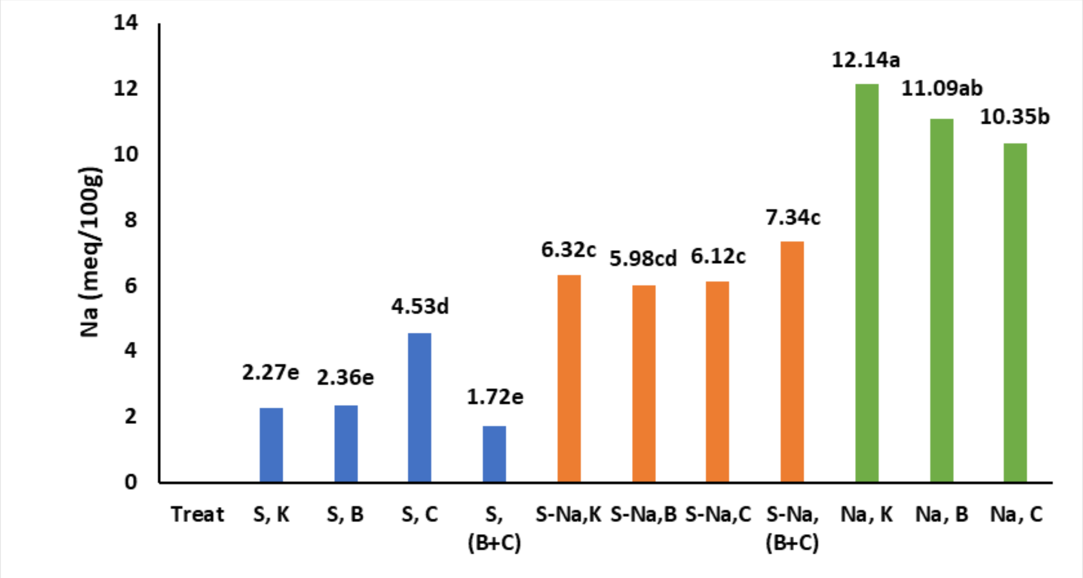

Figure 4.7: The amount of soil Na under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

However, in sodic soil (Fig 4.7), there was a significant decrease in sodium levels compared to the control. This indicates that the amendments had a significant effect in reducing the sodium content in sodic soil. Reducing sodium levels in sodic soil is beneficial as excessive sodium can lead to soil degradation and negatively impact plant growth. The amendments used in the study successfully contributed to lowering the sodium content, which can improve the soil's physical and chemical properties.

Biochar had substantial effects on the decrease of exchangeable Na+. This decrease may be attributable to the increase in total soil porosity and infiltration potential (Ksat) following biochar amendment, which improved salt leaching. (Phuong, Khoi et al. 2020). Biochar amendment enhanced soil cation exchange capacity, and as a result, decreased Na+ concentration in soil solution by absorbing Na^{+} in the newly available exchange sites. (Huang, Zhang et al. 2019). In contrast, the Ca^{2+} provided by biochar can promote Na^{+} displacement from exchange sites and facilitate Na+ dissolution in percolating water. (Lashari, Liu et al. 2013, Chaganti, Crohn et al. 2015, Dahlawi, Naeem et al. 2018). Composted biochar enhanced the soil's organic matter content and CEC in saline soils while lowering the soil's pH and exchangeable sodium levels. (Luo, Liu et al. 2017). Furthermore, Compost addition has been connected to soil Na adsorption and Na leaching ratios, resulting in Na removal from the root contact region. (Chaganti and Crohn 2015)

Compost treated plants in an environment of salinity were typically associated with salt stress effects mitigation in plants by increasing the selectivity of K+ and Ca2+ to plasmalemma mobilization sites rather than Na+ ions. (Ayub, Ahmad et al. 2020).(He, He et al. 2020) discovered a considerable increase in soil organic matter, N, P, K, and Mg levels in saline soil. The positive effect of biochar on plants under salt stress was explained by discharging K, Ca, and Mg and decreasing the Na+ equilibrium concentration in the soil solution. (Pavlíková, Zemanova et al. 2017)

4.2. Plant sample analysis

4.2.1. Biomass

The results of biomass yield are in the range of 0.31 to 10.90 gm (Fig. 4.8). There are no significant differences in any soil for any amendments. Biomass amount is higher in salt affected soil whereas the biomass decreased significantly for saline sodic soil or sodic soil. This clearly indicates that saline soil affected less for germination rate where sodium was more destructive. Sodium destroyed soil conditions more than saline soil.

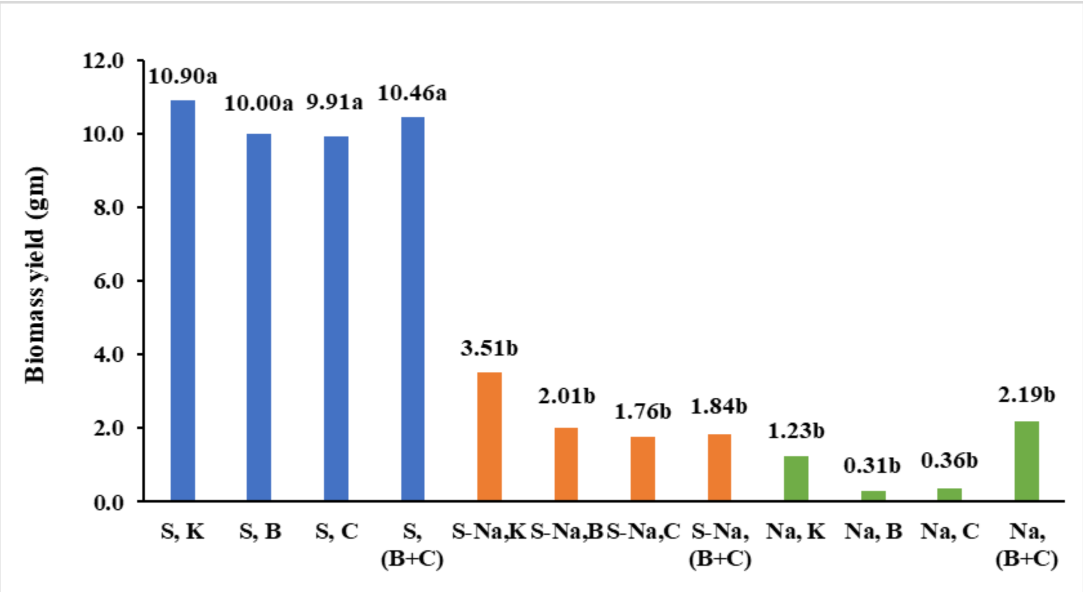

Figure 4.8: The amount of biomass under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

According(Afzal, Basra et al. 2006) salinity reduced germination and seedling vigor significantly. Research demonstrated that salinity stress negatively affected the growth of cabbage seedlings. Salt stress negatively impacted the germination of plant seeds (Parihar, Singh et al. 2015). Salinity primarily reduces shoot biomass by closing stomata and preventing leaf expansion.(Ali, Rizwan et al. 2017)

4.2.2. Calcium (Ca)

The plant analysis results revealed notable variations in calcium (Ca) concentrations among the different treatments (Fig. 4.9). The Ca concentrations in the plant samples ranged from 0.13% to 0.46%. These findings demonstrate the influence of different soil amendments on the uptake and accumulation of Ca in plants. In the case of salt-affected soil, the highest Ca concentration was observed in the compost-amended treatment, with a value of 0.39%. This result suggests that the addition of compost to salt-affected soil significantly enhanced Ca availability to plants, thereby promoting better calcium uptake and accumulation. The observed range of Ca concentration in salt-affected soil indicates the potential for variability in Ca uptake by plants within this soil type.

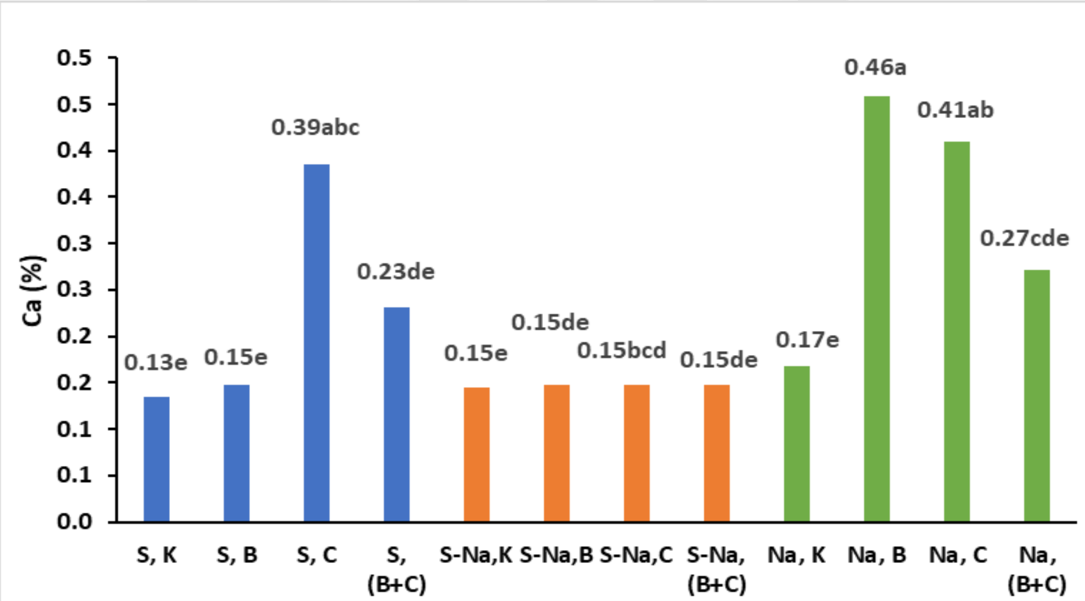

Figure 4.9: The amount of Ca under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

Contrarily, no significant differences in Ca concentration were observed among the different soil amendment treatments in saline-sodic soil. The Ca concentration in this soil type remained relatively consistent across all treatments, suggesting that the amendments, including biochar, compost, and their combination, did not significantly affect Ca uptake by plants. The unique characteristics of saline-sodic soil may interact differently with the applied amendments, leading to similar Ca concentrations in plants across the treatments. Furthermore, it was observed that in soils with high sodium concentrations, the Ca concentration in plants was higher compared to other soil types. Among the different amendments, biochar exhibited the highest Ca concentration, with a value of 0.46%. Compost and compost combined with biochar also showed significant effects, resulting in Ca concentrations of 0.41% and 0.27%, respectively. These findings suggest that biochar amendment, in particular, played a crucial role in increasing Ca levels in high-sodium soil, potentially enhancing the calcium uptake capacity of plants and mitigating the adverse effects of high sodium content on plant health. According to Farhangi-Abriz and Torabian (2018) Biochar addition in the soil enhanced growth and Ca content of root and shoot, when Na content decreased in root and shoot and reduced Na uptake. Researchers found that biochar contains Ca2+ reducing soil SAR directly by providing these minerals into the soil solution (Huang, Zhang et al. 2019) which helps to make nutrients available for plant. Hence it increases in plant body.

4.2.3. Magnesium (Mg)

The plant analysis results revealed significant variations in magnesium (Mg) concentrations among the different treatments, highlighting the influence of various soil amendments on Mg uptake and accumulation in plants (Fig. 4.10). The Mg concentrations in the plant samples ranged from 0.15% to 0.38%.

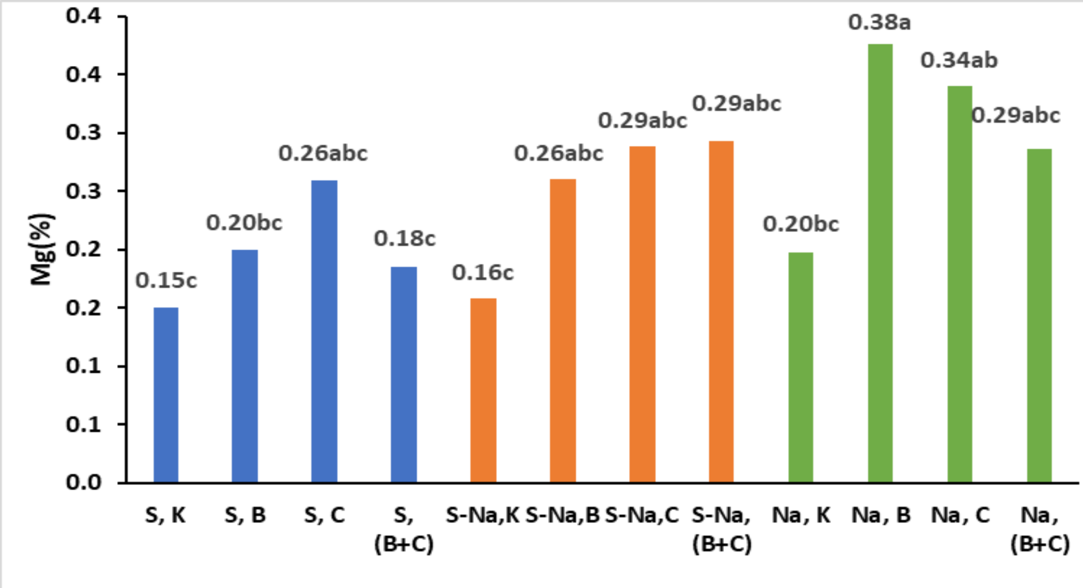

Figure 4.10: The amount of plant Mg under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

In saline soil, the compost-amended treatment exhibited the highest Mg concentration, measuring 0.26%. There is no particular differences among treatments. This result suggests that the addition of compost to saline soil significantly increased Mg availability for plants, resulting in enhanced Mg uptake and accumulation. The observed range of Mg concentrations in saline soil implies the slight potential variability in Mg uptake by plants within this soil type.

There are no noticeable significant differences in Mg concentrations were also observed for the biochar and biochar + compost treatments in saline soil, with values of 0.20% and 0.18%, respectively. These findings indicate that both biochar and the combination of biochar and compost had no significant impact on increasing Mg uptake in saline soil. On the other hand, in saline-sodic soil, significant differences in Mg concentrations were observed for the compost and compost + biochar treatments, with values of 0.29%. The biochar treatment also exhibited a relatively high Mg concentration of 0.26%. These results suggest that these amendments contributed to increased Mg availability and uptake in saline-sodic soil. In sodic soil, the highest Mg concentration was observed in the biochar treatment, measuring 0.38%. This indicates that biochar amendment significantly enhanced Mg uptake and accumulation in sodic soil. Additionally, the compost and compost + biochar treatments also showed significant differences in Mg concentrations, with values of 0.34% and 0.29%, respectively. According to Farhangi-Abriz and Torabian (2018) Biochar addition in the soil enhanced growth and Mg content of root and shoot, when Na content decreased in root and shoot and reduced Na uptake. Researchers found that biochar contains Mg2+, reducing soil SAR directly by providing these minerals into the soil solution (Huang, Zhang et al. 2019) which helps to make nutrient available for plant. Hence it increases in plant body.

4.2.4. Potassium (K)

Potassium ranges for plants are from 0.72% to 4.64% (Fig. 4.11). Neither saline nor sodic soils showed significant differences among treatments. For saline sodic soil, significant differences were observed in all treatments where the highest value was found in compost which was 4.64. There is moderate significance difference for biochar and compost + biochar.

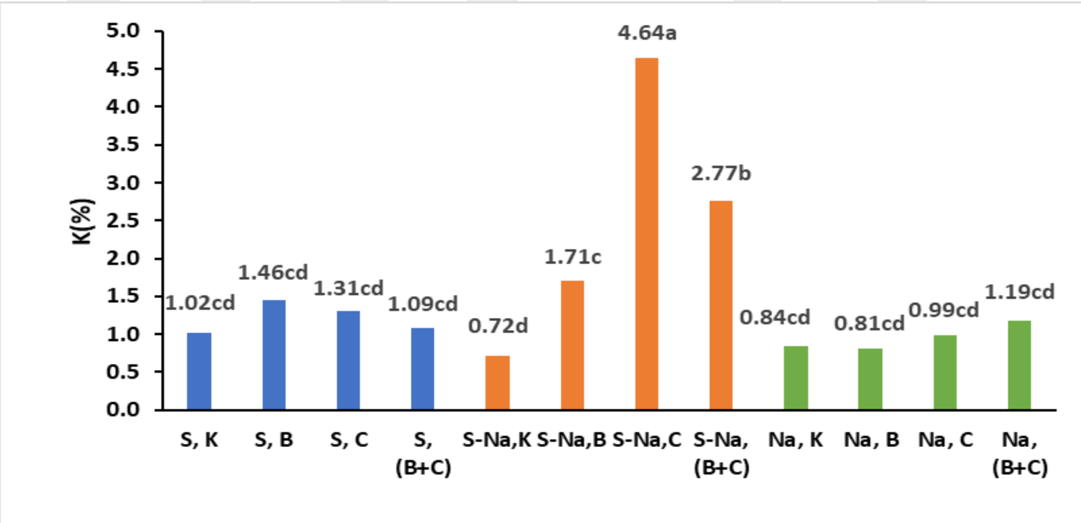

Figure 4.11: The amount of plant K under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

According to (Usman, Al-Wabel et al. 2016) biochar increased the K content of saline-irrigated tomato plants relative to non-saline irrigation which does not support our result. The reason might be the climatic condition, source of amendments or species.

4.2.5. Phosphorus

The analysis of phosphorus (P) concentrations in the plant samples revealed variations among the different treatments, indicating the influence of soil amendments on P uptake and accumulation (Fig. 4.12). The P concentrations ranged from 0.09% to 0.34%. In saline soil, no significant differences in P concentrations were observed among the different treatments. This suggests that the applied amendments, such as compost, biochar, or compost + biochar, did not have a significant effect on P uptake in saline soil. However, it is important to note that P availability and uptake can be influenced by various factors, including soil properties and plant species.

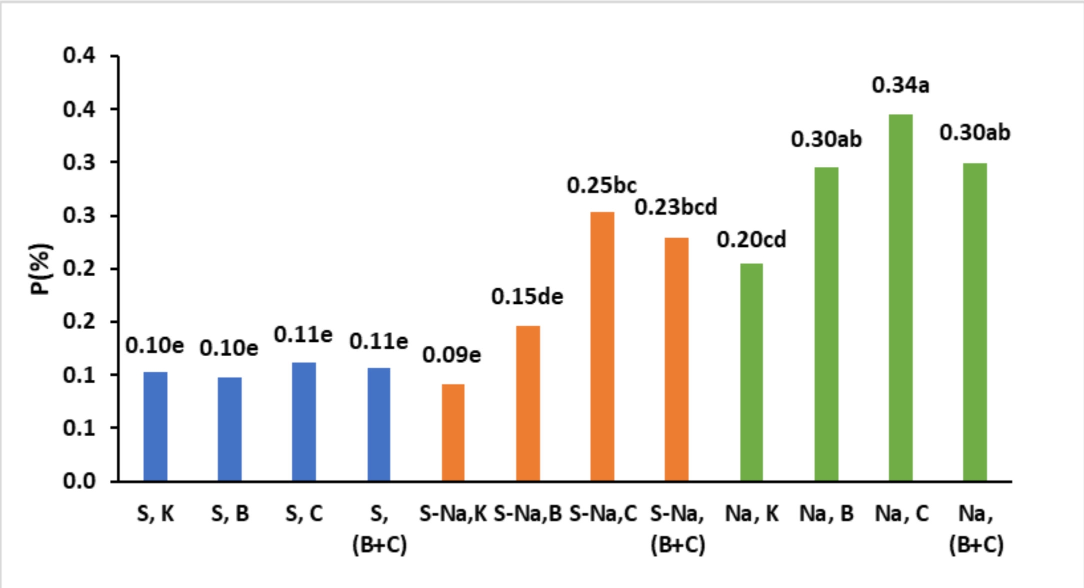

Figure 4.12: The amount of plant P under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

In saline sodic soil, the highest significance level for P concentrations was observed in the compost treatment, with a value of 0.25%. The compost + biochar treatment also showed a relatively high significance level of 0.23%. The biochar amendment exhibited a slightly significant effect, with a significance level of 0.15%. These findings suggest that the addition of compost or compost + biochar amendments significantly improved P uptake in saline sodic soil. The biochar amendment, although showing a slightly significant effect, had a comparatively lower impact on P concentrations in this soil type. Further investigation is needed to unravel the underlying mechanisms responsible for these effects.

In sodic soil, the compost treatment exhibited the highest significance level for P concentrations, with a value of 0.34%. The compost + biochar treatment also showed a relatively high and similar significance level of 0.30%. These findings indicate that the addition of compost or compost + biochar amendments significantly enhanced P availability and uptake in sodic soil. These results underscore the potential of compost amendment in improving P nutrition in sodic soil.

Under salinity stress, biochar application increased P concentrations in lettuce(Hammer, Forstreuter et al. 2015). Biochar application raised P concentrations in salt-stressed maize tissues in a dose-dependent manner (Kim, Kim et al. 2016). In a separate study, biochar increased P levels in tomato plants with saline irrigation compared to non-saline irrigation.(Usman, Al-Wabel et al. 2016). Biochar boosted soil available P by reducing the composition of Fe-P and Al-P compounds or preventing their formation.(Phuong, Khoi et al. 2020)

4.2.6. Iron (Fe)

The analysis of iron (Fe) concentrations in the plant samples revealed variations among the different treatments, indicating the influence of soil amendments on Fe uptake and accumulation. The Fe concentrations ranged from 23.5 ppm to 111.32 ppm (Fig.4.13)

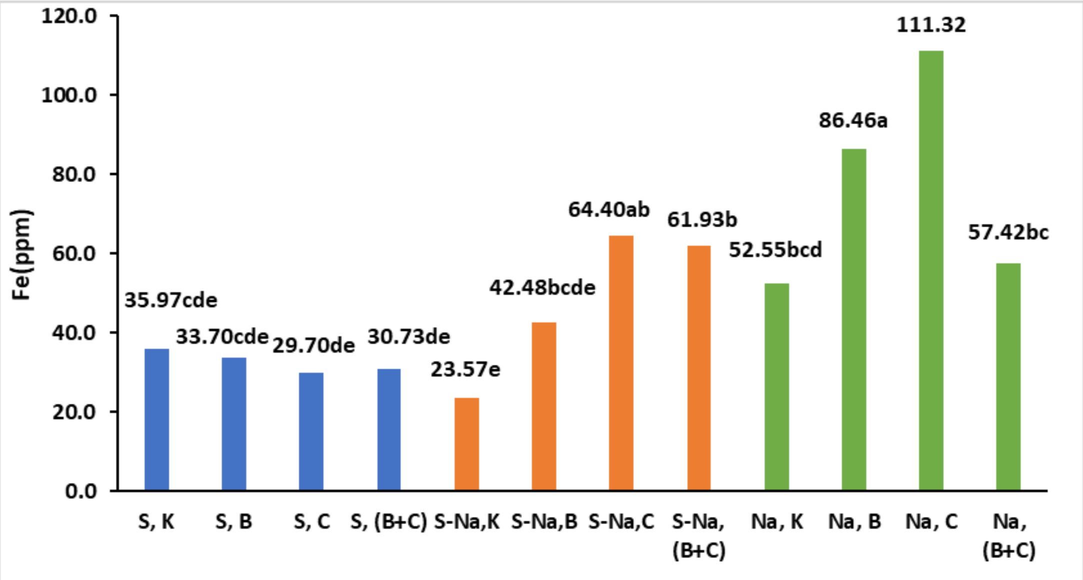

Figure 4.13: The amount of plant Fe under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

In saline soil, no significant differences in Fe concentrations were observed among the different treatments. This suggests that the applied amendments, such as compost, biochar, or biochar + compost, did not have a significant effect on Fe uptake in saline soil.

In saline sodic soil, significant differences in Fe concentrations were observed for the compost and biochar + compost treatments, with significant levels of 64.40 ppm and 61.93 ppm, respectively. The biochar treatment also showed a slight significant effect, with a significance level of 42.48 ppm. These findings suggest that the addition of compost or biochar + compost amendments enhanced Fe availability and uptake in saline sodic soil.

In sodic soil, the compost treatment exhibited the highest significant level for Fe concentrations, with a value of 111.32 ppm. The biochar treatment also showed a relatively high significant effect, with a significance level of 86.46 ppm. The biochar+compost treatment exhibited a slight significant effect, with a significance level of 57.42 ppm. These findings indicate that the addition of compost or biochar amendments significantly improved Fe uptake in sodic soil. These results underscore the potential of compost amendment in enhancing Fe nutrition in sodic soil, while biochar also showed promise. Biochar raised Fe levels in saline-irrigated tomato plants compared to non-saline-irrigated tomato plants. (Usman, Al-Wabel et al. 2016)

4.2.7. Manganese (Mn)

The analysis of manganese (Mn) concentrations in the plant samples revealed variations among the different treatments, indicating the influence of soil amendments on Mn uptake and accumulation. The Mn concentrations ranged from 8.72 ppm to 70.89 ppm.

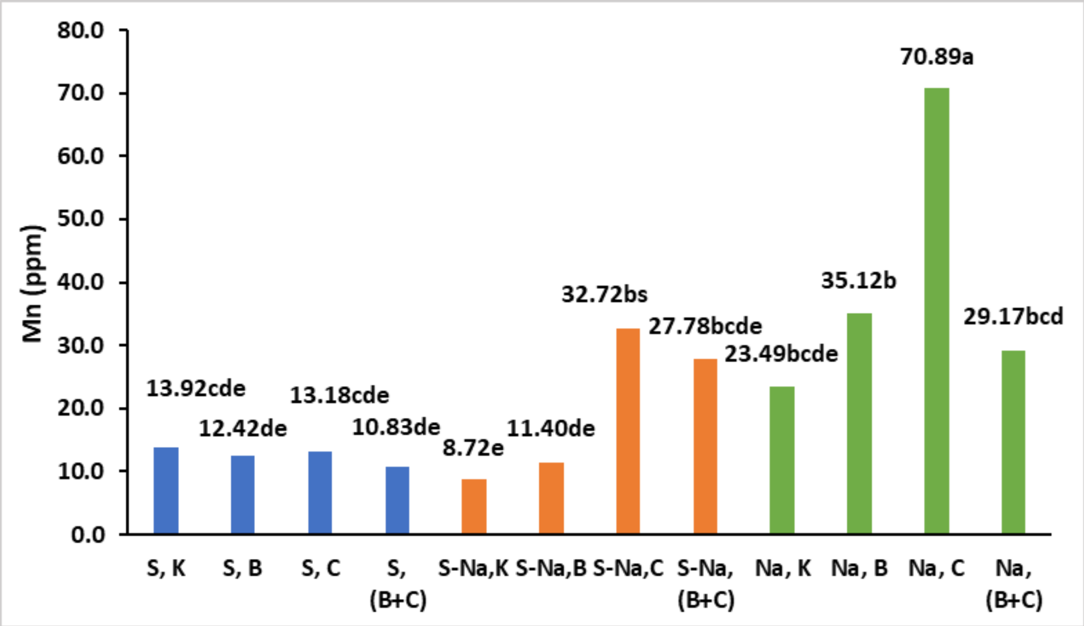

Figure 4.14: The amount of plant Mn under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

In saline soil, no significant differences in Mn concentrations were observed among the different treatments. This suggests that the applied amendments, including compost, biochar, and biochar + compost, did not have a significant effect on Mn uptake in saline soil. It is important to note that Mn availability and uptake can be influenced by various factors, including soil properties and plant species.

In saline sodic soil, significant differences in Mn concentrations were observed for the compost and biochar + compost treatments, with significance levels of 32.72 ppm and 27.78 ppm, respectively. However, no significant difference was observed for the biochar treatment. These findings suggest that the addition of compost or biochar + compost amendments enhanced Mn availability and uptake in saline sodic soil, while biochar alone did not have a significant impact on Mn concentrations.

In sodic soil, the compost treatment exhibited the highest significance level for Mn concentrations, with a value of 70.89 ppm. The biochar treatment also showed a moderate significant effect, with a significance level of 35.89 ppm. The biochar + compost treatment exhibited a slight significant effect, with a significance level of 29.17 ppm. These findings indicate that the addition of compost or biochar amendments significantly improved Mn uptake in sodic soil. These results highlight the potential of compost amendment in enhancing Mn nutrition in sodic soil, while biochar also showed promise.

Under salinity stress, biochar application increased Mn concentrations in lettuce plants (Hammer, Forstreuter et al. 2015). In a separate study, biochar increased manganese levels in tomato plants irrigated with salt water compared to those irrigated with fresh water. (Usman, Al-Wabel et al. 2016)

4.2.8. Zinc (Zn)

In this case, Zinc demonstrated the various types of changes that can occur in different treatments. The lowest significant level was found in the control under saline-sodic soil, while the highest level was discovered in compost under sodic soil. There is no significance noticed in saline soil.

In saline-sodic soil, the amount of significance found in compost was the highest, and the value was 14.85 ppm. Both biochar and biochar combined with compost demonstrated moderate levels of statistical significance, with 13.17 and 12.32 respectively. It can clearly be seen that the additives had a beneficial effect on the sodic and saline soil.

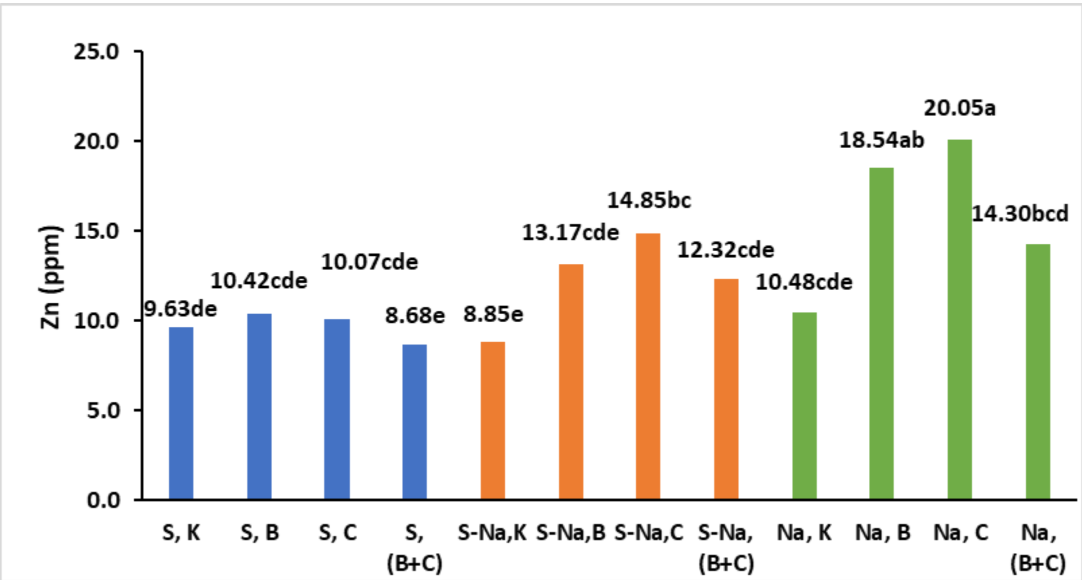

Figure 4.15: The amount of plant Zn under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.01

In the case of sodic soil, the maximum concentration was recorded in compost, which was 20.05 ppm. Ther are also high significance in biochar and biochar + compost value with 18.54 and 1430 respectively. Under saline soil, biochar increased Zn in tomato plants as compared to the non-saline irrigation (Usman et al. 2016).

4.2.9. Copper (Cu)

The copper (Cu) concentrations in the plant samples ranged from 4.93 ppm to 9.21 ppm. Among the different soil types, no significant differences were observed in Cu concentrations, except for biochar in sodic soil, which showed a highly significant difference.

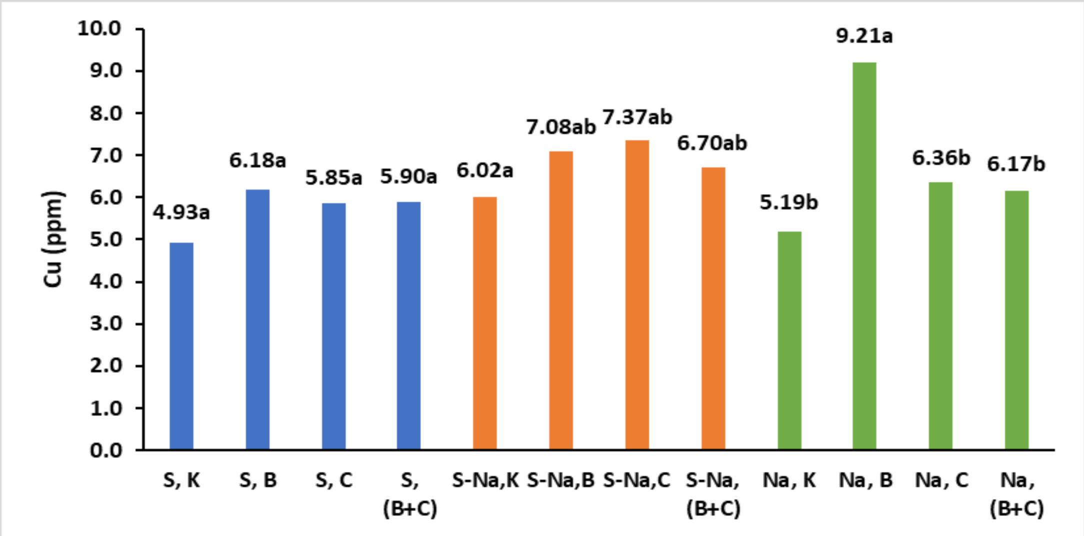

Figure 4.16: The amount of plant Cu under different treatments

(Biochar, compost, Biochar + compost) and different soil type (Saline, Saline-sodic, Sodic), Lettering indicates significance level, Significance level 0.05

In saline soil, the applied amendments (compost, biochar, and biochar + compost) did not significantly affect Cu uptake in plants. This indicates that these amendments did not have a noticeable impact on Cu concentrations in plants grown in saline soil. In saline sodic soil, slight significant differences were observed in Cu concentrations for the compost, biochar, and biochar + compost treatments compared to the control. In sodic soil, the addition of biochar significantly increased Cu uptake in plants, resulting in higher Cu concentrations. This suggests that biochar has the potential to enhance Cu availability and transport plants in sodic soil. These findings highlight the importance of considering the environmental implications of using biochar as a soil amendment, especially with respect to trace element enrichment. In summary, the addition of compost and biochar + compost did not significantly affect Cu concentrations in plants across different soil types, while biochar showed a significant increase in sodic soil. Under saline irrigation, biochar increased Cu in tomato plants with as compared to the non-saline irrigation (Usman et al. 2016).

5. CONCLUSION

This study was conducted to investigate the influence of biochar and compost application to saline, saline-sodic and sodic soil and wheat production. All the parameter showed significant differences with control except biomass. It’s noted that sodic was more destructive than saline soil for seed germination and reduced overall biomass.

Biochar treatments had considerable amount of impact on chemical properties of plant and soil. soil pH and OC exhibited a substantial increase trend when EC showed decreasing trend implying that cations and anions are becoming more available to plants for better growth and development. In biochar application, the exchangeable cations Ca, Mg, and K had varying effects. Sodium had a decreasing trend which means biochar improved saline and sodic condition. For plant analysis, there is no noticeable significant difference for micronutrients. Though there were no significant differences for Ca in saline and sodic saline soil, it was positive for sodic soil. Phosphorus and Mg showed increasing trend where K showed no significant differences.

Compost treatment had also significant amount of impact on chemical properties of plant and soil. Soil pH and EC exhibited a decreased trend where organic carbon showed increasing trend which indicate that it did not work for salinity or sodicity reduction but it improved soil condition through organic matter. In biochar application, the exchangeable cations Ca, Mg, and K had varying effects.

Sodium had a decreasing trend which means biochar improved saline and sodic condition. For micronutrients, there was varying effect for Fe, Zn, Mn in saline-sodic and sodic soil where Cu did not show any. Ca, Mg, P showed different effects when K did not.

Co-composting had varying effects of plant and soil chemical properties. Micro-nutrients exhibited no significant differences.

It is evident that biochar and compost helped to reduce sodium which improved soil nutrient availability and also improved organic carbon. Therefore, before suggesting biochar application as sustainable agriculture practice further research related to what biochar fraction, its dose level and type of soil to be applied on should be considered. At the same time, further research is necessary to find out their field level efficacy to improve crop growth and sustainable soil health management.

REFERENCES

Afzal, I., et al. (2006). "Physiological enhancements for alleviation of salt stress in wheat." Pak. J. Bot 38(5): 1649-1659.

Ait-El-Mokhtar, M., et al. (2022). "Compost as an eco-friendly alternative to mitigate salt-induced effects on growth, nutritional, physiological and biochemical responses of date palm." International journal of recycling organic waste in agriculture 11(1): 85-100.

Akhtar, S., et al. (2015). "Biochar mitigates salinity stress in potato." Journal of agronomy and crop science 201(5): 368-378.

Akhtar, S. S., et al. (2015). "Residual effects of biochar on improving growth, physiology and yield of wheat under salt stress." Agricultural Water Management 158: 61-68.

Ali, S., et al. (2017). "Biochar soil amendment on alleviation of drought and salt stress in plants: a critical review." Environmental Science and Pollution Research 24: 12700-12712.

Antonangelo, J. A., et al. (2021). "The roles of co-composted biochar (COMBI) in improving soil quality, crop productivity, and toxic metal amelioration." Journal of Environmental Management 277: 111443.

Atkinson, C. J., et al. (2010). "Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review." Plant and soil 337: 1-18.

Attia, A., et al. (2016). "Application of DSSAT-CERES-Wheat model to simulate winter wheat response to irrigation management in the Texas High Plains." Agricultural Water Management 165: 50-60.

Ayub, M. A., et al. (2020). Salinity and its tolerance strategies in plants. Plant life under changing environment, Elsevier: 47-76.

Ben-Laouane, R., et al. (2020). "Potential of native arbuscular mycorrhizal fungi, rhizobia, and/or green compost as alfalfa (Medicago sativa) enhancers under salinity." Microorganisms 8(11): 1695.

Bos, C., et al. (2005). "Postprandial metabolic utilization of wheat protein in humans." The American journal of clinical nutrition 81(1): 87-94.

Boutasknit, A., et al. (2021). "Improvement of garlic growth, physiology, biochemical traits, and soil fertility by Rhizophagus irregularis and compost." Gesunde Pflanzen 73(2).

Bouyoucos, G. J. (1962). "Hydrometer method improved for making particle size analyses of soils 1." Agronomy journal 54(5): 464-465.

Chaganti, V. N. and D. M. Crohn (2015). "Evaluating the relative contribution of physiochemical and biological factors in ameliorating a saline–sodic soil amended with composts and biochar and leached with reclaimed water." Geoderma 259: 45-55.

Chaganti, V. N., et al. (2015). "Leaching and reclamation of a biochar and compost amended saline–sodic soil with moderate SAR reclaimed water." Agricultural Water Management 158: 255-265.

Çimrin, K. M., et al. (2010). "Phosphorus and humic acid application alleviate salinity stress of pepper seedling." African Journal of Biotechnology 9(36).

Cooper, J., et al. (2020). "Effect of biochar and compost on soil properties and organic matter in aggregate size fractions under field conditions." Agriculture, Ecosystems & Environment 295: 106882.

Dahlawi, S., et al. (2018). "Biochar application for the remediation of salt-affected soils: Challenges and opportunities." Science of the Total Environment 625: 320-335.

Drake, J. A., et al. (2016). "Does biochar improve establishment of tree seedlings in saline sodic soils?" Land Degradation & Development 27(1): 52-59.

Egamberdieva, D., et al. (2022). "Biochar for improving soil biological properties and mitigating salt stress in plants on salt-affected soils." Communications in Soil Science and Plant Analysis 53(2): 140-152.

Evelin, H., et al. (2009). "Arbuscular mycorrhizal fungi in alleviation of salt stress: a review." Annals of botany 104(7): 1263-1280.

Farooq, M., et al. (2015). "Salt stress in maize: effects, resistance mechanisms, and management. A review." Agronomy for Sustainable Development 35: 461-481.

Gaffar, M., et al. (1992). "Effect of farmyard manure and sand on the performance of sorghum and sodicity of soils." Journal of the Indian Society of Soil Science 40(3): 540-543.

Ghosh, S. C., et al. (2001). "Effect of salt stress on some chemical components and yield of potato." Soil Science and Plant Nutrition 47(3): 467-475.

Gong, Z. (2021). "Plant abiotic stress: New insights into the factors that activate and modulate plant responses." Journal of Integrative Plant Biology 63(3): 429.

Greenway, H. and R. Munns (1980). "Mechanisms of salt tolerance in nonhalophytes." Annual review of plant physiology 31(1): 149-190.

Haider, F. U., et al. (2022). "An overview on biochar production, its implications, and mechanisms of biochar-induced amelioration of soil and plant characteristics." Pedosphere 32(1): 107-130.

Hammer, E. C., et al. (2015). "Biochar increases arbuscular mycorrhizal plant growth enhancement and ameliorates salinity stress." Applied Soil Ecology 96: 114-121.

He, K., et al. (2020). "Biochar amendment ameliorates soil properties and promotes Miscanthus growth in a coastal saline-alkali soil." Applied Soil Ecology 155: 103674.

Huang, M., et al. (2019). "Effect of straw biochar on soil properties and wheat production under saline water irrigation." Agronomy 9(8): 457.

Jamil, A., et al. (2011). "Gene expression profiling of plants under salt stress." Critical Reviews in Plant Sciences 30(5): 435-458.

Jeffery, S., et al. (2011). "A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis." Agriculture, Ecosystems & Environment 144(1): 175-187.

Kanwal, S., et al. (2018). "Application of biochar in mitigation of negative effects of salinity stress in wheat (Triticum aestivum L.)." Journal of Plant Nutrition 41(4): 526-538.

Kim, H.-S., et al. (2016). "Effect of biochar on reclaimed tidal land soil properties and maize (Zea mays L.) response." Chemosphere 142: 153-159.

Kul, R., et al. (2021). "Biochar as an organic soil conditioner for mitigating salinity stress in tomato." Soil Science and Plant Nutrition 67(6): 693-706.

Lakhdar, A., et al. (2009). "Effectiveness of compost use in salt-affected soil." Journal of hazardous materials 171(1-3): 29-37.

Lashari, M. S., et al. (2013). "Effects of amendment of biochar-manure compost in conjunction with pyroligneous solution on soil quality and wheat yield of a salt-stressed cropland from Central China Great Plain." Field Crops Research 144: 113-118.

Lehmann, J. and S. Joseph (2015). Biochar for environmental management: an introduction. Biochar for environmental management, Routledge: 1-13.

Levy, D. (1992). "The response of potatoes (Solunum tuberosum L.) to salinity: plant growth and tuber yields in the arid desert of Israel." Annals of Applied Biology 120(3): 547-555.

Liang, Y., et al. (2003). "Soil enzymatic activity and growth of rice and barley as influenced by organic manure in an anthropogenic soil." Geoderma 115(1-2): 149-160.

Liu, X., et al. (2013). "Biochar's effect on crop productivity and the dependence on experimental conditions—a meta-analysis of literature data." Plant and soil 373: 583-594.

Lu, H., et al. (2015). "Effect of biochar in cadmium availability and soil biological activity in an anthrosol following acid rain deposition and aging." Water, Air, & Soil Pollution 226: 1-11.

Luo, X., et al. (2017). "Use of biochar-compost to improve properties and productivity of the degraded coastal soil in the Yellow River Delta, China." Journal of Soils and Sediments 17: 780-789.

Ma, H., et al. (2019). "Effect of biochar and irrigation on the interrelationships among soybean growth, root nodulation, plant P uptake, and soil nutrients in a sandy field." Sustainability 11(23): 6542.

Maas, E. (1993). "Plant growth response to salt stress." Towards the rational use of high salinity tolerant plants: Vol. 1 Deliberations about High Salinity Tolerant Plants and Ecosystems: 279-291.

Mazac, R. (2016). "Assessing the use of food waste biochar as a biodynamic plant fertilizer."

McCance, R., et al. (1945). "The chemical composition of wheat and rye and of flours derived therefrom." Biochemical Journal 39(3): 213.

Meena, M. D., et al. (2016). "Changes in biological and chemical properties of saline soil amended with municipal solid waste compost and chemical fertilizers in a mustard–pearl millet cropping system." Catena 140: 1-8.

Munns, R. (2005). "Genes and salt tolerance: bringing them together." New phytologist 167(3): 645-663.

Munns, R. and M. Tester (2008). "Mechanisms of salinity tolerance." Annu. Rev. Plant Biol. 59: 651-681.

Mwando, E., et al. (2020). "Salinity tolerance in barley during germination—homologs and potential genes." Journal of Zhejiang University. Science. B 21(2): 93.

Parihar, P., et al. (2015). "Effect of salinity stress on plants and its tolerance strategies: a review." Environmental Science and Pollution Research 22: 4056-4075.

Patel, A., et al. (2017). "Biochar mitigates salinity stress in plants." Plant Adaptation Strategies in Changing Environment: 153-182.

Pavlíková, D., et al. (2017). "Effect of biochar application on the content of nutrients (Ca, Fe, K, Mg, Na, P) and amino acids in subsequently growing spinach and mustard." Plant, Soil and Environment 63(7): 322-327.

Phuong, N. T. K., et al. (2020). "Influence of rice husk biochar and compost amendments on salt contents and hydraulic properties of soil and rice yield in salt-affected fields." Agronomy 10(8): 1101.

Phuong, N. T. K., et al. (2020). "Potential use of rice husk biochar and compost to improve P availability and reduce GHG emissions in acid sulfate soil." Agronomy 10(5): 685.

Qadir, M., et al. (2014). Economics of salt-induced land degradation and restoration. Natural resources forum, Wiley Online Library.

Qayyum, M. F., et al. (2015). "Effects of various biochars on seed germination and carbon mineralization in an alkaline soil." Pak. J. Agric. Sci 51: 977-982.

Quan, R., et al. (2007). "SCABP8/CBL10, a putative calcium sensor, interacts with the protein kinase SOS2 to protect Arabidopsis shoots from salt stress." The Plant Cell 19(4): 1415-1431.

Rengasamy, P. (2006). "World salinization with emphasis on Australia." Journal of experimental botany 57(5): 1017-1023.

Rhoades, J. and J. Loveday (1990). "Salinity in irrigated agriculture." Agronomy(30): 1089-1142.

Rozelle, S. and J. Huang (1998). China and world wheat markets: assessing supply, demand, and trade in China.

Scotti, R., et al. (2016). "On-farm compost: a useful tool to improve soil quality under intensive farming systems." Applied Soil Ecology 107: 13-23.

Shamsi, K. and S. Kobraee (2013). "Biochemical and physiological responses of three wheat cultivars (Triticum aestivum L.) to salinity stress." Annals of Biological Research 4(4): 180-185.

Tahir, H., et al. (1991). "Brackish groundwater use technology in salt affected soils through soil fertility management." J. Drain. Irrig 3(2): 20-24.

Tari, A. F. (2016). "The effects of different deficit irrigation strategies on yield, quality, and water-use efficiencies of wheat under semi-arid conditions." Agricultural Water Management 167: 1-10.

Tejada, M., et al. (2006). "Use of organic amendment as a strategy for saline soil remediation: influence on the physical, chemical and biological properties of soil." Soil Biology and biochemistry 38(6): 1413-1421.

Tejada, M. and J. Gonzalez (2005). "Beet vinasse applied to wheat under dryland conditions affects soil properties and yield." European Journal of Agronomy 23(4): 336-347.

Thomas, S. C., et al. (2013). "Biochar mitigates negative effects of salt additions on two herbaceous plant species." Journal of Environmental Management 129: 62-68.

Tsai, W.-T., et al. (2012). "Textural and chemical properties of swine-manure-derived biochar pertinent to its potential use as a soil amendment." Chemosphere 89(2): 198-203.

Usman, A. R. A., et al. (2016). "Conocarpus biochar induces changes in soil nutrient availability and tomato growth under saline irrigation." Pedosphere 26(1): 27-38.

Van Zelm, E., et al. (2020). "Salt tolerance mechanisms of plants." Annual review of plant biology 71: 403-433.

Verheijen, F., et al. (2017). Biochar boosts tropical but not temperate crop yields. 6th International Symposium on Soil Organic Matter Healthy Soils for Sustainable Agriculture: https://www. researchgate.net/publication/320273037_Biochar_boosts_tropical_but_not_temperate _crop_yields.

Verheijen, F., et al. (2010). "Biochar application to soils." A critical scientific review of effects on soil properties, processes, and functions. EUR 24099(162): 2183-2207.

Walkley, C. (1934). "An examination of Degtjareff method of determining soil organic matter and proposed modification of the method of the chromic acid titration method." Soil Sci 37: 29-39.

Wang, L., et al. (2014). "Application of organic amendments to a coastal saline soil in North China: Effects on soil physical and chemical properties and tree growth." PloS one 9(2): e89185.

Wang, X., et al. (2015). "Impact of irrigation volume and water salinity on winter wheat productivity and soil salinity distribution." Agricultural Water Management 149: 44-54.

Xi, C. (1998). "Anthropogenic soils." Soil of China: 704-737.

Yildirim, E., et al. (2006). "Ameliorative effects of biological treatments on growth of squash plants under salt stress." Scientia Horticulturae 111(1): 1-6.

Zhang, X., et al. (2017). "Responses of yield and WUE of winter wheat to water stress during the past three decades—A case study in the North China Plain." Agricultural Water Management 179: 47-54.

Zhao, S., et al. (2021). "Regulation of plant responses to salt stress." International Journal of Molecular Sciences 22(9): 4609.

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2. Begum, M., Gulser, C., Parajuli, S. (2022). How does salt-stress affect on plant growth and yield?. International Soil Science Symposium on "Soıl Scıence and Plant Nutrıtıon" 2 – 3 December 2022, Samsun, Türkiye, Book of Proceedings, pp.55-59.

3. Parajuli, S., Gulser, C., Begum, M. (2022). Potential of organic amendments on reclaiming the soil properties affected under alkaline and/or sodic condition. International Soil Science Symposium on "Soıl Scıence and Plant Nutrıtıon" 2 – 3 December 2022, Samsun, Türkiye, Book of Proceedings, pp.223-228.

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