

The Effect of Biochar on the Salinity Reduction in Mung Bean Plant

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Abstract

The aim of research was investigation of biochar effect on salinity reduction in mung bean plant. The experiment was performed in a randomized complete block design with two replications and three treatments of saline, non-saline and saline + biochar. A silty soil was used for the plant substrate while calcium chloride and sodium chloride salts were employed in order to create the salinity levels in it. The results of variance analysis associated with the studied traits showed that the simple effects of salinity and plant organs as well as the interaction of salinity \times plant organs on the calcium, magnesium, chlorine, sodium, potassium, pH and electrical conductivity (EC) levels are significant at a level of 1%. Also, the results of comparing the mean interaction of salinity \times organ indicated that the highest calcium content in most cases is associated with the shoots. The biochar consumption has been found to reduce the calcium adsorption at high salinity in leaves and roots and increase it in the stem and pod. Increasing the calcium chloride and sodium chloride salinities in plant organs, the concentration of potassium decreased compared to calcium and with increasing salinity levels, the concentration of all mentioned elements increased in most treatments. The results showed that EC value was found to be improved by applying biochar. According to the results, effect of organ, salinity and organ \times salinity on all characteristics was significant. It has been found that the salinity resistance mechanism of this plant is the salt tolerance through the accumulation of ions in its organs. Therefore, biochar can be used in the improvement of saline soils, for the optimal use of soil resources and saline waters.

Key Words: Adsorbant, Forest Tree Leaves, Biochar, Salinity, Mung Bean.

1. Introduction

Lack of water resources, especially in arid and semi-arid regions such as Iran, has led to the use of saline waters in the agriculture and other uses as one of the main goals. Given that a large part of lands is saline due to special climatic conditions, nature of the parent materials and poor quality of the irrigation water, or their tendency is to become more saline, it is normal that the plants growth is facing several problems in these conditions. Hence, in order to prevent a decrease in the plant yield, measures is necessary.

the shortage of good quality water forces the farmers to rely on poor quality saline waters for crop production (Choudhary et al., 2021). Therefore, it is necessary to develop management practices for astute use of poor-quality waters for agriculture without or minimum reduction in crop yields.

The accumulation of harmful ions such as sodium and chlorine in leaves under salinity stress, while disrupting the distribution of

ions among plant tissues, has negative effects on the crop growth by disrupting other physiological processes such as chlorophyll stability, photosynthetic system efficiency, antioxidant enzyme activity, and leads to reduction in the plant height, dry weight, flower, fruit drop and economic yield reduction [1].

It is well established that high salt content in the root zone reduces nutrient uptake and transport from plant roots to shoots inducing nutrient imbalances, poor vegetative growth and yields [2,3].

The mung bean plant (*Radiata Vigna*) is considered as one of the most important legumes in Iran and the world, which is widely cultivated in the tropical regions. Khuzestan Province is one of the most important areas for mung bean cultivation in Iran, that lands are facing agricultural issues. Biochar is one of the organic materials which has recently attracted much attention due to its high stability properties.

Examined the physiological characteristics and dry matter of two mung bean cultivars under salinity stress conditions. Their results showed that the highest concentration of sodium ions is achieved at the levels of 9.4 and 9.7 dS/m of. However, it was found that the EC of 8.9, 9.7 and 9.7 dS/m, has reduced the potassium to sodium ratio corresponding to the leaf of cv. Partov to 1.1, 3.9 and 3.18, respectively. Furthermore, the highest concentration of malondialdehyde in this cultivar was observed at the EC of 9.7 dS/m. At the highest EC level, the highest dry weight of shoots, highest rate of photosynthesis as well as the highest potassium to sodium ratio were obtained from Pakistani cultivar, indicating the higher tolerance of this cultivar to the salinity stress compared to Partov one.

investigated about morphological and physiological response of different lettuce genotypes to salt stress. This suggests that the morphological and physiological response of 38 lettuce cultivars towards SS is genotype dependent [4]. Identifying SS's physiological, morphological, and biochemical attributes in lettuce may help plant-breeders develop salt-tolerant lettuce genotypes.

Several researchers have reported beneficial effects of organic amendments on soil functionality and crop yields in high salt conditions.

The addition of biochar has been found to reduce the bulk density. One of the most important physical parameters of the soil which strongly affects the crop yield is the water available to the plant. Recent studies have indicated that biochar increases the water holding capacity.

Rice straw biochar application to soil irrigated with saline water in a cotton-wheat system improves crop performance and soil functionality in north-west India.

The addition of organic materials like crop residues and manures to salt-affected soils has been suggested to lower electrical conductivity (EC), exchangeable Na⁺ and increase water infiltration, water-holding capacity, aggregate stability microbial biomass and enzymatic activities [5-7].

The addition of biochar to agricultural soils has been considered to enhance soil quality (Futa et al., 2020), accrue soil carbon for longer periods and It improves agriculture [8-11].

Moreover, the extent of influence of biochar on crop yield and soil properties largely depends on the nature of feedstock and pyrolysis conditions suggesting that results from different studies are often highly variable. Most reported positive effects of biochar application are context-dependent but some studies even reported negative effects of biochar on crop growth and soil properties [12-15].

The unpredictable nature of plant growth responses to biochar

application across different crops and cropping systems, soil types, and experimental conditions have limited its universal application [16]. Many greenhouses or laboratory incubation studies without adequate drainage provision showed increased soil EC values with biochar application [17-19].

Investigated about Role of biochar and organic substrates in enhancing the functional characteristics and microbial community in a saline soil [20].

Effects of the interaction between biochar and nutrients on soil organic carbon sequestration in soda saline-alkali grassland: A review [21]. The mechanism by which biochar and which biochar and nutrients interact to influence soil organic carbon sequestration in strongly soda saline-alkali grassland remains unclear.

Investigated about photocatalytic degradation of 2,4-dichlorophenol using bio-green assisted TiO₂-CeO₂ nanocomposite system [22]. the CeO₂ supported TiO₂ sample acts as the better visible light catalyst, due to the prevention of aggregation and existence of line dislocation that supported to access the additional electron trap sites.

investigated about Exploration of effective biorefinery approach to obtain the commercial value-added products from algae. In this study, biorefinery was used to test an algae-based bio-refining platform to produce energy, foodstuffs & pharmaceutical goods [23]. Using algal biomass to generate a variety of real-worth products as part of a comprehensive microalgae farming technique focused on isolating diverse bioactive substances from biomass to boost algae production efficiency. Furthermore, this study examines current breakthroughs in the use of microalgae biomass for diverse real-worth products.

Investigated Biodecolorization of Remazol dyes using biochar derived from *Ulva reticulata*: isotherm, kinetics, desorption, and thermodynamic studies. The kinetic study results indicate that the pseudo-second-order kinetic is the best fit model. Finally, the regeneration study concluded that of different elutant, NaOH showed the maximum desorption efficiency of greater than 99.2% for all four Remazol dyes.

Considering the major benefits of biochar for the agricultural soils, increasing the availability of elements in the soil, as well as the water shortage issue and the need to use water of poor quality, the present study seeks to study the effect of biochar on the soil salinity reduction in mung bean plant characteristics in greenhouse conditions. It is attempted to investigate the effect of biochar on some nutrients uptake at different salinity levels and determine the salinity tolerance of the mung bean plant.

2. Materials and Methods

Th current research was conducted in the greenhouse of Gonbad Kavous University. The soil used in this study was randomly

collected from the research farm of Gonbad Kavous University from the surface layer (0-30 cm). The soil samples were then transferred to the field, dried in the open air and passed through an 8 mm sieve.

The leaves of forest trees were also used in order to prepare biochar. The leaves were cut into smaller pieces using an electric mill and passed through a 2 mm sieve to make the particles uniform. The samples were placed in electric furnace at 400 °C for 4 h under limited oxygen conditions. Upon the furnace cooling, the biochars were removed and mixed with the soil with a ratio of 8%.

The number of pots used in this research is 28 with a height of 60 cm and diameter of 10 cm. After preparing the pots, the seeds of mung bean plant of VC1973A cultivar were soaked in the desired planting season, 24 hours prior to the planting and then transferred to the greenhouse for planting after a specified period of time. The irrigation was performed once every five days by weighing each pot. For the uniform germination under stress and non-stress conditions, the first few irrigations were carried out with municipal water. In two leaves stage, two plants were left in each pot and the rest were thinned. The salinity treatments were started from the beginning of the flowering stage of the plant.

In order to evaluate various salinity levels, calcium chloride (CaCl₂) and sodium chloride (NaCl) salts were used in equal proportions. The factorial experiment was conducted with two factors of combinations of biochar and salinity (with seven levels: three salinity levels of 2, 6 and 12 dS/m, salinity of 2 dS/m + biochar, salinity of 6 dS/m + biochar, salinity of 10 dS/m + Biochar, no salinity and biochar) and plant organs (with four

levels: leaf, stem, root and pod) in a completely randomized design with two replications. Pods have been irrigated with municipal water.

In two stages of podding and physiological maturation of the mung bean plant, the root, stem, pod and leaf organs were sampled and their characteristics were studied as well. The soil and plant samples were first air dried and then the nitrate and salinity characteristics were measured. In both stages of harvesting, the shoot and root of the plant were isolated and transferred to the laboratory in order to measure the fresh, dry and ash weights. After sampling, the plant and soil organ extracts were prepared and the concentration of salinity anions and cations (calcium, magnesium and chlorine) were measured using standard titration methods.

The flame photometer has been used for measuring the amount of sodium and potassium ions in the solution while the relative percentage of soil particles was measured by hydrometer (Gee and Bauder, 1986). Moreover, the pH value of saturated water, EC of saturated soil extract, nitrate concentration, EC and pH were measured using pH meter, EC meter, spectrophotometer, EC meter and pH meter, respectively (Ahiaei and Behbahanizadeh, 1993). Also, some growth parameters including the fresh and dry weights of shoots and roots (dried in an oven at 70 °C for 72 h), nitrate concentration in soil depths and plant organs, salinity level in soil and plant organs were used for the statistical analysis as average for each pot. The statistical analysis was performed separately in two stages of podding and maturation using SAS software. Excel software was used to plot the graphs. Some soil properties before the experiment are listed in Table 1.

Depth	EC(ds/m)	pH	NO ₃ ⁻	θ _s	ρ _b	n	Sand(%)	Silt(%)	Clay(%)	θ _m	θ _{fc}	θ _{wp}
0-30	0.175	6.11	8.52	2.27	1.15	0.44	22.2	72	5.8	4.08	0.22	0.08

Table 1: Some characteristics of the soil under study

3. Results and Discussion

3.1 Concentrations Calculated at the Beginning of the Podding Stage in the Mung Bean Plant

Effect of the salinity and organ on the calcium, magnesium, chlorine, sodium, potassium, pH and EC amounts showed in Table 2 and 3.

The results of analysis of variance of the studied traits in the first and second harvesting stages showed that the simple effects of salinity and plant organs as well as the interaction of salinity × plant organs on the calcium, magnesium, chlorine, sodium and potassium, pH and EC amounts are significant at a level of 1% (Tables 2 and 3).

Source	df	Ec	pH	K	Na	Cl	Mg	Ca
block	1	*12540	*0031/0	371 ^{ns}	58680 ^{ns}	2064 ^{ns}	3780 ^{ns}	714 ^{ns}
salinity	6	**18165	**256/0	**19680	**530860	**71130	**179900	245540**
Organ	3	**26086	**022/0	**317000	**824550	**178000	**40743	766000**
Salinity× Organ	18	**20783	**003/0	**3654	**227000	**20150	**267000	136000**
error	27	2671	0.0006	178	10024	3116	6874	3544
CV (%)	-	4.87	3.53	5.13	6.15	5.54	10.25	7.11
** and ns stand for being significant at a level of 1% and no significant difference, respectively.								

Table 2: Analysis of variance of the studied traits of mung bean in the first harvest under the influences of salinity stress and biochar

Source	df	Ec	pH	K	Na	Cl	Mg	Ca
block	1	3877 ^{ns}	0006/0 ^{ns}	9/107 ^{ns}	5013 ^{ns}	2893 ^{ns}	86/22 ^{ns}	71/5 ^{ns}
salinity	6	**211771	**016/0	**17447	**999375	**2390536	**299133	**209853
Organ	3	**1803326	**023/0	**154516	**4723186	**2270589	**1406634	**5946614
Salinity× Organ	18	**20869	**004/0	**32834	**225935	**258214	**271814	**159701
error	27	1112	0001/0	1073	10651	28113	3258	2394
CV (%)	-	3.29	8.41	9.04	4.9	6.43	5.73	4.41

Table 3 Analysis of variance of the studied traits under salinity stress and biochar of the second harvest of the mung bean plant

Tables 4 and 5 provide a comparison of the mean of the studied traits in the podding and maturation stages of the plant, respectively.

Treatment	EC	Na	Cl	K	Mg	Ca
Ls1	1460.5 ^d	2825 ^{ab}	1100 ^{ede}	380.8cd	1800b	2100b
Ls2	1586 ^{bc}	2911 ^a	1230 ^b	456.8b	2000a	2100b
Ls3	1906.5 ^a	2926 ^a	870 ^{kl}	498.5a	2120a	2900a
LBs1	1454 ^d	1498 ^{ghi}	1040 ^{defg}	295.2hi	700ef	1450f
LBS3	1648 ^b	2457 ^c	1110cd	357.9de	1510c	1810d
Lcontrol	1143.5 ^f	2685 ^b	1110cd	360.6de	1710b	1970c
Ss1	1278 ^e	1922 ^d	1130bcd	255.05jk	620efg	800h
Ss2	1477.5 ^d	2435 ^c	1410a	285.5hi	700ef	820h
Ss3	1533 ^{cd}	2458 ^c	1190bc	338ef	790e	1200g
SBs1	1236.5 ^{ef}	1522 ^{fgh}	910hijk	178.5n	100m	370klm
SBS2	1303 ^e	1182 ^{jk}	980fghij	196mn	220lm	660i
SBS3	1448 ^d	1316 ^{ij}	1060def	221lm	290jkl	740hi
Scontrol	727 ^{kl}	1522 ^{fgh}	1130bcd	247.9jkl	370ijkl	740hi
Rs1	717.5 ^{kl}	802 ^{lm}	1060def	137.3o	500ghi	290lmn
Rs2	739 ^{ijkl}	936 ^l	1090cdef	140.7o	500ghi	370klm
Rs3	936.5 ^g	1005 ^{kl}	1100cde	188n	550fgh	480jk
RBs1	763.5 ^{hijk}	342 ^o	830kl	80.5p	370ijkl	220n
RBS2	832.5 ^{ghij}	417 ^o	870jkl	83.6p	380hijkl	220n
RBS3	844.5 ^{ghi}	472 ^{no}	900 ^{ijk}	108p	390hijkl	260mn

Rcontrol	865gh	664mn	910hijk	103p	450ghij	270mn
Ps1	533mn	1754de	930ghijk	299.6gh	1110d	460jk
Ps2	633.5lm	1778de	990efghi	376.4d	1180d	500j
Ps3	692.5kl	1958de	1020defgh	405.2c	1240d	1360klm
PBs1	522.5n	1154jk	670m	200mn	240klm	280lmn
PBS2	651l	1333hij	830kl	230.5kl	360ijkl	310lmn
PBS3	781.5hijk	1676efg	850kl	249.2jk	400hijk	370klm
Pcontrol	465n	1718def	870lm	270.7ij	780e	400jkl

Table 4: Comparison of the mean examined traits in the podding stage

Treatment	EC	Na	Cl	K	Mg	Ca
Ls1	1607bc	2323fgh	3425cd	369/6fghi	1370c	2140b
Ls2	1669b	2368fg	3725bd	373/6fghi	1810b	2220b
Ls3	1823a	3044a	3900b	539/6c	1950a	2680a
LBS1	1051/5i	1724kl	2250im	245/21nop	460l	1480fg
LBS2	1466/5e	1827k	2250im	255/9mno	680jk	1590de
LBS3	1481/5de	2038/8j	2375hk	275/16klmn	730ijk	1590de
Lcontrol	1549cd	2244ghij	3175de	313/2ijklm	1250d	2130b
Ss1	1327/5f	1493mn	3125de	380/75fgh	1440c	1440fgh
Ss2	1347/5f	2057ij	3175de	570/05c	1450c	1530ef
Ss3	1423/5e	2226ghij	4700a	592/4c	1710b	1630d
SBS1	910/5k	2251ghi	2125j-n	265/3lmno	1240de	1060kl
SBS2	1220g	2790bcd	2725fg	276/95klmn	1400c	1340ij
SBS3	1184gh	2833bc	2725fg	349ghij	1410c	1390ghi
Scontrol	1227/5g	2251ghi	3000ef	358/05fghi	1420c	1410ghi
Rs1	905/5kl	581/2q	2425g-j	226/4opq	700jk	410pq
Rs2	1033ij	644/2q	2475ghi	235/35nopq	730ijk	540no
Rs3	1127/5h	866p	2675fgh	264/9lmno	870gh	560n
RBs1	730n	1277o	1925mno	114/5r	400l	260rs
RBS2	779/5mn	1377no	2125j-n	172/7qr	490l	380pq
RBS3	823/5m	1609lm	2250i-m	184/98pq	510l	380pq
Rcontrol	840lm	1233o	2275i-l	187/9pq	690jk	380pq
Ps1	773mn	1752kl	2350h-k	597/8c	1040f	460op
Ps2	837/5m	2144hij	2475ghi	688/6b	1070f	580n
Ps3	972jk	2248ghij	3150de	757/1a	1150def	1120k

PBs1	525/5p	2622de	1650o	225/5opq	630k	250s
PBS2	624/5o	2790bcd	2050k-n	336/45ghijk	770hij	350qr
PBS3	631/5o	2999ab	2125j-n	344/1ghij	830ghi	380pq
Pcontrol	620/5o	2383fg	2150i-n	427/3def	890g	410pq
Gs1	659o	1662klm	1825o	430def	1130ef	1350hi
Gs2	779/5mn	2138hij	2175i-m	452/8de	1430c	1440fgh
Gs3	946k	2484ef	2675fgh	467/55d	1440c	1800c
GBs1	526p	2823bcd	1950l-o	300/68jklm	200m	1010l
n						
GBS2	605o	abc2837	2325ijk	323/85hijkl	280m	1130k
GBS3	614/5o	2951abc	3425cd	371/fghi	440l	780m
Gcontrol	727/5n	2761cd	2200i-m	395/95def	850gh	J1250

Table 5: Comparison of the mean values of the studied traits in the maturation stage of the mung bean plant

3.2 Variation of Calcium Concentration

According to Table 4, a comparison of the mean interaction of salinity \times plant organs indicated that the highest amount of calcium is associated with the leaf organ of S3 treatment (LS3) at a concentration level of 2900 mg/l. The amounts of calcium associated with S3 treatment in stem, root and pod organs were estimated as 1200, 480 and 1360 mg/l, respectively, which are higher than those of other treatments. However, the lowest amounts of calcium in leaf, stem, root and pod organs were observed in BS1 and control treatments and were equal to 1450, 370, 220 and 280 mg/l, respectively (Table 4).

3.3 Variation of Magnesium Concentration

According to Table 4, with increasing salinity, the amount of magnesium accumulation increased in all organs. The highest amounts of magnesium was observed in S3 treatment, being calculated as 2120, 1240, 790 and 550 mg/l for the leaf, pod, stem and root organs, respectively. However, the lowest amounts of magnesium were associated with the leaf, root, pod and stem organs in BS1 treatment which were measured as 700, 370, 240 and 100 mg/l, respectively.

3.4 Variation of Potassium Concentration

A comparison of the mean interaction of salinity \times organ showed that the highest amount of potassium is observable in the leaf and S3 treatment (498.5 mg/l). However, the lowest amounts of potassium were observed in root organs in BS1, BS2, BS3 and control treatments estimated as 80.5, 83.6, 108 and 103 mg/l, respectively, and no significant difference was observed between them (Table 4).

In general, the accumulation of potassium in leaf organs was found to be more than other organs and the pod, stem and root were in the next places, respectively (Table 4). That is, the root organ absorbs less potassium under salinity stress and salinity + biochar

conditions. Despite the high amount of potassium in organic matter, it is not introduced into the structure of organic compounds and is in the form of potassium ions. Therefore, upon adding the plant residues to the soil, a large amount of this ion enters the soil solution. Due to the secretion of large amounts of salt that also contain potassium, as well as the addition of organic matter to the soil through biochar, a significant increase in the potassium content can be justified. These results are consistent with those reported by.

3.5 Variation of Chlorine Concentration

Comparison of the mean interaction of salinity \times organs showed that the highest chlorine concentrations are attributed to the leaf, stem, root and pod organs in S3 treatment with estimated amounts of 1230, 1190, 1100 and 1020 mg/l, respectively (Table 4). However, the lowest amount of chlorine was observed in the pod and BS1 treatment (670 $\mu\text{mho/cm}$).

With increasing salinity, the accumulation of chlorine increased in all organs of the plant, especially in the leaf. Consumption of biochar increased chlorine uptake in the root and leaves.

In general, a higher chlorine accumulation was observed in the stem organ than other counterparts, followed by leaf, root and pod, respectively. In addition, less chlorine has been absorbed in the pods under salinity and biochar consumption. The concentration of chlorine ion in the shoot was found to be higher than the root, which indicates the high transfer of this ion from the root to the shoot organ and its concentration in these organs as well. Other researchers have also reported a close relationship between the concentration of chlorine ions, especially in the shoots of plants, and their tolerance to salinity. These results comply with those via.

3.6 Variation of Sodium Concentration

A comparison of the mean interaction of salinity \times organs (Table

4) showed that the highest amount of sodium was observed in treatment of LS3 (leaf and 3044 ppm). The lowest amount of sodium accumulation was observed in root and BS1 (581.2 ppm). Furthermore, the amount of sodium accumulation in all organs increased by increasing of salinity level.

Comparing the mean interaction of salinity \times organs showed that the highest amount of sodium was observed in LS3 treatment (2926 mg/l). The lowest amount of sodium was observed in RBS1 treatment (1005 mg/l). With increasing salinity, the amount of sodium accumulation has increased in the organs. Besides, the biochar consumption led to a reduced sodium content in the plant organs. Also, the consumption of biochar has reduced the amount of sodium in the leaf organ and BS1, BS2 and BS3 treatments. With increasing salinity, the accumulation of sodium in the root organ has increased. Moreover, the consumption of biochar has led to an increased amount of sodium.

In general, the sodium accumulation in the leaf organ is higher than other ones, and the stem, pod and root are in the next places, respectively, thus indicating that this element is more absorbed in the shoot. Since sodium chloride is the most abundant and soluble salt available and its presence in the soil causes osmotic stress, the loss of ionic balance creates restrictions for the growth and reduced plant yield [24,25]. The consumption of biochar has caused less increase in the sodium amount rather than the salinity alone. The increasing sodium content may be due to the fact that the cation exchange capacity of the soil with increasing biochar has increased more than the amount of dissolved sodium in the soil and more sodium has been exchanged on the surface of soil particles. According to the reduced potassium concentration and increased sodium level in the plant can be attributed to the competition between sodium and potassium at the uptake site. These results are in agreement with those reported by.

In this investigation, the reduction of salinity in the roots and shoots of the plant under the conditions of biochar consumption at all levels indicates the role of biochar in improving the physical conditions and soil aeration. Numerous reports have reported the role of biochar in reducing the salinity effects on the plant growth and yield.

Arrived at similar findings in their research. In addition to improving the physical properties and soil moisture conditions, the major mechanism that causes the beneficial role of biochar in reducing the negative effects of salinity, can be attributed to its high capacity to absorb sodium ions. The present results are in line with the achievements of other researchers such as According to the ability of biochar and plant residues to increase the usable water for the soil can partially compensate the negative effects of salinity in the arable soils. In this study, increasing the growth of roots and shoots of the plant under the biochar consumption conditions at all salinity levels highlight the role of biochar in improving the physical and aeration conditions of the soil [26].

Biochar amendment likely caused Na immobilization from the soil solution onto the porous negatively charged surface or increased leaching of Na from the soil profile as a result of significant improvement (Table 5). Similarly, also argued that irrespective of the amendment rate, biochar could allow for greater salt leaching, and thus contribute to enhanced crop production in the coarse-textured saline soil.

A high level of Na in the growth environment of a plant has been reported to interfere with the uptake of essential nutrients. The present study demonstrated that biochar application improved selective nutrient ion uptake under saline irrigation water. Indeed, reported that biochar can retain significant amounts of cations on its surface and surface affinities to Na may differ from K ions [27]. This reduces entry of Na ions into cells while enriching plants with essential nutrients, thereby improving the growth of crops in saline soils [28]. Showed that improved K/Na ratio through enhancing K availability is a useful way to improve the yield of crops in saline-alkali soil. Consistently, in our study, a significant decrease in Na/K ratio due to an increase in K uptake in cotton and wheat was found at variable rates of biochar application under saline water irrigation (Table 5). Moreover, the inferior crop growth in saline soils is also closely associated with the decline in the availability of N [29]. Other studies also showed that biochar addition significantly enhanced the available N and P levels in saline-alkali soils. For example, biochar addition significantly enhances soil nutrient availability and increases maize production [30,31].

Likewise, attributed the increased plant growth responses observed to greater plant uptake of nutrients with increasing biochar applications [32]. Moreover, the application of crop residue biochar can recycle the valuable major and micronutrients as well as silicon thereby increasing the availability of plant nutrients in the soil [33,34]. Biochar often contains significant amounts of soluble nutrients (P, K, Ca, Mg) within its ash fraction that directly contributes to plant-available pools upon incorporation in the soil [35].

Also suggested that biochar application favours greater microbial activity and nutrient release in the amended soils for alleviating salt stress. Nevertheless, many short-term studies showed a non-significant effect of biochar application on MBC in non-saline soils and under salt stress [36-38]. These contrasting results were manifested in literature due to differences in feedstock and charring conditions, application rates and methods, experimental conditions (greenhouse or field, soil and climate), and usage of aged or fresh biochar.

3.7 Variation of the EC of the plant

The highest amount of EC was observed in LS3 treatment with estimated value of 1906. However, the lowest amount of EC was associated with BS1 in all organs. Table 5 presents a comparison of the mean of the studied traits in the maturation stages of the plant.

3.8 Variation of Calcium Concentration

A comparison of the mean interaction of salinity \times organ (Table 5) showed that the highest amount of calcium (2680 mg/l) is associated with BS2 treatment. The calcium concentrations in BS2 treatment were estimated as 2680, 1630, 560, 1120 and 1800 mg/l in leaf, stem, root, pod and mung bean grains, respectively.

In addition, the lowest amount of calcium was observed in the pod organ and control treatment (250 ppm), which was not significantly different from the corresponding value in BS2 one (Table 5). With increasing salinity, the amount of calcium accumulation in the roots decreased in S1, S2 and S3 treatments. Moreover, the biochar consumption has led to the reduced calcium uptake in all organs of the plant. In general, the calcium accumulation in the leaf organs was higher than other ones, followed by the stem, seeds, pod and root of the mung bean plant, respectively. It was also found that the consumption of calcium chloride, which contains calcium, has caused more accumulation of this element in the leaf and less accumulation in the root organs, indicating that this element is more absorbed in the shoot.

Calcium is one of the essential elements in the plant growth and modulation of environmental stresses. The consumption of calcium chloride, which contains calcium, seems to cause more accumulation of this element in the leaf and less accumulation in the root organs. The calcium concentration has also increased with increasing calcium chloride and sodium chloride (increasing salinity). This is mainly due to the fact that the evaporation and leaving of solutes on the soil surface and also the movement of water toward the soil surface might lead to the transfer of solutes to the surface layer and as a result cause more increase in the surface layer of the soil. According to the results of Tables 4 and 5, biochar has been able to make the plant stable against salinity and improve the absorption properties of this element. These results are consistent with those achieved by.

3.9 Variation of Magnesium Concentration

Comparison of the mean interaction of salinity \times organs showed that the highest amount of magnesium is associated with the leaf in S3 treatment (1950 ppm). However, the lowest amount of this element was observed in mung bean seed and BS1 treatment (200 ppm). Also, with increasing salinity, the accumulation of magnesium decreased in the leaf organ. Moreover, the biochar consumption has led to an increase in the magnesium absorption in the salinity + 2 dS/m biochar and salinity + 6 dS/m biochar and decreases in the salinity + 10 dS/m biochar treatments. With increasing salinity, the magnesium content in the stem first increased in the salinity of 2 dS/m, then decreased in the salinity of 6 dS/m and finally increased in the salinity of 10 dS/m. The consumption of biochar was also found to reduce the magnesium uptake in the stem. Also, with an increment in the salinity level, the accumulation of magnesium in the roots has decreased. With increasing salinity, the amount of magnesium in the mung bean seeds has led to an increased magnesium accumulation in the

salinity treatments. The consumption of biochar has reduced the magnesium accumulation.

In general, the magnesium accumulation was found to be higher in the leaf organ rather than other counterparts and then pod, stem and root organs were in the next places, respectively. With increasing salinity, the amount of magnesium increased, which is attributed to the competitive effect of magnesium with calcium. However, this increase was more than salinity alone in some treatments with biochar consumption (Table 4). This increase can be due to the concentration of the mentioned elements due to the reduced dry matter production. These results are in agreement with the achievements of Mahmoudi.

3.10 Variation of Potassium Concentration

Salinity seems to cause higher accumulation of potassium in the leaf and less one in the root organ, which indicates that this element is more absorbed in the shoot. The amount of potassium has also increased with increasing salinity. The increase of soluble potassium as a result of biochar application is related to their composition, especially the amount of potassium available in them, rate of potassium release and effect of organic molecules on this release from the soil minerals. Despite the high amount of potassium in the organic matter, it is not included in the structure of organic compounds and it is available in the form of potassium ion. As a result of adding plant residues to the soil, a large amount of this ion enters the soil solution. Due to the secretion of large amounts of salt which contains potassium and also the addition of organic matter to the soil through the biochar, a significant increase in the potassium amount can be justified. These results are consistent with those of.

3.11 Variation of Chlorine Concentration

According to Table 5, a comparison of the mean interaction of salinity \times organ shows that the highest amount of chlorine in the stem is associated with the salinity of S3, which has been measured as 4700 ppm. However, the lowest amount of chlorine was observed in the pod organ and control treatment (1650 mg/l) as well as the mung bean seed and BS1 one (1950).

It has been found that the amount of chlorine accumulation in the organs increases as the salinity level increases. The consumption of biochar has led to an increment in the chlorine uptake by the plant organs. In general, in treatments S3, BS2 and BS3, the accumulation of chlorine in the stem was higher compared to other organs, and the leaf, mung bean seed, pod and root were in the next places, respectively. In addition, the concentration of chlorine ion in the shoot was found to be higher than the root, which indicates the high transfer of this ion from the root to the shoot part and its concentration in these organs as well. The biochar consumption has increased the amount of chlorine in most organs rather than salinity alone, which might be due to the type of plants and the temperature used in the biochar preparation. These results are consistent with the results of.

3.12 Variation of Sodium Concentration

As would be observed from Tables 4 and 5, the biochar consumption has increased the amount of sodium in all organs of the plant. The concentration of sodium ion in the shoot was found to be higher than the plant root, which indicates the high transfer of this ion from the root to the shoot and its accumulation in this organ. With increasing consumption of sodium chloride and calcium chloride, the amount of sodium in the plant organs has also increased. The consumption of biochar has led to the less increment of this ion in some organs rather than in the salinity alone. The increase in the sodium level may be due to the fact that with increasing biochar, the cation exchange capacity of the soil has increased more than the amount of dissolved sodium in the soil and more sodium has been exchanged on the surface of soil particles. Bhivare and attributed the reduced potassium and increased sodium concentrations in the plant to the competition between sodium and potassium at the uptake site. These results are in line with the findings.

3.13 Variation of EC

According to Tables 4 and 5, the highest EC accumulation was related to S3 treatment and leaf, stem, root and pod organs within the podding stage, estimated as 1906, 1533, 936.5 and 781.5 mg/l, respectively. However, in the maturation stage, the highest EC accumulation was observed in BS2 treatment in the leaf, stem, root, pod and seed organs which have been measured as 1823, 1423.5, 1112.5, 972 and 946 mg/l, respectively.

According to Table 5, salinity has caused a further increase in the EC level associated with the leaf organ and the lowest accumulation in the mung bean seed, which indicates the higher uptake of this element in the shoot. Also, the consumption of biochar has led to the salinity reduction. The results of this research are consistent with those reported by.

In general, the amount of EC accumulation in the leaf organ was higher than the other ones, and the stem, root, pod, and mung bean seed were in the next places, respectively. This means that the mung bean seed organ has absorbed less EC under salinity conditions and biochar consumption. In the absence of salinity (control), the plant's pod and seed organs were found to absorb less EC in the podding and maturation stages, respectively.

As biochar is produced from organic material, it contains plant-available nutrients with variable rates of release, depending on production settings and feedstock type. The positive effects of biochar amendment in saline water irrigated plots on crop yields in the present study are supported by improvement in yield attributes of cotton such as boll weight and the number of bolls per plant and spike density and panicle length in wheat by [39].

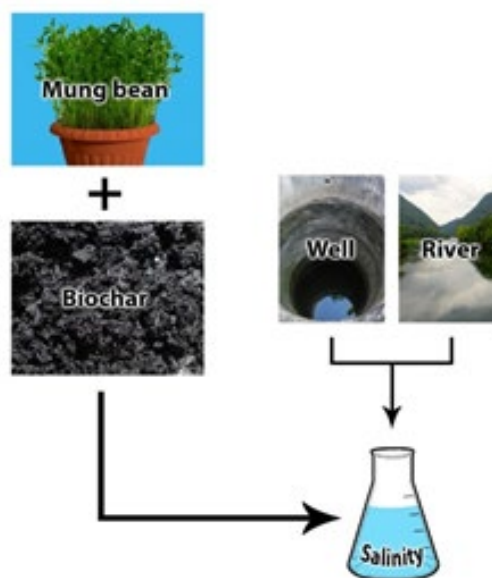
Generally, better plant nutrition status helps to overcome salinity stress.

Adequate amounts of essential plant nutrients will encourage the

growth of above- and under-ground biomass [40].

Investigated about Role of biochar and organic substrates in enhancing the functional characteristics and microbial community in a saline soil. The co-addition of biochar and organic substrates shifted microbial community, is in correspondence with the relative abundance of the phylum. Overall, the abundance of Firmicutes and Actinobacteria was higher in soils under a combination of lignite char with DI and COM respectively. Likely, the abundance of Euryarchaeota was dominant in the coapplication of corn straw biochar and DI. Redundancy analysis revealed the intactness between bacterial genera and their metabolisms with K, and Mg. Picrust disclosed the enhanced metabolic functions in soil with amalgam of DI and its biochar. The findings showed that the application of DI and its biochar mixture, as an amendment could be a better approach in the long-term reclamation of saline soil.

Application of biochar under saline conditions has two main advantages. The first is the enhancement of the structure and permeability of soil, thus increasing the leaching of salts from the root zone [41]. The second is the carbon dioxide produced during organic matter decomposition, which helps in reducing the soil pH and increasing the nutrient availability and uptake [42]. Plants under salt stress suffer from imbalances of essential nutrients, and biochar application can alleviate this imbalance by increasing the availability of native soil nutrients or from that applied with biochar [43]. Biochar application has another indirect action through its effect on enhancing the cation exchange capacity and the other soil conditions that encourage plant growth [44,45].



4. Conclusion

The results of comparing the mean interaction of salinity × organs showed that the highest amount of calcium in most cases is observable in the shoots. Also, the consumption of biochar has reduced the calcium uptake at high salinity levels in the leaf and

root and increased it in the stem and seed as well. With increasing salinity, the concentration of potassium was found to decrease compared to that of calcium. Furthermore, with increasing salinity levels, the concentration of all mentioned elements increased in most treatments [46-56]. The results showed that biochar has led to an increased pH amount in the plant organs. The EC level was also improved upon the biochar application. In general, the conversion of forest tree leaves to biochar has increased the salinity, but in most cases this increase was less than the salinity alone. From the above results, it can be inferred that although high salinity levels reduce the growth of mung bean plant, this plant shows an appropriate resistant to the low salinity. It can be concluded that the salinity resistance mechanism of this plant is the salt tolerance through the accumulation of ions in its organs. Therefore, biochar can be used to improve the saline soils, for the optimal use of soil resources and saline waters.

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