

Biochar Improves Soil Properties and Wheat Growth Under Saline Conditions: A Growth Chamber Study

Abdul Basir^{*1}, Muhammad Adnan¹, Muhsin Khan¹, Muhammad Sohaib¹, Mohammed Afaq Khan¹, Abdullah Shahid¹, Adeel Ahmad, Hamza Zaman¹

¹Department of Agriculture,
University of Swabi-Pakistan;

Correspondence

Abdul Basir

a.basir@uoswabi.edu.pk

Funding information

Not Applicable

Abstract

Application of biochar to agricultural soils is one of the recently proposed technologies of sustainable agricultural management. To this extent a pot experiment was conducted in completely randomized design (CRD) to evaluate the effect of biochar particle sizes ($B_1= 0.002$, $B_2= 0.05$, $B_3= 2$ mm) applied at the rate of 40 tons per ha^{-1} on soil properties and wheat growth under saline ($S_1= 0.1\%$, $S_2= 0.2\%$, $S_3= 0.3\%$) and non-saline (control= S_0) conditions. Biochar particle size significantly affected soil electrical conductivity, pH, water holding capacity, days to emergence, percent germination, shoot biomass, root biomass and chlorophyll content. Similarly, greater days to emergence (7.75) shoot biomass (2.74 g), root biomass (0.84 g) and chlorophyll content (55.67 CCI) was obtained for biochar with particle size of 0.002 mm. Biochar with particle size 2 mm significantly increase root:shoot ratio (0.33 %). Biochar with (2 mm) had reduced pH 7.12 and EC ($0.59 dSm^{-1}$) while enhanced germination (80 %). In case of salinity greater soil pH (7.49), days to emergence (8.22 days) and EC ($0.71 dSm^{-1}$) was observed for those pots treated with 0.3% NaCl while maximum germination (92 %), shoot biomass (3.05 g), root biomass (1.03 g), root to shoot ratio (1.03 %) and chlorophyll content (59.44 CCI) was calculated for those pots which received no salt content followed by pots where salt of 0.1% NaCl was applied. Therefore, biochar may be used at the rate of 40 t ha^{-1} with particle size of (0.002-0.05 mm) under no saline or limited saline conditions (0.1% NaCl content) for improving soil health and crop productivity.

KEYWORDS

Biochar, wheat, salt concentration, soil properties

1.0 INTRODUCTION

Wheat (*Triticum aestivum L.*) is a valuable staple food cereal crop of more than one third of the world population. Wheat is also called the king of cereals. It is extensively grown and preferred by the peoples and is the principal source of food in Pakistan. The wheat cultivated area, production and yield was 9052 thousand ha, 25.750 million tons and 2845 kg ha^{-1} respectively according to Pakistan Economic Survey 2016-17. Pakistan considerably producing low average yield of wheat as compare to other

wheat producing regions of the world. Some of the factors behind this low yield include meagre nutrient status of soil, improper use of fertilizers, lack of farmer's educations regarding use of advanced technology, environment and climatic conditions of the area, deficiency of essential nutrients and water shortage at critical growth stages [1].

Soil salinity is another major problem which has negatively affected the crop standard and yield of this important crop in some parts of the world [2] and specifically in those regions of the world where wheat is grown in arid and semi-arid conditions [3]. Due to

this salinity a substantial (6.3 m ha) cultivable land has been affected in Pakistan. In Sindh alone 2.3 m ha land is affected by different types of salts, mostly slats of chlorides and sulfates of sodium, magnesium and calcium [4]. When soil salts exceeds than tolerable level it affects plant growth from germination to maturity [5]. Salts can affect the plants in two ways: 1) by declining the rate of water entrance to plants and b) encouraging the entrance of toxic ions as well [6]. In salt stress conditions plants require a close fitting and balance nutrition of both macro and micronutrients to continue normal physiological functions for growth and development. Wheat can tolerate salts up to a concentration of 7.0 dS m^{-1} and its yield can be decreased up to 25% at concentration of 9.0 dS m^{-1} [7-8]. Crops cultivar varies for reduction in growth and yield at different salt concentrations due to its genetic make-up [9].

Biochar is new term in recent years, which is plant biomass derived materials in black carbon from [10]. Biochar is a rich source of mineral including calcium (Ca), magnesium (Mg) and inorganic carbonates. On the other hand, when organic matter is burned it creates ash and most of the minerals is lost. Because of rich in organic carbon, biochar can increase the content of soil organic carbon, soil organic matter and improve soil water holding capacity and nutrients. Biochar also contain huge amount of holes, which can increase content of minerals nutrients in soil, such as phosphorus, potassium, calcium, magnesium and nitrogen [11]. Biochar increases the shoot and root biomass of the plant significantly because it increases soil acidity by decreasing soil pH and enhance root growth [12]. Biochar also effect leaf chlorophyll content of the plant and considerably increase the chlorophyll content of the plant [13]. Keeping in view the various positive impacts of biochar on soil properties and escalating demand of wheat in the country having a

substantial salt affected agriculture land, this research was conducted to examine the effect of biochar particle sizes on soil properties and wheat growth in a loam clay soil under saline and non-saline conditions.

2.0 MATERIALS AND METHODS

A pot experiment was conducted to study the effect of biochar on soil pH and growth of wheat under saline condition at Agriculture laboratory, University of Swabi, Khyber Pakhtunkhwa, Pakistan. The experiment was conducted in two factorials completely randomized design (CRD) with three replications. Biochar particle sizes B1, B2 and B3 each consists of 0.002, 0.05 and 2mm at the rate of 40 tons ha^{-1} (23g per 1.3 kg soil) were used. While salt levels S1, S2 and S3 consist of 0.1, 0.2 and 0.3% at the rate of 1.3 g NaCl per 1.3 kg soil w. In control plot only salt was applied. Pots containing 1.3 kg soil were used. Pirsabak 2013 variety of wheat was sown in pots in June, 2016 at the rate of 20 seeds per plot. Plots were kept in growth chamber in the laboratory and all conditions were kept homogenous. NPK was applied at the time of sowing at the rate of 120, 90 and 60 kg ha^{-1} . Biochar (B) with different particle size and salt levels (S) were applied at the time of sowing. Soil was analysed for various physio-chemical properties and found pH (7.52) EC (1.46) C (57.65%) P (1.07%) N, 0.06%.

2.1 Statistical Analysis

Steel and Torrie [14] method was used for conducting Analysis of variance (ANOVA). Variations in the data were observed and noted for different parameters and means were compared based on least significant difference (LSD) test at 5% level of probability.

3.0 RESULTS AND DISCUSSION

3.1 Effect of biochar on soil physico chemical properties under saline conditions

The response of soil pH to biochar was non-significant while significant for salinity (Table 1). The interactive

effect of biochar x salinity were also non-significant. Statistically similar value of pH was obtained for biochar applied at different particle sizes. On the other hand, increasing trend in soil pH was observed for increasing salt content. Statistically greater soil pH (7.49) was recorded for salinity level of 0.3% followed by pH value (7.33) for salinity level 0.2% while lower soil pH (7.14) was recorded where no salt content were applied however this value was statistically similar to salinity level 0.1%. The results obtained for biochar were similar to those of Thomas, *et al.* (2013) and the results of salinity were similar to those of Muhammad *et al.* (2012).

Soil electrical conductivity (EC) responded significantly different to biochar and salinity however, EC response was non-significant for the interactive effect of biochar and salinity (Table 1). Maximum EC (0.61 dSm⁻¹) were measured for biochar particle size 0.002 mm, while lower value (0.59 dSm⁻¹) was measured for biochar particle size 2 mm. In case of salinity maximum EC (0.71 dSm⁻¹) were calculated at salinity level 0.3% salts while minimum EC (0.46 dSm⁻¹) were noted in control pot. These findings are in confirmation to Thomas *et al.* [15] who reported a significant response for soil EC to the interaction between biochar and salt treatments.

Table 1. Soil pH, electrical conductivity (EC), days to emergence and % germination as affected by biochar and salinity levels.

Biochar size (mm)	pH	EC (dSm ⁻¹)	Days to emergence	Germination (%)
0.002	7.33	0.61a	7.75 a	75b
0.05	7.28	0.60ab	7.50 a	76ab
2.00	7.25	0.59b	6.83 b	80a
LSD (P ≤ 0.05)	-	0.01	0.63	4.89
Salinity (%)				
0.0	7.14c	0.46d	6.22 c	92a
0.1	7.18c	0.59c	7.11 b	79b
0.2	7.33b	0.66b	7.89 a	72c

0.3	7.49a	0.71a	8.22 a	65d
LSD (P ≤ 0.05)	0.09	0.01	0.73	5.65
Interaction				
BC*S	ns	ns	ns	ns

Means followed by different letters in each row and column are significantly different ($\alpha = 0.05$) from each other.

3.2 Effect of biochar on growth parameters under saline condition

Days to emergence showed a significant effect for biochar and salinity while the interactive effect of biochar x salinity were non-significant (Table 1). Significantly greater days to emergence 7.75 and 7.50 were recorded for biochar particle size 0.002 and 0.05 mm respectively, while statistically minimum days to emergence (6.83) was noted at biochar particle size of 2 mm. In case of salinity significantly greater days to emergence 8.22 and 7.89 were noted at salinity levels of 0.3% and 0.2% respectively, while minimum days to emergence (6.22) were noted in control pots. Similar results were also obtained by Akhter *et al.* [16], who reported that emergence is affected by biochar and salinity.

Percent germination (Table 1) showed a significant effect for biochar and salinity. While the interactive effect of biochar and salinity were non-significant. Maximum percent germination (80%) was calculated for biochar particle size 2 mm, while lower percent germination (75%) was calculated at biochar particle size 0.002 mm. In case of salinity maximum % germination (92 %) were calculated where no salt were applied while minimum % germination (65%) were noted for salinity level of 0.3%. Application of biochar irrespective of its particle sizes improved germination percentage and vigour in all salt treated pots. The reason for improvement in germination in the biochar amended pots is proper availability of water due to improved water holding capacity of soil. Similar results were also obtained for increase in germination and other related parameters of wheat at

different biochar types and rate of application by Wang and Xu [10] (2013) and Rajalakshmi *et al.* [17]. Salts created water stress in the salt applied pots which negatively affected seed germination as compare to control pots [18]. The same results were also noted by Rahman *et al.* [19] who reported that germination depends on the amount of water absorbed and delay in germination is also caused by the salt concentration of the growing medium. One of the possible reasons for decrease in seed germination might be due to cell toxicity by salts that distract various reactions in cells [20]. Delay in hydrolysis of the stored molecule with in the endosperm and restricted water movement to the growing embryo might be another possible cause of the decrease in germination [21].

Data on shoot biomass (Table 2) showed a significant effect for both biochar and salinity levels while the interactive effect of biochar and salinity were non-significant. Statistically different values of shoot biomass were obtained for different biochar levels. Maximum value for shoot biomass (2.74) was calculated for biochar particle 0.002 followed by shoot biomass value (2.69) for biochar particle size 0.02 while lowest shot biomass value (2.59) for biochar particle size 2mm. Decreasing trend in shoot biomass was observed for increasing salt content. Maximum value for shoot biomass (3.05) was calculated where no salt content were applied while lower shoot biomass value (2.29) was calculated for salinity level 0.3%. When subjected to salt stress, maize plant showed the largest shoot biomass reduction up to 66.5%. Salinity affects the seedling growth of plants [22] by slow or less mobilization of reserve foods [23], suspending the cell division, enlargement [24] and injuring hypocotyls.

Results for the effect of biochar, salinity and their interaction on root biomass of wheat are present in table 2. Upon analysis of various result demonstrated that there is significant effect for both biochar and

salinity while the interactive effect of biochar and salinity were also non-significant. Statistically different values of root biomass were obtained for both the treatments. At biochar particle size 0.002mm maximum value (0.84) of root biomass was calculated and minimum value (0.71) was calculated by biochar particle size 2 mm. Decreasing trend in root biomass was observed for increasing salt content. The maximum root biomass value (1.03) was obtained where no salt was applied and lowest (0.60) at salinity level 0.3%. These findings are in confirmation to Azooz *et al.* [25] who shows that increase in salt concentration salt reduced root biomass. When subjected to salt stress, maize plant showed the largest root biomass reduction up to 61.4%.

Biochar and salinity showed significant effect for root to shoot ratio of wheat while their interaction was non-significant (Table 2). Biochar particle size of 2 mm resulted significantly greater roots to shoot biomass (0.33) followed by piratical size of 0.05 mm (0.29) and 0.002 mm (0.26) respectively. Decreasing trend in root to shoot ratio was observed for increasing salt content. Statistically greater root to shoot ratio (0.34) was obtained where no salt was applied and lowest root to shoot ratio of (0.26) resulted at salinity level of 0.3%. Basir *et al.* [26] also observed that increase in NaCl concentration decreased the root to shoot ratio in wheat crop.

The response of chlorophyll content of wheat leaves to different biochar and salinity levels was significant however its response to biochar x salinity interaction was non-significant (Table 2). Significantly greater chlorophyll content (55.67 CCI) was recorded for biochar particle size of 0.002 mm followed by (54.33 CCI) at particle size 0.05 mm and a minimum chlorophyll content (52.66 CCI) was observed at biochar particle size 2 mm. Similarly statistically decreasing trend in chlorophyll content was observed for increasing salt content. Greater chlorophyll content (59.44 CCI) was calculated where no salt

content were applied followed by a chlorophyll content (55.00 CCI) for salinity level 0.1% while lower chlorophyll content (49.33 CCI) was recorded for salinity level of 0.3%. These findings are in confirmation to those of Ullah, *et al.* [27]. A decreasing trend was observed in chlorophyll content under salt stress conditions. There was a decrease of 11% and 38% of chlorophyll in response to the 50 and 100 mM NaCl treatments, respectively, when compared to the control pots after 90 days of sowing.

Table 2. Shoot biomass, root biomass, root to shoot ratio and chlorophyll content as affected by biochar and salinity levels.

Biochar size (mm)	Shoot biomass (g)	Root biomass (g)	Root/shoot ratio	Chlorophyll content (CCI)
0.002mm	2.74a	0.84a	0.26c	55.67a
0.05mm	2.69a	0.81a	0.29b	54.33ab
2mm	2.55b	0.71b	0.33a	52.67b
LSD (P ≤ 0.005)	0.12	0.07	0.02	1.82
Salinity (%)				
0	3.05a	1.03a	0.34a	59.44a
0.1	2.77b	0.85b	0.31b	55.00b
0.2	2.56c	0.67c	0.27c	53.11b
0.3	2.29d	0.60c	0.26c	49.33c
LSD (P ≤ 0.005)	0.13	0.08	0.02	1.82
Interaction				
Biochar × salinity	ns	ns	ns	ns

Means followed by different letters in each row and column are significantly different ($\alpha = 0.05$) from each other.

4.0 CONCLUSION

It is concluded from the study that statistically greater EC, days to emergence, shoot and root biomass and chlorophyll was obtained for biochar with particles size of 0.002 and 0.05 mm. While statistically greater % germination was

recorded for biochar with particle size of 2 mm. In case of salt levels statistically greater response for % germination, shoot and root biomass and chlorophyll content was observed in those pots where no salt content were applied. On the other hand significantly greater soil pH, days to emergence and EC was recorded at pots where 0.3% salts were applied. On the basis of the experimental results it is suggested to the farming community that biochar as soil amendments may be used at the rate of 40 tons ha⁻¹ in grounded form up to 0.002 and 0.05 mm for getting better growth and growth traits.

ACKNOWLEDGMENTS

We acknowledge the University of Swabi for providing their research facilities for conducting this research work.

CONFLICT OF INTEREST

The corresponding author declares no conflict of interest on behalf of all authors.

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