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Effect of Bentonite and Biochar Application on Selected Physical Properties of Coarse-Textured Soil and Growth of Broccoli Plants

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Abstract. *Soils with rough texture have low fertility because they have low amounts of colloidal and organic matter resulting in low physical characteristics and the inability to retain water and nutrients. Thus, physically, organic amendments and soil conditioners are applied to enhance physical properties and their capacity to hold water and nutrients. The study was carried out in Babil Governorate, Iraq, at 32 o 47 W7.38 N, 44 o 25 W33.63 E, at 31 m above sea level, and during the 20252026 season, to examine the impact of the addition of bentonite and biochar on certain physical characteristics of coarse-textured soil and the development of broccoli plants. The experiment was carried out in the form of factorial experiment with the Randomized Complete Block Design (RCBD) with three replicas where each replica consisted of nine experimental units. In the research two factors were used. The first one was the addition of bentonite in the level of 0, 10 and 20 Mg ha^{-1} represented as B0, B1, and B2 respectively. The second was the biochar addition at 0, 5, and 10 Mg ha^{-1}, which was referred to as C0, C1, and C2 respectively. It was demonstrated that treatment of addition of bentonite at 20 Mg ha^{-1} reflected better in the mean bulk density, soil moisture content at field capacity, soil moisture content at wilting point and available water in the soil with percentage improvements of 4.19 , 26.86 ,12.11 and 41.71 respectively compared to the treatment without addition (control). The outcome of the addition of biochar also revealed that the treatment 10 Mg ha^{-1} showed the superiority of the treatment in terms of total porosity, soil moisture content at field capacity, soil moisture content at wilting point, and availability of water in the soil, which increased by percentage of 4.09, 10.54, 6.55, and 14.10, respectively, with respect to the control treatment (not added biochar). The binary interaction revealed that the treatment (20 Mg ha^{-1} bentonite + 10 Mg ha^{-1} biochar) performed better in the mean soil moisture content at the field capacity, soil moisture content at the wilting point and the available water in the soil, where the percentage changes were 41.50, 24.02, and 58.87, respectively.*

Keywords*: Bentonite, Biochar, Broccoli Growth, Coarse-textured Soil, Soil Physical Properties.*

1. INTRODUCTION

The low-fertility soils are coarse-textured soils because they have low contents of colloidal and organic materials besides poor ability to hold water, nutrients and other biological and physical properties. This situation makes it less efficient when it comes to the uptake of water and nutrients by plants, which something that requires the constant application of fertilizers and mineral and organic amendments to offset this lack. Bentonite is one of the significant clay minerals utilized in the enhancement of soil properties as it is among the materials that have been used to improve the soil properties through its high cation exchange capacity and a large surface area. This is mostly linked to the fact that it is rich in the mineral montmorillonite [1]. Another role of the added bentonite clay to the soil is to help enhance the physical and chemical characteristics of the soil especially in heavy soils since it enhances the capacity of the soil to retain water and nutrients and minimizes their drainage under leaching. The effect of bentonite on the soil quality is that it enhances the soil structure and improves the cohesion and stability of soil aggregates which has a positive influence on the growth of the plants and the higher the efficiency of fertilizer use thus making it an important mineral amendment to soil management and the boosting of soil productivity [2].

Besides mineral amendments, biochar is viewed as one of the organic solutions that help to enhance the soil fertility and boost the productivity. Its application has grown in popularity over the last few years because it has a large potential to improve soil water and nutrient capture [3]. Biochar is an organic carbon structure of a porous nature that is formed by the thermal breakdown of biomass in the presence of limited or absence of oxygen. It is regarded as a natural substance that can blend with the constituents of soil without adversely affecting the soil hence is an environmentally-friendly amendment to soil. It also helps minimize soil percolation of water, as well as it serves to maintain water in the root zone which enhances the efficiency of irrigation water use, and it also aids in curbing desertification [4].

Brassica oleracea var. L. Broccoli is a herbaceous plant that is classified under the family Brassicaceae and is one of the crops that are poorly cultivated in Iraq. It is placed 31st in the world in terms of production. It is an annual plant, whose taproot is deep and reaches the soil and the height is approximately 60 cm. It has plants with big leaves and a stem terminating in an extremely thick roster of flower buds making it a comparatively green head, and also several side heads appear [5].

It is not only significant in agricultural fields because it contains active compounds containing several medicinal properties, such as anticancer and antioxidant compounds. It is also useful in enhancing immune system and preventing some illnesses like diabetes and heart diseases besides keeping the cells safe against oxidative stress [6]. This research is conducted to determine the impact of the addition of bentonite and biochar on certain physical characteristics of coarse-textured soil, as well as the broccoli plant growth.

2. MATERIALS AND METHODS

The field experiment was carried out in Babil Governorate, Iraq, 76 km south of Baghdad, at coordinates 32 o 47 o 07.38 N, 44 o 25 o 33.63 E, and 31 m above the sea level to examine how addition of bentonite and biochar influences some physical properties of coarse-textured soil and development of broccoli plants. The experiment was carried out in the form of factorial experiment with the Randomized Complete Block Design (RCBD) with three

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replicas where each replica consisted of nine experimental units. In the research two factors were used. The first element was the addition of the bentonite in levels of 0, 10,and 20Mg ha -1, represented by B 0, B 1, and B 2, respectively, and the second element was the addition of biochar in levels of 0, 5 and 10 Mg ha -1, represented by C 0, C 1 and C 2, respectively.

The area was considered to be divided into three blocks and each block was separated by a distance of 1 m. Two blocks had nine experimental units each. The size of each experimental unit was 7.5 m 2 and its dimensions were 2.5 x 3 m and 50 cm was maintained between experimental units. Four rows were used in each experimental unit, with the space between rows being 75 cm and the space between the planting holes being 40 cm. One emitter was per plant, and it was treated using a drip irrigation system. As per the requirement, all agricultural practices were performed equally on all experimental treatments.

Before the planting process, the field was sampled using five random samples of soil that were then mixed to come up with representative composite sample. The soil was then air-dried after the removal of plant residues, and crushed with a wooden hammer, and sieved through a 2 mm mesh sieve. The soil was then mixed thoroughly as to be homogenous and samples were taken to perform the chemical and physical analysis of the soil. The findings are illustrated in Table (1).

Table (1): Some physical and chemical properties of the soil before planting.

Property	Value	Unit
Soil pH	7.76	—
Electrical conductivity (EC)	3.60	dS m^{-1}
Cation exchange capacity (CEC)	13.95	cmolc kg^{-1} soil
Bulk density	1.45	Mg m^{-3}
Particle density	2.65	—
Porosity	45.29	%
Moisture at 33 kPa	19.4	%
Moisture at 1500 kPa	10.1	%
Available water	9.3	%
Sand	551	g kg^{-1}
Clay	272	g kg^{-1}
Silt	177	g kg^{-1}
Soil texture	Sandy loam	—

The studied soil physical properties were estimated after harvest.

Bulk density: Soil bulk density for the different treatments was determined using the core method [7].

Porosity: Soil porosity was calculated from the values of bulk density and particle density according to the following equation[8]:

$$f = \left\{1 - \frac{\rho_b}{\rho_s}\right\} \times 100$$

Soil moisture content at field capacity and permanent wilting point: Soil moisture content at field capacity and permanent wilting point was determined at matric potentials of 33 and 1500 kPa, respectively, using the Pressure Plate apparatus according to the method described by [9].

Available water content: Available water content (Aw) represents the difference between the volumetric moisture content at field capacity (θ_fc) and the volumetric moisture content at the permanent wilting point (θ_pwp), according to the following equation:

$$A_w = \theta_{fc} - \theta_{pwp}$$

3. RESULTS AND DISCUSSION

3.1. RESULTS

3.1.1.Bulk Density (Mg m⁻³):

Table (2) results indicate that the study factors have a high degree of difference in mean bulk density. Bulk density with the addition of bentonite at 20Mg ha^{-1} was significantly greater with the highest mean of 1.49 Mg m^{-3} than the control (1.43 Mg m^{-3}), a 4.19 percent increase. In the case of biochar, the control treatment registered the highest mean (1.49 Mg m^{-3}) as compared to 10 Mg/ha (1.43 Mg m^{-3}), which was also 4.19 percentage increment. The response of the bentonite and biochar showed that combination of 20 Mg ha^{-1} bentonite and biochar yielded the highest mean (1.53 Mg m^{-3}) than 10 Mg ha^{-1} biochar and no bentonite (1.41 Mg m^{-3}), which increased by 8.51.

Table (2): Effect of bentonite and biochar addition on the mean bulk density (Mg m^{-3}).

Bentonite (Mg ha^{-1})	Biochar (Mg m^{-3}) 0 (C0)	5 (C1)	10 (C2)	Mean
0 (B0)	1.45	1.42	1.41	1.43
10 (B1)	1.49	1.46	1.43	1.46
20 (B2)	1.53	1.48	1.46	1.49
LSD (5%)		0.01		0.01
Mean	1.49	1.45	1.43	
LSD (5%)		0.01		

3.1.2. Total Porosity (%):

Table (3) shows that there was a strong difference among the study factors in the mean total porosity. The control treatment (no addition of bentonite) exhibited great superiority with the highest mean of 46.05 percent against the treatment with 20 Mg ha^{-1} bentonite; which had the lowest mean of 43.75 percent, with an improvement of 5.25 percent. On the biochar addition, the highest mean of 45.75% was attributed to treatment with 10 Mg ha^{-1} versus 43.95 to control, which is an increase of 4.09. The relationship between bentonite and biochar greatly influenced the total porosity where the highest mean of 46.59% was recorded in treatment (without bentonite + 10 Mg ha^{-1} biochar) and lowest mean of 42.46 was recorded in treatment (20 Mg ha^{-1} bentonite + without biochar) which increased by 9.72.

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Table (3): Effect of Bentonite and Biochar Addition on Mean Total Porosity (%)

Bentonite ($Mg\ ha^{-1}$)	Biochar ($Mg\ m^{-3}$) 0 (C0)	5 (C1)	10 (C2)	Mean
0 (B0)	45.41	46.15	46.59	46.05
10 (B1)	43.97	44.89	45.78	44.88
20 (B2)	42.46	43.88	44.89	43.75
LSD (5%)		0.40		0.23
Mean	43.95	44.98	45.75	
LSD (5%)		0.23		

3.1.3. Soil Moisture Content at Field Capacity (%):

The Table (4) results indicate that there are large differences in mean soil moisture content at field capacity between the factors of the study. The level of addition of bentonite at 20 Mg ha -1 had the highest mean of 25.64% relative to the control with the lowest mean of 20.21, which is an improvement of 26.86. With respect to the addition of biochar, the mean of 24.01% was significantly the highest in comparison with that of the control (21.72%), which was increased by 10.54. The relationship between the bentonite and the biochar had the greatest influence on soil moisture at the field capacity with the combination of 20 Mg ha or above biochar^{-1} bentonite^{-1} biochar having the highest mean at 27.65% as compared to the control soil with no bentonite and biochar that had the lowest mean value at 19.54%.

Table (4): Effect of Bentonite and Biochar Addition on Mean Soil Moisture Content at Field Capacity (%).

Bentonite ($Mg\ ha^{-1}$)	Biochar ($Mg\ m^{-3}$) 0 (C0)	5 (C1)	10 (C2)	Mean
0 (B0)	19.54	20.28	20.81	20.21
10 (B1)	21.39	22.53	23.56	22.49
20 (B2)	24.22	25.04	27.65	25.64
LSD (5%)		0.79		0.46
Mean	21.72	22.62	24.01	
LSD (5%)		0.46		

3.1.4. Soil Moisture Content at Permanent Wilting Point (%):

The Table (5) results reveal high differences in the study factors in the mean soil moisture content at the permanent wilting point. The highest mean of 11.38% was significantly recorded at the addition of bentonite 20 Mg ha^{-1} as compared to that of the control which had the lowest mean of 10.15, a reference point of 12.11. Concerning the addition of biochar, the level of 10 Mg ha^{-1} had the highest mean of 11.06% as opposed to the control (10.38) with a significant increase of 6.55%. On the association between bentonite and biochar, the mean of 12.08% was the highest at the permanent wilting point than the quanta of

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9.74% at the control with no addition of bentonite and biochar, and the difference in the quanta was 24.02.

Table (5): Effect of Bentonite and Biochar Addition on Mean Soil Moisture Content at Permanent Wilting Point (%).

Bentonite (Mg ha⁻¹)	**Biochar (Mg m⁻³)**			**Mean**
	0 (C0)	**5 (C1)**	**10 (C2)**	
0 (B0)	9.74	10.27	10.43	10.15
10 (B1)	10.50	10.62	10.67	10.60
20 (B2)	10.89	11.16	12.08	11.38
LSD (5%)		0.45		0.26
Mean	10.38	10.68	11.06	
LSD (5%)		0.26		

3.1.5. Available Water in Soil (%):

Table (6) results indicate that there is a significant difference between the study factors in mean available water. The highest mean of 14.26 percent was recorded with the addition of 20 Mg ha^{-1} as compared to the control which recorded the lowest mean of 10.06 percent an increase of 41.71. In the case of biochar addition, the best mean of 12.94 per cent was significantly registered on treatment with 10 Mg ha^{-1} over the control (11.34 per cent) and this is an increase of 14.10 per cent. Bentonite and biochar had a significant interaction with the available water, whereby the combination of 20 Mg ha^{-1} bentonite + 10 Mg ha^{-1} biochar means the highest 15.57% with the control with no bentonite and biochar having the lowest means 9.80 which was increased by 58.87.

Table (6): Effect of Bentonite and Biochar Addition on Mean Available Water in Soil (%)

Bentonite (Mg ha⁻¹)	**Biochar (Mg m⁻³)**			**Mean**
	0 (C0)	**5 (C1)**	**10 (C2)**	
0 (B0)	9.80	10.01	10.37	10.06
10 (B1)	10.89	11.91	12.89	11.89
20 (B2)	13.33	13.88	15.57	14.26
LSD (5%)		0.80		0.46
Mean	11.34	11.93	12.94	
LSD (5%)		0.46		

3.2. DISCUSSION

The driving forces in Tables (2, 3, 4, 5, and 6) were found to show that the addition of bentonite had a significant influence on soil physical properties. As the percentage of

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bentonite concentration was increased, the bulk density increased, total porosity decreased, as well as the soil moisture content at field capacity, permanent wilting point, and available water. This increment in bulk density and reduction in total porosity can be explained by the fine particles of bentonite which occupy small soil pores decreasing the soil volume and total porosity. Bentonite can probably have more moisture content at field capacity, wilting point and available water, as it has a high swelling capacity, a layered structure and a high percentage of surface area, which increases water retention and adsorption to clay particles. Also, fine grains of bentonite particles decrease big pores, particularly in coarse-textured soils, enhancing the water-carrying capacity. These results are in line with those of [10], [11].

Addition of biochar also led to significant changes in the physical properties of the soil, as it reduced bulk density and increased total porosity, soil moisture at field capacity, wilting point and available water. This can be explained by the fact that biochar is low in density and is highly porous, which helps in improving soil structure by binding the particles of soil, creating more micropores, improving water absorption and retention, preventing compaction and increasing the aeration and water movement. Biochar is an organic modification that also helps redistribute the pore spaces to the soil [12],[13].

The adsorption of the bentonite and biochar on soil water greatly enhanced the properties of the soil water, such as the moisture at the field capacity and wilting point thus availability of water. Structural physical properties, by contrast, had contrary effects, with bentonite causing bulk density to increase and total porosity to decrease, as, with its low density and porosity, biochar caused the creation of stable soil aggregation and improved distribution of pores. In general the addition of bentonite and biochar led to the attainment of the physical-water equilibrium in soil leading to the improvement of the root environment and the maximization of plant utilization of the available water.

4. CONCLUSIONS

The experiment outcomes revealed that when bentonite and biochar were added to the coarse-textured soil, some of its physical characteristics were enhanced. The improvement in the application levels evidently boosted total porosity, field capacity soil moisture, permanent wilting point, and available water. The combination of 20 Mg ha^{-1} bentonite and 10 Mg ha^{-1} biochar showed the most promising results than the control and their interaction produced more positive effect on soil water retention which positively impacted the soil physical characteristics and provided better conditions to grow broccoli.

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DECLARATION OF COMPETING INTEREST

None

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REFERENCES

[1] Borah, D., Nath, H., & Saikia, H. (2022). *Modification of bentonite clay & its applications: A review.* Reviews in Inorganic Chemistry, 42(3), 265–282.

[2] Abdel-Motaleb, M. A., Abdel-Hady, E. S., Zaghloul, A. K., Abdel Ghany, G. B., & Sheta, M. H. (2025). *Impact of bentonite, biochar and compost on physical and hydro-physical properties of a sandy soil.* Egyptian Journal of Soil Science, 65(1).

[3] Cernansky, R. (2015). Agriculture: state-of-the-art soil. *Nature, 517,* 258–260.

[4] Tomczyk, A., Sokołowska, Z., & Boguta, P. (2020). Biochar physicochemical properties: Pyrolysis temperature and feedstock kind effects. *Reviews in Environmental Science and Bio/Technology, 19*(1), 191–215.

[5] Sood, S., & Rana, M. K. (2017). Sprouting broccoli. In *Vegetable crop science* (pp. 277–288). CRC Press.

[6] Torres-Contreras, A. M., Nair, L., Cisneros-Zevallos, L., & Jacobo-Velázquez, D. A. (2017). Stability of bioactive compounds in broccoli as affected by cutting styles and storage time. *Molecules, 22*(4), 636.

[7] Al-Tamimi, M. I. A., & Mahdi, N. T. (2017). *Analysis of soil physical properties.* University Press for Printing, Publishing and Translation. University of Baghdad, College of Agriculture, Iraq.

[8] Hillel, D. (2012). *Applications of soil physics.* Elsevier.

[9] Black, C. A. (1965). *Methods of soil analysis. Part 1: Physical and mineralogical properties.* Inc. Publisher. Madison, Wisconsin, USA.

[10] Kayama, M., Nimpila, S., Hong Thong, S., Yoneda, R., Wichiennopparat, W., Himmapan, W., Vacharenghkuru, T., & Noda, I. (2016). Effect of bentonite, charcoal and corncob for soil improvement and growth characteristics of teak seedling planted on acrisols in Northeast Thailand. *Forests, 7*(36), 1–21.

[11] Al-Ziyadi, L. R. S. (2024). *The effect of adding the two amendments, bentonite and organic fertilizer, on some soil properties and the growth and yield of white corn in the Samawah desert under a drip irrigation system* [Master's thesis, University of Baghdad, College of Agricultural Engineering Sciences].

[12] Lehmann, J., & Joseph, S. (Eds.). (2015). *Biochar for environmental management: Science, technology and implementation* (2nd ed., Part III: Biochar and soil properties, pp. 141–182). Routledge.

[13] Al-Moosa, M. F., Nuhad, S., & Muhsin, S. J. (2021). Influence of different levels of biochar in some soil physical properties and growth parameters of oat (*Avena sativa* L.). *Journal of Al-Muthanna for Agricultural Sciences, 8*(2), 204–216.