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وحماية المستهلك

THE INTERACTION EFFECT OF BIOCHAR AND BINTONITE ON SOME PHYSICAL PROPERTIES OF DESERT SOIL AND BROAD BEAN PRODUCTIVITY

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ABSTRACT

A field experiment was carried out to evaluate effect of biochar and bentointe and their interaction on some physical properties of desert soil and broad bean productivity. The study included four levels of biochar (Seek) (0, 10, 20 and 30 Mg ha^{-1} (S_0, S_1, S_2 and S_3) and four levels of bentonite (0, 10,20 and 30 Mg ha^{-1}) (B_0, B_1, B_2 and B_3). The experiment was carried out according to randomized complete block design (RCBD) with three replicates. The results indicated that the application of biochar and bentonite significantly affected on physical properties. The fourth level of biochar and bentonite gave the highest values of moisture content at field capacity, wilting point and available water reached 16.38, 7.00 and 9.39%, respectively for biochar and reached 16.29, 6.75 and 9.54%, respectively for bentonite. While the fourth level of both two amendments gave lowest value of bulk density which reached 1.34 and 1.55 Mg m^{-3} for biochar and bentonite respectively. The results showed also that the fourth level of biochar and bentonite gave the highest values of green pods and seeds yield which reached 17.540 and 3.039 Mg ha^{-1}, respectively for biochar and 28.990 and 3.353 Mg ha^{-1}, respectively for bentonite, The interaction between two amendments, the treatment (S_3B_3) was the most efficient in giving the lowest value for bulb density and highest values for the other physical soil properties and plant productivity.

Keyword: Available water, Bulk density, Broad bean, Desertification, Field capacity.

[*] **The article is taken from a master's thesis by the first researcher.**

التأثير المتداخل للفحم الحيوي والبنتونايت في بعض الصفات الفيزيائية لتربة صحراوية وانتاجية الباقلاء

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الخلاصة

اجريت تجربة حقلية بهدف معرفة تأثير بعض مصلحات التربة (الفحم الحيوي والبنتونايت) في بعض الصفات الفيزيائية لتربة صحراوية وانتاجية الباقلاء. تضمنت التجربة اربعة مستويات من الفحم الحيوي نوع (Seek) هي 0 و5 و10 و 15 ميكاغرام ه-1 ورمز لها (S_0 و S_1 وS_2 و S_3) واربعة مستويات من البنتونايت هي 0 و 10 و 20 و 30 ميكاغرام هـ-1 و رمز لها (B_0 و B_1 و B_2 و B_3). نفذت تجربة عاملية باستعمال تصميم القطاعات العشوائية الكاملة وبثلاثة مكررات. أظهرت النتائج أن زيادة مستوى إضافة كل من الفحم الحيوي و البنتونايت اثرت تأثيراً معنوياً في الصفات الفيزيائية للتربة لقد حقق المستوى الرابع من الفحم الحيوي والبنتونايت أعلى القيم اذ بلغت 16.38 و 7.00 و 9.39% للمحتوى الرطوبي عند السعة الحقلية ونقطة الذبول وكمية الماء الجاهز على التتابع للفحم الحيوي و 16.29 و 6.75 و 9.54% للصفات على التتابع للبنتونايت بينما حقق المستوى الرابع من اضافة كلا المصلحين اقل قيمة للكثافة الظاهرية بلغت 1.34 و 1.55 ميكاغرام م-3 لكل من الفحم الحيوي والبنتونايت على التتابع. كما أوضحت النتائج ايضا بان المستوى الرابع من الفحم الحيوي والبنتونايت اعطى اعلى القيم في حاصل القرنات الخضراء وحاصل البذور بلغت 17.540 و 3.039 ميكاغرام هـ-1على التتابع للفحم الحيوي اما بالنسبة للبنتونايت فقد بلغت القيم 18.990 و 3.353 ميكاغرام هـ-1 على التتابع. أما بالنسبة للتداخل بين اضافة المصلحين فقد تفوقت المعاملة S_3B_3 (15 ميكاغرام هـ-1 فحم حيوي و 30 ميكاغرام هـ-1 بنتونايت) في تحقيق اقل قيمة للكثافة الظاهرية واعلى القيم للمحتوى الرطوبي في التربة واعلى انتاجية لنبات الباقلاء.

الكلمات المفتاحية: الماء الجاهز، الكثافة الظاهرية، السعة الحقلية، التصحر ، الباقلاء.

INTRODUCTION

Desertification threatens at the present time vast areas in Iraq, and that most regions of Iraq are affected by desertification in all its forms to one degree or another, and the areas of desertified lands threatened with desertification and sand dunes occupied the majority of the area of Iraq, and there are other areas threatened with desertification annually if measures are not taken in sufficient ways prevention and minimizing the effects of this phenomenon. The environmental statistics report for the year 2009 indicated that the percentage of lands threatened with desertification amounts to 92% of the total lands of Iraq **(Hammadi, 2009; Al-Timimi,2021).**

Desert soils are often coarse textured soils, which makes them suffer from many constraints related to the poor quality of some of their physical and chemical properties and low nutrients availability, which makes them have low productivity for the crops grown in them, which requires taking several measures to reduce their constraints in order to optimally exploit them agriculturally **(Al-Janabi, 2016)**. The means in this field, including the use of some compounds, which are called soil amendments. Many soil amendments have been used in coarse-textured soils with the aim of improving their physical, chemical and biological properties and improving their fertility and productivity for various agricultural crops, including bentonite clay **(Al-Kinani & Jarallah, 2021).** vermiculite and kaolinite **(Wyszkowski *et al.*, 2009).** Organic amendments were also used in different animal and plant sources, compost, and waste from cities and factories **(Al-Kinani & Jarallah, 2022; Abdulridha & Essa, 2023).**

Biochar was used as an improver in 1998 by the American Chemical Society and described as a solid product from biomass burning of plant waste **(Bapat & Monahan, 1998)**. **Lehmann *et al.* (2006)** suggested that the addition of biochar is one of the modern technologies to improve the properties of different soils. The different properties of the soil, including the physical ones, by increasing the ability of the soil to retain water and surface area, improving soil structure and reducing the bulk density, which contribute to increasing the productivity of agricultural crops in those soils **(Karhu *et al.*, 2011, Al-Tameemi & Jaber, 2019). Sudhir (2006)** noted that the addition of biochar at a level of 10% to two soils (sandy loam and sandy) led to an increase in the amount of available water by 52 and 124% for the two soils, respectively, compared to the control treatment.

Biochar has a high ability to improve the ability of sandy soil to retain water to a greater degree compared to clay and silty soils, in addition to its role in reducing water infiltration and increasing available water within the root zone of the plant, which increases the efficiency of irrigation water rationing and treatment of desertification, since its addition to the soil improves their structure, porosity, and decrease in bulk density **(Liu *et al.*, 2012; Alkheero *et al.*, 2019).** Many studies have indicated the positive effect of adding biochar on plant growth and productivity in various agricultural soils, especially degraded ones, for its role in improving the different soil properties and increasing nutrient availability **(Kayama *et al.*, 2016; Japakumar *et al.*, 2021; Li *et al.*, 2021).**

Several studies that used bentonite as an improver for sandy soils indicated an improvement in the physical properties of the soil such as soil structure, increased stability of soil aggregates, increased ability to retain water and bulk density, and decreased water conductivity **(Kayama *et al.*, 2016; Al-Hayani *et al.*, 2022). Semalulu *et al.* (2015)** indicated that increasing the level of bentonite addition from 0 to 5, 10, 15, and 20% to sandy soil led to an increase in the moisture content in the soil, and they obtained a positive correlation of the second degree between the level of bentonite addition and the moisture content of the soil ($R^2 = 0.996^{**}$). This study was aimed to evaluate the effect of two types of soil conditioners (biochar and bentonite) and their interaction on some physical properties of desert soil and broad bean productivity.

MATERIALS AND METHODS

A field experiment was conducted at desert soil with sandy loam texture in Al-Karma district of Al-Anbar Governorate. The experiment was divided into 3 blocks, each one includes 15 experimental unit and the distance between them was 1 m while the distance between blocks was 2 m. Soil samples were collected from the layer (0 – 0.3 m) before planting. Some physical and chemical properties of the soils were measured by **(Page *et al.*,1982)** Table 1.

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

Property		Value	Unit
$EC_{1:1}$		3.20	$dS\ m^{-1}$
$pH_{1:1}$		7.40	
O.M		7.60	$g\ kg^{-1}$ soil
Carbonate minerals		263.15	
CEC		4.11	$c\ mol_{+}kg^{-1}$ soil
Soluble ions	Ca^{++}	19.32	$m\ mole\ L^{-1}$
	Mg^{++}	9.24	
	Na^{+}	3.65	
	K^{+}	0.88	
	$CO_3^{=}$	-	
	HCO_3^{-}	1.00	
	$SO_4^{=}$	0.91	
	Cl^{-}	22.65	
Available nutrients	NH_4^{+}	11.20	$mg\ kg^{-1}$ soil
	NO_3^{-}	18.80	
	P	4.23	
	K	116.14	
Bulk density		1.64	$Mg\ m^{-3}$
Field capacity		9.38	%
Wilting point		2.50	
Available water		6.88	
Particle size analysis			
Clay		124.0	$g\ kg^{-1}$ soil
Silt		116.0	
Sand		760.0	
Texture		Sandy loam	

The experiment included four levels of biochar (Seek Chinese origin: it is an organic charcoal produced from bamboo cane) which are 0, 5, 10, and 15 Mg ha^{-1} and their symbols (S_0, S_1, S_2 and S_3) Table 2 shows some characteristics of the biochar. Four levels of bentonite were used which 0, 10, 20 and 30 Mg ha^{-1} and their symbols (B_0, B_1, B_2 and B_3) some characteristics of the bentonite clay (Table 3). Both conditioners were added after mixing them with the soil. Faba bean (*Vicia faba* L.)

Table (2): Some characteristics of biochar (Seek).

Characteristic	Value	Unit
$EC_{1:5}$	3.18	$dS\ m^{-1}$
$pH_{1:5}$	7.15	-
N	1.31	%
P	0.65	
K	1.65	
O.C	25.32	
O.M	43.65	
C / N	19.33	-

Spain cultivar (Luz-de-otono variety) was sown in 17/10/2021 for winter season, N was added at level 100 kg N ha^{-1} as urea (46% N) and P at level 120 kg P_2O_5 ha^{-1} was added as TSP. (46% P_2O_5) and K at a level of 40 kg K_2O ha^{-1} in the form of K_2SO_4 (50% K_2O) according to the fertilizers recommendation of board bean **(Ali *et al.*, 2014).** N was added in two doses, As for P and K fertilizers, they were added once. At the end of the experiment the crop was harvested in 26/3/2022.

Table (3): Some characteristics of bentonite**.**

Characteristic		**Value**	**Unit**
$EC_{1:1}$		3.14	dS m^{-1}
$pH_{1:1}$		7.00	
$CaCO_3$		130.10	g kg^{-1}
Gypsum		2.40	
CEC		60.1	c mol_+kg^{-1} clay
Oxides content	P_2O_5	0.65	%
	K_2O	0.50	
	CaO	0.58	
	MgO	0.18	
	Fe_2O_3	1.52	
	Al_2O_3	34.58	
	Na_2O	0.18	
	SO_3	0.23	
	SiO_2	51.96	
	Cl	0.05	
Particle size analysis			
Clay		899.0	g kg^{-1} clay
Silt		99.0	
Sand		2.0	
Texture		Clay	

A factorial experiment was carried out within randomized complete block design (RCBD) with three replications. Least significant differences test (LSD 0.05) was used to compare the means of the treatments **(Steel &Torrie, 1980).**

RESULTS AND DISCUSSION

Bulk density

The results shown in Table 4 showed that there were significant differences for the effect of biochar on the bulk density of the soil after harvest, as the a mean bulk density was 1.65, 1.56, 1.46 and 1.34 Mg m^{-3}, with a decrease of 5.45, 11.52 and 18.79% for the soil levels. Biochar added 5, 10 and 15 Mg ha^{-1}, respectively compared to the control treatment, as the bulk density of soil decreased with increasing the level of biochar addition and the fourth level of addition achieved the highest percentage of decrease in bulk density. Increasing the level of bentonite addition from 0 to 10, 20 and 30 Mg ha^{-1} led to an increase in the bulk density reaching an a mean of 1.45, 1.49, 1.52 and 1.55 Mg m^{-3}, with an increase rate of 2.76, 4.83 and 6.90% for bentonite levels. Sequentially compared to the control treatment, the fourth level of bentonite addition achieved the highest increase in bulk density.

The results shown in Table 4 showed that the interaction between the two study factors led to a decrease in the bulk density of the soil, as it reached its lowest value of 1.25 Mg m^{-3} in the interaction treatment S_3B_0 , with a decrease of 22.36% compared to the control treatment for the overlap S_0B_0 of 1.61. Mg m^{-3}. The results showed that the behavior of the two study factors were opposite in their effect on the bulk density, but the biochar was more effective through the interaction of adding it with bentonite.

Table (4): Effect of biochar and bentonite on soil bulk density after harvest (Mg m^{-3}).

Biochar (S)	Bentonite (B)				B Mean
	B_0	B_1	B_2	B_3	
S_0	1.61	1.62	1.66	1.70	1.65
S_1	1.51	1.56	1.57	1.61	1.56
S_2	1.41	1.46	1.48	1.49	1.46
S_3	1.25	1.33	1.37	1.39	1.34
S Mean	1.45	1.49	1.52	1.55	
LSD 0.05	Biochar	Bentonite	S x B		
	.001	0.01	0.02		

Water content at field capacity

The results showed in Table 5 that increasing the level of biochar addition from 0 to 5, 10 and 15 Mg ha^{-1} led to an increase in soil moisture content at field capacity by 18.44, 31.08 and 43.81%, respectively compared to the control treatment, the results also showed a significant increase For the addition of bentonite in the soil moisture content at the field capacity, it increased by 9.49, 25.52, and 36.78% for bentonite levels 10, 20, and 30 Mg ha^{-1}, respectively compared to the control treatment (0 Mg ha^{-1}). The fourth level of addition excelled in achieving the highest value of moisture content at field capacity and the highest increase percentage. Biochar was superior to bentonite in achieving the highest rates of increase in moisture content at the field capacity. The results showed that there was a significant effect of the interaction between the two study factors (biochar and bentonite) on the soil moisture content at the field capacity. The interaction treatment S_3B_3 gave the highest value, reaching 18.98%, with an increase of 103.21% compared to the comparison treatment

S_0B_0 which amounted to 9.34% , the interaction between the two study factors had a positive effect on the soil moisture content at the field capacity was better than if each factor added alone to the soil.

Table (5): Effect of biochar and bentonite on water content at field capacity of soil after harvest (%).

Biochar (S)	Bentonite (B)				B Mean
	B_0	**B_1**	**B_2**	**B_3**	
S_0	9.34	10.93	12.15	13.13	11.39
S_1	11.23	12.45	14.46	15.80	13.49
S_2	12.81	13.73	15.94	17.24	14.93
S_3	14.26	15.04	17.26	18.98	16.38
S Mean	11.91	13.04	14.95	16.29	
LSD 0.05	Biochar	Bentonite	S x B		
	.004	0.04	0.07		

Water content at wilting point

Increasing the level of biochar addition from 0 to 5, 10, and 15 Mg ha^{-1} increased the moisture content at the wilting point of the soil by 26.20, 43.99, and 68.27% for the levels of biochar addition, respectively compared to the control treatment, and the fourth level (15 Mg ha^{-1}) showed the highest value and increase in soil moisture content at wilting point compared to other levels Table 6. The addition of bentonite increased the moisture content by 3.36, 35.41 and 50.33% for the bentonite addition levels 10, 20 and 30 Mg ha^{-1}, respectively compared to the comparison treatment. An increase compared to other addition levels. Biochar was more effective than bentonite in increasing the moisture content of the soil to give it the highest values and rates of increase.

Table (6): Effect of biochar and bentonite on water content at wilting point of soil after harvest (%).

Biochar (S)	Bentonite (B)				B Mean
	B_0	**B_1**	**B_2**	**B_3**	
S_0	2.49	3.90	4.91	5.35	4.16
S_1	4.11	4.76	5.67	6.47	5.25
S_2	5.13	5.23	6.48	7.14	5.99
S_3	6.22	6.48	7.25	8.04	7.00
S Mean	4.49	5.09	6.08	6.75	
LSD 0.05	Biochar	Bentonite	S x B		
	.003	0.03	0.05		

As for the interaction between the addition of biochar and bentonite, the interaction treatment S_3B_3 achieved the highest value of 8.04%, an increase of 222.89% over the comparison treatment of the overlap S_0B_0 , which gave the lowest value of 2.49%. The results showed a positive effect of the interaction between the addition of biochar and bentonite.

Clearly, through the high rate of increase in moisture content at wilting point, it is clear that adding these two conditioners together to the soil is better than adding each conditioner separately.

Available water

Increasing the level of biochar addition from 0 to 5, 10, and 15 Mg ha^{-1} led to an increase in the available water in the soil by 13.83, 23.65, and 29.88% for the levels, respectively, compared to the comparison treatment Table 7. The fourth level of addition achieved the highest value and percentage increase in the available water. in the soil. The results also showed that there was a significant effect of the level of bentonite addition in the available water (bentonite 10, 20 and 30 Mg ha^{-1}). The highest value of available water and increase percentage was at the fourth level of bentonite addition. The results showed that there was a significant effect of the interaction between the level of adding biochar and bentonite in the available water in the soil. The comparison for the interference S_0B_0 59.71% gave the lowest value for available water 6.85%.

Table (7): Effect of biochar and bentonite on available water of soil after harvest (%).

Biochar (S)	**Bentonite (B)**				**B Mean**
	B_0	**B_1**	**B_2**	**B_3**	
S_0	7.78	7.24	7.03	6.85	7.23
S_1	9.33	8.79	7.69	7.12	8.23
S_2	10.10	9.47	8.61	7.59	8.94
S_3	10.94	10.01	8.82	7.79	9.39
S Mean	9.54	8.88	8.04	7.34	
LSD 0.05	Biochar	Bentonite	S x B		
	.004	0.04	0.07		

The addition of biochar to the soil led to a significant effect on the physical properties under study, as the increase in the level of biochar addition led to a decrease in bulk density and an increase in soil moisture content at field capacity, wilting point, and available water. Biochar has a bulk density of less than 0.6 Mg m^{-3}, which is much lower than the bulk density of soil. Adding it to the soil leads to a decrease in bulk density by mixing and thinning **(Omondi *et al.,* 2016)**. Also, biochar is an organic material that works to increase soil agglomerations and increase its volume and stability depending on the raw materials from which it is produced. In addition, biochar has a large proportion of micropores, which increase the surface area, which contributed to reducing the bulk density of soil **(Jien, 2019)**.

These results are consistent with what many researchers have obtained **(Al-Tamemi & Jaber, 2019; Simansky *et al.*, 2022).**

As for the increase in soil moisture content at field capacity, wilting point, and available water after adding biochar, this may be attributed to the fact that biochar works to improve soil structure, redistribute pores, and increase the specific surface area of soil, in addition to that it has the ability to hold large amounts of water because it possesses High porosity, which contributed to increasing the moisture content in the soil **(Kang *et al.,* 2018)**.

The increase in soil moisture content after adding biochar is also attributed to the fact that it has the ability to hold water at a rate of six times its dry weight **(Robb & Joseph, 2019).** Many researchers have emphasized an increase in soil moisture content, especially coarse-texture soil, after adding biochar to it **(Sudhir, 2006; Alkheero *et al.*, 2019; Al-Halfi & Al-Azzawi,2022; Jasim & Hamid,2023).**

As for the effect of bentonite on the physical properties of the soil under study, increasing the level of its addition led to an increase in the bulk density and moisture content at the field capacity and wilting point and the available water for the soil after harvesting. soil micropores, Hence, reducing soil volume and increasing its mass, as well as its contribution to reducing the total porosity of the soil **(Al- Ani, 2009).** The results obtained are consistent with what was found by **(Kayama *et al.*, 2016).**

As for the increase in soil moisture content at field capacity, wilting point, and available water after adding bentonite, it may be attributed to the fact that the bentonite mineral particles are soft because of their small size. Which leads to an increase in the ability of the soil to hold water and reduce infiltration, evaporation and the total water conductivity of the soil, in addition to that it has the ability to hold water at a rate of more than 10% than it is in sandy soils **(Salih, 2000; Kayama *et al.*, 2016).** It was also found that bentonite clay has the ability to hold water in a range ranging from 1-5 times its weight, which contributes to increasing the moisture content in the soil, especially the coarse texture of it. The results are consistent with what was also found by **(Al-Kinani & Jarallah, 2021).**

As for the interaction between the two factors of the study (biochar and bentonite), it had a significant positive effect on the moisture content of the soil at field capacity, wilting point, and available water. In bulk density, they had opposite effects, as biochar contributed to reducing it, while bentonite contributed to increasing it. Biochar outperformed bentonite in its effect in reducing bulk density of soil.
Adding the two conditioners together is better than if they were added alone to the soil, and this was found by a number of studies that used soil conditioners jointly **(Jabakumar *et al.*, 2021; Al-Mishyyikh & Jarallah, 2024).**

Green pods yield

The results shown in Table 8 showed an increase in the yield of green pods with an increase in the level of biochar addition with an increase rate of 11.59, 21.98 and 29.36% for the levels of biochar addition. 5, 10 and 15 Mg ha^{-1}, respectively compared to the control treatment. The results shown in Table 8 showed an increase in the yield of green pods with an increase rate of 20.67, 38.51 and 57.61% for the levels of bentonite addition 10, 20 and 30 Mg ha^{-1}, respectively compared to the control treatment. The results showed a significant effect of the interaction between biochar and bentonite on the yield of green pods. The interaction treatment S_3B_3 achieved the highest value of 20.543 Mg ha^{-1}, an increase of 107.36% over the comparison treatment S_0B_0 , which gave the lowest value for the yield of green pods, which reached to 9.907 Mg ha^{-1}.

Table (8): Effect of biochar and bentonite on green pods yield (Mg ha^{-1}).

Biochar (S)	**Bentonite (B)**				**B Mean**
	B_0	**B_1**	**B_2**	**B_3**	
S_0	9.907	12.807	14.280	17.240	13.559
S_1	11.447	13.750	16.676	18.650	15.131
S_2	13.790	15.517	17.320	19.527	16.539
S_3	15.050	16.087	18.480	20.543	17.540
S Mean	12.049	14.540	16.689	18.990	
LSD 0.05	Biochar	Bentonite	S x B		
	.0438	0.438	0.875		

Seeds yield

The results showed in Table 9 an increase in seed yield with an increase in the level of biochar addition, as it reached an average of 2.083, 2.398, 2.665, and 3.039 Mg ha^{-1}, with an increase rate of 15.12, 27.94 and 45.90% for the levels of addition 5, 10 and 15 Mg ha^{-1}, respectively compared to the control treatment (0 Mg ha^{-1}). As for the addition of bentonite, the results showed in Table 9 that increasing the level of bentonite addition from 0 to 10, 20 and 30 Mg ha^{-1} led to an increase in the seed yield, as it reached an average 1.744, 2.379, 2.709, and 3.353 Mg ha^{-1}, with an increase of 36.41, 55.33 and 92.26% for the addition levels, respectively, compared to the comparison treatment (0 Mg ha^{-1}). As for the interaction between the two factors of the study (biochar and bentonite), the results showed that the interaction treatment S_3B_3 was superior in achieving the highest value of seed yield amounted to 4.120 Mg ha^{-1} with an increase of 224.67% over the comparison treatment of interference S_0B_0 , which gave the lowest value of seed yield reached to 1.269 Mg ha^{-1}.

Table (9): Effect of biochar and bentonite on seeds yield (Mg ha^{-1}) .

Biochar (S)	**Bentonite (B)**				**B Mean**
	B_0	**B_1**	**B_2**	**B_3**	
S_0	1.269	2.028	2.352	2.681	2.083
S_1	1.651	2.247	2.574	3.120	2.398
S_2	1.844	2.518	2.808	3.491	2.665
S_3	2.211	2.722	3.103	4.120	3.039
S Mean	1.744	2.379	2.709	3.353	
LSD 0.05	Biochar	Bentonite	S x B		
	.0160	0.160	0.320		

The results showed the positive overlapping effect of biochar and bentonite in achieving a significant increase in seed yield was better than if each was added separately, and the increase in seed yield with an increase in the level of addition of biochar and bentonite was incremental, which indicates that the soil under study still needs to higher levels of these two reformers and did not reach the optimal levels of them in increasing plant indicators. This may be attributed to the role of biochar in improving the properties of the soil under study (sand mixture) (Table 1) through its contribution to improving soil structure, increasing soil agglomerations, decreasing bulk density, increasing the ability of soil to retain water and available water in the root zone, as well as reducing water loss. Irrigation, reducing the degree of soil interaction and electrical conductivity, and increasing the readiness of nutrients by increasing the exchange capacity of positive ions and the mineralization of nitrogen and phosphorus, as it is a source for them, as well as increasing the organic carbon in the soil, which contributed to increasing the biological activity in the soil and biological interactions. All of these roles that biochar contributes to improve most of the different soil characteristics (physical, chemical, and biological) and improve soil fertility, which contributes to increasing plant nutrient absorption, increasing vital and physiological processes, processing food and storing it in seeds, and increasing yield indicators and its components under study (**Kayama *et al*., 2016; Al-Tamemi & Jaber, 2019).** The results are consistent with the results of a number of studies that obtained an increase in the yield and its components for multiple crops (legumes, maize, and rice) when they added biochar to coarse-textured soils **(Armanto,2019; Lee *et al*., 2021).**

The results also indicated that the addition of bentonite had a significant effect on the yield indicators and its components under study, and this may be due to the positive effect of bentonite in the study soil in terms of increasing the ability of the soil to retain water, increasing its readiness for plants, and increasing the readiness of some nutrients, including (nitrogen, phosphorus and potassium) through its role in Increasing the exchange capacity of positive ions and preserving nutrients from loss, which contributed to increasing their readiness and absorption by the bean plant, and this was reflected in the increase in yield indicators and its components under study **(Dhary & Al-Baldawi,2017; Minhal *et al*., 2020).**

Many studies using bentonite clay as an improver for coarse-textured soils have confirmed an increase in the yield and yield components of different crops (yellow and white corn, barley and potatoes) (**Semalulu *et al*., 2015; Al-Kinani & Jarallah,2021)**. As for the interaction between the level of adding biochar and bentonite, it had a significant positive effect on increasing the yield indicators and its components under study. These two reformers excelled in achieving the highest value of the indicators under study within the fourth level for each of them. Most of the physical, chemical and fertility characteristics of the soil combined, and the interfering effect was superior in increasing yield indicators compared to if each reformer was added individually, and biochar was more efficient in increasing the indicators under study compared to bentonite **(Abbas *et al*., 2018; Hasin *et al*., 2021).**

CONCLUSION

It can be concluded the addition of soil conditioners (seek biochar and bentonite) significantly affects the soil physical properties (bulk density, water content at field capacity and wilting point and available water). The addition of biochar (15 Mg ha^{-1}) and bentonite (30 Mg ha^{-1}) with achieved a great response to the broad bean plant represented by increasing the parameters of vegetative growth and improving soil physical properties. The effect of the two conditioners to the soil together was more efficient under study compared to adding each of them separately.

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