ROLE OF BIOCHAR AND BENTONITE IN IMPROVING SOME CHEMICAL PROPERTIES OF DESERT SOIL, GROWTH AND YIELD OF BROAD BEAN (*Vicia faba* L.)

Saja. H. W. Al-Mishyyikh Abbas. K. A. Jarallah
Researcher Prof.
Dept. of Desert. Combat - Coll. Agric. Engin. Sci. – University of Baghdad
saja.Hatem1210a@coagri.uobaghdad.edu.iq abbas_altaae@hotmail.com

ABSTRACT

A field experiment was conducted to evaluate effect of some soil amendments (biochar and bentointe) in some chemical properties, growth and yield of broad bean in desert soil. The study included four levels of biochar (0, 10, 20 and 30 Mg ha^{-1} and Four levels of bentonite (0, 10,20 and 30 Mg ha^{-1}) . Randomized complete block design (RCBD) with three replicates were used. The results showed that the application of biochar and bentonite significantly affected all the soil chemical properties under study and plant parameters. The level 15 Mg ha^{-1} of biochar gave the lowest valuesreached 7.30 and 3.57 dS m^{-1} for soil pH and EC and gave highest values reached 51.93 g kg^{-1} soil and 19.13 C mol$_+$kg^{-1} soil for O.M and CEC and the highest valuesin plant height , leaf area, dry weight of vegetative part and fresh pods yield were 56.3 cm, 3028.6 cm^2 plant^{-1}, 81.53 g plant^{-1} and 17.540 Mg ha^{-1}, respectively. The results showed also that the level 30 Mg ha^{-1} of bentonite gave the highest values were 7.45, 4.48 dS m^{-1}, 34.48 g kg^{-1} and 18.69C mol$_+$kg^{-1} soil for pH, EC, O.M and CEC respectively while the highest values of plant parametersreached 56.9 cm, 3085.9 cm^2 plant^{-1}, 79.25 g plant^{-1} and 18.99030 Mg ha^{-1} for plant height , leaf area, dry weight of vegetative part and fresh pods yield, respectively. As for the interaction, the treatment (15 Mg ha^{-1}biochar, 0 Mg ha^{-1} bentonite) achieved the lowest value for pH and EC reaching 7.08 and 3.13 dS m^{-1}respectively while the treatment (15 Mg ha^{-1}biochar, 30 Mg ha^{-1} bentonite) achieved the highest value for O.M, CEC and plant parameters under study.

Keyword: CEC, EC, organic matter,soil (conditioners) amendments, desertification
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دور الفحم الحيوي والبنتونايت في تحسين بعض الصفات الكيميائية لتربة صحراوية ونمو وحاصل الباقلاء

سجى حاتم وهيب المشايخي عباس خضير عباس جارالله
باحث أستاذ
قسم مكافحة التصحر – كلية علوم الهندسة الزراعية – جامعة بغداد

المستخلص

اجريت تجربة حقلية بهدف معرفة تأثير بعض مصلحات التربة (الفحم الحيوي والبنتونايت) في بعض الصفات الكيميائية ونمو وحاصل الباقلاء في تربة صحراوية. تضمنت التجربة اربعة مستويات من الفحم الحيوي هي 0 و5 و10 و 15 ميكاغرام هـ$^{-1}$ واربعة مستويات من البنتونايت هي 0 و 10 و 20 و 30 ميكاغرام هـ$^{-1}$. 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 الكيميائية للتربة ومؤشرات النبات قيد الدراسة ، لقد حقق المستوى الرابع (15 ميكاغرام هـ$^{-1}$) من الفحم الحيوي أوطأالقيم في درجة تفاعل التربة والايصالية الكهربائية بلغت 7.30 و 3.57 ديسي سمنز م$^{-1}$واعلى القيم في محتوى المادة العضوية والسعة التبادلية للايونات الموجبة بلغت 51.93 غم كغم$^{-1}$ تربة و19.13 سنتي مول $_+$كغم$^{-1}$ تربة واعلى القيم في ارتفاع النبات والمساحة الورقية والوزن الجاف للجزء الخضري وحاصل القرنات الخضراء بلغت 56.3 سم و 3028.6 سم^2 نبات$^{-1}$ و 81.53 غمنبات$^{-1}$ و 17.540 ميكاغرام هـ$^{-1}$على التتابع بالمقارنة بالمستويات الاخرى. واوضحت النتائج ايضا بان المستوى الرابع من البنتونايت (30 ميكاغرام هـ$^{-1}$) اعطى اعلى القيم في درجة تفاعل التربة (pH) والايصالية الكهربائية (EC) ومحتوى المادة العضوية (O.M) والسعة التبادلية للايونات الموجبة (CEC) بلغت 7.45 و 4.48 ديس سمنز م$^{-1}$ و 34.48 غم كغم$^{-1}$ تربة و 18.69 سنتي مول$_+$ كغم$^{-1}$ تربة على التتابع واعلى القيم في مؤشرات النبات بلغت 56.9 سم و 3085.9 سم^2 نبات$^{-1}$ و 79.25 غم نبات$^{-1}$ و 18.990 ميكاغرام هـ$^{-1}$ لارتفاع النبات والمساحة الورقية والوزن الجاف للمجموع الخضري وحاصل القرنات الخضراء على التتابع. اما بالنسبة للتداخل بين اضافة المصلحين فقد تفوقت المعاملة (15 ميكاغرام هـ$^{-1}$ فحم حيوي و 0 ميكاغرام هـ$^{-1}$ بنتونايت) في تحقيق اقل قيمة ل pH و EC بينما تفوقت المعاملة (15 ميكاغرام هـ$^{-1}$ فحم حيوي و 30 ميكاغرام هـ$^{-1}$ بنتونايت) في تحقيق اعلى قيمة لـO.M و CEC ومؤشرات النبات قيد الدراسة.

الكلمات المفتاحية: السعة التبادلية، الايصالية الكهربائية، المادة العضوية، مصلحات (محسنات) التربة، التصحر
*البحث مستل من رسالة ماجستير للباحث الاول

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INTRODUCTION

Desertification threatens at the present time large areas in Iraq, and that most areas of Iraqi soil are affected by desertification in all its forms from degree to another. In order to confront this phenomenon and the phenomenon of drought, it is necessary to take all measures that would mitigate and reduce its risks, and one of these measures is the agricultural exploitation and desertified lands and the use of soil conditioners to improve the characteristics of degraded soil (39).Most of the desert lands consist of sandy soils, which include large areas in the world. In Iraq, Sandy soils suffer from many problems, although they are well and drained due to the high percentage of large pores, which makes their total porosity low when compared to clay soils and is quick to drain because of its low ability to retain water and the available water was few, the specific surface area and cation exchange capacity (CEC), which could reach 6 – 10 C mole $_+$ kg $^{-1}$ soil and its organic matter content is very lowas well as it is a poor soil in its nutrient availability and its ability to retain nutrients is low (11).Many methods have been used as practical attempts with the aim of optimal agricultural use of sandy or structureless soils in desert and desertified lands to overcome its agricultural determinants by improving the physical, chemical and biological properties of the soil, increasing its nutrients availability and productivity, the most important of these means is the use of some industrial or natural amendments (conditioners) which it was organic or mineral (12) . Mineral natural amendments, such as clay sediments represented by bentonite clay, have been used widely in the world for its role in improving many soil physical, chemical properties and increasing nutrient availability (36). Soil amendments known as organic or mineral materials that improve one or more properties of the soil, whether they are physical, chemical or biological and thus contribute to raising the fertility of the soil and increasing its productivity and these improvements could be natural or manufactured (39). Several soil conditioners have been used in coarse-textured soils with the aim of improving their physical, chemical and biological properties and improving their fertility and productivity of various agricultural crops (35), such as bentonite clay (11) and zeolite (24). Also, organic conditioners were used from different animal and vegetable sources, compost and waste from cities and factories (11).In addition, using biochar which is a modern soil conditioner (13, 28).Biochar is defined as a carbon-rich organic material produced from the thermal and chemical decomposition of living mass at a temperature of 400-800 °C under conditions of low oxygen or a limited amount of it (21). It was found that biochar is one of the compounds resistant to microbial decomposition in soil(14).Several studies that focused their attention on the use of biochar as a soil conditioner have indicated its role in improving the biological, physical and chemical properties of degraded soils as well as its role in improving soil fertility and productivity for various agricultural crops (25,26,37,40). Bentonite has been used by many researchers and found that this clay mineral enhancers different soils, especially coarse texture in different countries of the world due to its great role in improving most of the soil physical, chemical and biological properties, increasing nutrient availability, raising soil fertility, increasing plant growth and yield and improving its quality (4,7,11,30,41). The importance of the broad bean crop is not that it is a major source of protein and energy and a good and cheap alternative to meat and fish protein, but rather its ability to fix atmospheric nitrogen through root nodules formed on its roots with the presence of bacteria of the genus Rhizobiumand increasing the productivity of crops that sow with it in agricultural rotations cycles (20).This study was aimed to evaluatethe role of two types of soil conditioners (biochar and bentonite) on some chemical properties of soil, growth and yield of broad bean in Iraqi desert soil.

MATERIALS AND METHODS

A field experiment was conducted at desert soil with sandy loam texture in Al-Jazeera sub-district in Al-Karma district of Al-Anbar Governorate.The field was divided into three blocks, each block includes 15 plots (experimental unit) and the distance between the experiment units was 1 meter while the distance between blocks was 2 meters. Before planting soil samples were collected from the layer (0 – 30 cm). The samples were air dried, sieved through 2.0 mm sieve. Some physical and chemical properties of the soils were estimated according to Page et al., (33) (Table 1). 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 properties of the biochar.

Table 1. Some chemical and physical properties of soil

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	Cmol$_+$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	

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) Table 3 shows some properties of the bentonite clay used in the study.Biochar and bentonite were added after they were homogeneously mixed with the soil according to the experiment treatments. Broad bean (*Vicia faba* L.) Spain cultivar (Luz-de-otono variety) was sown in 17/10/2021 for winter season,Nitrogen was added at 100 kg N ha^{-1} as urea (46% N) and phosphorous at 120 kg P_2O_5 ha^{-1} was added as triple superphosphate (TSP). (46% P_2O_5) and potassium at a level of 40 kg K_2O ha^{-1} in the form of potassium sulfate (50% K_2O) according to the fertilizers recommendation of board bean (9).Nitrogen fertilizer was added in two doses, the first at planting stage and the second after 40 days of planting. As for phosphate and potassium fertilizers, it was added in one dose when planting and for all treatments.The experiment continued until the crop reached final maturity and the crop was harvested in26/3/2022.A mean plant height was measured for five plants,the dry weight of plant and green pods yield.

Table 2. Some properties of biochar (Seek) used in study

Property	Value	Unit
EC (1:5)	3.18	dS m^{-1}
pH (1:5)	7.15	-
Nitrogen	1.31	%
Phosphorus	0.65	
Potassium	1.65	
Organic carbon	25.32	
O.M	43.65	
C : N	19.33	-

Table 3. Some properties of bentonite used in study

Property		Value	Unit
ECe		3.14	dS m^{-1}
pH		7.00	
Carbonate minerals		130.10	
Gypsum		2.40	g kg^{-1} soil
O.M		-	
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	

A mean leaf area of ten leaves for five plants growing in each experimental unit was calculated by tablet method (34). 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 different treatments(38).

RESULTS AND DICUSSION

Chemical properties of soil after harvest

Soil reaction (pH): The results showed a significant effect of the two study factors (biochar and bentonite level addition) and their interaction in soil reaction (pH) (Table 4). Increased biochar level led to a decrease of soil pH values reached a mean 7.47, 7.42, 7.37 and by 0.67, 1.34, and 2.34% for added levels 5, 10 and 15 Mg ha^{-1}respectively, compared to the control (0 Mg ha^{-1}).The results in Table 4 show that increasing the level of bentonite addition from 0 to 10,20 and 30 Mg ha^{-1} led to increase pH values reached a mean 7.28, 7.39, 7.43 and 7.45 by 1.51, 2.06 and 2.34% for the levels of bentonite respectively, compared to the non-addition treatment.The results showed that the two study factors adversely affected soil pH interaction. Biochar contributed to reducing soil pH while bentonite contributed to raising it. Although both factors had a slight effect but it was significant. As for the interaction between biochar and bentonite, the results were show in Table 4 and its effect was significant on the soil pH. The results indicated that the lowest value 7.08 when treatment (S_3B_0), with a decrease of 4.45% compared to the control (S_0B_0) of 7.41 while the highest value was 7.52 for treatment (S0B_3), with an increase of 1.84% compared to the control (S_0B_0). The percentage of decrease in the soil pH was more than the percentage of increase compared to the treatment for the interaction. This indicates that the addition of biochar was more effective in the soil pH than bentonite.

Table 4. Effect of biochar and bentonite application in soil pH and EC after harvest.

Biochar (S)	pH Bentonite (B)				S Mean	EC (dS m^{-1}) Bentonite (B)				S Mean
	B_0	B_1	B_2	B_3		B_0	B_1	B_2	B_3	
S_0	7.41	7.45	7.49	7.52	7.47	4.43	4.67	4.77	5.00	4.72
S_1	7.35	7.40	7.45	7.47	7.42	4.00	4.20	4.50	4.63	4.33
S_2	7.28	7.37	7.41	7.43	7.37	3.57	3.83	4.07	4.30	3.94
S_3	7.08	7.34	7.39	7.40	7.30	3.13	3.43	3.70	4.00	3.57
B Mean	7.28	7.39	7.43	7.45		3.78	4.03	4.26	4.48	
LSD0.05										
Biochar			0.008					0.07		
Bentonite			0.008					0.07		
S X B			0.016					N.S		

***: N.S: Non Significant**

Electrical conductivity (EC)

The results showed a significant effect of the two study factors (biochar and bentonite level addition) in soil EC (Table 4). Increased biochar level led to a decrease of soil EC values and reached a mean of 4.72, 4.33, 3.94 and 3.57 dS m^{-1} with a decrease of 8.26, 16.53 and 24.36% for added levels 5, 10 and 15 Mg ha^{-1}respectively, compared to the control (0 Mg ha^{-1}). The results Table 5 show that increasing the level of bentonite addition from 0 to 10,20 and 30 Mg ha^{-1} led to increase EC values reached amean of 3.78, 4.03, 4.26 and 4.48 dS m^{-1} with an increase of 6.61, 12.70 and 18.52% for the levels of bentonite respectively, compared to control.The results showed that the two study factors adversely affected soil EC interaction. Biochar contributed to reducing soil EC while bentonite contributed to raising it. The interaction between biochar and bentonite show Table 5, Although there was an effect of both amendments on soil EC, the effect of their interaction was not significant.

Organic matter (O.M)

The results show in Table 5show that the O.M values of the organic matter content amean of 11.40, 22.10, 36.93 and 51.93 g kg^{-1} soil with an increase of 93.86, 223.42 and 355.53% for the levels of biochar for biochar levels 5, 10 and 15 Mg ha^{-1}, respectively compared to control. As for bentonite, the results showed a significant effect on the content of O.M in the soil after harvest (Table 5). Increasing the level of addition from 0 to 10, 20 and 30 Mg ha^{-1} led to an increase in the O.M values a mean were26.54, 29.29, 31.98 and 34.48 g kg^{-1} soil with an increase of 10.36, 20.50 and 29.29% for the levels of addition, respectivelycompared to the control treatment. The results showed that both amendments(biochar and bentonite) had a positive effect in increasing O.M and biochar was more effective compared to bentonite.Interaction between biochar and bentonite had a significant effect on O.M. The results showed that the highest value for the interaction between the two study factors was with the treatment (S_3B_3), as it reached 55.90 g kg^{-1} soil, with an increase of 571.07% over the control treatment for interaction (S_0B_0) reached 8.33 g kg^{-1}.

Cation exchange capacity (CEC)

The results in Table 5 show that the CEC values reached to 8.84, 12.57, 15.55 and 19.13 C mol_+kg^{-1}soil with an increase by 42.19, 75.90 and 116.40% when increasing biochar level from 0 to 5, 10 and 15 Mg ha^{-1},respectively compared to the control (0%), the level of 15 Mg ha^{-1} of biochar addition was higher in achieving the highest value of CEC.The results in Table 6 show that the addition of bentonite had a significant effect on CEC as increasing the level of addition from 0 to 10, 20 and 30 Mg ha^{-1} increased CEC values it reached 9.60,12.71, 15.10 and 18.69 C mol_+kg^{-1}soil with an increase by 32.40, 57.29 and 94.69% for the levels of bentonite, respectively compared to the control. The forth level of addition of 30 Mg ha^{-1} gave the highest increase in CEC, and biochar was the most efficient than bentonite in increasing the soil CEC.The results also showed a significant effect of the interaction between biochar and bentonite in CEC (Table 5).The highest value for CEC was at (S_3B_3) treatment, as it reached 24.17 $Cmol_+kg^{1-}$ soil, and its lowest value at the control (S_0B_0) was 4.74 $Cmol_+kg^{-1}$soil with an increase of 409.92%. This is evidenced by the large positive effect of the interaction between biochar and bentonite in increasing soil CEC which is better than adding each one of amendments individually.As for the addition of biochar and its effect on soil chemical properties of the soil under study, the addition of biochar led to a decrease in soil pH and this could be attributed to the formation of various organic acids as well as the release of hydrogen ions and carbon dioxide (CO_2) as a result of decomposition and forming carbonic acid (17).Several researchers have found a decrease in soil pH due to the addition of biochar (27, 31).The addition of biochar reduced the soil EC and this could be attributed to the ability of biochar to adsorb or retain salts on its surfaces, as well as the physical retention of salts in the micro pores (5,13, 22).

Table 5. Effect of biochar and bentonite application in soil O.M and CEC after harvest.

Biochar (S)	O.M ($g\ Kg^{-1}$) Bentonite (B)				S Mean	CEC ($C\ mol_+Kg^{-1}$ soil) Bentonite (B)				S Mean
	B_0	B_1	B_2	B_3		B_0	B_1	B_2	B_3	
S_0	8.33	10.73	12.27	14.27	11.40	4.74	6.73	10.26	13.64	8.84
S_1	18.80	20.70	22.93	25.97	22.10	7.91	12.04	13.36	16.96	12.57
S_2	31.47	35.50	38.73	41.77	36.87	10.55	14.84	16.83	19.98	15.55
S_3	47.57	50.23	54.00	55.90	51.93	15.21	17.21	19.93	24.17	19.13
B Mean	26.54	29.29	31.98	34.48		9.60	12.71	15.10	18.69	
LSD0.05										
Biochar			0.49					0.06		
Bentonite			0.49					0.06		
S X B			0.97					0.13		

As for the effect of biochar added on the organic matter content, the results indicated an increase in soil organic matter with an increase biochar addition. It could be due to the high organic matter content of biochar (Seek) used in this study (43.55%) (Table 2),which contributes to increasing O.M content. In addition to that, increasing the content of organic matter increases the activity of microorganisms in their decomposition and so on addition of organic waste, and biomass in the soil (3, 27,43). Biochar addition also led to an increase the soil CEC after harvest and could be due to the fact that it has a surface area and a high cations exchange capacity and its possession of high negative charges due to its possession of chemically active groups such as hydroxyl groups (OH) phenolic, alcohol groups (OH), methoxyl groups (OCH_3), carboxyl groups (COOH) and amines groups (NH_2) (26, 27). The addition of bentonite clay had an effect on the chemical properties of the soil under study (pH, EC, O.M, and CEC). The results indicated that soil pH increased with increasing bentonite level of addition. Although the increases were slight, it was significant, perhaps due to the fact that pH of the bentonite clay (pH 7.0) (Table 3) contributed to the increase in the release of the hydroxyl ion (OH^-) to the soil solution, as well as its high content of carbonate minerals ($CaCO_3$) (130.1 g kg^{-1} soil) has contributed to raising soil pH (6). Bentonite added in the study is Ca-bentonite containing high concentrations of calcium, magnesium and sodium which, when released from the bentonite, caused an increase in pH of the soil under study (15,32,36).The content of O.M increased with the increase bentonite level. This could be due to the fact that the mineral of bentonite clay form stable complexes with the organic matter within the clay layers and that each unit of organic matter is associated with 10 units of clay (16). It was found that the addition of bentonite increases the accumulation of organic carbon and total nitrogen, reduces the rate of their decomposition, and increases the activity of microorganisms (19). The addition of bentonite increased soil CEC. This could be attributed to the fact that the bentonite clay is of a type 2: 1 (three layers) and has a high specific surface area ranging from 80 - 150 C mol_+kg^{-1} and its particles have a strong negative charge, as it is a source of negative charges in soil (18), as well as the CEC of the bentonite clay used under the study is (60.1 C mol_+kg^{-1}) (Table 3) which contributed to increasing the cations exchange capacity and this is agree with were confirmed byCzaban and Siebielec (15) ,Minhal et al., (29) found a positive linear relationship between the CEC of sandy soil with bentonitelevel addition.The results showed that the addition of the two factors as soil conditioners had a significant rolein improving the chemical properties of the soil.

Plant parameters

Plant height (cm): The results in Table 6 show that the plant height increased with increasing biochar level by 3.86, 7.32 and 14.43% for the levels 5, 10 and 15 Mg ha^{-1}, respectively compared to the control. The results showed that the level 15 Mg ha^{-1} gave highest value (56.3 cm) for plant height compared to other levels.The results also showed that the addition of bentonite had a significant effect on plant height (Table 6). The plant height increased by 8.67, 13.74 and 20.30% for the levels of bentonite 10, 20 and 30 Mg ha^{-1}respectively, compared to the control. The fourth level of addition gave the highest value of plant height in comparison with the other levels.As for the interaction between the two factors (biochar and bentonite), its effect was significant on plant height (Table 6). The fourth level of biochar and bentonite in the treatment (S_3B_3) was superior in giving the highest value of plant height of 62.3 cm with an increase of 36.62% over the control treatment for interaction (S_0B_0) which gave a value of plant height of 45.6 cm. Both amendments (biochar and bentonite) contributed to their interacting effects in increasing plant height better than if they were added separately.

Leaf area (cm^2 plant^{-1})

The results show in Table 6a significant effect of biochar added in the leaf area it reached 2334.1, 2724.1, 2912.5 and 3028.6 cm^2 plant^{-1}withincreases by 16.71, 24.78 and 29.75% for levels 5, 10 and 15 Mg ha^{-1}, respectively compared to the control.

Table 6. Effect of biochar and bentonite application in plant growth parameters of board bean

Biochar (S)	Plant height (cm) Bentonite (B)				S Mean	Leaf area (cm^2 plant^{-1}) Bentonite (B)				S Mean
	B_0	B_1	B_2	B_3		B_0	B_1	B_2	B_3	
S_0	45.6	48.5	50.3	52.5	49.2	2035.1	2240.3	2397.1	2663.7	2334.1
S_1	46.4	49.3	53.3	55.4	51.1	2484.7	2592.9	2713.8	3104.8	2724.1
S_2	47.7	51.9	54.1	57.4	52.8	2696.6	2704.7	2975.5	3273.3	2912.5
S_3	49.4	55.9	57.5	62.3	56.3	2766.1	2964.9	3081.5	3301.8	3028.6
B Mean	47.3	51.4	53.8	56.9		2495.6	2625.7	2792.0	3085.9	
LSD0.05										
Biochar			0.85					151.7		
Bentonite			0.85					151.7		
S X B			1.70					303.4		

The results in Table 6indicate an increase in the leaf area it reached 2495.6, 2625.7, 2792.0 and 3085.9 cm^2 plant^{-1}with increases by 5.21, 11.88 and 23.65% for bentonite levels 10, 20 and 30 Mg ha^{-1} respectively, compared to the control.The results in Table 7 show that the interaction treatment (S_3B_3) gave the highest value for the leaf area of the plant which reached to 3301.8 cm^2 plant^{-1} with an increase of 62.24% compared to the interaction control (C_0B_0), which gave the lowest value for the leaf area which reached 2035.1 cm^2 plant $^{-1}$.

Dry weight (g plant^{-1})

Dry weight (dry weight of vegetative part without pods) increased significantly with the increase biochar level added, as the values of dry weight of the vegetative part reached a mean of 61.81, 68.24, 74.77 and 81.53 g plant^{-1} with an increase of 10.40, 20.97 and 31. 90%for levels 5, 10 and 15 Mg ha^{-1}, respectively compared to the control treatment. The results also showed (Table 7) the increase bentonite levels from 0 to 10, 20 and 30 Mg ha^{-1}increased the dry weight values reached a mean of 61.78, 70.92, 74.40 and 79.25 g plant^{-1}, with an increase of 14.79, 20.43 and 28.28% for bentonite levels,respectively compared to the control treatment. The interaction treatment (S_3B_3) gave the highest value for the dry weight of 88.93 g plant^{-1} with an increase of 69.13% over the control (S_0B_0) which gave the lowest value of 52.58 g plant^{-1}. The interaction of both factors gave the highest value to the dry weight indicating the positive effect of these two soil conditioners, which can be used together better than adding each of them separately.

Fresh pods yield (Mg ha^{-1})

The results in Table 7show thatthe fresh pods yieldincreased significantly with increasing biochar levels and their values reached 13.559, 15.131, 16,539 and 17,540 Mg ha^{-1} with an increase of 11.59, 21.98 and 29.36% for the levels of adding biochar 5, 10 and 15 Mg ha^{-1}, respectively, compared to the control treatment.The results showed that the level 15 Mg ha^{-1} gave highest value for fresh pods yield (81.53 Mg ha^{-1}).The bentonite addition had a significant effect on fresh pods yield which reaching a mean of 12.049, 14.540, 16.689 and 18.990 Mg ha^{-1}with an increase of 20.67, 38.51 and 57.61% for the levels of adding bentonite 10, 20 and 30 Mg ha^{-1}, respectively compared to the control treatment.As for the interaction between the two factors (biochar and bentonite), its effect was significant on fresh pods yield (Table 7). The treatment (S_3B_3) was superior in giving the highest value of fresh pods yield of 20.543 Mg ha^{-1} with an increase of 107.36% over the control treatment for interaction (S_0B_0) which gave a value of 9.907 Mg ha^{-1}. Both amendments (biochar and bentonite) contributed to their interacting effects in increasing fresh pods yield better than if they were added separately.

Table 7. Effect of biochar and bentonite application in dry weight and fresh pods yield

Biochar (S)	Dry weight (g plant^{-1}) Bentonite (B)				S Mean	Fresh pods yield(Mg ha^{-1}) Bentonite (B)				S Mean
	B_0	B_1	B_2	B_3		B_0	B_1	B_2	B_3	
S_0	52.58	60.71	65.00	68.96	61.81	9.907	12.807	14.280	17.240	13.559
S_1	57.77	68.80	70.77	75.60	68.24	11.447	13.750	16.676	18.650	15.131
S_2	62.45	74.32	78.81	83.52	74.77	13.790	15.517	17.320	19.527	16.539
S_3	74.32	79.83	83.03	88.93	81.53	15.050	16.087	18.480	20.543	17.540
B Mean	61.78	70.92	74.40	79.25		12.049	14.540	16.689	18.990	
					LSD0.05					
Biochar			1.20					0.438		
Bentonite			1.20					0.438		
S X B			2.40					0.875		

The results indicated that there were significant increases in the growth parameters of broad bean (plant height, leaf area, dry weight and fresh pods yield) with an increase in the level of addition of biochar. This could be attributed to the fact that biochar is a source rich in nutrients, especially nitrogen and phosphorous (Table 3), its availability increases as a result of the decomposition processes in addition to its role in improving chemical properties (reducing pH, and increasing CEC) which led to an increase in nutrient availability as well as the increase in organic carbon, which contributed to an increase in biological activity and biological processes in the soil which caused an increase in biological and physiological processes in plants, which contribute to the manufacture of food and storage in seeds and reflected in the increase broad bean growth and yield parameters (13,30,42).The results came in agreement with the results of a number of studies that obtained an increase in growth indicators and yield of leguminous and cereal crops when they added biochar to coarse-textured soils (8,26).The addition of bentonite also led to a significant increase in broad bean growth parameters, This could be attributed to its properties have varied roles in the soil, it has a role in increasing the ability of soil to retain water by close large pores in the soil, increasing water available in the root zone, and increasing plant growth. In addition, its role in increasing the soil CEC and the nutrients availability, preventing it from loss during the washing process and raising the efficiency of mineral fertilizers added to coarse textured soils such as study soil, which contributed to increasing the absorption of water and nutrients by the plant and this was reflected in the increase in plant growth and yield parameters (2,29, 32).The results are agree with what was confirmed by a number of studies that used bentonite as conditioner for sandy soils and obtained an increase in the growth and yield parameters of some crops (1,11). Interaction between the level of addition of biochar and bentonite, its positive effect was to increase the growth parameters of the broad bean. The interaction of both factors for the treatment (S_3B_3) gave the highest increase in plant height, leaf area, dry weight and fresh pods yield which achieved the increase in the plant parameters for each of the factor alone. The results agree with the results of other researchers they found in their study the superiority of the interacting effect of two amendments or more in increasing the plant parameters (1,23).

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