The Future of Agriculture

FSA

Article

Response of Faba Bean to Some Agricultural Practices Under Sandy Soils Conditions

Hosam A. Shoman

Plant Production Dept., Desert Research Center (DRC), El-Matariya, Cairo, Egypt.

***Corresponding author:** h.shoman77@gmail.com

Abstract: Two field experiments were conducted at the experimental station of Desert Research Center (D.R.C.) at EL-Kharga Oasis, New Valley Governorate, Egypt, during 2022/ 2023 and 2023/ 2024 growing seasons, to study the effect of some rates of bentonite, biochar and types of compost on productivity of faba bean (*Vicia faba* L.) and soil properties under sandy soil condition at New Valley. The results recommend to applying a bentonite at a rate of 4 ton fed.$^{-1}$, and vegetable compost at a constant rate of 10 m^{3} fed.$^{-1}$ and biochar at a rate of 1000 kg fed.$^{-1}$ to improvement of soil properties and maximum faba bean productivity are growing in sandy soils. Whereas, The percentage of increase in plant height was 24.69 %, number of pods plant^{-1} was 82.78 %, seed yield was 59.09 %, weight of 100 seeds was 57.78 %, protein yield was 31.25 %, WUE was 92.67 %, porosity was 7.94 %, soil WHC was 19.58 and organic matter was 64.00 % when using these rates of the three studied factors referred to, as compared of the control treatment (without addition).

Key words: Faba bean, sandy soil, bentonite, compost, biochar and yield.

CrossMark

Future Science Association

Available online free at
www.futurejournals.org

Print ISSN: 2687-8151

Online ISSN: 2687-8216

DOI:
10.37229/fsa.fja.2024.10.05

Received: 13 August 2024
Accepted: 17 September 2024
Published: 5 October 2024

1. Introduction

Legumes are considered one of the most important Egyptian food crops that are the source of calories and protein daily, and it is one of the basic crops in the Egyptian crop structure (**Luscher *et al.*, 2014**). Faba bean is considered one of the most important legume crops in the Egyptian agriculture and it occupies an important place in the diet because it represents a basic meal, especially among the poor and middle classes. It also provides it helped increase the nitrogen content in the soil and then increase it fertility (**Wang *et al.*, 2016**). One of the most important problems facing the production of faba bean in desert areas is the spread of sandy lands, more than 90% of which are sandy, and are characterized by low production efficiency as a result of their weak structural composition, low ability to retain water, and low content of organic matter and elements which results in poor physical, biological and chemical properties of these soils (**Shafeek *et al.*, 2013**). Sandy soils contain more than 700 g sand kg^{-1} and colloidal particles less than 150 g clay kg^{-1} (**FAO, 2001**). Thus, sandy soils have low capacity to retain water and nutrients and less supplying power of nutrients including N, P and K. Accordingly, amendments have been widely investigated to raise the use efficiency of fertilizers and thus improving plant growth and productivity (**Sadek *et al.*, 2021**).

Some methods have been used to improving the sandy soils in desert and desertified lands to overcome its agricultural determinants by improving the physical, chemical and biological properties of the soil, ability to retain water, increasing its nutrients availability and productivity, the most important of these means is the use of some natural amendments which it was organic. Natural amendments, such as compost and biochar that produced from palm waste, and bentonite have been used widely in the world for its role in improving many soil properties and increasing available nutrients (**Al-Kinani and Jarallah, 2021**). The increase in demand for suitable organic substrate has focused research on the search for local available affordable (low cost) with sufficient physicochemical properties. These date palm wastes consist of cellulose, hemicellulose, lignin and other compounds which would be utilized in many biological processes. The utilization of these wastes in the production of compost is very important from the environmental, agricultural and industrial point of view. Thus, there is an urgent need to find suitable and beneficial application for this waste. The large amounts of palm wastes produced every crop season constitute a big charge for the farmers who are always trying to burn or transport them outside of oasis. Therefore, composting could provide an economical and environmentally significant method to reduce date palm wastes (**Khiyami *et al.*, 2008**). **Ali (2017)** demonstrated that date palm compost increases growth and yield of many crops such as, wheat, maize, peanut, alfalfa and faba bean. **Mohammadi (2023)** reported that compost resulting from palm wastes to faba beans growing in sandy soils led to an increase in the amount of seed yield to 30% compared to not adding it, which is attributed to improving the natural and chemical properties of the soil in addition to enhancing its ability to retain water.

Moreover application of biochar to sandy soil was considered to improve a range of soil physical and hydraulic properties including soil bulk density **(Ahmed *et al.*, 2018)**, soil porosity (**Jacka *et al.*, 2018**), total soil organic matter (**Githinji, 2014**), soil hydrophobicity (**Ibrahim *et al.*, 2016**), soil water holding capacity **Suliman *et al.* (2017)** and **Al-Wabel *et al.* (2018)**, and soil available water (**Hansen *et al.*, 2016**), as well as crop production (**She *et al.*, 2018**), water use efficiency **Xiao *et al.* (2018)** and crop drought resistance (**Poormansour and Razzaghi, 2018**). Biochar is carbonaceous material produced by thermal decomposition of crops residues or burning under limited oxygen by exposure to pressure (**Lehmann and Joseph, 2009**). Biochar plays a key role in soil fertility and plant nutrition, such as improving soil cation exchange capacity, conserving nutrients against losses for a longer period and increase their utilization efficiency by plants (**Rizwan *et al.*, 2016**). Biochar has high porosity, specific surfaces and the high ability maintain water and exchange cations, which improves soil fertility and availability of nutrients for plant uptake (**Atkinson *et al.*, 2010**). **Khalifa and Yousef (2015)** suggested that biochar of date palm waste addition to sandy soil increases water holding capacity which might increase water availability for plant use and chemical propriety. **Guerena *et al.* (2015)** reported that the biochar addition to faba bean resulted in 35.75% increase in yield and 21.26% increase in N derived from the atmosphere over the control.

Bentonite is considered a natural precipitate used as an amendment to sandy soils by many researchers (**Lotfy and El-Hady, 1984**). They found that these deposits contain a high percentage of clay and a high percentage of smectite minerals, in addition to high surface area and cation exchange capacity (CEC). **Iskandar *et al.* (2011)** found that bentonite increases the ability of soil to store water and fertilizers. In addition, bentonite reduces soil fixation of phosphorus and potassium. **Jena and Kabi (2012)** reported that the use of bentonite increases available nutrients and the productivity of growing plants. **Tawfiq (2009)** reported that bentonite reduces the rate of decomposition of organic matter, so it can increase the quality and quantity of organic matter, improve the fertility of sandy soil, growth, yield and the chemical composition of plants. In this perspective, introducing clay-rich bentonite can improve the physical and chemical characteristics of these soils. This action will increase cation exchange capacity (**Dejou, 1987**), and improve soil structure leading to good water and nutrients retention and better soil ventilation (**Raimund and Dietmar, 1996**). **Aleem *et al.* (2000)** suggested that added bentonite to sand soil allow to improvement of the physical, chemical and hydrous characteristics on account of high capacity to keep back the water and its strong exchange cationic capacity and thus to increase the agricultural yield. A further benefits of bentonite its capacity to increase plan available water (PAW) as a function of increasing porosity finally increasing yield of growing many crops by 35% (**Soda *et al.*, 2006 and Al-Kinani and Jarallah, 2021**). The aim of this investigation is to maximizing the productivity of faba bean in sandy soils of the New Valley, improving the natural and chemical properties of sandy soil by adding organic materials resulting from palm waste, whether in the form of compost or biochar, which increases its production efficiency, which reflects positively on improving productivity of faba bean by achieving the best spraying rate of wood vinegar and maintaining the environmental balance through optimal exploitation of waste resulting from palm pruning waste.

2. Materials and Methods

2.1. Experiment Site

Two field experiments were conducted in Desert Research Center, Agricultural Experiment Station at EL-Kharga Oasis, New Valley Governorate, Egypt, during the two winter growing seasons of 2022/ 2023 and 2023/ 2024, to study the effect of some agricultural practices such as: compost and biochar that produced from palm pruning and bentonite on faba bean productivity under sandy soil conditions. The physical and chemical soil characteristics of the studied site were determined according to **Klute (1986)**, as recorded in Table (1). As well as, the chemical analysis of irrigation water carried out using the standard method of **Page *et al.* (1982)** and presented in Table (2).

Table (1). Physical and chemical properties of the experimental soil

Particle size distribution (%)			Texture soil	Ec dsm-1	pH	Available nutrients (Cations)					Available nutrients (Anions)			
sand	silt	clay				P (%)	K^+ (%)	Na^+ (%)	Ca^{++} me/l	Mg^{++} me/l	$Co_3^=$	HCO_3^- me/l	Cl^- me/l	$SO_4^=$ me/l
91.0	5.0	4.0	Sand	1.29	8.0	0.39	0.51	4.54	3.42	4.11	-	3.62	3.00	5.80

Table (2). Chemical analysis of irrigation water

Seasons	pH	E.C. (ppm)	S.A.R	Soluble cations (me/l)				Soluble anions (me/l)			
				Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_{3-}	$SO_4^=$	Cl^-
2022/ 2023	7.63	1411	3.55	3.41	3.12	8.47	0.63	0.17	3.22	2.38	7.47
2023/ 2024	7.74	1355	3.18	3.54	3.25	7.36	0.58	0.32	3.68	2.79	8.24

2.2. Treatments

The experiment included 27 treatments, which were the combinations between the wood vinegar, biochar and compost:

2.2.1. Bentonite rates

In this study, two rates of bentonite were compared with control and explained as follows:

a. Without (control)

b. 2 ton $fed.^{-1}$

c. 4 ton $fed.^{-1}$

Bentonite was added while preparing the land for planting. The analysis of bentonite is listed in Table (3).

2.2.2. Types of compost

Two types of compost were compared with control and explained as follows:

a. Without compost (control).

b. 100% vegetable compost.

c. 100% animal compost.

Therefore, the addition rate of compost is fixed at 10 m^3 $fed.^{-1}$ and produced from palm pruning waste. Animal compost was made from cow residue. The analysis of the compost used is listed in the following Table (3):

2.2.3. Biochar rates

Two rates of biochar that made of palm pruning waste were compared with control and explained as follows:

a. Without (control).

b. 500 kg $fed.^{-1}$

c. 1000 kg $fed.^{-1}$

Whereas, used bentonite, compost and biochar were added while preparing the soil for sowing. The biochar analysis data used are listed in the Table (3).

Table (3). Physical and chemical analysis of bentonite, compost and biochar

Parameters		**Bulk density** (g cm^{-3})	**Moisture content** (%)	**pH**	**EC** ds/ m	**Organic carbon**	**Total N**	**Total P**	**Total K**
						(%)			
Bentonite		0.96	6.41	8.52	3.11	1.24	1.79	2.31	1.14
Compost	**Veg.**	0.88	26.35	7.10	2.71	2.87	1.82	0.84	2.21
	Ani.	0.76	25.73	7.47	3.18	2.35	1.43	0.96	1.87
Biochar		0.47	03.84	8.58	4.69	6.37	0.26	0.17	0.91
Parameters		**C/N ratio**	**Ash (%)**	**CEC** C mol kg^{-}	**TOM** (%)	**Total micronutrients (mg kg)**			
						Fe	**Zn**	**Mn**	**Cu**
Bentonite		1.17	45.27	59.55	31.57	4.35	1.91	1.34	0.56
Compost	**Veg.**	1.19	34.14	42.37	23.24	1.94	3.63	0.49	0.38
	Ani.	1.12	41.48	40.11	20.88	1.61	2.87	0.42	0.34
Biochar		**32.4/01.2**	37.63	29.46	10.2	3.22	2.25	0.33	0.31

Veg. : Vegetable compost, Ani. : Animal compost, CEC: cation exchange capacity and TOM: total organic matter

2.3. Experimental Design

A split split plot design used with three replications. Where, main plots arranged by bentonite rates, the sub plots allotted with TC treatments and BR distributed in sub sub plots. Each experimental unit area in the two seasons was 10.5 m^2 (1/400 fed.), which consisting of five lines with a width of 60 cm , a length of 3 meters and the distance between plants were 20 cm. All the obtained data for each treatment were subject to analysis of variance according to the method described by **Gomez and Gomez (1985)**. The least significant difference (LSD) was at 5% level of significance.

2.4. Inoculants Preparation and Inoculation

Rhizobium (Okadeen) mixed well with 10 % sugar solution and added to faba bean seeds that spread on a clean plastic sheet under shading. Seeds were soaked in liquid inoculate after being diluted 1:1 with well water for 30 minutes before sowing.

2.5. Agricultural practices

Mariout 2 cultivar of faba bean (*Vicia faba* L.) was sowing on 1st November, the previous crop was peanut in both seasons. the experimental units were fertilized calcium super phosphates (15.5 %

P_2O_5) at the rate of 150 kg fed.$^{-1}$ was added to the soil during tillage operation and before sowing. 50 kg K_2O fed.$^{-1}$ of potassium sulphate (48 % K_2O) was added in two equal portions, before the first and second irrigation. Nitrogen in the form of ammonium sulphate (20 % N) at the rate of 25 kg N fed.$^{-1}$ as starter dose and was added before irrigation. Planting was performed on both sides of ridges at 25 cm between hills. Thinning was done after 21days from sowing to leave healthy two plants/ hill. Hand digging was done every 21 days to control weeds i.e. before, time of irrigations. Other cultural practices were applied as per the recommendations. The plants harvested by hand when the 60% of the pods are mature in both growing seasons.

2.6. Measurements

2.6.1. Yield and its components

At harvest five plants were taken from each experimental unit and the following characters were studied: first: yield and its components: plant height (cm), number of pods plant^{-1}, 100 seed weight (g), seed yield (kg fed.$^{-1}$), protein yield (g kg^{-1}) and water use efficiency (WUE) kg m^{-3}. Whereas, WUE which calculated using the equation of **Vites (1965)** for seed yield, as follows: equation (1) WUE = Seed yield kg fed^{-1} /actual consumptive use m^3 fed^{-1}. Protein yield (kg fed.$^{-1}$) was determined by using the Kjeldahl method (N %) with a conversion factor of 6.25 and the resulting value is multiplied by the amount of seed yield fed.$^{-1}$.

2.6.2. Soil estimations

Due to the use of study factors that have a significant impact on the physical and chemical properties of the sandy soil, some estimates of the soil can be taken from layer (20 -30 cm depth), which can be made taken two months after the date of adding organic fertilizers, i.e. (the date of sowing)، such as: total porosity (%), soil water holding capacity % (Soil WHC), bulk density (%) and organic matter (%)

- Total porosity (TP): calculated from equation (2) which mentioned in Black *et al.* (1965).

$$Tp = 1- pd/ps \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

Where:

tp: Total soil porosity (%)

pd: The dry bulk density (Mg m^{-3})

ps: The particle density (Mg m^{-3})

- Soil water holding capacity (Soil WHC): determined at different pressure by using watermark sensor, using soil samples on a tension table (33 kPa) and pressure plates (1500 kPa) (Klute 1986).

- Bulk density (BD): evaluated by core method, three replications of soil sample were collected per plot from specific depths in this study. Each sample was dried in oven at 105 °C and weighed then bulk density was calculated from equation (3) which noted in Black *et al.*, (1965).

$$Pd = ms/vt \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

Where:

pd: The dry bulk density (mg m^{-3}).

Ms: The weight of the dried soil sample (mg).

Vt: The total volume of the soil sample (m^3).

- Organic matter (OM): determined by the modified Walkley-Black method (**Black *et al.*, 1965)**.

3. Results and Discussion

3.1. Effect of Bentonite Rates

The results listed in Table (4) show that the bentonite added rates had a significant effect on all the studied traits in both seasons. The highest values for all studied characteristics were obtained when adding the highest rate of bentonite (4 tons fed.$^{-1}$), with the exception of the bulk density of the soil, which was with the control treatment (without bentonite). Adding 4 tons fed.$^{-1}$ of bentonite as compared with control increased plant height by 27.48 and 26.93 %, No. of pods plant^{-1} by 85.18 and 84.04 %, seed yield by 50.93 and 49.46 %, 100 seed weight by 56.47 and 54.55 %, protein yield by 30.70 and 29.65 %, WUE by 83.98 and 80.34 %, soil porosity by7.94 and 7.31 %, soil WHC by 26.71 and 25.56 % and organic by 71.43 and 62.50 %, while bulk density decreased by 6.33 and 4.49 % in the first and second seasons respectively.

The positive effect of bentonite at the rate of (4 tons fed^{-1}) may be due to its positive effect on water holding capacity in sandy soils (**Iskander *et al.*, 2011**), which reduces the leaching of various nutrients through its high colloid content (**Sitthaphanit *et al.*, 2010**), stimulating meristematic activity to produce more tissues and organs, as it plays major roles in structural structure (**Marisa *et al.*, 2009**) and its vital contribution to many biochemical processes related to plant growth and yield components (**Marschner, 1995**), as well as, increasing concentrations of nitrogen, potassium, and phosphorus, total chlorophyll and carotenoids in the leaves, which ultimately leads to enhanced photosynthesis and other metabolic activity, resulting in an increase in various plant metabolites responsible for cell division and elongation. Accordingly, bentonite addition enhanced sandy soil properties which reflected on increased soil fertility and productivity (**El-Etr and Hassan, 2017**). Bentonite has a high cation exchange capacity which increases the soil water content (**Kayama *et al.*, 2016**) and would be expected to have high nutrient retention. Use of bentonite may encourage sandy soil aggregates, water retention and increase nutrients (**Zhang *et al.*, 2020**).

Many researchers have reported that adding bentonite to sandy lands improves the supply of nutrients to growing plants, which reflects positively on improving growth and productivity due to the role of bentonite in improving soil properties, the most important of which is raising its content of organic matter and improving its ability to conserve water, including (**Czaban and Siebielec, 2013, Molla *et al.*, 2014, Abdulaziz *et al.*, 2018, Al-Kinani and Jarallah, 2021, Al-Hayani *et al.*, 2022 and Saja and Abbas, 2023**).

Table (4). Effect of bentonite rates on faba bean (*Vicia faba*, L.) productivity and soil properties during 2022/ 2023 and 2023/ 2024 growing seasons under sandy soils conditions at New Valley

Measurements	**Plant**						**Soil**			
Char. / **Bentonite**	**Plant height** cm	**No. of pods plant^{-1}**	**Seed yield** Kg fed.$^{-1}$	**100 seed weight** g	**Protein yield** g kg^{-1}	**WUE** kg m^{-3}	**Porosity** %	**Soil WHC** %	**Bulk density** mg m^{-3}	**Organic matter** %
2022/ 2023										
Control	102.33	11.54	1125	48.36	228	0.362	40.43	36.58	1.58	0.49
2 ton fed.$^{-1}$	119.14	19.86	1541	63.12	267	0.513	42.16	41.23	1.54	0.71
4 ton fed.$^{-1}$	130.45	21.37	1698	75.67	298	0.666	43.64	46.35	1.48	0.84
LSD at 5%	**5.53**	**1.46**	**78**	**4.33**	**12**	**0.125**	**1.37**	**2.10**	**0.04**	**0.12**
2023/ 2024										
Control	101.96	11.28	1118	.4774	226	0.356	40.22	35.87	1.56	0.48
2 ton fed.$^{-1}$	117.50	19.39	1510	62.70	257	0.502	41.80	40.12	1.51	0.68
4 ton fed.$^{-1}$	129.42	.2076	1671	.7378	293	0.642	43.16	45.04	1.49	0.78
LSD at 5%	**6.41**	**1.26**	**62**	**5.41**	**15**	**0.103**	**1.16**	**2.47**	**0.03**	**0.11**

Control: without bentonite, WUE: water use efficiency, soil WHC: soil water holding capacity and LSD: Least significant difference.

3.2. Effect of Compost Types

Table (5) summarizes the effect of compost types on faba bean productivity and some characteristics of sandy soil. The results indicate that the effect of adding types of vegetable or animal compost to sandy soils for the purpose of increasing their production efficiency was significant on all the studied traits. The use of vegetable compost is superior to animal compost in improving the studied characteristics of both faba bean and soil.

Applying the use of vegetable compost at a constant rate (10 m^3 $fed.^{-1}$) gave the highest values in the first season (2022/2023) for plant height (133 cm) an increase of 34.72 %, number of pods $plant^{-1}$ (22.16) an increase of 78.57 %, seed yield (1945 $fed.^{-1}$) an increase of 77.89 %, weight of 100 seeds (78.60 g) an increase of 68.06 %, protein yield (295 g kg^{-1}) an increase of (37.31 %), WUE (0.668 kg m^{-3}) an increase of 95.89 %, soil WHC (45.27 %) an increase of 20.14 % and organic matter (0.82 %) an increase of 60.78 % compared to the control treatment (Without compost). While soil porosity, its highest value of (44.37 %) was when adding 10 m^2 fed^{-1} of animal compost an increase of 10.81 % during the first season 2022/2023. On the other hand, the highest value of soil bulk density was (1.56 mg m^{-3}) with the control treatment (without compost) in the first season.

The superiority of vegetable compost over animal compost in improving the productivity of faba bean growing in sandy soil may be due to its abundant content of decomposed organic matter and available nutrients that are easily absorbed by the plant, in addition to the improving effect on the soil's ability to hold the water. The positive effect of compost on all soil characteristics and faba bean yield may be due to the compost content of organic compounds dissolved in water such as organic acids, amino acids, sugars and humic acids. All of these compounds contribute directly or indirectly to the growth and development of the plant. Its encourage growth by the stimulate enzymes or hormones, as well as containing the nutrients that the plant needs, or they affect the availability of nutrients already present in the soil by improving the pH of the soil and thus improving plant productivity (**Al-Bayati and Kamel, 2014**). These results are agreement with the obtained by **Ali (2018)**, **Al-Kinani and Jarallah (2021)**, **Mohammad *et al.* (2022)**, **Aya Attia *et al.* (2023)** and **Mohammadi (2023)**.

Table (5). Effect of compost types on faba bean (*Vicia faba*, L.) productivity and soil properties during 2022/ 2023 and 2023/ 2024 growing seasons under sandy soils conditions at New Valley

Measurements	Plant						Soil			
Char. / Compost	Plant height cm	No. of pods $plant^{-1}$	Seed yield kg/ fed.	100 seed weight g	Protein yield g kg^{-1}	WUE kg m^{-3}	Porosity %	Soil WHC %	Bulk density mg m^{-3}	Organic matter %
2022/ 2023										
Control	98.83	12.41	1094	46.77	215	0.341	40.04	37.68	1.56	0.51
100 % Veg.	133.14	22.16	1945	78.60	295	0.668	42.53	45.27	1.50	0.82
100 % Ani.	129.36	20.67	1863	76.15	279	.0539	44.37	42.36	1.52	0.69
LSD at 5%	**3.54**	**1.25**	**63**	**2.37**	**11**	**0.027**	1.66	**1.53**	**0.02**	**0.10**
2023/ 2024										
Control	98.55	12.50	1085	46.64	213	0.339	39.71	36.41	1.55	0.50
100 % Veg.	131.21	21.57	1912	78.22	284	0.632	42.18	45.29	1.49	0.81
100 % Ani.	126.68	20.12	1837	.7519	274	.0526	43.76	41.57	1.51	0.68
LSD at 5%	**4.15**	**1.17**	**58**	**2.66**	**14**	**0.021**	**1.56**	**2.20**	**0.02**	**0.11**

Control: without compost, 100 % Veg. : 100 % vegetable compost, 100 % Ani. : 100 % animal compost, WUE: water use efficiency, soil WHC: soil water holding capacity and LSD: Lest significant difference.

3.3. Effect of Biochar Rates

Regarding the effect of biochar rates on some traits of soil and faba bean in sandy soil, data in Table (6) illustrate that, excess up to control treatment (without biochar) led to a significant increase in all studied traits in both seasons. The highest values of all measurements can be obtained when using the high rate of biochar (1000 kg fed.$^{-1}$) in both seasons. The increase percentages obtained with this rate of biochar compared with the control treatment (without biochar) were 18.0 and 16.7 % of plant height, 42.0 and 39.8 % in number of pods plant^{-1}, 39.1 and 35.0 % of seed yield plant^{-1}, 37.8 and 36.7 % of 100 seed weight, 72.2 and 68.5 % of protein yield, 21.9 and 18.7 % of WUE, 38.7 and 37.1 % of soil porosity, 40.2 and 34.4 % of soil WHC, 19.0 and 18.1% of bulk density and 8.0 and 7.3 % of organic matter in the first and second seasons, respectively.

The good effect of biochar on soil and faba bean traits may be due to biochar have high carbon content above 50 %, varying C: N ratios or variable mineral content (**Xie *et al.*, 2015**), biochar can also contain varying amounts of aromatic compounds and aliphatic (**Liu *et al.* 2016**) and easily degraded oxidized carbon compounds (**Buss and Masek, 2016**). In addition, the fertilizer components contained in biochar are slowly released into plant-available forms, with higher temperatures and longer residence times, promoting the accumulation of total P and K (**Peng *et al.*, 2012**) and the release of Ca, Mg and Si and the retention of Fe, Mn and Zn (**Qambrani *et al.*, 2017**).

In support of these results, **Ibrahim *et al.* (2017)** reported that biochar increased 100 seed weight of faba bean by 54 %, seed yield by 61 %, number of pods plant^{-1} by 40 % and protein by 23 % as compared with control (no biochar). **Jiang *et al.* (2015)** indicated that increasing all traits of faba bean and soil under the application of biochar treatments could be due to the ability of biochar to increase nutrient retention capacity of the soil, where biochar can be adsorbed nutrients through cation exchange sites on the surface area of the soil biochar. Moreover, biochar can absorb soluble organic matter and its ability to absorb soluble inorganic nutrients, i.e., NPK from soil solution. These finding are in harmony with the obtained by **Mohammad *et al.* (2022)**, **Saja and Abbas (2023)** and **Tomasz *et al.* (2023)**.

Table (6). Effect of biochar rates on faba bean (*Vicia faba,* L.) productivity and soil properties during 2022/ 2023 and 2023/ 2024 growing seasons under sandy soils conditions at New Valley

Measurements	Plant						Soil			
Char. / Biochar	Plant height cm	No. of pods plant^{-1}	Seed yield kg/ fed.	100 seed weight g	Protein yield g kg^{-1}	WUE kg m^{-3}	Porosity %	Soil WHC %	Bulk density mg m^{-3}	Organic matter %
2022/ 2023										
Control	110.75	10.36	1161	49.73	230	0.350	41.20	40.53	1.59	0.50
500 kg fed.$^{-1}$	116.83	17.47	1462	61.25	268	0.511	43.92	42.06	1.54	0.67
1000 kg fed.$^{-1}$	125.34	19.19	1736	74.30	289	0.627	45.16	45.64	1.51	0.79
LSD at 5%	**5.07**	**1.45**	**84**	**6.3**	**17**	**0.110**	**1.07**	**1.35**	**0.03**	**0.12**
2023/ 2024										
Control	108.84	9.76	1122	48.65	227	0.341	41.10	39.17	1.59	0.49
500 kg fed.$^{-1}$	114.77	17.04	1414	60.50	266	0.498	43.56	41.36	1.52	0.63
1000 kg fed.$^{-1}$	123.26	18.61	1698	73.48	288	0.603	44.87	45.12	1.50	0.75
LSD at 5%	**5.28**	**1.52**	**91**	**5.29**	**16**	**0.102**	**1.51**	**1.42**	**0.01**	**0.11**

Control: without, WUE: water use efficiency, soil WHC: soil water holding capacity and LSD: Least significant difference.

3.4. Effect of the Interaction between Bentonite, Compost and Biochar

Results in Table (7 a and b) show that the interaction between the three studied factors had a significant effect on all the studied parameters of soil traits and faba bean that growing in sandy soil except of bulk density in the two growing seasons. The lowest values of all studied traits resulted in the three control treatments for the three studied factors. Whilst, the highest values were obtained when using bentonite at a rate of 4 ton fed.$^{-1}$, and vegetable compost at a constant rate of 10 m^3 fed.$^{-1}$ and biochar at a rate of 1000 kg fed.$^{-1}$ in the two growing seasons.

The percentage of increase in plant height was 24.69 %, number of pods plant^{-1} was 82.78 %, seed yield was 59.09 %, weight of 100 seeds was 57.78 %, protein yield was 31.25 %, WUE was 92.67 %, porosity was 7.94 %, soil WHC was 19.58 and organic matter was 64.00 % when using bentonite at a rate of 4 ton fed.$^{-1}$, and vegetable compost at a constant rate of 10 m^3 fed.$^{-1}$ and biochar at a rate of 1000 kg fed.$^{-1}$ in the first season as compared to the control treatment (control treatment of the three studied factors).

4. Conclusion

The results recommend applying a bentonite at a rate of 4 ton fed.$^{-1}$, and vegetable compost at a constant rate of 10 m^3 fed.$^{-1}$ and biochar at a rate of 1000 kg fed.$^{-1}$ to development of soil properties and maximum faba bean productivity are growing in sandy soils. Whereas, the percentage of increase in plant height was 24.69 %, number of pods plant^{-1} was 82.78 %, seed yield was 59.09 %, weight of 100 seeds was 57.78 %, protein yield was 31.25 %, WUE was 92.67 %, porosity was 7.94 %, soil WHC was 19.58 and organic matter was 64.00 % in the first season when using these rates of the three studied factors preferred to as compared of the control treatment (control treatment of the three studied factors).

Table (7 a). Effect of the interactions between factors studied on faba bean (*Vicia faba*, L.) productivity and soil properties during 2022/ 2023 growing season under sandy soils conditions at New Valley

Measurements			Plant						Soil			
Interactions / Char.			Plant height cm	No. of pods plant^{-1}	Seed yield kg/ fed.	100 seed weight g	Protein yield g kg^{-1}	WUE kg m^{-3}	Porosity %	Soil WHC %	Bulk density mg m^{-3}	OM %
Bent.	Compost	Biochar	2022/ 2023									
Control	Control	Control	103.97	11.44	1127	48.29	224	0.341	40.56	38.26	1.58	0.50
		500 kg fed.$^{-1}$	106.00	13.81	1227	52.13	237	0.395	41.46	38.77	1.56	0.56
		1000 kg fed.$^{-1}$	108.83	14.38	1318	56.48	244	0.433	41.88	39.97	1.55	0.60
	100 % Veg.	Control	115.41	14.69	1410	58.90	251	0.450	41.39	40.79	1.56	0.60
		500 kg fed.$^{-1}$	117.43	17.06	1511	62.74	264	0.504	42.29	41.30	1.54	0.66
		1000 kg fed.$^{-1}$	120.27	17.63	1602	67.09	271	0.542	42.71	42.50	1.53	0.70
	100 % Ani.	Control	114.15	14.19	1383	58.08	246	0.440	42.00	39.82	1.56	0.56
		500 kg fed.$^{-1}$	116.17	16.56	1483	61.92	258	0.494	42.91	40.33	1.55	0.62
		1000 kg fed.$^{-1}$	119.01	17.13	1575	66.27	265	0.533	43.32	41.53	1.54	0.66
2 ton fed.$^{-1}$	Control	Control	109.57	14.21	1265	53.21	237	0.401	41.13	39.81	1.56	0.57
		500 kg fed.$^{-1}$	111.60	16.58	1366	57.05	250	0.455	42.04	40.32	1.55	0.63
		1000 kg fed.$^{-1}$	114.44	17.15	1457	61.40	257	0.494	42.45	41.52	1.54	0.67
	100 % Veg.	Control	121.01	17.46	1549	63.82	264	0.510	41.96	42.34	1.54	0.68
		500 kg fed.$^{-1}$	123.04	19.83	1649	67.66	277	0.564	42.87	42.85	1.53	0.73
		1000 kg fed.$^{-1}$	125.87	20.40	1741	72.01	284	0.603	43.28	44.05	1.52	0.77
	100 % Ani.	Control	119.75	16.96	1522	63.00	259	0.501	42.58	41.37	1.55	0.63
		500 kg fed.$^{-1}$	121.78	19.33	1622	66.84	271	0.554	43.48	41.88	1.53	0.69
		1000 kg fed.$^{-1}$	124.61	19.91	1713	71.19	278	0.593	43.90	43.08	1.52	0.73
4 ton fed.$^{-1}$	Control	Control	113.34	14.71	1318	57.39	248	0.456	41.63	41.52	1.54	0.62
		500 kg fed.$^{-1}$	115.37	17.08	1418	61.23	260	0.509	42.53	42.03	1.53	0.67
		1000 kg fed.$^{-1}$	118.21	17.66	1509	65.58	267	0.548	42.95	43.22	1.52	0.71
	100 % Veg.	Control	124.78	17.96	1601	68.00	274	0.565	42.46	44.05	1.52	0.72
		500 kg fed.$^{-1}$	126.81	20.33	1702	71.84	287	0.618	43.36	44.56	1.51	0.78
		1000 kg fed.$^{-1}$	129.64	20.91	1793	76.19	294	0.657	43.78	45.75	1.50	0.82
	100 % Ani.	Control	123.52	17.47	1574	67.18	269	0.555	43.07	43.08	1.53	0.68
		500 kg fed.$^{-1}$	125.55	19.84	1674	71.02	282	0.609	43.98	43.59	1.51	0.73
		1000 kg fed.$^{-1}$	128.38	20.41	1766	75.37	289	0.647	44.39	44.78	1.50	0.77
LSD at 5%			**1.02**	**0.23**	**31**	**1.47**	**3.64**	**0.029**	**0.14**	**0.12**	**NS**	**0.01**

Bent.: bentonite rates, 100 % Veg. : 100 % vegetable compost, 100 % Ani. : 100 % animal compost, WUE: water use efficiency, soil WHC: soil water holding capacity, OM: organic matter and LSD: Least significant difference.

Table (7 b). Effect of the interactions between factors studied on faba bean (*Vicia faba*, L.) productivity and soil properties during 2023/ 2024 growing season under sandy soils conditions at New Valley

Measurements			Plant						Soil			
Interactions		Char.	**Plant height** cm	**No. of pods plant^{-1}**	**Seed yield** kg/ fed.	**100 seed weight** g	**Protein yield** g kg^{-1}	**WUE** kg m^{-3}	**Porosity** %	**Soil WHC** %	**Bulk density** mg m^{-3}	**OM** %
Bent.	**Compost**	**Biochar**	**2023/ 2024**									
Control	**Control**	**Control**	102.25	11.06	1106	47.24	222	0.330	40.34	36.82	1.57	0.48
		500 kg fed.$^{-1}$	104.23	13.48	1204	51.19	235	0.383	41.16	37.55	1.55	0.53
		1000 kg fed.$^{-1}$	107.06	14.01	1298	55.52	242	0.418	41.60	38.80	1.54	0.57
	100 % Veg.	**Control**	114.14	14.20	1384	58.14	239	0.438	41.20	39.78	1.55	0.58
		500 kg fed.$^{-1}$	116.11	16.63	1481	62.09	252	0.490	42.02	40.51	1.53	0.63
		1000 kg fed.$^{-1}$	118.94	17.15	1576	66.41	259	0.525	42.46	41.76	1.52	0.67
	100 % Ani.	**Control**	112.96	13.75	1362	57.23	244	0.429	41.76	38.54	1.56	0.54
		500 kg fed.$^{-1}$	114.94	16.18	1460	61.18	257	0.482	42.58	40.06	1.53	0.59
		1000 kg fed.$^{-1}$	117.77	16.70	1554	65.50	264	0.517	43.02	41.32	1.53	0.63
2 ton fed.$^{-1}$	**Control**	**Control**	107.63	13.76	1237	52.30	232	0.391	40.87	38.57	1.55	0.56
		500 kg fed.$^{-1}$	109.61	16.19	1334	56.25	245	0.443	41.69	39.30	1.53	0.60
		1000 kg fed.$^{-1}$	112.44	16.71	1429	60.57	253	0.478	42.13	40.55	1.52	0.64
	100 % Veg.	**Control**	119.52	16.91	1515	63.19	249	0.498	41.73	41.53	1.53	0.66
		500 kg fed.$^{-1}$	121.49	19.33	1612	67.14	262	0.551	42.55	42.26	1.51	0.71
		1000 kg fed.$^{-1}$	124.32	19.86	1707	71.47	270	0.586	42.98	43.51	1.50	0.75
	100 % Ani.	**Control**	118.34	16.46	1493	62.28	254	0.490	42.29	40.29	1.54	0.62
		500 kg fed.$^{-1}$	120.32	18.88	1590	66.23	267	0.542	43.11	41.81	1.51	0.66
		1000 kg fed.$^{-1}$	123.15	19.41	1685	70.56	275	0.577	43.54	43.07	1.51	0.70
4 ton fed.$^{-1}$	**Control**	**Control**	111.74	14.25	1292	56.04	244	0.444	41.32	40.54	1.54	0.60
		500 kg fed.$^{-1}$	113.71	16.68	1389	59.99	257	0.496	42.14	41.27	1.51	0.65
		1000 kg fed.$^{-1}$	116.54	17.20	1484	64.32	265	0.531	42.58	42.52	1.51	0.69
	100 % Veg.	**Control**	123.62	17.40	1569	66.93	261	0.552	42.18	43.50	1.52	0.70
		500 kg fed.$^{-1}$	125.60	19.82	1667	70.88	274	0.604	43.00	44.23	1.49	0.75
		1000 kg fed.$^{-1}$	128.43	20.35	1761	75.21	282	0.639	43.44	45.48	1.49	0.79
	100 % Ani.	**Control**	122.45	16.95	1548	66.02	266	0.543	42.74	42.26	1.52	0.66
		500 kg fed.$^{-1}$	124.42	19.37	1645	69.97	279	0.595	43.56	43.79	1.50	0.71
		1000 kg fed.$^{-1}$	127.25	19.90	1740	74.30	287	0.630	44.00	45.04	1.49	0.75
LSD at 5%			**1.3**	**0.17**	**26**	**1.58**	**4.19**	**0.028**	**0.17**	**0.03**	**NS**	**0.02**

Bent.: bentonite rates, 100 % Veg. : 100 % vegetable compost, 100 % Ani. : 100 % animal compost, WUE: water use efficiency, soil WHC: soil water holding capacity, OM: organic matter and LSD: Least significant difference.

References

Abdulaziz, G., Alghamdi, I., Anwar, A.A., Abdulrasoul, M.A. and Arafat, A. (2018). Impact of biochar, bentonite, and compost on physical and chemical characteristics of a sandy soil. Arabian Journal of Geosciences, 11:670-678.

Ahmed, F., Arthur, E. and Plauborg, F. (2018). Effects of biochar amendment on maize water uptake, growth and physiology. Journal of Agronomy and Crop Science, 204(2): 123–136.

Al-Bayati, H.J. and Kamel, T.J. (2014). Improving growth and yield by application organic fertilizers compared with chemical fertilizers on two cucumber varieties. Mesopotamia J. Agric., 42 (1):168-176.

Aleem, A.M., Hanna, N.S. and Sabry, S.R. (2000). Effect of bentonite on improvement the physical, chemical and hydrous characteristics of sand soil. J Soils Sediments. 13(2):754–762.

Al-Hayani, A.S., Al-Hassoon, S. N. and Al-Obaidi, M.A. (2022). Adsorption of nutrients on surfaces of feasible materials (plant waste, sludge and bentonite metal). Iraqi Journal of Agricultural Sciences, 53(3),654 – 659.

Ali, M., Benabderrahim, W.E., Hayfa, Belayadi, and Mansour, H. (2017). Effect of date palm waste compost on forage alfalfa growth, yield, seed yield and minerals uptake. Int J Recycl Org Waste Agricult. 35:219–230.

Al-Kinani, D.K., and Jarallah, A.K. (2021). Effect of bentonite and compost applications in some chemical properties of soil, growth of sorghum (*Sorghum bicolor* L.) in desert soil. Annals of the Romanian Society for Cell Biology, 25(6):9497-9513.

Al-Wabel, M.I., Qaiser, H., Adel, R.A., Mahtab, A., Adel, A.A. Sallam, and Yong, S. (2018). Impact of biochar properties on soil conditions and agricultural sustainability: A review. Land Degrad Dev.,29:2124–2161.

Atkinson, C.J., Fitzgerald, J.D and Hipps, N.A. (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. Plant and soil, 337(1), 1-18.

Aya, A.H. Attia, Farida, H. Badawy, Mahmoud, M. and Hashem, M. (2023). Impact of compost and microbial inoculants on nodulation, growth and P-uptake of faba bean (*Vicia faba* L.) grown on a sandy soil. Assiut Journal of Agricultural Sciences 54 (1): 239-250.

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L. and Clark, F.E. (1965). Methods of soil analysis Am. Soc. of Agronomy, Agronomy Series No. 9, Madison, Wisconsin, USA.

Buss, W., and Masek, O. (2016). Consistency of biochar properties over time and production scales: a characterisation of standard materials. J. Anal. Appl. Pyrol. 132, 200–210.

Czaban, J., Siebielec, G. and Czyz, F. (2013). Effects of bentonite addition on sandy soil chemistry. Pol. J. Environ. Stud., 22: 1661-1667.

Dejou, J.(1987). The specific surface of clay, its measurement, relationship with the CEC and its agronomic importance, in: Proc. Symp. AFES., 72-83.

El-Etr, W.M. and Hassan, W.Z. (2017). A study of some sandy soil characteristics treated with combinations of bentonite and vinasse which reflected on productivity of pea crop. J. Soil Sci. and Agric. Eng., Mansoura Univ., 8(10), 545-551.

FAO, (2001). Lecture notes on the major soils of the world. World Soil Resources Reports 94. FAO, Rome.

Githinji, L. (2014). Effect of biochar application rate on soil physical and hydraulic properties of a sandy soil. Archives of Agronomy and Soil Science, 60(4): 457–470.

Gomez, K.A. and Gomez, A.A. (1985). Statistical procedures in agricultural research. New York, Chichester, Wiley 1985, 2nd edition, paperback. pp 680.

Guerena, D., Lehmann, J., Hanley, K., Enders, A., Hyland, C. and Riha, S. (2015). Nitrogen dynamics following field application of biochar in a temperate North American faba bean-based production system. Plant Soil 365, 239–254.

Hansen, V., Hauggaard, H. and Petersen, C.T. (2016). Effects of biochar on plant-available water capacity and plant growth in two contrasting soil types. Soil and Tillage Research, 161: 1–9.

Ibrahim, M., Rasha, E.L., Maha, A., Fang, C.H. and Daivd, R. (2017). Interactive effects of biochar and micronutrients on faba bean growth, symbiotic performance, and soil properties. J. Plant Nutr. Soil Sci. 1–10.

Ibrahim, S., Abujabhah, Sally, A. and Bound, R. (2016). Effects of biochar and compost amendments on soil physico-chemical properties. Appl. Soil Ecol., 98: 243-253.

Iskander, A.L., Khald, E.M. and Sheta, A.S. (2011). Zinc and manganese sorption behavior by natural zeolite and bentonite. Ann. agric. Sci., 56: 43-48.

Jacka, L., Trakal, L. and Ourednicek, P. (2018). Biochar presence in soil significantly decreased saturated hydraulic conductivity due to swelling. Soil and Tillage Research, 184: 181–185.

Jena, D. and Kabi, S. (2012). Effect of bentonite on yield and nutrient uptake by hybrid rice - potato-green gram cropping system in an Inceptisol. Int. Res. J. Agric. Sci. Soil Sci., 2(5): 179-187.

Jiang, J., Yuan, M., Xu, R. and Bish, D.L. (2015). Mobilization of phosphate in variable-charge soils amended with biochar derived from crop straws. Soil and Tillage Research, 146,139-147.

Kayama, M., Nimpila, S., Hongthong, S., Yoneda, R., Himmapan, W., Vacharangkura, T. and Noda, I. (2016). Effects of bentonite, charcoal and corncob for soil improvement. Forests., 7 (36):1-21.

Khalifa, N. and Yousef, L. (2015). Changes of quality indicators for a sandy textured soil after treatment with biochar produced from fronds of date palm. Energy Procedia, 74, 960-965.

Khiyami, M., Masmali, I. and Abu-Khuraiba, M. (2008). Composting a mixture of date palm wastes, date palm pits, shrimp and crab shell wastes in vessel system. Saudi Journal of Biological Sciences 15(2): 199- 205.

Klute, A.A. (1986). Methods of Soil Analysis: Part 1: Physical and mineralogical Methods. (2nd Ed), Amer. Soc. Agron. Madison. 9: 635-662.

Lehmann, J. and Joseph, S. (2009). Biochar for environmental management: science and technology, Earthscan, London. 1-2.

Liu, X.F., Han, W., Liu, Z., Wang, X. and Zhao, X. (2016). Impacts of biochar amended soils on ryegrass (*Lolium perenne* L.) growth under different water stress conditions. Int. J. Agric. Biol., 18 pp. 630-636.

Lotfy, A. and El-Hady, O. (1984). Effect of bentonite on some characters, yield and water use efficiency of faba been in sandy soil. Egypt J. Soil Sci., 24 (3): 225 -340.

Luscher, A., Mueller, I., Soussana, J., Rees, R. and Peyraud, J. (2014). Potential of legume-based grassland-livestock systems in Europe: a review". The Journal of the British Grassland Society-The Official Journal of the European Grassland Federation, 69: 206-228.

Marisa, B.M., Paulor, A.P., Nelio, V., Milton, G.A., Marcelo, B.F., Helion, G.S., Helio, S.A., and Fernando, D.E. (2009). Nutrient release by a Brazilian sedimentary zeolite and bentonite. An Acad Bras Cienc, 81 (4) 341-355.

Marschner, H. (1995). Functions of mineral nutrients: Macronutrients. In: Mineral Nutrition of Higher Plants 2 Edition. Academicnd Press, N.Y: 299-312.

Mohammad, G., Reinhard, W., Neugschwandtner, P., Hossein, A., Marek, K. and Elnaz, A. (2022). Comparative effects of biochar and compost applications on water holding capacity and crop yield of rice under evaporation stress: a two-years field study. J. Environ. Manage166:73–83.

Mohammadi, G.A. (2023). Comparison of date-palm wastes and perlite as growth substrates on some faba bean growing indexes. African Journal of Biotechnology 10(24), 4871-48780.

Molla, A., Ioannou, Z., Dimirrkou, A. and Mollas, S. (2014). Zeolite-bentonite soil amendments with maize crop. International Journal Waste Resources, 4(3): 1-4.

Page, A., Milled, R. and Keeney, D. (1982). Methods of soil analysis, chemical and microbiological properties. Amer. Soc. Agron., Madison, Wisconsin, USA., 1018-1026.

Peng, Y., Verloo, G. and Sun, Y. (2012). Resources characteristics and market situation of biochar. Soil Use Manag., 9: 189-197.

Poormansour, S. and Razzaghi, F. (2018). Effect of biochar and irrigation levels on faba bean productivity. Acta Horticulturae, 1190:157–162.

Qambrani, N.A., Rahman, M.M., Won, S., Shim, S. and Ra, C. (2017). Biochar properties and eco-friendly applications for climate change mitigation, waste management, and wastewater treatment: A review. Renewable and Sustainable Energy Reviews, 79, 255–273.

Raimund, S. and Dietmar, S. (1996). Properties of soils under different types of management developed in a sandy substrate covering boulder clay at Mecklenburg (north eastern Germany). Sci. of Soils, 55(2): 314-330.

Rizwan, M., Ali, S., Qayyum, M.F., Ibrahim, M., Abbas M., and Ok, Y.S. (2016). Mechanisms of biochar-mediated alleviation of toxicity of trace elements in plants: a critical review. Environmental Science and Pollution Research, 23(3): 2230-2248.

Sadek, M.A., Liu J. and Chen Y. (2021). Simulating shear behavior of a sandy soil under different soil conditions, Journal of Terramechanics, 48, 451-458.

Saja H. and Abbas K. (2023). Effect of biochar and bentonite application in availability and uptake of N, P and K for faba bean in desert soil. Iraqi Journal of Desert Studies., 13 (1): 76-84.

Shafeek M.R., Helmy, Y.I. and Omer, R. (2013). Effect of foliar fertilizer with nutritional compound and humic acid on growth and yield of broad bean plants under sandy soil conditions. Journal of Applied Sciences Research, 9(6): 3674-3680.

She, D., Sun, X., Gamareldawla, A.H., Nazar, E.A., Hu, W. and Edith, K. (2018). Benefits of biochar amendments to sand soil. Scientific reports, 2(5): 63-69.

Sitthaphanit, S., Richard, W. and Limpinuntan, V. (2010). Effect of clay amendments on nitrogen leaching and forms in a sandy soil. World Congress of Soil Sci. 31(4), 120-135.

Soda, W., Noble, A.D., Suzuki, S., Simmons, S., Sindhusen, R. and Bhuthorndharaj, S. (2006). Composting of waste bentonite and their effects on soil properties and crop biomass. J. Environ. Quality 35: 2293–2301.

Suliman, W., Harsh, J.B. and Abu-Lail, N.I. (2017). The role of biochar porosity and surface functionality in augmenting hydrologic properties of a sandy soil. Science of the Total Environment, 574: 139–147.

Tawfiq, A. J. (2009). Improvement of sandy soil properties by using bentonite. Kufa J. of Eng., (1), 1:29-39.

Tomasz, N., Jan L., Wojciech, S. and Tadeusz, P. (2023). Analysis of the use of biochar from organic waste pyrolysis in Agriculture and Environmental Protection. Journal of Ecological Engineering, 24(4): 85–98.

Vites, F.G. (1965). Increasing water use efficiency by soil management. Amer. Sco. Agron., Madison,Wisc. P 259-274.

Wang, J., Xiong, Z. and Kuzyakov, Y. (2016). Biochar stability in soil: Meta-analysis of decomposition and priming effects. GCB Bio- energy, 8(3): 512–523.

Xiao, Y., Yang, S. and Xu, J. (2018). Effect of biochar amendment on water-saving irrigation. Sustainability, 10(5): 1–13.

Xie, T., Reddy, K.R., Wang, C., Yargicoglu, E. and Spokas, K. (2015). Characteristics and applications of biochar for environmental remediation: A review. Critical Reviews in Environmental Science and Technology, 45(9): 939–969.

Zhang, H., Chen, W., Zhao, B., Phillips, L.A., Zhou, Y., Lapen, D.R. and Liu, J. (2020). Sandy soils amended with bentonite induced changes in soil properties in maize fields. Applied Soil Ecology. 146:1-12.