Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Improving Some Properties of Saline Soil Using Zeoilite, Vermicompost and Biochar in the Growth and Yield of Sorghum

Mustafa Ali Adnan Al-Janabi[1], Abbas Khudhiar Abbas Jarallah[2]
[1] College of Veterinary Medicine, University of Baghdad, Iraq , Baghdad, Iraq
[2] Department of Desertification Combat, College of Agricultural Engineering Sciences, University of Baghdad, Baghdad,Iraq

ABSTRACT

A field experiment was conducted to improve the properties of saline soil using zeolite, vermicompost, biochar and their interaction on growth and yield of Sorghum. The study included three levels of zeolite (0, 6 and 12 Mg ha^{-1}) (Z_0, Z_1 and Z_2), two levels of vermicompost (0 and 10 Mg ha^{-1}) (V_0 and V_1) and three levels of biochar (0, 5 and 10 Mg ha^{-1}). The experiment was carried out according to randomized complete block design (RCBD) with three replicates. The results show that addition of zeolite, vermicompost and biochar had a significant effect on soil physical and chemical properties. 12 Mg ha^{-1} level of zeolite, 10 Mg ha^{-1} level of vermicompost, and 10 Mg ha^{-1} level of biochar achieved the lowest value for bulk density while they achieved the highest values, for moisture content at field capacity, permanent wilting point and available water, while they achieved the lowest values for EC, SAR and ESP. As for interaction between three factors, the $Z_2V_1B_2$ treatment (12 Mg ha^{-1} zeolite, 10 Mg ha^{-1} vermicompost and 10 Mg ha^{-1} biochar) excelled in achieving lowest value of bulk density reached 1.18 Mg m^{-3}, highest values of moisture content in soil reached 35.63, 18.63 and 17.00% for field capacity , permanent wilting point and available water, respectively, and lowest values of soil EC, SAR and ESP reached 3.00 dS m$^{-1,}$ 3.15 (mmol L^{-1})0.5 and 7.4% , respectively. The study factors and their interactions achieved the highest response in growth and yield plant parameters.

Key words: available water soil conditioners, bulk density, field capacity, wilting point .

Received: 16/2/2025, Accepted: 28/5/2025, Published: 31/8/2026

INTRODUCTION

Soil salinity is one of most important difficulties and challenges facing the world in achieving food security, such as high temperatures, the effects of high winds, erosion, drought, and floods. It is also most influential problem on agricultural and environmental sectors, which negatively affects food security (Shahbaz and Ashraf, 2013). Two major causes or conditions leading to soil salinization in Iraq have been identified: natural conditions and human-induced conditions resulting from human activities or practices. Iraq is considered, according to its geographical location within the hot region of world, and due to drought conditions, water scarcity, and other natural factors, in addition to human factors, desertification has invaded its lands, especially since deserts surround it from medium and south of Iraq (Al-Janabi, 2016; Hummadi, 2009). Statistics indicate that the desert and desertified lands amounted to 11.88%, and the lands threatened by desertification reached 54.88% which together constitute 66.76% of the total area of Iraq for the year 2020 due to the lack of vegetation cover, afforestation operations and urban encroachment on agricultural lands, in addition to the rise in summer temperatures to 50°C and low rainfall rate and its quantity vary between 5-15 cm, affected by high rate of evaporation and low annual revenues of the Tigris and Euphrates rivers .(Environmental Statistics Department, 2023). Adding soil conditioners is

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

one of technologies used to limit the problem of salinity and manage salts affected soil. Many of these conditioners, whether mineral, organic or chemical have been used in this field and their efficiency in reducing soil salinity and improving the various characteristics of soil has been tested with the aim of exploiting it agriculturally and limiting its degradation. Some soil conditioners have been found to be able to improve the properties of soils affected by salinity by reducing electrical conductivity, exchangeable sodium percentage (ESP), Sodium adsorption ratio (SAR) and ions concentrations (Na, Cl, and SO_4). Some of these conditioners are organic, such as biochar, vermicompost, organic animal and plant waste, while some are mineral, such as gypsum, zeolite and polymeric compounds (El-Sayed et al., 2021; Khalifa et al., 2021; Hoque et al., 2022). Many studies have shown the use of zeolite as a conditioner for degraded soils, especially salt affected soil physical chemical properties which is reflected in increasing their fertility and productivity (Belviso et al., 2022; Ghorbani et al., 2022; Xiao et al., 2022). Also reduce soil salinity making soil more suitable for the growth of many agricultural crops (Xiao et al., 2022; Suradkar et al., 2023). Many studies have focused on use of vermicompost and its role in improving various soil characteristics, especially saline or salt-affected soils, reducing the harmful effects of soil salinity and increasing crop tolerance to salt stress (Ai et al., 2023; Farooqi et al., 2024; Salim et al., 2024). Moreover adding vermicompost plays a role in improving soil structure by reducing bulk density, increasing porosity, increasing water conductivity, improving downward water drainage, leaching salts out of the root zone and reducing soil salinity (Khalifa et al., 2021; Kumar et al., 2023). Biochar is also considered an amendment that plays a role in improving degraded soils especially saline soils and salt-affected soils of all types, have shown that it reduces soil salinity, such as reducing electrical conductivity, Sodium adsorption ratio, exchangeable sodium percentage and soil salinizing ions (Na, Ca, Mg, Cl, and SO_4) and improving soil pH (Gao et al., 2024; Xiao et al., 2024). Also, its role in improving soil physical properties by increasing soil's ability to retain water and surface area, reducing bulk density and improving chemical properties such as increasing cation exchange capacity (CEC) and the content of organic matter (Zonayet et al., 2023). This study aimed to use zeolite, vermicompost, biochar and their interactions to improve the properties of saline soil and growth and yield of sorghum.

MATERIALS AND METHODS

A field experiment was conducted at one of the fields of College of Agricultural Engineering Sciences (old site) Abu-Ghrib District of Baghdad Governorate with clay loam texture. The experiment was divided into 3 blocks, each one includes 18 experimental unit and the distance between them was 1 m while the distance between blocks was 2 m. Soil samples were collected from the depth (0 – 0.3 m) before planting. Some physical and chemical properties of soils were determined by (Page et al., 2002) (Table 1). The experiment included three levels of zeolite which are 0, 6 and 12 Mg ha^{-1} and their symbols (Z_0, Z_1 and Z_2) (Table 2) shows some properties of zeolite. Two levels of vermicompost were used 0 and 10 Mg ha^{-1} and their symbols (V_0 and V_1) some chemical properties of vermicompost (Table 3) and three levels of biochar (Seek) which are 0, 5 and 10 Mg ha^{-1} and their symbols (B_0, B_1 and B_2)(Table 4) shows some chemical properties of biochar.

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

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

Properties		Value	Unit
EC (1:1)		8.50	dS m^{-1}
pH (1:1)		7.47	
O.M		11.30	g kg^{-1} soil
Carbonate minerals		189.4	
CEC		23.8	C $mol_{+}kg^{-1}$ soil
Soluble ions	Ca^{++}	24.35	m mole L^{-1}
	Mg^{++}	16.83	
	Na^{+}	44.57	
	K^{+}	0.49	
	$CO_3^{=}$	-	
	HCO_3^{-}	13.89	
	$SO_4^{=}$	10.01	
	Cl^{-}	58.09	
Available nutrients	N	18.00	mg kg^{-1} soil
	P	6.70	
	K	126.0	
ESP		22.51	%
SAR		6.95	$(mmol\ L^{-1})^{0.5}$
Bulk density		1.386	Mg m^{-3}
Field capacity		24.6	
Permanent wilting point		12.5	%
Available water		12.1	
Clay		313.0	
Silt		401.0	g kg^{-1} soil
Sand		286.0	
Texture		Clay loam	

Table 2. Some properties of zeolite

Property		Value	Unit
$EC_{1:1}$		0.68	dS m^{-1}
pH $_{1:1}$		7.60	
Bulk density		0.08	
Particle density		1.10	Mg m^{-3}
Porosity		92.7	%
CEC		74.2	C $mol_{+}kg^{-1}$ zeolite
Oxides content	Fe_2O_3	9.56	%
	MnO	0.13	
	TiO_2	2.00	
	CaO	9.28	

All conditioners were added after mixing them with soil. Sorghum (*Sorghum bicolor* L. Moench) (70 Booth variety) was sown in 19/7/2024 for fall season with plant density 80000 plant ha^{-1}. N was added at level 320 kg N ha^{-1} as urea (46% N) and P at level 87 kg P ha^{-1} was added as DAP (20% P) and K at a level of 83 kg K ha^{-1} in the form of K_2SO_4 (41.5% K) according to the fertilizers recommendation of sorghum (Ali et al., 2014). N was added in two doses, As for P and K fertilizers, they were added once. At the end of experiment crop was harvested in 22/11/2024. Leaf area was calculated by leaf area = length X width X 6.18 A factorial experiment was carried out within randomized complete block design (RCBD) with three replicates. Least significant differences test (LSD 0.05) was used to compare the means of treatments (Steel and Torrie, 1980).

Table 3. Some chemical properties of vermicompost

Properties	Value	Unit
EC $_{1:5}$	1.50	dS m^{-1}
pH $_{1:5}$	7.42	-
N	2.8	
P	1.5	
K	1.4	%
O.C	49.3	
O.M	85.0	
C / N	17.6	-

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Table 4. Some chemical properties of biochar

Properties	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	25.26	
O.M	43.55	
C / N	19.28	-

RESULTS AND DISCUSSION

Bulk density: The results in (Table 5) show that there were significant differences of the effect of adding zeolite on bulk density of soil, with a decreases rate of 3.91 and 5.47% for the two levels of zeolite 6 and 12 Mg ha^{-1}, respectively as compared to control (0 Mg ha^{-1}), The bulk density of soil decreased with vermicompost addition by 7.75 % as compared to control (V_0). Adding biochar led to a reduction in the bulk density of the soil with a reduction rate of 3.91 and 6.25% for 5 and 10 Mg ha^{-1} respectively, compared to control (B_0). As for the di and triple interactions between the study factors, their effects were significant on bulk density. The results show the superiority of the treatment with zeolite, vermicompost and biochar ($Z_2V_1B_2$) which amounted to 1.13 Mg m^{-3} a decrease of 18.12% over the comparison treatment ($Z_0V_0B_0$) which gave the highest value for bulk density, amounting to 1.38 Mg m^{-3}. Adding zeolite to soil resulted in a significant effect on bulk density of soil, as increasing levels of adding zeolite led to a reduction in the bulk density. This may be attributed to the crystalline structure of zeolite, which is interspersed with many pores and channels which contributed to redistributing soil particles, increasing its total porosity and improve its structure, in addition to its low apparent density (0.08 Mg m^{-3}) (Table 2) and add it to the study soil with an apparent density of (1.386 Mg m^{-3}) (Table 1) (Alwan et al., 2023; Suradkar et al., 2023). As for the addition of vermicompost, it led to a reduction in the apparent density of the study soil after harvesting, which may be attributed to its high organic matter content, low apparent density and high porosity, which reaches between 70-80% of the total volume (Ibrahim et al., 2015; Ceritoglu et al., 2018; EL-Shaieny et al., 2022). The addition of biochar to the soil reduced the bulk density of the soil. This may be due to the fact that biochar has a bulk density ranging from 0.2 to 0.5 Mg m^{-3} (Rajkovich et al., 2012), which is much lower than the bulk density of the study soil before planting (1.386 Mg m^{-3}) (Table 3). The addition of biochar to the soil also reduced the bulk density through dilution as a result of mixing it with the soil (Omondi et al., 2016; Zonayet et al., 2023).

Table 5. Effect of zeolite, vermicompost and biochar on soil bulk density (Mg m^{-3}).

Vermicompost (V)	Zeolite (Z)	Biochar (B)			(Z X V)
		B0	B_1	B_2	
V_0	Z_0	1.38	1.32	1.24	1.31
	Z_1	1.34	1.28	1.22	1.28
	Z_2	1.29	1.26	1.25	1.27
V_1	Z_0	1.29	1.24	1.19	1.24
	Z_1	1.21	1.16	1.15	1.17
	Z_2	1.18	1.15	1.13	1.15
LSD_{Z*V*B}			0.01		LSD_{Z*V} 0.01
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		1.34	1.28	1.24	1.29
V_1		1.23	1.18	1.16	1.19
LSD_{V*B}			0.01		LSD_V 0.01
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		1.33	1.28	1.22	1.28
Z_1		1.28	1.22	1.19	1.23
Z_2		1.24	1.21	1.19	1.21
LSD_{Z*B}			0.02		LSD_Z 0.01
Biochar		B_0	B_1	B_2	Mean B
		1.28	1.23	1.20	
LSD_B			0.01		

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Water content at field capacity

The results in Table (6) show that increasing level of zeolite addition from 0 to 6 and 12 Mg ha^{-1} led to an increase in moisture content at field capacity by 5.20 and 13.54%, respectively, compared to control. The soil moisture content increased with the addition of vermicompost at 10 Mg ha^{-1} with an increase of 11.36% as compared to control while adding biochar increased moisture content by 7.95 and 15.41% for two levels 5 and 10 Mg ha^{-1} respectively, as compared to control treatment. The triple interaction of the study factors shows a significant effect on moisture content of soil at field capacity. The treatment ($Z_2V_1B_2$) achieved the highest value, reaching of 35.63%, with an increase rate of 46.02% compared to the control ($Z_0V_0B_0$), which gave the lowest value of 24.40%.

Water content at permanent wilting point

The results in (Table 7) show increases in the moisture content at the permanent wilting point with an increase in levels of zeolite addition. The percentage increase reached 9.36 and 15.24% for the two addition levels of 6 and 12 Mg ha^{-1} respectively, compared to control (0 Mg ha^{-1}). As for the effect of the vermicompost, it increased the moisture content of soil at the permanent wilting point by 12.75% compared to soil treatment without the addition. Biochar also increased the moisture content of soil at the permanent wilting point by 11.66 and 19.99% for two levels 5 and 10 Mg ha^{-1}, respectively, compared to control As for triple interaction of study factors, it had a significant effect on moisture content of soil at permanent wilting point (Table 7). The treatment ($Z_2V_1B_2$) achieved the highest value, amounting to 16.25%, with an increase rate of 97.45 which amounted to 18.63%, an increase to 53.08% over comparison treatment ($Z_0V_0B_0$), which gave lowest value amounted to 12.17%.

Table 6. Effect of zeolite, vermicompost and biochar on water content at field capacity (%).

Vermicompost (V)	Zeolite (Z)	Biochar (B) B0	B$_1$	B$_2$	(Z X V)
V$_0$	Z$_0$	24.40	26.57	28.43	26.47
	Z$_1$	25.23	26.67	29.57	27.16
	Z$_2$	26.53	29.33	30.50	28.79
V$_1$	Z$_0$	26.80	28.03	29.70	28.18
	Z$_1$	28.00	30.33	32.63	30.32
	Z$_2$	30.63	33.50	35.63	33.26
LSD$_{Z*V*B}$			0.51		LSD$_{Z*V}$ 0.30
Vermicompost (V)		B$_0$	B$_1$	B$_2$	Mean V
V$_0$		25.39	27.52	29.50	27.47
V$_1$		28.48	30.62	32.66	30.59
LSD$_{V*B}$			NS*		LSD$_V$ 0.17
Zeolite (Z)		B$_0$	B$_1$	B$_2$	Mean Z
Z$_0$		25.60	27.30	29.07	27.32
Z$_1$		26.62	28.50	31.10	28.74
Z$_2$		28.58	31.42	33.07	31.02
LSD$_{Z*B}$			0.36		LSD$_Z$ 0.21
Biochar		B$_0$	B$_1$	B$_2$	Mean B
		26.93	29.07	31.08	
LSD$_B$			0.21		

*** N.S :Non significant**

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Table 7. Effect of zeolite, vermicompost and biochar water content at permanent wilting point (%).

Vermicompost (V)	Zeolite (Z)	Biochar (B)			(Z X V)
		B0	B_1	B_2	
V_0	Z_0	12.17	13.43	14.67	13.42
	Z_1	12.63	14.73	15.83	14.40
	Z_2	13.70	15.53	16.47	15.23
V_1	Z_0	13.90	14.77	15.73	14.80
	Z_1	14.83	16.47	18.07	16.46
	Z_2	15.60	17.60	18.63	17.28
LSD_{Z*V*B}			0.36		LSD_{Z*V} 0.21
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		12.83	14.57	15.66	14.35
V_1		14.78	16.28	17.48	16.18
LSD_{V*B}			NS*		LSD_V 0.12
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		13.03	14.10	15.20	14.11
Z_1		13.73	15.60	16.95	15.43
Z_2		14.65	16.57	17.55	16.26
LSD_{Z*B}			0.26		LSD_Z 0.15
Biochar		B_0	B_1	B_2	Mean B
		13.81	15.42	16.57	
LSD_B			0.15		

***N.S :Non significant**

Available water

Available water increased with increasing zeolite in levels of addition increase percentage reached 2.65 and 11.43% for two levels of 6 and 12 Mg ha^{-1} respectively, compared to treatment (0 Mg ha^{-1}) (Table 8). Adding vermicompost with 10 Mg ha^{-1} level increased the amount of available water by 8.91% compared to control. As for the biochar increased the amount of available water by 5.25 and 10.43% for the two levels 5 and 10 Mg ha^{-1} respectively, compared to control. The triple interaction of this study factors shows a significant effect on the amount of available water in soil after harvest (Table 8). The treatment ($Z_2V_1B_2$) shows the highest value for the amount of available water, amounting to 17.00% with an increase by 39.00 % compared to comparison treatment ($Z_0V_0B_0$) which gave lowest value of 12.23%.

Table 8. Effect of zeolite, vermicompost and biochar on available water content (%).

Vermicompost (V)	Zeolite (Z)	Biochar (B)			(Z X V)
		B_0	B_1	B_2	
V_0	Z_0	12.23	13.13	13.77	13.04
	Z_1	12.60	13.37	13.73	13.23
	Z_2	12.83	13.47	14.03	13.44
V_1	Z_0	12.90	13.27	13.97	13.38
	Z_1	13.20	13.87	14.57	13.88
	Z_2	15.10	15.90	17.00	16.00
LSD_{Z*V*B}			0.40		LSD_{Z*V} 0.23
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		12.56	13.32	13.84	13.24
V_1		13.73	14.34	15.18	14.42
LSD_{V*B}			NS		LSD_V 0.13
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		12.57	13.20	13.87	13.21
Z_1		12.90	13.62	14.15	13.56
Z_2		13.97	14.68	15.52	14.72
LSD_{Z*B}			NS		LSD_Z 0.16
Biochar		B_0	B_1	B_2	Mean B
		13.14	13.83	14.51	
LSD_B			0.16		

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Increasing levels of adding zeolite to soil led to increases in moisture content of soil at field capacity, permanent wilting point and amount of available water. This may be due to an increase in specific surface area of soil because it has a high surface area and an increase in the percentage of fine pores which increases the ability of soil to retain water inside. pores at low and medium tensile levels (Korkunna et al., 2006; Ramesh et al., 2015), As well as crystalline structure of the mineral zeolite contains many cavities and channels which have ability to absorb water and because it has a high density of negative charges which adsorbed water and leads to an increases in moisture content in soil and an increases in the amount of available water, it is considered a permanent store of water due to its ability to hold more than half its weight in water (55-60%) (Girijaveni et al., 2018; Alwan et al., 2023). As for adding vermicompost, its addition led to an increase in moisture content at field capacity, the permanent wilting point and available water. This may be attributed to its high organic matter content and high porosity, which ranges between 70-80%, which contributed to increasing the micropores and total porosity of soil, which led to an increase in the soil's ability to retain water. (Emamu and Wakgari, 2021; Hoque et al., 2022; Kumar et al., 2023). Adding biochar to study soil also led to an increase in moisture content at field capacity, permanent wilting point, and available water in the soil after harvesting the sorghum crop. May be this is due to fact that it contributes to improving soil structure, as it has a high content of organic matter and plays a role in redistributing soil pores and increasing its specific surface area. It also has a high porosity ranging from 50-300%, which is reflected in increasing moisture content of soil (Simansky et al., 2022; Sun et al., 2022; Chen et al., 2024).

Soil salinity parameters

Electrical conductivity (EC): The results in (Table 9) show that there were significant differences in effect of adding zeolite on soil EC with a decreases rate of 5.87 and 16.35% for two levels of zeolite 6 and 12 Mg ha^{-1}, respectively as compared to control, Soil EC decreased with vermicompost addition by 17.94 % as compared to control. Adding biochar led to a reduction in soil EC by 8.71 and 16.60% for 5 and 10 Mg ha^{-1} respectively, compared to control. As for the di and triple interactions between study factors, their effect were non significant on soil EC except the interaction between zeolite and vermicompost was significant in soil EC.

Table 9. Effect of zeolite, vermicompost and biochar on soil EC (dS m^{-1})

Vermicompost (V)	Zeolite (Z)	Biochar (B)			(Z X V)
		B_0	B_1	B_2	
V_0	Z_0	5.59	5.24	4.68	5.17
	Z_1	5.31	4.84	4.48	4.88
	Z_2	4.78	4.51	4.23	4.51
V_1	Z_0	4.73	4.35	4.02	4.37
	Z_1	4.53	4.04	3.71	4.10
	Z_2	4.00	3.42	3.00	3.48
LSD_{Z*V*B}			NS		LSD_{Z*V} 0.14
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		5.22	4.87	4.46	4.85
V_1		4.42	3.94	3.58	3.98
LSD_{V*B}			NS		LSD_V 0.08
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		5.16	4.79	4.35	4.77
Z_1		4.92	4.44	4.10	4.49
Z_2		4.39	3.97	3.62	3.99
LSD_{Z*B}			NS		LSD_Z 0.10
Biochar		B_0	B_1	B_2	Mean B
		4.82	4.40	4.02	
LSD_B			0.10		

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Sodium Adsorption Ratio (SAR): Soil SAR decreased with the increase in zeolite levels addition. The percentage decrease reached 2.63 and 11.62% for two levels of 6 and 12 Mg ha^{-1} respectively, compared to control (0 Mg ha^{-1}) (Table 10). Adding vermicompost with 10 Mg ha^{-1}level decreased soil SAR by 11.11% compared to control. As for biochar, the soil SAR decreased by 3.97 and 8.39% for the two levels 5 and 10 Mg ha^{-1} respectively, compared to control. The triple interaction of the study factors shows a significant effect on. The treatment ($Z_2V_1B_2$) shows the lowest value for soil SAR, amounting to 3.15 (mmol L^{-1})$^{0.5}$ with decrease by 35.58% compared to comparison treatment ($Z_0V_0B_0$), which gave highest value of 12.23%.

Exchangeable Sodium Percentage (ESP): The results in (Table 11) show that increasing level of zeolite addition from 0 to 6 and 12 Mg ha^{-1} led to decrease in soil ESP by 9.41 and 27.65%, respectively, compared to control. ESP decreased with the addition of vermicompost at 10 Mg ha^{-1} by 23.08% as compared to control. And also adding biochar decreased ESP by 14.53 and 25% for two levels 5 and 10 Mg ha^{-1} respectively, as compared to control. The triple interaction of study factors shows a significant effect on soil ESP. The treatment ($Z_2V_1B_2$) show lowest value for soil ESP amounting to 7.4% with decrease by 65.74% compared to comparison treatment ($Z_0V_0B_0$), which gave highest value of 21.6%. The addition of zeolite minerals led to a reduction in soil salinity parameters (EC, SAR and ESP). This may be attributed to its high ability to exchange ions and adsorption due to its cation exchange capacity and its ability to retain salts in dense pores that its crystals contain within its structural framework. In addition, it has a high ability to displace sodium from the exchange complex by calcium releasing from it and then leach sodium with salts to bottom of soil profile by improving physical and chemical properties of soil, such as increasing the soil porosity, water conductivity and the soil's ability to retain water (Aiad et al., 2021; Ghorbani et al., 2022; Xiao et al., 2022).

Table 10. Effect of zeolite, vermicompost and biochar on soil SAR (mmol L^{-1})$^{0.5}$

Vermicompost (V)	Zeolite (Z)	Biochar (B) B_0	B_1	B_2	(Z X V)
V_0	Z_0	4.89	4.70	4.55	4.71
	Z_1	4.75	4.63	4.39	4.59
	Z_2	4.64	4.45	4.42	4.50
V_1	Z_0	4.60	4.37	4.27	4.42
	Z_1	4.41	4.34	4.10	4.28
	Z_2	3.90	3.60	3.15	3.55
LSD_{Z*V*B}			0.41		LSD_{Z*V} 0.24
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		4.76	4.59	4.45	4.59
V_1		4.30	4.11	3.84	4.08
LSD_{V*B}			NS		LSD_V 0.14
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		4.74	4.54	4.41	4.56
Z_1		4.58	4.49	4.25	4.44
Z_2		4.27	4.03	4.03	4.03
LSD_{Z*B}			NS		LSD_Z 0.17
Biochar		B_0	B_1	B_2	Mean B
		4.53	4.35	4.15	
LSD_B			0.17		

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Table 11. Effect of zeolite, vermicompost and biochar on soil ESP (%).

Vermicompost (V)	Zeolite (Z)	Biochar (B)			(Z X V)
		B_0	B_1	B_2	
V_0	Z_0	21.6	19.0	16.7	19.2
	Z_1	19.9	15.7	15.2	16.9
	Z_2	16.2	14.5	13.2	14.6
V_1	Z_0	17.4	14.8	13.0	15.1
	Z_1	15.7	14.0	12.0	13.9
	Z_2	12.4	10.1	7.4	10.0
LSD_{Z*V*B}			1.1		LSD_{Z*V} NS
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		19.2	16.4	15.0	16.9
V_1		15.2	13.0	10.8	13.0
LSD_{V*B}			0.7		LSD_V 0.4
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		19.5	16.9	14.8	17.0
Z_1		17.8	14.9	13.6	15.4
Z_2		14.3	12.3	10.3	12.3
LSD_{Z*B}			0.8		LSD_Z 0.5
Biochar		B_0	B_1	B_2	Mean B
		17.2	14.7	12.9	
LSD_B			0.5		

The addition of vermicompost also led to a reduction in soil salinity parameters. This may be attributed to its role in displacing sodium ions from the exchange complex by providing with soluble cations (calcium, magnesium, and potassium) due to its high content of these ions. In addition, it plays a role in improving the physical properties of soil by improving soil structure and increasing the porosity of the soil, which encourages the salts leaching to ground water (Ai et al., 2023; Alabi et al., 2023; Al-Maamori, 2024). As for biochar, its addition to reducing soil salinity parameters under study may be attributed to its high ability to adsorb salt ions and prevent their movement, as it has a high cation exchange capacity, as well as its role in displacing sodium ions from the surfaces of soil colloids by calcium, magnesium and potassium ions, in addition to its role in improving soil permeability, which encouraged leaching of dissolved salts (Lee et al., 2022; Ullah et al., 2022; Xiao et al., 2024).

Plant Parameters: Plant height: The results in (Table 12) show that increasing levels of adding zeolite from 0 to 6 and 12 Mg ha^{-1} led to an increases in plant height by 0.71 and 3.04% for two zeolite levels respectively, compared to control treatment . Addition of vermicompost also increased plant height by 3.16% compared to control. Adding biochar also increased plant height by 2.39 and 3.50% for the two levels 5 and 12 Mg ha^{-1} respectively, compared to the control. As for triple interaction, The treatment ($Z_2V_1B_2$) show the highest value for plant height, amounting to 305.8 cm with an increase by 11.16% compared with control ($Z_0V_0B_0$) which gave the lowest value 275.1 cm.

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Table 12. Effect of zeolite, vermicompost and biochar on plant height (cm).

Vermicompost (V)	Zeolite (Z)	Biochar (B) B_0	B_1	B_2	(Z X V)
V_0	Z_0	275.1	283.6	288.5	282.4
	Z_1	276.0	279.2	278.5	277.9
	Z_2	281.1	284.9	289.1	285.1
V_1	Z_0	279.8	284.1	290.5	284.8
	Z_1	284.3	290.0	295.1	289.8
	Z_2	286.1	300.5	305.8	297.5
LSD_{Z*V*B}			3.0		LSD_{Z*V} 1.7
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		277.4	282.6	285.4	281.8
V_1		283.4	291.5	297.1	290.7
LSD_{V*B}			1.7		LSD_V 1.0
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		277.4	283.9	286.8	282.7
Z_1		280.1	284.6	289.5	284.7
Z_2		283.6	292.7	297.4	291.3
LSD_{Z*B}			2.1		LSD_Z 1.2
Biochar		B_0	B_1	B_2	Mean B
		280.4	287.1	291.2	
LSD_B			1.2		

Leaf area: Results in (Table 13) show an increases in leaf area of 1.99 and 3.18% for the zeolite addition levels of 6 and 12 Mg ha^{-1} respectively, compared to control treatment (0 Mg ha^{-1}). Adding vermicompost also increased the leaf area of 9.98% compared to treatment without addition. Adding biochar increased the leaf area by 11.62 and 20.97% for levels 5 and 10 Mg ha^{-1}, respectively, compared to control treatment. As for triple interaction of the study factors, highest value of leaf area was achieved 4202.5 cm^2 plant^{-1} in the treatment ($Z_2V_1B_2$), with an increase of 27.05% compared to control treatment ($Z_0V_0B_0$), which gave the lowest value 3296.2 cm^2 plant^{-1}.

Table 13. Effect of zeolite, vermicompost and biochar on leaf area (cm^2 plant^{-1}).

Vermicompost (V)	Zeolite (Z)	Biochar (B) B_0	B_1	B_2	(Z X V)
V_0	Z_0	3296.2	3617.0	3829.9	3581.0
	Z_1	3476.0	3635.9	4027.1	3713.0
	Z_2	3524.5	3818.5	4045.4	3796.1
V_1	Z_0	4015.9	4129.8	4170.7	4109.4
	Z_1	4028.3	4161.8	4183.2	4124.4
	Z_2	4036.2	63.914	4202.5	4134.2
LSD_{Z*V*B}			92.7		LSD_{Z*V} 53.5
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		3583.5	3690.5	3967.5	3747.2
V_1		4026.8	4151.6	4185.5	4121.3
LSD_{V*B}			53.5		LSD_V 30.9
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		3656.0	3873.1	4000.3	3843.1
Z_1		3752.1	3898.9	4105.2	3918.7
Z_2		3780.4	3991.2	4124.0	3965.2
LSD_{Z*B}			65.6		LSD_Z 37.9
Biochar		B_0	B_1	B_2	Mean B
		3729.5	3921.1	4076.5	
LSD_B			37.9		

Dry weight: Increasing levels of zeolite addition from 0 to 6 and 12 Mg ha^{-1} led to an increase in dry weight by 12.98 and 28.% for the two zeolite levels respectively, compared to control (0 Mg ha^{-1}) (Table 14). Adding vermicompost also led to increases in dry weight by 21.41% compared to the soil without addition. Adding biochar led to an increase in dry weight by 10.85 and 21.77% for two levels 5 and 10 Mg ha^{-1} respectively, compared to control treatment. As for triple interaction of the study factors (zeolite, vermicompost, and biochar), it led to an increase in dry weight, and highest value was in treatment ($Z_2V_1B_2$), which amounted to 23.13 Mg ha^{-1} with an increases rate of 89.28% compared to comparison treatment ($Z_0V_0B_0$) which gave lowest value of 12.22 Mg ha^{-1}.

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Table 14. Effect of zeolite, vermicompost and biochar on dry weight (Mg ha^{-1})

Vermicompost (V)	Zeolite (Z)	Biochar (B) B_0	B_1	B_2	(Z X V)
V_0	Z_0	12.22	13.07	14.33	13.21
	Z_1	13.85	14.61	15.96	14.81
	Z_2	15.42	17.13	18.80	17.12
V_1	Z_0	14.72	16.07	17.41	16.07
	Z_1	16.21	18.48	20.14	18.28
	Z_2	17.67	20.51	23.13	20.44
LSD_{Z*V*B}			0.32		LSD_{Z*V} 0.19
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		13.83	14.94	16.36	15.04
V_1		16.20	18.35	20.22	18.26
LSD_{V*B}			53.5		LSD_V 30.9
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		13.47	14.57	15.87	14.64
Z_1		15.03	16.55	18.05	16.54
Z_2		16.54	18.82	20.96	18.78
LSD_{Z*B}			0.23		LSD_Z 0.13
Biochar		B_0	B_1	B_2	Mean B
		15.02	16.65	18.29	
LSD_B			0.13		

Grains yield: Increasing levels of zeolite addition led to increases in grains yield 9.14 and 13.68% for two levels 6 and 12 Mg ha^{-1}, respectively, compared to control (Table15). The addition of vermicompost increased grains yield 8.12% compared to control. As for biochar, its addition led to an increase in grains yield by 15.29 and 26.50% for two levels 5 and 10 Mg ha^{-1} respectively, compared to control treatment. As for triple interaction, the treatment ($Z_2V_1B_2$) excelled in achieving highest value of the grains yield, which amounted to 6.735 Mg ha^{-1}, an increase of 55.76% over comparison treatment ($Z_0V_0B_0$) which gave lowest value reaching to 4.324 Mg ha^{-1}. Adding mineral zeolite to soil led to an increases in sorghum parameters this may be due to fact that adding zeolite to soil improved its physical and chemical properties and reducing soil salinity which led to increased water absorption by plant, reduced water loss, and increased growth and development of the plant's root system, of water and nutrients by the plant, increasing vital processes, and increasing food formation and storage in grains (Ghorbani et al., 2022).

Table 15. Effect of zeolite, vermicompost and biochar on grains yield (Mg ha^{-1}).

Vermicompost (V)	Zeolite (Z)	Biochar (B) B_0	B_1	B_2	(Z X V)
V_0	Z_0	4.324	5.236	5.809	5.143
	Z_1	4.543	5.743	6.514	5.600
	Z_2	5.436	5.762	6.580	5.926
V_1	Z_0	4.618	6.011	6.185	5.605
	Z_1	5.713	6.024	6.633	6.123
	Z_2	5.814	6.328	6.735	6.292
LSD_{Z*V*B}			0.385		LSD_{Z*V} 0.223
Vermicompost (V)		B_0	B_1	B_2	Mean V
V_0		4.768	5.580	6.321	5.556
V_1		5.382	6.121	6.517	6.007
LSD_{V*B}			0.223		LSD_V 0.129
Zeolite (Z)		B_0	B_1	B_2	Mean Z
Z_0		4.471	5.624	6.027	5.374
Z_1		5.128	5.884	6.574	5.865
Z_2		5.625	6.046	6.658	6.109
LSD_{Z*B}			.0273		LSD_Z 0.157
Biochar		B_0	B_1	B_2	Mean B
		5.075	5.851	6.420	
LSD_B			0.157		

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

The addition of vermicompost led to increases in the parameters of sorghum crop under study. This may be due to improving physical properties of the soil, reducing its salinity, and making root zone a suitable environment for root growth and development, which encouraged the absorption of water and nutrients and increased vital processes, which led to an increase in plant's yield (Choudhary et al., 2023; Mebrahtom, 2024; Salim et al., 2024). The addition of biochar led to increases in plant parameters under study. This may be attributed to role of biochar in improving various properties of soil, including the physical by reducing bulk density, increasing the available water, reducing its loss and reducing soil salinity in root zone through adsorption of salt ions and their leaching down, which was reflected in increase in absorption of water and nutrients and increase in plant parameters (Sun et al., 2022; Tang et al., 2023).

CONCLUSION

It can be concluded the addition of soil conditioners (zeolite, vermicompost and biochar conditioners) significantly improving soil physical properties (bulk density, water content at field capacity and permanent wilting point and available water), reducing soil salinity The addition of zeolite (12 Mg ha^{-1}), vermicompost (10 Mg ha^{-1}) and biochar (10 Mg ha^{-1}) with achieved a great response to the sorghum crop represented by increasing plant parameters and improving soil physical properties and soil salinity. The effect of conditioners to soil together was more efficient under study compared to adding each of them separately.

REFERENCES

Ai, F., He, L., Li, Q., Li, B., Zhang, K., Yang, H., & Zhang, C. (2023). Vermicompost combined with soil conditioner improves the ecosystem multifunctionality in saline-alkali land. Water, 15(17), 1–17. https://doi.org/10.3390/w15173075

Aiad, M. A., Khalifa, T. H. H., Shabana, M. M. A., Zoghdan, M. G., Shaker, E. M., Eid, M. S. M., Ammar, K. A., Al-Dhumri, S. A., & Kheir, A. M. S. (2021). Combined application of compost, zeolite and a raised bed planting method alleviate salinity stress and improve cereal crop productivity in arid regions. Agronomy, 11(12), 1–12. https://doi.org/10.3390/agronomy11122495

Alabi, D. O., Coopoosamy, R., Naidoo, K., & Georgina, A. (2023). Vermicompost a sustainable bio-stimulant and control for agricultural enhancement in Africa. Journal of Agricultural Science and Food Research, 13(2), 1–8. https://doi.org/10.3389/2593-489

Ali, N. S., Rahi, H. S., & Shaker, A. A. (2014). Soil fertility. Dar Al-Kotob Alamya.

Al-Janabi, H. Y. (2016). Applied Land Reclamation. Department of the Univ. Printing Press, Faculty of Agriculture, Al-Qasim Green University.

Al-Maamori, H. A. (2024). Vermicompost production by earthworms and its role in sustainable agriculture. International Journal of Agriculture and Plant Science, 6(3), 39.

Alwan, Y. A. H., Abbood, M. A., & Mohammed, H. A. (2023). Effect of zeolite and silica gel in regulating the water requirement of cabbage and their effect on some physical properties of the soil. IOP Conference Series: Earth and Environmental Science, 1262(8), 082015. https://doi.org/10.1088/1755-1315/1262/8/082015

Belviso, C., Satriani, A., Lovelli, S., Comegna, A., Coppola, A., Dragonetti, G., Cavalcante, F., & Rivelli, A. R. (2022). Impact of zeolite from coal fly ash on soil hydro physical properties and plant growth. Agriculture, 12(3), 356–369. https://doi.org/10.3390/agriculture12030356

Ceritoglu, M., Şahin, S., & Erman, M. (2018). Effects of vermicompost on plant growth and soil structure. Selcuk Journal of Agriculture and Food Sciences, 32(3), 607–615. https://doi.org/10.15316/SJAFS.2018.143

Chen, X., Liu, L., Yang, Q., Xu, H., Shen, G., & Chen, Q. (2024). Optimizing biochar application rates to improve soil properties and crop growth in saline–alkali soil. Sustainability, 16(6), 2523. https://doi.org/10.3390/su16062523

Choudhary, G., Swaroop, N., Thomas, T., David, A. A., & Kumar, K. (2023). Effect of vermicompost and Zn on physico-chemical properties of soil in cultivation of okra (Abelmoschus esculentus L.) var. supper green. International Journal of Environment and Climate Change, 13(8), 1638–1644. https://doi.org/10.9734/ijecc/2023/v13i82114

El-Sayed, M. E. A., Hazman, M., Abd El-Rady, A. G., Almas, L., McFarland, M., Shams El Din, A., & Burian, S. (2021). Biochar reduces the adverse effect of saline water on soil properties and wheat production profitability. Agriculture, 11(11), 1–12. https://doi.org/10.3390/agriculture11111112

EL-Shaieny, A-H. A. H., Farrag, H. M., Bakr, A. A. A., & Abdelrasheed, K. G. (2022). Combined use of compost, compost tea, and vermicompost tea improves soil properties, and growth, yield, and quality of (Allium cepa L.). Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 50(1), 1–27. https://doi.org/10.15835/nbha50112565

Emamu, T., & Wakgari, T. (2021). The effect of integrated application of Vermicompost and NPS fertilizer on soil physicochemical properties and yield of maize (Zea mays L.) crop at Toke Kutaye district, Western Ethiopia. Stechnolock Plant Biology Research, 1(1), 1–16. https://doi.org/10.11648/j.ijaas.20210705.16

Environmental Statistics Department. (2023). Environmental Statistics for Iraq (Agricultural Indicators) for 2022. Central Statistical Organization, Ministry of Planning.

Farooqi, Z. U. R., Abdul Qadir, A., Khalid, S., Murtaza, G., Ashraf, M. N., Rahman, S. U., Javed, W., Waqas, M. A., & Xu, M. (2024). Greenhouse gas emissions, carbon stocks and wheat productivity following biochar, compost and vermicompost amendments: Comparison of non-saline and salt-affected soils. Scientific Reports, 14(1), 1–14. https://doi.org/10.1038/s41598-024-56381-y

Gao, Z. W., Ding, J., Ali, B., Nawaz, M., Hassan, M. U., Ali, A., Rasheed, A., Khan, M. N., Ozdemir, F. A., Iqbal, R., & Çig, A. (2024). Putting Biochar in Action: A black gold for efficient mitigation of salinity stress in plants. ACS Omega, 9(29), 31237–31253. https://doi.org/10.1021/acsomega.3c07921

Ghorbani, M., Amirahmadi, E., Konvalina, P., Moudry, J., Barta, J., Kopecky, M., Teodorescu, R. I., & Bucur, R. D. (2022). Comparative influence of biochar and zeolite on soil hydrological indices and growth characteristics of corn (Zea mays L.). Water, 14(21), 3506. https://doi.org/10.3390/w14213506

Girijaveni, V., Reddy, K. S., Sharma, K. L., & Moulika, G. (2018). Zeolites are emerging soil amendments for improving soil physical and chemical properties in agriculture: A Review. International Journal of Agriculture, Environment and Biotechnology, 11(6), 841–849. https://doi.org/10.30954/0974-1712.12.2018.5

Hoque, M. N., Imran, S., Hannan, A., Paul, N. C., Mahamud, M. A., Chakrobortty, J., Sarker, P., Irin, I. J., Brestic, M., & Rhaman, M. S. (2022). Organic amendments for mitigation of salinity stress in plants: A review. Life, 12(10), 1632–1654. https://doi.org/10.3390/life12101632

Hummadi, A. S. (2009). National Action Program to Combat Desertification in Iraq. Ministry of Agriculture.

Ibrahim, M. M., Mahmoud, E. K., & Ibrahim, D. A. (2015). Effects of Vermicompost and Water Treatment Residuals on Soil Physical Properties and Wheat Yield. International Agrophysics, 29, 157–164. https://doi.org/10.1515/intag-2015-0029

Khalifa, T. H. H., Ramadan, M. S. A., & Eid, M. S. (2021). Using Zeolite and Vermicompost Amendments to Improve Water Productivity of Wheat Irrigated by Low-quality Water in the Northern Nile Delta. International Journal of Plant & Soil Science, 33(24), 121-135. DOI: 10.9734/IJPSS/2021/v33i2430760

Korkunna, O., Leboda, R., Skubiszewska-Zieba, J., Vrublevs'ka, T., Gun, V. M., & Ryczkowski, J. (2006). Structural and physicochemical properties of natural zeolites: clinoptilolite and mordenite. Microporous and Mesoporous Materials, 87(3), 243–254. https://doi.org/10.1016/j.micromeso.2005.08.002

Kumar, M., Bharose, R., Thomas, T., & Naga, I. R. (2023). Influenced of vermicompost and biofertilizer on physico-chemical properties of soil under hybrid maize (Zea mays L.). International Journal of Plant & Soil Science, 35(15), 336–342. https://doi.org/10.9734/ijpss/2023/v35i153114

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

Lee, X., Yang, F., Xing, Y., Huang, Y., Xu, L., Liu, Z., Holtzman, R., Kan, I., Li, Y., Zhang, L., & Zhou, H. (2022). Use of biochar to manage soil salts and water: Effects and mechanisms. Catena, 211, 106018. https://doi.org/10.1016/j.catena.2022.106018

Mebrahtom, S. (2024). Short term effect of vermicompost on soil chemical properties under maize (Zea mays L.) field in northern Ethiopia. Asian Soil Research Journal, 8(1), 46–55. https://doi.org/10.9734/asrj/2024/v8i1144

Omondi, M. O., Xia, X., Nahayo, A., Liu, X., Korai, P. K., & Pan, G. (2016). Quantification of biochar effects on soil hydrological properties using meta-analysis of literature data. Geoderma, 274, 28–34. https://doi.org/10.1016/j.geoderma.2016.03.029

Page, A. L., Miller, R. H., & Kenney, D. R. (2002). Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. American Society of Agronomy, Inc.

Rajkovich, S., Enders, A., Hanley, K., Hyland, C., Zimmerman, A. R., & Lehmann, J. (2012). Corn growth and nitrogen nutrition after addition of biochars with varying properties to a temperate soil. Biology and Fertility of Soils, 48, 271–284. https://doi.org/10.1007/s00374-011-0624-7

Ramesh, K., Biswas, A. K., & Patra, A. K. (2015). Zeolitic farming. Indian Journal of Agronomy, 60(2), 185–191. https://doi.org/10.59797/ija.v60i2.4453

Salim, M. N., Ahmad, Z. I., Shah, G. A., Saifullah, K., & Anwar, A. (2024). Comparative efficiency of different organic fertilizers on sorghum growth, nutrient uptake and soil chemical properties. Journal of Tianjin University Science and Technology, 57(6), 521–537. https://doi.org/10.5281/zenodo.12530162

Shahbaz, M., & Ashraf, M. (2013). Improving salinity tolerance in cereals. Critical Reviews in Plant Sciences, 32(4), 237–249. https://doi.org/10.1080/07352689.2013.758544

Simansky, V., Horak, J., & Bordoloi, S. (2022). Improving the soil physical properties and relationship between soil properties in arable soils of contrasting texture enhancement using biochar substrates: Case study in Slovakia. Geoderma Regional, 28, e00443. https://doi.org/10.1016/j.geodrs.2021.e00443

Steel, R. G. D., & Torrie, J. H. (1980). Principles and Procedures of Statistics. McGraw–Hill, Inc.

Sun, Y., Chen, X., Yang, J., Luo, Y., Yao, R., Wang, X., Xie, W., & Zhang, X. (2022). Biochar effects coastal saline soil and improves crop yields in a maize-barley rotation system in the tidal flat reclamation zone, China. Water, 14(20), 1–13.

Suradkar, R. K., Kadu, P. P., Kadlag, A. D., Durgude, A. G., & Surve, U. S. (2023). Effect of zeolite application on physico-chemical properties of soil at grand growth stage and after harvest of preseasonal sugarcane grown on inceptisol. The Pharma Innovation Journal, 12(8), 705–710.

Tang, C., Yang, J., Xie, W., Yao, R., & Wang, X. (2023). Effect of biochar application on soil fertility, nitrogen use efficiency and balance in coastal salt-affected soil under barley–maize rotation. Sustainability, 15(4), 2893. https://doi.org/10.3390/su15042893

Ullah, I., Khan, S., Nawab, J., Khan, M. A., & Jehan, S. (2022). Hardwood modified and unmodified biochar amendments used for saline alkali soil remediation: phosphorus availability and its plant uptake. Arabian Journal of Geosciences, 15, 910. https://doi.org/10.1007/s12517-022-10157-8

Xiao, F., Zhou, B., Wang, H., Duan, M., & Feng, L. (2022). Effects of different soil amendments on physicochemical property of soda saline-alkali soil and crop yield in Northeast China. International Journal of Agricultural and Biological Engineering, 15(1), 192–198.

Xiao, W., Ding, J., Han, L., Tan, J., Ge, X., & Nan, Q. (2024). Biochar addition reduces salinity in salt-affected soils with no impact on soil pH: A meta-analysis. Geoderma, 443, 116845. https://doi.org/10.1016/j.geoderma.2024.116845

Zonayet, M., Paul, A. K., Faisal-E-Alam, M., Syfullah, K., Castanho, R. A., & Meyer, D. (2023). Impact of biochar as a soil conditioner to improve the soil properties of saline soil and productivity of tomato. Sustainability, 15(6), 4832. https://doi.org/10.3390/su15064832

Iraqi Journal of Agricultural Sciences –2026:57(8):2219-2233
P-ISSN: 0075- 0530 /E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/ceep9j72

تحسين صفات تربة ملحية بأستعمال الزيولايت والفيرمكمبوست والفحم الحيوي في نمو وحاصل الذرة البيضاء

صطفى علي عدنان الجنابي[1] ، عباس خضير عباس جارالله[2]
[1]كلية الطب البيطري – جامعة بغداد - العراق [2] قسم مكافحة التصحر، كلية علوم الهندسة الزراعية، جامعة بغداد - العراق

المستخلص

اجريت تجربة حقلية بهدف تحسين صفات تربة ملحية بأستعمال الزيولايت والفيرمكبوست والفحم الحيوي وتداخلاتهم في نمو وحاصل الذرة البيضاء. تضمنت التجربة ثلاثة مستويات من الزيولايت هي 0 و6 و12 ميكاغرام هـ$^{-1}$ ورمز لها (Z_0 وZ_1 وZ_2) ومستويين من الفيرمكمبوست هي 0 و10 ميكاغرام هـ$^{-1}$ ورمز لها (V_0 وV_1). وثلاثة مستويات من الفحم الحيوي هي 0 و5 و10 ميكاغرام هـ$^{-1}$ ورمز لها (B_0 وB_1 وB_2). نفذت تجربة عاملية باستعمال تصميم القطاعات العشوائية الكاملة وبثلاثة مكررات. أظهرت النتائج أن زيادة مستوى إضافة كل من الزيولايت والفيرمكبوست والفحم الحيوي أثرت تأثيراً معنوياً في الصفات الفيزيائية والكيميائية للتربة، لقد حقق المستوى 12 ميكاغرام هـ$^{-1}$ من الزيولايت والمستوى و10 ميكاغرام هـ$^{-1}$ من الفيرمكمبوست والمستوى و10 ميكاغرام هـ$^{-1}$ من الفحم الحيوي اقل قيمة للكثافة الظاهرية بينما حقق أعلى القيم للمحتوى الرطوبي عند السعة الحقلية ونقطة الذبول وكمية الماء الجاهز بينما حقق أقل القيم الايصالية الكهربائية ونسبة الصوديوم الممتز ونسبة الصوديوم المتبادل. أما بالنسبة للتداخل بين عوامل الدراسة فقد تفوقت المعاملة $Z_2V_1B_2$ (12 ميكاغرام هـ$^{-1}$ زيولايت و10 ميكاغرام هـ$^{-1}$ فيرمكمبوست و10 ميكاغرام هـ$^{-1}$ فحم حيوي) في تحقيق اقل قيمة للكثافة الظاهرية بلغت 1.18 ميكاغرام م$^{-3}$ واعلى القيم للمحتوى الرطوبي في التربة بلغت 35.63 و18.63 و17.00% لكل من السعة الحقلية ونقطة الذبول الدائم والماء الجاهز بالتتابع واقل القيم بلغت 3.00 ديسي سمنز م$^{-1}$ و3.15 (ملي مول لتر$^{-1}$)$^{0.5}$ و7.4 % لكل من الايصالية الكهربائية ونسبة الصوديوم الممتز ونسبة الصوديوم المتبادل بالتتابع. حققت عوامل الدراسة وتداخلاتهم اعلى استجابة في نمو وحاصل الذرة البيضاء.

الكلمات المفتاحية: الكثافة الظاهرية، السعة الحقلية، نقطة الذبول، الماء الجاهز، محسنات التربة.