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EFFECTS OF ALUM APPLICATION AND WATER QUALITY ON SOME PROPERTIES IN DEGRADED SOIL AND YIELD OF SORGHUM (*Sorghum bicolor* L.)

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ABSTRACT

Soil degradation and water scarcity are considered the main challenges that are faced the agricultural production, particularly with changing climate. The objective of this study was to study the effectiveness of alum in improving some soil chemical properties using two qualities of irrigation water . The experimental study was conducted in the Anbar Governorate / Al-Khayrat district in the fall season in degraded clay loam soil. The experimental design for the study site was the split- Block arrangement with a randomized complete block design (RCBD) with three replicates. This study included two factors: the main factor was water quality with river water (1.8 dS m^{-1}) and well water (3.8 dS m^{-1}), and the secondery factor was alum application with eight levels (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, and 1.4 %) based on dry soil. The results showed that pH, EC were decreased by 12.7, 65.1%, respectively when applied 0.8% of alum at the irrigation of river water and decreased by 11.9, 61.4 %, respectively when applied 1.0% of alum at irrigation with well water as compared to control treatment. While an increase occurred in CEC of about 20.0 and 19.8% at the irrigation of river and well water, respectively as compared to control treatment.While the addition of all levels of aluminum sulfate (alum) led to a significant effect on the available nitrogen in the soil and the biological yield when treating alum a5, which reached 48.6% and 48.50, respectively.

Key words: Cation Exchange Capacity, Climate change, drip irrigation, soil amendments, salinity,.
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INTRODUCTION

Providing food for an estimated 9.6 billion people by 2050 is a major challenge facing researchers and agricultural professionals, particularly in arid and semi-arid regions around the world, in light of the challenges of climate change, including rising temperatures and declining rainfall (Hossain.2019). Irrigated land has declined by 1–2% annually due to soil degradation, desertification, increased salinity, and worsening drought (Phocaides,2001). Addressing these challenges requires intensive efforts to rehabilitate marginal lands and transform them from environmental burdens into sustainable productive and economic resources. This includes exploring non-conventional water sources, such as saline water or treated wastewater for irrigation, and cultivating crops that are tolerant to salinity and drought (Hossain.2019). Desertification is a complex dynamic process resulting from land degradation in arid, semi-arid, dry, and sub-humid regions, driven by the environmental characteristics of these areas and exacerbated by unsustainable human practices in exploiting natural resources (Ambalam, 2014.). Soil salinization is one of the most prominent drivers of desertification, as low rainfall reduces the area of arable land and significantly reduces crop productivity and quality (Phocaides, 2001). This problem is exacerbated in the saline soils of central and southern Iraq, which are characterized by high clay content and low water permeability through soil layers, making their reclamation more challenging than sandy soils (Qureshi, *et al.*2013). Soil salinization becomes more complex when

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reclaiming soils with high sodium content. Sodium hydration causes soil swelling after irrigation and increases the thickness of the electrical double layer, impeding the washing process and rendering it virtually nonexistent (32). To address this problem, the use of chemical amendments, such as alum (aluminum sulfate), is an effective solution, as it helps replace sodium ions (Na^+) in the exchange complex with aluminum ions (Al^+) (Zhou,*et al*.2019) The decomposition of aluminum hydroxide also produces alum with a single or double positive charge, which works to neutralize the negative charges of colloidal clay particles, which enhances the aggregation of these particles to form larger clumps, thus improving the soil structure, increasing its porosity, and greatly facilitating water permeability (Zhou,*et al*.2019)and(Asgari and Fakher. 1994).

$Al_2(SO_4)_3 + Clay \rightarrow Al[Clay] + 3(H_2SO_4)$

and $Al^{+3} + OH^- \rightarrow Al(OH)^{++}$

$Al(OH)^{++} + OH^- \rightarrow Al(OH)_2^+$ (=Aluminum hydroxyl ions)

The sulfuric acid produced by the decomposition of alum dissolves the calcium carbonate present in the soil, leading to the release of calcium cations (Ca^{2+}), which gradually replace sodium ions on the surfaces of colloidal particles in the soil, thus contributing to the improvement of its properties (Lou , *et al.* 2015). Adding alum to saline soil, along with repeated washings (once, twice, and then three times), reduces the electrical conductivity and promotes the electrostatic precipitation of colloidal particles. These repeated washings improve soil stability and significantly reduce its salinity with each washing. The concentration of sulphates and chlorides and the soil content of carbonates and bicarbonates significantly decreases and becomes more suitable for crop growth (El-Shazly,*et al*.2014 and Sun . 2011). It was also found that the addition of aluminum sulfate with soil amendments such as gypsum and mole drain filled back with sand under rotational filtration processes to the saline-sodic clay soil led to a significant decrease in the values of EC, pH, and ESP, while aluminum sulfate was the most effective, followed by gypsum and sand (Farag, et al .2013). The addition of alum (aluminum sulfate) to saline-sodic soil with mineral and organic fertilizers leads to a decrease in the value of pH, EC, Exchangeable sodium percentage, total alkalinity, sodium adsorption ratio, carbonates and bicarbonates, and an increase in cation exchange capacity, sulphates and available N, P, K. These results are related to washing sodium from the root growth layer to the lower soil layers and increasing the soil organic carbon (SOC), which leads to improving colloidal properties and increasing soil fertilizer retention (Zhou,*et al*.2019). To demonstrate the effect of amendments in alkaline saline soils, a laboratory experiment was conducted using 13 kinds of amendments and their combinations (Citric acid (NM), Phosphogypsum (LS), Aluminum sulfate + citric acid (AL+NM), Aluminum sulfate + phosphogypsum (AL+LS), Aluminum sulfate + citric acid + phosphogypsum (HH), Zeolite (Z), Acidified zeolite (ZH), Aluminum sulfate (AL), Aluminum sulfate + zeolite (AL+Z), Aluminum sulfate + acidified zeolite (AL+ZH), Poly Aluminum chloride (ALCL), Polyaluminium chloride + zeolite (ALCL+Z), Polyaluminium chloride + acidified zeolite (ALCL+ZH)). All amendments reduced pH, ESP, and exchange Na^+, The best five amendments were selected for application in the field (Z, ZH, AL, AL+Z, and AL+ZH). The results showed that the effect of adding aluminum sulfate at a rate of 0.6% to the soil was the best among the amendments with dry field (maize), while the aluminum sulfate amendment with acidic zeolite was the best with paddy field (rice) (Xiao, et al 2022). Although many studies dealt with the role of alum in improving the chemical properties of soil but very little is known about its effect on degraded soil properties when irrigated with saline water. This study was aimed to evaluate the effect of alum and irrigation water quality on some soil chemical properties.

MATERIALS AND METHODS

A field experiment was carried out during the fall season of 2021 in degraded soil due to salinization in one of the private fields within the Al-Khayrat sub-district of Anbar Governorate, which is located 5 km northwest of Baghdad at coordinates N 33°29'06.846''

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and E 44°07'13.983" according to the Split-Block arrangement with a randomized complete block design (RCBD) with two factors. The main factor included the irrigation water quality (WQ) at two levels, the first is river water wq_1 and the second is well water wq_2, which were assigned in the main plots. On the other hand, the sub factor is an alum (A) at eight levels (a_0, a_1, a_2, a_3, a_4, a_5, a_6, and a_7) that were assigned in the subplots, at a rate of addition (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, and 1.4 %) based on dry soil, respectively with three replicates, as the number of experimental units reached 48 units. After adding alum to the saline soil, it was irrigated twice to remove excess salts (Sun . 2011). Two weeks later, bicolor sorghum (L. Sorghum bicolor, Buhuth 70 variety) seeds were planted on August 5, 2021, using the drilling method. A distance of 0.2 meters was maintained between each hole and 0.6 meters between each row, achieving a plant density of 83,333 plants per hectare. Nitrogen fertilizer was added at a rate of 320 kg of nitrogen per hectare, divided into three batches: the first at the time of planting using DAP fertilizer (18% N), the second one month after planting using urea fertilizer (46% N), and the third during the flowering stage. Phosphate fertilizer was also added at a rate of 200 kg of P_2O_5 per hectare in a single batch when planting using DAP fertilizer (46% P_2O_5). Potassium was added at a rate of 100 kg K2O per hectare in the form of potassium sulfate (50% K_2O) in a single application at planting, according to fertilization recommendations for sorghum (Ali, 2012). The experiment involved irrigation using a drip system powered by a 4.5-horsepower gasoline pump. This system was connected to a central control unit containing valves and meters to regulate water pressure and flow.Irrigation timing was determined based on soil moisture consumption, with the system switched on when the moisture depletion rate reached 50% of the total moisture available to the plant.. The experiment continued until the crop reached final maturity, and harvesting took place on November 20, 2021. Before planting, soil samples were collected from a depth of 0-30 cm for analysis of their chemical and physical properties, as shown in Table 1. After harvest, a soil sample was taken from each experimental unit, air-dried, ground, and passed through a 2 mm sieve for analysis.the analyzes of soil and water samples were carried out using the standard methods. The electrical conductivity was estimated by the Conductivity Bridge and the soil reaction by the pH meter with 1:1 aqueous extract. The exchangeable sodium percentage (ESP) was estimated using ammonium acetate and measurement by the flame photometer. Cation exchange capacity (CEC) was estimated using ammonium acetate (1N at pH = 7) as mentioned in (Page,el al 1982). Biological yield (megagram h^{-1}): The average weight of the dry vegetative mass (leaves and stems) was calculated, followed by the weight of the heads after drying in an electric oven at 65°C until the weight was constant, and the average was multiplied by the plant density.

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

Property		Value	Unit
Electrical conductivity EC*		5.82	$dS.m^{-1}$
Soil reaction pH		.831	
Organic matter		4.6	$g\ kg^{-1}soil$
Carbonate minerals		237	
Dissolved ions*	Sodium	21.4	$mmol\ L^{-1}$
	Calcium	8.7	
	Magnesium	3.6	
	potassium	1.3	
	bicarbonate	3.1	
	chloride	19.7	
	Sulfates	7.4	
Sodium adsorption ratio SAR		8.65	$(mmol\ L^{-1})^{0.5}$
CEC		23.8	$cmol_{+}\ kg^{-1}$ soil
Exchangeable sodium		2.76	
ESP		11.6	%
Bulk density		1.63	$Mg\ m^{-3}$
Particle density		2.65	
Porosity		38	%
Soil separates	Sand	262	$g\ kg^{-1}soil$
	Silt	438	
	Clay	300	
Soil texture	Clay loam		

* Estimated at 1:1 extract

The dissolved sodium and potassium were estimated by a flame photometer and the dissolved bicarbonate by titration with sulfuric acid (0.01 N) and using the methyl orange reagent. The soil content of carbonate minerals was estimated using hydrochloric acid (1 N) and titration with sodium hydroxide with the use of phenolphthalein reagent (Richards, 1954.). The dissolved calcium and magnesium were estimated by titration with vresnite (EDTA-Na_2) and chloride by titration with silver nitrate ($AgNo_3$ 0.03 N) and using potassium chromate reagent (Jackson, 1958), and the (ESP) was calculated in the following equation.

$$ESP = \frac{Na_{(ex)}}{CEC} \times 100 \quad ....(1)$$

The particle size distribution was estimated by the hydrometer method (Black, 1965), and the organic matter was estimated by the wet oxidation method by potassium dichromate according to the Black and Wakelly method (Page,el al 1982). Samples were taken from river and well water to determine some chemical characteristics were determined as in Table 2. The water was classified according to the FAO classification for irrigation water (Phocaides,2001). The experiment results were analyzed by the commercial software (Gen stat) program and the means were compared using the least significant difference (LSD) test treatment 0.05 level.

Table 2. Chemical properties of irrigation water

Property	River water wq_1	Well water wq_2	Unit
EC	1.8	3.8	$dS\ m^{-1}$
pH	7.24	7.05	-
Sodium	3.22	16.46	
Calcium	6.33	9.62	
Magnesium	2.35	6.17	$mmol\ L^{-1}$
Potassium	0.98	2.27	
Sulfates	2.71	6.37	
Bicarbonate	2.26	5.95	
Chlorine	9.52	24.58	
SAR	1.54	5.88	$(mmol\ L^{-1})^{0.5}$
Water class	C3-S1	C4-S1	-

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RESULTS AND DISCUSSION

The results of the statistical analysis in Table 3 showed the significant effect on soil reaction (pH) when adding alum and the irrigation water quality, as the addition of alum led to a significant decrease in soil pH, which amounted to 7.29 at treatment a_7, with a decrease of 12.17% compared to the control treatment 8.3. This decrease may be attributed to the sulfuric acid resulting from the hydrolysis of alum. These results are consistent with the findings of (Farag, et al.2013 and Zhou,*et al*.2019) that adding alum (aluminum sulfate) led to a decrease in the soil reaction. The results in Table 3 show that there was a significant decrease in the soil pH with the quality of irrigation water, which reached to 7.73 when irrigating with river water and 7.64 when irrigating with well water. The reason for the decrease may be attributed to the accumulation of neutral salts such as sulfates and chlorides of calcium, magnesium, and sodium in the soil, which makes the soil reaction near neutralization. These results are likewise consistent with what was found by (Al-Obaidi, 2015 and Mahmoud, and Al-Zubaidi. 2011.). As for the interaction between the addition of alum and the irrigation water quality, it had a significant effect on reducing the degree of soil reaction. The treatments a_7wq_1 and a_7wq_2 recorded the lowest value of 7.31 and 7.26 with a decrease of 12.46% and 11.89% compared to the control treatments a_0wq_1 and a_0wq_2 which reached 8.35 and 8.24 when irrigating with river and well water, respectively.

Table 3. Effect of adding alum and irrigation water quality on soil reaction (pH) after harvesting

Water quality WQ	Alum Levels A a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	Mean of water quality
River water (wq_1)	8.35	7.10	7.86	7.78	7.67	7.50	7.41	7.31	7.73
Well water (wq_2)	8.24	7.92	7.78	7.64	7.56	7.42	7.34	7.26	7.64
LSD	0.12								0.01
Mean of concentrations of alum	8.30	7.95	7.82	7.71	7.61	7.46	7.38	7.29	
LSD_a	0.12								

Electrical Conductivity (EC)

The results of the statistical analysis in Table 4 showed the significant effect on the soil electrical conductivity (EC) when adding alum and the irrigation water quality. The addition of alum led to a significant decrease in the electrical conductivity amounted to 1.83 dS m^{-1} at treatment a_5 with a decrease of 61.80% compared to the control treatment a_0 (4.79 dS m^{-1}). The reason for the decrease may be attributed to the role of monomeric aluminum hydroxide $Al(OH)_2^+$ and binary $Al(OH)^{+2}$ resulting from the hydrolysis of alum in neutralizing the negative charges of clay particles less than 0.005 mm. Besides, aggregating them to form larger particles, which improves soil structure and increases its porosity and permeability, and then increases the efficiency of the process of washing salts from the soil. These results are consistent with the findings of (Farag, et al. 2013 and Zhou,*et al*.2019). The results in Table 4 show that there was a significant increase in the soil electrical conductivity for the irrigation water quality, as it reached 2.54 dS m^{-1} for irrigation with river water and 2.84 dS m^{-1} for irrigation with well water. The reason for the increase may be attributed to the increase in the ionic content of the well water compared to the river water, and these results are consistent with the

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findings of (Haj-Amor, et al .2018 and Pessoa, et al. 2019.). As for the interaction between alum and the irrigation water quality, it had a significant effect in reducing the soil electrical conductivity. The two treatments a_4wq_1 and a_5wq_2 recorded the lowest value by 1.57 and 1.93 dS m^{-1} with a decrease of 65.11% and 61.93% compared to the control treatments a_0wq_1 and a_0wq_2 which amounted to 4.50 and 5.07 dS m^{-1} when irrigating with river and with well water, respectively.

Table 4. Effect of alum addition and irrigation water quality on soil electrical conductivity (EC) dS m^{-1} after harvesting

Water quality				Alum Levels A					Mean of
WQ	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	water quality
River water (wq_1)	4.50	3.07	2.53	2.13	1.57	1.73	2.13	2.63	2.54
Well water (wq_2)	5.07	3.23	2.80	2.50	2.13	1.93	2.33	2.70	2.84
LSD				0.26					0.11
Mean of concentrations of alum	4.79	3.15	2.67	2.32	1.85	1.83	2.23	2.67	
LSD_a				0.20					

Cation Exchange Capacity (CEC)

The results of the statistical analysis in Table5 showed the significant effect on the CEC when adding alum to water quality, as the addition of alum led to a significant increase in the CEC, which amounted to 28.30 $cmol_+ \ kg^{-1}$ soil at treatment a_4 with an increase of 18.12% than the control treatment a_0 of 23.94 $cmol_+ \ kg^{-1}$ soil. The reason for the increase in the CEC may be attributed to the decrease in the proportion of calcium carbonate in the soil as shown in (Table 5) after dissolving it by sulfuric acid resulting from the hydrolysis of alum. Calcium carbonate binds and encapsulates clay and silt particles and prevents them from participating in the ion exchange process, as the surface area of the soil increases after removing carbonate minerals and then increases the CEC (Al-Mamouri, 2012. and Al-Sinjari, 2000.). These results are agreed with the findings of (Xiao,et al 2022. and Zhou,*et al*.2019) that the addition of alum (aluminum sulfate) led to an increase in the cation exchange capacity. The results in Table 5 show a significant decrease in the cation exchange capacity for the irrigation water quality, as it reached 26.94 $cmol_+ \ kg^{-1}$ when irrigating with river water and 26.48 $cmol_+ \ kg^{-1}$ when irrigating with well water. The reason for the decrease may be attributed to the well water content of calcium and bicarbonate and the possibility of their precipitation in the form of calcium carbonate, which causes a decrease in the e cation exchange capacity. This is consistent with what was indicated by (Al-Zubaidi, 1989 and Arora, et al. 2018.) that irrigation with water with high concentrations of sodium leads to a decrease in the cation exchange capacity. As for the interaction between alum and the irrigation water quality, it had a significant effect on increasing the cation exchange capacity. CEC highest value was 28.93 and 28.33 $cmol_+ \ kg^{-1}$ for treatments a_4wq_1 and a_5wq_2 with an increase of 20.04% and 19.81% compared to the control treatments a_0wq_1 and a_0wq_2 which amounted to 24.10 and 23.77 $cmol_+ \ kg^{-1}$ respectively.

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Table 5. Effect of adding alum and irrigation water quality on soil CEC (c mol_+ kg^{-1} soil) after harvesting

Water quality WQ	Alum Levels A								Mean of water quality
	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	
River water (wq_1)	24.10	24.90	26.10	27.70	28.93	28.27	27.93	27.57	26.94
Well water (wq_2)	23.77	24.20	26.20	27.10	27.90	28.33	27.27	27.07	26.48
LSD				0.44					0.30
Mean of concentrations of alum	23.94	24.55	26.15	27.40	28.42	28.30	27.60	27.32	
LSD_a				0.37					

Available Nitrogen in Soil

The results of the statistical analysis (Table 6) showed a significant effect on available nitrogen in the soil when alum was added and on water quality. The addition of alum led to a significant increase in available nitrogen, reaching 29.42 mg kg $^{1-}$soil in the alum A5 treatment, a 48.06% increase over the control A0 treatment, which reached 19.87 mg kg $^{1-}$ soil. The reason for the increase in nitrogen availability in the soil may be attributed to the reduced soil reactivity, which prevents the volatilization of nitrogen in the form of ammonia ($NH^+{}_3$) ,as it combines with hydrogen to form ammonium (NH^4) .$^+$This is consistent with the findings of (Al-Furaiji and Shamsullah. 2019. and Hassan,et al. 2023 and ,Shamsullah, et al, 2023), who found that the addition of alum (aluminum sulfate) increased nitrogen availability in the soil.The results (Table 6) also showed a significant decrease in available soil nitrogen due to the quality of irrigation water, reaching 27.06 mg kg^{-1} soil when irrigated with river water and 23.83 mg kg^{-1} soil when irrigated with well water. The reason for the decrease may be attributed to the effect of salinity of irrigation water on the bacteria responsible for the second stage of the nitrification process, as in the first stage, ammonium (NH_4^+) is oxidized to nitrite (NO_2^-, while the second stage, in which nitrite is oxidized to nitrate (NO_3^-), does not occur (Lodhi, et al 2009.). This is consistent with the findings of (Akhtar et al .2012). The interaction between the net and the quality of irrigation water had a significant effect on increasing the available nitrogen in the soil, which amounted to 31.17 mg kg^{-1} for the a4wq1 treatment, with an increase rate of 64.92% compared to the two comparison treatments a0wq2, which amounted to 18.90 mg kg^{-1} .

Table 6. Effect of adding alum and irrigation water quality on Available Nitrogen in Soil (mg kg $^{1-}$soil) after harvesting.

Water quality WQ	Alum Levels A								Mean of water quality
	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	
River water (wq_1)	20.83	24.37	27.10	29.10	31.17	29.70	28.03	26.20	27.06
Well water (wq_2)	18.90	20.87	22.30	24.00	26.37	29.13	25.77	23.30	23.83
LSD		0.35							0.28
Mean of concentrations of alum	19.87	22.62	24.70	26.55	28.77	29.42	26.90	24.75	
LSD_a					0.30				

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Biological Yield

The results of the statistical analysis (Table 7) showed a significant effect on the biological yield of sorghum when alum was added, as well as on water quality. The addition of alum led to a significant increase in the biological yield, reaching 20.82 µg h^{-1} in the alum A5 treatment, a 48.50% increase over the control A0 treatment, which reached 14.02 µg h^{-1}. This may be attributed to the effect of alum in improving the soil's chemical properties and increasing nutrient availability (Tables 5, 6, 7 and 8), which led to an increase in the biological yield. (Kukadia, et al 1983.) indicated that yield increases with an increase in its components. The results (Table 7) also showed a significant decrease in the biological yield of the irrigation water quality, reaching 19.37 µg h^{-1} when irrigated with river water and 17.87 µg h^{-1} when irrigated with well water. This may be attributed to the deterioration of the soil's chemical properties resulting from irrigation with well water and the effect of high osmotic pressure on water and nutrient absorption, which affected photosynthesis and energy production necessary for growth, thus reducing the biological yield. This is consistent with the findings of (Manzoor, 2019), who found that irrigation with saline water reduced the biological yield of sorghum. The interaction between alum and irrigation water quality significantly affected the biological yield of sorghum, reaching 21.96 µg h^{-1} for the a4wq1 treatment, an increase of 45.62 and 56.60% compared to the control treatment a0wq2, which reached 12.95 µg h^{-1}.

Table 7. Effect of adding alum and irrigation water quality on Biological Yield (µg h^{-1}) after harvesting.

Water quality WQ	Alum Levels A								Mean of water quality
	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	
River water (wq_1)	15.08	17.78	19.50	21.10	21.96	21.36	19.89	18.23	19.37
Well water (wq_2)	12.95	16.30	17.83	18.95	19.63	20.28	19.20	17.82	17.87
LSD									0.27
Mean of concentrations of alum	14.02	17.04	18.67	20.03	20.80	20.82	19.55	18.03	
LSD_a					0.27				

CONCLUSION

The addition of sulfate a decrease in pH , EC and increase in CEC,Available Nitrogen in Soil and biological yield as the application of aluminum sulfate, could be used as an effective practice for the reclamation of saline and sodic lands when irrigating with fresh water or with saline water.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

AUTHOR/S DECLARATION

We confirm that all Figures and Tables in the manuscript are original to us. Additionally, any Figures and images that do not belong to us have been incorporated with the required permissions for re-publication, which are included with the manuscript.

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Author/s signature on Ethical Approval Statement.

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تأثير إضافة الشب ونوعية مياه الري في بعض صفات تربة متدهورة وحاصل الذرة البيضاء (*Sorghum bicolor* L.)

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المستخلص

تعد مشكلة تدهور التربة وشحة المياه من المشاكل الخطيرة التي تواجه الانتاج الزراعي ولاسيما في ظل التغير المناخي. بهدف دراسة تأثير الشب (كبريتات الالمنيوم) في تحسين الصفات الكيميائية للتربة وباستعمال نوعين من مياه الري، أجريت تجربة حقلية أثناء الموسم الخريفي 2021 في محافظة الانبار/ ناحية الخيرات في تربة مزيجة طينية متدهورة. وفق ترتيب القطاعات المنشقة (The Split–Block Design) ضمن تصميم القطاعات العشوائية الكاملة تضم عاملين، العامل الرئيسي نوعية مياه الري، مياه نهر(1.8 ديسيمنز م$^{-1}$) ومياه بئر (3.8 ديسيمنز م$^{-1}$) والعامل الثانوي هو الشب، بمستوى إضافة (0 و0.2 و 0.4 و 0.6 و 0.8 و 1.0 و 1.2 و 1.4%) من الوزن الجاف للتربة وبثلاثة مكررات، أظهرت النتائج انخفاض pH وEC بنسبة 12.7 و65.1 % على التتابع عند إضافة الشب بنسبة 0.8% والري بمياه النهر، وانخفضت بنسبة 11.9 و61.4 % على التتابع عند إضافة الشب بنسبة 1.0% والري بمياه البئر بالقياس مع معاملة المقارنة ، بينما زادت CEC بنسبة 20.0 و19.8% عند الري بمياه النهر وبمياه البئر على التتابع بالقياس مع معاملة المقارنة. بينما أدت إضافة جميع مستويات كبريتات الألومنيوم (الشب) إلى زيادة معنوية في النيتروجين الجاهز في التربة والحاصل البيولوجي عند معاملة الشب a5 والتي بلغت 48.6٪ و48.50 على التوالي. أدت إضافة الشب الى خفض تركيز الصوديوم وتحسين الصفات الكيميائية للتربة المتدهورة قيد الدراسة عند الري بالمياه العذبة والري بالمياه المالحة.

الكلمات المفتاحية: السعة التبادلية الكتيونية، التغير المناخي، الري بالتنقيط، محسنات التربة، الملوحة.

* جزء من رسالة ماجستير للباحث الاول