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The Role of Bentonite and Plant Residuals in Reducing the Salinity of Well Water and Improving Some Properties of Sandy Soils and The Growth and Plant of Tomato

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Abstract

The laboratory experiment was carried out in the laboratories of the Department of Soil Sciences and Water Resources, College of Agriculture, University of Basra, using a complete randomized block design with two factors, the first factor is the type of filter [three filters of palm kernels mixed with sand at mixing ratios (25%, 50% and 75%) and three filters of bentonite mixed with sand at mixing ratios (25%, 50% and 75%)] and the second factor is the period for passing the salty well water through the filters (1, 24 hours). The chemical properties of the water were estimated after filtration, and the percentage of removal efficiency was calculated to determine the best filters. The results showed that the adoption of the bentonite filter mixed with sand at a mixing ratio of 75% recorded the lowest electrical conductivity when filtration for 24 hours, with reduction rates of 46.50%, 49.20%, and 51.94 % in treating well water. This indicates its high efficiency in reducing water salinity and suggests the possibility of using it to irrigate cultivated tomato plants. In mixed sandy soils and it also gave the lowest concentration of all positive and negative ions in the treated water compared to water treated at other times. An experiment was conducted in the agricultural fields of the College of Agriculture, University of Basra, using a randomized complete block design (RCBD) with three factors. The first factor is the natural mineral and organic amendments (bentonite and palm kernel oil). The second factor is three levels of the mineral amendment (bentonite) (0, 5, 10, M0, M1, M2) megagram ha-1. The third factor is adding three levels of the organic amendment (palm kernel oil) (0, 5, 10, O2, O1, O0) (megagram ha-1) in succession. The results showed that the type and level of addition of amendments used in the study affected the improvement of some chemical properties of sandy soils. The result showed that the best treatment was for the soil treated with bentonite amendment at a level of 10 tons ha-1, reaching 3.02, while the degree of soil reaction increased when the soil was treated with bentonite amendment compared to the palm kernel amendment treatment. As for the fertility properties of the soil, it is noted from the results that the effect of all amendments was positive in these characteristics, as it led to an increase in the available nitrogen, phosphorus, and potassium ions in sandy mixed soils. The amendments took the following order in improving the soil content of ions ready for absorption by the plant: bentonite > palm kernel. The bentonite amendment treatment outperformed the rest of the amendments in the production of dry matter of the vegetative and root systems and the total yield. The treatment of the addition level of 10 tons ha-1 outperformed the rest of the treatments in the production of dry matter of the vegetative and root systems and the total yield.

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Introduction

Natural minerals and organic amendments play a crucial role in treating saline water, allowing for its reuse in irrigation, and solving many problems from poor soils with sandy texture by improving some physical, chemical, and biological properties. When applied to the soil, they form part of the adsorption complex responsible for holding ions and retaining them in a way that they are not lost through evaporation or leaching and releasing them into the soil solution at a steady rate over time. They also increase the soil biomass content so that the environment can accommodate growth for other useful organisms, and the water content of the soil (Govedar et al., 2022). This is because the improvers possess a large ion exchange capacity (Altınışık & Yağlıoğlu, 2022). Improvers, especially bentonite, can be used for long periods and on a large scale as it is an excellent and affordable material with high ion exchange capacity (Zhou et al., 2016 and Al-Saadi and Al-Wardy, 2019).

Bentonite also has many physical and chemical properties that have positioned it at the forefront of investigation by researchers for use in many fields, e.g., a conditioner of soils and water treatment, as the physical structure of bentonite is porous with wide channels of different sizes into which positive ions and water molecules can easily infiltrate the structural framework of the mineral, hence the outer and inner surfaces to absorb water and release it gradually (Wahabet al., 2010) and (Kayama et al., 2016). Bentonite clay is characterized by a high specific surface area of 80-150 cmol kg-1 soil, making bentonite capable of holding and retaining a high amount of ions, and the high ion exchange capacity, in addition to several other characteristics, including its high water-holding capacity, higher proportion of interstitial space, low density, and high cation exchange capacity (Minhal et al., 2020; Fakhrian et al., 2022).

Palm waste is a low-cost material for filtration, as it purifies groundwater and industrial water from contaminants due to its high adsorption capacity, in addition to being available in large quantities. Organic amendments of diverse origins also improve the physical and chemical properties of degraded and poor soils as well as sandy soils by improving the soil structure, aggregate stability, reducing apparent density, and improving the availability of nutrients and positive ion exchange capacity (AL-Aeedet al., 2020; Lakshmi Gokul & Kanagaraj, 2015).

This study aims to find appropriate solutions to reduce the risk of saltwater and its impact on productivity in poor sandy soils and improve the chemical, physical and fertility properties of the soil through natural mineral and organic amendments (bentonite and palm kernel) (Choudhary & Reddy, 2025).

Materials and Methods

The study included conducting two experiments, one laboratory and the other agricultural, to study the possibility of reclaiming saline well water in Basra and adding conditioners to the soil and their impact on the growth and productivity of tomato plants.

Laboratory Experiment

The factorial experiment was carried out in the laboratories of the Department of Soil Sciences and Water Resources, College of Agriculture, University of Basra, using a complete randomized block design with two factors. The first factor is the type of filter [three filters of palm kernels mixed with sand at mixing ratios (25%, 50% and 75%) and three filters of bentonite mixed with sand at mixing ratios (25%, 50% and 75%)] and the second factor is the period for passing the salty well water through the filters (1, 24 hours). The number of treatments was 12 treatments with three replicates to reach 36 experimental units.

Collection of Well Water Samples

Water samples for the laboratory experiment were taken from three wells in the district of Al-Zubair and adjusted to 6, 10, and 16 dS-1 by mixing tap water with well water. The following equation was used to calculate the required mixing ratio:

ECW (blend water) = [ECW (canal water) a] + [ECw (well water) b] (Ayers and Westcot, 1985)

The water was filtered through the aforementioned filters based on salinity levels of (6, 10, and 16 dS m-1), following the periods used, and then its electrical conductivity (ECiw) and chemical composition were measured.

Preparation and Setup of Filters Used in Treating Well Water

Palm Kernel and Sand Filter

Palm kernel waste samples from the Halawi variety were obtained from Abu Al-Khaseeb district, Basra. The samples were subjected to cleaning and washing with distilled water to remove any impurities and dust. They were then air-dried, ground, and passed through a sieve with 0.1 micron diameter pores. The selected plastic pipes were 7.5 cm in diameter and 20 cm high, each terminating in a cone connected to a valve to regulate water outflow. To avoid escaping ash, glass wool was placed in the stem shaft of the pipettes. For this filter, the total volume of palm kernel and sand was 450 cm^3 based on proportions (25%, 50%, and 75%) of palm kernels to sand. Each filtration cycle would filter 300 cm^3 of water. Two intervals of one hour and 24 hours were used for filtration. After the set time for each water sample in the filter had elapsed, the valve was opened to draw off the treated water.

Bentonite and Sand Filter

The same method used in paragraph 3-1-2-1 was adopted

Chemical and Physical Properties of Water Samples Before Treatment

Water was collected in tightly sealed plastic containers, and physical and chemical properties of water samples were determined before treatment according to the methods described in APHA (2005) and as shown in Table 1.

Table 1. Some chemical properties of well water samples studied before treatment

Characteristics of well water samples	The attribute										
	EC	pH	HCO_3^-	CO_3^{-2}	NO_3^-	CL^-	$SO_4^=$	Na^+	K^+	Mg^{+2}	Ca^{+2}
Unit of measure	ds m^{-1}	-	mmol L^{-1}								
1	6	7.93	494.31	0	18.94	1443.71	344.46	794.85	104.51	110.66	235.43
2	10	7.01	596.67	0	20.89	1944.51	431.69	1011.23	167.04	147.77	276.83
3	16	7.46	861.48	0	24.86	3514.63	524.63	1734.51	261.27	303.29	346.82

Agricultural Experiment

A factorial experiment was conducted in the agricultural fields of the College of Agriculture, University of Basra, using a randomized complete block design (RCBD) with three factors. The first factor is the natural mineral and organic amendments (bentonite and palm kernel), the second factor is three levels of the mineral amendment (bentonite) (0, 5, 10, M0, M1, M2) megagram ha-1, and the third factor is adding three levels of the organic amendment (palm kernel) (0, 5, 10, O2, O1, O0 (megagram ha-1) in succession. The number of treatments was 18, with three replicates to reach 54 experimental units. The study soil was brought from one of the agricultural fields in the Al-Zubair area, south of Basra Governorate, from the surface layer (0-30 cm), impurities were removed, then air-dried and sifted through a sieve with a diameter of 4 mm (for planting in pots) and 2 mm. The Physical and chemical analyses of the soil were performed before planting. After harvesting, according to the methods mentioned in Page et al. (1982), Jackson (1958), and Black et al. (1965), as shown in Table 2.

Table 2. Some of the soil's chemical and physical characteristics are studied before planting

Adj.											
EC	**pH**	Ca^{+2}	Mg^{+2}	K^+	Na^+	$SO_4^=$	CL^-	NO_3^-	CO_3^{-2}	HCO_3^-	**Bulk Density**
dS m^{-1}		**mmol L^{-1}**									**Mcg m^{-3}**
5.37	7.58	6.3	4.0	0.9	6.40	8.70	5.00		0	3.0	1.36
CaCO3		**SOM**		**Cationic exchange capacity:**		**Available Nutrient**			**gm kgm^{-1}**		
						N	**P**	**K**	**Silt**	**Sand**	**Clay**
gm kgm^{-1}				**Cmol Kgm^{-1}**		mg Kgm^{-1}			766.00	101.90	132.00
163.00		0.8		4.30		24.54	6.78	40.56	Sand Loamy		

The agricultural experiment was carried out using plastic pots with dimensions of 20 cm depth and 25 cm average diameter and filled with 10 kg of dry soil during the agrarian season 2023. Two types of natural soil conditioners (palm carob and bentonite) were added and mixed with the soil at three levels for each conditioner (0, 5, and 10 mg ha-1). The pots were fertilized according to the recommendations of the Agriculture Ministry of /General Authority for Agricultural Services (1991). The pots were irrigated with tap water, and 90 days after transplanting the seedlings, the soil measurements mentioned in paragraph (3-4-1) were taken. After the plant harvest was completed, some analyses were conducted on the plant, including the root vegetative group's dry weight and the plant's total yield was calculated. The study was done in a completely random design of a 2-\text{factorial} experiment with three replications for each treatment and analyzed with variance analysis in SPSS (version 11). Means were compared using least significant differences (Al-Rawi and Khalaf Allah, 1980).

Results and Discussion

Laboratory Experiment

Effect of Filters on Electrical Conductivity (EC) of Well Water During Different Periods

The different filters used in the wells were analyzed in terms of their efficacy for the reduction of the electrical conductivity values of well water (6, 10, and 16 dS m^{-1}) over various filtration periods. Electricity conductivity was closely related to the type of filter used. The bentonite mineral filter mixed with sand at a ratio of 75% had the lowest electrical conductivity values out of the available options at 3.62, 4.66, and 6.27 dS m^{-1}, with reduction rates of 39.67%, 53.30%, and 60.81%, respectively. On the other hand, the palm kernel filter mixed with san at a 25% ratio had the highest conductivity values at 5.23, 8.60, and 11.57 dS m^{-1}, while also showing the lowest reduction rates of 12.83%, 14.00%, and 27.69%.

As the filtration continued over time, the electrical conductivity values were observed to decrease, falling from 5.07, 7.63, and 12.32 dS m^{-1}, with reduction efficiencies of 15.50%, 23.70%, and 23.00% after an hour of filtration. After 24 hours, this shifted to 4.28, 6.46, and 9.52 dS m^{-1} resulting in a further reduction efficiency of 28.67%, 35.40%, and 40.50%. This is likely to be the case, as the organic and mineral filters have specific limits in absorbing dissolved ions at a certain rate. Table 3. Electrical conductivity of wells water with an initial conductivity of 6 dS.m-1 after treating with filters

The combination of filter type and filtration time affected well water's electrical conductivity reduction for values 6, 10, and 16 dS m^{-1}. After filtering for 24 hours with a bentonite mineral filter mixed with sand at a 75% ratio, the conductivity values attained were 3.21, 5.08, and 7.69 dS m^{-1} which correspond to 46.50%, 49.20%, and 51.94% reduction rates (see Tables 3, 4, and 5). The highest value of electrical conductivity while passing the water through the palm kernel filter with sand mixed in a 25% ratio was 5.63 and 14.82 dS m^{-1} after an hour of filtration for 6 and 10 dS m^{-1} water qualities, with reduction rates of 14.50% and 7.38%. After 12 hours, the conductivity reduced to 6.94 dS m^{-1} which corresponds to a 30.60% reduction.

Table 3. Electrical conductivity of well water with an initial conductivity of 6 dS.m-1 after treating with filters

Type of filters	Filtration time (hr)			Average of filtered water
	1	12	24	
Bentonite+ Sand (25%)	5.57	5.34	5.34	5.34
Bentonite+ Sand (50%)	5.14	4.74	4.67	4.67
Bentonite+ Sand (75%)	4.42	3.63	3.75	3.75
palm kernel + +sand (25%)	5.63	5.44	5.47	5.47
palm kernel +sand (50 %)	5.47	5.21	4.72	5.13
palm kernel +sand (75%)	5.28	4.56	4.14	4.66
Time	5.25	4.82	4.44	
LSD (p=0.05)				
Type of the filter	Time			Time the ×filtered
0.04518	0.01845			0.02609

Table 4. Electrical conductivity of r wells water with initial conductivity of 10 dS.m-1 after treating with filters

Type of filters	Filtration time (hr)			Average of filtered water
	1	12	24	
Bentonite+ Sand (25%)	8.55	8.01	7.12	7.89
Bentonite+ Sand (50%)	7.02	6.63	6.23	6.63
Bentonite+ Sand (75%)	5.78	5.81	5.08	5.56
palm kernel +sand (25%)	8.61	8.63	8.47	8.57
palm kernel +sand (50 %)	7.65	6.94	6.73	7.11
palm kernel +sand (75%)	6.94	6.22	5.87	6.34
Time	7.43	7.04	6.58	7.89
LSD (p=0.05)				
Type of the filter	**Time**			**Time type of the ×filtered**
0.3854	0.2725			0.6676

Table 5. Electrical conductivity of r wells water with initial conductivity of 16 dS.m-1 after treating with filters

Type of filters	Filtration time (hr)			Average of filtered water
	1	12	24	
Bentonite+ Sand (25%)	14.12	13.78	13.09	13.33
Bentonite+ Sand (50%)	13.21	11.57	10.47	11.75
Bentonite+ Sand (75%)	10.38	8.73	7.69	8.93
palm kernel +sand (25%)	14.82	13.44	12.69	13.98
palm kernel +sand (50 %)	14.36	11.05	11.41	12.27
palm kernel +sand (75%)	9.89	9.13	8.87	9.30
Time				
LSD (p=0.05)				
Type of the filter	**Time**			**Time type of the ×filtered**
0.2306	0.1630			0.399

Calculating the Concentrations of Ions and Their Removal Efficiency Under the Influence of Filters for Well Water During Different Periods

The mineral and organic filters used in the study (F1, F2, F3, F4, F5, F6) differed in reducing the concentration of positive ions (calcium, magnesium, and sodium) and negative ions (chloride and sulfate), which was positively reflected in reducing the electrical conductivity values depending on the characteristics of the filters used and the technologies they operate with, which determine the efficiency of these filters and enable them to reduce ions in water.

Table 6 shows the effect of the type of filters on the calcium concentration in the water resulting from the treatment, where a positive effect was found for the type of filter in reducing the calcium concentration, as the efficiency of the filters used in the study varied in reducing the calcium ion concentration for the water type with initial electrical conductivity of 6, 10 and 16 dS-1 and with a calcium concentration before treatment of 235.43, 276.83 and 346.82 mg L-1, respectively, as the treatment of the bentonite filter mixed with sand at a mixing ratio of (75%) outperformed the rest of the filters under study in reducing the calcium ion concentration and obtaining the highest removal efficiency, which amounted to 76.37, 66.65 and 64.91%, respectively.

The results of Table 6 indicate the effect of the filter type on the magnesium ion concentration of well water after treatment with different initial electrical conductivity values (6, 10 and 16) dSm-1 in sequence, as the current results in reducing the magnesium concentration were taken on the previous path line (Table 6) in the general direction but with some differences in the values, as the treatment of the bentonite filter mixed with sand at a mixing ratio of (75%) outperformed the rest of the other filters when using well water with electrical conductivity of 6, 10 and 16 dS-1 and with a magnesium concentration before treatment of 110.66, 147.77 and 303.29 mg L-1 (Table 2) and a reduction ratio of 62.99, 63.06 and 65.77% (Table 6), while the palm kernel filter mixed with sand at a mixing ratio of (25%) recorded the highest concentration of magnesium ions in the treated water with a reduction ratio of 27.26%, 32.88% and 43.68% on Sequence. This is also what happened for the same ions studied above when using water with an initial electrical conductivity of 6, 10 and 16 dSm-1 (Table 6). The results also show a decrease in the removal efficiency of all ions in the treated water with increasing mixing ratio with sand. This confirms the positive role of palm kernel and bentonite in trapping positive and negative ions due to the presence of interstitial spaces and gaps within the structural composition of organic and mineral waste, thus increasing the chance of contact with the solute, which leads to trapping ions (Ali and Salem, 2012) and Al-Sofy, 2015).

Table 6. Ion concentration rates (mmol L-1) in water treated with filters with initial conductivities of 6, 10, and 16 (decimals-1) during different periods and removal efficiency (%)

EC=6										
Type of filters	**Ca^{-2}**	**Removal efficiency**	**Mg-2**	**Removal efficiency**	**Na+**	**Removal efficiency**	**$SO_4^{=}$**	**Removal efficiency**	**CL^{-}**	**Removal efficiency**
F1	132.48	43.72	77.32	30.12	363.35	54.28	255.32	25.88	393.84	72.72
F2	101.92	56.70	68.16	38.41	210.67	73.49	215.68	37.38	320.36	77.81
F3	55.63	76.37	40.95	62.99	168.29	78.82	182.46	47.03	198.39	86.25
F4	170.08	27.76	80.49	27.26	257.81	67.56	268.36	22.09	414.29	71.30
F5	82.27	65.06	65.21	41.07	236.82	70.21	210.84	38.79	322.74	77.64
F6	72.37	69.26	43.37	60.80	192.02	75.84	193.22	43.90	205.84	85.7485.74
EC=10										
Type of filters	**Ca^{-2}**	**Removal efficiency**	**Mg-2**	**Removal efficiency**	**Na+**	**Removal efficiency**	**$SO_4^{=}$**	**Removal efficiency**	**CL^{-}**	**Removal efficiency**
F1	170.74	38.32	95.14	35.61	445.39	55.95	337.96	21.71	541.37	72.15
F2	158.13	42.87	71.57	51.56	341.83	66.19	312.64	27.58	406.53	79.09
F3	92.32	66.65	54.59	63.06	211.86	79.04	210.29	51.29	238.55	87.73
F4	182.91	33.93	99.18	32.88	507.57	49.81	308.52	28.53	544.96	71.97
F5	169.05	38.93	76.21	48.42	421.28	58.33	301.38	30.18	396.44	79.61
F6	125.11	54.80	60.39	59.13	258.54	74.43	189.44	56.12	337.17	82.66
EC=16										
Type of filters	**Ca^{-2}**	**Removal efficiency**	**Mg-2**	**Removal efficiency**	**Na+**	**Removal efficiency**	**$SO_4^{=}$**	**Removal efficiency**	**CL^{-}**	**Removal efficiency**
F1	229.36	33.86	146.68	51.63	601.17	65.34	320.73	38.87	855.12	75.67
F2	180.95	47.83	117.12	61.38	385.82	77.75	241.05	54.05	598.54	82.97
F3	121.71	64.91	103.79	65.77	194.32	88.79	153.95	70.65	265.98	92.43
F4	261.63	24.56	170.82	43.68	697.35	59.79	313.48	40.24	931.56	73.49
F5	221.56	36.11	114.15	62.36	515.13	70.30	204.94	60.93	678.34	80.69
F6	154.99	55.31	99.16	67.30	249.51	85.62	120.51	77.02	357.89	89.82

Agricultural Experiment

The Effect of Adding Conditioners on the Electrical Conductivity of Field Soil After Harvest

As shown in Table 7, the type of conditioner used has a remarkable effect on the electrical conductivity values in sandy field soil. The addition of bentonite surpassed the palm kernel treatment with average decreases of 4.49 and 5.31 dS m^{-1}, which is a reduction rate of 15.44%. The improvement noticed perhaps is due to conditioners having significant effects on the physical, chemical and biological characteristics of the soil such as increasing soil moisture content, which diminishes the negative impacts of salts and enhances the soil's porosity, which works to increase the washing of salts, especially sodium and chloride ions from the soil profile, causing a reduction in the electrical conductivity values of the soil (Jena and Kabi, 2012). The results also show that there is a significant effect of the level of adding the conditioner on the electrical conductivity values of the soil, as all treatments to which it was added outperformed The reformer compared to the comparison treatment, as the electrical conductivity values for the reformer level treatments reached 4.86 and 3.57 dSm-1 for the addition level of 5 and 10 tons ha-1 respectively, while the conductivity value for the comparison treatment (without addition) reached 6.28 dSm-1 with a reduction rate of 22.62 and 43.15% with the comparison treatment respectively as the level of 10 tons ha-1 outperformed the level of 5 tons ha-1 with a reduction rate of 26.54%. The decrease in electrical conductivity values of sandy soils with the increase in the addition of bentonite is likely due to the mineral's capability to increase the moisture level of the soil. This is brought about by the extensive ability of bentonite crystals to adsorb water, causing the reduction of salt concentration in the soil solution. This effect becomes more pronounced as more bentonite is incorporated into the soil (Czaban et al., 2014; Abd-Alkany, 2009). Also, the reason for the decrease in the electrical conductivity of the soil may be attributed to the presence of Palm ash improves the physical properties of the soil including soil porosity and apparent density as mixing plant waste with soil at different levels leads to improving the soil structure, as organic waste is characterized by low specific weight and increased specific surface area (Ali and Shaker, 2018).

Table 7. Effect of type and level of amendment (ton ha-1) on electrical conductivity values of the study soil after harvest

Type of amendment	**Addition level (tons/ha-1)**			**Average of the amendment**
	0	5	10	
Bentonite	6.28	4.17	3.02	4.49
palm kernel	6.28	5.54	4.11	5.31
Addition level	6.28	4.86	3.57	
LSD (p=0.05)				
Type of amendment	**Addition level**			**Type of amendment x Average of amendment**
0.0355	0.0435			0.0616

The results of Table 7 show that there is a significant effect of the interaction between the type of amendment and the level of addition on the values of the electrical conductivity of the soil as it is clear that the significant decrease in the values of the electrical conductivity of the bentonite treatment compared to the palm kernel treatment varies according to the level of addition of the amendment. The bentonite amendment at the level of addition of 10 tons ha-1 and the palm kernel amendment at the level of addition of 10 tons ha-1 outperformed the comparison treatment without addition, as the value of the electrical conductivity reached 3.02 and 4.11 dSm-1, respectively while the comparison treatment without addition gave the highest value of 6.28 dSm-1. These results agree with what was reached by Abdul Ghaniet al (2009). who confirmed the existence of a significant decrease in the values of the electrical conductivity of the soil with the increase in the rates of added bentonite (0, 2, 4 and 6%), with a reduction rate of 18.2, 14.4 and 29.2%.

The Effect of Adding Conditioners on the Degree of Field Soil Reaction After Harvest

Table 8 shows that the pH values of the soil were significantly different between the treatments (bentonite and palm kernel amendments), even though the pH values of the soil presented the same magnitude between the two soil amendments. The results also showed an increase in pH with the bentonite treatment versus the palm kernel treatment. The results showed a significant effect of the rate of application of the amendments on soil pH, since all levels of amendments at 5 and 10 tons per hectare improved pH in comparison to the control treatment (no amendments). With the levels of amendments (bentonite or palm kernel) added at a rate of 5 tons or 10 tons per hectare, pH increased with higher amendment application in the sandy mixed soil. These results agreed with Semalulu (2015), who showed an increase in pH of sandy soil when bentonite levels rose from 0% to 20%. This increase in pH could have been due to either the chemical or organic nature of the enhancement to pH when organic sources are added to soil. The results in Table 8 also demonstrate that there is a significant interaction effect of the kind of amendment and the application rate on soil reaction as we observe that there is an increase in the value of the soil reaction with the increase in the amount of bentonite added (5 and 10 tons ha-1) in the soil growing tomato plants, which reached 7.84 and 7.95, respectively, compared to the control (7.58) as the pH value increased with an increase in the level of conditioner added and that is what was found by Osman et al (2008).

Table 8. Effect of type and level of amendment (ton ha-1) on the degree of reaction of the study soil after harvest

Type of amendment	**Addition level (tons.ha^{-1})**			**Average of the amendment**
	0	5	10	
Bentonite	7.58	7.84	7.95	7.79
palm kernel	7.58	7.68	7.71	7.67
Addition level	7.58	7.76	7.83	
LSD (p=0.05)				
Type of amendment	**Addition level**			**Type of amendment x Average of amendment**
0.0205	0.0251			0.0355

The Role of Amendments (Bentonite and Palm Kernel) in the Availability of Nutrients in the Soil After Harvest

Available Nitrogen

Table 9 shows that the amendments have varying effects on the soil content of available nitrogen. The bentonite amendment was particularly notable for its capacity to achieve the maximum available nitrogen concentration in sandy soil, at 43.48 mg kg-1.

The superiority of the bentonite over the organic amendment (palm kernel) noted can be attributed to its capacity to favor nutrient utilization particularly for nitrate and ammonium ions. Bentonite not only increases nitrogen absorption but also boosts the release of ammonium ions (NH+4) in the soil. As a 2:1 clay mineral, having water molecules intervening between its layers causes it to release ammonium ions (Minhal et al., 2020).

The results indicate an increasing trend in the amount of available nitrogen in soil with higher rates of applied amendment (5 and 10 tons ha-1) as illustrated in Table 8. This highlights the contribution of mineral and organic amendments in controlling nitrogen levels in soil to ensure its sustained availability to plants, which constitutes an essential indication of soil fertility.

The result concurs with findings generated by Yssaadet al. (2011), who demonstrated a marked increase in the level of available nitrogen ions in sandy soil with higher rates of applying natural bentonite. They attributed this effect to the ability of clay minerals to reduce nitrogen leaching through ammonium adsorption onto bentonite surfaces.

Besides, the results presented in Table 8 show a significant interaction between the rate of application and the type of amendment applied to the sandy mixed soil concentration of available nitrogen. Especially the application of bentonite at a dose of 10 tons ha-1 well exceeded the organic fertilizer (palm kernel) with the highest content of nitrogen in the soil treated with 56.65 mg kg-1. Conversely, the content of nitrogen with bentonite applied at a dose of 5 tons ha-1 was 49.25 mg kg-1 soil.

Table 9. Effect of type and level of amendment (ton ha-1) on available nitrogen values (mg kg-1 soil) of the study soil after harvest

Type of amendment	**Addition level (tonsha^{-1})**			**Average of the amendment**
	0	5	10	
Bentonite	24.54	49.25	56.65	43.48
palm kernel	24.54	39.36	44.88	36.26
Addition level	24.54	44.31	50.77	
LSD (p=0.05)				
Type of amendment	**Addition level**			**Type of amendment x Average of amendment**
0.423	0.518			0.732

Available Phosphorus

The results in Table 10 reveal a distinction in the content of available phosphorus in the sandy soil mixture at the close of the cropping season based on the type of amendments used. The bentonite treatment had a better performance than palm kernel treatment, having phosphorus contents of 20.40 and 17.21 mg kg-1, respectively. The superiority of the bentonite amendment is probably because it can retain and accumulate phosphorus ions within its channels. The mineral has numerous cavities and channels, making it more efficient at retaining and holding onto ions within the soil or environment and not losing them through filtration. Besides, it encourages the gradual release and higher solubility of phosphorus into the soil solution when needed, which is one of the very significant characteristics of clay minerals that renders phosphorus more accessible in the soil (Sitthaphanitet al., 2010; Iskanderet al., 2011).

Overall, the results indicate that available phosphorus in the soil increased with ascending rates of the amendments (bentonite and palm kernel) applied at 5 and 10 tons ha-1rates of application. Particularly, 10 tons ha-1rate of application gave the highest concentration of available phosphorus in the amended soils as much as 29.49 mg kg-1(Table 10). The results are in close conformity with findings from Czaban and Siebielec (2013).

Furthermore, the results in Table 10 indicate that there is a significant interaction effect of the amendment type and rate added to the soil on the concentration of available phosphorus. The 10 tons ha-1 bentonite amendment treatment outperformed the remaining treatments, with the highest available phosphorus values of 32.03 mg kg-1. It was preceded by the palm kernel amendment at the same level of application, which reached 26.94 mg kg-1 compared to the control treatment without addition, which reached 10.57 mg kg-1. These results indicate that all of the factors being investigated have a positive effect on soil phosphorus availability, which is in agreement which is in agreement with the findings of Khalaf and Al-Galbi (2019).

Table 10. Effect of type and level of amendment (ton ha-1) on the values of available phosphorus (mg kg-1 soil) for the study soil after harvest

Type of amendment	Addition level (tonsha^{-1})			Average of the amendment
	0	5	10	
Bentonite	10.57	18.59	32.03	20.40
palm kernel	10.57	14.11	26.94	17.21
Addition level	10.57	16.35	29.49	
LSD (p=0.05)				
Type of amendment	**Addition level**			**Type of amendment x Average of amendment**
0.424	0.519			0.734

Available Potassium

The information presented in Table 11 demonstrates that the content of ready potassium in sandy mixed soil is quite different based on the types of amendments used. Bentonite amendment treatment recorded the best with potassium content at 198.72 mg kg-1 of soil, which was significantly higher than palm kernel amendment treatment with a concentration of 168.48 mg kg-1 of soil. This advantage of the bentonite amendment is due to the high adsorption capacity of the clay mineral and the capacity of the clay mineral to regulate the ion exchange process in the soil, serving as a reservoir of nutrients and a slow fertilizer supplier (Tangmitcharoen et al., 2012).

Moreover, it was observed that the amount of available potassium in the soil was greater with greater amounts of added bentonite and palm kernel (5- and 10-tons ha-1), respectively, as evidenced from Table 11. This indicates the importance of such amendments in maintaining potassium content in the soil, making it accessible to plants, and this is a critical soil fertility indicator. These results are in line with those of Al-Bassiam et al. (2009), who reported a significant rise in the concentration of potassium available in sandy soil with the rising rates of bentonite use, noting an 168% rise at the 30% level compared to other levels of application.

In addition, the findings presented in Table 11 show a significant interaction effect of amendment type and application rate on the concentration of available potassium in the soil. The bentonite amendment with an application rate of 10 tons ha-1 showed significantly better performance than the other treatments, with a maximum available potassium value of 312.68 mg kg-1 of soil. This was followed by the palm kernel amendment, also 10 tons ha-1, with a total of 267.49 mg kg-1 of soil. Greater potassium availability in the bentonite amendment might be behind its improved performance. These results align with Minhal et al. (2020).

Table 11. Effect of type and level of fertilizer (ton ha-1) on available potassium values (mg kg-1 soil) of the study soil after harvest

Type of amendment	Addition level (tonsha^{-1})			Average of the amendment
	0	5	10	
Bentonite	40.56	242.91	312.68	198.72
palm kernel	40.56	197.39	267.49	168.48
Addition level	40.56	220.15	290.09	
LSD (p=0.05)				
Type of amendment	**Addition level**			**Type of amendment x Average of amendment**
1.026	1.256			1.776

Total Yield

The results of Table 12 reveal that the amendment factor has a significant influence on the total yield of tomato (megagram ha-1), as the amendment treatments differed in their influence on the total yield of the plant, as the bentonite amendment treatment outcompeted the other amendments and achieved an overall yield rate of 506.02 gm-1.

The overall yield increase can be attributed to the amount of major nutrients such as nitrogen, phosphorus, and potassium provided by the amendments and their promotion of availability, which raised the absorption processes of the elements, which stimulated the process of photosynthesis and, in turn, the increase in the synthesis of nutrients in the leaves and their translocation to the fruits (Zhou et al., 2016).

The results also indicated that the total plant yield continues to increase with the increasing level of the amendment applied (5- and 10-tons ha-1) respectively, Table 12, which indicates the contribution of amendments in increasing the productivity of plants cultivated in sandy soils, as the 10 tons ha-1 level provided the maximum yield of the plant, having a value of 618.43 gm. As-1, with an increasing percentage of 22.34 and 181.71% over the 5 tons ha-1 level and the comparison treatment, respectively. The 5-ton ha-1 level also recorded an increasing percentage of 130.27% over the comparison treatment. These results are consistent with those reached by Shaheen et al. (2013) and El-Etr and Hassan (2017). The results presented in Table 12 show there is a significant interaction effect of amendment type and level of application on the overall yield of tomato plants grown in sandy soils. The 10 tons ha-1bentonite amendment performed better than the rest of the amendments, with the highest yield per plant in the treated soil, at 720.45 g. Comparatively, the 5 tons ha-1 bentonite amendment and 5 tons ha-1 palm kernel amendment yields were 578.10 g and 516.40 g, respectively. The findings are in line with the results concluded by Abbas et al. (2018).

Table 12. Effect of the type and level of amendment (ton ha-1) on the total yield of tomato plants (gm. As-1) grown in the study soil

Type of amendment	Addition level (tonsha^{-1})			Average of the amendment
	0	5	10	
Bentonite	219.52	578.10	720.45	506.02
palm kernel	219.52	432.90	516.40	389.61
Addition level	219.52	505.50	618.43	
LSD (p=0.05)				
Type of amendment	**Addition level**			**Type of amendment x Average of amendment**
0.593	0.727			1.028

Conclusion

The laboratory and field experiments conducted at the University of Basra demonstrated the significant impact of both filter types and soil amendments on water quality and soil fertility. The results revealed that a bentonite filter mixed with sand at a 75% ratio, when used for 24 hours, effectively reduced water salinity and improved water quality for irrigation, particularly in tomato cultivation. Furthermore, the study highlighted the beneficial effects of bentonite and palm kernel oil amendments on sandy soils, with bentonite proving to be more effective in enhancing soil properties such as pH and nutrient content. The highest levels of available nitrogen, phosphorus, and potassium, along with improved plant growth and higher yields, were observed in soils treated with 10 tons per hectare of bentonite. Overall, the findings suggest that both the use of bentonite filters for water treatment and the application of bentonite amendments can significantly enhance agricultural productivity in sandy soils.

Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

All authors' contributions are equal for the preparation of research in the manuscript.

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