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Effect of Wetting and Drying Cycles on Soil Properties under Irrigation with Water of Varying Salinity Concentration

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study examines the impact of alternating wetting and drying cycles, typical of field irrigation, on soil chemical properties under different salt concentrations. It focuses on how these cycles, combined with high thermal conditions, affect soil fertility and structure, especially in summer, The aim was to assess the effect of wetting and drying cycles on the soil's chemical properties, focusing on the influence of varying salinity levels in irrigation water,This study was conducted at five sites in Nineveh Governorate, northern Iraq, selected for soil texture variation. Surface soil samples were collected from the (0-20) cm depth, and both chemical and physical analyses were performed. Soil columns were also irrigated with well water at different salinity concentrations. Soil underwent ten cycles of wetting and drying, each lasting ten days. After the final cycle, samples were taken for

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chemical analysis to evaluate changes in properties such as electrical conductivity, pH, ion concentrations, calcium carbonate, and cation exchange capacity, Results indicated that wetting and drying cycles increased electrical conductivity, decreased soil pH, and raised ion concentrations. Calcium carbonate content decreased, while cation exchange capacity and structural stability increased. Organic matter remained unchanged.

Keywords: Humidification; drying; salt concentration; dispersion.

1. INTRODUCTION

Soils naturally go through cycles in the field of wetting and drying depending on the climate and topography of the region, which affects their chemical and physical properties, such as the balance of ions, states of oxidation, reduction, dissolution, and sedimentation, as well as the dispersion and stability of aggregates. The process of repeated irrigation (wetting and drying) and rainfall contribute to influencing soil properties, such as dissolution Limestone, the expansion and contraction of soil masses, and the decrease in the percentage of soil aggregates (Wang et al., 2020). The study of the transfer of water and salts through the soil bed is one of the important topics that is related to the chemical and physical properties of the soil. This may occur during two stages of flow, namely saturated and unsaturated, and most of the interference Between the solid phase, which includes soil particles, and the liquid, represented by water and dissolved salts, occurs under unsaturated conditions, which affects the overall processes in the root zone (Schindler et al., 2010). The process of successive irrigation cycles has an effect on the chemical and physical properties of the soil by causing the expansion and contraction of various soil aggregates, and this affects the movement of water within the porous medium. The presence of different concentrations of dissolved salts has an effect in causing a change in the chemical and physical properties of the soil. When there is a high concentration of Sodium ions in irrigation water increases electrical conductivity and thus causes dispersion of soil particles and deterioration of its structure (Al-Obaidi et al., 2017).

The quality and quantity of irrigation water greatly affect the composition of the exchange complex and the concentration of ions in the soil solution, the study conducted by Al-Rawi and Al-Hadidi, (2022) showed a decrease in the values of the degree of interaction of the washing water of soil columns with an increase in the number of irrigation cycles (wetting and drying), and this was attributed to the reason This is due to the role of the released salts in influencing the values of the degree of interaction, as well as an increase in the values of the degree of electrical conductivity of the washing water resulting from an increase in the release of ions with the washing water due to ion exchange processes between the solid and liquid phases of the soil. Al-Sultani (2015) used three types of water (River water, well water, and tap water) to study the effect of the ionic strength of these waters in dissolving and washing calcium carbonate. The results showed that tap water with a high ionic strength led to the washing of small amounts of carbonates compared to river water with a low ionic strength, and showed that the efficiency of fresh water for the washing process Once this water enters the interstitial pores of the soil, it will be free of any ionic pairs, so its energy for displacement will be high, especially the calcium ion, which is one of the difficult ions to liberate when treated with water with high ionic strength, because these salts have the ability to form ionic pairs, which obstructs the dissolution process and reduces the dissolution yield (Al-Kattan, 2023) concluded in his study the effect of wetting and drying cycles on the behavior of positive basic ions in two soils, the first with a sandy clay mixture texture and the second a mixture using two types of water, the first river water and the second well water in order to know the effect of the ionic strength of irrigation water. In the case of equilibrium, the values of the dissolved and exchanged basic positive ions decreased with the increase in the number of wetting and drying cycles, with the exception of the sodium ion, which had a different behavior from the rest of the ions, and the ionic strength of the water had a clear effect through an increase in the amount of ions released when using well water compared to Its quantity when using river water for all wetting and drying cycles and in the two study soils. Given the alternating wetting and drying conditions in our soil, which is surrounded by harsh thermal conditions, which makes it susceptible to rapid drying and the need for re-irrigation, especially in the summer, this study came from this standpoint, which aims to know the effect of wetting and drying cycles similar to actual irrigation operations in the field and using fresh water. different salt concentration on soil physico-chemical properties (Al-Hadeth and Falahi, 2019).

2. MATERIALS AND METHODS

2.1 Locations

Five sites were chosen within Nineveh Governorate basis of the variation in texture variation (Table 1). The sites include: the first site with silty clay loam, the second with clay loam, the third with clay, the fourth with loam, and the fifth with silty clay Samples were taken. Soil samples were collected from each site for laboratory analysis taking natural, undisturbed soil columns to a depth of (20 cm) These samples were treated with well water having salt concentrations of 1, 5, and 10 dS.m^{-1}, and subjected to ten cycles of wetting and drying.

2.2 Laboratory Tests

Chemical and physical analyses were conducted on soil and well water samples in the laboratories of the Department of Soil Sciences and Water Resources/College of Agriculture and Forestry/University of Mosul according to the methods described by Salem and Ali (2017), Soil samples were air-dried, ground, and sieved through a 2 mm. A soil extract was made with a ratio of (1:1) distilled water: soil. The degree of reaction was measured using a pH-meter and the electrical conductivity using an EC-meter. The ions were estimated as follows: Calcium and magnesium using the electrophoresis method with ferricin M (0.01), sodium and potassium. using a Flame Photometar device, the chloride ion was determined by electrophoresis with silver nitrate M(0.01), carbonate and bicarbonate by titration with dilute sulfuric acid (0.01 M), and sulfate by precipitation using barium chloride.

Calcium carbonate was determined by adding an excess amount of hydrochloric acid (1.0N). The remaining acid was estimated by elution with sodium hydroxide (1.0 M) in the presence of pH evidence. The organic matter was determined by the wet oxidation method using potassium dichromate (1.0 N) according to Walkley and Blak mentioned in (Black, 1965b) The exchange capacity of positive ions was estimated using sodium acetate (1.0M) with PH = 8.2), and the sodium in the extract was measured, and from it the CEC was calculated according to Page et al, (1982). The hydrometer method was used to estimate the soil texture according to Gee and Bauder, (1986), and the Cation Ratio of Soil Structural Stability (CROSS) values were calculated according to Marchuk et al., (2013) using the following equation:

$$CROSS = \frac{Na+0.56}{\sqrt{(Ca+0.6Mg/2)}} \qquad (1)$$

Table 1. The geographical location of the study sites

No.	location	Geographical location	Land use
1	Bieuza	36º 2551.42 "◌́N 43º 0943.99 "E	field crops
2	Tal Zalat	36º.1612.75 "◌́N 42º 4940.29 "E	field crops
3	Hamam Al-Alai	35º 0927.16 "◌́N 43º 1451.84 "E	field crops
4	Qayyarah	36º 4755.54 "◌́N 43º 1730.41 "E	field crops
5	Talkif	35º 2859.2 "◌́N 43º 0633.76 "E	field crops

Table 2. Values of electrical conductivity, degree of reaction, and dissolved ions for soil samples before wetting and drying

No.	Location	pH	EC	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{-2}
			dS m^{-1}	meq l^{-1}						
1	Bieuza	7.6	0.6	5.0	1.5	0.6	0.3	2.0	1.0	4.4
2	Tal Zalat	7.7	0.8	5.5	1.0	0.7	0.2	1.0	1.0	5.4
3	Hamam Al-Alaiel	7.4	2.5	25.0	2.5	1.1	1.1	3.5	1.0	25.2
4	Qayyarah	7.1	3.4	30.5	15.0	8.1	1.5	6.0	1.0	48.1
5	Talkif	7.9	0.8	5.0	1.5	0.7	0.2	1.5	1.0	4.7

Table 3. Some chemical and physical properties of the study soil samples before wetting and drying

Location No.	$CaCO_3$	O.M	CEC	CROSS	Clay	Silt	Sand	Textuer
	gm kg^{-1}			mmol$_c$ l^{-1}	gm kg^{-1}			
first	320	20.0	27.0	0.68	370	460	170	S-C-L
second	300	11.4	26.0	0.72	300	475	225	C-L
third	275	8.6	23.1	0.45	450	350	200	C
fourth	210	12.2	25.6	1.98	225	325	450	L
fifth	360	14.0	30.0	0.73	415	410	175	S-C

Table 4. Some chemical properties of well water samples used in the study

Well No.	EC ds.m^{-1}	pH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{-2}
			mmol$_c$ l^{-1}						
1	1.0	7.4	3.5	1.5	5.2	0.05	5.5	0.5	4.3
2	5.0	7.8	13.5	18.5	17.4	0.30	10.0	2.0	19.8
3	10.0	7.9	28.5	35.5	34.3	0.60	64.0	6.5	28.4

2.3 Preparing and Preparing Soil Columns

Natural, undisturbed soil columns were taken from the selected study sites. Plastic columns were used with an internal diameter of (10 cm) and a length of (20 cm). The inner wall of each column was coated with silicone oil to reduce the effect of the walls on water flow, and a base with a diameter slightly larger than the outer diameter was placed at the bottom of the column. The column has a screen wire installed inside it, the diameter of its holes is (0.1 mm) to prevent the passage of large soil particles. Glass wool and gravel washed with 1M HCl acid and with a thickness of (0.3 cm) are used as a filter. The columns are then placed on a wooden stand and the columns are then treated with well water based on Pore size and ten cycles of wetting and drying. The duration of each cycle is ten days. After the end of the tenth cycle of wetting and drying processes, soil samples were taken from columns treated with water with different salt concentrations to conduct chemical analyzes on them and compare them with the properties of the soil before treating it with water in order to identify the effect of the wetting and drying processes.

3. RESULTS AND DISCUSSION

The results are showned in Table (5) of the electrical conductivity values, the degree of interaction, and the positive and negative dissolved ions of the equilibrium from soil column after the tenth wetting and drying cycle, where an increase in the electrical conductivity values was observed form all study sites, and that the increase was proportional to each site with the increase in the salt concentration of the water used, as it reached the lowest value was (1.6) m-1.dS in the first location treated with water with a salt concentration of (1.0) dS m^{-1}, while the highest value of electrical conductivity was (13.5) dS m^{-1} in the third location treated with water with a salt concentration (10.0).) dS m^{-1}. The reason for this is the role of salts liberated with the washing water due to ion exchange processes between the liquid and solid phases of the soil, as well as the variation of the soil in electrical conductivity and texture (Tables 2 and 3), while the wetting and drying processes led to a reduction in the degree values. The lowest value of the degree of interaction was (6.8) in the fourth site treated with water with a salt concentration of (1.0) dS m^{-1}, while the highest value of the degree of interaction was (7.5) in the third site treated with water with a salt concentration of (10.0) dS m^{-1}. The reason for this cold be due to the role of the released salts in influencing the values of the degree of interaction, as well as an increase in the values of the degree of electrical conductivity of the washing water resulting from an increase in the release of ions with the washing water due to ion exchange processes between the liquid and solid phases of the soil, and this is consistent with (Al-Rawi and Al-Hadidi, 2022). and the results indicate an increase in the values of positive and negative dissolved ions. The smallest increase in calcium ion values was (7.5) mmolc l^{-1} in the first site treated with water with a salt concentration of (1.0) dS m^{-1}, while the highest increase in calcium values was (74.0) mmol$_c$ l^{-1} in the second site treated with water with a salt concentration of (10.0) dS m^{-1}, while the smallest increase in

Table 5. Values of electrical conductivity, soil (pH) and dissolved ions of soil samples after the tenth wetting and drying cycle

Location No.	EC ds.m^{-1}	pH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{-2}
		mmol$_c$ l^{-1}							
Site 1	1.6	7.2	7.5	5.0	1.5	0.5	8.0	1.2	5.4
	6.1	7.1	26.5	18.5	10.5	0.7	42.5	1.5	12.6
	12.1	7.0	60.0	27.0	25.0	1.0	101.0	2.5	10.5
Site 2	1.8	6.9	12.5	6.0	1.4	0.2	10.0	0.8	9.5
	6.0	7.1	39.0	11.0	10.8	0.4	42.5	1.2	17.5
	12.2	7.3	74.0	23.0	25.2	0.6	101.0	1.8	20.2
Site 3	3.2	7.1	32.5	7.5	2.2	0.2	11.5	1.0	30.0
	7.2	7.2	39.0	18.0	13.4	0.9	51.0	2.0	18.3
	13.5	7.5	48.0	44.5	25.5	1.3	102.5	2.7	14.7
Site 4	2.8	6.8	16.0	9.5	2.2	0.8	10.0	0.7	17.8
	6.7	6.9	21.0	26.5	12.6	0.8	36.0	1.7	23.2
	11.5	7.1	39.0	43.5	18.7	1.4	82.0	2.5	18.0
Site 5	1.8	7.2	12.5	4.5	1.3	0.1	9.5	1.0	8.0
	6.8	7.1	45.0	9.0	12.0	0.2	53.5	1.0	18.5
	11.1	7.2	54.0	20.0	22.4	0.4	102.5	1.3	10.0

magnesium ion values was (4.5) mmol$_c$ l^{-1} in the site. this sentence is not connected to any information (Farzamian et al. 2019).

The highest increase in magnesium values was (44.5) mmol$_c$ l^{-1}in the third site treated with water with a salt concentration of (10.0) dS m^{-1}, while the smallest increase in sodium ion values was (1.3) mmol$_c$ l^{-1}in the fifth treated site. with water with a salt concentration of (1.0) m-1.dS, while the highest increase in sodium values was (25.5) mmol$_c$ l^{-1}in the third site treated with water with a salt concentration of (10.0) dS m^{-1}, while the smallest increase was in the values of Potassium ion was (0.1) mmol$_c$ l^{-1} in the fifth site treated with water with a salt concentration of (1.0) dS m^{-1}, while the highest increase in potassium values reached (1.3) mmol$_c$ l^{-1}in the third site treated with water with a salt concentration of (10.0).) dS m^{-1}, while the smallest increase in chloride ion values was (8.0) dS m^{-1}in the first site treated with water with a salt concentration of (1.0) dS m^{-1}, while the highest increase in chloride values was (102.5) dS m^{-1}in the third and fifth sites treated with water with a salt concentration of (10.0) dS m^{-1}, while the smallest increase in bicarbonate ion values was (0.7) mmol$_c$ l^{-1} in the fourth site treated with water with a salt concentration of (1.0) dS m^{-1}, while the highest increase in bicarbonate values was (2.5) mmol$_c$ l^{-1}in the first and fourth sites treated with water with a salt concentration of (10.0) dS m^{-1}, while the smallest increase in sulphate ion values was (5.4) mmol$_c$ l^{-1} In the first site treated with water with a salt concentration of (1.0) dS m^{-1}, while the highest increase in sulphate values reached (30.0) mmol$_c$ l^{-1} in the third site treated with water with a salt concentration of (1.0) dS m^{-1}, the results above, indicated a clear discrepancy in the values of positive and negative dissolved ions from the soils of this study, and this depends on the properties of the soil in terms of the degree of electrical conductivity, texture, and organic matter, in addition to the increase in the salt concentration of the water used, as we notice the smallest increase in ion values occurred in the first and fifth locations, and the highest increase in values occurred in the third and fourth sites with high electrical conductivity and high content of separated clay, and this is consistent with the findings of Al-kattan, (2023).

The results in Table (6) showed that the wetting and drying processes led to a decrease in the values of calcium carbonate ($CaCO_3$) for all soil sites, and that the delete decrease was when water with a salt concentration of (10.0) dS m^{-1} was used. This is due to the effect of the electrolytic concentration of salts in the processes. Weathering and dissolution of carbonate minerals, especially calcium carbonate, as it is one of the factors that control this occurrence, as it is consistent with the dissolution rate of each carbonate mineral. These results are consistent with what was reached by Al-Obaidi et al., (2019). The results also showed a difference in the values of calcium carbonate with different soil textures. The soil content is calcium carbonate, so the dissolution

Table 6. Some chemical properties of soil samples after the tenth wetting and drying cycle

Location No.	EC ds.m^{-1}	pH	CaCO$_3$	O.M	CEC	CROSS
			gm kg^{-1}		Cmol$_c$ l^{-1}	mmol$_c$ l^{-1}
Site 1	1.0	7.4	322	20.1	27.0	0.90
	5.0	7.8	314	20.2	29.2	2.55
	10.0	7.9	306	20.0	31.5	4.14
Site 2	1.0	7.4	303	11.3	26.3	0.69
	5.0	7.8	288	11.2	27.8	2.38
	10.0	7.9	282	11.3	28.4	3.89
Site 3	1.0	7.4	278	8.5	23.3	0.64
	5.0	7.8	264	8.7	24.2	2.80
	10.0	7.9	257	8.6	25.7	4.21
Site 4	1.0	7.4	214	12.4	25.2	0.83
	5.0	7.8	208	12.2	26.6	3.08
	10.0	7.9	203	12.3	27.3	3.37
Site 5	1.0	7.4	362	14.1	30.3	0.67
	5.0	7.8	354	14.0	32.2	2.51
	10.0	7.9	341	14.2	33.7	4.00

of calcium carbonate depends on the ionic strength of the water used for dissolution, with the availability of conditions that help dissolution to occur, including salinity, CO$_2$ pressure, temperature, and degree of soil interaction. Ionic strength and salinity have a role in influencing the dissolution and precipitation of carbonates. Increasing salinity will reduce the speed of carbonate deposition (Al-Shamaa, 2023, Waleed et al. 2017). However, the soil content of organic matter treated with water with a salt concentration did not change with the soil being exposed to cycles of wetting and drying, and this is consistent with what was obtained (Farouk et al, 2017), and it is noted from the results in Table (6): An increase in the values of the cation exchange capacity (CEC) with an increase in the salt concentration of the water used for all sites. The reason for this is attributed to the dissolution of calcium carbonate with an increase in the salt concentration of the water used, which led to the exposure of the surfaces and thus an increase in the surface area and then an increase in the values of the exchange capacity. Cationic acidity of the soil treated with this water, and this is consistent with what was indicated by Williams et al, (2007).

The results in Table (6) showed an increase in the values of Cation Ratio of Soil Structural Stability (CROSS) after the tenth cycle of wetting and drying and with an increase in the salt concentration of the water used. This standard is one of the standards used recently to measure dispersion, The highest values were when wetting with water with a salt concentration of (1.0) dS m^{-1}, and the highest values were when using water with a salt concentration of (10.0) dS m^{-1}, as high values of CROSS indicate the occurrence of high dispersion compared to low values, and this indicates the role of sodium in the dispersion process and thus the degradation process in soil construction (Marchuk, 2013).

4. CONCLUSION

1. Knowing the effect of the interaction between the wetting and drying cycles for its importance in managing irrigation, soil salinity, and the chemical and physical properties of the soil.
2. Proper water management and controlling thermal conditions are important in reducing salinity stress, preserving the soil environment, and ensuring sustainable crop growth.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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