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EFFECT OF IRRIGATION WITH WATER TREATED WITH NANOMATERIALS ON PLANT HEIGHT AND DRY WEIGHT YIELD OF BARLEY (HORDEUM VULGARE L)

T. A. Hamid **A. Marzoog** *

College of Agriculture - University of Anbar

***Correspondence to:** A. Marzoog., Department of Soil Science and Water Resources, College of Agriculture, University of Anbar, Ramadi, Iraq.
Email: ahmed.mohammed@uoanbar.edu.iq

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Abstract

A potting experiment was carried out to determine the impact of water treated with nanomaterials (nano zero-valent iron, nano-carbon, nano-clay, Portland cement, white cement) and Euphrates River water compared with untreated water (Haditha diesel power plant water) on plant height and dry weight yield of the barley crop *Hordeum Vulgar* L. A factorial experiment was applied according to RCBD design using two factors (water quality and two soil types) with three replicates. The results showed that the desert soil was superior to sedimentary soil in plant height and dry weight by 8.53 and 16.67%, respectively. As for water treatments, water treated with nZVI, P cement, w cement, n carbon, and n clay were superior at 15.82, 13.77, 11.31, 9.24, and 3.08%, respectively, compared to untreated water. There were significant differences in terms of dry weight with increases of 34.43, 32.67, 31.02, and 31.02% for each of the water treated with n clay, water treated with P cement, water treated with w cement, and water treated with n carbon, respectively, compared to the untreated water. As for the water treated with nZVI, it harmed dry weight. The dry weight decreased by 43.12% compared to the dry weight of untreated water. The results also showed that the plant leaves were free of cadmium.

Keywords: Oil wastewater, Nano zero valent iron, Nano carbon, Nano clay, Cement.

تأثير الري بالمياه المعاملة بالمواد النانوية في ارتفاع النبات وحاصل الوزن الجاف لنبات الشعير (Hordeum Vulgare L)

تسنيم عادل حامد أحمد مرزوك *

كلية الزراعة – جامعة الانبار

***المراسلة الى:** احمد مرزوك محمد، قسم التربة والموارد المائية، كلية الزراعة، جامعة الانبار ، الرمادي، العراق.

البريد الالكتروني: ahmed.mohammed@uoanbar.edu.iq

الخلاصة

نفذت تجربة اصص لدراسة تأثير المياه المعالجة بالمواد النانوية (الحديد النانوي الصفري، الكاربون النانوي، الطين النانوي، الاسمنت البورتلاندي، الاسمنت الابيض) ومياه نهر الفرات ومقارنتها مع المياه غير المعالجة (مياه محطة كهرباء ديزلات حديثة) في ارتفاع النبات وحاصل الوزن الجاف لمحصول الشعير Hordeum Vulgare L وعلى وفق تصميم القطاعات الكاملة المعشاة RCBD وباستخدام عاملين العامل الاول نوعية المياه والعامل الثاني تربتين وبثلاث مكررات، اظهرت نتائج التجربة تفوق التربة الصحراوية على التربة الرسوبية في ارتفاع النبات والوزن الجاف وبنسبة (8.53 و16.67)% على التوالي. اما بالنسبة لمعاملات المياه فقد تفوقت معاملات المياه المعالجة بكل من الحديد النانوي الصفري والاسمنت البورتلاندي والاسمنت الابيض والكاربون النانوي والطين النانوي بنسبة 15.82 و13.77 و11.31 و9.24 و3.08% بالتتابع مقارنة مع المياه غير المعالجة، كما أظهرت النتائج فروقات معنوية بالنسبة للوزن الجاف وبنسبة زيادة 34.43 و32.67 و31.02 و31.02% لكل من المياه المعالجة بالطين النانوي والمياه المعالجة بالاسمنت البورتلاندي والمياه المعالجة بالاسمنت الابيض والمياه المعالجة بالكاربون النانوي بالتتابع مقارنة بالمياه غير المعالجة، وفي ما يخص المياه المعالجة بالحديد النانوي الصفري فكان لها تأثير سلبي في الوزن الجاف فقد انخفض الوزن الجاف بنسبة 43.12% بالمقارنة مع الوزن الجاف للمياه غير المعالجة، كذلك أظهرت النتائج خلو أوراق النباتات من عنصر الكادميوم.

كلمات مفتاحية: مياه المخلفات النفطية، الحديد النانوي الصفري، الكاربون النانوي، الطين النانوي، الاسمنت.

Introduction

Water is the basis of life, as no vital process can occur without it. Also, population growth and the massive expansion in agricultural and industrial production, along with the accompanying energy consumption and the abundance of waste, have led to an increase in all types of pollution (water, air, soil) (15). Water is considered polluted when its constituent elements change in quantity or quality, or its properties change directly or indirectly, making the water less suitable for natural or human uses (2, 4 and 7). The most important sources of water pollution are agricultural and household waste and industrial facilities such as power plants, cement factories, and oil refineries that affect water and aquatic organisms (3 and 8). Pollution by oil waste is considered one of the most important sources of water pollution in terms of impact and spread, which occurs due to the leakage of oil materials into water bodies (13). Petroleum hydrocarbon compounds spread on the surface of the water, forming a thin layer due to their low density, and are affected by a group of factors such as heat, wind, sunlight, and aquatic organisms (5 and 1).

Wastewater from petroleum factories contains hydrocarbons and heavy elements. Polycyclic aromatic hydrocarbons (4,5,6 rings) have a greater carcinogenic potential than (2,3 rings). This is due to human exposure to polycyclic aromatic hydrocarbons through inhaling polluted air in the work environment or eating grilled and spoiled meat and other foods (15). It contains many heavy element ions whose density is more than 5 times that of water (22) and profoundly affects the environment, as their effects are toxic and inhibit biological activity. These elements include cadmium, lead, mercury, nickel, chromium, and arsenic (17 and 18), which are classified as persistent environmental pollutants because they are not biodegradable, which leads to their persistence in the environment (6). Heavy elements in low proportions do not affect plant growth, but continuous accumulation negatively affects the plant and humans through its transmission through the food chain (18 and 24). Water and materials are used after being treated in various ways to irrigate crops because they contain the nutrients necessary for plant growth (9 and 21). Several methods exist for treating water polluted with oil waste (primary, secondary, and advanced). Since the diesel power plant in Haditha uses primary treatment to remove impurities and floating pollutants, not all pollutants, including heavy elements, are removed. Therefore, adsorption was used, which is considered an advanced treatment process and is one of the chemical methods used to remove pollutants from water using adsorbents, which can attract pollutants (adsorbents) from water. It is also the process of adhesion of molecules, atoms, or ions of gas or liquid to solid surfaces (12).

The Hadith diesel power plant is one of the largest in Anbar province. This plant uses large quantities of water to cool the engines that generate electricity. The water resulting from the cooling process will be loaded with oil waste and containing heavy elements, so the water is passed through preliminary treatment stages before being thrown into the river. The study aims to test the possibility of using water contaminated with oil waste after treating it with adsorbent materials (nano-zero iron nZVI, nano-carbon n Carbon, nano-clay n Clay, Polyartland cement P Cement, white cement W Cement) and compare it with untreated water and Euphrates River water in irrigating barley plants and their effect on growth, dry matter yield and plant cadmium content.

Materials and Methods

The experiment was conducted at the College of Agriculture, University of Anbar, Iraq, to study the effect of contaminated water treated with nanomaterials and untreated (oil wastewater) on barley plant height and dry matter yield, also to test the best nanomaterials used in treatment in irrigation of barley plants. Two sources of water were brought: the first source was natural water (Euphrates River), and the second was polluted water from Haditha Diesel Power Station used to cool the generator engines used to generate electricity. Five water treatment materials were used to obtain seven types of water (untreated, Euphrates River water, water treated with nano-iron, water treated with nano-carbon, water treated with nano-clay, water treated with Portland cement and water treated with white cement). The materials were prepared by dissolving the nano-materials at a 1:500 g: ml ratio, shaking for 3 hrs, and filtered to be ready for irrigation purposes. Then, the prepared water was stored in plastic containers to carry out the agricultural experiment. Table 1 shows some characteristics of irrigation water. Two soil samples were used: desert soil from a Haditha Diesel Power Plant and sedimentary soil from areas near the Euphrates River. Table 2 shows some of the soil characteristics. The soil was dried and sieved with a 2 mm hole diameter sieve, then packed in plastic pots (22 cm high and 25 cm in diameter) weighing 7 kg per pot. The experiment was designed according to the randomized complete block design (RCBD). It was irrigated using natural water (Euphrates water), polluted water (untreated), (water treated with nano-iron Z, water treated with nano-carbon C, water treated with nano-clay L, water treated with Portland cement P, and water treated with white cement W).

Table 1: Some properties of irrigation water.

Chemical Properties	River water (A)	Polluted water (B)	Zero Iron Nano Treated Water (Z)	Nano carbon treated water (C)	Nano clay treated water (L)	Portland cement treated water (P)	White cement treated water (W)
EC (ds m^{-1})	1.4	1.4	2.7	2	2.4	1.8	2.7
pH	6.4	6.86	7.5	6.9	7	8.8	9
Ca (meq L^{-1})	5	5	5	8.5	8.5	14	15
Mg (meq L^{-1})	4.5	5.2	6.5	7.5	6.5	2	1
Na (meq L^{-1})	5.95	11.34	21.26	12.30	9.56	9	8.86
Cd (mg L^{-1})	0.036	0.015	ND	ND	ND	ND	ND
SAR	2.72	5.04	8.90	4.36	3.50	3.19	3.14

Soils S1 and S2 were prepared, desert soil and sedimentary soil, respectively, with 42 pots (7 types of irrigation water × 2 soil × 3 replicates), 10 seeds of barley Hordeum Vulgare L, Samir variety, were planted on 12-13-2022. After germination, they were thinned to 5 plants per pot, and the plants were watered using the volumetric method based on the water consumption of barley according to the following equation:

$$V = A \times d$$

Where V: volume of added water ($L.month^{-1}$),
A: area of pots (cm^2)
d: depth of added water (water consumption of barley) (cm).

Phosphate and potassium fertilizers were added, and half of the recommended nitrogen fertilizer (200 kg $N.ha^{-1}$, 180 kg $P_2O_5.ha^{-1}$, 80 kg $K_2O.ha^{-1}$) was added, and the other half of the recommendation was added 50 days after planting (15and 24). The experiment was completed after three months of planting, and the plants were harvested by cutting them from the soil surface after measuring their height. They were washed with distilled water and dried in an electric oven at 65°C. The dry weight of the plant was calculated and then used to estimate Cd in the plant after wet digestion using a mixture of acids (sulfuric acid H_2SO_4, nitric acid HNO_3, and perchloric acid $HCLO_4$), Jackson, 1958 (8).

The data were statistically analyzed using the GenStat 12th Edition program according to the randomized complete block design, and the means were compared using the least significant difference (LSD) at a significance level of 0.05.

Table 2: Some physical and chemical properties of the study soil.

Soil Properties	Unit	Desert Soil	Sedimentary Soil	
Soil Texture	g/kg	Gypsic soil	Sand	**492**
			Silt	**396**
			Clay	**112**
			Loam	
$CaCO_3$	%	12.46	**19.10**	
$CaSO_4$	%	48	**ND**	
1:5 ratio				
pH	-	7.10	**7.70**	
EC	$ds.m^{-1}$	13.5	**6.5**	
Ca	$mm.L^{-1}$	21	**9**	
Mg	$mm.L^{-1}$	9	**5**	
Na	$mm.L^{-1}$	8.78	**7.69**	
K	$mm.L^{-1}$	1.53	**1.22**	
CO_3	$mm.L^{-1}$	ND	**ND**	
HCO_3	$mm.L^{-1}$	3	**5**	
SO_4	$mm.L^{-1}$	3.77	**3.34**	
Cd	$mg.L^{-1}$	0.065	**0.022**	
Pb	$mg.L^{-1}$	0.777	**0.735**	
Fe	$mg.L^{-1}$	19	**23**	
Mn	$mg.L^{-1}$	1.870	**6.330**	
Cu	$mg.L^{-1}$	0.379	**0.489**	
Zn	$mg.L^{-1}$	0.457	**0.832**	

Results and Discussion

Effect of treated water on plant height and dry weight yield:

Effect of plant height: Figure 1 shows the effect of irrigation with water treated with nanomaterials, untreated water, and Euphrates River water on plant height. It is noted that the irrigation treatment with water treated with nano-iron significantly outperformed the plant height trait compared to untreated water as an average for all treatments.

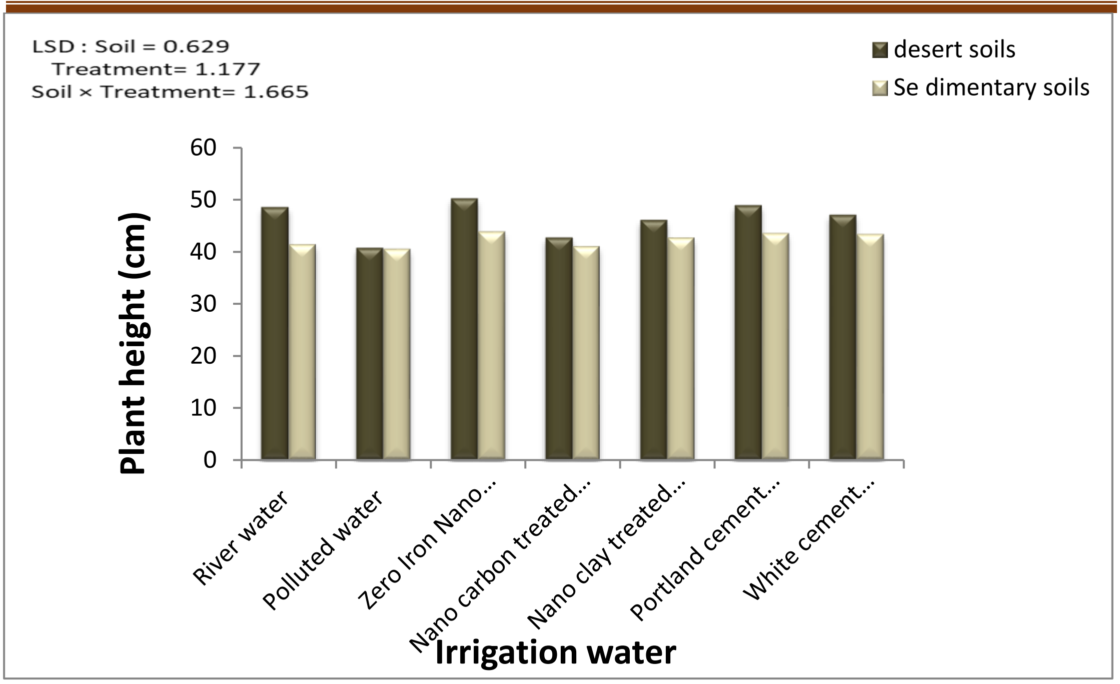

Figure 1: Effect of irrigation with treated water on the height of barley plants grown in two sedimentary and desert soils.

There was also a significant difference between the two soils, with desert soils outperforming the sedimentary soils in plant height compared to the irrigated soils, with an increase of 8.53%. As for the river water irrigation treatment, it outperformed with a plant height of 44.92 cm compared to untreated water, with a percentage of 10.69%. The treatment treated with nano-iron witnessed a plant height of 47 cm, with a significant increase of 15.82% compared to untreated water, while the plant height average reached 41.83 and 44.33 cm for the water treated with nano-carbon and nano-clay, respectively, with a significant increase of 3.08 and 9.24%, compared to untreated water. As for the treatments treated with Portland cement and white cement, their average plant height reached 46.17 and 45.17 cm, with a significant increase of 13.77 and 11.31%, respectively, compared to untreated water. Likewise, the average plant height of plants irrigated with river water was 48.50 cm, with a significant increase of 10.65% compared to untreated water (4).

The results of the statistical analysis also showed significant differences as a result of the interaction between soil and treated water, with a significant increase of 23.35, 20.06, 19.25, 15.56, 13.10, and 4.92% for each of the water treated with nano-iron, Portland cement, river water, white cement, nano-clay, and nano-carbon, respectively, compared with the rate of plant growth for water irrigated with untreated water for desert soil.

In the sedimentary soil, significant differences were shown for each of the water treated with nano iron, water treated with Portland cement, water treated with white cement and water treated with nano clay by an increase of 8.22, 7.40, 6.98, and 3.35% compared to untreated water. There were no significant differences between the river water and water treated with nanocarbon compared to untreated water. Table 3 shows the results of the statistical analysis of plant height.

Table 3: Effect of treated and untreated irrigation water on barley plant height (cm) grown in sedimentary and desert soils.

Soils (S)	Treatments (T)							
	River water (A)	Polluted water (B)	Zero Iron Nano Treated Water (Z)	Nano carbon treated water (C)	Nano clay treated water (L)	Portland cement treated water (P)	White cement treated water (W)	Mean (S)
desert soils (S1)	48.50	40.67	50.17	42.67	46	48.83	47.00	46.26
Sedimentary soils (S2)	41.33	40.50	43.83	41	42.67	43.50	43.33	42.31
Mean (T)	44.92	40.58	47.00	41.83	44.33	46.17	45.17	
$LSD_{0.05}$	T=1.177		S=0.629			T×S =1.665		

Effect on dry weight yield: Figure 2 shows the effect of irrigation with water treated with nanomaterials, untreated water, and Euphrates River water on the dry weight yield of plants. It is noted that irrigation treatment with water treated with nano clay significantly outperformed the dry weight trait, and the least was with water treated with nano-iron zero as an average for all treatments. The results showed a significant superiority in dry weight yield of desert soil 12.00 g and a significant increase of 16.67% compared to sedimentary soil because desert soil contains higher nutrients than sedimentary soil.

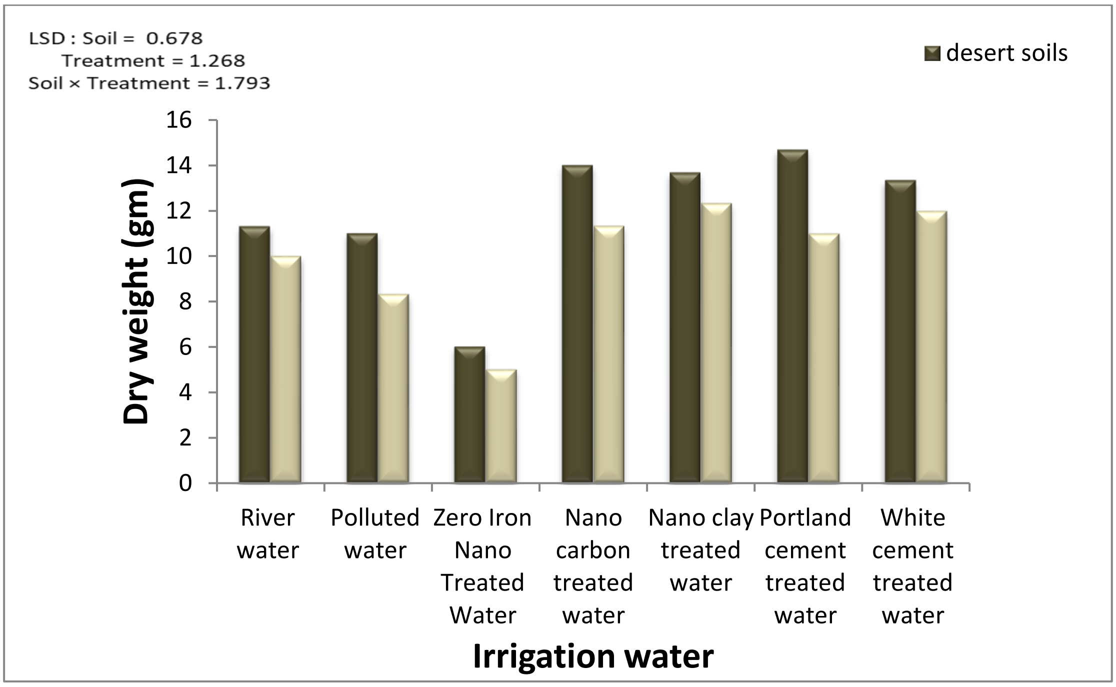

Figure 2: Effect of irrigation with treated water on the dry weight yield of plants grown in sedimentary and desert soils.

It is noted from the figure that there is no significant difference between the dry weight of plants irrigated with river water compared to untreated water, while significant differences were found in the rest of the treatments. The increase in dry weight was 34.43, 32.67, 31.02 and 31.02% for plants irrigated with water treated with nano clay, water treated with Portland cement, water treated with white cement, and water treated with nanocarbon, respectively, compared to untreated water. As for the zero nano iron treatment, it decreased by 43.12% compared to the dry weight of untreated water due to the zero nano iron containing large amounts of sodium, which greatly affected the dry weight of the plant, which caused an increase in the SAR value of irrigation water, Table 1. Many studies have warned of the toxicity of nanomaterials to many living organisms (14 and 16), and other studies have shown that the toxicity of nanomaterials and their harmful effects appear in laboratory experiments greater than their effect in reality or field experiments (10 and 23).

The results of the statistical analysis showed significant differences as a result of the interaction between soil and treated water, with a significant increase of 33.36, 27.27, 24.27 and 21.18% for each of the water treated with Portland cement, water treated with nano-carbon, and nano-clay and water treated with white cement, respectively, compared to the dry weight of plants irrigated with untreated water. These results are for desert soil. In the sedimentary soil, there were significant differences for each of the water treated with nano clay, water treated with white cement, water treated with nanocarbon, and water treated with Portland cement with an increase of 48.01, 44.05, 36.01, and 32.05%, respectively, compared to the dry weight of plants irrigated with untreated water. The dry weight of plants irrigated with water treated with nano-iron has a negative effect, as the dry weight decreased by 39.97% compared to the dry weight of plants irrigated with untreated water. (19) Nano-iron, Portland cement, white cement, and nano-alginite (a type of rock) were used after adding them to soil contaminated with cadmium and studying their effect on watercress plants. The study showed that watercress plants did not develop when treated with nano-iron, and the results were good for the rest of the materials. Studies on using nanomaterials for water treatment and their use in agriculture are very few, so no research was reported that is consistent with these results. Table 4 shows the results of the statistical analysis of the dry weight of barley plants.

Table 4: Effect of treated and untreated irrigation water on dry weight yield of barley (g) in sedimentary and desert soils.

Soils (S)	Treatments (T)							
	River water (A)	**Polluted water (B)**	**Zero Iron Nano Treated Water (Z)**	**Nano carbon treated water (C)**	**Nano clay treated water (L)**	**Portland cement treated water (P)**	**White cement treated water (W)**	**Mean (S)**
desert soils (S1)	11.30	11.00	6.00	14.00	13.67	14.67	13.33	12.00
Sedimentary soils (S2)	10.00	8.33	5.00	11.33	12.33	11.00	12.00	10.00
Mean (T)	10.67	9.67	5.50	12.67	13.00	12.83	12.67	
$LSD_{0.05}$	T=1.268		S=0.678			T×S=1.793		

Conclusions

Zero nano iron showed poor results for the barley plant's dry matter weight, and water treated with nano iron cannot be used for plant irrigation.

Other treatments showed positive results regarding plant height and dry weight; it is possible to use them in irrigating crops, but after intensifying studies on the effect of nanomaterials and their use in irrigation for long periods.

Supplementary Materials:

No Supplementary Materials.

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Author Tasneem Adil Hamid methodology, writing—original draft preparation, Author Ahmed Marzoog writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

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