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ORIGINAL ARTICLE

The Efficiency of Using Magnetic Treatment Technology and Nano-Ferric Oxide (Fe_3O_4) in Improving The Quality of Well Water and its Effect on Some Growth Characteristics of Mung Bean *(Vigna Radiata L.)*

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Competing Interests:

The authors declare that this manuscript was approved by all authors in its form and that no competing interest exists.

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ABSTRACT:

Background: *Freshwater scarcity is a serious global challenge, particularly in arid regions such as Iraq, where declining groundwater quality threatens agricultural productivity. Sustainable water treatment approaches, including water magnetisation and nanoferric oxide (Fe_3O_4), offer promising solutions for improving water quality and enhancing plant growth.*

Methods: *This study evaluated the effects of water magnetisation and Fe_3O_4 nano-iron oxide on the physicochemical characteristics of well water and their subsequent influence on the growth of Vigna radiata L. Treated water (T2–T4) and untreated well water (T1, control) were analyzed for key water quality parameters. Plant response was assessed through seed germination percentage, vegetative growth attributes, nutrient uptake, and the accumulation of potentially toxic elements in plant tissues.*

Results: *Treatment T4 showed the greatest improvement in water quality, recording 110 mg/L BOD, 400 mg/L COD, 260 mg/L SO_4, 0.02 mg/L Cr, 0.33 mg/L Zn, 0.01 mg/L Ni, 0.08 mg/L Fe, 0.26 mg/L Cu, 3140 mg/L TDS, and 6.34 dS/m EC. Seed germination reached 100% under T4 and T3, compared to 60.30% in the control. T4 significantly increased plant height (23.83 cm), dry vegetative weight (2.57 g), and leaf area (25 cm^2) relative to T1. Nutrient concentrations of N (2.76 ppm), P (0.26 ppm), and K (2.06 ppm) were higher under T4, while toxic elements and salts were substantially reduced.*

Conclusion: *The combined application of water magnetisation and Fe_3O_4 nano-iron oxide effectively improved well-water quality and enhanced germination, growth, and nutrient balance of Vigna radiata L., demonstrating strong potential for sustainable agricultural water management in water-scarce regions.*

KEYWORDS: Well water treatment, magnetic treatment, Fe_3O_4 nanoparticles, *Vigna radiata L*. plant.

INTRODUCTION:

Water is one of the most important natural resources on Earth, as it is essential for drinking, agriculture, industry, and energy production [1]. The world in general, and third world countries in particular, face the problem of water scarcity, which is one of the most serious environmental and social challenges of the modern era [2]. Water is one of the most important elements on which sustainable development programmes of all kinds – human, agricultural and industrial – depend. It is of paramount importance in arid and semi-arid regions due to its scarcity. Population growth and socio-economic changes are among the main factors causing increased water consumption [3].

Water scarcity in the Arab region in general, and Iraq in particular, especially in the last decades of the last century, has encouraged these countries to use modern technologies in various fields to treat polluted water, which contributes to preserving the environment on the one hand and improving the agricultural situation on the other. Given the extreme importance of modern technologies in the fields of agriculture and water, it has become possible to implement several important technologies, such as the use of magnetisation in water treatment [4]. The use of magnetic fields in water treatment is a modern and important method that improves many water properties, including reducing water viscosity by 30%, decreasing surface tension by 1-3 N/m, and increasing solubility, which increases the availability of nutrients in the soil [5]. Magnetic treatment is a physical method [6, 7] that has been used in various fields, such as agriculture, as it is one of the most promising methods for protecting the environment from pollutants, which can improve plant growth and enhance agricultural production [8].

One of the modern and important techniques in well water treatment is adsorption, which is a highly effective and economical method for removing metal ions and some pollutants from groundwater and improving its quality. The selection of a good adsorbent depends on several characteristics, including density, surface area, and high adsorption capacity. A significant change in the properties of adsorbents (chemical, physical, and mechanical) [9] has been observed when the particle size of the adsorbent decreases to the nanoscale [10]. Increasing the surface area of materials by converting them into nanomaterials results in an increase in their ability to adsorb and remove contaminants from water [11].

The *Vigna radiata L*. plant is one of the most important crops in Iraq because its seeds contain proteins, carbohydrates, fats, and some amino acids such as lysine. It has a short life cycle and is cultivated for many purposes, including the production of seeds for use as good food for humans and animals [12]. It is also used to increase soil fertility by fixing nitrogen due to the symbiotic relationship between the plant and bacteria such as Bradyhizobium [13]. The problem of freshwater availability that the world is experiencing, especially in Iraq, has led farmers to rely on well water as an alternative source of freshwater. These reasons prompted this study to investigate the effect of nano-treatment using Fe3O4 and magnetisation technology and their interaction in improving some of the physical and chemical properties of well water, and the extent of their effect on vegetative growth characteristics and the accumulation of some elements in parts of the *Vigna radiata L*. plant.

METHODS AND MATRIALS

Conducting experiments:

The first experiment was conducted in the laboratories of the Graduate Studies Department/Life Sciences Division at Samarra University. It involved measuring the effect of nano-treatment with ferric oxide and magnetite and their interaction on well water compared to river water on the one hand and untreated well water on the other hand on the germination rate of *Vigna radiata L*. The seeds were placed in sterilised plastic dishes with a diameter of 10 cm. Ten seeds from the mash plant were placed in each dish and distributed according to the experiment conditions (T0, T1, T2, T3, T4) with three replicates for each condition, Then, the seeds were watered with the wastewater used in the above experiment, and the dishes were placed in an incubator at a temperature of 25 °C. Seven days after the start of the experiment, the percentage of germination was calculated according to the equation mentioned by [14,15]:

$$\text{germination percentage } = \frac{\textbf{Number of germinated seeds}}{\textbf{Total number of seeds}} \times 100\%$$

As for the field experiment, soil samples were collected from an arable area located at latitude 34.1383° north and longitude 44.0817° east. The topsoil was removed and air-dried, then sieved through a 2 mm mesh sieve and mixed thoroughly to ensure homogeneity. A sample was analysed in the laboratory to identify some of its physical and chemical properties at the Soil Department Laboratory, Faculty of Agriculture, University of Tikrit, and the Chemical Engineering Laboratory, Faculty of Engineering, University of Tikrit. Table 1 shows the results of some of the physical and chemical analyses of the soil.

Table (1) Some chemical and physical properties of soil before cultivation

The attribute		value	Unity
pH		7.89	-
Electrical conductivity		3.51	decisiemens.m $^{-1}$
Total dissolved salts TDS		7.58	mg/L -1
soil separators	Sand	38	%
	Clay	25	%
	Green	37	%
tissue		Mixed	
organic matter		1.10	%
Magnesium		567	mg/L-1
sodium		418	
Nitrogen		16	
Phosphorus		13	
Potassium		32	
Magnesium		567	

The field experiment was conducted in the Mu'tasim district, 20 km south of Samarra-Salah al-Din, to determine the effect of the experiment treatments on some growth characteristics of alfalfa in July 2024. using plastic pots made from 18-litre disposable drinking water bottles, which constitute a burden on the environment, as part of the exploitation of these bottles in other areas such as agriculture. After cleaning the bottles with sterilised water, painted black on the outside, then pierced at the bottom to drain excess water and filled the pots with 10 kg of soil. Pot^{-1}, The field

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experiment was designed according to the completely randomized block design (CRD) with five treatments and three replicates for each treatment, with a total of 15 pots, as shown in Figure 1 below. Use triple superphosphate fertiliser P_2O_5 45% to fertilise the soil at a rate of 80 kg .h-1 and mix the fertiliser well with the planting soil [16]. Plant the seeds in pots (at a rate of 10 seeds per pot^{-1}) and then watered according to the treatment parameters for well water and control water, using the same amount of water for each pot, A modern irrigation method was adopted for watering the pots, namely drip irrigation, as illustrated in Figure 1, After germination, the plants were thinned to five seedlings per pot.

For magnetic water treatment in this study, a 6000 kA magnetic device manufactured by Mageco was used, and its strength was tested in the laboratories of the Physics Department/Faculty of Science/University of Samarra using a Tesla-metar device to ensure its efficiency. American-made Fe3O4 nano-iron oxide with a size of 20 nanometres was also used at a concentration of 100 milligrams per litre^{-1}. The concentration was selected based on the recommendation [4].

Water sampling and treatment methods:

Well water samples were taken from one of the wells in the Mu'tasim area, and the samples were collected in 20-litre plastic containers. The well water was treated by adding 100 mg. The treated solution was left for 120 minutes, and the concentration and contact time were selected according to the recommendation [4]. The filter was then transferred from the treated water to the tank designated for watering the plastic pots planted with alfalfa, as shown in Figure 1.

The well water was treated with the magnetic device locally after being filled into the designated tank, where the device was attached to the plastic pipe coming out of the tank directly. After flowing through the device, the water was transferred to the planted pots to be used for watering.

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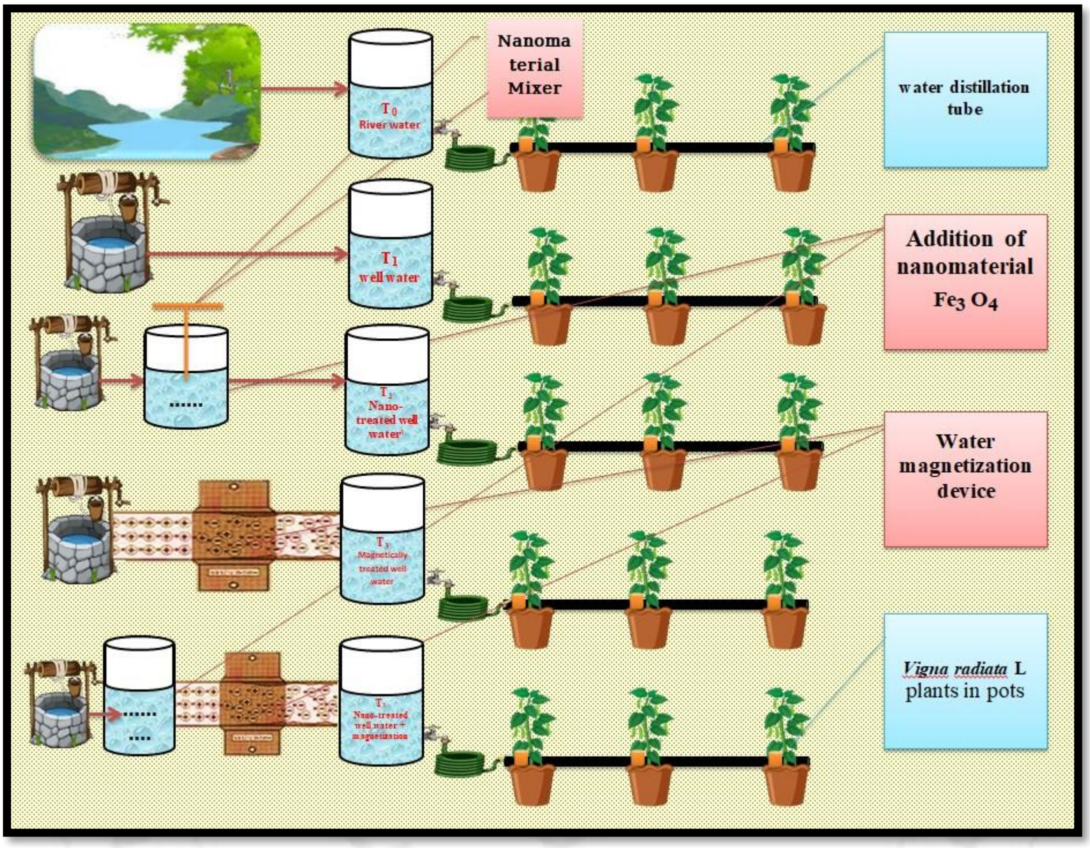

Figure (1) Schematic design of the experiment

The combined treatment of well water with nanomaterials and magnetisation was carried out in the same way as described above for the nanomaterial treatment of well water, with the nanomaterial-treated water then passing through a pipe fitted with a magnetisation device. The following diagram shows the steps of the complete treatment process.

Table 2. Chemical and physical properties of well water before and after treatment.

Chemical Properties	river water	Well water before treatment	Well water Nanoya water purifier	Well water Magnetically treated	Treated well water Nanotechnology and magnetism	Unit of measurement
PH	7.30	7.70	8.10	7.80	8.01	-
BOD5	5.00	21.00	18.00	15.00	15.00	Mg/L
COD	52.00	117.00	109.00	112.00	110.00	
Ca	69.90	440.00	400.00	480.00	400.00	
CaCo3	174.83	880.00	720.00	800.00	735.00	
Mg	29.70	268.40	195.50	195.20	204.30	
P	0.19	0.15	0.17	0.17	0.17	
K	12.00	30.00	31.00	31.00	30.00	
Na	22.00	935.00	852.00	871.00	820.00	
SO4	81.00	288.00	263.00	276.00	260.00	
Cl	123.00	720.00	651.00	684.00	638.00	
NO3	2.80	7.82	7.82	7.80	7.91	
Cr	0.01	0.09	0.03	0.07	0.02	
Zn	1.80	1.62	0.51	1.48	0.33	
Ni	0.01	0.04	0.02	0.03	0.01	
Fe	0.03	0.15	0.09	0.14	0.08	
Cu	0.02	1.28	0.32	1.18	0.26	
TDS	283	3150	3142	3133	3140	PpM
EC	0.812	6.61	6.29	6.45	6.34	Ds/cm

Total Dissolved Solids (Total Dissolved Solids, TDS)

Total Dissolved Solids TDS were measured according to the method described in (APHA, 2003), using the WTW digital Conductivity device after filtering the sample through fine filters with holes of 0.45 µm, and the results were expressed in mg/L unit.

Electrical conductivity (electrical Conductivity, EC)

The electrical conductivity of the samples was measured using the WTW digital Conductivity device, with the device whistling each time using distilled water, and the results were expressed in microsiemens/CM.

PH value (pH)

The pH value was measured using the JENWAY pH-Meter after calibrating the device in the laboratory using standard solutions with different pH values (4, 7, 9).

Dissolved oxygen (Dissolved Oxygen, DO)

Dissolved oxygen was measured according to the method described in (APHA, 2017) using the Oxygen Meter EZ D.O. The device was calibrated at each reading using atmospheric air (20.9%).

Biological oxygen Demand (biological Oxygen Demand, BOD5)

The same method of measuring dissolved oxygen was used. The BOD bottles were filled with a volume of 250 ml of each sample, and then kept for five days in an incubator at a temperature of 20°C. The bod5 value is calculated from the difference between DO1 and DO5:

$$\mathbf{BOD_5 = DO_1 - DO_5}$$

Total Suspended Solids (total Suspended Solids, TSS)

The gravimetric method of measuring TSS (Gravimetric Method), which is the measurement method described in (APHA, 2003), was used to calculate the concentration of total suspended solids and the suspended solids were measured by filtering 100 ml of the sample on a filter paper, then drying the leachate in an oven with a temperature (103-105) for 24 hours and then weighed .

Total hardness (Total hardness, TH)

The total hardness was measured according to the method (ASTM , 1984) to estimate the total hardness by taking 50 ml of sample water and adding 0.5 ml of (NH3OH + NH3Cl), then adding a few drops of (Eriochrome Black T) to it, to turn the color to wine, then withdrawn with a standard na2edta solution at a concentration of (0.05 N) until the solution turns blue. The total difficulty is calculated by the equation:

Total hardness = (EDTA volume used × calibre × 1000 × CaCO3 equivalent weight) / sample size Calcium ion (Calcium Ion, Ca_2)

The method (ASTM , 1984) was adopted to estimate calcium hardness by taking 50 ml of sample water, adding 2 ml of sodium hydroxide solution (2.5 N), A few drops of دليلiochrome black T, and then drawing with the standard na2edta solution (0.05 N) until the color changes from reddish pink to greenish blue. The amount of calcium hardness is calculated by the same formula as the total hardness, and the result is expressed in mg/l.

Magnesium ion (Magnesium Ion, Mg2)

The value of the magnesium ion was calculated by the method described in (APHA, 2017). In calculating the magnesium concentration from the calcium concentration and the total hardness values of the samples as in the equation:

Magnesium (mg/l) = total dyscalcemia – (2.5 × calcium) × 0.243

Sodium ion (Sodium Ion, Na)

The sodium ion of the candidate sample was measured using the JENWAY PFP7 Flame Photometer. After preparing the standard solutions, measuring the absorbency of the sample and drawing the standard curve, the sodium concentration was found, and the output was expressed in mg/l.

Chloride ion (Chloride Ion, Cl)

Chloride was measured according to the method (ASTM , 1984), by taking 50 ml of sample water, then a few drops of potassium chromate ($K2CrO_4$) were added, then withdrawn with silver nitrate $AgNO_3$ at a concentration of (0.025 N) until the color turned from yellow to dark red. And chloride was calculated according to the equation:

Chloride (mg/l) = (silver nitrate volume × calibre × 1000 × 34.45) / sample volume

Nitrate (Nitrate, NO3)

Using the method used before (ASTM, 1989), a Spectrophotometer was used to measure nitrates from JENWAY and at a wavelength of 410 Nm. The Blank value of the zeroing device is read first, then the sample is read and nitrates are calculated in mg/L unit.

Phosphate (Phosphate, PO_4)

For the estimation of phosphate ions , the ASTM method was adopted, 1984)), it was measured with a Spectrophotometer from JENWAY and at a wavelength of 885 Nm, the results were expressed in mg/l.

Heavy metal measurement

Heavy metals were measured according to the method described (APHA, 2005) in measuring heavy metal concentrations, whereby 100 ml of the sample was taken and 5 ml of concentrated nitric acid was added to it and heated on a hot plate until almost dry, then another 5 ml of acid was added to ensure complete digestion. After cooling, the sample was transferred to a volumetric flask and the volume was made up to 100 ml with distilled water. The samples were measured using a Flame Atomic Absorption Spectrometer (FAAS), and the results were expressed in mg/L.

Statistical analysis

The data were analysed statistically using one-way ANOVA to study the effect of different water treatments. When significant differences appeared between the means, they were compared using Duncan's Multiple Range Test at a probability level of 0.05% using SPSS statistical software, version 2023.

Definition of treatments represented by treatment

1- River water (control) symbol (T0) .

2- Untreated well water treatment symbol (T1) .

3- Well water treated with Fe3O4 nanoparticles symbol (T2).

4- Treatment of well water treated with a magnetisation device, symbol (T3).

5- Treatment of well water treated with a combination of Fe3O4 nanoparticles and magnetisation, symbol (T4).

RESULTS AND DISCUSSION:

Table (3) shows the effect of using a water magnetisation device and Fe_3O_4 nanoferric oxide on some physical and chemical properties of well water before and after treatment, the effect of treating wastewater with ferric oxide nanoparticles and a magnetic field and the interaction between them on the average of some physical and chemical properties of water. Treatment T1 significantly outperformed all other treatments in terms of average pH value, which reached 8.20 compared to treatment T0, which recorded the lowest average value. Treatment T0 significantly outperformed all other treatments in terms of average BOD5 concentration, which reached 5 mg/L. Litre $^{-1}$ Compared to treatment T1, which recorded the highest average BOD5 concentration of 146 mg/L. Treatment T0 significantly outperformed all other treatments in the experiment in terms of the average COD concentration, which reached 52 mg/L, compared to treatment T1, which recorded the highest average COD concentration of 448 mg/L.

Also, the T0 treatment with a low average TDS ratio was significantly superior to all the experimental ones, the average concentration of which was 283 mg.L1-compared with the T1 treatment, which recorded the highest average concentration of 1536 mg.Ltr^{-1} followed by a morally superior T4 treatment in reducing the average concentration of TDS on all trial transactions, with an average concentration of 1113 mg.Liter1-compared with the control treatment T1, which recorded the highest average value of 1536 mg.Lt ^{1} -, and the T0 treatment was morally superior to all the experiment coefficients in reducing the EC ratio and its average concentration was 0.81 decisimens.Liter^{-1}compared to T1, which recorded the highest average of 3.01 decisimens.Liter^{-1}.

The T0 treatment morally outperformed the average reduction of chromium, zinc, nickel, copper and iron on all Experimental parameters and their concentrations(0.01 , 1.80 , 0.013 , 0.02 0.03) amalgam.Liter^{-1} respectively when compared to treatment T1, which recorded the highest average concentrations of the same elements (0.25, 3.30, 0.12, 0.42, 0.68) mg/L-1 respectively, followed by treatment T4, which was superior with significant differences to the rest of the treatments in the experiment, with average concentrations of (0.04, 0.85, 0.014, 0.21, 0.14) mg/L compared to treatment T1, which represents the control treatment.

The reason for the decrease in the average concentrations of heavy elements and total salts may be due to the role of ferric oxide nanoparticles in adsorbing heavy elements and some salts from their solutions [17] This may be due to the role of the magnetic field in attracting charged ions to the poles of the field when water passes through the tube [18] The effect of well water treated with magnetic field and Fe_3O_4 nano-iron oxide and their interaction on seed germination in the laboratory. The T4 treatment significantly exceeded the average seed germination rate and achieved a germination rate of 100% when compared to the T1 treatment, which achieved the lowest germination rate of 60.30%. The increase in the average seed germination rate for treatment T4 may be attributed to the improvement in the physical and chemical properties of the well water due to the combined effect of ferric oxide nanoparticles and the magnetic field, as the nanoparticles reduced the level of contaminants in the water, particularly the level of salts and toxic heavy elements present in the well water, which have a negative effect on the germination process due to their impact on the physiological processes that take place inside the seeds [19].

Treatment T3 significantly exceeded treatment T1 in terms of average germination rate by 39.70%. The increase in the average germination rate may be attributed to the fact that magnetic water treatment increases the amount of water containing ions absorbed by the seed, which is reflected in an increase in the seed germination rate through changes in the ion concentration of the cell wall, leading to an effect on the negative osmotic potential of the seeds [20]. These results are consistent with those obtained by [21] when using magnetically treated water and its effect on the germination rate of chickpea seeds, which exceeded 20.00% compared to those not treated magnetically, and differ from the findings of [22] when using magnetically treated water and its effect on seed germination rates.,

Table (3) Effect of well water treated with magnetic field and Fe_3O_4 nano-iron oxide and their interaction on seed germination rate and some vegetative traits of *Vigna radiata L*

Adjective Treatment	Number of flowers (flower.plant-1)	Dry root weight (g/plant-1)	Dry vegetative weight (g/plant-1)	Paper area (cm^2)	Plant height (cm)	Percentage of germination (%)
T0	2.33 b	0.19 c	0.73 c	14.13 b	14.93 b	97.76 a
T1	0.00 c	0.06 d	0.25 e	6.20 c	10.50 c	60.30 c
T2	0.66 c	0.07 d	0.42 d	7.56 c	14.00 b	66.50 b
T3	3.66 a	0.23 b	2.29 b	23.43 a	22.70 a	100 a
T4	4.33 a	0.29 a	2.57 a	25.00 a	23.83 a	100 a

**Identical letters mean no significant differences.*

Figure (2) shows a significant superiority of treatment T4 in terms of average plant height over all treatments in the experiment after 45 days of cultivation, with a plant height of 23.83 cm compared to treatment T1, which reached 10.50 cm. while there was no significant difference between it and T3. The reason for the increase in the average height of the T4 treatment may be due to the combined effect of the nanomaterial and the magnetic field, as the nanomaterial adsorbs heavy elements such as cadmium, chromium and others from well water, thereby reducing the damage caused by their accumulation in plants [23].

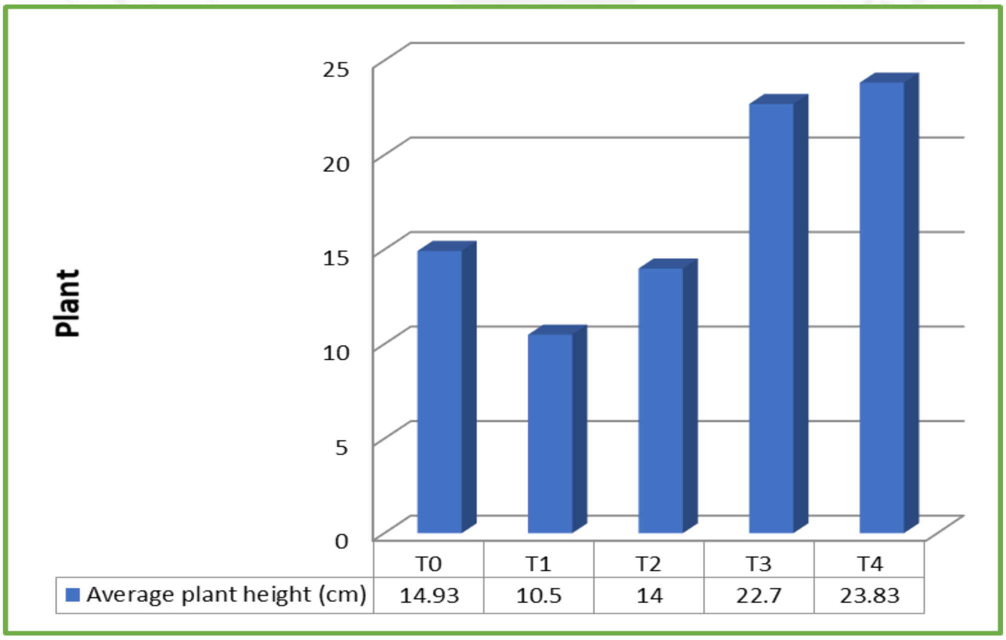

Figure 2: The efficiency of using Fe_3O_4 nanoparticles and a magnetisation device in treating well water and its effect on the average height of *Vigna radiata L*. plants (cm).

The increase in the average height may also be attributed to the fact that ferrous oxide nanoparticles increase the activity of certain enzymes, such as peroxidase, which stimulates photosynthesis and thus leads to an increase in Plant growth: The increase in average plant height in this treatment may be attributed to the role of magnetic water treatment in increasing the availability of elements in the soil and increasing their efficiency of transport and absorption by root cells [24]. The increase in average plant height may be due to the ease with which magnetically treated water molecules penetrate cell membranes because of their small molecular weight, as magnetic treatment reduces the number of water molecules in the clusters that make them up, with the number of molecules being (6-7) compared to non-magnetically treated water, which has(12-13) molecules [25]. These results are consistent with the findings of Tahir and Karim [26] of a significant increase in the average height of chickpea plants irrigated with magnetically treated water, which reached 17.97 cm, compared to the control treatment, which reached 15.49 cm.

The results in Table 4 show that the T4 treatment was significantly superior to all other treatments in terms of average leaf area, reaching 25.00 cm2 when compared to the T1 treatment, which gave an average leaf area of 6.20 cm2, while there was no significant difference between it and T3. The increase in the average leaf area for treatment T4 may be due to the improvement of water quality by reducing stress from dissolved salts and some heavy elements through the adsorption of a proportion of the salts by the nanomaterial. This leads to increased water absorption by the plant and increased cell division, thereby increasing the rate of growth, which results in an increase in leaf area [27]. Magnetically treated well water also increases the availability of nutrients in the soil due to its high ability to dissolve nutrients and minerals, facilitating their absorption and transfer to the plant and increasing the plant's water absorption rate, which leads to improved growth characteristics that are reflected positively in increased leaf area [28]. These results are consistent with those of in their study on *Vigna unguiculata L.* irrigated with magnetically treated water, which achieved a 26% increase in leaf area compared to untreated water[29].

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The results in Figure (3) showed the effect of magnetic treatment and Fe_3O_4 nano-iron oxide on the average dry vegetative weight 45 days after planting. Treatment T4 significantly outperformed all other treatments, with an average dry vegetative weight of 2.57 g, compared to treatment T1, which achieved the lowest average weight of 0.250 g, This was followed by treatment T3, which significantly outperformed the other treatments in the experiment, with an average dry vegetative weight of 2.29 g. The reason for the significant increase in the total dry vegetative weight of the plants achieved by treatment T4 may be due to the combined effect of the two treatments used in the experiment and their role in increasing the availability of some elements in water and reducing the proportions of some harmful elements, as well as the role of plant nanodimers in their effect on the absorption of some compounds such as nitrate and their effect on enzyme activity such as nitrate reduction as a cofactor. This enzyme plays an important role in the production of plant receptors such as chlorophyll, nucleic acids, proteins and other plant materials, which in turn affects the process of photosynthesis and increases the biomass of the plant, Magnetic treatment plays a crucial role in reducing the density and viscosity of water, as well as forming small clusters of water molecules that are bound together by breaking some of the hydrogen bonds in water, which makes it easier for them to pass through cell membranes.

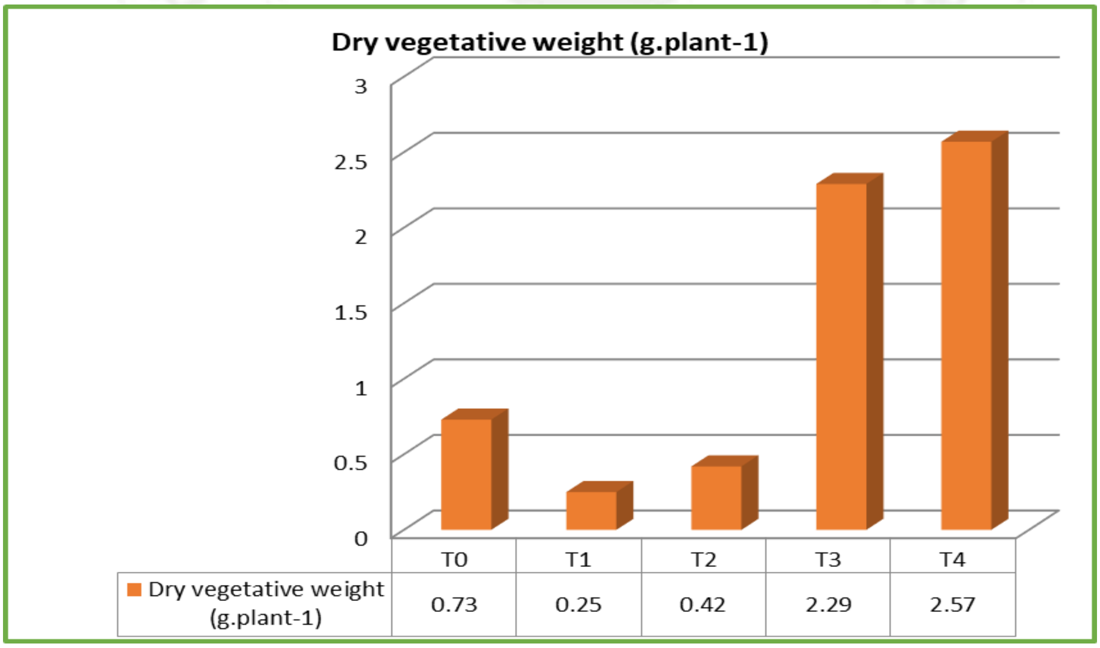

Figure (3): Efficiency of using Fe_3O_4 nanoparticles and a water magnetisation device in treating well water and its effect on the dry vegetative weight of *Vigna radiata L*. plants.

This results in an increase in the entry of nutrients into the cells, which leads to increased vegetative growth and, consequently, an increase in the dry weight of the plant's vegetative mass [22]. These results are consistent with [29], who found a 20% increase in the dry vegetative mass of Vigna unguiculata L. Walp plants irrigated with magnetically treated water compared to their counterparts irrigated with non-magnetically treated water.

The results of Table (4) showed significant differences between the different treatments in terms of dry root weight, with treatment T4 significantly outperforming all other treatments, with an average dry root weight of 0.29 g compared to the lowest average weight for treatment T1, which was 0.06 g, representing a percentage increase of 75%.

Table (4): The effect of using Fe_3O_4 nanoferric oxide and a magnetic field in treating well water on the concentrations of certain heavy elements (ppm) in the vegetative part of *Vigna radiata L*.

Treatment	Cu	Cr	Ni	Fe	Cl	Zn
T0	8.26 b	5.00 c	135.33 b	231.00 c	4.85 c	43.66 c
T1	9.50 a	5.83 a	151.66 a	249.66 a	8.32 a	50.33 a
T2	6.46 c	4.60 d	131.66 c	215.00 d	4.71 d	27.66 d
T3	8.63 b	5.50 b	138.33 b	235.66 b	5.19 b	45.66 b
T4	5.20 d	4.50 d	122.66 d	208.33 e	4.16 e	23.66 e

The results of the statistical analysis in Table (4) indicate significant differences in the concentrations of certain elements depending on the experimental conditions. The table shows that there are significant differences in the conditions. The double treatment with nano-Fe_3O_4 and the magnetic field of well water reduced the average concentrations of copper, chromium, nickel, iron, zinc and chlorine in the vegetative part of the plant in all experimental treatments, with average concentrations of (5.20, 4.20, 122.66, 208.33, 23.66, 4.16) ppm compared to untreated well water, which gave averages of (9.50, 5.83, 151.66, 249.66, 50.33, 8.32) ppm for the same elements, respectively. These elements are harmful to various living organisms when their concentrations exceed the permissible limits due to their physiological damage to plants, which negatively affects the health of the organisms that consume them.

Figure (4) shows the effect of using Fe_3O_4 nanoferric oxide and a magnetic field in treating well water and its effect on reducing the concentration of copper (ppm) in the vegetative part of *Vigna radiata L*.

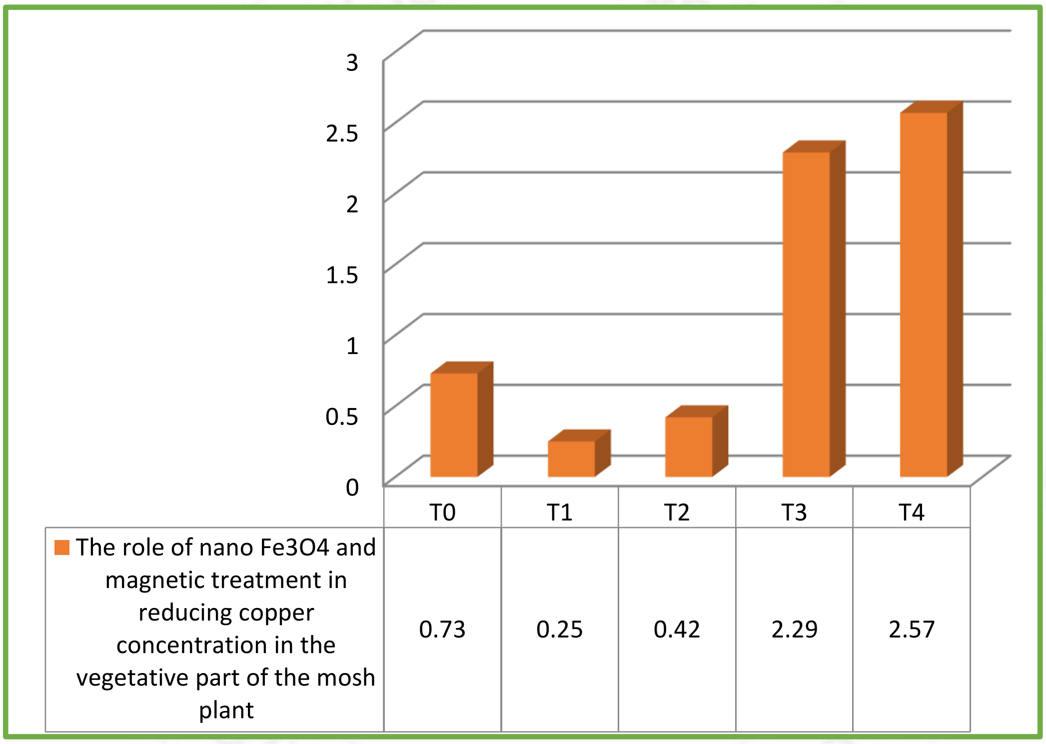

Figure (4): The effect of well water treated with Fe3O4 nanoferric oxide and magnetic field on the concentrations of certain elements in the vegetative part of *Vigna radiata L*. (ppm):

The reason for the decrease in the concentrations of copper, zinc, nickel, chromium, iron, and chlorine in the dual treatment with nanomaterials and magnetic fields may be due to the role of magnetic technology in changing some of the physical and chemical properties of water and reducing the concentrations of these elements in water. This has a positive effect on plants when absorbing treated water in which the concentrations of elements, especially heavy ones, are lower than in untreated well water. This reduces the concentration of elements in plant parts and may be due to the role of magnetic water treatment in maintaining the balance of elements in plants by breaking the hydrogen bonds between water molecules and reducing the surface tension and viscosity of water, which leads to the plant absorbing a greater amount of water. This reduces the concentration of elements in the water entering the plant's cells and tissues, in addition to the role of the magnetic field in ion balance [30]. The role of nanoferric oxide in reducing heavy elements may be due to its role in adsorbing heavy elements from well water and significantly reducing their concentrations. The combined effect of the two treatments in a single treatment achieved more positive results with significant differences compared to the other treatments and untreated well water. These results are consistent with those of [31] who found a reduction in the concentrations of iron, copper, lead and chloride when using magnetic technology in water treatment.

Table (5) shows that the double treatment between the Fe3O4 ferric oxide nanoparticle and the magnetic field reduced the average concentrations of sodium and magnesium in the vegetative part of the plant (0.23, 0.35) mg.GM-1 compared with untreated well water treatment, the concentration of which was (19.61, 0.56) mg.GM-1, respectively, the reason for the low concentrations of sodium and magnesium in the double treatment treatment may be due to the role of the magnetic field in reducing their concentration in the soil solution by the action of magnetically treated water, which has a great ability to wash away soil salts and the speed in filtering salts may reach twice as fast as non-magnetically treated water, as well as the role of ferric oxide nanoparticles in reducing These results are consistent with the findings of [32] when they used magnetically treated water to irrigate plants and compared it with non-magnetically treated water that reduced sodium and magnesium concentrations.

Table (5) : The effect of using Fe_3O_4 nanoferric oxide and a magnetic field in treating well water on the concentrations of certain elements in the vegetative part of *Vigna radiata L.* (mg/g).

The Element Treatment	N	P	K	Ca	Mg	Na	So4	N03
T0	2.26 c	0.18 c	1.67 b	0.64 b	0.42 c	0.27 c	0.54 c	0.13 b
T1	1.74 e	0.10 e	1.38 c	0.68 a	0.56 a	19.61 a	0.62 a	1.08 a
T2	2.12 d	0.16 d	1.45 c	0.63 b	0.38 d	0.25 d	0.49 d	0.09 c
T3	2.51 b	0.24 b	1.72 b	0.64 b	0.51 b	11.31 b	0.56 b	0.14 b
T4	2.76 a	0.26 a	2.06 a	0.46 c	0.35 e	0.23 d	0.48 e	0.08 c

Table (5) shows that the average concentrations of nitrogen , phosphorus and potassium in the vegetative part of the treatment of nanoferric oxide dual treatment and the magnetic field of well water increased significantly , reaching their average concentrations(2.76, 0.26, 2.06) mg.GM - 1 when compared with the concentrations of the same elements in the untreated well water sample gave (1.76 , 0.10 , 1.38) mg.GM-1 respectively. The reason for the increase in the concentrations of nitrogen, potassium and phosphorus in the parameter of magnetic treatment of water may be due to the fact that the passage of water through the magnetic field will lead to changes in the water and break some hydrogen bonds of the water molecule, which makes water more uniform, which increases its ability to dissolve and pass into cells, and may be due to the role of magnetic treatment of water in changing some chemical and physical properties of water such as surface tension, viscosity and density, which facilitates the entry of larger amounts of water to the plant, and these results agree with [31] who used magnetically treated water to irrigate plants and achieved significant differences from non-magnetically treated water .

CONCLUSIONS:

From the results obtained, we conclude that treating well water using a water magnetisation device and ferric oxide nanoparticles (Fe_3O_4) has a positive effect on reducing the heavy metal content in water, as shown in Table 1. (2), as well as its positive effect on reducing the same elements in plants and its positive effect on some growth and yield characteristics of Vigna radiata L. plant. It was also found to be significantly effective in reducing the concentrations of heavy elements in the vegetative parts of the plant and improving the growth and yield characteristics of Vigna radiata L. plant. Furthermore, the synergy between Fe3O4 and the magnetisation device achieved the best results in reducing heavy elements in water and in the vegetative parts of the plant and improving the growth and yield characteristics *of Vigna radiata L.*

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