



Research Article

The Impact of Magnetized Irrigation Water and Humic Acid on Soil Macronutrients, Broccoli Growth, and Yield

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Abstract | An experiment was run in the Al-Dura neighborhood of Baghdad, Iraq, in the 2020–2021 season. Investigating humic acid and magnetized water irrigation on silty clay to see how it affects macronutrients, broccoli, and yield. Randomized Complete Block Design (RCBD) was used for the experiment. Treatments magnetized irrigation water with two levels 0%(M1) and 100%(M2)s of the magnetic flux density 1750 Gauss and humic acid with three levels (0,1,2) gL⁻¹ as (H0,H1,H2), respectively in three replicates. The results indicated that the highest results were (6657 cm², 2.500 mgkg⁻¹, 9830 g plant⁻¹, 13.35 Mgha⁻¹ and 3.65 % for (plant leaf area, chlorophyll concentration, biological yield, economic yield and Potassium concentration) for the interaction (M2H2) compared with results of (1733 cm², 1.639 mgkg⁻¹, 1850 g plant⁻¹, 1.37 Mgha⁻¹, 3.21 %) for interaction (M1H0) respectively, while the best results of N and P were (41.14 and 25.44) mgkg⁻¹ of soil for interaction (M2H1) and K was (293.7 mgkg⁻¹ of soil) for interaction (M1H2) compared with (24.65, 18.66, 194.3) mgkg⁻¹ of soil for (M1H0) respectively.

Received | January 18, 2026; **Accepted** | April 3, 2026; **Published** | September 03, 2026

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Citation | Hamid, B.A., J.A. Shamsullah, Y.A.M. Abd Sabry and A.M. Rezooqi. The impact of magnetized irrigation water and humic acid on soil macronutrients, broccoli growth, and yield. *Pakistan Journal of Agricultural Research*, 39(3): 13-20.

DOI | <https://dx.doi.org/10.17582/journal.pjar/2026/39.3.13.20>

Keywords | Leaf area, Chlorophyll concentration, Biological yield, Economic yield, Residual nitrogen, NPK content in soil, Nutrient uptake in plants, Safe agriculture, Food safety



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Introduction

A member of the cruciferous family, broccoli (*Brassica oleracea* var. *Italica*) is grown for a variety of uses. While its delicious florets end up on our plates, its rich foliage is a great source of animal feed. It includes antioxidants that shield human cells from harm and cancer risk, whether it is eaten crisp and fresh or added to a variety of delicious meals, such

as colorful salads. A flexible and nourishing addition to our meals, soups, and other dishes is broccoli. There are 2.82g of protein, 0.37g of fat, and 6.64g of carbs in 100g of broccoli blossoms. (Al-Issawi *et al.*, 2021; Salman and Abdulrasool, 2025, Zaghdoud *et al.*, 2021). Fertilization and the quality of the irrigation water have an impact on the amount of broccoli produced per unit area. These elements are crucial in controlling the growth of plants. Because of the enormous levels of

pollution worldwide, as documented and research has demonstrated (Hamza and Al-Taey, 2020; Hassan *et al.*, 2023; Page *et al.*, 1982). Investigating alternatives to chemical fertilization is urgently needed. Non-excessive concentrations of key nutrients or organic fertilizers are among the solutions available. Water is made up of a number of molecules that are attracted to one another and can dissolve a variety of things. One essential characteristic that makes water's dissolving properties possible is its polarity. (Kobe *et al.*, 2001). A water molecule experiences numerous changes when exposed to a magnetic field. Water becomes more soluble and permeable as a result of the molecule's expansion. This increased permeability makes it easier for nutrients to be transported, which enhances the absorption of water and the compounds it contains. It has been shown that the transportation and supply of nutrients to the cells are improved by the decrease in surface tension and the ensuing increase in surface area. (Abdel Nabi *et al.*, 2019; Horwitz, 1975; Mani *et al.*, 2018). This procedure simplifies the body's process of eliminating harmful free radicals. Additionally, it serves as a preventative measure against the accumulation of calcium carbonate and magnesium carbonate ions on water pipe inner linings. By successfully resolving these problems, this procedure not only enhances general wellbeing but also guarantees the longevity and optimal operation of water supply systems, cooling systems, heating devices, and similar equipment, thereby aiding in their maintenance and protection. (Halshoy *et al.*, 2024; Doklega and Abd El-Hady, 2017). This study aims to improve the quantitative and qualitative aspects of production, while enhancing the quality characteristics of the crop traits by proposing the use of organic fertilizers, especially humic materials (Ismael and Sarhan, 2024; Shamsullah, 2020) and improving the quality of irrigation water by exploiting their magnetic properties. Furthermore, humic acid is useful for the animal when it uses in its food so it lowers serum cholesterol while boosting protein levels in the blood (Al-Furaiji and Ali, 2025; Al-Hadethi, 2024). Grain NPK content increased by 26.23%, 133.83%, and 150.68%, respectively, when saline sodic soil was leached using a combination of 2gl-1 humic acid and 2gl-1 phosphogypsum. (Al-Issawi *et al.*, 2021, Gioia *et al.*, 2018). The goal of the study is to reduce the accumulation of salts in the soil and dangerous poisons within plants. By doing this, it hopes to advance the cause of a cleaner and healthier ecosystem by promoting human health, cultivating

a pristine environment, and reducing the prevalence of contaminants. (Al-Furaiji and Ali, 2025).

Table 1: *Some chemical , physical and fertility properties of the soil before planting**

Property		Value	Unit
Hydrogen potential (pH) (1:1)		7.70	-
Electrical conductivity (EC) (1:1)		3.52	dS m ⁻¹
Available nitrogen		35.00	mg kg ⁻¹ soil
Available phosphorus		12.0	
Available potassium		297	
Cations	Ca ²⁺	1.10	C mol L ⁻¹
	Mg ²⁺	0.40	
	K ⁺	0.12	
	Na ⁺	1.00	
Anions	SO ₄ ²⁻	1.23	
	Cl ⁻	0.80	
	HCO ₃ ⁻	0.60	
	CO ₃ ²⁻	Nil	
Sand		147	g kg ⁻¹
Silt		422	
Clay		431	
Soil texture class		Silty clay	

Materials and Methods

A field trial was carried out at a location in Baghdad's Dora neighborhood during the 2020–2021 season. The parameters of the clay soil used for the experiment, which was combined with torifluents, are displayed in Table 1. The analyses were carried out in the Ministry of Agriculture's Horticulture Department's Research and Studies Section laboratories. Broccoli seeds were first planted in trays for the experiment, and once the fourth leaf had grown, they were moved to a designated field. The plants were spaced 40 centimeters apart from one another. Three distinct humic acid concentrations—0 g/L (coded as H0), 1 g/L (coded as H1), and 2 g/L (coded as H2)—were added to the soil as part of the experiment. Table 2 lists some humic acid characteristics. In accordance with the chemical recommendation of 90 kg N ha⁻¹, nitrogen was added as urea (46% N). Phosphorus, in the form of super phosphate (46% P₂O₅), was added at a rate of 184 kg P₂O₅ ha⁻¹, while potassium was added in the form of potassium sulfate at a rate of 96 kg K ha⁻¹. The field was irrigated using magnetized water, which was locally sourced in accordance with the patent (4402, dated December 17, 2015). As

per the assertions made by the device's developer, it is recommended to have two levels of intensity, specifically denoted as 0% and 100%.

Table 2: *A few of humic acid's chemical characteristics*

Studied qualities	Humic acid	Nitro-gen	Potas-sium	Phos-phor	pH
Unit	mg kg ⁻¹ dry substance	%	%	%	
Value	12.8%	3.20	6.00	0.90	6.20

It is advised to use these components successively inside a drip irrigation system with a random sector design. The codes allocated to these components are M1 and M2. Saline solution was used to water the plants, [Table 3](#). An EC-meter was used to measure the soil extract's electrical conductivity (EC) at a 1:1 soil-to-water ratio. Similarly, a pH meter was used to measure the soil response degree (pH) at a 1:1 soil-to-water ratio.

The concentrations of the cations Ca²⁺, Mg²⁺, and Na⁺ in the extract were determined in a 1:1 ratio. The concentrations of calcium (Ca²⁺) and magnesium (Mg²⁺) were determined using the correction technique including the chelating agent EDTA-Na2. Sodium (Na⁺) were quantified using a flame apparatus. The correction of H₂SO₄ acid (0.01 N) was utilized for the estimation of carbonates and bicarbonates. Chlorine It was manufactured. by the use of a silver nitrate patch with a concentration of 0.005 moles. The process of sulfation may be determined using the turbidity technique, which involves the utilization of barium chloride (BaCl₂). The nitrogen content was specified using the Kjeldahl apparatus (microkjeldahl) and following the methodology developed by [Ryan et al. \(2001\)](#).

The phosphorus that was prepared underwent assessment using the Olsen Method ([Ryan et al., 2001](#)) ,The procedure involves the using of ammonium acetate to elicit pre-prepared potassium Concentrations were measured quantitatively using a

flame photometer ([Black, 1965](#)). The size distribution of soil were particles estimated using the condensate approach described in [Zaghdoud et al. \(2012\)](#). Humic acid was estimated using the procedure described in (18).The nitrogen was measured using the kaldal apparatus as described in [Ryan et al. \(2001\)](#). According to [Ryan et al. \(2001\)](#) the existence of potassium is detected in the film photometer. The spectrophotometric analysis of phosphor was conducted using the methodology outlined in [Ryan et al. \(2001\)](#).The analysis of chlorophyll was conducted in accordance with [Horwitz \(1975\)](#).

The data was gathered upon completion of the experiment, and a leaf from the uppermost part of the plant was selected for laboratory investigation. A complete randomized block design was used to analyze the data statistically ([Alsahooki and Wahib, 1990](#)).

Results and Discussion

The area of leaves and their overall chlorophyll content

A notable and statistically significant increase in leaf area and chlorophyll content is shown in [Table 4](#). This enhancement was noted when different soil humic acid levels were combined with magnetic irrigation water. Interestingly, as compared to the M2 treatment, the fertilization treatment combined with magnetized irrigation showed significantly higher values, with measurements reaching 4183 cm² and 2.138 mg/kg for leaf area and chlorophyll content respectively. The interaction treatment of M2H2 exhibited the highest values in these indicators, with significant differences observed, reaching 6657 cm² and 2.500 mg/kg for each of the quotient of the leaf area and the chlorophyll content respectively. The use of humic acid contributed to significant differences in the growth and development of these plants indicator.

Essential nutrients like potassium, magnesium, calcium, sulfur, and nitrogen are necessary for the production of chlorophyll types A and B. ([Shamsullah, 2020](#)). Humic acid improves soil fertility and increases

Table 3: *Some characteristics of irrigation water before and after magnetization*

irrigation water	EC (dS m ⁻¹)	pH	The dissolved ions will form L ⁻¹						
			Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Cl ⁻	HCO ₃ ⁻	SO ₄ ²⁻
Before magnetization	3.56	7.67	0.200	0.280	1.623	0.161	1.008	0.361	0.581
after magnetization	3.55	7.27	0.215	0.285	1.611	0.166	1.002	0.223	0.593

Table 4: Impact of humic acid and irrigation water magnetism on a broccoli plant's leaf area (cm^2) and chlorophyll (mg kg^{-1}).

Magnetization of Irrigation Water (M)	Plant Leaf Area (cm ²)			Effect Mean- M	Chlorophyll Concentration (mg kg ⁻¹)			Effect Mean- M
	Humic Acid				Humic Acid			
	H ₀	H ₁	H ₂		H ₀	H ₁	H ₂	
M ₁	1733	2041	2737	2170	1,639	1.920	2.339	1.966
M ₂	3039	2854	6657	4183	1.930	1.983	2.500	2.138
LSD 0.05	1888.8			1090.5	0.053			0.031
Effect Mean- H	2386	2447.5	4697		1.785	1.952	2.420	
LSD 0.05	1335.6				0.037			

Table 5: The effect of magnetization of irrigation water and humic acid on biological yield (g plant^{-1}) and economic yield (m tan ha^{-1}) of broccoli.

Magnetization of Irrigation water (M)	Biological yield (g plant ⁻¹)			Effect mean M	Economic yield (Mg ha ⁻¹)			Effect mean M
	Humic Acid				Humic acid			
	H ₀	H ₁	H ₂		H ₀	H ₁	H ₂	
M ₁	1850	2540	6190	3527	1.37	1.65	6.01	3.01
M ₂	5280	7140	9830	7417	4.25	6.57	13.35	8.05
LSD 0.05	1635			944	1.54			0.89
Effect Mean H	3565	4840	8010		2.81	4.11	9.68	
LSD 0.05	1156				1.09			

the amounts of calcium, potassium, magnesium, and other necessary minerals in the soil solution, which boosts the effectiveness of the synthesis of carotene and chlorophyll (Shamsullah, 2020). Humic substances, such as humic acid, have been shown to enhance chlorophyll a.

To contribute to plant health and vitality, these substances act as a primary and nutritional source for the synthesis of protective and structural pigments. The enhanced accessibility of energy for construction operations (Ryan *et al.*, 2001; Shamsullah *et al.*, 2023). The phenomenon of magnetism in salt water, which improves the physical and chemical properties of water and soil, is responsible for the enhancement of vegetative qualities. The result is improved photosynthesis, improved nutrient balance, improved carbohydrate utilization, increased plant growth and transpiration. The growth aspects are represented in cell expansion and the synthesis of basic compounds, and the final result is increased crop production. (Al-Issawi *et al.*, 2021; Hassan *et al.*, 2023, Hossain and Islam, 2024).

Biological and economic yield

Based on the findings of the study and the data presented in Table 5, there was a statistically significant

increases in both the biological yield and economic yield when there were changes in the magnetization of irrigation water and the levels of humic acid added to the soil. Specifically, the biological and economic quotients reached ($7410 \text{ g plant}^{-1}$) and ($8.05 \text{ m tons ha}^{-1}$), respectively, when the fertilization treatment and irrigation water magnetization achieved the values of M2. Furthermore, there were notable variations when humic acid was added at treatment H2, with biological quotient and economic quotient values of (8010 g/plant) and (9.68 tons/ha), respectively. With notable variations, the intraction treatment of M2H2 showed the highest values in these parameters, reaching (9830 g/plant-1) and (13.35 tons/ha-1) for each of the quotients of the biological yield and the economic yield, respectively. This is consistent with Shamsullah, (2020).

The use of humic acid in agricultural practices has been found to enhance crop productivity due to its composition of essential nutrients such as nitrogen, potassium, and phosphorus, as seen in Table 2. Additionally, it has been shown that the presence of this substance leads to a decrease in

soil pH. This decrease in reactivity subsequently enhances the availability of nutrients within the

solution, hence facilitating their absorption by plant roots (Abdel Nabi *et al.*, 2019). The phenomenon whereby the magnetic field generated by the magnetization device induces enhanced mobility of water molecules, leading to improved electrical insulation and decreased formation of water clusters, might also account for the observed augmentation in broccoli crop yield. This process results in the transformation of detrimental salts into benign substances by the creation of minuscule crystals, which then seep through the soil's pores rather than accumulating on the soil's surface or near the plant's roots (Abdel Nabi *et al.*, 2019; Al-Issawi *et al.*, 2021).

The soil content of nitrogen and phosphorus

The results in Table 6 show that there are notable increases in the soil's residual nitrogen and phosphorus at the magnetization of irrigation water and humic acid, as well as a significant increase in the soil's residual nitrogen and phosphorus at the magnetization of irrigation water and the change in the soil's humic acid addition levels. The addition of humic acid also recorded significant differences at treatment H1 and were (39.54) g plant⁻¹ and (14.17) mg kg⁻¹ soil for each of the remaining nitrogen and phosphorus in the soil, respectively. The interaction treatment M2H1 had recorded the highest values in the aforementioned indicators, with significant differences being (41.14) mg kg⁻¹ soil and (25.44) mg kg⁻¹ soil for each of the remaining nitrogen and phosphorus in the soil, respectively.

Nitrogen, and Phosphorus content According to the data in Table 2, humic acid exhibits active complexes that interact with different element cations, resulting in the formation of organometallic complexes. These complexes play a crucial role in facilitating the availability and accessibility of elements. All of these complexes have electron-donating properties, which

enables them to form bonds with positively charged nutrients such as potassium and macronutrients that act as electron acceptors (Hamza and Al-Taey, 2020, Ali *et al.*, 2021). This phenomenon is attributed to the role of humic acid in facilitating the transfer of electrons. The absorption of nutrients in the soil solution is facilitated by plant roots (Doklega and Abd El-Hady, 2017).

The increases in nutrient availability resulting from the magnetization of saline irrigation water can be due to several factors. First, it reduces soil pH and facilitates the dissolution of salts, including phosphate and sulfate. This dissolution leads to lower pH values and lower concentrations of toxic ions such as sodium (Na) and chloride (Cl). Second, when water passes through a magnetic field, it increases the concentration of hydrogen ions. The result is an increase in hydrogen ions and an enhancement of the concentration of nutrients in the soil solution (Gioia *et al.*, 2018, Salman and Abdulrasool, 2025).

Plant and soil potassium content

Following humic acid treatment, residual potassium levels in the soil increased statistically significantly, as shown by the data in Table 7. A residual potassium content of 285.7 mg kg⁻¹ soil was obtained from the soil treatment that surpassed humic acid H2. However, applying water magnetization did not significantly alter the soil's residual potassium levels. Additionally, the plant's potassium level varied significantly when water magnetization and humic acid treatment were combined. The potassium concentration was 3.49% for treatment M2 and 3.51% for treatment H2. Potassium content in the plant (3.65%) and residual potassium in the soil (277.7 mg/kg soil⁻¹) were both highest in treatment M2H2. It was determined that these variations were statistically significant. The coordinates and the provided data point line up

Table 6: Magnetization of irrigation water and humic acid in the residual nitrogen in the soil (mg kg⁻¹ soil) and the residual phosphorus in the soil (mg kg⁻¹ soil).

Magnetization of Irrigation Water (M)	Nitrogen (mg kg ⁻¹ soil)			Effect Mean M	Phosphorus (mg kg ⁻¹ soil)			Effect Mean M
	Humic Acid				Humic Acid			
	H ₀	H ₁	H ₂		H ₀	H ₁	H ₂	
M ₁	24.65	37.94	30.54	31.04	18.66	22.89	20.29	20.61
M ₂	31.41	41.14	36.34	36.30	20.50	25.44	24.52	23.49
LSD 0.05	3.76			2.17	2.01			1.16
Effect Mean H	28.03	39.54	33.44		19.58	24.17	22.41	
LSD 0.05	2.66				1.42			

Table 7: *Impact of humic acid and magnetization irrigation water on soil residual potassium (mg kg⁻¹) and broccoli plant absorption (%).*

Magnetization of Irrigation water (M)	Potassium (mg kg ⁻¹ soil)			Effect mean M	Potassium concentration (%)			Effect mean M
	Humic acid				Humic acid			
	H ₀	H ₁	H ₂		H ₀	H ₁	H ₂	
M ₁	194.3	271.0	293.7	253.0	3.21	3.34	3.38	3.31
M ₂	232.7	248.7	277.7	253.0	3.36	3.46	3.65	3.49
LSD 0.05	39.14			22.59	0.09			0.05
Effect Mean H	213.5	259.9	285.7		3.29	3.4	3.52	
LSD 0.05	27.67				0.06			

(Mani *et al.*, 2018).

Changes in the properties of water due to the presence of a magnetic field in the magnetometer, especially related to hydrogen bonds and their effect on the magnetic field, and the result is a change in the physical and chemical properties of water, and the result is an increase in the movement of water molecules, and the result of this is an increase in the movement of water molecules leading to enhancing electrical insulation and reducing water clumping and disrupting hydrogen bonds. Due to these modifications, the properties of water adapt, making it more soluble and reducing surface tension. The result of this is the transformation of salts from a harmful state to a harmless state and microscopic crystals are formed and can penetrate the pores of the soil instead of accumulating on the surface of the soil or around plant roots. This process also works to enhance the availability of nutrients, including potassium (Ali *et al.*, 2021; Devi *et al.*, 2023).

Conclusions and Recommendations

According to the research results, the significant importance of humic acid is highlighted, as it showed significant improvements in plant growth parameters, such as leaf surface area, leaf chlorophyll content, and biological and economic productivity. The use of magnetically treated water improved the physical and chemical properties of soil and water, enhancing productivity. Furthermore, the use of magnetized water as a growth and production factor in irrigation water management is recommended. Organic acids can be used in specific quantities as soil conditioners to enhance soil fertility.

Acknowledgment

The authors express their sincere gratitude to the
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College of Agricultural Engineering Sciences, University of Baghdad, and the College of Agricultural Engineering Sciences, University of Salahaddin, for providing the facilities and technical support required to conduct this study. Appreciation is also extended to the laboratories of the Ministry of Agriculture for their assistance in soil, plant, and water analyses.

Novelty Statement

This study presents an integrated evaluation of magnetized irrigation water combined with humic acid application under saline soil conditions, highlighting their synergistic effects on soil macronutrient availability, broccoli growth, and yield. The research provides novel field-based evidence supporting magnetized water as a sustainable irrigation strategy, alongside organic soil conditioners, to enhance crop productivity and nutrient dynamics while contributing to environmentally safe agricultural practices.

Author Contribution

Bassam Alaudeen Hamid: Conceptualized the research, supervised the experimental work, and contributed to manuscript preparation.
Jaafar Abbas Shamsullah: Participated in soil and water analysis and data interpretation.
Yahya Abdul- Munim Abd Sabry: Contributed to experimental design, statistical analysis, and discussion of results.
Ahmed Mohey. Rezooqi: Assisted in laboratory measurements and data collection.
All authors reviewed and approved the final version of the manuscript.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this

manuscript.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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