Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Effect of magnetization of irrigation water and humic acid on the availability of macronutrients NPK in soil, growth and yield of broccoli

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ABSTRACT
A field experiment was carried out in the season 2020-2021 in a field site in the Dora, Baghdad area, Iraq in a clay loam soil under the Type Torrfluvent group. The experiment included treating the soil with three levels of humic acid and irrigation with magnetized water by designing random sectors. The results of the research showed a significant increase in the leaf area. The chlorophyll content of leaves when magnetizing the irrigation water and the change in the levels of humic acid adding to the soil. The M_2H_2 interaction treatment recorded the highest values in the mentioned indices with significant differences, amounting to 6657 cm^2 and 1,150 mg L^{-1} for each of the leaf area and the content of chlorophyll leaves as well. Significant differences were recorded in the biological yield and economic yield, and the M_2H_2 interaction treatment recorded the highest values in the mentioned indices with significant differences amounting to 9830 g/plant and 13.35 ton ha^{-1} for each of the biological yield and economic yield, respectively. In the case of the soil nutrient content of NPK in the soil, significant increases were recorded in the remaining nitrogen and phosphorous in the soil when magnetizing irrigation water. Humic acid K and the M_2H_1 interaction treatment recorded the highest values in the mentioned indices with significant differences amounting to 39.54 and 24.16 mg kg $^{-1}$ of soil for each of the remaining nitrogen and phosphorous in the soil, respectively. The M_2H_2 interaction recorded the highest values in the remaining potassium in soil and its plant content were 277.7 mg kg^{-1} and 3.65% for each of the remaining and absorbed potassium, respectively.

Key word: Chlorophyll, Biological Yield, Phosphorous, Nitrogen.
Article type: Research Article.

INTRODUCTION
Broccoli is one of the plants of the cruciferous family and is grown for the purpose of obtaining its leaves as animal feed and its flowers for human consumption, which are either eaten fresh or for the purpose of making salads, soups or the rest of the dishes. Plant growth and as a result of the increase in global pollution rates, as indicated by reports and studies. There was an urgent need to use alternatives to chemical fertilization, such as organic fertilizers, or to simulate the non-excessive concentration of the element. Water consists of many molecules that attract each other and are able to dissolve different substances. The polarization of water is one of the properties that make it able to dissolve (Kobe *et al.* 2001; Al Qaisi 2009). Once a water molecule passes in a magnetic field, it changes in several ways:

1- The molecule increases in size, and consequently, this elevates the solubility and water permeability (the ability to distinguish and penetrate substances). The increase in permeability helps to carry more nutrients and then improves the absorption of water and materials carried with it.

2- Reducing the surface tension and increasing the surface area, which upraises the carrying and delivery of nutrients to the cells (Rahim 2009).

3-The ions in the water are affected, which leads to a reduction in the content of free radicals (substances harmful to the body) and also prevents the deposition of calcium carbonate and magnesium carbonate ions on the inner walls of water pipes, cooling and heating devices etc., thus protecting and maintaining these devices (Kobe *et al.* 2001).

The study aimed to increase production in quantity and quality, improve the qualitative characteristics of the crop and reduce the accumulation of toxins in plants and salts in the soil, which contributes to support human health and obtaining a clean environment with the least amount of pollutants as possible.

MATERIALS AND METHODS

A field experiment was conducted in the season 2020-2021 in a field site in Al-Dora, Baghdad area in clay loam soil under the Type Torrfluvent group (Table 1). The broccoli seeds were planted in a tray and after the completion of the fourth leaf, they were transferred to the permanent field. The plants were planted at a distance of 40 cm. The treatments of soil with three levels of humic acid (Table 2) included ground addition and at the concentrations of 0, 1 and 2 g L^{-1}, which symbolized by H_0, H_1 and H_2, respectively. Nitrogen was added at the chemical recommendation at a rate of 96 kg N ha^{-1} in the form of urea (46% N), while phosphorous at a rate of 184 kg P ha^{-1} in the form of superphosphate (46% P) and potassium in the form of potassium sulphate (96 kg ha^{-1}) (Al Issawi *et al.* 2021). Then irrigation was performed with water Magnetized and produced locally according to the patent 4402 on 12/17/2015 (Abdul Razzaq 2015) and in two intensity according to the inventor's recommendation for the device as 0 and 100 %, which symbols for each of them are M_1 and M_2, for each of them, respectively. It was carried out under the drip irrigation system and by designing random sectors and irrigating the plant with saline water (Table 3) (Al Sahoki & Karima 1990). The electrical conductivity (EC) of a soil: water extract (1:1) was estimated using an EC-meter, and the degree of soil reaction (pH) was estimated in a soil: water extract (1:1) using a pH-meter (Ryan *et al.* 2005).

Table 1. Some chemical and physical properties of the soil of the experimental field.

Properties		**value**
pH		7.65
EC (dS m^{-1})		3.61
Elements available (mg kg^{-1})	Nitrogen	32.00
	Potassium	281
	phosphorous	0.013
Cations (Cmol L^{-1})	Ca^{++}	1.20
	K^{+}	0.12
	Na^{+}	1.00
	Mg^{++}	0.40
Anions (Cmol L^{-1})	$SO_4^{=}$	1.11
	Cl^{-}	0.80
	HCO_3^{-}	0.56
	$CO_3^{=}$	Non
Aggregate soil (g Kg^{-1})	Sand	147
	Silt	432
	Clay	430

-The Cations (Ca^{+2}, Mg^{+2}, and Na^{+1}) were determined in a 1:1 extract. Ca^{+2} and Mg^{+2} were measured by titration using EDTA-Na2 and the dissolved Na^{+1} was measured by a flame apparatus (Ryan *et al.* 2005).

-Carbonates and bicarbonates were determined by titration with H_2SO_4 (0.01 N) acid (Ryan *et al.* 2005).

-The chlorine was measured by titration it with silver nitrate (0.005 N) (Ryan *et al.* 2005).

- Sulphate by turbidity using barium chloride (Ryan *et al.* 2005).

- Available nitrogen was estimated using the Micro-Kjeldahl device according to the method used by Bremner (Ryan *et al.* 2005).

- Available phosphorous was estimated according to the Olsen method (Ryan *et al.* 2005).

- The potassium was extracted by means of ammonium acetate and measured using the Flame photometer (Ryan *et al.* 2005).
-Estimating the volume distribution of soil particles using the density method (Page *et al.* 1982).
-Humic acid was determined according to the method described in (Page *et al.* 1982), by adding 0.1 N sodium hydroxide and precipitating humic acid using 2 N hydrochloric acid, then separated by centrifuge and dried at a temperature of 40 °C.
The following analyses were performed on the resulting humic acid:
-Samples of humic acid were digested using sulfuric acid, per and chloric acid (Ryan *et al.* 2005) and the elements were estimated:
-Nitrogen in the Kjeldahl device according to (Ryan *et al.* 2005).
-Potassium by means of a flame photometer, according to (Ryan *et al.* 2005).
-Phosphorous with a spectrophotometer according to the method mentioned in (Ryan *et al.* 2005).
-Chlorophyll was analysed according to (Association of Official Analytical Chemistry 1975).

Table 2. Some chemical properties of humic acid

property		**phosphate**	**potassium**	**nitrogen**	**humic acid**
measuring unit	**pH**	**%**	**%**	**%**	mg kg dry matter^{-1}
value	6.20	0.90	6.00	3.20	128000

-The yield was collected at the end of the experiment and the fourth leaf was taken from the developing top of a plant for the purpose of laboratory analysis. The statistical analysis was performed according to the complete random blocks (Al Sahoki & Karima 1990).

Table 3. Some characteristics of irrigation water.

EC ds.m^{-1}	**pH**	**Dissolved Ions Cmol.L^{-1}**						
		SO_4	**HCO_3**	**Cl**	**K**	**Na**	**Mg**	**Ca**
3.56	7.67	0.58	0.36	1.00	0.16	1.62	0.28	0.20

RESULTS AND DISCUSSION

Leaf area and total chlorophyll content in leaves

The results of this study (Table 4) showed a significant increase in leaf area and chlorophyll content of leaves when magnetizing irrigation water and changing the levels of humic acid addition to the soil. For each of the leaf area and its chlorophyll content, the addition of humic acid led to significant differences in these indices when in the H_2 treatment these indices were 4697 cm^2 and 1.094 mg L^{-1}, while the M_2H_2 interaction treatment recorded the highest values (6657 cm^2 and 1.150 mg L^{-1}) with significant differences. This is consistent with what was found on sunflower and paprika (Rahim 2009, Shamsullah 2020). A significant effect of humic acid and magnetization of irrigation water on vegetative indices can be explained by the fact that the formation of chlorophyll of its types (A and B) and carotenoids on three factors: genetic factor, light and availability of nutrients such as potassium, magnesium, calcium, sulphur and nitrogen. Moreover, the addition of humic acid in the soil increases its readiness and upraises concentrations of potassium, magnesium, calcium and the rest of the nutrients in the soil solution, thus elevating the efficiency of building pigments, i.e., chlorophyll and carotene (Rahim 2009; Al Qaisi 2009; Zaghdoud *et al.* 2012; Aljumail 2017; Al Furaiji & Shamsullah 2019). The humic acids, including humic, increase the content of leaves from chlorophyll and carotene, as they are a necessary food source for building structural and protective pigments, and then elevating the availability of energy for building processes (Ryan *et al.* 2005; Abdul Razzaq 2015; Kamali Omidi *et al.* 2022; Gurova & Sartakov 2023). The reason for the enhancement of vegetative characteristics can be attributed to the fact that the magnetization of salt water improves the physical and chemical properties of water and soil, and then increases the process of photosynthesis in the plant, the use of carbohydrates, the balance of nutrients, as well as an increase in the processes of transpiration and the general growth of the plant, which includes the growth and expansion of cells and the production of compounds vitality, and thus upraises the crop productivity (Manea *et al.* 2019; Winkle & Crappy 1987; Al Issawi *et al.* 2021).

Table 4. Effect of magnetization of irrigation water and humic acid on leaf area (cm^2) and chlorophyll (mg. l^{-1}) of Broccoli plant.

Irrigation water magnetization M	humic acid H	leaf area (cm^2)	chlorophyll mg L^{-1}	leaf area (cm^2)			Chlorophyll mg L^{-1}		
	H0	1733	0.393						
M1	H1	2041	0.620	2170	H0	2386	0.680	H0	0.511
	H2	2737	1.039						
	H0	3039	0.630		H1	2447		H1	0.651
M2	H1	2854	0.683	4183			0.820		
	H2	6657	1.150		H2	4697		H2	1.094
	A				CL				
LSD $_{0.05}$	M	H	MH		M		H		MH
	1090.5	1335.6	1888.8		0.031		0.037		0.053

Biological and economic yield

It is evident from the results of the research and from Table 5 that there is a significant increase in the biological and economic yields, and there is a significant increase in the biological and economic yields when magnetizing irrigation water and changing the levels of humic acid addition to the soil. plant and 8.05 ton ha^{-1} for each of the biological yield and the economic yield, respectively.

Table 5. Effect of magnetization of irrigation water and humic acid on the biological yield (g $plant^{-1}$) and the economic yield (ton ha^{-1}) of Broccoli plant

Irrigation water magnetization M	humic acid H	Biological yield (g $plant^{-1}$) HP	The economic yield (ton ha^{-1}) W	Biological yield (g $plant^{-1}$) HP			Economic yield (ton ha^{-1}) W		
	H_0	1850	1.37						
M1	H_1	2540	1.65	3530	H0	3560	3.00	H0	2.80
	H_2	6190	6.01						
	H_0	5280	4.25		H1	4840		H1	4.11
M2	H_1	7140	6.57	7410			8.05		
	H_2	9830	13.35		H2	8010		H2	9.68
	A				CL				
LSD $_{0.05}$	M	H	MH		M		H		MH
	944	1156	1635		0.89		1.09		1.54

The addition of humic acid with H_2 treatment led to significant differences in the biological yield and the economic yield (8010) g $plant^{-1}$ and 9.68 tons ha^{-1} respectively. The M_2H_2 interaction treatment also recorded the highest values in the abovementioned indices with significant differences (9830 g $plant^{-1}$ and 13.35 tons ha^{-1} respectively), in agreement with (Abed El Hady & Doklega 2018; Ali *et al.* 2019; Shamsullah 2020) on broccoli. The increase in yield when adding humic acid may be attributed to its content of nitrogen, potassium and phosphorous elements (Table 2). It also contributes to reduction in the degree of reaction of the soil solution and thus the elevated availability of nutrients in the soil solution, along with their absorption by plant roots (Winkle & Crappy 1987; El Metwally & Ahmed 2012; Ali *et al.* 2014; Abdel Nabi *et al*. 2019; Turbekova *et al*. 2023). It also explains the effects of the increased production of the broccoli, so that, the magnetic field generated by the magnetization device works to bring about a change in the properties of water, since it affects the hydrogen bonds in the water, influencing by the magnetic field. It leads to a change in the physical and chemical properties of water, causing an upraise in the movement of water molecules. Thus, the increased electrical insulation, minimizing water clusters, breaking hydrogen bonds, adapting the properties of water and making it more soluble (reducing surface tension), lead to the transformation of salts from harmful to harmless by the formation of microscopic crystals and their leakage through the pores of the soil, followed by their non-deposition on the surface of the soil or around the roots of the plant (Rahim 2009; Al Qaisi 2009; Aoda & Fattah 2011; Yahya & Abdul Razaq 2017; Aljumail 2017; Abdulameer & Ahmed 2019; AL Fadhly *et al.* 2019; Ali *et al.* 2019; AL Fadhly *et al.* 2020).

Soil content of nitrogen and phosphorous

The results in Table 6 indicate a significant increase in the residual nitrogen and phosphorous in the soil when magnetizing irrigation water and humic acid, exhibiting a significant elevation in these two elements in the soil when water magnetization and adding different levels of humic acid to the soil. The fertilization treatment outperformed the magnetization of irrigation water (M_2; 36.30 mg kg^{-1} and 23.49 mg kg $^{-1}$).

Table 6. Effects of the magnetization of irrigation water and different levels of humic acid on the residual nitrogen and phosphorous (mg kg^{-1}) in the soil for Broccoli.

Irrigation water magnetization (M)	humic acid (H)	N	P		N			P	
		mg kg^{-1}							
M_1	H_0	24.65	18.66	31.04	H_0	28.03	20.61	H_0	19.58
	H_1	37.94	22.89		H_1	39.54		H_1	24.16
	H_2	30.54	20.29		H_2	33.44		H_2	22.41
M_2	H_0	31.41	20.50	36.30			23.49		
	H_1	41.14	25.44						
	H_2	36.34	24.52						
		A					CL		
LSD $_{0.05}$	M	H		MH	M		H		MH
	2.17	2.66		3.76	1.16		1.42		2.01

Once the H_1 treatment led to 39.54 mg kg^{-1} and 24.16 mg kg^{-1} remaining nitrogen and phosphorous in the soil, respectively, the M_2H_1 interaction treatment recorded the highest values in these indices with significant differences (39.54 and 24.16 mg kg^{-1} respectively) . The addition of humic acid works due to its content of nitrogen, potassium and phosphorous elements (Table 2). Humic acid contains effective groups that participate in the reactions of humic acids with cations of the elements to form organic-metallic complexes, which are of great importance in the readiness of elements, and that all of these groups behave like electrons donor. So they exhibit the ability to bind with cations of positively charged nutrients, including potassium and micronutrients, which behave as electrons acceptor (Shamsullah 2020; Al Issawi *et al.* 2021). Humic acid contributes to lower the temperature of interaction in the soil solution, thus elevates the availability of nutrients in the soil solution and their uptake by plant roots (El Metwally & Ahmed 2012; Abd El Tawab *et al.* 2018). The role of the magnetization of saline irrigation water in increasing the availability of nutrients (nitrogen and phosphorous) can be attributed to the fact that this process reduces the alkalinity of the soil and the dissolution of salts such as phosphates and sulphates. It works to lower pH values and reduces the concentration of toxic ions such as Na, Cl as well as elevation in the ion hydrogen content when water passes through the magnetic field. So, it leads to the water cluster disintegration, partial dissolution of water molecules, liberating the H-O ion and combining it with water, forming the acidic H_3O^+ ion, and lowering the pH of the soil extract, thus upraising the concentration of nutrients in the soil solution (Al Qaisi 2009; Di Gioia *et al.* 2018; Lateef *et al.* 2019).

Potassium content of plants and soil

It is evident from Table 7 that there was a significant increase in the potassium residual in the soil when treating the soil with humic acid. The treatment of soil with humic acid (H_2) was superior (285.7 mg kg^{-1}) while no significant differences were recorded in the remaining potassium in the soil when the water magnetization was also recorded. Water magnetization and the addition of humic acid led to significant differences in the plant potassium content when M_2 and H_2 treatments were 3.49% and 3.51% (277.7 mg kg^{-1} and 3.65% of each of the remaining and absorbed potassium respectively). This is consistent with (Zaki *et al.* 2015; Abed El Hady & Doklega 2018).

Table 7. Effect of magnetization of irrigation water and humic acid on the residual potassium in the soil (mg.kg $soil^{-1}$) and potassium uptake (%) of Broccoli.

Irrigation water magnetization (M)	humic acid (H)	K mg kg^{-1} soil	AK (%)	K mg kg^{-1} soil			AK (%)		
				mg kg^{-1} soil					
M_1	H_0	194.3	3.21	253.0	H_0	213.5	3.31	H_0	3.28
	H_1	271.0	3.34						
	H_2	293.7	3.38						
M_2	H_0	232.7	3.36		H_1	259.8		H_1	2.34
	H_1	248.7	3.46	253.0			3.49		
	H_2	277.7	3.65		H_2	285.7		H_2	3.51
		A				CL			
LSD $_{0.05}$	M	H	MH	M		H		MH	
	22.59	27.67	39.14	0.05		0.06		0.09	

The elevation in the absorption of potassium when applying magnetizing irrigation water and humic acid treatment is due to the high content of nutrients in humic acid (Table 2). In the case of the magnetic field, it is due to the magnetizing device with its magnetic field, working to bring about a change in the properties of the water. It affects the existing hydrogen bonds in water, leading to a change in the physical and chemical properties of water, followed by causing an elevation in the movement of water molecules, upraising the electrical insulation, reducing water clusters, breaking hydrogen bonds and adapting the properties of water, making it more capable of dissolving (reducing surface tension). As a consequent, this leads to the conversion of salts from harmful to harmless by the formation of microscopic crystals and their leakage through the pores of the soil, as well as their lack of deposition on the surface of the soil or around the roots of the plant followed by the elevation in the readiness of nutrients, including potassium (Rico *et al.* 2014; Zaki *et al.* 2015; Rabee 2016).

CONCLUSION

In this study, significant results were observed when using experimental variables in leaf area and chlorophyll content of leaves when magnetizing irrigation water and changing the levels of humic acid addition to the soil. According to the results of the current study, we recommend applying humic acid, because of its effect on the studied properties and an important source in improving the properties of fertile soil, which was clearly reflected in the results of the study. According to the results of our experience, these practices can be repeated for years to increase soil quality and sustainable production.

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