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EFFECT OF HUMIC ACIDS AND THE AMOUNT OF MINERAL FERTILIZER ON SOME CHARACTERISTICS OF SALINE SOIL, GROWTH AND YIELD OF BROCCOLI PLANT UNDER SALT STRESS CONDITIONS

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ABSTRACT. A pots experiment was undertaken to determine the combined effect of humic acids and mineral fertilizer on some characteristics of saline soil, growth, and yield components of broccoli. The experiment was conducted in a randomized complete block design with three replications. The first factor consists of two levels of humic acids, namely without humic acid (H0 = 0.00 g L^{-1}) and humic acid application (H1 = 0.35 g L^{-1}), while the second factor included nine fertilizer (92 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1}) application rates that were (100, 100, 100%), (120, 120, 120%), (120, 120, 100%), (80, 120, 120%), (100, 100, 120%), (80.100, 100%), (120, 80, 80%), (100, 80, 80%), (80, 80, 80%) which added as a percentage of original fertilizer recommendation taking the symbols of R1 to R9 respectively. The treatment R1 was designated as a control treatment. The results indicated that humic acid application (H1) and increasing the amount of applied mineral fertilizer (R2) reduced the hydraulic conductivity of the soil for different soil depths. Humic acid addition (H1) increased concentrations of calcium and magnesium while reducing sodium concentration compared to control (H0). Contrary to humic acid, increasing the supplied mineral fertilizer led to a reduction in concentrations of calcium and magnesium while increasing sodium concentration in the soil. The sodium adsorption in soil particles in the ground was decreased due to humic acid application while improving the mineral fertilizer. Humic acid (H1) combined with increasing the amount of chemical fertilizer (R2) gave the desirable results in decreasing the sulphate, chloride and bicarbonate in the soil profile. The addition of humic acid (H1) and increasing mineral fertilizer application (R2) led to a significant increase in plant height, leaf area and head weight of broccoli per plant. Similarly, the interaction between humic acids and chemical fertilizers (H1R2) led to a significant increase in plant height, leaf area and head weight of broccoli per plant.

Introduction

Soil salinization is one of the most global challenges in the arid and semi-arid areas that strongly affect the sustainability of agricultural production (El Azzouzi, 2019). Consequently, encouraging long-term sustainable water management is required to achieve a sustainable water supply. Therefore, in regions facing water deficiency, it is common practice to exploit the saline water in irrigated agriculture (Pereira *et al.*, 2009); however, when saline water is used, the annual production is possibly subject to yield damage due to salt uptake by the plant, which causes a high risk to plant growth and a limiting factor for the productivity of most major crops (Sahi *et al.*, 2006), especially in the arid and semi-arid regions of the world (Munns, 2002), owing to the high salinity result in osmotic stresses, osmotic ions, disruption of the nutritional balance (Ashraf, 2004; Al-Khafajy *et al.*, 2020). Although difficult to accurately estimate the area of the salinized soil, it continues to expand, and this phenomenon is particularly acute in irrigated soils (Machado, Serralheiro, 2017). Worldwide, over 930 million hectares have been estimated to be salt-affected (Bacilio *et al.*, 2016; AL-Azawi, 2015). Therefore, for sustainable agriculture under saline irrigation water, the suggested strategies should focus on improving the soil's physical and chemical properties (Singh, 2014; Mahmood *et al.*, 2020). Many different practical methods have been suggested involving selecting suitable irrigation systems, salt-tolerant crops and proper field drainage (Kiremit, Arslan 2016; Redeef *et al.*, 2021). Humic acid (HA) is one of the considered methods. It is a fundamental component of humic substances, which form more than 60% of the soil's organic matter (Sani, 2014; Canellas *et al.*, 2015). It can amend the soil properties and improve plant metabolic processes (Bacilio *et al.*, 2016).

Moreover, it induces plant tolerance to various environmental stressors (Hatami *et al.*, 2018). Currently, humic acids are becoming obtainable as a commercial supplement for plant melioration (Rose *et al.*, 2014; Ali *et al.*, 2021). It is the critical component of organic fertilizers and contains a considerable amount of nutrients (Canellas *et al.*, 2015). Humic substances have antioxidant activity, which is assumed to prevent ROS production and protect cells from oxidative damage (Khan *et al.*, 2010; Hussain *et al.*, 2021). It does not merely assist in reducing the negative impacts of salinity but may also contribute to preserving sustainable cultivation in an adverse environment (AL-Taey, Burhan, 2021).

Moreover, it could help increase the yield per unit area, counterbalancing any needed increase in the cultivated area, and protecting the environment from additional negative impacts. Broccoli (*Brassica oleracea*) was considered one of the important vegetable cancer because it comprises considerable amounts of antioxidants and fibre. It can be cultivated worldwide (Sotelo *et al.*, 2014). Besides being a good source of minerals, vitamins and phenolics, several studies have recommended broccoli for cataract prevention. This research was conducted to investigate the combined effect of humic acid, and the amount of mineral fertilizer on some characteristics of saline soil, growth and yield components of broccoli.

Materials and Methods

A pots experiment was conducted from October to February in the agricultural season 2020–2021. A two-factor experiment was performed as a randomized complete block design with three replications. The first factor consists of two levels of humic acids (consist of humic and fulvic acid), namely without humic acids (H0 = 0.00 g. L^{-1}) and humic acids application (H1 = 0.35 g. L^{-1}). In contrast, the second factor consisted of nine treatments with different doses of fertilizer combinations. The nine treatments of mineral fertilizer were added as a percentage of the original fertilizer recommendation of broccoli (92 kg N h^{-1}, 200 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1}) according to El Magd *et al.* (2005). The details of applied treatments were (100, 100, 100%), (120, 120, 120%), (120, 120, 100%), (80, 120, 120%), (100, 100, 120%), (80, 100, 100%), (120, 80, 80%), (100, 80, 80%), (80, 80, 80%) taking the symbols of R1 to R9 respectively. The treatment R1 (100, 100, 100%) was designated as a control treatment. Before fieldwork commenced, six disturbed samples were randomly taken from the plough layer (0–30 cm depth) from a private farm and comprehensively mixed to form one representative composite sample. The representative sample was air-dried and preserved in a sealed polythene bag. Subsequently, it was transferred to the laboratory, crushed and passed across a 2 mm sieve to determine the principal selected soil chemical and physical properties Table 1. Soil from the study field was passed through a 4 mm sieve and packed in 30 kg plastic pots. The humic acids were obtained from the local markets in a powder with dark brown colour (country of origin: Spain). The humic acids understudy is 100% soluble in water and composed of 68% humic acid, 17% fulvic acid (humic acids of 85%) and 12% K_2O. The humic acids (humic and fulvic acid) were applied by mixing with irrigation water. Urea fertilizer was applied as a nitrogen source in two equal splits; the first dose was applied at planting, and the second dose was applied after two months of planting. Triple superphosphate (44% P_2O_5) and potassium sulfate fertilizer (50% K_2O) was applied to the soil as a source of phosphorous and potassium once at planting. Broccoli seedlings were planted with one seedling per pot, and irrigation water with an electrical conductivity (EC) of 4.2 dS m^{-1} was used for plant watering. Some chemical properties of irrigation water are listed in Table 1. The gravimetric method was adopted for irrigation to bring soil moisture to the limits of field capacity. Throughout the experiment, all treatments were irrigated when 35% of available water was consumed. Leaching requirements of 13% were added according to Ayers and Westcot (1985). Agricultural practices such as weeding were adopted when required. Crops were harvested on 05/02/2021. Data concerning plant height (cm), leaf area (cm^2) and yield per plant (g $plant^{-1}$) were taken.

The obtained data were statistically analyzed using analysis of variance (ANOVA) with SPSS 20. Mean data were compared using the least significant difference (LSD) at a 0.05% probability level. To measure the electrical conductivity, of cations and anions, soil samples were taken from three depths, namely 0–10, 10–20 and 20–30 cm. The pH and EC for the soil under study were estimated from the 1:5 soil-water suspensions using a pH and EC meter. The soil organic matter was determined according to the acid extraction method (Jackson, 1967). While the total nitrogen was determined using the Kjeldahl method as described by (Mulvaney *et al.,* 1982). Olsen and Sommers method was used to determine the available P (Olsen, Sommers, 1982). Titrations measured chloride with silver nitrate (Richards, 1954), while the bicarbonate was estimated by titration according to the sodium adsorption ratio (SAR) using the concentration values of the sodium, calcium and magnesium (mmol L^{-1}) according to the Equation 1. Regarding the sulphates, it was estimated by the turbidity method. Atomic absorption spectrophotometry was used to measure Ca and Mg, while flame photometers used for Na and K (Polemio, Rhoades, 1977).

$$Sodium\ Adsorption\ Ratio\ (SAR) = \frac{Na}{\sqrt{Ca + Mg}} \qquad (1)$$

Table 1. Some properties of soil and irrigation water before planting

Parameter		In soil	In irrigation water	Unit
pH		7.40	7.60	
SAR		4.42	3.83	
EC		7.30	4.20	dS m^{-1}
Organic matter		8.72		mg kg^{-1}
Ca^{+2}		16.55	5.35	mmol L^{-1}
Mg^{+2}		15.80	8.00	
Na^{+1}		25.15	14.00	
K^{+}		0.62	0.15	
SO_4^{-2}		16.50	3.10	
HCO_3^{-}		1.10	0.10	
Cl^{-}		37.80	12.20	
N		100.50		mg kg^{-1}
P		52.00		
Na		139.50		
Bulk density		1.34		mg $m^{3\ -1}$
Soil particles	sand	650.00		g kg^{-1}
	silt	100.00		
	clay	250.00		
Texture	Sandy clay loam			

SAR – sodium adsorption ratio

Results and Discussion

Effect of humic acids and the amount of mineral fertilizer on soil electrical conductivity

The effect of humic acids mixed with irrigation water and the amount of mineral fertilizer led to a decrease in the soil electrical conductivity values with depth (0–10, 10–20 and 20–30 cm) Table 2. Where the electrical conductivity values (ECe) decreased with depth when the humic acids have been used (H1) compared to without humic acids (H0 = 0.00 g L^{-1}). The ECe were 4.71, 4.71 and 4.82 dSm^{-1} for the soil depths of 0–10, 10–20 and 20–30 cm respectively when adding humic acids at the level of H1 (0.35 g L^{-1}), while the average of electrical conductivity values ascending order 5.10, 5.26, 5.47 dS m^{-1} for the same depths respectively when humic acids (H0) were not added with a decrease of 7.64, 10.45 and 11.88% compared to without humic acids. Soil electrical conductivity decreased for the depths of 0–10, 10–20 and 20–30 cm with increasing the application of mineral fertilizer, where the lowest obtained values of soil electrical conductivity were 4.61, 4.75 and 4.95 dS m^{-1} for the aforementioned depths respectively at the R2 treatment. On the contrary, the treatment R9 gave the highest values of soil electrical conductivity reaching 5.11, 5.25 and 5.32 dS m^{-1} for the same previous mentioned depths respectively, with decreasing rate of 9.78, 9.52 and 6.95% respectively for the same depths. Whereas the interaction (between humic acids and mineral fertilizers) led to a decrease in the electrical conductivity values for the three different soil depths. The lowest average of the electrical conductivity values were 4.26, 4.40 and 4.50 dS m^{-1} for the three different soil depths respectively, at the combination of H1R2, while the highest values of the electrical conductivity were 5.29, 5.56 and 5.68 dS m^{-1} for the three different soil depths respectively at the combination of H0R9.

The reason for the reduction of ECe in the aforementioned depths of the soil could be due to the application of humic acids and its role in improving the soil chemical properties because humic acids are relatively complex molecules containing a wide range of effective groups. Such as carboxyl and hydroxyl that work on chelating, complicating and adsorption of salt ions, and changing the ionic composition of the soil solution, through leaching out the sodium salts out of the soil profile, thereby reduces their effect on the soil (Tchiadje, 2007). In addition, to the ability of humic acids to improve the physical properties of soil such as structure and bulk density, increasing permeability and speed of salt leaching out (Nan *et al.,* 2016). The findings of this research are consistent with (Khattak, Dost, 2014). Decreasing the soil electrical conductivity with increasing the levels of chemical fertilizers application probably due to the role of humic acids in improving plant growth which in turn absorbs considerable amount of dissolved ions from the soil solution, consequently reduces the soil electrical conductivity, in addition, urea is a non-ionic mineral fertilizer. Borzouei *et al.,* (2014) found that the use of urea led to a decrease in the electrical conductivity of the soil, as well as the effect of the added fertilizer on the plant, where it compensates for the deficiency in the availability of elements, including potassium and phosphorous, which plays significant regulatory roles in plant vital activities and its relationship to an increase in vegetative growth and absorption essential and non-essential elements for the plant due to the nutritional imbalance resulted from salinity where the excessive dissolved salts accumulated in the plant salt glands or into salt bladders for temporary storage and then the salt will scatter from salt bladders when it encounters strong winds moreover old leaves fall is one of the means of protecting the plant from salinity (Chen *et al.,* 2018).

Effect of humic acids and the amount of mineral fertilizer on the concentration of Ca, Mg and Na in the soil

The results listed in Table 3 show an increase in dissolved calcium, and magnesium and a decrease the sodium for three different soil depths with the application of humic acids H1 compare to H0. Where the dissolved calcium, magnesium and sodium values reached 13.05, 20.66 and 15.33 mmol L^{-1} and 6.95, 12.17 and 17.81 mmol L^{-1} for the depth of 0–10 cm respectively for H1 and H0 respectively, with an increasing rate of 87.76 and 69.76% for calcium and magnesium while sodium decreased 13.92% for the same depth. The next two depths (10–20 and 20–30 cm) show similar trends to the depth of 0–10 cm, in terms of increasing calcium, magnesium and decreasing sodium. Where under the effect of humic acids, the average values of dissolved calcium, magnesium and sodium were 18.15, 22.83 and 16.28 mmol L^{-1} respectively compared to 8.87, 13.77 and 18.66 mmol L^{-1} in the absence of humic acids for the depth of 10–20 cm with an increase of 104.62 and 65.79% for calcium and magnesium and with a decrease of 12.75% for sodium.

Table2. Effect of humic acids and the amount of mineral fertilizer on the soil electrical conductivity for the three different soil depths (0–10, 10–20 and 20–30cm) after planting

Soil depth, cm	Levels of humic acids, g L^{-1}	Supplied mineral fertilizer. %									
		R1	R2	R3	R4	R5	R6	R7	R8	R9	Average of
		Electrical conductivity values, dS m^{-1}									humic acids
0–10	H0 (0.00)	4.98	4.97	5.12	5.15	5.10	5.10	4.98	5.26	5.29	5.10
20–10		5.12	5.10	5.43	5.40	5.10	5.10	5.15	5.45	5.56	5.26
20–30		5.44	5.40	5.50	5.43	5.43	5.34	5.42	5.62	5.68	5.47
0–10	H1 (0.35)	4.36	4.26	4.68	4.66	4.65	4.50	4.48	4.88	4.93	4.71
10–20		4.48	4.40	4.87	4.83	4.76	4.60	4.58	4.93	4.95	4.71
20–30		4.60	4.50	4.94	4.94	4.93	4.82	4.76	4.98	4.97	4.82
											mineral fertilizer
0–10	Average of mineral fertilizer	4.67	4.61	5.40	4.90	4.87	4.80	4.73	5.07	5.11	4.90
10–20		4.80	4.75	5.15	5.11	4.93	4.85	4.86	5.19	5.25	4.98
20–30		5.02	4.95	5.32	5.18	5.18	5.08	5.09	5.30	5.32	5.15

R1 to R9 – fertilizer (92 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1}) application rates (100, 100, 100%), (120, 120, 120%), (120, 120, 100%), (80, 120, 120%), (100, 100, 120%), (80.100, 100%), (120, 80, 80%), (100, 80, 80%), (80, 80, 80%), respectively.

Table 3. Effect of humic acids and the amount of mineral fertilizer on the concentration of Ca, Mg and Na mmol L^{-1} for the three different soil depths (0–10, 10–20 and 20–30cm) after planting

Soil depth, cm	Levels of humic acids, g L^{-1}	Supplied mineral fertilizer, %									Average of
		R1	R2	R3	R4	R5	R6	R7	R8	R9	
					Ca, mmol L^{-1}						humic acids
0–10	H0 (0.00)	7.5	6.0	7.5	7.5	7.5	7.0	5.5	6.8	7.3	6.95
10–20		8.5	8.0	9.0	10.0	8.5	10.0	8.5	8.0	9.4	8.87
20–30		9.5	9.0	10.0	10.2	10.5	10.3	9.4	9.0	12.0	9.98
0–10	H1 (0.35)	17.5	10.0	12.5	15.0	12.0	9.5	16.0	10.0	15.0	13.05
10–20		19.0	17.5	17.5	17.5	17.5	20.5	17.9	18.5	17.5	18.15
20–30		21.5	19.0	19.0	20.0	20.0	21.0	22.5	23.0	22.5	20.94
											mineral fertilizer
0–10	Average of mineral fertilizer	12.5	8.0	10.0	11.3	9.8	8.3	10.8	8.4	11.2	10.00
10–20		13.8	12.8	13.3	13.8	13.0	15.3	13.2	13.3	13.5	13.51
20–30		15.5	14.0	14.5	15.1	15.3	15.7	16.0	16.0	17.3	15.46
					Mg, mmol L^{-1}						humic acids
0–10	H0 (0.00)	10.5	11.0	12.5	13.0	12.6	13.0	12.5	12.5	12.0	12.17
10–20		13.0	13.0	14.0	14.0	14.50	14.0	13.5	14.0	14.0	13.77
20–30		13.5	13.5	14.5	14.5	15.0	15.0	14.5	15.5	14.5	14.50
0–10	H1 (0.35)	21.0	20.5	20.0	19.5	20.0	20.0	22.5	22.5	20.0	20.66
10–20		22.5	22.0	22.5	23.0	22.5	23.0	24.0	22.5	23.5	22.83
20–30		27.0	22.5	25.5	25.5	25.0	26.0	26.5	24.6	28.0	25.62
											mineral fertilizer
0–10	Average of mineral fertilizer	15.75	15.75	16.25	16.25	16.3	16.5	17.5	17.5	16.00	16.41
10–20		17.75	17.5	18.25	18.5	18.5	18.5	18.75	18.25	18.75	18.30
20–30		20.25	18	20.00	20.00	20.00	20.5	20.5	20.05	21.25	20.06
					Na, mmol L^{-1}						humic acids
0–10	H0 (0.00)	17.61	17.50	17.38	17.60	16.90	18.40	18.20	18.00	18.70	17.81
10–20		18.34	18.10	18.29	18.16	17.20	19.37	18.96	20.46	19.10	18.66
20–30		19.50	18.90	19.40	19.72	18.60	20.30	19.84	20.61	21.00	19.76
0–10	H1 (0.35)	14.41	15.27	15.05	14.73	14.61	14.72	16.40	15.95	16.83	15.33
10–20		16.03	15.96	15.53	15.81	14.73	15.46	18.17	17.31	17.60	16.28
20–30		17.17	16.64	16.28	16.60	17.84	16.72	18.73	18.33	18.50	17.42
											mineral fertilizer
0–10	Average of mineral fertilizer	16.01	16.38	16.21	16.16	15.75	16.56	17.30	16.97	17.76	16.57
10–20		17.18	17.03	16.91	16.98	15.96	17.41	18.56	18.88	18.35	17.47
20–30		18.33	17.77	17.84	18.16	18.22	18.51	19.28	19.47	19.75	18.59

R1 to R9 – fertilizer (92 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1}) application rates (100, 100, 100%), (120, 120, 120%), (120, 120, 100%), (80, 120, 120%), (100, 100, 120%), (80.100, 100%), (120, 80, 80%), (100, 80, 80%), (80, 80, 80%), respectively.

Likewise, at the depth of 20–30 cm, the average values of dissolved calcium, magnesium and sodium were 20.94, 25.62 and 17.42 mmol L^{-1} respectively compared to 9.98, 14.50, and 19.76 mmol L^{-1} in the absence of humic acids with an increase of 109.81 and 76.68% for calcium and magnesium, respectively, and a decrease of 11.84% for sodium. The research results show that increasing the chemical fertilizers application led to a decrease in the values of calcium, magnesium and sodium for soil depths 0–10, 10–20 and 20–30 cm. where the lowest value of calcium and magnesium obtained from the treatments R2 while the lowest value of sodium obtained from the treatments R5. Increasing the concentration of calcium and magnesium while decreasing the concentration of sodium in the soil under the effect of humic acids may be attributed to the role of humic acids on the chelation of the dissolved ions from the soil solution and humic acids may also induce the formation of organic complexes because it contains functional groups such as carboxyl (COOH-) and phenol (OH-), which was one of the main reasons for the large reactions of adsorption, cation exchange, complex and chelation, in addition, the complexes formed with calcium and magnesium have less mobility compared to the movement of complexes formed with sodium (Zhang *et al.*, 2013). While decreasing the values of calcium, magnesium and sodium under the effect of mineral fertilizer application probably due to the increase in the growth rate of the plant (Table 6), consequently increased the absorption of nutrients due to the role of potassium in inducing the plant to absorb the dissolved nutrients from the soil, including sodium, which thereafter the plants get rid of or sequestering the harmful ion by different means (Munns 2002), or probably due to the levels of applied potassium to the soil contributed to release the sulfur that can be grouped with calcium to precipitate in the form of calcium sulfate, which characterized as scarcely soluble salt (Rahmati *et al.*, 2019).

Effect of humic acids and the amount of mineral fertilizer on the sodium adsorption ratio (SAR)

Table 4 presents the effect of mixing humic acids with irrigation water and the amount of mineral fertilizer on the values of SAR for the three different soil depths (0–10, 10–20 and 20–30 cm). The results indicated that there was a decrease in the values of SAR for the three different soil depths with the addition of humic acids (H1) compared to the treatment without humic acids (H0). The obtained values of the sodium adsorption ratio were 2.64, 2.54 and 2.55 for the three successive soil depths (0–10, 10–20 and 20–30 cm) respectively under the effect of humic acids (H1), with a decrease of 35.13, 35.03 and 36.09% compared to without humic acids application treatment that gave 4.07, 3.91 and 3.99 for the same previous mentioned depths respectively. The research results show that increasing the chemical fertilizers application led to an increase in the values of the sodium adsorption ratio for the three different soil depths (0–10, 10–20 and 20–30 cm), especially those containing a high percentage of nitrogen, where the highest value of the sodium adsorption ratio reached 3.50 for a depth of 0–10 cm at the treatment R2, while the lowest value was 3.17 for the same depth at the treatment R5. The highest value of the sodium adsorption ratio was 3.53 and 3.40 for the depths of 10–20 and 20–30 cm respectively at the treatment R9, while the lowest values of sodium adsorption ratio were 2.95 and 3.16 respectively, for the same depths at the treatment R5. The general decline in the sodium adsorption ratio is probably due to those humic acids containing functional groups such as the carboxylic and hydroxyl groups that work on chelating, complex and adsorption of sodium ions and forming soluble and movement organic complexes thus increasing the possibility of its leaching out. The functional groups in humic acids also chelate and complex the calcium and magnesium ions to form organic complexes that are less mobile than sodium ions in the soil, which reduces the process of their leaching out (Zhang *et al.*, 2013), and these findings are consistent with (Nan *et al.*, 2016). On contrary with humic acids, the amount of mineral fertilizer increases the values of the sodium adsorption ratio in the soil by increasing the rate of mineral fertilizers application. possibly due to the increase of plant growth rate, which increased the nutrients uptake by the plant such as calcium and magnesium, or the competition between sodium and ammonium on the absorption sites on the surface of the roots, which reduced the absorption of sodium by the plant (Pardo, Rubio 2011) and thus increased the sodium adsorption ratio values. This is consistent with the findings of (Tester, Davenport 2003).

Table 4. Effect of humic acids and the amount of mineral fertilizer on the sodium adsorption ratio for the three different soil depths (0–10, 10–20 and 20–30cm) after planting

Soil depth, cm	Levels of humic acids, g L^{-1}	Supplied mineral fertilizer (%)									Average of
		R1	R2	R3	R4	R5	R6	R7	R8	R9	
		Sodium adsorption ratio									humic acids
0–10	H0 (0.00)	4.15	4.24	3.88	3.88	3.76	4.11	4.28	4.09	4.25	4.07
10–20		3.95	3.94	3.81	3.70	3.58	3.95	4.04	4.36	3.94	3.91
20–30		4.06	3.98	3.91	3.96	3.68	4.03	4.05	4.16	4.07	3.99
0–10	H1 (0.35)	2.32	2.76	2.63	2.50	2.58	2.71	2.64	2.79	2.84	2.64
10–20		2.48	2.53	2.45	2.48	2.32	2.34	2.80	2.70	2.74	2.54
20–30		2.46	2.58	2.44	2.46	2.65	2.43	2.67	2.65	2.60	2.55
											mineral fertilizer
0–10	Average of mineral fertilizer	3.23	3.5	3.25	3.19	3.17	3.41	3.46	3.46	3.44	3.35
10–20		3.21	3.23	3.13	3.09	2.95	3.14	3.42	3.42	3.53	3.22
20–30		3.26	3.28	3.17	3.21	3.16	3.23	3.36	3.36	3.40	3.27

R1 to R9 – fertilizer (92 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1}) application rates (100, 100, 100%), (120, 120, 120%), (120, 120, 100%), (80, 120, 120%), (100, 100, 120%), (80.100, 100%), (120, 80, 80%), (100, 80, 80%), (80, 80, 80%), respectively.

Effect of humic acids and the amount of mineral fertilizer on the concentration of dissolved ions SO_4, Cl, and HCO_3 in the soil

The results listed in Table 5 present the effect of mixing humic acids with irrigation water and the amount of mineral fertilizer on the dissolved values of sulphate, chloride and bicarbonate for the three different soil depths (0–10, 10–20 and 20–30 cm). The observed trend in dissolved values of former salts is a decrease for different depths under the effect of humic acids (H1 = 0.35 g L^{-1}) compared to the treatments without humic acids addition (H0) for the three different soil depths. Where the average values of dissolved sulphate, chloride and bicarbonate were 3.73, 14.83 and 0.13 mmol L^{-1} respectively for depth 0–10 cm with the addition of humic acids (H1), while the average values of dissolved sulphate, chloride and bicarbonate for the treatments without humic acids were 4.31, 25.50, and 0.39 mmol L^{-1} for the same depth, respectively, with a decrease of 13.45, 41.84, and 66.66% for sulphate, chloride and bicarbonate, respectively. For the depth of 10–20 cm, the average values of the dissolved sulphate, chloride and bicarbonate were 4.33, 23.15 and 0.19 mmol L^{-1} respectively, with the addition of humic acids (H1). While the average values of dissolved sulphate, chloride and bicarbonate for the treatments without humic acids were 5.17, 30.86, and 0.64 mmol L^{-1}, respectively, for the same depth, with a decrease of 16.24, 24.98 and 70.31%, respectively. Similarly, the effect of humic acids continues to decrease the values of dissolved sulphate, chloride and bicarbonate in the depth of 20–30 cm. Where the dissolved former mentioned salts were 5.35, 30.68 and 0.27 mmol L^{-1} respectively. Contrastingly, the average values of dissolved sulphate, chloride and bicarbonate in the absence of humic acids were 5.51, 34.62 and 0.86 mmol L^{-1}, respectively, for the same depth, with a decrease of 2.90, 11.38, and 68.60%, respectively. Regarding the effect of mineral fertilizer application, mineral fertilizers led to a decrease in the values of chloride and bicarbonate for the three soil depths, where the lowest values resulted from the treatment R2, while the highest resulted from the treatment R9. Concerning the sulphate, its values were varied because the potassium fertilizer contains sulphate, thus it increased with the increase in the levels of potassium sulphate fertilizer addition. Decreasing the concentration of dissolved sulphates, chlorides and bicarbonates in the soil under the effect of humic acids may be attributed to the role of humic acids in improving the soil's physical properties such as soil structure, bulk density and porosity, increasing permeability and increasing the rate of leaching in the soil (Paksoy *et al.*, 2010; Turan *et al.*, 2011). The research findings are in agreement with Aydin *et al.* (2012) and Khattak and Dost (2014).

Table 5. Effect of humic acids and the amount of mineral fertilizer on dissolved SO_4, Cl, and HCO_3 for the three different soil depths (0–10, 10–20 and 20–30 cm) after planting

Soil depth, cm	Levels of humic acids. g L^{-1}	Supplied mineral fertilizer (%) R1	R2	R3	R4	R5	R6	R7	R8	R9	Average of
						SO_4, mmol L^{-1}					humic acids
0–10	H0 (0.00)	4.00	4.70	4.41	4.61	4.19	4.55	4.22	4.00	4.14	4.31
10–20		5.00	5.00	5.25	5.22	5.62	5.11	5.13	5.00	5.25	5.17
20–30		5.30	5.32	5.86	6.00	5.9	5.56	5.23	5.14	5.31	5.51
0–10	H1 (0.35)	3.22	3.37	3.8	4.06	4.10	4.00	3.72	3.66	3.67	3.73
10–20		4.00	3.43	4.00	5.11	4.32	4.19	4.40	4.53	5.00	4.33
20–30		5.35	5.73	5.46	5.80	5.11	5.22	5.11	5.26	5.13	5.35
											mineral fertilizer
0–10	Average of mineral fertilizer	3.61	4.03	4.10	4.33	4.14	4.27	3.97	3.83	3.90	4.02
10–20		4.50	4.21	4.62	5.16	4.97	4.65	4.76	4.76	5.12	4.75
20–30		5.32	5.52	5.66	5.90	5.50	5.39	5.17	5.20	5.22	5.43
						Cl, mmol L^{-1}					humic acids
0–10	H0 (0.00)	25.22	16.75	20.08	24.75	24.41	26.66	26.15	33.43	32.08	25.50
10–20		30.41	26.75	30.18	29.75	30.90	30.22	31.11	34.32	34.11	30.86
20–30		33.45	30.18	33.41	34.12	35.45	35.55	36.31	36.43	36.75	34.62
0–10	H1 (0.35)	13.47	13.41	13.43	13.41	13.41	17.46	16.75	14.75	17.44	14.83
10–20		27.75	22.06	26.45	25.55	25.41	20.44	20.45	19.75	20.50	23.15
20–30		31.19	29.42	29.34	30.27	29.22	31.67	31.98	31.42	31.65	30.68
											mineral fertilizer
0–10	Average of mineral fertilizer	19.34	15.08	16.75	19.08	18.91	22.06	21.45	24.09	24.76	20.16
10–20		29.08	24.40	28.31	27.65	28.15	25.33	25.78	27.03	27.30	27.00
20–30		32.32	29.80	31.37	32.19	32.33	33.61	34.14	33.92	34.20	32.65
						HCO_3, mmol L^{-1}					humic acids
0–10	H0 (0.00)	0.54	0.50	0.50	0.52	0.52	0.56	0.58	0.61	0.59	0.54
10–20		0.62	0.60	0.61	0.62	0.63	0.72	0.67	0.67	0.66	0.64
20–30		0.86	0.80	0.82	0.85	0.84	0.88	0.9	0.89	0.90	0.86
0–10	H1 (0.35)	0.11	0.10	0.10	0.11	0.11	0.13	0.19	0.18	0.19	0.13
10–20		0.17	0.16	0.16	0.16	0.17	0.21	0.22	0.25	0.25	0.19
20–30		0.21	0.20	0.21	0.21	0.20	0.34	0.35	0.35	0.39	0.27
											mineral fertilizer
0–10	Average of mineral fertilizer	0.32	0.30	0.30	0.31	0.31	0.34	0.38	0.39	0.39	0.33
10–20		0.39	0.38	0.38	0.39	0.4	0.46	0.46	0.46	0.45	0.41
20–30		0.53	0.50	0.51	0.53	0.52	0.61	0.62	0.62	0.64	0.56

R1 to R9 – fertilizer (92 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1}) application rates (100, 100, 100%), (120, 120, 120%), (120, 120, 100%), (80, 120, 120%), (100, 100, 120%), (80.100, 100%), (120, 80, 80%), (100, 80, 80%), (80, 80, 80%), respectively.

While decreasing the concentration of chloride and bicarbonate in the soil by increasing the application of mineral fertilizers could attribute to the increase in plant growth and consequently uptake of relatively larger amounts of these ions, which is reflected in decreasing their concentration in the soil solution with depth (Sayyad-Amin *et al.,* 2018) .while increasing the sulfate concentration, probably due to release the sulfur from the applied fertilizer, which causes an increase in the dissolved amount in the soil (Klikocka, Marks 2018).

Effect of humic acids and the amount of mineral fertilizer on some growth and yield components of broccoli

Table 6 presents the effect of mixing humic acids with irrigation water and the fertilizer recommendation on growth and some yield components of broccoli (plant height, leaf area, head weight per plant). The results show a significant increase in the aforementioned traits under the effect of humic acids, where the average plant height reached 35.75 cm for the H1 level of humic acids and 25.29 cm in the absence of humic acids (H0), with an increase of 41.36% compared to without humic acids treatment. Likewise, the average leaf area increased under the effect of humic acids achieving 215.52 cm^2 for treatment H1, while the treatment H0 gave 138.40 cm^2 with an increase of 55.72%. Similarly, humic acids led to an increase in the head weight per plant. Where the highest head weight resulted from the treatment H1 by achieving 246.46, g $plant^{-1}$ while the lowest weight was obtained from the treatment H0 by achieving 117.73 g $plant^{-1}$, with an increase of 109.34%. In the same way, the mineral fertilizer led to a significant increase in the plant height reaching 36.17 cm at the treatment R2, while the lowest value of plant height was 27.03 cm at the treatment R9 with an increase of 33.81%, the highest average in leaf area was 211.82 cm^2 at the treatment R2, and the lowest average in leaf area was 135.28 cm2 at the treatment R9 with an increase of 56.57%, while the highest head weight per plant was 271.74 g and lowest head weight per plant was 120.50 g $plant^{-1}$, with an increase of 125.51%.

The interaction effect of humic acids, and the amount of mineral fertilizer, show significant differences in the traits of plant height, leaf area, and head weight per plant. The highest value of the plant height trait was 41.75 cm at the combination of H1R2. While the lowest was 23.13 cm at the combination of H0R9. Regarding the leaf area, the highest value of the leaf area has resulted from the combination H1R2 reaching 244.22 cm^2. While the lowest value of the leaf area trait was 85.39 cm^2 obtained from the combination H0R9. Concerning head weight per plant, the highest and lowest head weight per plant was 368.60 and 74.82 g $plant^{-1}$ attained from the combination of H1R2 and H0R9 respectively. The study revealed that the main reason for the increase in the plant height, leaf area, and head weight per plant was probably because humic acids change the pattern of carbohydrate metabolism, leading to the accumulation of soluble sugars that increase the osmotic pressure inside the cell walls thus make the plant more resistant to osmotic stresses moreover, humic acids increase the availability of crucial nutrients in the vegetative growth of plants such as nitrogen, phosphorous and potassium (Suh *et al.,* 2014) also the absorption of humic acids increase the division and elongation of cells, which is positively reflected in increased growth and leads to an increase in the level of protein representation and synthesis of DNA and RNA within the plant Pettit, 2004). Furthermore, humic acids enhanced the soil's chemical, physical and biological properties (Chen, Aviad, 1990), consequently reducing the effect of toxic elements and improving the plant's resistance to saline stresses, so, which affected the aforementioned traits. These results are in agreement with the findings of Asik *et al.* (2009).

Table 6. Effect of humic acids applied and saline irrigation water and the amount of mineral fertilizer on plant height (cm), leaf area (cm^2), head weight (g) per plant of broccoli

Levels of mineral fertilizer	Plant height, cm			Leaf area, cm^2			Head weight, g $plant^{-1}$		
	Levels of humic acids, g L^{-1}		Average of fertilizer	Levels of humic acids, g L^{-1}		Average of fertilizer	Levels of humic acids, g L^{-1}		Average of fertilizer
	H0	H1		H0	H1		H0	H1	
R1	24.80	34.18	29.49	136.26	220.45	178.35	125.32	234.90	180.11
R2	30.60	41.75	36.17	179.43	244.22	211.82	174.88	368.60	271.74
R3	27.40	40.67	34.03	170.37	231.47	200.92	159.89	349.67	254.78
R4	25.60	38.90	32.25	160.73	227.84	194.28	136.43	309.39	222.91
R5	25.04	35.55	30.29	148.97	225.69	187.33	131.68	244.22	187.95
R6	23.83	33.58	28.70	131.04	210.74	170.89	94.55	194.85	144.70
R7	23.67	33.25	28.46	119.98	200.30	160.14	86.67	185.77	136.22
R8	23.55	32.94	28.24	113.43	193.82	153.62	75.35	177.68	126.51
R9	23.13	30.94	27.03	85.39	185.18	135.28	74.82	166.19	120.50
Average of humic acids	25.29	35.75		138.4	215.52		117.73	247.91	
$LSD_{0.05}$									
H		0.392			2.034			6.55	
R		0.913			4.315			13.62	
R*H		1.167			6.103			19.59	

R1 to R9 – fertilizer (92 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1}) application rates (100, 100, 100%), (120, 120, 120%), (120, 120, 100%), (80, 120, 120%), (100, 100, 120%), (80.100, 100%), (120, 80, 80%), (100, 80, 80%), (80, 80, 80%), respectively.
H0 and H1 – with and without humic acid (H0 = 0.00 g L^{-1} and H1 = 0.35 g L^{-1})

While increasing the plant height in response to the mineral fertilizer, probably due to the increase of fertilizer application that increased the availability of nitrogen, phosphorous and potassium ions in the soil solution consequently the plant will uptake an adequate amount of limiting nutrients such as nitrogen, phosphorous and potassium. which increases plant growth as a result of the vital role of these elements in vegetative growth, division and elongation of the meristematic cells by achieving a perfect swelling of the cell wall, the accumulation of carbohydrates in the stem and an increase in the number of nodes, thickness and elongation of the stem, which positively affected the increase of these traits.

Conclusion

The present study indicated that using the humic acids and chemical fertilizers reduced soil salinity and the concentration of harmful ions in the soil solution on plant growth, consequently reducing the effect of salt stress in saline soil which positively reflected in the increase of the growth and production of broccoli. Also, the combination of d the humic acids with mineral fertilizers reduced the electrical conductivity and SAR, sulfate ions, chloride, bicarbonate and sodium, and increased the concentration of calcium and magnesium in the soil. Additionally, led to an increase in the growth and yield components of broccoli.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author contributions

MNAA-F – designed the experimental setup;
KHA-D – analysed the data and results, and wrote the manuscript;
ETAG, KJF – performed biochemical analyses;
DKAA-T – editing the manuscript.

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