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Synergistic Effect of Magnetized Humic Substances and Nitrogen Fertilizers on Enhancement Faba Bean (*Vicia faba* L.) Productivity and Mitigate Soil Salinity

Ramy M. El-Khayat, Khaled A. H. Shaban, Shimaa M. Abdelaziz and Mohamed I. Mohaseb

Soils, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.
khaledshaban2004@yahoo.com; shaimaam.saad@arc.sci.eg; mohasebmohamed@yahoo.com

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ABSTRACT

Soil salinity is a major threat to plants. It is likely that the use of humic and fulvic acids can reduce salinity stress and improve the physical, chemical and microbiological properties of soils. To test these materials, humic substances (humic and fulvic acids) were extracted from mature compost and then magnetization of these acids was done by magnetic field system. A field experiment was conducted with a split-plot design consisting of 18 treatments with three replicates during successful winter season 2022/2023 on a farm at Sahle El- Hossinia Research Farm Station, Agric. Res. Center, El-Sharkia Governorate, Egypt to evaluation between two methods of treatments (magnetic humic and fulvic acids foliar application and seed soaking) integrated with nitrogen fertilization on some soil chemical and microbial properties. Also, its effects on faba bean (*Vicia faba* L.) productivity under soil saline conditions. The results showed that the use of magnetized humic acid (either foliar application or seeds soaking) integration with nitrogen fertilization (40 kg-N/fed) led to a decrease in soil pH, EC and an increase its contents of N, P and K. In addition, it improved the counts of total bacteria, actinomycetes, fungi, as well as activity of dehydrogenase and nitrogenase enzymes. Also, led to a significant increase in the number of nodules, as fresh weight and their enzyme activity. Beside to, increased the concentration of chlorophyll and macronutrients. Moreover, it reduced the concentration of proline in the plant and achieved highly significant on growth parameters compared to other treatments. Magnetic technique for both humic and fulvic acids integrated with N-fertilization are promising application for improve soil properties and increase productivity of faba bean in saline soil.

Keywords: Faba bean, humic acid, fulvic acid, magnetic field, nitrogen fertilization, soil salinity.

1. Introduction

Soil salinity poses an existential threat to global food security, especially in arid and semi-arid regions (Parveen *et al.,* 2024). This phenomenon causes soil fertility to deteriorate and significantly reduces productivity, negatively impacting agricultural crops. This problem covers vast areas of agricultural land in over 100 countries, leading to a significant decline in global agricultural production. The primary cause of this problem is the accumulation of soluble salts in the soil, which creates osmotic and ionic stress on plant roots, hindering the absorption of water and essential nutrients. Consequently, soil salinity negatively affects plant growth and vitality, leading to reduced crop yields and the quality of agricultural products (Singh, 2022; Farid *et al.,* 2025). Egypt is classified among the countries most severely affected by soil salinity, which arises from a combination of environmental and managerial factors. This problem leads to the degradation of soil fertility and reduces its productivity, thereby threatening food security and negatively impacting the agricultural economy (Farid *et al.,* 2025).

The total production of Faba bean in Egypt reached 214491 tons for agriculture year, 2020/2021, produced from an area of 126344 feddan (Economic Affairs Sector, 2022). Cultivating faba beans (*Vicia*

Corresponding Author: Ramy M. El-Khayat, Soils, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.
E-mail: - ramydr03@gmail.com, Orcid: https://orcid.org/0009-0003-0155-8532

faba) in Egypt poses a significant challenge due to its nutritional and economic importance. However, this cultivation faces numerous obstacles, such as soil degradation, particularly in alkaline soils. Therefore, developing strategies to enhance faba bean productivity under these conditions is crucial to ensure the sustainability of agricultural production in Egypt (El-Sonbaty and El-Sherpiny, 2024). Plant growth is significantly influenced by a variety of environmental stressors, including biotic stresses (such as diseases and pests) and abiotic stresses (such as salinity, drought, and nutrient deficiencies). These challenges pose a major constraint on sustainable agricultural (Alakhdar *et al.,* 2020).

Modern methods to enhance crop production involve treating seeds, organic fertilizers, and magnetic fields. This treatment has been shown to improve seed germination, plant growth, yield, and yield parameters in many crops (Mohaseb *et al.,* 2023).

Magnetic treatment of agricultural water significantly enhances water and nutrient utilization efficiency. This technique alters the molecular structure of water, positively influencing its surface properties and its ability to dissolve salts and minerals. As a result, plants treated with magnetically treated water exhibit improved germination rates, growth, and nutrient uptake. The smaller, more structured water clusters facilitate easier penetration into the soil and plant tissues, optimizing the delivery of essential nutrients (Ahmed *et al.,* 2023). Numerous studies have demonstrated that treating seeds and irrigation water with magnetic fields exerts a positive influence on the growth of various agricultural crops. Aladjadjiyan (2007) observed that soaking the seeds of vegetable crops such as tomatoes, eggplants, cucumbers, and zucchini in a magnetic field with a strength of 4000 Gauss for one hour, along with irrigation using magnetized water, led to improved plant growth. Shahin *et al.* (2016) revealed that increasing the duration of soaking cucumber seeds in magnetized water at varying magnetic field strengths, up to 300 minutes, resulted in increased crop yield, enhanced growth, and elevated levels of essential nutrients like nitrogen, phosphorus, and potassium within the plant, while also reducing soil salinity. Investigations have also encompassed the impact of magnetic treatment on other crops like cotton. These studies indicated that increasing the magnetic field strength of the irrigation water led to augmented seedling growth and dry weight, as well as increased nitrogen uptake, particularly under saline conditions (Mohamed, 2020).

Humic substances are natural stimulants contribute to improving the physical and chemical properties of the soil, enhancing root growth and nutrient availability for plants, and consequently increasing agricultural productivity while reducing pressure on natural resources (Abd El-Hady *et al.,* 2024). Humic substances (HS), as a component of soil organic matter, are compounds resulting from the chemical, microbiological, and physical transformation (humification) of biomolecules (Taha *et al.,* 2016). These substances form complex aggregates of brown to dark-colored amorphous materials. HS play crucial roles in enhancing soil fertility and are considered to be of primary importance for stabilizing soil aggregates (Lipczynska-Kochany, 2018). Based on their solubility, HS can be divided into three components: humic acids, fulvic acids, and humin (Sarlaki *et al.,* 2019). Due to their good water solubility and strong resistance to hard water, HS are primarily used as soil amendments or under fertigation systems (Abdel-Sattar *et al.,* 2024).

The foliar application of humic and fulvic acids resulted in a noticeable improvement in root growth, plant morphological traits, and increased agricultural productivity. Moreover, foliar application of a mixture of humic acid (0.4%), fulvic acid (4%), and calcium chelate with amino acids (0.25%), either individually or in combination, led to increased vegetative growth, productivity, fruit quality, and reduced the incidence of blossom end rot in tomatoes (Abou El Hassan and Hussein, 2016). Other studies demonstrated that foliar application of liquid humic acids (0.1% and 0.2% in sandy saline soil) enhanced the uptake of essential nutrients such as nitrogen, phosphorus, and potassium in maize (Khaled and Fawy, 2011), and increased protein and nitrogen content in legume seeds (Shafeek *et al.,* 2013).Studies have shown that applying potassium humate and potassium fulvate in the form of spray solutions at a rate of 0.5 to 10% in water has a positive impact on seed germination, root development, and the availability of essential nutrients (nitrogen, phosphorus, and potassium) in saline and sandy soils. Consequently, this leads to increased yields in crops such as sweet potatoes. Additionally, potassium humate has been found to improve soil physical and chemical properties, reducing the harmful effects of salt stress (Mohamed, 2020).

Thus, the purpose of this research was to ascertain the impact of magnetized humic and fulvic acids, either through seed soaking or foliar spraying of faba bean plants, this to mitigating the negative effects of salt stress on plant growth, enhanced yield, quality, increased enzymatic activity, soil microbial populations and the productivity of faba beans crop grown in this saline soil.

2. Materials and Methods

A field experiment was conducted on a farm at Sahle El- Hossinia Res. Farm Station, Agric. Res. Center (ARC), El-Sharkia Governorate, Egypt (coordinates: 31°00′59.2″N 32°04′17.2″E) during the winter season 2022/2023. The evaluation between two methods treatments (magnetic humic and fulvic acid foliar application and seed soaking) integrated with nitrogen fertilization on some soil chemical and microbial properties and its productivity of faba bean (*Vicia faba* L.) under soil saline conditions. Soil samples of the experimental were taken of the studied area before planting. Samples were air dried, crushed and sieved via a 2 mm sieve. Physical, chemical and microbiological of the investigated soil are presented in Table (1). Soil pH and organic matter were estimated according to the methods described by Page *et al.* (1982). The total soluble salts (EC) were determined in soil paste extract as dSm^{-1} according to Jackson (1973). Particle size distribution was carried out by the pipette method described by Klute (1986). The content of available macronutrients (N, P, and K) in the soil was determined according to the methods described by Cottenie *et al.* (1982). Determine total bacteria counts (Allen, 1959), total Actinomycetes counts (Williams and Davis, 1965) while total fungi counts (Martin, 1950) as index for soil biological activity.

Table 1: Mean values of Physical, chemical and biological properties of the experimental soil

Type of analysis	Unit	Soil
Particle size distribution		
Sand	%	15.00 %
Silt	%	39.70 %
Clay	%	45.30 %
Textural class		clay
Chemical analysis		
pH (1:2.5) soil – water suspension		8.12
EC (saturation paste extract)	dS/m	8.00
Organic matter	%	0.66
Organic carbon	%	0.38
N	mg/kg	35.00
P	mg/kg	2.48
K	mg/kg	165.00
Soluble cations and anions		
Ca^{++}	$mmol_cL^{-1}$	7.80
Mg^{++}	$mmol_cL^{-1}$	5.50
Na^{+}	$mmol_cL^{-1}$	65.40
K^{+}	$mmol_cL^{-1}$	1.30
HCO_3^{-}	$mmol_cL^{-1}$	2.80
Cl^{-}	$mmol_cL^{-1}$	71.20
$SO_4^{=}$	$mmol_cL^{-1}$	6.00
Microbiological analysis		
Total bacterial count	cfu/g × 10^5	6.00
Total actinomycetes	cfu/g × 10^3	7.00
Total fungi	cfu/g × 10^3	2.00

cfu/g: Colony forming unit/gram

Faba bean (*Vicia faba* L) seeds cultivar Giza 843 was kindly obtained from Crops Res. Institute, Agric. Res. Center (ARC), Giza, Egypt.

Compost was obtained from the Training Center for Recycling Agricultural Residues at Moshtohor (TCRAR), Agricultural Research Center (Egypt). Its physical, chemical and biological properties are presented in Table (2). This compost used in preparing the humic and fulvic acids used in this study. The physical and chemical properties were determined according to APHA (1989). Total nitrogen, phosphorus and potassium were also estimated to Black (1965). Total, fecal coliform bacteria, *Salmonellae* and *Shigella* were determined according to Difico (1985). Weed seeds in were examined according to Yu *et al.* (2010) and nematodes were examined according to Rice *et al.* (2017).

Table 2: Physical, chemical and biological properties of the compost used for extraction of the HA and FA used for soaking and foliar applications

Composition	Units	Compost
Density	kg/m³	675.00
Moisture content	%	24.50
pH (1:10)		7.80
EC (1:10)	dSm^{-1}	3.62
N-NH_4	mg kg^{-1}	35.00
N-NO_3	mg kg^{-1}	140.00
Total nitrogen	%	1.25
Organic matter	%	32.56
Organic carbon	%	18.88
Ash	%	67.44
C/N ratio		15: 1
Total phosphorus	%	1.12
Total potassium	%	0.75
Weed seeds		Nill
Nematode	Larava/200g	Nill
Total bacterial count	cfu/g × 10^6	3.40
Total actinomycetes	cfu/g × 10^4	205.00
Total fungi	cfu/g × 10^4	133.00
Total coliform	cfu/g	Not detected
Faecal coliform	cfu/g	Not detected
Salmonella* and *Shigella	cfu/g	Not detected
Total humic substances	%	20.00
Humic acid	%	10.75
Fulvic acid	%	8.25

cfu/g: Colony forming unit/gram

The humic substances were taken out of the previously prepared compost using the techniques outlined by Sanchez-Monedero *et al.* (2002). Data shown in Table (3) clear the elemental composition of humic and fulvic acids. Total acidity determined according to Dragunova (1958). Schintzer and Gupta (1965) methodology was used in order to determine the carboxyl groups. The phenolic groups were identified according to Kononova (1966).

Table 3: Characteristic of Humic and fulvic acids extracted from compost

Character	Units	Humic acid	Fulvic acid
C	**%**	49.00	44.25
N	**%**	4.55	2.27
H	**%**	4.37	4.19
S	**%**	2.41	2.87
O	**%**	39.67	46.42
C/N ratio		10.77	19.49
C/H ratio		11.21	10.56
O/H ratio		9.08	11.08
N/H ratio		1.04	0.54
Total acidity	**(mmol / 100g)**	429.00	795.00
Carboxyl groups	**(mmol / 100g)**	198.00	217.00
Phenolic groups	**(mmol / 100g)**	231.00	578.00

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Magnetic field system using a tube with specific properties (70 cm length, 2-inch diameter, 1.5 Tesla magnetic field intensity) as shown in Figure (1).

Fig 1: Magnetic field system

Humic and fulvic acids were exposed to the magnetic field for 15 minutes. The treated acids were obtained by passing the solutions through the magnetic field, and then used in seed soaking and foliar spray experiments (Mohaseb *et al.,* 2023).

2.1. Experimental treatments

The experiment was carried out in split-plot design in three replicates. Figure (2) illustrates the flowchart of the current research work.

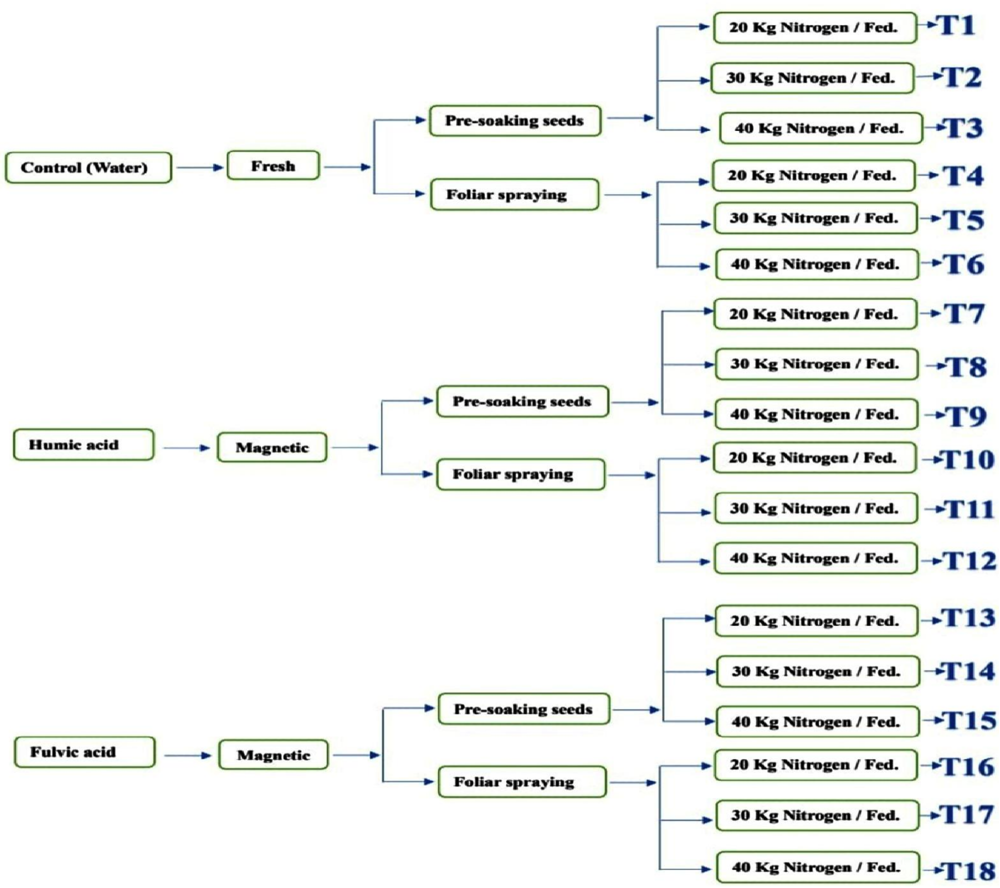

Fig. 2: Flowchart of the experiment.

Each experimental plot was 10.5 m^2 (3.5 m × 3 m) plot area. Each plot contained 5 rows between each row 60 cm. The plots were planted by hand with one seed per hull. The faba bean seeds were sown on the 20th November 2022. The seeds were soaked either by magnetized humic or fulvic acids (0.6 L acid /100L water) or fresh water about 6 hours before planting. As for the treatments in which the plants are foliar sprayed (washing all parties of plant), whether by magnetized humic or fulvic acids or fresh water, these treatments were foliar sprayed twice at a concentration of 2.4L /400Lwater /fed. The first time of foliar spraying was about 30 days after planting, while the second time was about 65 days after planting. Supper calcium phosphate (15.5 % P_2O_5) was applied at rate 200 kg /fed before planting during tillage of soil. Potassium sulphate (48 % K_2O) was applied at rate 75 kg/fed after 30 and 45 days from planting. Urea (46 % N) was applied at different rates 20, 30 and 40 kg/fed after 30, 45 and 70 days from planting. After harvest was taken of data number of branches /plant, number of pods /plants, number of seeds / plants, seed weight /plant (g), and seed yield (ton/fed). Determinations of the macro elements (N, P and K) in leaves were determined according to Martin-Préval *et al.* (1984) and Ibrahim (2010).

Total bacteria count, fungi and actinomycetes (cfu/g soil rhizosphere) were determined after 55 days and 85 days from sowing.

Enzymes, Plant roots were collected after 55 days and 85 days from sowing for determination of the numbers and fresh weight of nodules, nitrogenase activity (µmole C_2H_4 /gm nodules) while nitrogenase activity in the rhizosphere (µmole C_2H_4/gm soil) was estimated according to the methods of Somasegaran and Hoben (1994). While, dehydrogenase enzyme activities were determined according to Page *et al.* (1982).

Chlorophyll determination was determined at ages of 85 days, where one gram of fresh tissue leaves of faba bean plants, taken and extracted with dimethylformamide and was determined Spectrophotometrically by the method of Inskeep and Bloom (1985). Meanwhile, proline content was measured following the method described by Troll and Lindsley (1955) and streamlined and developed by Dreier and Göring (1974) Thus, 100 mg of fresh leaf material was homogenized in 2 ml of 40% methanol, and then heated in a water bath at 85°C for 60 min. The absorbance was measured at 528 nm in a spectrophotometer.

2.2. Statistical analysis

All data collected were subjected to analysis of variance to test treatment effects for significance. The means were compared using LSD at 0.05 level of significant method and multiple range tests according to Snedecor and Cochran (1991).

3. Results and Discussion

3.1. Impact of magnetized humic and fulvic acids application on soil chemical properties

The results in Table 4 indicated that the application of magnetized humic and fulvic acids, either through foliar spraying or seed soaking before sowing, led to a decrease in pH and EC values, while organic matter (OM), and available N, P, and K values were increased. The soils of all experimental pilot units are characterized by slightly to moderately alkaline conditions, where the pH value always around 8.07-7.95. The decrease of soil pH and EC values were unsignificant when foliar application of magnetic humic acid combined with nitrogen fertilization at rate (40 kg-N/fed) where it recorded 7.98 to 7.95 and 2.28 to 2.00 dSm^{-1}, respectively, compared to the other treatments. The increase was clear in OM, N, P and K when using magnetic humic acid with nitrogen fertilization (40 kg-N/fed) where OM was obtained 0.78, 0.80%, N was 53.18 and 57.13 mg kg^{-1}, P was recorded 3.25 and 4.10 mg kg^{-1} while K was recorded 178 and 183 mg kg^{-1} with soaking and spray treatments, respectively for magnetic humic acid foliar application compared with other treatments. The results also indicated that applying magnetized humic and fulvic acids as a foliar spraying treatments were better than seed soaking treatments before sowing. In general, soaking seeds with magnetized humic or fulvic acids had no significant values in the chemical properties of the soil, while using both acids by spraying no significant differences in all chemical properties of the soil except EC and P, while the nitrogen fertilization rate gave significant in EC and N (using soaking seeds with both acids). However, there were no significant differences in studied parameters interaction between application of nitrogen fertilizer and soaking or spraying with magnetized humic or fulvic acid. This is due to, the effect of the magnetic field on the solvated ions in the solution. This effect weakens the bonds between water molecules, dissolved salts, humic, and fulvic acids leading to increased availability of essential plant nutrients such as nitrogen, phosphorus, and potassium. Additionally, the activation of water molecules by the magnetic field contributes to the activation of cation exchange sites on the soil surface, which in turn alters the concentration

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Table 4: Soil pH, EC (dSm^{-1}), organic matter and available macronutrients contents in soil after harvest

Treatments	Rate of Nitrogen (Kg)	pH (1: 2.5)		EC (dSm^{-1})		Organic Matter (%)		Available macronutrients (mg/kg)					
								N		P		K	
		S	F	S	F	S	F	S	F	S	F	S	F
Control	**20**	8.09	8.07	6.46	6.10	0.69	0.73	38.12	44.00	2.80	2.96	169.00	173.00
	30	8.07	8.05	5.24	4.99	0.71	0.75	43.25	46.30	2.95	3.10	172.00	174.00
	40	8.06	8.03	5.00	4.20	0.73	0.77	46.15	49.50	3.10	3.17	175.00	178.00
Mean		**8.07**	**8.05**	**5.57**	**5.10**	**0.71**	**0.75**	**42.51**	**46.60**	**2.95**	**3.08**	**172.00**	**175.00**
Humic acid	**20**	8.04	8.03	6.12	5.88	0.72	0.75	43.17	47.00	3.09	3.22	172.00	176.00
	30	8.00	8.00	4.88	3.22	0.75	0.77	48.00	52.22	3.15	3.75	175.00	179.00
	40	7.98	7.95	2.28	2.00	0.78	0.80	53.18	57.13	3.25	4.10	178.00	183.00
Mean		**8.00**	**7.99**	**4.43**	**3.70**	**0.75**	**0.77**	**48.12**	**52.12**	**3.16**	**3.69**	**175.00**	**179.33**
Fulvic acid	**20**	8.07	8.04	6.30	6.02	0.70	0.74	41.00	45.80	2.90	3.10	170.00	175.00
	30	8.05	8.02	5.45	4.20	0.73	0.75	44.20	47.90	3.08	3.34	173.00	177.00
	40	8.00	7.98	4.84	3.15	0.75	0.78	47.53	53.10	3.13	3.75	175.00	179.00
Mean		**8.04**	**8.01**	**5.53**	**4.46**	**0.73**	**0.76**	**44.24**	**48.93**	**3.04**	**3.40**	**172.67**	**177.00**
LSD (0.05)	**T**	**ns**	**ns**	**ns**	**0.33**	**ns**	**ns**	**ns**	**ns**	**ns**	**0.09**	**ns**	**ns**
	R	**ns**	**ns**	**0.27**	**0.21**	**ns**	**ns**	**2.75**	**ns**	**ns**	**0.23**	**ns**	**ns**
	TR	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

S: soaking seed before sowing, **F:** foliar spraying, **T:** treatments, **R:** rate of nitrogen (Kg), **TR:** interaction between treatment and rate of nitrogen and **ns:** not significantly.

of soluble cations in the soil solution (Mohamed, 2020). Decrease in soil pH leads to a change in EC. This is due to the effect of humic materials on the root zone, which affects the chemical and physical properties of the soil, improving absorption and thus increasing production (Abdel-Baky *et al.,* 2019). Humic and fulvic acids act as a source of organic matter in the soil, which leads to increased microbial activity in the soil, formation of bonds and improvement of soil properties (Heba *et al.,* 2024). Humic substances provide phosphorus, increase nutrients, prevent their loss from the soil, and prevent ion fixation. In addition, magnetized water increases the benefit from N, P, and K (Mohamed, 2020).

3.2. Effect of magnetized humic and fulvic acids application on biological parameters in faba bean rhizosphere

Data presented in Table (5) showed that the total population density of bacteria, fungi, and actinomycetes, as well as the rates of dehydrogenase and nitrogenase enzyme activities. The results indicated that the total counts of bacteria, actinomycetes and fungi were higher in the root zone of plants that were 85 days old compared to plants that were 55 days old in all treatments. The results also, showed that foliar spraying with magnetized humic or fulvic acids gave higher counts of total bacteria, actinomycetes and total fungi compared to applying these acids in seed soaking before sowing. The table also shows that the total bacterial counts were higher than both total actinomycetes and fungi counts in the rhizosphere of the plant for all treatments. In addition, the results showed that applying magnetized humic acid, whether by spraying or soaking the seeds, gave the best results in terms of the number of microbes present in the rhizosphere of the plant root. It was also shown that using humic acid with nitrogen fertilization (40 kg-N/fed) gave the highest counts of total bacteria (25, 49, 43 and 64×10^5 cfu/ g) total actinomycetes (31, 57, 47 and 64×10^3 cfu/ g) while (20, 29, 33 and 41×10^3 cfu/ g) of total fungi after 45 and 75 days, respectively. Humic substances stimulate microbial activities by increasing organic carbon in the soil (Qin *et al.,* 2019). Also, its give electrons to bacteria so they can breathe (Coates *et al.,* 2002). In addition to, using humic acid by spraying or as a cover for soybean seeds leads to an increase in the number of nodes and nitrogen fixation, thus increasing productivity (Mosa *et al.,* 2020).

The data in the same table show that the activity of dehydrogenase enzyme increased as a result of using magnetized humic acid when compared to the rest of the treatments when estimated after 55 and 85 days of planting. The results also showed that the highest activity of dehydrogenase enzyme was when applying magnetized humic acid with nitrogen fertilization (40 kg-N/fed), reaching 19.4, 25.6, 30.4 and 40.7 µTPF/g, respectively. The results also showed that applying humic or fulvic acids by foliar spraying to the plant gave positive results for dehydrogenase enzyme activity compared to applying both acids in seed soaking before sowing. In general, the results showed that dehydrogenase enzyme activity was higher in all treatments after 85 days of sowing. Data indicate that there were significant differences in all treatment but rate of nitrogen and interaction between treatment and rate of nitrogen had no significant differences. These findings are consistent with those reported by (Gomaa and Afifi, 2021), they found that the activity of the dehydrogenase enzyme was higher in soil samples taken from the soil at the age of 11 week for the plant. Humic acids help increase the activity of soil enzymes (Mosa *et al.,* 2020). Li *et al.* (2020) found that the use of humic materials increases organic carbon as well as carbon and nitrogen of microbial biomass in the soil.

As, the results showed that magnetized humic and fulvic acids increase the activity of nitrogenase enzyme. The results also clearly showed that nitrogenase enzyme activity was higher in the root zone of plants that were 85 days old compared to plants that were 55 days old in all treatments. In addition, the application of magnetized humic or fulvic acid by foliar spraying gave a higher enzyme activity than their application by soaking the seeds. The results also indicated that the application of humic acid with nitrogen fertilization (40 kg-N/fed) gave the best nitrogenase enzyme activity, as it reached 17.8, 23.9, 25.9, and 45.3 µ mole C_2H_4/g. Data indicate that there were significant differences in all treatment (humic and fulvic) but rate of nitrogen and interaction between treatment and rate of nitrogen had no significant differences. Afifi *et al.* (2017) found that humic and fulvic acids increase the activity of dehydrogenase and nitrogenase enzymes by increasing the age of the plant after 45 and 75 days of sowing faba bean. Humic substances increase the rate of decomposition of organic matter in the soil, and thus increase the count and activity of microbes in the soil, including those that fix nitrogen (Ekin, 2019).

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Table 5: Changes of some microbial parameters in the rhizosphere of faba bean treated with magnetized humic and fulvic acids after 55 and 85 days from sowing

Treatments	Rate of Nitrogen (Kg)	Total Bacterial Counts (10^5 cfu/g soil)				Total Actinomycetes (10^3 cfu /g soil)				Total Fungi (10^3 cfu/g soil)				Dehydrogenase activity (µg TPF/g dry rhizosphere)				Nitrogenase activity (µmole C_2H_4 /g dry rhizosphere)			
		After 55 Day		After 85 Day		After 55 Day		After 85 Day		After 55 Day		After 85 Day		After 55 Day		After 85 Day		After 55 Day		After 85 Day	
		S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Control	**20**	9.0	10.0	10.0	13.0	12.0	13.0	14.0	17.0	3.0	4.0	6.0	7.0	4.9	5.0	11.4	11.6	4.1	4.2	9.4	9.7
	30	11.0	12.0	12.0	15.0	14.0	15.0	15.0	19.0	5.0	6.0	7.0	9.0	5.1	5.2	11.9	12.2	4.3	4.5	10.7	11.0
	40	12.0	13.0	14.0	17.0	17.0	19.0	21.0	22.0	9.0	8.0	10.0	12.0	5.8	6.0	13.2	13.5	4.9	5.0	11.8	12.4
Mean		**10.7**	**11.7**	**12.0**	**15.0**	**14.3**	**15.7**	**16.7**	**19.3**	**5.7**	**6.0**	**7.7**	**9.3**	**5.3**	**5.4**	**12.2**	**12.4**	**4.4**	**4.6**	**10.6**	**11.0**
Humic acid	**20**	20.0	27.0	37.0	53.0	23.0	35.0	43.0	60.0	15.0	17.0	21.0	26.0	17.6	23.3	28.3	37.2	14.2	21.4	23.4	41.9
	30	23.0	36.0	39.0	57.0	26.0	42.0	46.0	61.0	16.0	25.0	27.0	35.0	19.1	23.9	29.7	39.1	15.3	22.1	25.1	43.5
	40	25.0	49.0	43.0	64.0	31.0	57.0	47.0	64.0	20.0	29.0	33.0	41.0	19.4	25.6	30.4	40.7	17.8	23.9	25.9	45.3
Mean		**22.7**	**37.3**	**39.7**	**58.0**	**26.7**	**44.7**	**45.3**	**61.7**	**17.0**	**23.7**	**27.0**	**34.0**	**18.7**	**24.3**	**29.5**	**39.0**	**15.8**	**22.5**	**24.8**	**43.6**
Fulvic acid	**20**	19.0	22.0	30.0	45.0	22.0	27.0	37.0	48.0	13.0	17.0	17.0	24.0	14.4	20.8	19.8	32.8	13.1	18.3	20.3	33.7
	30	21.0	28.0	32.0	49.0	25.0	33.0	40.0	51.0	18.0	23.0	23.0	29.0	15.1	21.1	21.6	33.6	13.9	18.9	21.9	36.1
	40	24.0	31.0	33.0	50.0	30.0	38.0	41.0	53.0	22.0	26.0	27.0	37.0	17.9	22.5	23.3	35.7	15.4	20.7	22.8	37.3
Mean		**21.3**	**27.0**	**31.7**	**48.0**	**25.7**	**32.7**	**39.3**	**50.7**	**17.7**	**22.0**	**22.3**	**30.0**	**15.8**	**21.5**	**21.6**	**34.0**	**14.1**	**19.3**	**21.7**	**35.7**
LSD (0.05)	**T**	-	-	-	-	-	-	-	-	-	-	-	-	**1.53**	**1.25**	**1.82**	**1.91**	**0.94**	**1.43**	**1.17**	**1.92**
	R	-	-	-	-	-	-	-	-	-	-	-	-	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**1.34**
	TR	-	-	-	-	-	-	-	-	-	-	-	-	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

S: soaking seed before sowing, **F:** foliar spraying, **T:** treatments, **R:** rate of nitrogen (Kg), **TR:** interaction between treatment and rate of nitrogen and **ns:** not significantly.

3.3. Effect of magnetized humic and fulvic acids application on numbers and fresh weight of nodules and nitrogenase in nodules

The results in Table (6) showed the change in the number of nodules in the roots of faba bean as a result of using magnetized humic and fulvic acids, where significant differences in the numbers were found. It was also shown that the number of nodules were higher in plants after 85 days than in plants that were 55 days in all treatments. It was also noted that applying humic or fulvic acids by foliar spraying gave an increase in the number of nodules compared to their application in seed soaking before sowing. The results indicated that applying humic acid with nitrogen fertilization by rate 40 kg-N/fed gave the highest increase in the number of nodules (36.00, 58.00, 68.00 and 124.00 Nodules number) for seed soaking before sowing and foliar spraying compared other treatments. Data indicate that there were significant differences in all treatment (humic and fulvic acids) but rate of nitrogen and interaction between treatment and rate of nitrogen had no significant differences. Adding organic matter increases nutrients and energy compounds, which leads to an increase in the number of nodules in the roots of the faba bean plant under any soil conditions (Abou Hussien *et al.,* 2021). These findings are consistent with those reported by (Gomaa and Afifi, 2021).

In the same table, data indicate that nodule fresh weight (g/plant) was significant differences in all treatment (humic and fulvic acids) but rate of nitrogen (except for foliar spraying application after 85 day) and interaction between treatment and rate of nitrogen had no significant differences. The results clearly showed that nodules fresh weights increased with the age of the plants, as the nodules fresh weight in plants aged 85 days was greater than their weight in plants aged 55 days. In addition, the nodules fresh weights increased as a result of using humic or fulvic acid compared to the control. The results indicated that applying humic acid with nitrogen fertilization (40 kg-N/fed) gave the highest increase in the nodules fresh weight (2.21, 3.15, 32.19 and 55.52 g/plant) for seed soaking before sowing and foliar spraying compared other treatments. Mosa *et al.* (2020) found that using humic and fulvic acids with soybeans increased the number of nodes, their fresh weight, nitrogenase activity and increased the yield by about 22%.

The results in the same table also showed that the activity of the nitrogenase enzyme increased significantly as a result of using magnetized humic and fulvic acid compared to the control. The results also showed that the activity of nitrogenase was superior as a result of using humic acid with nitrogen fertilization (40 kg-N/fed) gives the highest increase in activity of the nitrogenase (0.64, 0.80, 0.97 and 1.19 µmole C_2H_4 /g) for seed soaking before sowing and foliar spraying compared other treatments. Data indicate that there were significant differences in all treatment (humic and fulvic acid) but rate of nitrogen and interaction between treatment and rate of nitrogen had no significant differences.

These results agree with those of Afifi *et al.* (2017) and Gomaa and Afifi (2021), they found the same results. Humic substances play an effective role in stimulating plant growth, increasing the number of nodules, and fixing nitrogen, thus increasing the biomass, plant and root height, chlorophyll content, nitrogenase enzyme activity, and, the nodule fresh weight (Zhang *et al.,* 2023).

3.4. Effect of magnetized humic and fulvic acids application on chlorophyll, proline and macronutrients (N, P and K) contents in leaves of faba bean after 85 days from planting

The content of chlorophyll (mg/g.f.w), nitrogen, phosphorus and potassium percentages in the leaves of the faba bean increased, while proline (mg/g.f.w) decreased as shown in Table (7) as a result of using magnetized humic, fulvic acid, and nitrogen fertilization rates. The results indicated that using magnetized humic acid with nitrogen fertilization gave the highest increase in chlorophyll (mg/g.f.w), nitrogen, phosphorus and potassium percentages. In contrast they achieved the lowest decrease in proline (mg/g.f.w) compared to the control. The increase in the chlorophyll was 6.33 and 9.20 mg/g.f.w. Meanwhile, nitrogen was 4.89 and 4.96%, phosphorus 0.47 and 0.49%, and potassium 2.94 and 3.12% for the application of humic acid (seed soaking before sowing and foliar spraying) with high rate nitrogen fertilization (40 kg-N/fed). In contrast, the proline decreased by 44.10 and 33.20 mg/g.f.w for the application of humic acid (seed soaking before sowing and foliar spraying) with nitrogen fertilization (40 kg-N/fed). These results indicate that the increase in chlorophyll and macronutrients concentration and the decrease in proline are due to the biostimulator by humic and fulvic acids. The results indicated that the effect of humic and fulvic acids on increasing chlorophyll (except for soaking seeds), decreasing proline (except for foliar spraying application) and increasing macronutrients were not significant. In addition, the effect of using nitrogen fertilization rates (except for proline with foliar

Table 6: Effect of magnetized humic and fulvic acids on nodules number, fresh weight and nitrogenase activity in nodules of faba bean after 55 and 85 days from sowing

Treatments	Rate of Nitrogen (Kg)	Nodules number				Nodule fresh weight (g/plant)				Nitrogenase activity (µmole C_2H_4/g dry nod.)			
		After 55 Day		After 85 Day		After 55 Day		After 85 Day		After 55 Day		After 85 Day	
		S	F	S	F	S	F	S	F	S	F	S	F
Control	20	14.00	15.00	16.00	18.00	0.60	0.63	7.83	8.21	0.29	0.31	0.44	0.45
	30	16.00	17.00	19.00	20.00	0.65	0.69	8.30	8.91	0.31	0.34	0.46	0.48
	40	18.00	19.00	21.00	25.00	0.79	0.85	8.88	10.24	0.37	0.39	0.49	0.51
Mean		**16.00**	**17.00**	**18.67**	**21.00**	**0.68**	**0.72**	**8.34**	**9.12**	**0.32**	**0.35**	**0.46**	**0.48**
Humic acid	20	33.00	55.00	60.00	115.00	1.87	2.99	30.71	52.21	0.58	0.73	0.85	1.11
	30	34.00	57.00	63.00	119.00	1.93	3.13	31.63	53.19	0.60	0.77	0.94	1.17
	40	36.00	58.00	68.00	124.00	2.21	3.15	32.19	55.52	0.64	0.80	0.97	1.19
Mean		**34.33**	**56.67**	**63.67**	**119.33**	**2.00**	**3.09**	**31.51**	**53.64**	**0.61**	**0.77**	**0.92**	**1.16**
Fulvic acid	20	23.00	37.00	52.00	100.00	1.35	2.76	27.61	42.14	0.51	0.66	0.69	0.98
	30	25.00	38.00	55.00	107.00	1.41	2.79	28.14	47.93	0.54	0.68	0.75	1.04
	40	27.00	41.00	60.00	110.00	1.53	2.87	29.53	49.81	0.55	0.72	0.82	1.08
Mean		**25.00**	**38.67**	**55.67**	**105.67**	**1.43**	**2.81**	**28.43**	**46.63**	**0.53**	**0.69**	**0.75**	**1.03**
LSD (0.05)	T	**5.82**	**3.10**	**4.69**	**13.28**	**0.32**	**ns**	**1.30**	**1.79**	**0.04**	**0.04**	**0.10**	**0.06**
	R	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**1.56**	**ns**	**ns**	**ns**	**ns**
	TR	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

S: soaking seed before sowing, **F:** foliar spraying, **T:** treatments, **R:** rate of nitrogen (Kg), **TR:** interaction between treatment and rate of nitrogen and **ns:** not significantly.

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spraying application) and the interaction with the application of humic and fulvic acid was not significant. These results are similar to the results reported by Abdelaal (2019) and El-Kamar (2020). Proline plays an important role in reducing the harmful effects of salt and increasing plant tolerance to stress (El-Tayeb, 2005). Also, Alsudays *et al.* (2024) found that treating plants with humic and fulvic acids decreases the concentration of proline and thus improves the agricultural characteristics of the plant as it increases the amount of chlorophyll and nutrients.

Table 7: Chlorophyll, proline and macronutrients contents in leaves faba bean after 85 days from planting

Treatments	Rate of Nitrogen (Kg)	Chlorophyl (mg/g.f.w)		Proline (mg.f.w)		Macronutrients (%)					
						N		P		K	
		S	F	S	F	S	F	S	F	S	F
Control	20	3.20	3.26	65.30	64.90	3.22	3.24	0.25	0.27	2.10	2.15
	30	3.69	3.73	58.30	57.40	3.75	3.84	0.31	0.32	2.23	2.30
	40	3.90	3.95	58.20	53.40	4.12	4.16	0.35	0.37	2.31	2.42
Mean		**3.60**	**3.65**	**60.60**	**58.57**	**3.70**	**3.75**	**0.30**	**0.32**	**2.21**	**2.29**
Humic acid	20	6.20	7.50	45.30	37.40	4.11	4.55	0.35	0.38	2.59	2.80
	30	6.29	8.40	44.20	37.20	4.66	4.80	0.42	0.45	2.85	2.94
	40	6.33	9.20	44.10	33.20	4.89	4.96	0.47	0.49	2.94	3.12
Mean		**6.27**	**8.37**	**44.53**	**35.93**	**4.55**	**4.77**	**0.41**	**0.44**	**2.79**	**2.95**
Fulvic acid	20	5.22	6.50	49.20	43.20	3.89	4.22	0.33	0.37	2.55	2.66
	30	5.49	6.79	48.30	41.30	4.60	4.75	0.41	0.44	2.77	2.88
	40	5.80	6.90	48.10	38.40	4.88	4.91	0.44	0.48	2.80	3.10
Mean		**5.50**	**6.73**	**48.53**	**40.97**	**4.46**	**4.63**	**0.39**	**0.43**	**2.71**	**2.88**
LSD (0.05)	T	**0.65**	**ns**	**ns**	**3.87**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	R	**ns**	**ns**	**ns**	**3.20**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	TR	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

S: soaking seed before sowing, **F:** foliar spraying, **T:** treatments, **R:** rate of nitrogen (Kg), **TR:** interaction between treatment and rate of nitrogen and ns: not significantly.

3.5. Effect of magnetized humic and fulvic acids application on the contents of macronutrients concentration (N, P and K) and protein in faba bean grains

Table 8 show the effect of magnetized humic, fulvic acids and nitrogen fertilization rates on the concentration of macronutrients (N, P and K) and protein percentage in faba bean grains after harvest. The results showed that there was an increase in all the studied estimates as a result of using magnetized humic and fulvic acids (soaking seeds before sowing or foliar spraying on the plant) compared to the control treatment. The results also showed that foliar applying humic and fulvic acids on the plant were better than applying both acids by soaking seeds before sowing. It is also noted from the results that applying humic acid with a nitrogen fertilization (40 kg-N/fed) increased the concentration of N%, P%, K% and protein % by (3.16 and 4.46%), (0.45 and 0.55%), (2.29 and 2.67%) and (19.75 and 27.88%), respectively compared other treatments. This increase is due to humic and fulvic acids, which contain a high percentage of organic matter that improves the chemical and physical properties of the soil. Also, they play an effective role in attracting nutrients around the plant roots, which leads to increased absorption of elements by the plant roots. The results indicated that the effect of humic and fulvic acids on increasing nitrogen phosphorus, potassium and protein (except for foliar spraying application) and were not significant. In addition, the effect of using nitrogen fertilization rates (except for protein with foliar spraying application) and the interaction between the application of humic and fulvic acids with nitrogen fertilization was not significant. These results are similar to the results reported by El-Kamar (2020). Alsudays *et al.* (2024) found that treating plants grown in saline soil with humic or fulvic acid increases the plant's absorption of N, P and K. Applying humic or fulvic acid to the plant reduces the effect of salinity on the plant and increases the absorption of nutrients and growth, thus counteracting the effect of salinity on the plant (El-Beltagi *et al.,* 2023).

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Table 8: Effect of magnetized humic and fulvic acid on the contents of total nitrogen, phosphorus, potassium and protein percentages in faba bean grains.

Treatments	Rate of Nitrogen (Kg)	Macronutrients concentration (%)						Protein (%)	
		N		P		K			
		S	F	S	F	S	F	S	F
Control	20	2.75	2.91	0.18	0.20	1.30	1.37	17.19	18.19
	30	2.89	3.01	0.22	0.23	1.39	1.48	18.06	18.81
	40	3.10	3.18	0.23	0.25	1.44	1.51	19.38	19.88
Mean		**2.91**	**3.03**	**0.21**	**0.23**	**1.38**	**1.45**	**18.21**	**18.96**
Humic acid	20	2.85	3.35	0.42	0.52	2.21	2.59	17.81	20.94
	30	2.98	4.22	0.43	0.54	2.26	2.61	18.63	26.38
	40	3.16	4.46	0.45	0.55	2.29	2.67	19.75	27.88
Mean		**3.00**	**4.01**	**0.43**	**0.54**	**2.25**	**2.62**	**18.73**	**25.07**
Fulvic acid	20	2.80	3.22	0.36	0.46	1.97	2.37	17.50	20.13
	30	2.94	3.99	0.37	0.47	2.01	2.41	18.38	24.94
	40	3.14	4.23	0.40	0.51	2.09	2.49	19.63	26.44
Mean		**2.96**	**3.81**	**0.38**	**0.48**	**2.02**	**2.42**	**18.50**	**23.84**
LSD (0.05)	T	ns	0.16	ns	ns	ns	0.16	ns	0.70
	R	ns	ns	ns	ns	ns	ns	ns	1.25
	TR	ns	ns	ns	ns	ns	ns	ns	ns

S: soaking seed before sowing, F: foliar spraying, T: treatments, R: rate of nitrogen (Kg), TR: interaction between treatment and rate of nitrogen and ns: not significantly.

3.6. Effect of magnetized humic and fulvic acids application on plant height, yield and yield components during the winter season of 2022/2023

Data in Table 9 indicate that the application of magnetized humic and fulvic acids on faba bean plant led to an insignificant increase in plant height (except application seed soaking before sowing), yield and yield components. In addition, it was noted that the use of nitrogen fertilization led to an insignificant increase in plant height, number of branches/plant, number of pods/plant (except application seed soaking before sowing), seed weight (except application foliar spraying on plant) and seed yield. The results also showed that the interaction between the applications of magnetized humic and fulvic acids with nitrogen fertilization gave significant results only in weight of 100 seed (except application seed soaking before sowing). The results clearly showed that the application of magnetized humic and fulvic acids with nitrogen fertilization gave an increase in plant height, yield and yield components compared to the control, as well as, the results showed that the application of magnetized humic acid (seed soaking and foliar application) with nitrogen fertilization (40 kg-N/fed) gave the best increase in plant height (cm), No. of branches/plant, No. of pods/plant, weight of 100 seed (g), seed weight (g/plant) and seed yield (Ton./fed) by 90.40 cm, 98.60 cm, 7.10, 8.60 branch/plant, 35.00, 45.00, pod/plant 88.00 g, 105.00 g, 52.00 g/plant, 59.00 g/plant, 1.19 Ton/fed. and 1.36 Ton/fed., respectively compared with other treatments. The reason for the increase in plant height, yield and yield components is due to the fact that humic and fulvic acids contain carboxyl and phenolic groups which form a complex with elements ions, thus making these ions available to the plant for better use, in addition to the role played by humic and fulvic acid in improving the physical, chemical and microbiological properties of the soil, which is reflected in the benefit of improving plant growth. These results are similar to the results reported by Yousf *et al.* (2019), Mohamed (2020) and El-Kamar (2020). They found the same results. Alsudays *et al.* (2024) found that applying humic and fulvic acid to barley plants grown in saline soil made the plant more tolerant to salinity and thus increased plant height, yield and its components compared to the control. This is due to the role of humic and fulvic acids in increasing the plant's ability to breathe, increasing cell viability, increasing root cell division, increasing photosynthesis and absorption of O_2 and P.

Table 9: Effect of magnetized humic acid and magnetized fulvic on plant height, yield and yield components during the winter season of 2022/2023

Treatments	Rate of Nitrogen (Kg)	Plant height (cm)		No. of branches /plant		No. of pods /plant		Weight of 100 seed (g)		Seed weight (g/plant)		Seed yield (ton. /fed)	
		S	F	S	F	S	F	S	F	S	F	S	F
Control	20	75.10	75.25	2.60	3.10	16.00	25.00	55.00	58.00	35.00	36.00	0.99	1.00
	30	75.80	75.93	3.10	3.30	23.00	33.00	70.00	74.00	44.00	45.00	1.02	1.03
	40	76.30	76.52	3.50	3.80	27.00	38.00	79.00	83.00	46.00	48.00	1.09	1.05
Mean		**75.73**	**75.90**	**3.07**	**3.40**	**22.00**	**32.00**	**68.00**	**71.67**	**41.67**	**43.00**	**1.03**	**1.03**
Humic acid	20	87.90	97.80	6.30	8.10	20.00	33.00	75.00	80.00	39.00	44.00	1.13	1.18
	30	89.10	98.10	6.80	8.20	28.00	41.00	82.00	92.00	48.00	54.00	1.15	1.29
	40	90.40	98.60	7.10	8.60	35.00	45.00	88.00	105.00	52.00	59.00	1.19	1.36
Mean		**89.13**	**98.17**	**6.73**	**8.30**	**27.67**	**39.67**	**81.67**	**92.33**	**46.33**	**52.33**	**1.16**	**1.28**
Fulvic acid	20	82.40	93.70	5.60	7.50	18.00	26.00	70.00	78.00	37.00	38.00	1.09	1.10
	30	83.80	95.20	5.90	7.80	24.00	38.00	77.00	88.00	46.00	51.00	1.10	1.23
	40	85.50	96.10	6.00	8.00	30.00	40.00	85.00	95.00	50.00	56.00	1.13	1.30
Mean		**83.90**	**95.00**	**5.83**	**7.76**	**24.00**	**34.67**	**77.33**	**87.00**	**44.33**	**48.33**	**1.11**	**1.21**
LSD (0.05)	T	**3.99**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	R	**ns**	**ns**	**ns**	**ns**	**5.56**	**ns**	**5.33**	**3.72**	**ns**	**4.16**	**ns**	**ns**
	TR	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**6.44**	**ns**	**ns**	**ns**	**ns**

S: soaking seed before sowing, **F:** foliar spraying, **T:** treatments, **R:** rate of nitrogen (Kg), **TR:** interaction between treatment and rate of nitrogen and ns: not significantly.

4. Conclusions

In this research, the results are cleared that the application of magnetized humic and fulvic acids either soaking seeds or foliar application with nitrogen fertilization are an effective tools for the tolerance of the faba bean plant to salinity, and thus increasing the absorption of nutrients in addition to, enhance enzyme activity and increasing the yield and its components. Where, the results showed that the use of magnetized humic acid with nitrogen fertilization (40 kg-N/fed) led to improving the physical, chemical and microbiological properties of the soil, and thus improving the growth of the plant, the yield and its components. Based on the results, application of humic substances in combination with nitrogen fertilizer as a promising strategy to increase the growth and productivity of faba bean cultivated in saline soils.

5. Recommendation

The use of the foliar application of magnetic humic acid was an effective method that enhanced soil chemistry and increased faba bean productivity in saline soil.

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