The effect of adding agricultural sulfur and humic acid on the availability and absorption of NPK and sulfur nutrients

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Abstract

A field experiment was conducted in the Al-Mussaib project area, 35 km north of Babylon Governorate, within the coordinates of longitude 32º 47′ north and latitude 44º 26′ east, at an altitude of 27 m above sea level, to study the effect of adding agricultural sulfur and humic acid on the availability and absorption of some nutrients by the Fennel plant (Foeniculum vulgare L)., whose seeds were soaked with different levels of the growth regulator gibberellin. The study factors were agricultural sulfur at levels (0, 500, 1000 kg h-1) and humic acid at levels (0, 15, 30 ml L-1). The results were analyzed statistically according to the design of RCBD experiment and the averages were compared using the least significant difference test at the 5% probability level. The results were as follows: The treatment of adding sulfur (1000 kg ha-1) was significantly superior and gave the highest averages in the characteristics of available of nitrogen, phosphorus, potassium, and sulfates in the soil and absorbed by the leaves, while the treatment of adding humic acid at a level of (30 ml L-1) was significantly superior and gave the highest averages for the above characteristics.

Keywords: sulfur , humic acid , micronutrients, Fennel

The research is extracted from the master's thesis of the first researcher.

Introduction

Sulfur is one of the major nutrients necessary for plant nutrition. The sulfur content of plants ranges from 0.1 to 1%. Symptoms of its deficiency appear on plants when the sulfur content of the plant drops below 0.1%. It is slow-moving in the plant. Plants absorb sulfur from the soil in the form of sulfate ions $SO_4^{=}$, while atmospheric sulfur H_2S and SO_2 can be absorbed by the plant through the stomata and the cuticle layer. After that, sulfur can be reduced and represented in the plant in the form of amino acids cysTeine, which enter into the construction of proteins, namely Cysteine and Cystine at a rate of 2.7% S, and Mithionine, in which the sulfur content is 21% S. It was also found that sulfur enters into the composition of the vitamin B group such as Biotine and Thiamine, as well as in the composition of Glutathione, which has an important effect on the oxidation and reduction processes and the renewal of the protoplasm of plant cells and is important in reducing nitrates in the plant[15].

[13] indicated that humic organic acids, which include humic acid and fulvic acid, play an effective role in plant growth and the availability of nutrients in the soil. The use of humic and fulvic acids, even in low concentrations, increases the permeability of the cell membrane, and therefore the absorption of water and elements becomes more effective in the plant. This helps in the movement and transfer of elements in the plant. The activation of plant enzymes is one of the important properties performed by humic acid. This can be explained by the presence of the quinine group in humic acid, which acts as a hydrogen receptor, while at the

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same time oxygen is a stimulator and chemical mediator of oxidation and reduction processes.

The growth regulator Gibberellins are a large group of chemical compounds that are naturally occurring in plants and fungi. Gibberellins were first discovered in Japan, where it was observed that the fungus Gibberella Fujikuori secretes secretions that cause the stems of the parasitic plants to increase in length, which exposes the plant to dormancy and damage before the flowering stage. In 1939, some researchers were able to obtain the substance in crystalline form and named it Gibberellin A. In Britain, gibberellic acid was discovered. After that, the presence of gibberellin was proven in higher flowering plants, and many types of it were discovered. No artificial growth regulators are known to belong to the gibberellin group, but gibberellin is still extracted from fungi as an easy and economical method [1]. The physiological effects of gibberellin are due to its effect on the activity of the amylase enzyme, which breaks down starch molecules inside cells into monosaccharides, which leads to an increase in osmotic pressure and increased water absorption by cells. In addition, gibberellin increases the flexibility of the cell wall of plant cells and thus increases their size as a result of swelling with water [10]

The study aims to know the effect of agricultural sulfur and humic acid on the availability and absorption of NPK and Sulfate nutrients.

Materials and methods

A field experiment was conducted in the Al-Musayyab 35 project area, north of Babylon Governorate, within the coordinates of longitude 32º 47′ north and latitude 44º 26′ east and at an altitude of 27 m above sea level, to study the effect of adding agricultural sulfur and humic acid on the avaialability and absorption of some nutrients for the Fennel plant (Foeniculum vulgare L.), whose seeds were exposed to soaking with growth regulator gibberellin.

The field soil was ploughed with a triple-reversible plough to a depth of 50 cm, smoothed with disc harrows, leveled, and then main and secondary irrigation channels were opened. It was then divided into three sectors, each sector containing 27 experimental units, each with an area of 12 square meters (4 * 3 m). The experimental unit included 5 lines with a length of 3 m, the distance between one line and another was 75 cm, and the distance between one hole and another was 25 cm. A distance of one meter was left between one sector and another, and a distance of 50 cm between one experimental unit and another. Phosphate fertilizer was added at a level of 80 kg P ha-1 in the form of triple superphosphate (TSP) (20% p) in one batch before planting. Potassium fertilizer was added at a level of 120 kg K ha-1 in the form of potassium sulphate (41.5% K) and nitrogen at a level of 100 kg N ha-1 in the form of urea (46%) in two batches during the vegetative growth stage and the flowering stage [3]. All service operations were carried out equally for all experimental treatments in the study and whenever necessary. Three samples were taken from the field soil randomly, mixed together, and then a sample was selected for soil analysis before planting. After removing the plant remains, the soil was air-dried and ground using a wooden hammer and passed through a sieve with holes diameter of 2 mm and mixed well to homogenize it. Representative samples were taken from it for the purpose of conducting chemical and physical analyses of the soil according to the methods mentioned in [11] and [17],the results of which are shown in table (1). The seed

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planting process was carried out on 5/9/2024 by placing 3-4 seeds in each hole. The plants were thinned to one plant in each hole after the plant height reached 10 cm. Irrigation and weeding of the bushes were carried out manually and continuously whenever necessary. Soil samples were taken at the flowering stage of the plant [20]. The study factors represented agricultural sulfur at levels (0, 500, 1000 kg ha-1) and was added when preparing the soil for cultivation and humic acid at levels (0, 15, 30 ml L-1) and was added to the soil after 30 days of cultivation. The studied characteristics represented nitrogen, phosphorus, potassium, and sulfate availability and absorbed according to the methods mentioned in [11]

and [17]. The results were analyzed statistically according to the design implemented for the RCBD experiment with 81 experimental units and three sectors using the Genstat program and the averages were compared using the least significant difference test at a probability level of 5% according to the methods mentioned in [8].

Table (1) shows some of the physical and chemical properties of soil study before planting.

Characteristics	Value	Unit	
pH 1-1	7.8		
ECe	2.3	$dS\ m^{-1}$	
Organic Matter	7.8	$g\ kg^{-1}$	
$CaCO_3$	221		
CEC	22.4	Cmole charge kg^{-1} soil	
Avalaible Nitrogen	28.67	$mg\ kg^{-1}$ soil	
Avalaible Phosphorus	8.46		
Avalaible Potassium	121.55		
Avalaible Zinc	2.851		
Avalaible Iron	3.68		
Avalaible Boron	1.55		
Avalaible Sulfate	588.6		
Soil Particles	295.8	Clay	$g\ kg^{-1}$ soil
	379.2	Silt	
	325.0	Sand	
Texture	Clay Loam		

Results and Discussion

-1Available nitrogen and nitrogen in leaves

The results of Table (2) indicate that there are significant differences between the levels of factors in influencing the two characteristics of available nitrogen in the soil and the percentage of nitrogen in the leaves. The agricultural sulfur treatment (1000 kg ha-1) was significantly superior and gave the highest average for the two characteristics, reaching 42.53 mg kg-1 soil and 2.29% respectively, compared to the comparison treatment (without adding sulfur), which gave the lowest average for the two characteristics, reaching 33.17 mg kg-1 soil and 1.96% respectively. As for the factor of adding humic acid, the

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treatment (30 ml L-1) was significantly superior and gave the highest average, reaching 41.39 mg kg-1 soil and 2.25% respectively, compared to the treatment without adding acid, which gave the lowest average, reaching 34.45 mg kg-1 soil and 2.01% sequentially, as for the interaction between the two factors, the treatment (1000 kg h-1 sulfur + 30 ml L-1 humic acid) was superior significantly and gave the highest average for the two traits, reaching 45.72 mg kg-1 soil and 2.46% sequentially, while the comparison treatment gave the lowest average, reaching 28.80 mg kg-1 soil and 1.78% sequentially.

-2Available phosphorus and phosphorus in leaves

The results of Table (3) indicate that there are significant differences between the levels of factors in influencing the two characteristics of available phosphorus in the soil and the percentage of phosphorus in the leaves. The agricultural sulfur treatment (1000 kg ha-1) was significantly superior and gave the highest average for the two characteristics, reaching 11.32 mg kg-1 soil and 0.50%, respectively, compared to the comparison treatment (without adding sulfur), which gave the lowest average for the two characteristics, reaching 10.21 mg kg-1 soil and 0.36%, respectively. As for the factor of adding humic acid, the treatment (30 ml L-1) was significantly superior and gave the highest average, reaching 12.14 mg kg-1 soil and 0.46%, respectively, compared to the treatment without adding acid, which gave the lowest average, reaching 9.66 mg kg-1 soil and 0.41%, respectively. As for the interaction between the two factors, it was superior. The treatment (1000 kg ha-1 sulfur + 30 ml L-1 humic acid) was significant and gave the highest average for both traits, reaching 13.13 mg kg-1 soil and 0.54%, respectively, while the comparison treatment gave the lowest average, reaching 8.52 mg kg-1 soil and 0.33%, respectively .

-3Available potassium and potassium in leaves

The results of Table (4) indicate that there are significant differences between the levels of factors in influencing the two characteristics of available potassium in the soil and the percentage of potassium in the leaves. The agricultural sulfur treatment (1000 kg ha-1) was significantly superior and gave the highest average for the two characteristics, reaching 138.23 mg kg-1 soil and 3.34% respectively, compared to the comparison treatment (without adding sulfur), which gave the lowest average for the two characteristics, reaching 127.29 mg kg-1 soil and 2.43% respectively. As for the factor of adding humic acid, the treatment (30 ml L-1) was significantly superior and gave the highest average, reaching 137.83 mg kg-1 soil and 3.29% respectively, compared to the treatment without adding acid, which gave the lowest average, reaching 127.58 mg kg-1 soil and 2.68% sequentially, as for the interaction between the two factors, the treatment (1000 kg ha-1 sulfur + 30 ml L-1 humic acid) was superior morally and gave the highest average for the two characteristics, reaching 142.39 mg kg-1 soil and 3.52% sequentially, while the comparison treatment gave the lowest average, reaching 121.31 mg kg-1 soil and 1.93% sequentially.

-4Available sulfates and sulfates in leaves

The results of Table (5) indicate that there are significant differences between the levels of factors in influencing the two characteristics of available sulfates in the soil and the percentage of sulfates in the leaves. The agricultural sulfur treatment (1000 kg ha-1) was significantly superior and gave the highest

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average for the two characteristics, reaching 759.72 mg kg-1 soil and 0.85% respectively, compared to the comparison treatment (without adding sulfur), which gave the lowest average for the two characteristics, reaching 607.91 mg kg-1 soil and 0.58% respectively. As for the factor of adding humic acid, the treatment (30 ml L-1) was significantly superior and gave the highest average, reaching 714.61 mg kg-1 soil and 0.77% respectively, compared to the treatment without adding acid, which It gave the lowest average of 645.82 mg kg-1 soil and 0.63% respectively, as for the interaction between the two factors, the treatment (1000 kg ha-1 sulfur + 30 ml L-1 humic acid) was superior significantly and gave the highest average for the two traits of 804.14 mg kg-1 soil and 0.95% respectively, while the comparison treatment gave the lowest average of 596.90 mg kg-1 soil and 0.51% respectively .

It is noted from Tables (2-5) that the effect of adding different levels of agricultural sulfur and humic acid and the interaction between them had a significant effect on increasing the soil and plant leaf nutrients content after the flowering stage. Agricultural sulfur had a significant effect on increasing the availability of sulfur, nitrogen, phosphorus, potassium, in the soil, which indicates that the time factor in adding sulfur, as it was added before planting and when preparing the soil, has a decisive role in the oxidation process [12] The reason may also be attributed to the fact that the higher the rate of adding sulfur, the more it oxidizes sulfur in the soil and forms sulfuric acid H_2SO_4, which in turn reduces the degree of soil reaction, which leads to an increase in the availability of nutrients in it and an increase in the release of nitrogen, which contributes to increasing its availability in the soil [12]. The addition of sulfur and its role in reducing the soil pH contributed to the dissolution of some of the precipitated phosphorus compounds and the release of phosphorus from them to the soil solution, which increases its availability in the soil [2] and [9]. The addition of different levels of agricultural sulfur also led to an increase in the availability of major nutrients, including potassium, by dissolving some materials containing potassium in the soil, in addition to increasing the effectiveness of hydrogen ions released as a result of the oxidation process, which contributed to competing with the potassium ion absorbed on the surfaces of the exchange complexes, and then releasing potassium into the soil solution and increasing its availability in the soil. Also, the addition of agricultural sulfur enhances the role of microorganisms in increasing the availability of potassium by secreting enzymes and organic acids (citric and oxalic) that play a role in the weathering of minerals containing potassium and preserving potassium from fixation processes to be released into the soil solution [18]. The reason may also be attributed to the fact that adding different levels of agricultural sulfur can improve the growth environment. It increases the availability of nutrients in the soil as a result of root secretions [4], and the same tables above indicate the presence of significant differences and an increase in the availability of elements as a result of adding humic acids, which also contributed to reducing the degree of soil reaction, which increases the solubility of some phosphate compounds in the soil and increases the release of most nutrients, especially major ones. These results are consistent with [21] , [16] , and [7] , who indicated that the decomposition of humic acids leads to an increase in the availability of nutrients with addition levels, as [5] and [4]

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indicated that organic compounds work to coat the adsorption surfaces of phosphorus in addition to competing with phosphate on the adsorption surfaces, which allows phosphorus and the rest of the nutrients to remain dissolved and adsorbed and availability for preparation. The reason for the increase in the availability of nutrients in the soil as a result of adding humic acids may be attributed to improving its physical properties, such as its ability to Water retention and raising soil temperature in winter, as it works to reduce soil pH and also showed an improvement in the fertility properties of the soil, so the availability of all nitrogen, phosphorus, potassium, iron, zinc, boron and sulfur increased [7]. The dual interaction of adding agricultural sulfur and humic acids also led to the availability of an integrated and parallel nutritional system and increased soil productivity and fertility from nutrients, including nitrogen, in addition to the positive role of this interaction that enhances plant growth and increases metabolic activities through the formation of organic acids that dissolve compounds, releasing elements in their ready form available to the plant and activating cell and mineralization processes and secreting enzymes and growth regulators, all of which works to increase the readiness of the major essential nutrients in the soil. These results were consistent with many studies in this field, including what was stated by [19]. The interaction of study factors also leads to an increase in the root system and works to build a large root group that releases H+, which contributes to the release of these nutrients in the soil. After harvest [13] and [6] . The increase in the availability of sulfur in the soil is due to the increase in the amount added to the soil, which led to the sulfur-oxidizing bacteria of the type Thiobacillus thioparus, which, through the oxidation process, converted it into sulfuric acid, which caused a decrease in the degree of soil reaction and increased the availability of sulfur and other minor and major elements [14 .[

We conclude from the study that the addition of agricultural sulfur at a level of (1000 kg ha-1) and humic acid at a level of (30 ml L-1) led to a significant increase in the availability of nitrogen, phosphorus, potassium, zinc, iron and sulfate elements in the soil, in addition to a significant increase in the absorption of these elements by the leaves of the sweet seed plant.

Table 2. Effect of agri.sulfur and humic acid on available nitrogen in the soil and leaves

Sulfur kg ha^{-1}	Available N mg kg^{-1} soil			Aver.	N in leaves %			Aver.
	Humic acid ml L^{-1}				Humic acid ml L^{-1}			
	0	15	30		0	15	30	
0	28.80	33.98	36.73	33.17	1.78	2.02	2.08	1.96
500	35.04	38.09	41.73	38.29	2.12	2.10	2.22	2.15
1000	39.50	42.37	45.72	42.53	2.14	2.26	2.46	2.29
Aver.	34.45	38.15	41.39		2.01	2.13	2.25	
	Inter.	Humic	Sulfur		Inter.	Humic	Sulfur	$LSD_{0.05}$
	5.34	2.96	2.96		0.15	0.08	0.08	

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Table 3. Effect of agri.sulfur and humic acid on available phosphorus in soil and in leaves

Sulfur kg ha^{-1}	Available P mg kg^{-1} soil			Aver.	P in leaves %			Aver.
	Humic acid ml L^{-1}				Humic acid ml L^{-1}			
	0	15	30		0	15	30	
0	8.52	10.83	11.28	10.21	0.33	0.36	0.38	0.36
500	10.17	10.97	12.02	11.05	0.42	0.43	0.46	0.44
1000	10.30	10.53	13.13	11.32	0.47	0.50	0.54	0.50
Aver.	9.66	10.78	12.14		0.41	0.43	0.46	
	Inter.	Humic	Sulfur		Inter.	Humic	Sulfur	$LSD_{0.05}$
	0.49	0.26	0.26		0.05	0.03	0.03	

Table 4. Effect of agri.sulfur and humic acid on available potassium in soil and in leaves

Sulfur kg ha^{-1}	Available K mg kg^{-1} soil			Aver.	K in leaves %			Aver.
	Humic acid ml L^{-1}				Humic acid ml L^{-1}			
	0	15	30		0	15	30	
0	121.31	128.23	132.32	127.29	1.93	2.53	2.82	2.43
500	126.82	133.82	138.78	133.14	2.98	3.17	3.54	3.23
1000	134.61	137.69	142.39	138.23	3.13	3.38	3.52	3.34
Aver.	127.58	133.25	137.83		2.68	3.03	3.29	
	Inter.	Humic	Sulfur		Inter.	Humic	Sulfur	$LSD_{0.05}$
	7.33	3.82	3.82		0.21	0.11	0.11	

Table 5. Effect of agri.sulfur and humic acid on available sulfates in soil and in leaves

Sulfur kg ha^{-1}	Available SO_4 mg kg^{-1} soil			Aver.	SO_4 in leaves %			Aver.
	Humic acid ml L^{-1}				Humic acid ml L^{-1}			
	0	15	30		0	15	30	
0	596.90	606.32	620.50	607.91	0.51	0.58	0.66	0.58
500	641.34	680.83	719.18	680.45	0.61	0.65	0.71	0.66
1000	726.22	748.80	804.14	759.72	0.76	0.83	0.95	0.85
Aver.	645.82	678.65	714.61		0.63	0.69	0.77	
	Inter.	Humic	Sulfur		Inter.	Humic	Sulfur	$LSD_{0.05}$
	53.75	28.56	28.56		0.13	0.07	0.07	

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