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The Effect of Soil Fertilizing With Humic Acid And AAgricultural sulfur in Some Traits of Okra Plant

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ABSTRACT

Okra (*Abelmoschus esculentus*) is an important vegetable crop valu its nutritional and economic significance. Enhancing soil fertility th organic and mineral amendments such as humic acid and agricu sulfur can play a key role in improving its growth and productiv factorial experiment was conducted at the nursery of the Colle Education for Pure Sciences, University of Diyala, from March 1, 20 April 30, 2025, to evaluate the effects of soil fertilization with humi and agricultural sulfur on some growth characteristics of okra plant treatments consisted of a control (no fertilization), humic acid a concentrations (5 and 10 g L^{-1}), and agricultural sulfur at concentrations (5 and 10 g L^{-1}), arranged in a completely rando design (CRD) with three replications. Black plastic pots (20 cm dia 20 cm height) were used, each containing 5 kg of soil. The fertilizers added to the soil after germination and seedling emergence, and responses were observed daily throughout the study period, which 59–61 days. The results showed that humic acid fertilization at 10 produced the highest significant increases in plant height (159.6 cm) weight (78.0 g), and dry weight (54.0 g). The highest chlorophyll c (74.3 SPAD units) was recorded with agricultural sulfur fertilization g L^{-1}. Agricultural sulfur fertilization also resulted in signi improvements in other traits, although the magnitude of these inc was generally lower than those observed with humic acid fertiliz These findings indicate that both humic acid and agricultural sulfu significant positive effects on okra growth, with humic acid particularly effective for vegetative growth traits.

1-Introduction

Okra (Abelmoschus escullantus L) is a member of the family Malvaceae. It is endemic to Ethiopia and Sudan. It is a summer crop grown in open fields and can also be grown in greenhouses [1]. Okra fruits are rich in nutritional value. 100 grams of fresh fruit contain 85.7% water, 35 calories, 2.4 grams of fat, 1.9 grams of potassium, 6.4 grams of carbohydrates, 66 mg of calcium, 56 mg of protein, 249 mg of phosphorus, 30 mg of sulfur, 53 mg of magnesium, 0.19 mg of copper, 0.35 mg of iron, 1.2 g of fiber, 520 IU of vitamin A, 0.01 mg of vitamin B1, and 0.07 mg of vitamin B2. , 0.6 mg vitamin B3, 88.21 µg vitamin B9, and 13 mg vitamin C [2]. Okra fruits have many uses, including as both a food and medicinal substance, as they help in treating many diseases, including general weakness, kidney inflammation, diarrhea, urinary tract diseases, and anemia [3]. Okra is known in many English-speaking countries as lady's fingers, Bhindi in India and Gombo, and Kobi Arab in East Asia, and in the Middle East as Bamia and Bamia [4]. India the world's largest producer of okra (67.1%), then Nigeria (15.4%) and Sudna (9.3%) [5]. Okra is grown in a wide variety of soils, but fertile, well-drained soil with adequate organic matter results in high yields [6].

Organic fertilization is defined as the addition or increase of organic matter to the soil [7]. Organic fertilizers are also defined as fertilizers derived from animal or dead plant waste, organic waste in its liquid or solid state, and microorganisms that help increase the nutrient and organic matter content in the soil. They can also improve the chemical, physical, and biological properties of the soil. Organic fertilizer can increase the activity of soil microorganisms, leading to the availability of nitrogen and phosphorus to plants [8,9]. The addition of organic fertilizers plays a fundamental role in increasing the total pore volume. They can also improve soil structure and development and stimulate plant roots, which leads to improved soil fertility and efficiency, thus improving plant growth. They also improve the soil's ability to retain water and retain moisture, which significantly improves crop quality by enhancing nutrient balance [10]. Humic acid is the main component of organic matter and the most active and effective in soil. It has been proven that this acid stimulates plant growth and increases yield by affecting the mechanisms of many important plant biological processes, such as water and nutrient absorption, respiration, protein synthesis, and increased activity and photosynthesis [11]. Humic acids, a component of humic substances, are known to improve seed germination. The use of humic acid as an organic fertilizer significantly reduces the rate of use of chemical fertilizers [12].

Sulfur is one of the most important of the seventeen main elements and ranks fourth among the essential nutrients for plant absorption. Sulfur is a macronutrient, as it is a component of volatile oils, as well as allicin. It is also a component of plant cells and has a positive effect on plants when added to them [13]. It contributes to the Chlorophyll production but not involved in the structure of it. It also plays a large role in… Strengthening plant growth and productivity. (Sulphur is present in a lot of 'metabolic' chemicals, e.g. Amino Acids like Methionine & Cysteine, Anti-oxidants and proteins). Sulfur is essential since it is a constituent of coenzyme A [14].

Despite the well-documented individual effects of humic acid and aAgricultural sulfur on plant growth, limited research has investigated their combined application on okra (*Abelmoschus esculentus* L.), particularly under specific soil conditions. Most studies have focused on either organic fertilization or sulfur application separately, without examining their potential synergistic effects on vegetative growth, yield components, and fruit quality in okra. Furthermore, there is a lack of information regarding the optimal application rates and combinations of humic acid and sulfur for maximizing okra productivity. Therefore, this study seeks to address this gap by evaluating the interactive effects of humic acid and Agricultural sulfur on key traits of the okra plant. The present study was undertaken to evaluate the effects of humic acid and aAgricultural sulfur, applied separately and in combination, on the growth, yield, and fruit quality of okra (*Abelmoschus esculentus* L.). The specific aims were to determine the most effective application rates of these amendments, to assess their potential synergistic interactions, and to provide practical recommendations for improving okra productivity through integrated soil fertilization.

2-Materials and Methods

2-1Experimental site and duration

A factorial experiment was conducted at the nursery of the College of Education for Pure Sciences, University of Diyala, from March 1, 2025, to April 30, 2025, to evaluate the effects of soil fertilization with humic acid and agricultural sulfur on some growth characteristics of okra plants (*Abelmoschus esculentus* L. cv. Petra).

2-2Soil properties

The soil used in the experiment was sandy soil. Representative soil samples were collected before planting for physical and chemical analysis. The initial properties of the soil were as follows: pH (1:2.5 soil-water suspension) 7.8, electrical conductivity (EC) 1.2 dS m^{-1}, organic matter (OM) 0.4%, available nitrogen 25 mg kg^{-1}, available phosphorus 8 mg kg^{-1}, and available potassium 120 mg kg^{-1}.

2-3 Experimental design and treatments

The experiment was arranged in a completely randomized design (CRD) with three replications. Black plastic pots (20 cm diameter, 20 cm height) were used, each containing 5 kg of air-dried sandy soil. The treatments consisted of:

- **Control:** No fertilization
- **Humic acid at 5 g L^{-1}**
- **Humic acid at 10 g L^{-1}**
- **Agricultural sulfur at 5 g L^{-1}**
- **Agricultural sulfur at 10 g L^{-1}**

Thus, a total of 5 treatments × 3 replications = 15 experimental units (pots) were used.

2-4 Fertilizer sources and composition

- **Humic acid:** Commercial product (potassium humate) containing 70% humic acid, 12% potassium oxide (K_2O), pH 8–10, soluble in water.
- **Agricultural sulfur:** Commercial product containing 90% elemental sulfur (S), fine powder (particle size < 0.5 mm).

2-5 Planting and fertilizer application

Five okra seeds (cv. Petra) were sown per pot at a depth of 2–3 cm. After full germination (10 days after sowing), seedlings were thinned to two uniform plants per pot.

Fertilizers were applied as soil drenches. For humic acid treatments, the required amount (5 or 10 g) was dissolved in 500 mL of distilled water and applied evenly to the soil surface around the plants. For agricultural sulfur treatments, the required amount (5 or 10 g) was thoroughly mixed with the top 5 cm of soil in each pot. The control pots received 500 mL of distilled water only. All treatments were applied once, immediately after thinning (10 days after sowing).

Irrigation and maintenance

Plants were irrigated daily with tap water as needed to maintain field capacity. No additional chemical fertilizers were applied during the experiment.

2-6 Measured traits and data collection

Plant responses were monitored daily for general observations (germination rate, visible abnormalities, and general health). The following specific traits were measured at the end of the experiment (59–61 days after sowing):

1. **Plant height (cm):** Measured from the soil surface to the tip of the main stem using a measuring tape.
2. **Fresh weight (g):** Whole plants (shoots) were harvested, washed, blotted dry, and weighed immediately using a digital balance.
3. **Dry weight (g):** After fresh weight measurement, plant samples were oven-dried at 70°C for 72 hours until constant weight, then weighed.
4. **Chlorophyll content (SPAD units):** Measured on fully expanded young leaves using a portable SPAD-502 chlorophyll meter (three readings per leaf, three leaves per plant).

2-7 Growth Traits Studied

2-7-1- Plant Height (cm)

Plant height was determined by measuring the distance from the soil surface to the tip of each plant at termination using a graduated measuring tape and an average height was recorded for five plants.

2-7-2- Fresh Weight of the Leaf (g)

The weight of the plant (fresh) was determined with a sensitive electric balance for five plants from which the average was taken.

2-7-3- Dry Weight of the Root (g)

The dry weight of the leaf was calculated using a sensitive balance, after air-drying the leaf for 72 hours until the weight stabilized.

2-7-4- Total Chlorophyll Index (SPAD)

The chlorophyll index of different okra leaves was determined with a chlorophyll meter (SPAD-502 Plus). Five random leaves for each pot were scanned and an average value was calculated.

2-8 Statistical analysis

All data were subjected to analysis of variance (ANOVA) using appropriate statistical software. Means were compared using Duncan's multiple range test at a probability level of $P \leq 0.05$.

3-Results and Discussion

Plant height (cm)

Table (1) shows significant differences in the studied plant traits. The highest mean, which was significantly different from the control, was observed for plant height (cm) in the fertilization treatment with humic acid at a concentration of 10 g L^{-1}, where the highest mean reached 159.6 cm, while the lowest mean (127.9 cm) was recorded in the unfertilized treatment.

Table 1. Effect of soil fertilization with humic acid and agricultural sulfur on okra plant height (cm)

Humic acid (g L^{-1})	Agricultural sulfur (g L^{-1})			Mean of humic acid
	0	5	10	
0	121.1 e	127.6 d	135.0 c	127.9 C
5	128.3 d	157.7 b	165.4 ab	150.4 B
10	137.4 d	169.9 a	171.7 a	159.6 A
Mean of agricultural sulfur	128.9 C	151.7 B	157.3 A	

Means followed by similar letters within the columns (single factors) and within the interaction means do not differ significantly according to Duncan's multiple range test at $P \leq 0.05$.

The increase in plant height is attributed to the fact that organic fertilizers, including humic acid, had a significant effect on plant height as a result of their essential and effective role in increasing cell division and cell elongation, as humic acids have an effect similar to that of plant hormones, providing the best conditions for the plant, including raising the rate of plant growth and cell division, and thus increasing plant height [15]. The direct reason may also be attributed to the composition of humic acid, which is rich in essential nutrients, including phosphorus, potassium, and nitrogen, which have important and essential roles in respiration, carbon metabolism, and increasing growth hormones. Enzymes, enzyme cofactors, and increased DNA and RNA synthesis are essential for cell division and elongation in the stem's structural tissues, thus increasing plant height [16,17].

Table (1) also shows that in the agricultural sulfur treatment at 10 g L^{-1}, the highest mean was observed (157.3 cm), while the lowest mean was recorded in the control (128.9 cm). This improvement in plant height may be due to the role of agricultural sulfur in plant metabolism, as it is required for amino acids, essential proteins, and some hormones [17].

Fresh weight (g)

Table (2) shows that the highest mean, which was significantly different from the control, for fresh weight (g) was observed in the humic acid fertilization treatment at 10 g L^{-1}, where the highest mean reached 78.0 g, while the lowest mean was 63.6 g in the unfertilized treatment.

Table 2. Effect of soil fertilization with humic acid and agricultural sulfur on fresh weight (g)

Humic acid (g L^{-1})	Agricultural sulfur (g L^{-1})	Mean of humic acid		
	0	5	10	
0	61.4 a	63.6 d	66.0 c	63.6 C
5	69.3 d	71.7 b	76.4 ab	72.4 B
10	77.4 d	75.9 a	80.7 a	78.0 A
Mean of agricultural sulfur	69.3 C	70.4 B	74.3 A	

Means followed by similar letters within the columns (single factors) and within the interaction means do not differ significantly according to Duncan's multiple range test at $P \leq 0.05$.

The reason for this increase in fresh weight may be attributed to the primary role of humic acid in increasing the plant's tolerance to drought by retaining water in the soil. This helps maintain soil aggregates and soil moisture, which encourages increased root growth and branching. In turn, this facilitates better absorption of all nutrients, especially those transported by mass flow in the plant, which is reflected in an increase in the root and vegetative mass, thus increasing the fresh weight of the plant [18].

This weight gain can also be attributed to the vital and significant role of sulfur in agriculture. Sulfur stimulates cell division and elongation, as it is a component of amino acids such as methionine, cysteine, and biotin. It is also one of the basic components of coenzyme A, which plays an important role in the synthesis of auxins [13,19,20]. Moreover, sulfur is involved in essential reactions in the plant that promote vegetative growth [21].

Dry weight (g)

Table (3) shows that the highest mean, which was significantly different from the control, for dry weight (g) was observed in the humic acid fertilization treatment at 10 g L^{-1}, where the highest mean reached 54.0 g, while the lowest mean was 39.3 g in the unfertilized treatment.

Table 3. Effect of soil fertilization with humic acid and agricultural sulfur on dry weight (g)

Humic acid (g L^{-1})	Agricultural sulfur (g L^{-1})	Mean of humic acid	
	0	5	10

Humic acid (g L^{-1})	Agricultural sulfur (g L^{-1})	Mean of humic acid		
0	28.3 a	34.6 d	45.0 c	39.3 C
5	36.3 d	37.7 b	51.4 ab	45.2 B
10	49.4 d	50.9 a	61.7 a	54.0 A
Mean of agricultural sulfur	38.0 C	41.0 B	52.7 A	

Means followed by similar letters within the columns (single factors) and within the interaction means do not differ significantly according to Duncan's multiple range test at $P \leq 0.05$.

The reason for the increase in dry weight may be due to the fact that adding organic fertilizers improved the physical properties of the soil, provided the soil with necessary nutrients, and reduced soil acidity, which helped dissolve some nutrient compounds and thus contributed to increasing nutrient availability, leading to increased vegetative growth and consequently increasing plant dry weight [22,23]. This superiority may also be due to the essential role of organic acids, which have a positive impact on increasing nutrient availability and absorption by the plant. This contributes to the production of nutrients within the plant, such as proteins and carbohydrates, and the formation of new cells, which induces enhanced vegetative growth as manifested in plant height and fresh weight, with ultimate increases in dry weight [22]. Humic acid also helps regulate cell membrane permeability and element absorption. This is then positively reflected on cell size, elongation, and division, leading to increased vegetative growth indicators [24,25].

Table (3) also shows that in the agricultural sulfur treatment at 10 g L^{-1}, the highest mean reached 52.7 g, while the lowest mean was 38.0 g in the unfertilized treatment. The increase in dry weight is attributed to the role of sulfur as a major element that enters into the formation of some basic and important organic compounds in plants. Sulfur participates in oxidation-reduction reactions, in addition to its important role in reducing soil pH and increasing the availability and absorption of many essential nutrients by the plant [26]. This leads to an increase in the nutritional status of the plant, which increases its growth and activity, as the roots of plants treated with sulfur are several times larger than the roots of untreated plants [27]. Consequently, nutrient absorption increases, all of which works to increase the efficiency of photosynthesis and the use of compounds in growth and biosynthesis processes [28].

Chlorophyll content (SPAD)

Table (4) shows that the highest mean, which was significantly different from the control, for chlorophyll content (SPAD) was observed in the agricultural sulfur treatment at 10 g L^{-1}, where the highest mean reached 74.3 SPAD, while the lowest mean was 57.5 SPAD in the unfertilized treatment. This is due to the importance of sulfur as a major nutrient having a basic and important role in the formation of chlorophyll (although it does not participate directly in its composition), as well as its role in improving plant productivity and growth. The plant absorbs sulfur in two forms: SO_4^{2-} and SO_2. The first form (sulfates) is absorbed through the roots, while a small part of the second form (sulfur dioxide) is absorbed through the leaves [29].

Table (4) also shows that in the humic acid fertilization treatment at 10 g L^{-1}, the highest mean was 69.6 SPAD, while the lowest mean was 61.8 SPAD in the unfertilized treatment. This is due to humic acid promoting the magnesium content in leaves. This factor enhances chlorophyll content, either as a material incorporated into its composition or by actively aiding cellular processes for chlorophyll production. The increase in chlorophyll may also be attributed to the direct involvement of humic acid in basal activities such as metabolism and respiration, in addition to its role in enhancing antioxidants and preserving leaf chlorophyll content from decomposition [30].

Table 4. Effect of soil fertilization with humic acid and agricultural sulfur on chlorophyll content (SPAD)

Humic acid (g L^{-1})	Agricultural sulfur (g L^{-1})			Mean of humic acid
	0	5	10	
0	55.0 a	60.6 d	70.0 c	61.8 C
5	57.3 d	66.7 b	74.4 ab	66.1 B
10	60.4 d	69.9 a	78.7 a	69.6 A
Mean of agricultural sulfur	57.5 C	65.7 B	74.3 A	

Means followed by similar letters within the columns (single factors) and within the interaction means do not differ significantly according to Duncan's multiple range test at $P \leq 0.05$.

4-Conclusions

The study demonstrated that soil fertilization with humic acid and agricultural sulfur positively influences the growth and physiological traits of okra plants. Humic acid was more effective in promoting vegetative growth traits, specifically plant height, fresh weight, and dry weight, while agricultural sulfur was superior in enhancing chlorophyll content.

We conclude from these results that humic acid is a good and effective fertilizer for soil and plants when added within the permissible range, followed by agricultural sulfur fertilization. Furthermore, fertilization with organic fertilizers is necessary and important for improving plant traits due to their availability, low cost, time efficiency, and ability to produce acceptable results.

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