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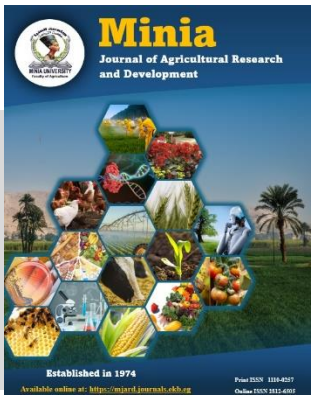


# Productivity of fennel grown in newly reclaimed soils as affected by humic acid and amino acids treatments

**Abdou, M.A.H. and Abd El-Karim, Z.A.Z.**
Ornamental plants, Fac. of Agric., Minia Univ., Egypt.

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## ABSTRACT

This research was undertaken in the two seasons 2023/2024 and 2024/2025 in a private Farm at Balansoura village, Abu Qurqas district, El-Minya Governorate, Egypt to test the response of fennel plant grown in new reclaimed soils to humic acid (0.0, 1.0, 2.0 and 4.0 g/l), amino acids (0.0, 0.5, 1.0 and 2.0 ml/l) and their interaction treatments.

The findings pointed out that all examined vegetative growth characters (plant height, number of main branches per plant, and herb dry weight per plant), yield and its components (the number of umbels per plant, the weight of 1000 fruits, and the fruit yield per either plant and per feddan), essential oil productivity (essential oil percentage and its yield per plant and per feddan) and some chemical constituents (chlorophyll a, b and carotenoids contents and NPK%) of fennel were considerably increased by all used treatments concentrations of humic acid and/or amino acids facing the control throughout both seasons. The treatment of humic acid at 4.0 g/l and amino acids at 2.0 ml/l produced the highest values.

**Keywords:** fennel – humic acid – amino acids – growth – yield – essential oil – pigments – NPK%.

## 1. INTRODUCTION

Approximately 700,000 feddan of recently reclaimed land are owned by the Minia Governorate. Because aromatic and medicinal plants are prioritized when responding to both domestic and international markets, this expanded region depends on new irrigation systems and environmentally friendly materials to produce organic and healthful products—a practice known as "green agriculture." One of the most important medicinal plants is fennel.

The volatile oil is widely used in laxative formulations as a flavoring and carminative **(Lawless, 1995)**. Additionally, it has a potent anti-inflammatory and antispasmodic impact on the smooth muscle and is useful in treating children's colic and flatulent dyspepsia **(Stary and Jirasck,**

* Corresponding author: Abd El-Karim, Z.A.Z.
E-mail address: zeinahmed3265@gmail.com

**1975 and Mahfouz and Sharaf Eldin, 2007)**. Due to its therapeutic qualities, fennel is considered an important aromatic and medicinal herb. Traditional medicine uses it as a sedative, diuretic, galactagogic, carminative, stimulant, antispasmodic, expectorant, and emmenagogic **(Chiej, 1984 and Charles *et al*., 1993)**. Fruits are also useful for the food business, baking, tincturing, infusion, sauces, and gourmet spices **(Lawless, 1995)**.

Numerous authors have noted the beneficial effects of humic compounds and/or amino acids on yields, vegetative development, the synthesis of essential oils, and certain chemical elements like **Abdul-Hafeez *et al*. (2020), Mohamed (2020), Ghaderimokri *et al*. (2022), Tawfik (2022), Hegazi *et al*. (2023), Abobaker *et al*. (2024)** and **Samy *et al*. (2025)** on fennel concerning humic acid. Likewise, **El-Awadi and Hassan (2010), Hendawy and Ezz El-Din (2010), Mostafa (2015), Mohamed (2020)** and **Zatimeh and Al-Fraihat (2025)** on fennel regarding amino acids.

Therefore, the purpose of this study was to assess how humic and amino acid treatments affected fennel plants cultivated in recently reclaimed soils.

## 2. MATERIALS AND METHODS

This study investigated the effects of humic and amino acid treatments on fennel plants cultivated on newly reclaimed soils over the two seasons of 2023-2024 and 2024-2025 at a private farm in Balansoura village, Abu Qurqas district, El-Minya Governorate, Egypt.

**Plant material:**

Fruits of fennel were acquired from Minia University's Faculty of Agriculture's Nursery of Ornamental and Medicinal Plants. The new restored sandy soil was used to plant the fennel plant's fruits. The **ICARDA (2013)** approach was followed in conducting the soil analysis and was shown in Table (a).

**Table (a): Physical and chemical properties of the used soil during the two growth seasons of 2023/2024 and 2024/2025.**

| Soil character | Values | Soil character | Values |
|---|---|---|---|
| **Physical properties:** | | **Exchangeable nutrients:** | |
| Sand (%) | 94.40 | $Ca^{++}$ (mg/100 g soil) | 4.54 |
| Silt (%) | 2.91 | $Mg^{++}$ (mg/100 g soil) | 1.95 |
| Clay (%) | 2.69 | $Na^{+}$ (mg/100 g soil) | 0.78 |
| Texture | Sandy | $K^{+}$ (mg/100 g soil) | 0.18 |
| **Chemical properties:** | | **Available nutrients:** | |
| pH (1:2.5) | 8.54 | $Ca^{++}$ (ppm) | 109 |
| E.C. (dS/m) | 1.27 | $Mg^{++}$ (ppm) | 3.66 |
| O.M. (%) | 0.11 | $Na^{+}$ (ppm) | 29.42 |
| $CaCO_3$ (%) | 8.73 | $K^{+}$ (ppm) | 16.61 |

**Layout of the experiment:**

Four humic acid treatments (0.0, 1.0, 2.0, and 4.0 g/l, as the main plot) and four amino acid treatments (0.0, 0.5, 1.0, and 2 ml/l, as sub-plots) with three replicates each made up the 16 treatments in the study, which was set up in a split plot design. The experimental site was set up and separated into terraces that were 30 cm apart and 70 cm wide. There are two irrigation lines on each terrace, spaced 40 cm apart. On October 15, fennel plant fruits were planted in both seasons on a hill (3–4 fruits/hill) spaced 25 cm apart (the drippers were 25 cm

apart, with a rate of 4 l/hour) next to the drip irrigation lines. With two irrigation lines and 20 plants (42000 plants/fed.), the unit area measured 2 m in length by 1.0 in width (2 m2 = 1/2100 fed.). The plants were thinned twice: once after three weeks from the date of planting (7 November) and once after one week (two plants per hill).

Both humic and amino acids were sprayed three times using a hand sprayer; the first was applied forty-five days after the planting date (December 1st), and the second and third were repeated twenty-one days apart (December 22nd and January 15th, respectively).

Star Gold for Agricultural Development, Assiut District, Assiut Governorate, Egypt, released Diamond Grow, an organic humic acid powder. The chemical composition of the humic acid utilized in the study, as indicated by its label, was displayed in Table (b).

**Table (b): Chemical composition of Diamond Grow (organic humic acid powder) that used during the two growth seasons of 2023/2024 and 2024/2025.**

| Character | Values |
|---|---|
| **Humic acid** (Derived from sub-bituminous coal | 95% |
| **Other ingredients** (inert materials – moisture …….) | 5% |

Chema Industries, Egypt, released Amino Forte (amino acids). The chemical makeup of the amino acids employed in the study, as indicated by their label, was displayed in Table (c).

**Table (c): Chemical composition of Amino Forte (amino acids) that used during the two growth seasons of 2023/2024 and 2024/2025.**

| Character | Values | Character | Values |
|---|---|---|---|
| **Amino acids** | 13 - 20% | **Potassium** | 5.20% |
| **Seaweed** | 3.9% | **Phosphorus** | 1.30% |
| **Organic carbon** | 29.9% | **Iron** | 0.65% |
| **Organic nitrogen** | 3.5% | **Manganese** | 0.39 |
| **Cytokinin** | 100 ppm | **Boron** | 0.13% |
| **Gibberellic** | 200 ppm | **Zinc** | 1.04% |
| **Calcium** | 0.51% | **Copper** | 0.01% |

Fennel plants were harvested on the last week of April in both experimental seasons.

**Data recorded:**

**Vegetative growth parameters:**

Plant height (cm), number of main branches/plants, and herb dry weight (g/plant).

**Yield and its components:**

Number of umbels per plant, weight of 1000 fruits (g) and fruit yield either per plant (g) and per feddan (kg).

**Essential oil production:**

Essential oil percentage **(**according to the method described by **Egyptian Pharmacopoeia, 1984)** and its yields per plant (ml) and per feddan (l).

**Chemical constituents:**

Chlorophyll a, b and carotenoids in the fresh leaves (mg/g FW) according to **Moran (1982)** and nutrients % (N, P and K) in the dry herb according to the procedure of **ICARDA (2013)**.

**Statistical analysis:**

The data collected for each feature was organized into tables and statistically examined using **MSTAT-C (1986)** and the

LSD test (at 0.05) to facilitate comparisons between treatment means.

## 3. RESULTS WITH DISCUSSIONS

### 3.1. Vegetative growth parameters

Plant height, number of main branches per plant, and herb dry weight per plant were increased significantly when treated fennel plants with the three humic acid concentrations (1, 2, and 4 g/l) in comparison to the control treatment over both seasons (Table 1). In the first season, the better treatment (4 g/l) raised the plant height, number of main branches per plant, and herb dry weight per plant by 62.38, 6.28, and 62.41%, respectively, compared to the control. In the second season, the same patterns were noted.

It has already been noted that humic acid promotes the vegetative growth of fennel plants as mentioned by **Zulfiqar *et al*. (2019), Mohamed (2020), Tawfik (2022), Hegazi *et al*. (2023), Abobaker *et al*. (2024)** and **Samy *et al*. (2025)**.

According to the data in Table (1), all three of the amino acid concentrations employed (0.5, 1.0, and 2.0 ml/l) during both seasons significantly increased the fennel plant's height, number of main branches per plant, and herb dry weight per plant as compared to the check treatment. The 2.0 ml/l treatment outperformed the control and other treatments. The treatment of 2.0 amino acids resulted in improvements of 8.41, 8.56, and 8.41% in the first season over the control of plant height, main branches per plant, and herb dry weight per plant, respectively. The same patterns were noted in the second season.

Amino acids had an improvement role on vegetative growth of fennel plant as demonstrated by **El-Awadi and Hassan (2010), Mostafa (2015), Mohamed (2020)** and **Zatimeh and Al-Fraihat (2025)**.

For every vegetative parameter examined in both seasons, the interaction impact between the humic and amino acid treatments was substantial facing the control. Plants treated with 4.0 g/l humic acid and sprayed with 2.0 or 1.0 ml/l amino acids had the highest overall results.

### 3.2. Yield and its components

According to the data in Table (2), treating fennel plants with three concentrations of humic acid (1, 2, and 4 g/l) during both seasons resulted in a significant increase in the number of umbels per plant, weight of 1000 fruits (g), and fruit yield (g/plant and kg/feddan) when compared to the check treatment. Plants treated with 4 g/l humic acid in both seasons produced the greatest results (29.39 and 34.27 umbels per plant), (10.68 and 10.85 g for weight of 1000 fruits), (35.19 and 41.04 g fruit/plant), and (1477.85 and 1723.62 kg fruit/feddan), respectively.

The positive role of humic acid on yield traits was previously mentioned by **Sharaf-El-Deen *et al*. (2012), Abdul-Hafeez *et al*. (2020), Mohamed (2020), Ghaderimokri *et al*. (2022), Hegazi *et al*. (2023)** and **Samy *et al*. (2025)** on fennel plant.

According to data in Table (2), the three used concentrations of amino acids (0.5, 1.0, and 2.0 ml/l) significantly increased the number of umbels per plant, the weight of 1000 fruits (g), and the fruit yield (g/plant and kg/feddan) when compared to untreated plants during both experimental seasons. The number of umbels per plant, the weight of 1000 fruits (g), and the fruit production (g/plant and kg/feddan) in the first season all increased by 8.47, 16.97, 8.41, and 8.42% above the control, respectively, as a result of the 2.0 ml/l amino acids treatment. The same patterns were noted in the second season.

Foliar application of amino acids showed a significant effect on yield

components of medicinal plants as mentioned by **El-Awadi and Hassan (2010)** and **Mohamed (2020)** on fennel plant, **Aly *et al*. (2022)** on anise plants and **Soliman *et al*. (2023)** on cumin.

The quantity of umbels per plant, the weight of 1000 fruits (g), and the fruit yield (g/plant and kg/feddan) in all seasons were all significantly impacted by the interaction between the humic and amino acids treatments. The plants that were sprayed with amino acids at 2.0 or 1.0 ml/l and treated with 4.0 g/l humic acid had the highest overall values.

**3.3. Essential oil production**

Table (3) demonstrated that, in comparison to the control treatment throughout both seasons, the proportion of essential oil and its yield per plant (ml) and per feddan (l) were significantly augmented when fennel plants were treated with the three concentrations of humic acid (1, 2, and 4 g/l). In the first season, 4 g/l humic acid increased essential oil yield per plant (ml), essential oil percentage, and essential oil per feddan (l) by 73.25, 18.35, and 181.54% over the control, respectively, compared to the control. During the second season, the same patterns were observed.

Treating plants with humic acid improved essential oil of plants as reported by **Sharaf-El-Deen *et al*. (2012), Khalid *et al*. (2015), Mostafa (2015), Abdul-Hafeez *et al*. (2020), Ghaderimokri *et al*. (2022), Hegazi *et al*. (2023), Abobaker *et al*. (2024)** and **Samy *et al*. (2025)** on fennel.

The data in Table (3) shows that, in comparison to untreated plants throughout both experimental seasons, the three utilized doses of amino acids significantly increased the amount of essential oil (%) and its yield per plant or per feddan. In the first season, the essential oil percentage, essential oil production per plant (ml), and essential oil yield per feddan (l) increased by 37.29, 26.24, and 37.33%, respectively, as a result of 2.0 ml/l amino acids. During the second season, the same patterns were observed.

Amino acids had beneficial role in increasing essential oil production as mentioned by **Hendawy and Ezz El-Din (2010), Mostafa (2015), Peymaei *et al*. (2024)** and **Zatimeh and Al-Fraihat (2025)** on fennel.

The percentage of essential oil and its yield per plant (ml) and per feddan (l) in both seasons were significantly impacted by the interaction between the humic and amino acid treatments. The plants treated with either 2.0 or 4.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l for essential oil percentage and 4.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l for essential oil yields per plant or per feddan had the highest overall values.

**3.4. Photosynthetic pigments**

The data in Table (4) demonstrated that applying the three humic acid concentrations (1, 2, and 4 g/l) to fennel plants significantly increased their photosynthetic pigments (carotenoids, mg/g FW, and chlorophyll a, b) in comparison to the control treatment over both seasons. For the three examined features in both seasons, 4 g/l humic acid was the most effective therapy.

In agreement with our results those obtained by **Mohamed (2020)** and **Hegazi *et al*. (2023)** on fennel; **El-Khateeb *et al*. (2017)** and **Hammam *et al*. (2019)** on marjoram; **El-Serafy (2018), Fahmy and Hassan (2019)** on roselle; **Mohammadi *et al*. (2018)** on cumin and **Omer *et al*. (2020)** on caraway.

The three utilized concentrations of amino acids significantly increased photosynthetic pigments (chlorophyll a, b, and carotenoids, mg/g FW) compared to untreated plants over both seasons, as shown by the findings in Table (4). In both seasons,

2.0 ml/l of amino acids produced the maximum contents.

Our results matched those stated by **El-Awadi and Hassan (2010)** and **Mohamed (2020)** on fennel, **Al-Fraihat *et al*. (2023)** on rosemary, **Deveikyte *et al*. (2024)** and **Deveikyte *et al*. (2025)** on basil, and **Yasini *et al*. (2024)** on lemon balm.

The interaction effect between humic and amino acids treatments was significant for chlorophyll a, b and carotenoids in both seasons. The highest contents were obtained from plants treated with 4.0 or 2.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l for chlorophyll a, 4.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l for chlorophyll b, and with 4.0 or 2.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l for carotenoids in the first season and while in the second season was obtained from 4.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l.

**3.5. Nitrogen, phosphorus and potassium in dry herb (%)**

Applying plants with the three humic acid concentrations (1, 2, and 4 g/l) significantly increased the amounts of nitrogen, phosphorus, and potassium (%) in dried fennel plants that were exposed to the control treatment during both seasons, according to the data in Table (5). For the three examined features in both seasons, 4 g/l humic acid was the most effective therapy.

In our results were agreed with those obtained by **Mohamed (2020)** and **Hegazi *et al*. (2023)** on fennel; **El-Khateeb *et al*. (2017)** and **Hammam *et al*. (2019)** on marjoram; **Dehsorkhi *et al*. (2018)** on cumin and **Omer *et al*. (2020)** on caraway.

According to the data in Table (5), applying plants with the three used amino acids levels resulted in considerably higher percentages of nitrogen, phosphorus, and potassium compared to untreated plants during both seasons. In both seasons, the maximum percentages were achieved with 2.0 ml/l of amino acids.

Our results are in agreement with those investigated by **Mohamed (2020)** on fennel, **Hassan *et al*. (2013) and Al-Fraihat *et al*. (2023)** on rosemary, and **El-Attar and Ashour (2016)** and **Hassan and Fahmy (2020)** on chamomile plants.

For the percentages of nitrogen, phosphorus, and potassium in both seasons, there was a substantial interaction impact between the main and sub-plot treatments. For nitrogen and phosphorus, plants treated with 4.0 or 2.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l yielded the highest percentages; for potassium, the highest percentages were obtained from 4.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l during the first season and during the second season using 4.0 or 2.0 g/l humic acid and sprayed with amino acids at 2.0 ml/l.

**Discussion**

Plant physiology was improved by humic compounds. Although there is contradictory evidence to support this notion, humic substances have been shown to contain auxin, and humic compounds have been proposed to have a "auxin-like" function **(Nardi *et al*., 2021 and Ampong *et al*., 2022)**. Furthermore, humic compounds actively alter the metabolism of plants. According to **Erro *et al*. (2016)** and **Tiwari *et al*. (2023)**, their effects seem to be primarily focused on enhancing photosynthetic pigments and encouraging nutrient intake.

Research has demonstrated that amino acids are essential components in the process of protein and oil synthesis **(Rai, 2002; Omer *et al*., 2013** and **El-Tarawy *et al*., 2017)** and can either directly or indirectly affect the physiological activities involved in plant growth and development

**(Yassen *et al*., 2010** and **Zatimeh and Al-Fraihat, 2025)**. They are crucial for the development of chlorophyll and vegetative tissue **(Amin *et al*., 2011** and **Souri and Hatamian, 2019)**. Additionally, they chelate micronutrients by facilitating the plant's uptake and transportation of them **(Singh, 1999 and Hendawy and Ezz El-Din, 2010)**.

As a previous discussion, treating fennel plants with both humic and amino acids, especially, 4 g/l humic acid with 1 or 2 ml/l amino acids, gave synergistic effect on vegetative growth, yield and its components, essential oil production and some chemical constituents **(Aly *et al*., 2022** on anise**)**.

**Table (1):** Response of **vegetative growth parameters** of fennel to humic, amino acids and their interactions during both seasons (2023/2024 and 2024/2025).

| Amino acids treatments (B) | Humic acid (g/l) treatments (A) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0 | 1.0 | 2.0 | 4.0 | Mean (B) | 0.0 | 1.0 | 2.0 | 4.0 | Mean (B) |
| | First season (2023/2024) | | | | | Second season (2024/2025) | | | | |
| **Plant height (cm)** | | | | | | | | | | |
| **Control** | 88.01 | 123.91 | 131.27 | 142.99 | 121.55 | 90.60 | 127.56 | 135.14 | 147.19 | 125.12 |
| **AA (0.5 ml/l)** | 92.85 | 130.73 | 138.49 | 150.85 | 128.23 | 96.04 | 135.21 | 143.25 | 156.02 | 132.63 |
| **AA (1.0 ml/l)** | 94.17 | 132.58 | 140.46 | 153.00 | 130.05 | 96.94 | 136.49 | 144.60 | 157.49 | 133.88 |
| **AA (2.0 ml/l)** | 95.55 | 134.32 | 142.27 | 154.93 | 131.77 | 98.35 | 138.26 | 146.45 | 159.47 | 135.63 |
| **Mean (A)** | 92.65 | 130.39 | 138.12 | 150.44 | | 95.48 | 134.38 | 142.36 | 155.04 | |
| **L.S.D. at 5 %** | **A: 7.71** | | **B: 1.70** | | **AB: 3.4** | **A: 7.77** | | **B: 1.73** | | **AB: 3.46** |
| **Number of main branches per plant** | | | | | | | | | | |
| **Control** | 2.46 | 3.46 | 3.66 | 3.99 | 3.39 | 2.51 | 3.53 | 3.74 | 4.08 | 3.47 |
| **AA (0.5 ml/l)** | 2.59 | 3.65 | 3.86 | 4.21 | 3.58 | 2.66 | 3.75 | 3.97 | 4.32 | 3.67 |
| **AA (1.0 ml/l)** | 2.63 | 3.70 | 3.92 | 4.27 | 3.63 | 2.69 | 3.78 | 4.01 | 4.36 | 3.71 |
| **AA (2.0 ml/l)** | 2.67 | 3.75 | 3.97 | 4.32 | 3.68 | 2.72 | 3.83 | 4.06 | 4.42 | 3.76 |
| **Mean (A)** | 2.58 | 3.64 | 3.85 | 4.20 | | 2.64 | 3.72 | 3.94 | 4.29 | |
| **L.S.D. at 5 %** | **A: 0.15** | | **B: 0.04** | | **AB: 0.08** | **A: 0.16** | | **B: 0.04** | | **AB: 0.08** |
| **Herb dry weight (g/plant)** | | | | | | | | | | |
| **Control** | 40.05 | 56.39 | 59.74 | 65.07 | 55.32 | 42.20 | 59.42 | 62.95 | 68.56 | **58.28** |
| **AA (0.5 ml/l)** | 42.26 | 59.50 | 63.03 | 68.65 | 58.36 | 44.74 | 62.98 | 66.73 | 72.67 | **61.78** |
| **AA (1.0 ml/l)** | 42.86 | 60.34 | 63.92 | 69.63 | 59.19 | 45.15 | 63.58 | 67.35 | 73.36 | **62.36** |
| **AA (2.0 ml/l)** | 43.48 | 61.13 | 64.75 | 70.51 | 59.97 | 45.81 | 64.40 | 68.22 | 74.28 | **63.18** |
| **Mean (A)** | 42.16 | 59.34 | 62.86 | 68.47 | | **44.48** | **62.59** | **66.31** | **72.22** | |
| **L.S.D. at 5 %** | **A: 3.57** | | **B: 0.77** | | **AB: 1.54** | **A: 3.71** | | **B: 0.80** | | **AB: 1.60** |

**Table (2):** Response of **yield and its components** of fennel to humic, amino acids and their interactions during both seasons (2023/2024 and 2024/2025).

| Amino acids treatments (B) | Humic acid (g/l) treatments (A) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0 | 1.0 | 2.0 | 4.0 | Mean (B) | 0.0 | 1.0 | 2.0 | 4.0 | Mean (B) |
| | First season (2023/2024) | | | | | Second season (2024/2025) | | | | |
| **Number of umbels per plant** | | | | | | | | | | |
| **Control** | 17.18 | 24.22 | 25.64 | 27.94 | **23.74** | 20.03 | 28.19 | 29.87 | 32.54 | **27.66** |
| **AA (0.5 ml/l)** | 18.14 | 25.53 | 27.06 | 29.47 | **25.05** | 21.22 | 29.90 | 31.66 | 34.48 | **29.32** |
| **AA (1.0 ml/l)** | 18.39 | 25.91 | 27.45 | 29.88 | **25.41** | 21.42 | 30.18 | 31.98 | 34.82 | **29.60** |
| **AA (2.0 ml/l)** | 18.66 | 26.24 | 27.80 | 30.26 | **25.74** | 21.73 | 30.55 | 32.37 | 35.25 | **29.98** |
| **Mean (A)** | **18.09** | **25.48** | **26.99** | **29.39** | | **21.10** | **29.71** | **31.47** | **34.27** | |
| **L.S.D. at 5 %** | **A: 1.50** | | **B: 0.31** | | **AB: 0.62** | **A: 1.74** | | **B: 0.27** | | **AB: 0.54** |
| **Weight of 1000 fruits (g)** | | | | | | | | | | |
| **Control** | 6.94 | 8.72 | 8.82 | 10.39 | **8.72** | 7.05 | 8.86 | 8.96 | 10.56 | **8.86** |
| **AA (0.5 ml/l)** | 7.21 | 8.75 | 10.44 | 10.56 | **9.24** | 7.33 | 8.89 | 10.61 | 10.73 | **9.39** |
| **AA (1.0 ml/l)** | 8.25 | 8.78 | 10.59 | 10.76 | **9.60** | 8.39 | 8.92 | 10.76 | 10.93 | **9.75** |
| **AA (2.0 ml/l)** | 8.53 | 10.35 | 10.93 | 11.00 | **10.20** | 8.67 | 10.52 | 11.10 | 11.18 | **10.37** |
| **Mean (A)** | 7.73 | 9.15 | 10.20 | 10.68 | | 7.86 | 9.30 | 10.36 | 10.85 | |
| **L.S.D. at 5 %** | **A: 0.47** | | **B: 0.12** | | **AB: 0.24** | **A: 0.48** | | **B: 0.13** | | **AB: 0.26** |
| **Fruit yield per plant (g)** | | | | | | | | | | |
| **Control** | 20.57 | 28.99 | 30.70 | 33.45 | **28.43** | 23.98 | 33.76 | 35.77 | 38.97 | **33.12** |
| **AA (0.5 ml/l)** | 21.72 | 30.56 | 32.40 | 35.29 | **29.99** | 25.41 | 35.80 | 37.91 | 41.29 | **35.10** |
| **AA (1.0 ml/l)** | 22.01 | 31.03 | 32.86 | 35.78 | **30.42** | 25.65 | 36.14 | 38.29 | 41.69 | **35.44** |
| **AA (2.0 ml/l)** | 22.34 | 31.42 | 33.29 | 36.23 | **30.82** | 26.02 | 36.58 | 38.77 | 42.20 | **35.89** |
| **Mean (A)** | **21.66** | **30.50** | **32.31** | **35.19** | | **25.27** | **35.57** | **37.68** | **41.04** | |
| **L.S.D. at 5 %** | **A: 1.78** | | **B: 0.40** | | **AB: 0.80** | **A: 2.01** | | **B: 0.33** | | **AB: 0.66** |
| **Fruit yield per feddan (kg)** | | | | | | | | | | |
| **Control** | 864.11 | 1217.66 | 1289.23 | 1404.90 | **1193.98** | 1007.24 | 1417.75 | 1502.17 | 1636.74 | **1390.98** |
| **AA (0.5 ml/l)** | 912.24 | 1283.69 | 1360.80 | 1482.01 | **1259.69** | 1067.22 | 1503.68 | 1592.39 | 1734.01 | **1474.33** |
| **AA (1.0 ml/l)** | 924.59 | 1303.09 | 1380.20 | 1502.68 | **1277.64** | 1077.30 | 1518.05 | 1608.01 | 1751.15 | **1488.63** |
| **AA (2.0 ml/l)** | 938.45 | 1319.47 | 1398.10 | 1521.83 | **1294.46** | 1092.92 | 1536.44 | 1628.17 | 1772.57 | **1507.53** |
| **Mean (A)** | **909.85** | **1280.98** | **1357.08** | **1477.85** | | **1061.17** | **1493.98** | **1582.69** | **1723.62** | |
| **L.S.D. at 5 %** | **A: 72.1** | | **B: 17.9** | | **AB: 35.8** | **A: 82.3** | | **B: 14.2** | | **AB: 28.4** |

**Table (3):** Response of **essential oil production** of fennel to humic, amino acids and their interactions during both seasons (2023/2024 and 2024/2025).

| Amino acids treatments (B) | Humic acid (g/l) treatments (A) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0.0** | **1.0** | **2.0** | **4.0** | **Mean (B)** | **0.0** | **1.0** | **2.0** | **4.0** | **Mean (B)** |
| | **First season (2023/2024)** | | | | | **Second season (2024/2025)** | | | | |
| **Essential oil (%) in fennel fruits** | | | | | | | | | | |
| **Control** | 1.44 | 1.99 | 2.22 | 2.43 | **2.02** | 1.50 | 2.08 | 2.32 | 2.54 | **2.11** |
| **AA (0.5 ml/l)** | 1.51 | 2.05 | 2.50 | 2.59 | **2.17** | 1.58 | 2.15 | 2.62 | 2.71 | **2.27** |
| **AA (1.0 ml/l)** | 1.58 | 2.15 | 2.67 | 2.74 | **2.29** | 1.65 | 2.25 | 2.79 | 2.86 | **2.39** |
| **AA (2.0 ml/l)** | 1.74 | 2.37 | 2.97 | 3.11 | **2.55** | 1.82 | 2.47 | 3.10 | 3.26 | **2.66** |
| **Mean (A)** | **1.57** | **2.14** | **2.59** | **2.72** | | **1.64** | **2.23** | **2.71** | **2.84** | |
| **L.S.D. at 5 %** | **A: 0.12** | | **B: 0.10** | | **AB: 0.20** | **A: 0.13** | | **B: 0.12** | | **AB: 0.24** |
| **Essential oil yield/plant (ml)** | | | | | | | | | | |
| **Control** | 0.30 | 0.58 | 0.68 | 0.81 | **0.59** | 0.36 | 0.70 | 0.83 | 0.99 | **0.72** |
| **AA (0.5 ml/l)** | 0.33 | 0.63 | 0.81 | 0.92 | **0.67** | 0.40 | 0.77 | 0.99 | 1.12 | **0.82** |
| **AA (1.0 ml/l)** | 0.35 | 0.67 | 0.88 | 0.98 | **0.72** | 0.42 | 0.81 | 1.07 | 1.19 | **0.87** |
| **AA (2.0 ml/l)** | 0.39 | 0.74 | 0.99 | 1.13 | **0.81** | 0.47 | 0.90 | 1.20 | 1.37 | **0.99** |
| **Mean (A)** | **0.34** | **0.65** | **0.84** | **0.96** | | **0.42** | **0.80** | **1.02** | **1.17** | |
| **L.S.D. at 5 %** | **A:0.11** | | **B: 0.04** | | **AB: 0.08** | **A: 0.14** | | **B: 0.05** | | **AB: 0.10** |
| **Essential oil yield/feddan (liter)** | | | | | | | | | | |
| **Control** | 12.40 | 24.23 | 28.59 | 34.08 | **24.83** | 15.16 | 29.48 | 34.80 | 41.64 | **30.27** |
| **AA (0.5 ml/l)** | 13.82 | 26.30 | 34.08 | 38.44 | **28.16** | 16.90 | 32.30 | 41.77 | 47.04 | **34.50** |
| **AA (1.0 ml/l)** | 14.64 | 28.00 | 36.89 | 41.21 | **30.19** | 17.81 | 34.11 | 44.90 | 50.10 | **36.73** |
| **AA (2.0 ml/l)** | 16.35 | 31.22 | 41.53 | 47.30 | **34.10** | 19.91 | 37.87 | 50.46 | 57.73 | **41.49** |
| **Mean (A)** | **14.30** | **27.44** | **35.27** | **40.26** | | **17.44** | **33.44** | **42.98** | **49.13** | |
| **L.S.D. at 5 %** | **A: 3.99** | | **B: 2.01** | | **AB: 4.02** | **A: 4.55** | | **B: 2.11** | | **AB: 4.22** |

**Table (4):** Response of **photosynthetic pigments content (mg/g FW)** of fennel fresh leaves to humic, amino acids and their interactions during both seasons (2023/2024 and 2024/2025).

| Amino acids treatments (B) | Humic acid (g/l) treatments (A) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0.0** | **1.0** | **2.0** | **4.0** | **Mean (B)** | **0.0** | **1.0** | **2.0** | **4.0** | **Mean (B)** |
| | **First season (2023/2024)** | | | | | **Second season (2024/2025)** | | | | |
| **Chlorophyll a content (mg/g FW)** | | | | | | | | | | |
| **Control** | 1.570 | 1.811 | 1.898 | 1.979 | **1.814** | 1.613 | 1.863 | 1.953 | 2.037 | **1.866** |
| **AA (0.5 ml/l)** | 1.613 | 1.814 | 1.982 | 2.017 | **1.856** | 1.663 | 1.866 | 2.040 | 2.075 | **1.911** |
| **AA (1.0 ml/l)** | 1.622 | 1.834 | 2.237 | 2.251 | **1.986** | 1.669 | 1.886 | 2.301 | 2.318 | **2.043** |
| **AA (2.0 ml/l)** | 1.674 | 1.944 | 2.272 | 2.343 | **2.058** | 1.721 | 1.999 | 2.338 | 2.411 | **2.117** |
| **Mean (A)** | **1.619** | **1.850** | **2.097** | **2.147** | | **1.666** | **1.903** | **2.158** | **2.210** | |
| **L.S.D. at 5 %** | **A: 0.050** | | **B: 0.040** | | **AB: 0.080** | **A: 0.052** | | **B: 0.042** | | **AB: 0.084** |
| **Chlorophyll b content (mg/g FW)** | | | | | | | | | | |
| **Control** | 0.521 | 0.602 | 0.631 | 0.658 | **0.603** | 0.536 | 0.619 | 0.649 | 0.677 | **0.620** |
| **AA (0.5 ml/l)** | 0.536 | 0.603 | 0.659 | 0.670 | **0.617** | 0.552 | 0.620 | 0.678 | 0.690 | **0.635** |
| **AA (1.0 ml/l)** | 0.539 | 0.609 | 0.744 | 0.748 | **0.660** | 0.554 | 0.627 | 0.765 | 0.771 | **0.679** |
| **AA (2.0 ml/l)** | 0.556 | 0.646 | 0.755 | 0.779 | **0.684** | 0.572 | 0.664 | 0.777 | 0.802 | **0.704** |
| **Mean (A)** | **0.538** | **0.615** | **0.697** | **0.714** | | **0.553** | **0.632** | **0.717** | **0.735** | |
| **L.S.D. at 5 %** | **A: 0.016** | | **B: 0.008** | | **AB: 0.016** | **A: 0.017** | | **B: 0.010** | | **AB: 0.020** |
| **Carotenoids content (mg/g FW)** | | | | | | | | | | |
| **Control** | 0.527 | 0.608 | 0.637 | 0.664 | **0.609** | 0.542 | 0.625 | 0.655 | 0.683 | **0.626** |
| **AA (0.5 ml/l)** | 0.542 | 0.609 | 0.665 | 0.676 | **0.623** | 0.558 | 0.626 | 0.684 | 0.696 | **0.641** |
| **AA (1.0 ml/l)** | 0.545 | 0.615 | 0.750 | 0.754 | **0.666** | 0.560 | 0.633 | 0.771 | 0.777 | **0.685** |
| **AA (2.0 ml/l)** | 0.562 | 0.652 | 0.761 | 0.785 | **0.690** | 0.578 | 0.670 | 0.783 | 0.808 | **0.710** |
| **Mean (A)** | **0.544** | **0.621** | **0.703** | **0.720** | | **0.559** | **0.638** | **0.723** | **0.741** | |
| **L.S.D. at 5 %** | **A: 0.016** | | **B: 0.090** | | **AB: 0.018** | **A: 0.017** | | **B: 0.012** | | **AB: 0.024** |

**Table (5):** Response of **NPK%** of fennel dry herb to humic, amino acids and their interactions during both seasons (2023/2024 and 2024/2025).

| Amino acids treatments (B) | Humic acid (g/l) treatments (A) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0 | 1.0 | 2.0 | 4.0 | Mean (B) | 0.0 | 1.0 | 2.0 | 4.0 | Mean (B) |
| | First season (2023/2024) | | | | | Second season (2024/2025) | | | | |
| **Nitrogen (%)** | | | | | | | | | | |
| **Control** | 2.22 | 2.71 | 2.87 | 3.06 | **2.71** | 2.41 | 2.89 | 3.02 | 3.25 | **2.89** |
| **AA (0.5 ml/l)** | 2.28 | 2.76 | 3.13 | 3.20 | **2.84** | 2.50 | 2.95 | 3.31 | 3.37 | **3.03** |
| **AA (1.0 ml/l)** | 2.36 | 2.82 | 3.26 | 3.32 | **2.94** | 2.57 | 3.00 | 3.43 | 3.48 | **3.12** |
| **AA (2.0 ml/l)** | 2.51 | 2.99 | 3.52 | 3.66 | **3.17** | 2.69 | 3.23 | 3.65 | 3.78 | **3.34** |
| **Mean (A)** | **2.34** | **2.82** | **3.20** | **3.31** | | **2.54** | **3.02** | **3.35** | **3.47** | |
| **L.S.D. at 5 %** | **A: 0.10** | | **B: 0.07** | | **AB: 0.14** | **A: 0.11** | | **B: 0.08** | | **AB: 0.16** |
| **Phosphorus (%)** | | | | | | | | | | |
| **Control** | 0.217 | 0.277 | 0.302 | 0.328 | **0.281** | 0.242 | 0.308 | 0.336 | 0.362 | **0.312** |
| **AA (0.5 ml/l)** | 0.226 | 0.285 | 0.339 | 0.349 | **0.300** | 0.258 | 0.316 | 0.365 | 0.378 | **0.329** |
| **AA (1.0 ml/l)** | 0.235 | 0.293 | 0.358 | 0.367 | **0.313** | 0.269 | 0.325 | 0.389 | 0.396 | **0.345** |
| **AA (2.0 ml/l)** | 0.251 | 0.321 | 0.394 | 0.411 | **0.344** | 0.285 | 0.353 | 0.424 | 0.441 | **0.376** |
| **Mean (A)** | **0.232** | **0.294** | **0.348** | **0.364** | | **0.263** | **0.326** | **0.379** | **0.394** | |
| **L.S.D. at 5 %** | **A: 0.014** | | **B: 0.010** | | **AB: 0.020** | **A: 0.016** | | **B: 0.011** | | **AB: 0.022** |
| **Potassium (%)** | | | | | | | | | | |
| **Control** | 1.99 | 2.33 | 2.51 | 2.62 | **2.36** | 2.09 | 2.42 | 2.56 | 2.74 | **2.45** |
| **AA (0.5 ml/l)** | 2.04 | 2.39 | 2.67 | 2.71 | **2.45** | 2.13 | 2.47 | 2.76 | 2.80 | **2.54** |
| **AA (1.0 ml/l)** | 2.11 | 2.45 | 2.76 | 2.82 | **2.53** | 2.18 | 2.51 | 2.87 | 2.90 | **2.61** |
| **AA (2.0 ml/l)** | 2.20 | 2.57 | 2.93 | 3.04 | **2.68** | 2.27 | 2.69 | 3.03 | 3.13 | **2.78** |
| **Mean (A)** | **2.08** | **2.43** | **2.72** | **2.80** | | **2.17** | **2.52** | **2.80** | **2.89** | |
| **L.S.D. at 5 %** | **A: 0.08** | | **B: 0.05** | | **AB: 0.10** | **A: 0.09** | | **B: 0.06** | | **AB: 0.12** |

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**المخلص العربي**

**إنتاجية الشمر المزروع في الأراضي المستصلحة حديثًا متأثراً بمعاملات حمض الهيوميك والأحماض الأمينية**

**محمود عبدالهادي حسن عبده ، زين أحمد زين العابدين عبدالكريم**
قسم البساتين – كلية الزراعة – جامعة المنيا – مصر.

تم إجراء هذا البحث في موسمي 2024/2023 و 2025/2024 في مزرعة خاصة بقرية بلنصورة، مركز أبو قرقاص، محافظة المنيا، مصر، لاختبار استجابة نبات الشمر النامي في أرض مستصلحة حديثاً لحمض الهيوميك (0.0، 1.0، 2.0 و 4.0 جم / لتر)، والأحماض الأمينية (0.0، 0.5، 1.0 و 2.0 مل / لتر) ومعاملات التفاعل بينهما.

أشارت النتائج إلى أن جميع صفات النمو الخضري المدروسة (ارتفاع النبات، عدد الأفرع الرئيسية للنبات، والوزن الجاف للنبات)، والمحصول ومكوناته (عدد النورات للنبات، وزن الألف ثمرة، ومحصول الثمار للنبات والفدان)، وإنتاجية الزيت الطيار (نسبة الزيت الطيار ومحصوله للنبات والفدان)، وبعض المكونات الكيميائية (محتوى الكلوروفيل أ، ب والكاروتينويدات ونسبة NPK%) قد ازدادت بشكل ملحوظ مع استخدام جميع تركيزات حمض الهيوميك و/أو الأحماض الأمينية مقارنة بمعاملات الكنترول في كلا الموسمين. وقد تم الحصول علي أعلى القيم لكل الصفات المدروسة من معاملة حمض الهيوميك بتركيز 4.0 جم/لتر والأحماض الأمينية بتركيز 2.0 مل/لتر، وهي أفضل معاملة تداخل.

**الكلمات المفتاحية**: الشمر – حمض الهيوميك – الأحماض الأمينية – النمو – المحصول – الزيت العطري – الصبغات – NPK%.