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**Anbar Journal of Agricultural Sciences**
(University of Anbar – College of Agriculture)

# Effect of Humic Acid and Magnesium on The Qualitative and Quantitative Characteristics and Yield of Okra

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**Article info**

**Received:** 2024-08-01
**Accepted:** 2025-02-26
**Published:** 2025-12-31

**DOI-Crossref:**
10.32649/ajas.2025.189415

**Cite as:**
Jassim, A. N., and Hanshal, M. A. (2025). Effect of Humic Acid and Magnesium on The Qualitative and Quantitative Characteristics and Yield of Okra. Anbar Journal of Agricultural Sciences, 23(2): 1088-1099.



**Abstract**

The objective of this experiment was to increase the productivity per unit area and improve the qualitative characteristics of okra plants. It was conducted at the College of Agricultural Engineering Sciences, University of Baghdad in summer 2023. Four concentrations each of humic acid at 0, 1, 2, 3 g $L^{-1}$ and magnesium sulfate at 0, 0.5, 1.5, 2.5 g $L^{-1}$ were used to study their role and interaction in improving the plants' qualitative and quantitative characteristics. The experiment used a randomized complete block design (RCBD) with three replicates with each including 16 experimental units. The results were analyzed using the Gen stat statistical program and compared with the least significant difference (LSD) test at a 0.05 probability level. The interaction treatment between humic acid and magnesium (H3M3) showed significant superiority, as the dry weight of the okra plant totaled 446.0 g $plant^{-1}$. The percentage of potassium in the okra pods and leaves was 1.55% and 1.95%, respectively while protein content was 14.25%. The highest amount of carbohydrates was 20.36%, the lowest amount of fiber in the pods was 6.02% while oil levels were 2.67%. H3M3 also gave the highest percentage of total soluble solids, reaching 7.87%, while H3M2 showed superiority in pod weight at 4.68 gm. $pod^{-}$. Early yield was reached at 767.0 kg. $ha^{-1}$.

**Keywords:** Effect, Humic acid, Magnesium, Interaction, Okra.

# تأثير حامض الهيوميك والمغنيسيوم في الصفات النوعية والكمية وحاصل الباامية

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**الخلاصة**

لغرض زيادة الانتاجية في وحدة المساحة وتحسين الصفات النوعية لنبات الباميا، اجريت هذه التجربة في جامعة بغداد كلية علوم الهندسة الزراعية للموسم الصيفي 2023, استخدمت فيها اربعة تراكيز من حامض الهيومك 0، 1، 2، 3 غم. لتر$^{-1}$ واربعة تراكيز من كبريتات المغنيسيوم 0، 0.5، 1.5، 2.5 غم.لتر$^{-1}$ لدراسة دور كل منهما وتداخلهما في تحسين الصفات النوعية والكمية. أجريت التجربة وفق تصميم القطاعات الكاملة المعشاة (RCBD) وبثلاث مكررات، كل مكرر تضمن 16 وحدة تجريبية، وتم تحليل النتائج وفق برنامج الإحصاء Gen stat ومقارنتها باختبار فرق معنوي (LSD) بمستوى احتمالية 0.05، اظهرت النتائج زيادة معنوية, حيث أعطت أعلى قيمة لمعاملة التداخل بين كبريتات المغنيسيوم وحمض الهيوميك H3M3 حيث بلغ الوزن الجاف للمجموع الخضري 446 غم.نبات$^{-1}$ والنسبة المئوية للبوتاسيوم في القرنات 1.55%، ونسبة البوتاسيوم في الاوراق بلغت 1.95%، والنسبة المئوية للبروتين 14.25%، واعلى نسبة مئوية للكاربوهيدرات بلغت 20.36%، واعطت اقل نسبة الالياف في القرنات بلغت 6.02%، واعلى نسبة الزيت في القرنات بلغت 2.67%، وأعلى نسبة مئوية للمواد الصلبة الذائبة بلغت 7.87%، في حين تفوقت معاملة H3M2 بأعلى معدل وزن القرنة بلغ 4,68 غم. قرنة$^{-1}$ واعلى حاصل مبكر بلغ 767.0 كغم.ه$^{-1}$.

**كلمات مفتاحية:** تأثير، حامض الهيومك، المغنيسيوم، التداخل، الباميا.

## Introduction

Okra (*Abelmoschus esculentus* (L) Moench) is a member of the Malvaceae family and is grown in most tropical and subtropical regions of the world. It is one of the summer vegetable crops preferred by consumers. Okra is grown to obtain immature green pods that are 2-3 days old and are consumed after cooking, freezing, drying, or canning for winter consumption. It provides a source of livelihood for many rural farmers, whether as food or cash. Farmers prefer to grow okra due to its high demand and good returns (18). To produce healthy food, farmers are gradually moving away from chemical fertilizers that are harmful to human health and resorting to organic fertilizers, which are capable of supplying plants with nutrients of natural origin. These fertilizers contribute to the release of organic acids when they decompose, such as humic acids, phosphoric acids, and help to modify or reduce the pH of the soil. To increase production, and secure satisfactory economic returns for the farmer, it is crucial to provide the necessary nutrients for achieving high yields and better product quality (12).

The okra contains compounds such as quercetin, polyphenols, unsaturated fatty acids, essential amino acids, antioxidants, antimicrobial agents, and anti-nutrient compounds (11). Therefore, okra is sometimes used to treat cardiovascular diseases (17).

Shortfalls in crop production from this need to be compensated through research in the area of foliar nutrition with macro-and microelements, including humic acid and magnesium, these two essential elements are crucial for promoting the growth of okra plants (10). Humic acid enhances soil nutrient uptake efficiency, promotes root growth, and improves plant cellular respiration. Magnesium is found in the leaves more than any other plant part (7). It is one of the nine important nutrients in the plant's physiological and biochemical processes (4).

The intensive cultivation of vegetables has led to the high absorption of nutrients in the soil, which leads to using large quantities of chemical fertilizers in order to achieve the highest yield. Its deficiency may cause a physiological imbalance as a result of nutritional imbalance that may occur due to soil conditions, type, and fertilization methods. Therefore, soil type and the amount of nutrients it contains are determining factors for the growth and production of plants (1).

This experiment had the following objectives:

1. To study the role of humic acid in improving the growth, quantity, and quality of okra yield.
2. To study the role of magnesium in improving the growth, quantity, and quality of okra yield.
3. To study the role of humic acid and magnesium, and their interaction, in improving the growth and quantity of okra plants.

## Materials and Methods

The experiment was conducted in summer 2023 at Research Station B of the Department of Horticulture, College of Agricultural Engineering Sciences, University of Baghdad to study the effect of spraying magnesium and adding humic acid on the growth and yield of okra. The soil was analysed to determine its chemical and physical properties before preparing the field for planting, The experiment included two factors. The first involved adding humic acid four times at concentrations at 0, 1, 2, 3 g $L^{-1}$ (denoted by H0, H1, H2, H3, respectively), the first after 20 days of germination followed 15-day intervals for the rest. Humic acid (H) produced by Silk Land was also used in the addition treatments, with each concentration placed separately in a 20-liter water tank and added to the experimental unit as recommended. The second factor involved spraying magnesium sulphate at four concentrations of 0, 0.5, 1.5, 2.5 g $L^{-1}$ (M0, M1, M2, M3, respectively). The number of treatments was 16. The magnesium sulphate was sprayed four times for each plant until completely wet. The first spraying was 25 days after germination, and repeated every 15 days. The magnesium sulphate was by S.B.A Green Has Italia, and spraying was carried out in the early morning and evening until completely wet using a 12-liter hand sprayer. The plants in the control treatment were sprayed with distilled water only.

Measured characteristics:

1. Dry weight of the foliage of okra plants: measured by drying in an oven at 70 $^{0}C$.
2. Potassium percentage in okra pods: measured by a flam photometer.
3. Potassium percentage in okra leaves: measured by a flam photometer.
4. Weight of okra pods: measured by dividing total yield by the total number of pods.
5. Early yield (ton. $ha^{-1}$): measured by adding the first three fairies and averaging them.
6. Protein content of okra pods: measured by a Kjeldahl device using the equation: protein% = n% x 6.25
7. Percentage of carbohydrates in okra pods: measured by Joslyn using the equation: concentration x dilution/sample weight x 1ml x 1000
8. Percentage of fiber in okra pods: measured by the equation: weight after drying – weight after burning/sample weight x 100
9. Percentage of oil in okra pods: measured by Soxhlet using equation: oil weight/sample weight x 100
10. Percentage of TSS: measured by a hand refractometer.

**Table 1: Some chemical and physical properties of the soil in the experimental field.**

| Measured traits | | Values | Unit of measurement |
|---|---|---|---|
| **$EC_{1:1}$** | | 2.2 | $ds.m^{-1}$ |
| **$PH_{1:1}$** | | 7.2 | ---------- |
| **Soluble ions** | Ca | 11 | mmole. liter^-1 |
| | K | 2 | mmole. liter^-1 |
| | Mg | 5 | mmole. liter^-1 |
| | Na | 6 | mmole. liter^-1 |
| | Cl | 11 | mmole. liter^-1 |
| | $HCO_3$ | 2.5 | mmole. liter^-1 |
| | $SO_4$ | 6.5 | mmole. liter^-1 |
| | $CO_3$ | Nill | mmole. liter^-1 |
| **OM** | | 0. 9 | g. kg^-1 |
| **$CaCO_3$** | | 314 | g . kg^-1 |
| **Available in soil** | Nitrogen | 24 | Mg. kg of soil^-1 |
| | Phosphorus | 3.33 | Mg. kg of soil^-1 |
| | Potassium | 121 | Mg. kg of soil^-1 |
| | Magnesium | 12 | Mg. kg of soil^-1 |
| **Clay** | | 340 | Mg. kg of soil^-1 |
| **Silt** | | 480 | Mg. kg of soil^-1 |
| **Sand** | | 180 | Mg. kg of soil^-1 |
| **Soil texture** | | Sandy loam | -- |

## Results and Discussion

Dry weight of okra plants (gm. plant$^{-1}$): Table 2 shows that the M3 spray treatment excelled in giving the highest average weight of okra plants, which reached 373.3 gm. plant$^{-1}$, compared to the lowest for the M0 treatment of 338.8 gm. plant$^{-1}$. The H3 treatment also showed the highest average weight, reaching 426.3 gm. plant$^{-1}$, compared to the H0 measurement at 300.5 gm. plant$^{-1}$. The interaction treatment of spraying and additions led to a significant increase in the average weight of the okra with H3M3 yielding the highest average at 446 gm. plant$^{-1}$, while the lowest was for the H0M0 treatment at 291.0 gm. plant$^{-1}$.

**Table 2: The effect of humic acid and magnesium sulfate and their interaction on the dry weight of the foliage of the okra plants.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g L$^{-1}$ | H1(1) g L$^{-1}$ | H2(2) g L$^{-1}$ | H3 (3) g L$^{-1}$ | |
| M0 (0) g L$^{-1}$ | 291.0 | 309.0 | 348.0 | 407.0 | **338.8** |
| M1(0.5) g L$^{-1}$ | 297.0 | 319.0 | 369.0 | 420.0 | **351.3** |
| M2(1.5) g L$^{-1}$ | 302.0 | 327.0 | 381.0 | 432.0 | **360.5** |
| M3(2.5) g L$^{-1}$ l | 312.0 | 341.0 | 394.0 | 446.0 | **373.3** |
| H Range | 300.5 | 324.0 | 373.0 | 426.3 | |
| **LSD: H=5.78*, M=5.78*, Interaction: HxM: 9.706*** | | | | | |

Percentage of potassium in okra plant pods (%): Table 3 shows the significant effect of the treatment of spraying magnesium sulfate and adding humic acid on increasing potassium values in the plant. The M3 spraying treatment gave the highest average percentage, reaching 1.398%, compared to M0, which resulted in 1.35% in the pods. The H3 treatment excelled with the highest percentage of 1.50% compared to the H0 measurement treatment's lowest percentage rate of 1.21%. The interaction treatment H3M3 yielded the highest percentage of potassium at 1.55%, compared to the H0M0's lowest at 1.17% per pod.

**Table 3: Effect of humic acid and magnesium sulfate and their interaction on potassium percentage in the okra pods.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g L$^{-1}$ | H1(1) g L$^{-1}$ | H2(2) g L$^{-1}$ | H3(3) g L$^{-1}$ | |
| M0(0) g L$^{-1}$ | 1.17 | 1. 31 | 1. 36 | 1.46 | **1.33** |
| M1(0.5) g L$^{-1}$ | 1.21 | 1. 32 | 1. 37 | 1. 49 | **1.35** |
| M2(1.5) g L$^{-1}$ | 1.22 | 1.33 | 1.42 | 1. 52 | **1.37** |
| M3(2.5) g L$^{-1}$ | 1. 24 | 1. 35 | 1. 45 | 1. 55 | **1.40** |
| H Range | 1.21 | 1.32 | 1. 40 | 1. 51 | |
| **LSD: H=0.985*, M=0.985*. Interaction: HxM: 1.759*** | | | | | |

Percentage of potassium in okra plant leaves (%): As seen in Table 4, a significant positive effect of magnesium sulfate spraying and adding humic acid was recorded on the percentage of potassium found in the okra plant leaves. The M3 spraying treatment gave the highest average percentage of leaves, at 1.77%, compared to the control M0, of 1.67%. The H3 treatment excelled with the highest rate of 1.89% compared to the measurement treatment H0, which gave the lowest at 1.56%. The H3M3 interaction treatment gave the highest percentage of potassium in the leaves at 1.95%, compared to the H0M0 treatment's lowest rate of 1.53%.

**Table 4: Effect of humic acid and magnesium sulfate and their interaction on potassium percentage in the okra leaves.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g $L^{-1}$ | H1(1) g $L^{-1}$ | H2(2) g $L^{-1}$ | H3(3) g $L^{-1}$ | |
| M0(0) g $L^{-1}$ | 1.53 | 1.64 | 1.73 | 1.78 | **1.67** |
| M1(0.5) g $L^{-1}$ | 1.54 | 1.71 | 1.78 | 1.88 | **1.71** |
| M2(1.5) g $L^{-1}$ | 1.58 | 1.68 | 1.75 | 1.94 | **1.74** |
| M3(2.5) g $L^{-1}$ | 1.62 | 1.65 | 1.72 | 1.95 | **1.77** |
| H Range | 1.56 | 1.67 | 1.75 | 1.89 | **---** |
| **LSD: M=0.10, MxH=0.32, H=0.10** | | | | | |

Weight of okra pods (gm.$pod^{-1}$): The results in Table 5 illustrate the significant effect of magnesium sulfate spraying and adding humic acid in increasing the weight of the okra pods, with the M3 treatment having the highest average increase at 4.54gm, compared to the control M0, which resulted in 4.14gm. The H2 addition treatment excelled with the highest rate of 4.51gm compared to the H0 control's lowest rate of 4.24gm. The H2M3 intervention treatment gave the highest weight (4.68gm), compared to the H0M0's lowest (4.01% gm.)

**Table 5: Effect of humic acid and magnesium sulfate and their interaction on the weight of the okra pods.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g $L^{-1}$ | H1(1) g $L^{-1}$ | H2(2) g $L^{-1}$ | H3(3) g $L^{-1}$ | |
| M0(0) g $L^{-1}$ | 4.01 | 4. 06 | 4.3 7 | 4.1 1 | **4.140** |
| M1(0.5) g $L^{-1}$ | 4.22 | 4.27 | 4.5 8 | 4.4 6 | **4.383** |
| M2(1.5) g $L^{-1}$ | 4.53 | 4.4 5 | 4.4 1 | 4.39 | **4.445** |
| M3(2.5) g $L^{-1}$ | 4.2 0 | 4.6 0 | 4.6 8 | 4.4 8 | **4.540** |
| H Range | 4.240 | 4.345 | 4.510 | 4.360 | **---** |
| **LSD: M=0.219, HxM= 0.466, M: 0.219** | | | | | |

Early yield (kg. $ha^{-1}$): Table 6 shows that the M3 treatment was superior, giving the highest average early production of 726.5 kg. $ha^{-1}$, compared to the M0 or control, which gave the lowest rate of 691.5 kg. $ha^{-1}$. The H3 addition treatment had a significant effect, giving the highest average of 744.5 kg. $ha^{-1}$, compared to the H0 measurement treatment's lowest average of 654.75 kg. $ha^{-1}$. The H3M2 intervention treatment outperformed the others by giving the highest early production rate of 767 kg. $ha^{-1}$ compared to the H0M1 treatment, which gave the lowest productivity of 636 kg. $ha^{-1}$.

**Table 6: Effect of humic acid and magnesium sulfate and their interaction on the early yield of the okra plants.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g $L^{-1}$ | H1(1) g $L^{-1}$ | H2(2) g $L^{-1}$ | H3(3) g $L^{-1}$ | |
| M0(0) g $L^{-1}$ | 652.0 | 668.0 | 725.0 | 721.0 | **681.5** |
| M1(0.5) g $L^{-1}$ | 636.0 | 712.0 | 785.0 | 738.0 | **717.7** |
| M2(1.5) g $L^{-1}$ | 643.0 | 727.0 | 713.0 | 767.0 | **712.5** |
| M3(2.5) g $L^{-1}$ | 68 8.0 | 70 3.0 | 763.0. | 752.0 | **726.5** |
| H Range | 654.75 | 702.5 | 746.5 | 744.5.0 | |
| **LSD: H=12.580, M=2.58, Interaction HxM= 25.17*** | | | | | |

Percentage of protein in the okra pods (%): Table 7 shows the significant effect of magnesium sulfate spray treatments and humic acid addition in increasing the percentage of protein in leaves and pods. The M3 treatment provided the highest percentage, reaching 13.387% of the pods, compared to the standard M0 treatment, which resulted in 12.106%. The addition treatment H3 also produced the highest protein percentage, amounting to 13.625%, compared to the standard treatment H0, which gave the lowest at 11.625% in the pods. For the intervention treatments, H3M3 produced the highest percentage of protein, amounting to 14.25%, compared to the lowest for the H0M0 treatment at 11.25%.

**Table 7: Effect of humic acid and magnesium sulfate and their interaction on the protein content of the okra pods.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g $L^{-1}$ | H1(1) g $L^{-1}$ | H2(2) g $L^{-1}$ | H3(3) g $L^{-1}$ | |
| M0(0) g $L^{-1}$ | 11.25 | 11. 5 | 12. 81 | 12.87 | **12.10** |
| M1(0.5) g $L^{-1}$ | 11.62 | 12. 18 | 13 | 13. 50 | **12.57** |
| M2(1.5) g $L^{-1}$ | 11.75 | 13.12 | 13.68 | 14. 00 | **13.13** |
| M3(2.5) g $L^{-1}$ | 11. 81 | 13.4 3 | 14.06 | 14. 25 | **13.38** |
| H Range | 11.62 | 12.56 | 13.37 | 13.62 | |
| **LSD: H= 0.0017*, M= 0.0017*, *Interaction HxM=0.024*** | | | | | |

Carbohydrate content in the okra pods (%): Table 8 shows the significant increase in pod carbohydrate content from the magnesium sulfate spraying and humic acid addition treatments. The M3 spraying treatment yielded the highest average carbohydrate value of 19.05% compared to the M0 control treatment which had the lowest average percentage at 17.67%. The H3 addition treatment also produced the highest average of 19.65% compared to the H0 treatment which gave the lowest average of 17.47%. The H3M2 intervention treatment gave the highest rate of 20.36% compared to the H0M0 treatment's lowest at 16.93%.

**Table 8: Effect of humic acid and magnesium sulfate and their interaction on the percentage of carbohydrates in the okra plant pods.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g $L^{-1}$ | H1(1) g $L^{-1}$ | H2(2) g $L^{-1}$ | H3(3) g $L^{-1}$ | |
| M0(0) g $L^{-1}$ | 16.93 | 17.18 | 18.52 | 18.43 | **17.67** |
| M1(0.5) g $L^{-1}$ | 17.06 | 17.26 | 18.53 | 19.67 | **18.18** |
| M2(1.5) g $L^{-1}$ | 17.33 | 18.27 | 18.90 | 20.36 | **18.72** |
| M3(2.5) g $L^{-1}$ | 18.56 | 18.39 | 19.13 | 20.12 | **19.05** |
| H Range | 17.47 | 17.78 | 18.77 | 19.65 | |
| **LSD: H=0.144, M=0.144, Interaction HxM=0.384*** | | | | | |

Content of fiber in the okra pods (%): Table 9 illustrates the significant impact on fiber in the okra pods from the magnesium sulfate spraying and addition of humic acid, with the M3 treatment recording the lowest average percentage of 6.60%, compared to the control's highest at 7.00%. The H3 addition treatment excelled with the lowest rate of 6.34% compared to the H0 treatment's highest rate of 7.21%. The intervention treatment H3M3 gave the lowest percentage of fiber, at 6.02%, compared to the H0M0 measurement treatment which gave the highest (7.49%).

**Table 9: Effect of humic acid and magnesium sulfate and their interaction on the fiber percentage in the okra pods.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g $L^{-1}$ | H1(1) g $L^{-1}$ | H2(2) g $L^{-1}$ | H3(3) g $L^{-1}$ | |
| M0(0) g $L^{-1}$ | 7.4 9 | 7.08 | 6.79 | 6.6 5 | **7.00** |
| M1(0.5) g $L^{-1}$ | 7.2 5 | 7.01 | 6.7 7 | 6.4 4 | **6.87** |
| M2(1.5) g $L^{-1}$ | 7.08 | 6.94 | 6.6 3 | 6.23 | **6.75** |
| M3 (2.5) g $L^{-1}$ | 7.00 | 6.88 | 6.5 0 | 6.02 | **6.60** |
| H Range | 7.21 | 6.98 | 6.67 | 6.34 | **---** |
| **LSD: H=0.0095*, M=0.0095*, Interaction HxM=0.014*** | | | | | |

Oil content in the okra pods (%): Table 10 shows the significant effect of the treatment of spraying magnesium sulfate and adding humic acid on the oil content of the okra pods. The M3 treatment gave the highest average value at 2.53%, compared to the M0 control which had 2.26% oil content. The addition treatment H3 excelled with the highest rate of 2.60% compared to the measurement treatment H0, which had the lowest at 2.13%. Both the H3M3 and H3M2 intervention treatments gave the highest oil content of 2.67% oil, compared to the measurement treatment H0M0, which gave the lowest at 1.92%.

**Table 10: Effect of humic acid and magnesium sulfate and their interaction on the content of oil in the okra pods.**

| M | H | | | | Range M |
|---|---|---|---|---|---|
| | H0(0) g $L^{-1}$ | H1(1) g $L^{-1}$ | H2(2) g $L^{-1}$ | H3(3) g $L^{-1}$ | |
| M0(0) g $L^{-1}$ | 1.92 | 2.25 | 2.39 | 2.46 | **2.26** |
| M1(0.5) g $L^{-1}$ | 2.08 | 2.34 | 2.46 | 2.59 | **2.37** |
| M2(1.5) g $L^{-1}$ | 2.23 | 2.41 | 2.54 | 2.67 | **2.46** |
| M3(2.5) g $L^{-1}$ | 2.29 | 2.52 | 2.63 | 2.67 | **2.53** |
| H Range | 2.13 | 2.38 | 2.50 | 2.60 | **---** |
| **LSD: H=0.218*, Interaction HxM=0.397*, M=0.218*** | | | | | |

Level of total soluble solids in the okra pods (%): Table 11 shows that the M3 spraying treatment gave the highest average level of dissolved solids, reaching 6.49%, compared to the M0 measurement treatment of 5.98%. This was repeated for the H3 addition treatment which amounted to 7.26%, compared to H0 which gave the lowest average at 5.42%. Meanwhile, the H3M3 interference treatment was significantly superior for this trait at 7.78%, compared to H0M0 which registered 23.5%.

**Table 11: The effect of humic acid and magnesium sulfate and their interaction on the percentage of total soluble solids in the okra pods.**

| M | H | | | | M Range |
|---|---|---|---|---|---|
| | H0(0) g $L^{-1}$ | H1(1) g $L^{-1}$ | H2(2) g $L^{-1}$ | H3(3) g $L^{-1}$ | |
| M0(0) g $L^{-1}$ | 5.23 | 5.69 | 5.79 | 6.89 | **5.98** |
| M1(0.5) g $L^{-1}$ | 5.32 | 5. 78 | 6.03 | 7.07 | **6.01** |
| M2(1.5) g $L^{-1}$ | 5.48 | 5.89 | 6.36 | 7.28 | **6.26** |
| M3(2.5) g $L^{-1}$ | 5.66 | 5. 97 | 6.53 | 7.781 | **6.49** |
| H Range | 5.42 | 5. 83 | 6.18 | 7.26 | |
| **LSD: H= 0.224*, M=0.224*, Interaction HxM: 0.498*** | | | | | |

Humic acid enhances the soil's ability to retain moisture, reduces its bulk density, improves its aeration, and increases microorganism activity in it, which increases the availability of nutrients and their absorption by plants. This leads to an increase in most of the vegetative growth index (1). This ultimately leads to the accumulation of proteins, carbohydrates, oil, dissolved solids, and vitamins in the leaves and, subsequently, their transfer to the pods. The growth increase raises photosynthesis rates which help in manufacturing large amounts of food within the plant, including carbohydrates (3).

The higher percentage of dissolved solids may be due to the larger leaf areas producing more nutrients and then transferring them to the pods. Or it could be due to the evaporation of a large portion of the water from the fruits as the measurements were made away from the field to where the fruits were transported.

The increase in the qualitative characteristics can be attributed to magnesium's central role in photosynthesis and its participation in regulating osmotic potential and transporting carbohydrates manufactured in the leaves. It contributes to and helps form many organic compounds such as oils, proteins, and carbohydrates. Sulfur has a key role in most of the vital activities of plants, including the formation of proteins, due to its inclusion in synthesizing some organic amino acids such as cysteine, cysteine, and methionine (8 and 9).

It is clear from the results in Tables 2-5 that a clear significant response occurred in most of the vegetative growth and yield characteristics of okra plants due to changes in the levels (concentrations) of humic acid and magnesium sulfate used in the study. This may be due to the contribution of these compounds to all the physiological processes necessary for growth (5).

The rapid decomposition of organic materials produces a group of elements ready for absorption by the plant, including potassium (TabIe 3), which reflects positively on increased vegetative growth and yield (6). When sprayed with magnesium, the increase in the plants' vegetative and fruit growth characteristics can be attributed to this primary factor. It is an important element for a large number of vital activities that occur inside the plant cell, and it is included in its formation, which leads to plants absorbing phosphorus in larger quantities, thus improving root growth, and increasing their efficiency in absorbing and accumulating nutrients, thus promoting vegetative growth and yield (9 and 16). The weight of the fruit (Table 5) is among the important characteristics as it represents one of the main components of yield. The weight of the fruit depends on the high ability of the plant in the process of photosynthesis and on the transfer of manufactured nutrients from the source to the sink (13).

Spraying with magnesium sulfate contributed to significant differences in vegetative growth indicators, number of leaves, leaf area, leaf chlorophyll content, and an increase in the total dry matter of the plant (Tables 2 - 5). Higher leaf areas and amounts of chlorophyll in the leaves play an important role in increasing the weight of the pods (early yield). Photosynthesis manufactures nutrients and transports them to the pods, and more carbohydrates and proteins were produced by increasing the photosynthesis process (Table 4) (2).

Spraying magnesium on potatoes gave significant differences in the percentage of carbohydrates (Table 6). Increasing growth raises the rate of photosynthesis, which then manufactures a large amount of food within the plant, including carbohydrates. Some carbohydrates were converted into TSS (Table 7) (14). Spraying magnesium and adding humic acid also led to a significant increase in the absorption of nutrients and a 11% increase in TSS in the okra fruits (15).

## Conclusions

Adding humic acid and spraying magnesium sulfate had a positive effect on improving growth and yield characteristics of the okra plants. The results showed that adding humic acid had a greater effect on growth characteristics and yield compared to spraying magnesium sulfate. The interaction coefficients between humic acid and magnesium sulfate significantly increased production, while the fiber content in pods decreased with increasing concentrations of added humic acid, and harvesting was earlier.

1. Adding humic acid at a concentration of 3 g/l significantly affected most of the vegetative growth traits, plant yield, and quality traits.
2. Spraying with magnesium sulfate at a 2.5 grams/liter concentration significantly affected most vegetative growth traits, plant yield, and quality traits.
3. The reaction coefficients between humic acid and magnesium sulfate were significantly higher in increasing production.
4. The percentage of dissolved solids and carbohydrates increases together with the concentration of fertilizer applied.

**Supplementary Materials:**

No Supplementary Materials.

**Author Contributions:**

Author 1; methodology, writing—original draft preparation, Author 2 writing—review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding:**

This research received no external funding.

**Institutional Review Board Statement:**

The study was conducted following the protocol authorized by the Head of the Ethics Committee, University of Baghdad, Iraq Republic.

**Informed Consent Statement:**

Not applicable.

**Data Availability Statement:**

Data available upon request.

**Conflicts of Interest:**

The authors declare no conflict of interest.

**Acknowledgments:**

The authors are thankful to The College Dean and the Head of the Hort. and Landscape, the Coll. of Agric. Engine. Sci., University of Baghdad, Iraq.

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## References


1. Ahmad, I., Usman Saquib, R., Qasim, M., Saleem, M., Sattar Khan, A., and Yaseen, M. (2013). Humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus. Chilean journal of agricultural research, 73(4): 339-344. http://dx.doi.org/10.4067/S0718-58392013000400002.
2. Barczak, B., and Nowak, K. (2013). Content of macroelements and their ionic ratios in oat grain depending on the sulphur form and dose. Journal of Central European Agriculture, 14(1): 114-123. http://dx.doi.org/10.5513/JCEA01/14.1.1167.
3. Gmizo, G., Alsiņa, I., and Dubova, L. (2012). The effect of colour plastic films on the growth, yield and plant pigment content of tomatoes. Acta Horticulturae, 952: 217-224. https://doi.org/10.17660/ActaHortic.2012.952.26.
4. Hussain, J., Rehman, N. U., Khan, A. L., Hamayun, M., Hussain, S. M., and Shinwari, Z. K. (2010). Proximate and essential nutrients evaluation of selected vegetables species from Kohat region, Pakistan. Pak. J. bot, 42(4): 2847-2855.
5. Jones, J. R. (2012). Plant nutrition and soil fertility manual. CRC press, 230. https://doi.org/10.1201/b11577.
6. Kartina, A. M., Utama, P., and Dimyati, I. (2019). Response growth and yield of okra (Abelmoschus esculentus l.) to giving dosage levels of chicken manure and variation of plants spacing. In IOP Conference Series: Earth and Environmental Science, 383(1): 012028. DOI: 10.1088/1755-1315/383/1/012028.
7. Naser, H. M., Mahmud, N. U., Sultana, S., Gomes, R., and Rahman, M. (2012). Trace elements content in vegetables grown in industrially polluted and non-polluted areas. Bangladesh Journal of Agricultural Research, 37(3): 515-527. https://doi.org/10.3329/bjar.v37i3.12128.
8. Nazar, R., Iqbal, N., Masood, A., Syeed, S., and Khan, N. A. (2011). Understanding the significance of sulfur in improving salinity tolerance in plants. Environmental and Experimental Botany, 70(2-3): 80-87. https://doi.org/10.1016/j.envexpbot.2010.09.011.
9. Ozyigit, I. I., Hasan, C. A. N., Uyanik, O. L., Yalcin, I. E., and Demir, G. (2024). Fruit mineral nutrient contents of field and greenhouse grown tomatoes and comparison with standard values. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 52(1): 13479. https://doi.org/10.15835/nbha52113479.
10. Pasha, N., Vasanthakumari, R., Hanamantharaya, B. G., Nirmala, K. S., and Vidya, A. (2021). Effect of Humic acid on Growth of Okra (Abelmoschus esculentus L.) cv. Arka Anamika. International Journal of Current Microbiology and Applied Sciences, 10(2): 3530-3534. https://doi.org/10.20546/ijcmas.2021.1002.388.
11. Ramadan, M., and El Mesairy, M. (2015). Effect of Humic acid and Chitosan on

growth and yield of Okra (Abelmoschus esculentus L.) under saline conditions. Egyptian Journal of Desert Research, 65(1): 47-60. https://doi.org/10.21608/ejdr.2015.5798.

12. Ramesh, E., Jana, J. C., Chatterjee, R., and Banik, G. C. (2019). Effect of foliar application of secondary and micronutrients on growth and yield of potato. Journal of Pharmacognosy and Phytochemistry, 8(2): 656-660.
13. Rowland, S. D., Zumstein, K., Nakayama, H., Cheng, Z., Flores, A. M., Chitwood, D. H., ... and Sinha, N. R. (2020). Leaf shape is a predictor of fruit quality and cultivar performance in tomato. New Phytologist, 226(3): 851-865. https://doi.org/10.1111/nph.16403.
14. Santos, H. C., Pereira, E. M., Medeiros, R. L. D., Costa, P. M. D. A., and Pereira, W. E. (2019). Production and quality of okra produced with mineral and organic fertilization. Revista Brasileira de Engenharia Agrícola e Ambiental, 23(2): 97-102. https://doi.org/10.1590/1807-1929/agriambi.v23n2p97-102.
15. Schafleitner, R., Lin, C. Y., Lin, Y. P., Wu, T. H., Hung, C. H., Phooi, C. L., ... and Hsiao, Y. Y. (2021). The world vegetable center okra (Abelmoschus esculentus) core collection as a source for flooding stress tolerance traits for breeding. Agriculture, 11(2): 165. https://doi.org/10.3390/agriculture11020165.
16. Singh, N., Sharma, R., Kumar, D., and Verma, J. (2024). Effect of calcium and magnesium nutrition on vegetative growth and tuber yield of potato (Solanum tuberosum). Environment Conservation Journal, 25(1): 144-155. https://doi.org/10.36953/ECJ.23652613.
17. Tufaro, D., Bassoli, A., and Cappa, C. (2022). Okra (Abelmoschus esculentus) powder production and application in gluten-free bread: Effect of particle size. Food and Bioprocess Technology, 15(4): 904-914. https://doi.org/10.1007/s11947-022-02784-6.
18. Woldemariam, S. H., Lal, S., Zelelew, D. Z., and Solomon, M. T. (2018). Effect of potassium levels on productivity and fruit quality of tomato (Lycopersicon esculentum L.). Journal of Agricultural Studies, 6(1): 104-117. https://doi.org/10.5296/jas.v6i1.12262.