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*Article*

# Effect of Different Levels of Humic and Fulvic Acids on the Growth and Yield of Two Barley (*Hordeum vulgare* L.) Varieties

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**Abstract:** A field experiment was conducted in Al-Qadisiyah Governorate during the winter agricultural season of 2025–2026. The study evaluated two barley (*Hordeum vulgare* L.) cultivars, Ebaa 265 and Ebaa 99, grown in a silty loam soil. The experiment followed a split-plot design with three replicates, where cultivars were allocated to the main plots and organic acid levels were assigned to the sub-plots. The results revealed the following findings; **Effect of Humic and Fulvic Acids:** Application of these organic acids led to a significant increase across all yield traits and their components. The treatment levels of 40 and 60 L·ha$^{-1}$ achieved the highest averages for the number of spikes per square meter, number of grains per spike, 1000-grain weight, total grain yield, and biological yield. **Cultivar Performance:** Distinct genetic variations were observed between the two cultivars. Ebaa 99 significantly outperformed Ebaa 265 in most studied traits, securing the highest grain yield, biological yield, and harvest index (37.71%). Conversely, Ebaa 265 showed a significant superiority solely in the 1000-grain weight. **Two-Way Interaction:** The combination of the Ebaa 99 cultivar with the higher organic acid application rates yielded the best interactive outcomes regarding spike count, grain number per spike, and total grain yield. This study concludes that applying humic and fulvic acids at a rate of 40 L·ha$^{-1}$ represents the optimal economic and physiological choice. This concentration provides sufficient nutrition to maximize crop productivity without requiring higher doses, while Ebaa 99 demonstrates a clear production advantage under the environmental conditions of the study area.

**Keywords:** *Hordeum vulgare L., Barley cultivars, Humic acid, Fulvic acid.*

## 1. Introduction

Barley (*Hordeum vulgare* L.) ranks fourth globally in terms of total cultivated area and production, following wheat, rice, and maize. The crop is well-known for its high tolerance to harsh environmental conditions, low nutritional requirements, rapid growth cycle, and faster maturation compared to wheat. Consequently, barley is extensively cultivated in the central and southern regions of Iraq, with the local cultivated area reaching approximately 4.528 million hectares, producing an estimated 1,756 tons (Agricultural Statistics Directorate, 2020). Beyond its agricultural resilience, barley features diverse applications in human nutrition, animal feed, industrial processing, and pharmaceuticals due to its rich nutritional value [1][2].

Humic substances derived from organic matter, which include or consist partly of humic and fulvic acids, play a critical role in soil fertility [3]. These acids possess essential nutrients that stimulate the accumulation of plant dry matter, leading to the synthesis of organic compounds with varying molecular weights [4]. Furthermore, applying these organic acids to plants can elevate the endogenous levels of cytokinins and auxins [5]. Humic acid significantly enhances soil structure and texture due to its nutrient content and hormone-like activities, driven by the presence of active hormonal groups within its chemical composition [6]. In this context, Muscolo et al. [7] reported that the application of humic and fulvic acids enhances root system development and increases total plant protein content.

Additionally, Nardi et al. [8] observed a positive effect on the proliferation of soil microorganisms. Anonymous [9] further indicated that the agricultural application of humic and fulvic acids exerts direct biochemical effects that enhance cell membrane permeability. Investigating different concentrations of soil-applied humic acid (0, 1, and 2 $g \cdot kg^{-1}$ soil) on barley, Roozbahani [10] found that the 1 $g \cdot kg^{-1}$ rate recorded the highest average plant height and dry weight. Similarly, Hellal [11] noted significant improvements in most growth traits when humic and fulvic acids were applied as foliar sprays on barley. Al-Jumaili [12] also confirmed significant structural enhancements across four humic acid application levels compared to the unfertilized control treatment.

Regarding cultivar variations, Ali and Al-Hassan [13] evaluated four barley cultivars (Local Black, Arabi Black, Furat, and Zanbaqa) and reported the superiority of 'Arabi Black', which achieved the highest average flag leaf area of 15.19 $cm^2$ during the 2009–2010 season. Yassin et al. [14] studied three cultivars (Abu Ghraib 244, Abu Ghraib 256, and Samir) and highlighted the dominance of 'Abu Ghraib 244' in flag leaf area, averaging 26.62 $cm^2$. Conversely, Al-Bayati and Siddiq [15] examined eight barley cultivars and found that 'Buraq' outperformed the others, recording the highest average flag leaf area of 16.96 $cm^2$. In an extensive evaluation of eighteen introduced genotypes alongside six local cultivars (Shua'a, Buraq, Amal, Samir, Al-Warkaa, and Al-Khair), Al-Bayati et al. [16] demonstrated that the local cultivar 'Al-Warkaa' was superior, achieving flag leaf area averages of 31.21 $cm^2$ and 16.00 $cm^2$ for the 2013–2014 and 2014–2015 seasons, respectively.

Furthermore, Al-Fahdawi and Al-Qaisi [17] investigated three barley cultivars and found that 'Ebaa 265' registered the highest average flag leaf area (18.49 $cm^2$), which did not differ significantly from 'Buhouth 244' (18.32 $cm^2$), whereas 'Ebaa 99' produced the lowest average (13.43 $cm^2$). In contrast, Al-Raju and Al-Amin [18] observed no significant differences in flag leaf area between the 'Zanbaqa' and 'Furat 4' cultivars.

## 2. Methods

A field experiment was carried out in Al-Qadisiyah Governorate at a private commercial farm during the winter agricultural season of 2025–2026. The experiment was established in soil with physical and chemical characteristics as detailed in Table 1

**Table 1: Chemical and physical properties of the experimental soil for the 2023–2024 agricultural season.**

| | | | |
|---|---|---|---|
| | Soil Analysis / Property | Value | unit |
| | Electrical Conductivity(EC) | 6.4 | Ds.m-1 |
| | Soil Reaction (pH) | 6.5 | |
| | Available Nitrogen (N) | 19.9 | Mg.g-1 |
| | Available Phosphorus(P) | 25.65 | Mg.g-1 |
| | Available Potassium (K) | 144.5 | Mg.g-1 |
| | Sand | 250 | Soil g.kg-1 |
| | Silt | 610 | Soil g.kg-1 |
| | Clay | 140 | Soil g.kg-1 |
| | Soil Texture | Silt Loam | |

The study comprised two experimental factors. The first factor included two barley cultivars: Ebaa 265 and Ebaa 99, designated as **V1** and **V2**, respectively. The second factor involved four application levels of a commercial humic and fulvic acid product: a control treatment (without application), 20 L·ha$^{-1}$, 40 L·ha$^{-1}$, and 60 L·ha$^{-1}$, which were designated as **A0**, **A1**, **A2**, and **A3**, respectively. The applied organic acid product was manufactured by *Superior Company* and imported by *Al-Reef Al-Khadraa Company*.

**Table 2.** Chemical composition and contents of the commercial humic and fulvic acid product (manufactured by Superior Company).

| Component / Property | Content / Value |
|---|---|
| Humic Acids | 10% |
| Fulvic Acid | 2% |
| Potassium Oxide K2O | 2% |
| Denaity g/L | 1.1 |

The experiment was conducted using a split-plot design with three replicates. Cultivars were allocated to the main plots, while the organic acid application levels were assigned to the sub-plots. All necessary soil management practices, including plowing, basal fertilization, and soil smoothing, were uniformly performed. Following these preparations, the field was divided according to the experimental design into individual plots, with each plot measuring (2 *2m. The layout comprised a total of 24 experimental units, structured across three replicates, with each replicate containing 8 experimental units [19]. Sowing was carried out on November 15, 2023.

Studied Characteristics

1- Number of fertile spikes per square meter

The number of spikes was calculated after they reached full maturity for all harvested plants from two central rows in each experimental unit.

2- Number of grains per spike

This was calculated from the average number of grains in ten spikes after manually threshing them and counting the grains.

3- Weight of 1000 grains (g)

1000 grains were randomly selected from each experimental unit and then weighed using a sensitive balance.

4- Grain Yield (ton $ha^{-1}$)

The grain yield of the harvested plants from the two middle rows was estimated after hand-threshing the plants from each experimental unit. After separating the straw from the grain, it was weighed, and the grain yield (ton $ha^{-1}$) was calculated.

5- Biomass Yield (ton $ha^{-1}$)

The entire plant population of the two middle rows (straw + grain) was weighed, and the weight was converted from $g/m^2$ to tons $ha^{-1}$ after drying.

6-Harvest Index(%)

The following equation was calculated based on the harvested sample: Harvest Index = Grain Yield / Biomass Yield x 100 (Donald, 1962)

**Statistical analysis**:

The data related to the studied growth and yield traits were statistically analyzed using the Genstat statistical software. The least significant difference (LSD) test was used to compare the arithmetic means of the treatments at a probability level of 0.05, as described by Al-Rawi and Khalafallah (1980).

## 3. Results and Discussion

1- Number of ears per m2

The results in Table (3) show a clear and significant positive increase in the number of ears per square meter with increasing levels of humic acid application. Levels A3 and A2 gave the highest averages compared to the control (A0) without humic acid. This increase can be attributed to the direct role of humic and fulvic acids in improving the physical and chemical properties of the soil by increasing its ability to retain adequate moisture and facilitating the absorption of macronutrients such as nitrogen and phosphorus in the early stages of plant life (seedling and tillering). Furthermore, the absorbed nitrogen may stimulate the production of natural plant hormones such as auxins an increase in the total and cytokinins, which encourage cell division and the growth of axillary buds, leading to number of tillers that ultimately produced ears. As for the significant superiority of the variety (Ibaa 99) over the variety (Ibaa 265), this may be due to genetic differences between them. The two varieties; where the variety (Aba' 99) has higher genetic efficiency in forming the number of tillers and producing master and branch stems compared to the other variety under the study conditions.

Table (3) Effect of different levels of humic acid, varieties, and their interaction on the characteristic of number of spikes per square meter

| acid levels | | V1 | V2 | Mean |
|---|---|---|---|---|
| A0 | 281 | | 264 | 272.5 |
| A1 | 311 | | 289 | 300.0 |
| A2 | 343 | | 317 | 300.0 |
| A3 | 355 | | 315 | 335.5 |
| mean | 322.5 | | 296.5 | |
| L.S.D0.05V | | A | Interaction | |
| 8.5 | 12.1 | 17.2 | | |

2- Number of grains per spike/g

The statistical results in Table (4) showed a significant improvement in the number of grains per spike when humic acid was added. The combination of variety (Aba 99) and level A3 yielded the highest averages. This can be attributed to the fact that the number of grains per spike is determined during the spike-forming and fertilization stages. Supplying the plant with humic acid ensures a continuous and stable flow of nutrients (especially phosphorus and boron) to the growing tip during the formation of flower vesicles. This nutritional support can reduce the phenomenon of flower abortion within the spike and enhance pollen viability and self-fertilization efficiency, resulting in an increase in the number of grains actually formed per spike. This positive interaction confirms the favorable response of the variety (Ibaa 99) to increased humic and fulvic acid concentrations, enabling it to fully realize its genetic potential by increasing the number of fertile spikes compared to the variety (Ibaa 265(.

Table (4) Effect of different humic acid levels, varieties, and their interaction on the number of grains per spike

| acid levels | | V1 | V2 | Mean |
|---|---|---|---|---|
| A0 | 43.2 | 37.4 | 40.3 | |
| A1 | 44.4 | 42.3 | 43.2 | |
| A2 | 50.9 | 44.5 | 47.7 | |
| A3 | 53.2 | 43.0 | 48.1 | |
| mean | 47.92 | 41.8 | | |
| L.S.D0.05V | | A | Interaction | |
| 1.8 | 1.4 | 3.3 | | |

3- Weight of a thousand grains/g

The results in Table (5) showed that the trait of weight of a thousand grains had a significant response to the levels of humic and fulvic acid, while the statistical interaction between the varieties and levels was not significant (N.S.). The variety (Aba'a 265) was also observed to be significantly superior to the variety (Aba'a 265) in this trait, with a higher average yield of 48.8 g. This is due to the fact that the increase in grain weight depends on the efficiency of photosynthesis and the rate of transfer of manufactured carbohydrates from the leaves and sheaths (source) to the developing grains (destination) during the filling stage. Humic and fulvic acids contain active functional groups (such as carboxyl and phenol) that increase the chlorophyll content in the leaves and also prolong their photochemical efficiency period (delaying leaf senescence), which allowed for a longer period for grain filling and an increase in their density and dry weight. As for the genetic superiority of the variety (Aba'a 265) in this trait, it is a common physiological compensation in wheat and barley grains; Since the variety exhibited fewer spikes and grains per spike (as shown in Tables 3 and 4), the products of photosynthesis were distributed across fewer grains, allowing for a greater increase in individual grain size and weight compared to the variety (B99), which was characterized by abundant grains and spikes.

Table (5) Effect of different humic acid levels, varieties, and their interaction on the 1000-grain trait

| acid levels | V1 | V2 | Mean |
|---|---|---|---|
| A0 | 35.4 | 40.0 | 37.7 |
| A1 | 40.1 | 39.4 | 39.8 |
| A2 | 41.2 | 44.0 | 42.6 |
| A3 | 42.5 | 43.8 | 43.5 |
| mean | 39.8 | 41.8 | |
| L.S.D0.05V | A | Interaction | |
| 1.2 | 1.6 | N.S | |

Grain Yield (tons/ha-1) - 4

The results of the statistical analysis in Table (6) showed that the addition of humic and fulvic acids affected the overall grain yield and significantly impacted the response of barley varieties to different application levels. The variety (B99) yielded the highest averages (3.90 and 3.68 tons/ha-1) at levels A2 and A3. This can be attributed to the fact that grain yield is the complex final result of three basic components discussed previously: (number of spikes per square meter, number of grains per spike, and grain weight). Therefore, the significant increase in grain yield is a logical reflection of the significant improvement in these components combined by humic and fulvic acids, which contributed to reducing environmental stresses and providing an ideal root environment. This ultimately led to increased efficiency in converting dry matter into economic yield. It was also observed that the increase between levels A2 and A3 was not significant, indicating that the plant had reached a certain stage. Physiological sufficiency at level two, and any further addition did not translate into a real increase in productivity .

Table (6) Effect of different levels of humic and fulvic acids, varieties, and their interaction on grain yield (tons/ha) - 1

| acid levels | V1 | V2 | Mean |
|---|---|---|---|
| A0 | 3.10 | 2.85 | 2.97 |
| A1 | 3.55 | 3.15 | 3.35 |
| A2 | 4.20 | 3.60 | 3.90 |
| A3 | 4.25 | 3.68 | 3.68 |
| mean | 3.77 | 3.32 | |
| L.S.D0.05V | A | Interaction | |
| 0.14 | 0.22 | 0.31 | |

The results in 6- Biomass Yield (tons/ha). Table (7) show that different levels of humic and fulvic acids significantly affected the biomass (total weight of grain and straw) for both varieties. Biomass refers to the efficiency of the plant's vegetative system and its structural capacity throughout the growing season. Humic and fulvic acids act as auxin-like growth promoters. Their absorption activates metabolic enzymes within barley cells, increases cell membrane permeability, and deepens the root system in the soil to absorb larger quantities of water and nutrients. This resulted in increased plant height, stem thickness, and total leaf area, leading to an increase in straw and accumulated dry matter, which, along with the grain yield, contributed to the high overall biomass value. The variety (Ebaa 99) excelled in this trait, recording the highest average of 10.01, demonstrating its high flexibility and ability to build and synthesize a larger dry matter content when organic amendments are present, compared to the variety (265 Ebaa).

Table (7) Effect of different humic acid levels, varieties, and their interaction on the biological yield trait.

| acid levels | | V1 | V2 | Mean |
|---|---|---|---|---|
| A0 | 8.40 | | 7.60 | 8.00 |
| A1 | 9.42 | | 8.63 | 9.02 |
| A2 | 11.11 | | 9.79 | 10.45 |
| A3 | 11.36 | | 9.94 | 10.65 |
| mean | 10.07 | | 8.99 | |
| L.S.D0.05V | | A | Interaction | |
| 0.35 | 0.48 | 0.65 | | |

6-Harvest Index %

The statistical results in Table (8) showed that the variety (Aba 99) had the highest harvest index value, recording the highest average of 37.71, while the variety Aba 265 had the lowest average of 66. The results also showed that humic acid levels and their interaction with the varieties did not have a significant effect (N.S.) on this trait. This could be attributed to the fact that the harvest index is a measure of "physiological conversion efficiency" within the plant, as it expresses the extent to which the plant succeeds in directing and transporting the products of photosynthesis (dry matter) accumulated in the leaves and stems and storing them within the grain (economic yield) instead of consuming them only in vegetative growth (straw). Furthermore, the significant effect of the varieties on the harvest index (37.71%) on the variety (Aba 265) is due to its higher genetic efficiency in the source-to-sink translocation process. This means that the Abaa 99 variety was more physiologically efficient in distributing processed carbohydrates for grain building, which is perfectly consistent with its prior superiority in total grain yield (Table 6). The effect of humic and fulvic acids (N.S.) is also evident: there may be a significant effect of humic acid levels in the organic acid harvest index, which stimulated and improved both grain and biological yields in very balanced and similar proportions. As we observed in Tables 6 and 7, the addition of humic acid increased the weight of the foliage and straw (biological yield) and simultaneously increased the number of spikes and grains (grain yield). Since the harvest index is the percentage resulting from dividing the yields by each other, the simultaneous and equivalent increase in the numerator and denominator kept the final percentage almost constant and within a similar range, making the statistical differences between fertilizer levels insignificant. Thus, the physiological picture of the experiment is complete, as humic acid proved to increase the overall productivity of the crop (growth and yield) without disrupting the plant's internal physiological balance.

Table (8) Effect of different humic acid levels, varieties, and their interaction on the harvest index %

| acid levels | | V1 | V2 | Mean |
|---|---|---|---|---|
| A0 | 37.81 | | 36.52 | 37.16 |
| A1 | 37.77 | | 36.40 | 37.08 |
| A2 | 37.84 | | 36.72 | 37.28 |
| A3 | 37.45 | | 36.97 | 37.21 |
| mean | 37.71 | 36.66 | | |
| L.S.D0.05V | | A | Interaction | |
| 0.65 | N.S | N.S | | |

## 5. Conclusion

Results indicated that humic and fulvic acid application substantially improves barley (Hordeum vulgare L.) growth and yield, especially through enhancement of key yield components such as number of spikes per m-2, number of grains per spike, 1000-grain weight, grain yield And biological yield. The 40 L·ha$^{-1}$ treatment was the most effective and economically efficient application rate tested, as at higher rates this crop response plateaued with above-average yields. In the majority of agronomic traits, including grain yield and biological yield, the cultivar Ebaa 99 exceeded the other cultivar type (Ebaa 265), indicating that it has a greater genetic potential and adaptability to environmental conditions of Al-Qadisiyah Governorate. Additionally, the interaction results reaffirmed that mixing Ebaa 99 with moderate to higher rates of humic and fulvic acids resulted in optimal performance. Importantly, these experiments illustrate the pragmatic application of integrating improved barley cultivars with organic biostimulants for enhancing yield in a sustainable manner under semi-arid conditions. Future studies should concentrate on extended field evaluations of humic and fulvic acid applications in diverse soils and climatic zones, as well as their synergistic effects with mineral fertilizers along with the relevant physiological and molecular mechanisms

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