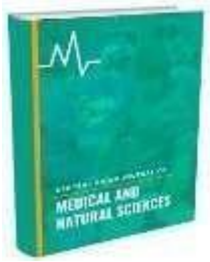

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Article

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

Hawraa naeem jalal[1], Saja Abdullah Mohammed[2], Amir Malik H. Al-Shammari[3]

[1]College of Basic Education, Al-Muthanna University, Al-Muthanna, Al-Samawah, Iraq.
[2]University of Al-Qadisiyah/College of Science /Department of Biology.
[3]Department of Field Crops, College of Agriculture, Al-Muthanna University, Al-Muthanna, Al-Samawah, Iraq
Correspondence: hawraa.naeem@mu.edu.iq

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Abstract: A field trial was carried out in Al-Qadisiyah Governorate during the winter season of 2025–2026 to assess two barley (Hordeum vulgare L.) cultivars, namely Ebaa 265 and Ebaa 99, in silty loam soil. The experiment was laid out in a split-plot design with three replications. Cultivars occupied main plots while sub-plots were earmarked for levels of organic acids. The results could be summed up as follows: Humic and Fulvic Acids: Both organic acids significantly increased all yield traits and their components. The maximum average values of spike length, number of spikes per square meter, number of grains per spike, 1000-grain weight, total grain yield, and biological yield were recorded for the 40 and 60 $L \cdot ha^{-1}$ levels of application. Cultivar Performance: The two cultivars exhibited distinct genetic variability. Ebaa 99 performed significantly better than Ebaa 265 in most studied traits, recording the highest grain yield, biological yield, and harvest index (37.71%). Ebaa 265 only showed significant superiority in the 1000-grain weight. Two-Way Interaction: Ebaa 99 in combination with the higher organic acid application rates had the best interactive outcomes on spike count, grain number per spike, and total grain yield. This study concludes that the optimal economic and physiological choice is to apply humic and fulvic acids at a rate of 40 $L \cdot ha^{-1}$. Such a concentration would provide sufficient nutrition to maximize the productivity of crops without the necessity of higher doses, while Ebaa 99 shows 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.) Is ranked fourth in the world in terms of total area and production after wheat, rice, and maize. The crop has a well-earned reputation for high environmental adaptability, low nutrient requirements, short growth period, and early maturation compared with wheat. Barley is therefore widely grown in the central and southern regions of Iraq. The total area under local cultivation has reached about 4.528 million hectares, with an estimated production of 1,756 tons (Agricultural Statistics Directorate, 2020). Apart from its value as a hardy crop, barley is an important source of nutrition for humans and animals and is used in many industries and pharmaceuticals because of its rich nutritional components [1][2].

Organic matter, of which humic and fulvic acids form a part, is important in maintaining soil fertility [3]. These acids contain some essential elements that would promote the accumulation of dry matter in plants, and hence the formation of organic compounds of different molecular weights [4]. Besides, their application to the plant can increase the endogenous levels of cytokinins and auxins [5]. Humic acid enhances soil structure and texture significantly because of its nutrient content and hormonelike activities, which are due to the presence of active hormonal groups in its chemical composition [6]. In this sense, Muscolo et al. [7] stated that the application of humic and fulvic acids improves the development of the root system and increases the total protein content of the plant.

Nardi et al. [8] also noted a positive effect on the proliferation of microorganisms in the soil. In another study, it was indicated that the agricultural application of humic and fulvic acids has direct biochemical effects in enhancing cell membrane permeability. In barley plants, Roozbahani [10] recorded the highest average plant height and dry weight at a rate of 1 $g \cdot kg^{-1}$ humic acid applied to the soil. Hellal [11] applied humic and fulvic acids as foliar sprays on barley and observed significant improvements in most growth traits. Al-Jumaili [12] confirmed significant structural enhancements in four levels of humic acid compared to the unfertilized control treatment.

Concerning cultivar differences, Ali and Al-Hassan [13] worked with four barley cultivars (Local Black, Arabi Black, Furat, and Zanbaqa), and among which, 'Arabi Black' was superior with the highest average flag leaf area of 15.19 cm^2 for the 2009–2010 season. In a similar study, Yassin et al. [14] worked with three cultivars (Abu Ghraib 244, Abu Ghraib 256, and Samir) and 'Abu Ghraib 244' was the best in dominance of flag leaf area, averaging

26.62 cm^2. In a study on eight barley cultivars, Al-Bayati and Siddiq [15] found ‘Buraq’ to be the best of all and it had the highest average flag leaf area of 16.96 cm^2. In a very comprehensive evaluation of eighteen introduced genotypes and six local cultivars (Shua'a, Buraq, Amal, Samir, Al-Warkaa, and Al-Khair) in which the two years (2013–2014 and 2014–2015) were combined, it was proved that the local cultivar ‘Al-Warkaa’ was better because it gave the means of flag leaf areas of 31.21 cm^2 and 16.00 cm^2 for the 2013–2014 and 2014–2015 seasons, respectively.

Al-Fahdawi and Al-Qaisi [17] worked on three barley cultivars and found that 'Ebaa 265' recorded the highest average flag leaf area (18.49 cm^2), which was at par with 'Buhouth 244' (18.32 cm^2) but significantly different from 'Ebaa 99' which had the lowest average (13.43 cm^2). On the other hand, Al-Raju and Al-Amin [18] did not find any significant differences in the 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	

Two experimental factors were involved in the study. The first factor included two barley cultivars, designated as V1 and V2: Ebaa 265 and Ebaa 99. The second factor involved four levels of application of a commercial humic and fulvic acid product — a control

treatment (without application) and 20 $L \cdot ha^{-1}$, 40 $L \cdot ha^{-1}$, and 60 $L \cdot ha^{-1}$ were designated as A0, A1, A2, and A3, respectively. The organic acid product applied 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 laid out in a split-plot design with three replications. The cultivars occupied the main plots while levels of application of organic acids were assigned to the sub-plots. All soil management practices such as plowing, basal fertilization, and soil smoothing were carried out in a uniform manner. After these preparations, the field was divided according to the experimental design into individual plots. Each plot measured 2m*2m. There were 24 experimental units in all laid out in three replicates of eight experimental units each. Sowing was done 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

It improves its physical and chemical properties, giving it the ability to hold enough water while allowing the uptake of vital macronutrients like nitrogen and phosphorus in the early stages of plant growth, particularly in the seedling and tillering phases. The nitrogen absorbed can induce the production of endogenous phytohormones (auxins and cytokinins) responsible for cellular division and growth of axillary buds. This, in turn, leads to an increased number of tillers in the end that produce ears. The difference between Ibaa 99 and Ibaa 265 could be due to genetic differences between the two. The Ibaa 99 variety shows higher genetic efficiency in producing both tillers and main and branch stems when compared with the other variety under the conditions of this study. Table 3 shows the effects of varying levels of humic acid, the different varieties, and their interaction on the 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

Table (4) presents the statistical results of the number of grains per spike. It can be observed that there was a highly significant difference between the means of the treatments. The interaction of variety (Aba 99) and level A3 produced the highest averages. This is probably because the spike-forming and fertilization stages determine the number of grains per spike. An application of humic acid to the plant ensures a constant and uniform supply of nutrients to the growing tip, particularly during the formation of flower vesicles where phosphorus and boron are most needed. Such nutritional support can check the phenomenon of flower abortion within the spike and increase the viability of pollen as well as efficiency in self-fertilization; thus, more grains will actually be set 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. 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 because grain weight increase can only occur if there is effective photosynthesis and relatively fast transportation of assimilates from the leaves plus sheaths (source) to the developing grains at the filling stage (sink). Humic and fulvic acids have active functional groups (carboxyl, phenol) that enhance chlorophyll buildup in the leaves while also sustaining their photochemical period of effectiveness (it delays senescence of leaves), hence allowing more time for grain filling and an increase in their density and dry weight. Concerning the genetic superiority of the variety (Aba'a 265) in this trait, it is a common physiological compensation in grains of wheat and barley; because it had fewer spikes and grains per spike (as detailed in Tables 3 and 4), the assimilate supply was distributed to fewer grains, thus allowing a more substantial increment in individual grain size and weight in comparison to the B99 variety, which had 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) reveal that grain yield was influenced by the addition of humic and fulvic acids, and similarly, there was significant impact observed in the response of barley varieties to different application levels. The highest averages, 3.90 and 3.68 tons/ha-1, at levels A2 and A3, were recorded in variety B99. Grain yield is considered the complex final outcome of three basic components previously discussed: (number of spikes per square meter, number of grains per spike, and grain weight). Therefore, the significant improvement in grain yield provides logical evidence of the significant improvement in these components combined by humic and fulvic acids, which helped to alleviate environmental stresses and provide an ideal root environment. This eventually led to enhanced efficiency in converting dry matter into economic yield. The increase between levels A2 and A3 was not statistically significant, indicating that the plant had reached a particular 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) indicate that different levels of humic and fulvic acids had a significant effect on biomass (total weight of grain and straw) for both varieties. Biomass reflects the efficiency of the plant's vegetative system and its structural capability throughout the growing season. Auxin-like growth promoters are humic and fulvic acids. Absorbed by the plant, they stimulate metabolic enzymes in barley cells; they also raise permeability of the cell membrane and deepen the root system into the soil where more water and nutrients are to be taken up. This led to increased plant height, thickness of stem, and total leaf area hence increase in straw and accumulated dry matter which together with grain yield contributed to high overall biomass value. The variety (Ebaa 99) excelled in this trait, recording the highest average of 10.01, showing 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 data in Table (8) indicate that the highest harvest index value was obtained by variety (Aba 99), with an average of 37.71, while the lowest average was recorded by variety Aba 265, at 36. Additionally, it was observed that humic acid levels and their interaction with the varieties had no significant effect on this trait (N.S.). Perhaps the reason for this non-significance is that the harvest index is an indicator of "physiological conversion efficiency" in the plant, showing how well the plant directs and transports the products of photosynthesis (dry matter) from the leaves and stems to be stored in the grain (economic yield) as opposed to simply using them for vegetative growth (straw). The significant influence of the varieties on the harvest index (37.71%) for the variety (Aba 265) clearly indicates its superior genetic efficiency in the source-to-sink translocation process. This indicates that the variety Aba 99 showed better physiological efficiency in the translocation of assimilates to the grain, which is consistent with its earlier superiority in total grain yield (Table 6). The effect of humic and fulvic acids is non-significant (N.S.). It is also noted that the effect of levels of humic acid on organic acid harvest index was significant since it induced and increased both biological and grain yields in very good and close to equal proportions. As shown in Tables 6 and 7, the application of humic acid resulted in the increase of weight for both foliage and straw (biological yield) and at the same time enhanced the number of spikes and grains (grain yield). Since the harvest index is the ratio of these yields, the simultaneous and proportional increase in both the numerator and denominator kept the final percentage almost constant and within a comparable range; hence the statistical differences among levels of fertilizer were insignificant. Thus, the physiological overview of the experiment is comprehensive as humic acid has been shown to increase the total productivity of the crop, that is, growth plus yield, without disturbing the internal physiological equilibrium of the plant..

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

This would mean that humic and fulvic acid treatments significantly enhance the growth and yield of barley (Hordeum vulgare L.) by improving important yield components such as the number of spikes per m-2, number of grains per spike, 1000-grain weight, grain yield and biological yield. The most effective and economically efficient application rate tested was 40 $L \cdot ha^{-1}$, as the crop response plateaued at higher rates with above-average yields. In most agronomic traits, including grain yield and biological yield, Ebaa 99 was significantly higher than Ebaa 265, which confirms that it has better genetic potential and adaptability to environmental conditions in Al-Qadisiyah Governorate than the other cultivar type. The interaction results also confirm that mixing Ebaa 99 with moderate to higher rates of humic and fulvic acids gave the best results. The above experiments can be considered as an example of the practice approach of integrating improved barley cultivars with organic biostimulants for increasing yield in a sustainable way under semi-arid conditions. Future studies should focus on extended field evaluations of humic and fulvic acid applications in different soils and climatic zones, as well as their synergistic effects with mineral fertilizers, together with the relevant physiological and molecular mechanisms

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