The effect of adding several levels and timings of humic and fulvic acids on some characteristics of barley yield

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Abstract

A field experiment was conducted at Al-Dawwar Research Station, Agricultural Research Directorate, located in Anbar province, Ramadi city during the 2024–2025 agricultural season, The aim is to determine the optimal concentration levels of humic and fulvic acids, the most suitable planting dates for their application, and the relationship of this to grain yield. The experiment was carried out using a Randomized Complete Block Design (RCBD) with three replications. Treatments consisted of three concentrations of humic and fulvic acids (0.5%, 1.0%, and 2.0% of organic matter) applied at three distinct growth stages: pre-sowing, stem elongation, and flowering. Yield and its components were assessed, including: number of spikes per m^2, number of grains per spike, 1000-grain weight (g), grain yield (ton ha^{-1}), and biological yield. The results indicated that the 2%concentrations of humic and fulvic acids yielded the highest averages for number of spikes, tillers, 1000-grain weight, total grain yield, and biological yield (406.4 spikes·m^{-2}, 4.32 tillers plant, 50.59 g, 3.919 t·ha^{-1}, and 15.15 t·ha^{-1}, respectively). Moreover, the results showed that application at the flowering stage produced the highest averages for number of spikes, number of tillers, 1000-grain weight, total grain yield, and biological yield, with values of (380.3 spikes·m^{-2}, 3.98 plants, 47.64 g, 3.641 t·ha^{-1}, and 14.33 t·ha^{-1}, respectively). Meanwhile, the interaction between humic and fulvic acids at a concentration of 2%, applied at the flowering stage, yielded the highest values for the studied traits.

Keywords: Barley, Humic Levels, Application times

Introduction

Organic fertilizers are a cornerstone of sustainable agriculture, contributing to improved soil fertility and enhanced biological activity without disrupting the ecological balance. These fertilizers are derived from natural sources such as animal waste, crop residues, and food industry byproducts, which decompose through the action of microorganisms in the soil, forming organic matter rich in nutrients essential for plant growth [1].

Although barley has been cultivated in Iraq since ancient times, its grain yield remains low, with an average production of 0.9 tons ha-1 from an area of 360,000 hectares in 2023, compared to the average yield of agriculturally advanced countries such as Russia, where the average production reached 2.57 tons ha-1 from a cultivated area of 8.03 million hectares (FAO. 2024). Perhaps the most prominent reason for the decline in average yield in Iraq is the low percentage of organic matter in the soil, which makes the plant unable to utilize its latent genetic and physiological capabilities to the highest required level [2].

Organic acids extracted from organic matter-such as humic and fulvic acids-serve as readily available nutrient sources essential for plant growth, particularly when soil levels are insufficient. In such cases, their deficiency restricts plant growth and ultimately reduces yield. Conversely, excessive application beyond the plant's requirements may cause undesirable effects, such as excessive vegetative growth at the expense of reproductive development [1].

Adding humic acid to the soil improves its physical, chemical, and biological properties, leading to an increase in the soil's ability to retain water and increase ion exchange, which in turn increases the plant's ability to absorb nutrients and increases the strength of its root and shoot systems.

Therefore, optimizing the concentration and timing of humic acid application is essential to maximize grain yield. Accordingly this, experiment was conducted to determine the optimal concentrations of humic and fulvic acids, as well as the most suitable application timings-aligned with specific growth stages-for barley plants.

Materials and Methods

A field experiment was conducted at Al-Dawwar Research Station, affiliated with the Agricultural Research Department, Located in Anbar province, Ramadi city during the 2024–2025 growing season, on soil with physical and chemical properties detailed in Table 1. The objective was to determine the optimal concentrations levels of humic and fulvic acids and the most suitable application timings for specific growth stages of barley (cultivar Abaa 99) to maximize grain yield .

The experiment was carried out by arranging the split pieces according to a randomized complete block design (RCBD) with three replicates. It included three concentrations of humic and fulvic acids: 0.5%, 1%, and 2% (based on organic matter content), applied at three distinct barley growth stages: pre-sowing, elongation, and flowering . The soil was plowed twice using a moldboard plow in perpendicular directions, followed by harrowing to ensure a fine tilth. The field was divided into 27 experimental plots, arranged across three blocks; with a 2-m buffer zone between adjacent blocks. Within each block, three main plots (each corresponding to one acid concentration: 0.5%, 1%, and 2%) were allocated, separated by 1-m alleys .

Each main plot comprised five rows, spaced 20 cm apart. The experimental plot was fertilized with nitrogen fertilizer (N 46%) at a rate of 120 kg ha^{-1} in two applications: the first after planting and the second at the elongation stage. Triple superphosphate fertilizer (P2O5 46%) was added at a rate of 40 kg ha^{-1} in a single dose after plowing and before harrowing. Seeds were sown on November 28, 2024, at a rate of 100 kg ha^{-1}. Standard agronomic practices-including irrigation, hoeing, and weeding-were performed as required throughout the growing seas. Data were statistically analyzed using analysis of variance (ANOVA), and means were compared using the Least Significant Difference (LSD) test at the 5% probability level.

Table (1): Some physical and chemical properties of the nursery soil used in the experiment.

Adjective		the value	Unit
The degree of soil reaction Ph		7.51	------
The electrical conductivity Ec		7.56	dSiemens M^{-1}
Soil organic matter		5.4	gm km^{-1}
Calcium carbonate Caco3		10.3	%
bulk density		1.3	megagrams m^{-3}
cation exchange capacity		23.8	Centimol kg $^{-1}$ soil
Positive dissolved ions	Ca^{2+}	21.9	Meg.L -1
	Mg^{2+}	6.1	
	Na^{+}	22.7	
	K^{+}	1.39	
Negative dissolved ions	$So_4{}^{-2}$	21.7	
	$Hco_3{}^{-}$	4.3	
	Cl^{-}	25.8	
Ready nitrogen		12.5	mlg kg $^{-1}$ soil
Ready Phosphorus P		15.66	
Ready Potassium K		130.4	
Ready zinc Zn		1.22	
Ready manganese Mn		4.6	
Soil chapters	Sand	506	mg kg^{-1} soil
	Silt	174	
	Clay	317	
Tissue			Clay sandy mixture

Studied Traits

Number of spikes ($spike.m^2$): One square meter was randomly harvested from each experimental plot at the full maturity stage, and the number of spikes was counted .
Number of tillers (tiller. Plant): Determined as the average number of tillers per plant, based on random sampling of plants from each experimental plot .

Thousand-grain weight (g): Estimated by randomly counting 1000 grains using a seed counter from the yield of one square meter per experimental plot; each sample was then weighed .

Grain yield ($ton.ha^{-1}$): Manual threshing was performed on the harvested one-square-meter area from each experimental plot; after separating grains from straw, the grains were weighed, and the weight of the 1000-grain sample (used for the thousand-grain weight determination) was added back. The total grain weight ($g.m^2$) was converted to ton/ha, adjusted to 14% moisture content .

Biological yield (ton.ha^{-1}): Calculated from the same harvested plants used for grain yield estimation; the total aboveground biomass (grains + straw) was weighed (g.m²) and converted to ton/ha.

Results and Discussion

Number of spikes (spike.m²)

The results presented in Table(2) indicate a significant difference among the concentrations of humic and fulvic acids applied, regarding the average number of barley spikes per square meter. The barley plants treated with a 2% concentration of humic and fulvic acids exhibited the highest average spike count, reaching 406.4 spikes·m^{-2}, whereas the treatment with a 0.5% concentration yielded the lowest statistically significant value of 265.2 spikes·m^{-2}. These findings are consistent with the results reported by previous researchers [8,13,15].

Furthermore, Table (2) reveals a significant difference among application timings concerning the average number of barley spikes. The flowering-stage application resulted in the highest spike count (380.3 spikes·m^{-2}), whereas the pre-planting application produced the lowest mean value for this trait (263.6 spikes·m^{-2}).

Moreover, the interaction between application timing and concentration of humic and fulvic acids significantly influenced the average spike number. The combination of the 2% concentration applied at the flowering stage produced the highest spike number (459.7 spikes·m^{-2}), while the lowest value (200.01 spikes.m^{-2}) The lowest average number of spikes when a 0.5% concentration was added before planting was 200.01 spikes.

The results show that adding high concentrations of humic and fulvic acids before planting provided the necessary nutrients, which contributed to increased vegetative growth at the expense of reproductive growth.[12]

Table (2): Effect of concentrations and application timings of humic and fulvic acids on the number of barley spikes (spikes·m^{-2}).

Addition timings	Concentrations of humic and fulvic acids			
	0.5%	1%	2%	Average
Before planting	200.1	277.1	313.6	263.6
Elongation stage	290.0	366.4	446.0	367.5
Flowering stage	305.7	375.6	459.7	380.3
Average	265.2	339.7	406.4	L.S.D 0.05 62.3
L.S.D 0.05	44.9			

Number of Tillers (tiller. plant)

As observed from the results in Table 3, significant differences were found in the concentrations of humic and fulvic acids applied regarding the number of tillers in barley plants. The highest average number of tillers (4.32 plants) was recorded at the 2% concentration, whereas the average number of tillers was 3.4 plants at the 0.5% concentration. Furthermore, Table 3 reveals a statistically significant difference among application timings, with the highest average number of tillers (3.98 plants) observed at the flowering stage, compared to the lowest value (3.43 plants) recorded for the pre-sowing application timing. These findings are consistent with those reported by [6,2] .

Moreover, the interaction effect between concentration and timing was also significant for the average number of tillers: the combination of the flowering-stage application with the 2% concentration of humic and fulvic acids yielded the highest average number of tillers (4.79 plants), while the lowest value (2.87 plants) was obtained with the 0.5% concentration applied pre-sowing. This outcome can be attributed to the role of humic substances in enhancing soil nutrient availability, which, in turn, positively influenced barley growth parameters. These results align with the findings of [3].

Table (3): Effect of concentrations and timing of humic and fulvic acid application on the number of tillers per plant.

Addition timings	Concentrations of humic and fulvic acids			
	0.5%	1%	2%	Average
Before planting	2.87	3.48	3.95	3.43
Elongation stage	3.33	3.56	4.22	3.70
Flowering stage	3.45	3.72	4.79	3.98
Average	3.21	3.58	4.32	L.S.D 0.05 0.27
L.S.D 0.05	0.23			

Weight of 1000 Grains

As observed from the results in Table 4, there are significant differences among the concentrations of humic and fulvic acids regarding the average weight of 1,000 barley grains. The highest mean value (53.94 g) was recorded at a concentration of 2% for both humic and fulvic acids, differing significantly from all other applied concentrations-particularly from the 0.5% concentration, which yielded the lowest mean of 40.71 g. These findings are consistent with those reported by[5,7].

Furthermore, Table 4 indicates a significant effect of application timing, with the highest mean weight (47.64 g) achieved at the flowering stage, compared to 45.61 g at the pre-sowing stage. These results align with[8]Regarding the interaction between application timing and humic/fulvic acid concentrations, a statistically significant effect was observed on the 1,000-grain weight of barley. The highest mean (56.68 g) was obtained at the 2% concentration applied during the flowering stage, whereas the lowest significant value (37.10 g) was recorded at the 0.5% concentration applied pre-sowing. The increase in 1,000-grain weight at the 2% concentration applied during flowering may be attributed to the enhanced availability of nutrients-particularly nitrogen-in sufficient quantities, promoting grain filling and thus increasing individual grain weight, which positively reflects on the overall 1,000-grain weight.

Table (4): Effect of concentrations and timing of humic and fulvic acid application on 1,000-grain weight (g) of barley.

Addition timings	**Concentrations of humic and fulvic acids**			
	0.5%	1%	2%	Average
Before planting	37.16	46.23	53.45	45.61
Elongation stage	39.29	47.34	51.70	44.11
Flowering stage	39.21	47.03	56.68	47.64
Average	40.71	46.86	53.94	L.S.D 0.05
L.S.D 0.05	0.17			0.23

Total Grain Yield (t·ha⁻¹)

Table 5 shows statistically significant differences in application timings for total grain yield (t·ha⁻¹). The highest mean grain yield was recorded at the flowering stage, reaching 3.641 t·ha⁻¹, whereas the lowest barley grain yield occurred with the pre-sowing application, amounting to 2.046 t·ha⁻¹. These results are consistent with findings reported by other researchers [7,3,4].

The same table also indicates significant differences among concentrations of humic and fulvic acids applied. The highest barley grain yield (3.919 t.ha⁻¹) was achieved at a 2% concentration of humic and fulvic acids, whereas the lowest grain yield (2.316 t.ha⁻¹) was observed at the 0.5% concentration. This finding aligns with the results of previous studies [3,10,2.]

Moreover, the interaction between humic and fulvic acid concentrations and application timings significantly affected the mean barley grain yield. The highest grain yield (4.693 t.ha⁻¹) was obtained when a 2% concentration of humic and fulvic acids was applied at the flowering stage, whereas the lowest grain yield (1.662 t.ha⁻¹) resulted from the 0.5% concentration applied prior to sowing This may be because the increase in organic matter in the soil has led to increased vegetative growth at the expense of reproductive growth.

Table (5): Effect of concentrations and application timings of humic and fulvic acids on total grain yield (t.ha⁻¹) of barley.

Addition timings	**Concentrations of humic and fulvic acids**			
	0.5%	1%	2%	Average
Before planting	1.662	2.033	2.443	2.046
Elongation stage	2.644	3.589	4.622	3.618
Flowering stage	2.642	3.588	4.693	3.641
Average	2.316	3.070	3.919	L.S.D 0.05
L.S.D 0.05	0.002			0.002

Biological Yield

Table 6 results indicate a statistically significant difference among concentrations of humic and fulvic acids application regarding biological yield, with the highest yield reaching 15.15 t.ha^{-1} at the 2% concentration, while the lowest yield for this trait was 12.13 t.ha^{-1}. Furthermore, results from the same table reveal a significant effect of application timing, as the highest biological yield (14.33 t.ha^{-1}) was recorded at the flowering stage, whereas the lowest yield (13.37 t.ha^{-1}) occurred when the acids were applied before sowing. These findings align with those reported by [12,9].

Table (6)*:* Effect of concentrations and timing of humic and fulvic acids application on biological yield (t.ha^{-1}) of barley.

Addition timings	Concentrations of humic and fulvic acids			
	0.5%	1%	2%	Average
Before planting	11.23	14.30	14.60	13.37
Elongation stage	12.50	14.45	15.10	14.01
Flowering stage	12.66	14.57	15.76	14.33
Average	12.13	14.44	15.15	L.S.D 0.05
L.S.D 0.05	0.1			0.03

Additionally, the interaction between concentration and application timing had a significant effect on biological yield, with the highest value (15.76 t.ha^{-1}) observed at the flowering stage combined with the 2% concentration. Conversely, the lowest average biological yield (11.23 t.ha^{-1}) was recorded at the 0.5% concentration applied before sowing. This enhancement in biological yield can be attributed to the positive influence of humic and fulvic acids on the availability of essential nutrients-particularly phosphorus and potassium-which, in turn, improved yield components such as seed weight and shoot dry weight [13].

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