Effect of Bentonite Mineral and Humic Acid Application on Growth and Yield of Wheat (*Triticum aestivum* L.)

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Abstract
The effects of bentonite and humic acid, both separately and together, on wheat (Triticum aestivum L.) were studied in a plot experiment. growth and yield. A Randomized Complete Block Design (RCBD) with three replications was employed. The combined treatment (M2F2) exhibited the best means for most of the traits in this study, with plant height of 92.4 cm in comparison to 78.6 cm under the control (+17.6%). The number of spikes was raised to 410 spikes m^{-2}, grains per spike to 52, 1000-grain weight to 41.8 g producing the maximum grain yield of 5.30 t ha^{-1}. The findings reveal the bentonite mineral and humic acid enhanced the soil quality and wheat production.
Keywords: Bentonite mineral; Humic acid; Soil amendments; Wheat; Yield components; Semi-arid agriculture

1. Introduction

One of the most significant cereal crops in the world, wheat (Triticum aestivum L.) is crucial to global food security. especially crucial for dry and semi-dry areas [6,9,1]. Soil degradation, minimal organic matter content and less nutrient holding capacity are high constraints to crop productivity [2,8]. Hence, soil amendments are being applied increasingly to enhance the quality of soil and ensure sustainable agricultural production [9,10] .Bentonite is a clay mineral with high cation exchange capacity and the ability to hold water and nutrients, which improves physical conditions of soil [11,8]. Humic acid is a significant portion of soil organic matter ,which promotes nutrient absorption, root growth, and microbial activity [13,12,4 .[Synergistic actions of organic and mineral amendments have proven to enhance soil fertility and yield substantially [5,3].Hence, the objective of this article was to investigate the separate and combined impacts of bentonite mineral and humic acid on the the wheat growth and yield.

2. Materials and Methods

A RCBD with three replicates was applied. [7].

Treatments

- Bentonite: M0 (0 t ha^{-1}), M1 (5 t ha^{-1}), M2 (10 t ha^{-1})
- Humic acid: F0 (0 kg ha^{-1}), F1 (10 kg ha^{-1}), F2 (20 kg ha^{-1})

Measured traits

The plant's height, weight of 1000 grains, number of spikes (m^{-2}), number of grains per spike, and grain yield (t ha^{-1}).

Statistical analysis

Data were analyzed using ANOVA and means were separated using LSD at $P \leq 0.05$ [7].

3. Results and Discussion

3.1 Plant Height (cm)

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There was a positive effect of bentonite, humic acid and their interaction on the plant height [7,11]. The maximum (92.4 cm) height of the plants was observed under M2F2, whereas the minimum (78.6 cm) was found in the control (M0F0 .(This rise was attributed to the higher availability of moisture and nutrients in the soil [11,8].Bentonite promotes holding water and it decreases leach loss [11], humic acid induces nutrients uptake by increasing membrane permeability and root physiologic activity stimulation. [13,4].

Table 1. Plant Height (cm)

Humic Acid	M0	M1	M2	Mean
F0	78.6	82.3	85.1	82.0
F1	84.2	88.7	90.5	87.8
F2	86.5	90.8	92.4	89.9
Mean	83.1	87.3	89.3	—
LSD (0.05)	M = 2.10, F = 1.85, M×F = 3.20			

3.2 Number of Spikes (spikes m^{-2})

Number of spikes was significantly increased by treatments [7,9 .[The maximum number of spikes (410 spikes m^{-2}) was observed in M2F2 over control .This is related to better tillering and nutrient recycling [10,11].Bentonite enhanced rheological soil water conditions [11], and humic acid promoted root growth and microorganism activity. [13,12].

Table 2. Number of Spikes (spikes m^{-2})

Humic Acid	M0	M1	M2	Mean
F0	320	345	360	341
F1	350	380	395	375
F2	370	400	410	393
Mean	347	375	388	—
LSD (0.05)	M = 12.5, F = 10.8, M×F = 18.2			

3.3 Grains per Spike

Humanized task Grains per head were increased by treatments [7,6,9]. The maximum value (52) was observed at M2F2 . Humic acid promoted nutrient translocation and decreased floret abortion.[13,4] Bentonite increased moisture availability in the flowering stage. [11,8].

Table 3. Grains per Spike

Humic Acid	M0	M1	M2	Mean
F0	38	42	45	41.7
F1	44	48	50	47.3
F2	46	50	52	49.3
Mean	42.7	46.7	49	—
LSD (0.05)	M = 2.30, F = 2.00, M×F = 3.50			

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3.4 1000-Grain Weight (g)

The 1000-grain weight was significantly improved [7,1]. The maximum value (41.8 g) was obtained under M2F2.Humic acid enhanced photosynthesis and carbohydrate production [14,4], whereas bentonite supply could be continued water meteriolesR. [11,8, 5].

Table 4. 1000-Grain Weight (g)

Humic Acid	M0	M1	M2	Mean
F0	32.5	34.8	36.2	34.5
F1	35.6	38.4	40.1	38.0
F2	37.2	40.3	41.8	39.8
Mean	35.1	37.8	39.4	—
LSD (0.05)	M = 1.40, F = 1.25, M×F = 2.10			

3.5 Grain Yield (t ha^{-1})

Grain production was significantly increased by the application of treatments [7,2,3]. The maximum yield (5.30 t ha-1) was recorded in M2F2. Yield enhancement occurs as a consequence of the joint influence on yield attributes [10,9].Bentonite enhanced the physical properties of the soil [11] and humic acid increased the nutrients availability and the metabolic potential. [13,12].

Table 5. Grain Yield (t ha^{-1})

Humic Acid	M0	M1	M2	Mean
F0	3.2	3.6	3.9	3.57
F1	3.8	4.2	4.6	4.20
F2	4.1	4.7	5.3	4.70
Mean	3.7	4.2	4.6	—
LSD (0.05)	M = 0.30, F = 0.25, M×F = 0.45			

4. Conclusion

The integrated use of bentonite mineral and humic acid had the most significant positive effect on wheat growth and grain yield relative to the individual treatments.

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