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### Impacts of K-humate on Wheat Production and Soil Salinity: A Review

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#### Abstract

Wheat (*Triticum aestivum* L) is the most significant staple food in terms of cultivation and consumption by humans around the globe. Most people worldwide regularly consume wheat or wheat products in their daily diet. Recently, wheat production has been negatively affected by climate change, especially drought. On the other hand, the population of wheat-consuming countries is also increasing rapidly. Thus, the production of wheat cannot meet the rising demand of the world's growing population. Furthermore, excessive application of mineral fertilizer in soil to increase wheat production has degraded most of the soils. Soil salinity and drought stress, particularly in arid regions, negatively impact wheat production. Thus, it is urgent to improve wheat production sustainably using bio-stimulants. The impacts of K-humate on wheat production and soil salinity together have not been investigated in previous studies. The review provides an overview, summary, and synthesis of recent research related to the topic. The objective of the review was to summarize the previous understanding of the impacts of K-humate on wheat production and soil salinity. Application of K-humate has not only increased wheat production sustainably but also improved soil properties and wheat tolerance to soil salinity and drought stress. The provided information may be helpful to researchers, policymakers, and wheat farmers in preparing their wheat-production plans using eco-friendly organic fertilizers, such as K-humate, to improve wheat production and reduce environmental constraints.

**Keywords:** Drought stress; Growth; K-humate; Soil salinity; Wheat

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### Introduction

Cereal crops constitute the primary staple food sources worldwide, accounting for more than 50% of the global population's daily caloric intake (El-Hashash et al., 2022). Among these, wheat is one of the most important crops, supplying approximately 20% of the total caloric intake for a substantial proportion of the world's population (Awad et al., 2022). In addition to its caloric contribution, wheat provides essential amino acids, minerals, vitamins, beneficial phytochemicals, and dietary fiber, making it a key component of human nutrition globally (Shewry, 2009). Wheat is predominantly consumed by humans and is cultivated in more than

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100 countries worldwide (Shewry, 2009). Furthermore, wheat represents the principal staple food in Afghanistan and plays a central role in national food security (Popal, 2024).

The application of humic acid has been reported to significantly enhance wheat growth and yield attributes, including plant height, flag leaf area, number of tillers per square meter, spike length, number of spikes per square meter, grains per spike, thousand-grain weight, and overall grain yield (Al-Fayyadh et al., 2020; Salihi et al., 2024). Similarly, soil application of potassium humate at rates of 4 and 8 kg fed<sup>-1</sup> (1.038 acres), either alone or in combination with foliar application of potassium silicate at concentrations of 500 and 1000 ppm, markedly improved growth characteristics and yield components of wheat grown under salinity stress conditions (Salem et al., 2017). Moreover, K-humate application resulted in increased grain yield under both zero phosphorus (P<sub>0</sub>) and moderate phosphorus fertilization (17.5 kg ha<sup>-1</sup>) regimes, highlighting its effectiveness across varying nutrient conditions (Yossif & Gezgin, 2020).

The physico-chemical properties of soil, including bulk density, cation exchange capacity, and electrical conductivity, were significantly altered by the application of various organic amendments (Sorour et al., 2021). In addition, organic amendments markedly increased the availability of essential soil nutrients, including nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), and zinc (Zn) (Sary et al., 2024). Furthermore, the application of potassium humate significantly increased the proportion of soil macro-aggregates and enhanced the mean weight diameter of water-stable aggregates, indicating improved soil structural stability (Wei et al., 2021).

Recently, climate change has negatively affected crop production worldwide. Wheat productivity has been particularly affected by drought and changes in precipitation timing and amount, especially in arid and semi-arid regions, including Afghanistan. The inherently low quality of soils in arid zones makes them highly susceptible to erosion, further reducing agricultural productivity (Kamilov et al., 2021). Soil salinity, alkalinity, and poor soil structure represent major constraints to global agriculture, significantly reducing crop growth and yield in arid environments (Kamilov et al., 2021; Abu-Ria et al., 2024; Zaghoul et al., 2024). At the same time, both the population of wheat-consuming countries and per capita wheat consumption have increased rapidly, intensifying the demand for wheat production. Consequently, there is an urgent need to enhance wheat productivity and improve soil properties through sustainable and environmentally friendly strategies to ensure food security for the world's growing population, particularly in least developed countries such as Afghanistan. Recent studies have shown that eco-friendly amendments, including organic matter and bio-stimulants, offer promising solutions to these challenges (Zaghoul et al., 2024). The application of bio-stimulants, particularly potassium humate (K-humate), has been shown not only to improve wheat production but also to enhance soil properties and mitigate drought stress under saline conditions in arid regions.

Despite these benefits, limited information is available in the existing literature on the combined impacts of K-humate on wheat production and soil salinity. Therefore, this review was conducted to address this knowledge gap and provide information on the combined

impacts of K-humate on wheat production and soil salinity. The objective of the review is to summarize current understanding of the impacts of K-humate on wheat production and soil salinity.

## **Methods and Materials**

This narrative literature review provides an overview, summary, and synthesis of recent research related to the topic. Major scientific databases, including Scopus, Web of Science, Science Direct, and Google Scholar, were systematically searched to identify high-quality and recently published studies using relevant keywords and synonyms such as "growth," "production," "soil salinity," "wheat," "drought stress," and "yield." Peer-reviewed research and review articles published in English during the past two decades were included in the analysis. In contrast, non-peer-reviewed publications, conference abstracts, and studies published more than two decades ago were excluded. From an initial pool of approximately 50 selected papers, 27 studies were considered most relevant and were thoroughly reviewed for inclusion in the manuscript. Targeted keywords organized the selected articles, and pertinent information was identified, extracted, and highlighted. Subsequently, the extracted information was synthesized, paraphrased, and integrated throughout the manuscript to provide a comprehensive understanding of the subject.

## **Findings**

### ***Effects of K-humate on the Growth of Wheat***

Humic substances have been shown to positively influence several physiological attributes of plants, including increased chlorophyll content, reduced proline accumulation, and enhanced protein and carbohydrate levels, particularly under saline conditions (Mosaad et al., 2025). Similarly, the application of humalite in combination with recommended rates of NPK fertilizers had a positive overall effect on various wheat growth parameters under controlled environmental conditions (Rathor et al., 2024). Moreover, such treatments shortened the crop maturation period by approximately 2–3 days and increased plant height by 4–7 cm (Kassenova et al., 2025).

In addition, the combined application of humate with CO<sub>2</sub> has been reported to enhance nutrient uptake, accelerate phenological development, and promote vegetative growth, even under limited rainfall conditions (Kassenova et al., 2025). Potassium humate application, either alone or in combination with CO<sub>2</sub>, primarily stimulated vegetative growth and consistently reduced the maturation period by an average of 2–3 days (Kassenova et al., 2025). Furthermore, soil application of potassium humate at rates of 4 and 8 kg fed<sup>-1</sup> (1.038 acres), along with foliar application of potassium silicate at concentrations of 500 and 1000 ppm either individually or in combination, significantly enhanced the growth parameters of wheat plants (Salem et al., 2017).

### ***Effects of K-humate on the Yield of Wheat***

Wheat plants treated with 120% of reference crop evapotranspiration (ET<sub>o</sub>) combined with magnetic wheat grains and either potassium humate or potassium silicate produced the highest

grain yields, recording 6.83 and 6.73 t/ha, respectively (El-Metwally et al., 2025). Similarly, potassium humate application significantly increased grain yield under both zero potassium (Po) and moderate potassium fertilization (17.5 kg/ha) conditions (Yossif & Gezgin, 2020). The highest grain yield of 44.34 q ha<sup>-1</sup> was obtained with 100% recommended dose of fertilizer (RDF) combined with vermicompost (VC) at 3.0 t/ha, followed closely by 42.38 q ha<sup>-1</sup> in the treatment receiving 75% RDF plus VC at the same rate. Additionally, potassium humate applied at 3.0 kg/ha increased yields (Singh et al., 2019). Moreover, soil application of potassium humate at rates of 4 and 8 kg fed<sup>-1</sup> (1.038 acres), along with foliar application of potassium silicate at concentrations of 500 and 1000 ppm, either individually or combined, significantly enhanced yield components of wheat (Salem et al., 2017). The integrated microbiome-based K-Humate approach is a sustainable, eco-friendly biofertilizer strategy for improving crop yields (Mostafa et al., 2024).

Crop production with reduced chemical inputs has attracted considerable interest due to improvements in product quality (Mutlu & Tas, 2022). The combined application of 6% potassium humate and proline at 100 mg L<sup>-1</sup> significantly enhanced the concentrations of nitrogen (N), phosphorus (P), and potassium (K) in both wheat grains and straw, increased protein content, and resulted in the highest grain yield (Othman et al., 2020). Notably, the highest proline levels were observed in the control treatment, with proline concentrations decreasing as humic acid doses increased (Mutlu & Tas, 2022). Furthermore, application of potassium humate improved soil fertility and significantly increased both the quantity and quality of the crop (Mostafa et al., 2024).

### ***Effects of K-humate on Soil Properties and Nutrient Availability***

The application of rice husk biochar combined with potassium humate has demonstrated positive effects on soil properties (Thu et al., 2025). K-humate application exhibited significant improvements in mean weight diameter across different soil types (Imbufe et al., 2005). Potassium humate significantly increased the proportion of soil macroaggregates and the mean weight diameter of water-stable aggregates (Wei et al., 2021). Thus, potassium humate has potential as an effective soil conditioner, enhancing aggregate stability in acidic and sodic soils and mitigating the adverse impacts of cyclic seasonal wetting and drying (Imbufe et al., 2005). Furthermore, the co-application of molasses, potassium humate, and compost tea resulted in superior improvements in bulk density, soil porosity, electrical conductivity, cation exchange capacity, and nitrogen uptake and recovery compared to other treatments (Sorour et al., 2021). Overall, various organic amendments significantly influenced key physico-chemical soil properties, including bulk density, cation exchange capacity, and electrical conductivity (Sorour et al., 2021).

Organic amendments have been shown to significantly improve the availability of essential soil nutrients, including nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), and zinc (Zn) (Sary et al., 2024). Notably, nitrogen loss was substantially reduced at the highest application rates of biochar, bentonite, and potassium humate, with reductions in leachate nitrogen of 36.07%, 35.82%, and 23.81%, respectively (Abdeen, 2020). Application of K-Humate significantly enhanced the phyto-availability of nitrogen (N-RAQs) and

phosphorus (P-RAQs) up to a rate of 2 g K-Humate per kg of soil across various salinity levels in three tested soils (Sherif & Hedia, 2015).

Moreover, the combined use of rice husk biochar and potassium humate increased soil phosphorus content and significantly increased the availability of key nutrients (N, P, and K) (Thu et al., 2025). This treatment also positively influenced soil pH, further enhancing nutrient accessibility (Thu et al., 2025). Humic products help plants take up and use nutrients more effectively by reducing nutrient losses and increasing their availability in the soil (Rathor et al., 2024). The application of humic acid was found to improve soil nitrogen availability and enhance nutrient uptake during wheat's flowering stage (Rathor et al., 2024).

### ***Effects of k-humate on Soil Salinity and Drought Stress***

Soil salinity adversely affects nutrient phytoavailability and plant growth, particularly in arid and semi-arid regions (Sherif & Hedia, 2015). Humic substances, produced through the decomposition of organic matter, have been shown to enhance plant resilience to environmental stresses (Abu-Ria et al., 2024). The integrated microbiome-based K-Humate approach offers a sustainable, eco-friendly biofertilizer strategy to improve soil health in saline environments (Mostafa et al., 2024). Investigating the physiological and ecological functions of potassium humate holds considerable theoretical and practical significance for ameliorating saline soils and enhancing agricultural productivity (Wei et al., 2021).

Application of potassium humate and potassium silicate, either individually or in combination, plays a vital role in mitigating the negative effects of soil salinity (Salem et al., 2017). Potassium humate treatments applied at rates of 2.5, 5, 10, 15, 20, and 30 kg ha<sup>-1</sup> reduced salt accumulation within the 0–40 cm soil depth by 63.0%, 67.9%, 68.9%, 70.5%, 75.4%, and 100%, respectively, compared to untreated soils (Wei et al., 2021). Furthermore, the detrimental impacts of salinity were alleviated through soil amendments involving biochar, foliar application of potassium humate, or their combined application (Abdelrasheed et al., 2021). In the absence of humic acid, drought stress reduced maize biomass by 37.0% and 58.7% under low and high drought levels, respectively, compared with 21.2% and 32.3% in sorghum (Abu-Ria et al., 2024).

## **Discussion**

The increase in wheat growth parameters with K-humate may be due to improved availability of macro- and micronutrients in the soil, facilitated by its application. Additionally, the application of K-humate may improve the assimilation and translocation of nutrients in wheat plants, leading to faster growth by increasing carbohydrates produced during photosynthesis. Similar findings were reported by Kassenova et al. (2025), who stated that the application of K-humate with CO<sub>2</sub> increases nutrient uptake, accelerates phenological development, and promotes vegetative growth, even under limited rainfall conditions.

Yield and yield components in wheat may also increase due to the availability of soil nutrients provided by K-humate application. It may also be due to improvements in the wheat source, supported by fast growth and the provision of more carbohydrates to the sink, caused by the application of K-humate, which can stimulate plant metabolism. El-Metwally et al. (2025) and

Yossif & Gezgin (2020) also reported that the application of K-humate increased wheat grain yield. Wheat grain quality and nutrient content improvement were due to the translocation of macronutrients from the leaves to the spike of the wheat, which was improved and stimulated by the application of K-humate to the soil or foliar application. Mostafa et al. (2024) confirmed that integrating cyanobacteria, yeast, and mycorrhizae with K-humate and 25% mineral NPK fertilizer increased wheat productivity.

The reduction of the negative effects of salinity may result from reduced salt accumulation in the soil and improved plant tolerance to saline conditions, both enhanced by the application of K-humate. Abu-Ria et al. (2024) and Wei et al. (2021) also reported similar findings: the application of K-humate enhances plants' ability to withstand environmental stresses and improves the quality of saline soils. The drought stress in wheat is also reduced by the application of K-humate, due to the increased soil moisture and improved wheat plant's ability to withstand drought. Abu-Ria et al. (2024) also reported that humic acid priming increases drought tolerance in maize, sorghum, and other crops.

The application of K-humate alone or in combination with other organic and chemical fertilizers in the soil not only improves soil properties, thereby enhancing wheat growth, yield, and even quality by making nutrients available, but also stimulates wheat plant roots to take up macro- and micronutrients. Moreover, K-humate stimulates enzyme activity and improves metabolism in plant cells, leading to rapid growth.

## Conclusion

Humic acid ingredients and bio-stimulants, such as K-humate, alone or in combination with other bio-stimulants, increase wheat growth parameters under normal or stressed conditions. In addition to the application of K-humate, combined with other bio-stimulants or nutrients, such as P, wheat growth increased significantly. Furthermore, K-humate also increases wheat grain nutrient content and quality. Moreover, the application of K-humate also improves soil properties. For instance, the application of K-humate, molasses, and compost tea together improved soil physical and chemical properties, including bulk density, soil porosity, electrical conductivity, and cation exchange capacity. In the meantime, K-humate increases the availability of N, P, and K in the soil, enhances nutrient uptake by wheat, and reduces nutrient loss from the soil.

On the other hand, the application of K-humate in the saline soil has reduced the adverse effects of salinity and reduced the soil accumulation rate. Similarly, K-humate increases drought tolerance in cereals, including wheat. It is concluded that K-humate not only improved wheat growth, yield, and quality but also increased soil properties. As well as playing a crucial role in reducing salinity and drought stresses. Thus, the application of K-humate is recommended alongside regular fertilizers to improve wheat production, especially in arid regions and on saline soils. Further research is also recommended to study the specific effects of different types, amounts, and application methods on wheat production in local arid regions in saline soils.

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