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Impacts of Humic Acid on Growth and Yield of Wheat: A Review

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ABSTRACT

Wheat (*Triticum aestivum* L.) is a crucial crop, providing 20% of caloric intake for many populations worldwide. Soil organic matter, an essential component of soil, directly influences soil fertility and texture. Humic substances, derived from biomolecules' physical, chemical, and microbiological transformation, are integral to soil humus. Humic acid has become a standard method for enhancing crop growth, yield, and soil fertility. While the effects of humic acid on wheat have been extensively studied, the optimal type and application method for wheat cultivation remain undetermined. This review investigates sustainable wheat production methods using humic acid to mitigate the negative impacts of chemical fertilizers and climate change factors. Research indicates that humic acid significantly increases wheat plant growth parameters: shoot length (18%), root length (29%), shoot dry weight (76%), root dry weight (100%), and chlorophyll content (96%). Moreover, humic acid substantially improves wheat yield and yield components, including spike length (14.66%), number of spikes per square meter (28.73%), number of spikelets per spike (23.52%), and 1000-grain weight (23.90%). As a sustainable organic substance, humic acid application offers a promising approach to improving wheat production. This method could help meet the food demands of the growing global population, particularly in countries like Afghanistan, where food security is a pressing concern.

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INTRODUCTION

Cereal crops are the primary staple food worldwide, directly contributing more than 50% of the total human daily staple foods (El-Hashash et al. 2022, Salihi, 2024). Wheat is one of the most significant crops worldwide, providing 20% of the calories for a large population worldwide (Awad et al., 2022). Wheat also provides essential amino acids, minerals, vitamins, beneficial phytochemicals, and dietary fibers for the human diet around the globe (Shewry, 2009). Wheat is mainly consumed by humans and is cultivated in more than 100 countries worldwide (Shewry, 2009). Wheat is also the staple food in the Afghan food basket and is central to food security in Afghanistan (Popal, 2024). On the other hand, the world's total wheat cultivated area is nearly 1.425×10^{-6} hectares; the total wheat production globally is 9.279×10^{-6} tons, while the average output is 6.511 tons per hectare (Awad et al. 2022). Furthermore, the world requires around 840 million tonnes of wheat by 2050 from the current production level of 642 million tonnes, and it has to be achieved with less land and resources through genetic, physiological, and agronomic interventions, particularly resource conservation technologies (Sharma et al. 2015).

Soil organic matter is one of the most essential parts of the soil, and it directly affects soil fertility and texture (Khaled & Fawy, 2011). Humic substances are part of humus in soil organic matter produced from biomolecules' physical, chemical, and microbiological transformation (Mindari et al., 2019). Humic acids are an essential soil component that can improve nutrient availability and impact other important chemical, biological, and physical properties of soils (Khaled & Fawy, 2011). Humic acid fertilizer incorporation is a standard method for improving crop growth, yield, and soil fertility (Zheng et al., 2022). Similarly, Humic acid not only positively affects the growth and yield of plants but also affects grain quality. Noroozisharaf & Kaviani (2018) reported that Humic acid is a natural biological organic that has a high effect on plant growth and quality.

Moreover, it is also reported that applying Humic acid increased wheat plant growth parameters such as shoot length, root length, shoot dry weight, root dry weight, and chlorophyll content by (18%),(29%),(76%), (100%) and (96%) respectively (Arjumend et al., 2015). Iqbal et al. (2016) reported that Humic acid (15 Kg ha^{-1}) with nitrogen (150 Kg ha^{-1}) increased productive tillers m^{-2}, 1000 grain weight, grain $spike^{-1}$, grain yield, biological yield, and harvest index. Furthermore, Humic acid significantly increased wheat yield and yield components such as spike length (14.66%), number of spike m^{-2} (28.73%), number of spikelets per spike (23.52%), and 1000 grain weight (23.90%) (Gomaa et al., 2015). Moreover, spraying the wheat plant with 15 g/L of Humic acid increased plant height, flag leaf area, and leaf chlorophyll content in a wheat plant (Alfatlawi & Alrubaiee, 2020).

Humic acid also significantly increased the roots' fresh and dry weight; for example, by using 54 mg HA L^{-1}, the wheat dry matter yield of the shoot increased by 22% (El-Hashash et al. 2022). The treatment with (90 Kg P2O4 ha^{-1}) and (5Kg HA ha^{-1}) also increased wheat plant height (89cm) than the control (77cm) (Shafi et al. 2020). Furthermore, adding a single superphosphate and Humic acid improved wheat plant height and spike length (Shafi et al. 2020). Moreover, applying Humic acid with the (60 mg kg^{-1} soil) treatments significantly increased wheat plant height, shoot fresh, and dry weight by 10%, 25%, and 18%, respectively (Tahir et al. 2011).

The population of wheat-consuming countries and wheat consumption per capita are increasing rapidly. Hence, wheat production for the current growing world population is not enough. Furthermore, due to industrialization, global warming, and heat stress, worldwide wheat production is affected negatively. Moreover, continuous use of chemical fertilizers accelerates the depletion of soil organic matter and impairs soil's physical and chemical properties, causing micronutrient deficiencies. There is an urgent need to increase production using sustainable methods to fulfill the wheat demands of the world's growing population.

The effects of humic acid on wheat production have been studied worldwide; however, the best type of humic acid and the proper method of applying humic acid to the soil for wheat is still not stated at the same time for wheat plants. The study focuses on sustainable wheat production using Humic acid to increase wheat growth and yield and reduce the adverse effects of chemical fertilizers worldwide. Humic acid can improve wheat production sustainably to produce sufficient food for the world's increasing population. This review article will facilitate future research and improve wheat production using sustainable methods such as humic acid. The main objectives of the review are as follows:

1. To address Humic acid's impact on wheat growth and yield.
2. To investigate the most beneficial type and method of application of humic acid in wheat.

METHODS & MATERIALS

The current study employs a comprehensive review method. The process involves several steps:

1. Identification of target journals: International, reputable journals in the field of study were identified using various prominent search engines.
2. Literature collection: These journals' most recent relevant published journals were searched, downloaded, and organized using Mendeley reference management software.
3. In-depth analysis: Each manuscript was carefully studied, with pertinent information marked, collected, summarized, cited, and paraphrased.
4. Data integration: The gathered information was systematically incorporated into different sections of the manuscript as needed, ensuring a cohesive and well-supported review.

FINDINGS

Importance of Wheat in Human Nutrition

Cereal crops are the primary staple food worldwide, directly contributing more than 50% of the total human daily staple foods (El-Hashash et al., 2022). The first wheat cultivation occurred about 10000 years ago, as part of the 'Neolithic Revolution,' which transitioned from hunting and gathering food to settled agriculture (Shewry, 2009). Wheat is the most important crop worldwide, supplying about 20% of the foods worldwide (Awad et al., 2022). Wheat also contributes essential amino acids, minerals, vitamins, beneficial phytochemicals, and dietary fiber components to the human diet, particularly enriched in whole-grain products (Shewry, 2009).

The world's total cultivated wheat area is nearly 1.425 x 10^6 hectares, and the total wheat production globally is 9.279 x 10^6 tons, while the average output is 6.511 tons per hectare (Awad et al., 2022). Furthermore, the world will require around 840 million tonnes of wheat by 2050 from the current production level of 642 million tonnes, and it has to be achieved with less land and resources through genetic, physiological, and agronomic interventions, particularly resource conservation technologies (Sharma et al., 2015).

Benefits of Humic Acid for Plants and Soil Condition

As part of humus-soil organic matter, humic substances are compounds arising from biomolecules' physical, chemical, and microbiological transformation (humification) (Mindari et al., 2019). Soil organic contents are one of the essential parts that directly affect soil fertility and textures (Khaled & Fawy, 2011). Humic acid is decomposed organic matter that accumulates in ecological systems and enhances plant growth by chelating unavailable nutrients and buffering pH (Tahir et al., 2011). However, humic acids are effective agents that complement synthetic or organic fertilizers (Khaled & Fawy, 2011). Humic acids are also an essential soil component that can improve nutrient availability and impact other important chemical, biological, and physical properties of soils (Khaled & Fawy, 2011). However, The effects of humic substances on plant growth depend on the source, concentration, and molecular fraction weight of humus (Saha et al., 2013).

Moreover, Humic acid also has the advantage of increasing the yield and quality of grains (Awad et al., 2022). On the other hand, it is reported that humic acids are technically not fertilizers, although some consider them fertilizers (Khaled & Fawy, 2011). Regular humic acid use often reduces the need for fertilization due to the soil and plant's ability to use it better (Khaled & Fawy, 2011). Humic acid improves the soil's physical, chemical, and biological properties and influences plant growth by controlling the growth of roots (Saha et al., 2013). Humic acid not only positively affected the growth and yield of plants but also affected grain quality. Noroozisharaf & Kaviani (2018) reported that Humic acid is a natural biological organic that dramatically affects plant growth and quality.

It is also reported that organic fertilizers such as humic acid can improve soil fertility (Ehsan et al., 2016). Furthermore, it is suggested that humic acid has the potential as a low-cost organic fertilizer to improve soil fertility on a sustainable basis, resulting in high crop growth and yield (Khan et al., 2010), such as the most important results from the study obtained that by the combining of the chemical fertilizer with Humic acid will reduce up to 50% expenses of fertilizer use.

Effects of Humic Acid on the Growth of Wheat

It is reported that all parameters of the wheat studied with all three treatments of the Humic acid were demonstrated higher (El-Hashash et al., 2022). The results also revealed that the application of Humic acid increased wheat plant growth parameters such as shoot length (18%), root length (29%), shoot dry weight (76%), root dry weight(100%), and chlorophyll content (96%) (Arjumend et al., 2015). Furthermore, adding a single superphosphate and Humic acid improved wheat plant height and spike length (Shafi et al., 2020). Moreover, Humic acid application increased wheat growth and nutrient uptake (Tahir et al., 2011).

Spraying wheat plants with the 15 g/L increased plant height, flag leaf area, and chlorophyll content (Alfatlawi & Alrubaiee, 2020). The three years of collected data from the wheat plants also significantly increased plant height, number of tillers per plant, and spike length with applying (NPK+ HA liquid) treatment (Ehsan et al., 2016). Humic acid also increased the roots' fresh and dry weight significantly; for example, by using 54 mg HA L-1, the wheat dry matter yield of the shoot increased by 22% (El-Hashash et al., 2022).

Humic acid (15 Kg ha^{-1}) with nitrogen (150 Kg ha^{-1}) increased plant height, tillers m^{-2} (Iqbal et al., 2016). Moreover, applying Humic acid with the (60 mg kg-1 soil) treatments significantly increased wheat plant height, shoot fresh, and dry weight by 10%, 25%, and 18%, respectively (Tahir et al., 2011). The treatment with (90 Kg P_2O_4 ha^{-1}) and (5Kg HA ha^{-1}) also increased wheat plant height (89cm) than the control (77cm) (Shafi et al., 2020). As well as the spike length was also significantly increased in wheat plants by Humic acid application (Shafi et al., 2020). The results also demonstrated that all Humic substances treatments have considerably affected the leaf Fe, Mn, Zn, and Cu contents (Awad et al., 2022).

Effects of Humic acid on Yield and Yield Components of Wheat

The humic acid application resulted in a significant increase in the grain yield (2540 Kg ha^{-1}) of wheat than the control (2338Kg ha^{-1}) (Shafi et al., 2020). Furthermore, the Humic substances with application rates of (4.03 ton ha^{-1}) resulted in the highest yield of durum wheat (Pacuta et al., 2021). Moreover, the highest grain yield was recorded using 60 Kg Humic acid ha^{-1} under normal and dough-stress conditions (El-Hashash et al., 2022). It is also reported that urea with Humic acid increased the wheat grain, straw, and total above-ground biomass of mature wheat by 5.15-16.93%, 5.32-20.23%, and 5.23-18.38% respectively (Gao et al., 2022).

Furthermore, . (2010) reported that in the first growing season (2007-2008), the combination of humic acid increased rainfeed wheat yield by 46.9% compared to the control. In the second year (2008-2009), applying 3 Kg ha^{-1} Humic acid significantly increased grain yield by 24% and saved 100% of the expenses of chemical fertilizer (Khan et al., 2010). Moreover, the grain yield recorded 67.5 Kg P_2O_5 ha^{-1} with HA, comparable statistically with 112.5 P_2O_5 ha^{-1} applied as commercial SSP (Shafi et al., 2020). Also, the biological yield (grain+ straw yield) was increased significantly under the liquid fertigation fertilizer and liquid foliar fertilizer of Humic acid along wight 50 Kg urea application. In contrast, the highest yield was recorded using 12 liters of liquid fertilizer, 50 Kg of urea, and foliar fertilizer as a foliar spray solution (Ahmad et al., 2018). The biological yield, grain yield, and harvest index of wheat are also significantly affected by Humic acid application (Dinçsoy & Sönmez, 2019).

However, the plant-derived humic acid (PDHA) and coal-derived humic acid (CDHA) application with 50 mg Kg^{-1} in two different types of alkaline soil increased grain yield by 21% and 11%, respectively, as well as the grain yield of the wheat plant increased significantly by 10% and 22% respectively, with the application of 100 mg/kg of PDHA and CDHA in both types of soil(Khan et al., 2018). As well as the foliar application of the bioactive substances increased durum wheat yield significantly while maintaining or increasing the quality of the grain (Pacuta et al., 2021). On the other hand, adding Humic acid increased P efficiency, improving crop yield and plant P uptake in calcareous soils (Shafi et al., 2020). Moreover, the application of Humic acid also increased K concentration in the soil after crop harvest (Tahir et al., 2011). The seaweed and Humic-based preparations were foliar sprayed at the vegetative stage of durum wheat three times, which also caused an increase in grain yield compared to the control (Pacuta et al., 2021).

Yield components of wheat, for instance, 1000 grain weight (8-16%), biological yield (18-36%), dry matter yield (15-25%), and grain yield (19-48%) increased significantly and respectively by Humic acid application (Arjumend et al., 2015). Moreover, by using (4 kg/fed, 1feddan=0.4 ha), Humic acid increased significantly wheat yield and yield components such as spike length (14.66-15.56%), number of spike m^{-2} (28.73%), number of spikelet per spike (23.52%- 29.03%) and 1000 grain weigh (23.90%) (Gomaa et al., 2015). Furthermore, the results demonstrated that spraying wheat with 15 g/L increased the number of spikes per square meter, grains per spike, total grain yield, and biological yield (Alfatlawi & Alrubaiee, 2020). The spraying in the flowering stage also increased significantly the number of spikes per square meter, the number of grains per spike, total grain yield, and biological yield (Alfatlawi & Alrubaiee, 2020).

Humic acid (15 Kg ha^{-1}) with nitrogen (150 Kg ha^{-1}) increased productive tillers m^{-2}, 1000 grain weight, grain $spike^{-1}$, grain yield, biological yield, and harvest index (Iqbal et al., 2016). The usage of humic acid with 5 Kg ha-1 also increased grain per spike of the wheat plant significantly more than the control (Shafi et al., 2020). Humic acid application increased 1000 grain weight considerably than the control in the wheat plant (Shafi et al., 2020). Moreover, adding a single superphosphate and humic acid improved the wheat's number of grain spike-1, 1000 grain weight, grain, straw, and biological yield (Shafi et al., 2020). Moreover, the three years of collected data from the wheat plants also demonstrated a significant increase in grain per spike and 1000 grain weight under (NPK+ HA liquid) treatment (Ehsan et al., 2016). Also, urea with Humic Acid significantly increased the spike number per pot and 1000-grain weight (Gao et al., 2022).

DISCUSSION

Humic acid, technically not considered a fertilizer, is a soil conditioner used with fertilizer as complementary, as Kahled & Fawy (2011) stated. Humic acid stimulates plant growth due to improved nutrient availability and positively impacts the soil's properties. Similar findings were reported by Tahir et al., 2011 and Khaled & Fawy (2011). Furthermore, humic acid also affects plant growth and yield due to the improvement of the development of the roots and absorption of available nutrients in the soil, which causes plants to grow fast and increase yield. Nooroozisharaf & Kaviany (2018) also reported that humic acid positively affected plant growth and yield.

The increment of different wheat growth parameters such as shoot length, root length, shoot dry weight, root dry weight, leaf chlorophyll content, plant height, spike length, flag leaf area, and number of tillers per plant using different treatments and methods of application of Humic acid may due to fast cell division, and elongation that stimulated by Humic acid different application methods caused improvement of roots of wheat resulted in increases the photosynthesis rate and rapid growth. Furthermore, the rise in grain yield, biological yield, and yield components of wheat by the different methods of application of Humic acid and Humic acid with other fertilizers also may be due to the stimulation of photosynthesis rate resulting in high accumulation of carbohydrates and increasing yield and yield components. Similar results were also reported by Alfatlawi & Alrubaiee (2020),and Salihi et al., 2023.

Future Directions and Challenges in Applying Humic Acid to Wheat Plant

Since the Industrial Revolution, chemical fertilizers have been used for wheat plants to improve wheat growth and yield in developing countries; however, organic fertilizers, especially Humic acid, have not been considered. At the same time, it is reported that humic acid as a soil conditioner increased wheat growth and yield, soil fertility, nutrient uptake, micronutrient availability, and increased soil physical, chemical, and biological properties sustainably. It is also reported that using Humic acid will reduce the 50% of chemical fertilizers expenses for farmers. Currently, most developed and developing countries suffer from unfavorable soils due to the continuous use of chemical fertilizers and climate change negatively affecting soil properties worldwide. Furthermore, wheat production is not enough for the world's increasing population, and there is an urgent need to produce more wheat to fulfill wheat demands in the world and Afghanistan. In this regard, sustainable methods and substances are the most important in reaching the abovementioned target. Humic acid is the best option for all developing countries, including Afghanistan, to increase wheat production sustainably due to increased growth and yield of wheat, maintain soil fertility, and reduce the harmful effects of chemical fertilizers and climate on the soil and plants.

Furthermore, in most countries, humic acid is available locally in different types and shapes at lower prices than chemical fertilizers. However, there is a lack of knowledge regarding the benefits of humic acid for local farmers. Government and nongovernmental active agencies are recommended to extend the benefits of humic acid to wheat farmers and provide them subsidies to grow using humic acid to improve wheat production sustainably around the world and in Afghanistan.

CONCLUSION

Wheat is the world's most essential and first staple food, cultivated in over 100 countries. By 2050, the world wheat production is projected to be 200 tons more than current wheat production. The increase in wheat demand worldwide could be due to an increased population and wheat use per capita. Humic acid is one of the world's most critical organic substances that increase wheat growth and yield. Humic acid positively affected wheat growth and yield and improved soil fertility, condition, and nutrient uptake.

Furthermore, humic acid is a sustainable soil conditioner that reduces the adverse effects of chemical fertilizers used in the soil. Moreover, humic acid is derived from natural resources, is available in many types, can be applied in various methods, and is economical to the farmers. Besides, applying humic acid reduces the amount of chemical fertilizer used and the expenses, which is beneficial for soil conservation. The application of humic acid increased most wheat growth parameters such as shoot length, root length, shoot dry weight, root dry weight, and chlorophyll content. Humic acid increased wheat yield parameters such as 1000 grain weight, biological yield, dry matter, and grain yield. The study stated that granule is the most important and influential type of humic acid for wheat plants, affecting wheat plant growth and yield among the various kinds of humic acid. It is also stated that the most significant method of application of Humic acid for wheat is the application of Humic acid with soil before wheat cultivation. It is suggested that further research should be conducted on wheat in unfavorable soil and climate change conditions.

Conflict of Interests: The author declare that there is no conflict of interests.

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