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Impacts of Humic Acid on Growth, Yield, and Quality of Tomato: A Review

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ABSTRACT

Tomato (*Solanum lycopersicum*) is one of the most adaptable, popular, and widely consumed vegetable crops in the world. However, current production levels of tomatoes fall short of consumer needs. Enhancing soil fertility presents a viable solution to address the issue of low productivity in tomato cultivation. Humic acids (HA) are organic molecules that significantly improve soil characteristics, plant growth, yield, and quality. There was limited information available in previous studies regarding the issue; therefore, the review was conducted to investigate the issue in greater detail. The review aims to consolidate existing knowledge on the topic and encourage further investigation to refine agricultural practices and enhance crop production. In the narrative literature, keywords related to the topic investigated in popular databases over the last three decades were screened for relevant papers, and the information was presented in different sections of the manuscript. The application of humic acid has positively influenced several parameters, including growth, development, yield, and quality of tomatoes. Humic acid increased the stem diameter, number of leaves per plant, and plant height. Additionally, humic acid topically improved fruit weight, fruit diameter, fruit number per plant, and yield. Furthermore, skin color, lycopene content, fruit juice acidity, ascorbic acid, and total soluble solids were all markedly improved by applying humic acid. The information synthesized here may benefit policymakers, agricultural advisors, and experts in the field, supporting the development of effective strategies for sustainable tomato production using humic acid.

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INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the most adaptable, popular, and widely consumed vegetable crops in the world. As a member of the genus *Lycopersicon* within the *Solanaceae* family, it belongs to a relatively small genus in the large and varied family, which includes about 90 genera (Usman, 2015). Tomatoes are versatile and can be eaten raw in salads or, more frequently, added to savory stews, pure sauces, juices, and ketchup. Their vivid color enhances the appeal of green salads, and they are great flavorings for soups and refreshing additions to beverages (Ilodibia & Chukwuma, 2015).

Grown from the wild tomato *Lycopersicum esculentum* var. caraciform, tomatoes are a staple in many kitchens around the world and have great dietary and cultural significance. In addition to their nutritional value, tomatoes, which are high in vitamins A and C and minerals like calcium, phosphorus, and iron, may also have therapeutic uses, such as preventing cancer and treating heart disease (Mallick, 2021; Friedman, 2013). Lycopene, ascorbic acid, and ß-carotene, which are prized for their vivid colors and mouthwatering flavors, are health-promoting gems that tomatoes give us (Kumar et al., 2013). Carotenoid, a non-pro-vitamin A, is the focus of attention due to its anticancer properties, while lycopene is praised as an antioxidant powerhouse (Yin et al., 2019). It ranks second in the world after potatoes and is one of the most widely consumed and essential vegetables (FAOSTAT, 2023). Tomato yield variability persists despite the crop's nutritional value and is frequently ascribed to variables like changes in soil fertility. Optimizing soil fertility is essential in efforts to increase food security and achieve agricultural development goals (Ola, 2024).

Under ongoing intensive cropping practices, the use of synthetic fertilizers by itself does not improve crop productivity status; however, the addition of organic materials to chemical fertilizers improves soil physical characteristics and sustains higher soil fertility status with higher yield production (Elankavi et al., 2020). Humic acid is one of the largest organic compounds in terms of molecular weight and plays a significant role in several agronomic parameters and soil characteristics (Ampong et al., 2022). Humic acid is primarily made from the decomposed waste products of plants and animals. Recently, Humic acid has become a standard method for enhancing crop growth, yield, and soil fertility (Salihi et al., 2024). It has several important functions in agricultural systems, including improving the biochemical and physical characteristics of soil by increasing its texture, structure, microbial activity, and water-holding capacity (Nardi et al., 2021; Shah et al., 2018); increasing the availability of micronutrients in the soil as a chelating agent and increasing the uptake of nutrients by plants (Yang et al., 2021); lowering the intake of heavy metals that are harmful to plants (Wu et al., 2017).

By increasing growth-promoting hormones such as cytokinin and auxin, which support nutrient metabolism, stress tolerance, and photosynthesis activity, humic acid application also enhanced crop growth (Canellas et al., 2020; Jindo et al., 2020). Furthermore, humic acid benefits plant cell membranes, promoting increased protein synthesis, increased mineral transport, increased enzyme activity, decreased activity of harmful elements, and an increased microbial population (Khaled & Fawy, 2011). Additionally, the application of humic acid increased the stem diameter (1.9 cm), number of leaves per plant (45), and plant height (264.6 cm) (Suliman et al., 2020). Additionally, Yildimir (2007) found that applying 20 milliliters per liter of humic acid topically improved tomato yield, early yield, mean fruit weight, fruit diameter, and fruit number per plant. Furthermore, tomato quality parameters like skin color, lycopene content, fruit juice acidity and pH, ascorbic acid, and total soluble solids were all markedly improved by applying humic acid at the recommended dosage (Rajendiran & Purakayastha, 2014).

The current production of tomatoes is not fulfilling market demand, and their productivity is low. Furthermore, due to the excessive application of mineral fertilizers in tomato production, environmental problems have arisen. In order to fulfill the demand for tomatoes in the market, increase productivity, and avoid excess use of mineral fertilizer, it is crucial to use bio-stimulants as a sustainable approach in tomato production. While Humic acid is a natural organic fertilizer and a bio-stimulant that has the potential to improve tomato growth, yield, and quality sustainably. Thus, the application of humic acid not only avoids soil and water pollution, but also increases the growth, yield, and quality of tomato. Moreover, the application of humic acid improves soil fertility, making the availability of nutrients in the soil for plants to absorb and transport into plant tissues. There was limited information regarding the topic in the previous literature, and it was necessary to investigate the impacts of Humic acid on tomato production deeply. Thus, the current review was conducted to explore and describe the significant impacts of humic acid on the growth, yield, and quality of tomato.

METHOD AND MATERIALS

The narrative literature was conducted in order to provide an overview, synthesizing, summarizing, and interpreting existing literature on the impacts of Humic acid on the growth, yield, and quality of tomato. The purpose of the review was to describe and discuss relevant literature from a theoretical point of view and identify themes and trends accordingly. To search for quality, recently published, and relevant papers, the most popular databases, such as Scopus, Web of Science, ScienceDirect, and Google Scholar, were utilized to search for keywords related to the topic, including growth, Humic acid, Quality, Tomato, and Yield. The review included peer-reviewed journal research and review articles published in the last three decades, written in English. Exclusion criteria included non-peer-reviewed articles, conference abstracts without complete data, studies older than 30 years, and manuscripts that were not relevant to the key word of the topic. A total of 75 papers were selected from different sources, and about 60 papers were reviewed in the paper. Then, the papers most relevant to the topic in terms of growth, yield, and quality of tomatoes were targeted, organized, and screened, with relevant information highlighted and extracted. Then the information is paraphrased, summarized, and stated in different parts of the manuscript in order to provide a fresh concept on the issue.

FINDINGS

Structure, Properties, and Function of Humic Acid

Humic acid's structures are linkable to their functions (Rupiasih, 2005; Garciá et al., 2016; García et al., 2019; Nardi et al., 2021; van Tol de Castro et al., 2021). The primary Humic acid functional groups that improve soil physical and chemical characteristics and plant growth are the COOH and OH functional groups (Figure 1) (De Melo et al., 2016; Nardi et al., 2021). When these functional groups dissociate, polar and nonpolar ends—the hydrophilic and hydrophobic portions, respectively—are produced; both ends are involved in the processes that provide beneficial Humic acid functions (Figure 2). Phenolic (OH) and carboxylic (COOH) groups are the most common functional groups in the Humic acid structure, even though it contains many others (Figure 1) (Nardi et al., 2021). While the hydrophobic end is associated with repelling purposes, the hydrophilic end is mainly involved in chelating functions (Davies et al., 2001). According to De Melo et al. (2016), humic acids with low molecular weight (LMW) have more carboxylic and phenolic functional groups than Humic acid with high molecular weight (HMW).

The polar end of the anionic portion forms complexes with cationic metals through electrostatic bonding in the soil after the OH and COOH groups separate, keeping the metals in the soil (Figure 2). The water-loving, hydrophilic portion creates a micelle that raises the WHC of the soil. Conversely, the non-polar end deters water molecules, lowering water infiltration and enhancing the stability of clay aggregates (Billingham, 2012). LMW, which is effective in changing the biochemical properties of the soil, and HMW, which is effective in enhancing the physical conditions of the soil, have also been linked to the chelating ability of Humic acid (Yang & Antonietti, 2020).

An earlier finding by Garciá et al. (2016) demonstrated that Humic substances are aliphatic and aromatic functional groups stimulated root growth in rice seedlings, while a recent study by van Tol de Castro et al. (2021) reports that the aromatic and aliphatic functional groups of Humic acid were responsible for increasing N uptake and soluble sugars, which resulted in a corresponding yield increase in rice (Figure 1). When both HMW and LMW fractions of HA from vermicompost were applied to Arabidopsis and maize seedlings, an increase in root growth was also observed (Canellas et al., 2010). It has also been discovered that HA and HMW stimulate plasma membrane H+ ATPase, which enables LMWHA to co-transport nutrients and carry out additional biological functions in plants (Figure 1) (Nardi et al., 2021). A summary of Humic acid chemical and molecular components and functions is presented in Figure 1.

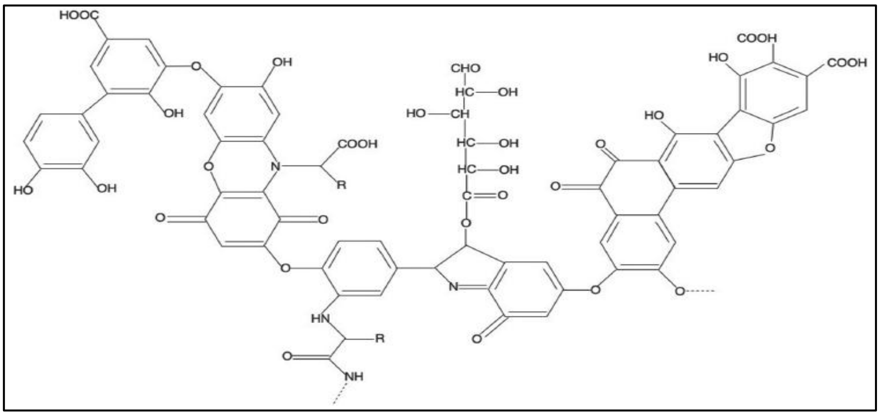

***Figure 1.** Molecular structure of humic acid (Stevenson 1994)*

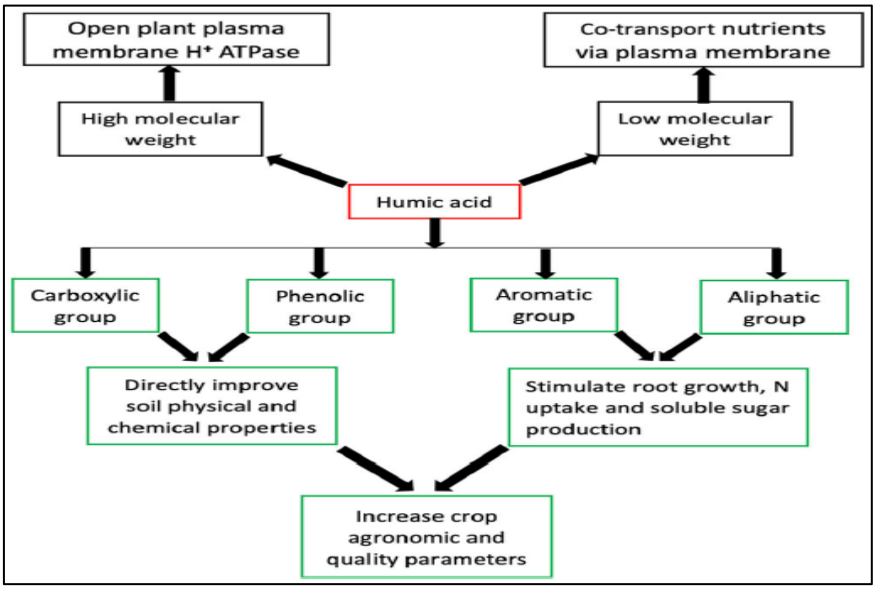

Figure 2. *Graphical representation of humic acid, its chemical and molecular constituents and functions (Ampong et al., 2022)*

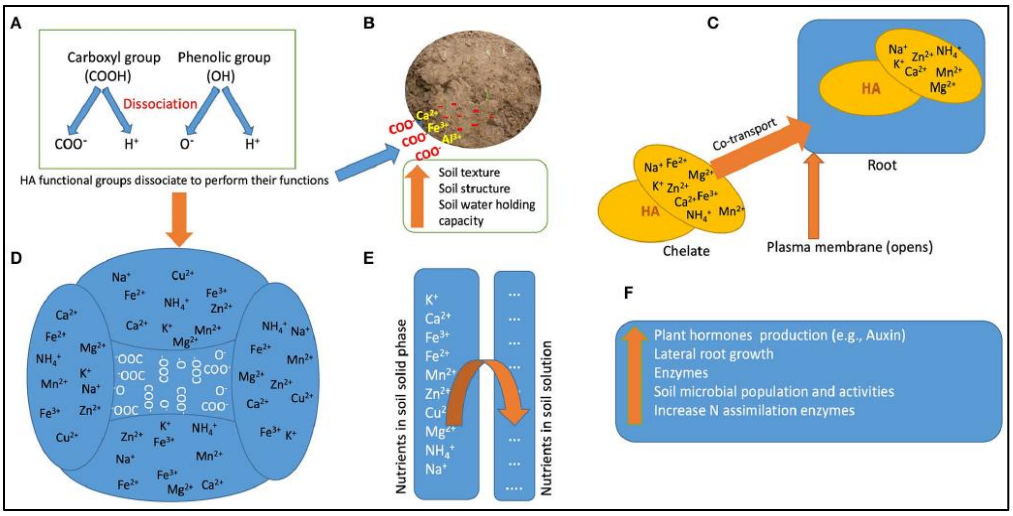

Figure 3. Model summarizing the mechanisms and functions of humic acids (HA) in soils and plants; (A) dissociation of functional groups of HA; (B) hydrophilic ends of dissociated groups form a bridge between metal ions and soil surface; (C) humic acids chelate cationic nutrients and transport them through root's plasma membrane; (D) hydrophilic ends of dissociated group attract cations (increase soil cation exchange capacity); (E) humic acids replenish nutrients in the soil solution (increase soil buffering capacity); (F) other functions of HA (Ampong et al., 2022).

Effects of Humic Acid on The Growth of Tomato

The combined application of mineral fertilizers and humic acid results in the slow release of complex nutrients, which helps in the subsequent absorption of nutrients and positively affects crop growth, development, and yield (Rose et al., 2014; Olaetxea et al., 2020). Moreover, foliar applications of Humic acid led to higher leaf and stem dry matter (Yildirim, 2007). Growth parameters such as the number of branches, plant height, and dry weight were significantly increased by humic acid or Calcium foliar applications. The interaction effect between humic acid and Calcium foliar application at 30 ppm humic acid +15 mM Calcium concentration gave the highest values of growth parameters as compared with either individual foliar application or control plants (Kazemi, 2014). Applying humic Acid increased tomato plant height (78.0 cm), number of leaves per plant (57.8), Fresh weight (250.2 g), and dry weight (75.1 g) of aerial parts (Abdelkader et al., 2019).

Humic acids also stimulated growth, and considerable changes occurred in the morphology of tomato (Dunoyer et al., 2022). It was determined that humic acid application significantly increased the shoot/root length, root fresh/dry weight, shoot fresh/dry weight, and chlorophyll values of plants under salt stress (Ural et al., 2023). Soil application of Humic acid at a higher dose, 1.5 g $L^{-1,}$ exhibited better results in all three tested tomato cultivars (Luanova, Savarona, and Tessera), in terms of their vegetative and reproductive growth (Alenazi & Khandaker, 2021).

Furthermore, Abdellatif et al. (2017) reported that the application of Humic acid has shown significant positive effects on the growth and productivity of tomato plants. The application of Humic acid at 14.4 kg·ha^{-1} enhanced vegetative growth traits such as plant height and fresh weight, as well as flowering attributes including the number of flower clusters and flowers per plant. Cimrin et al. (2010) also reported that the application of Humic acid at varying doses (0, 750, and 1500 mg/kg soil) in combination with phosphorus (0, 50, 100, and 150 mg/kg soil) significantly influenced early growth traits in pepper. The treatment with 150 mg phosphorus and 1500 mg/kg Humic acid resulted in the highest shoot fresh weight (4.82 g), root fresh weight (1.72 g), and improved cotyledon development, with maximum cotyledon length (18.73 mm) and width (7.80 mm). Similarly, Dursun et al. (2002) reported that humic acid application enhances growth and nutrient uptake in vegetable seedlings under greenhouse conditions.

Effects of Humic Acid on the Yield of Tomato

The Application of humic acid increased the early yield of tomato, the highest yield recorded in the foliar 20 ml/l HA treatment. Application of humic acid at the rate of 500 ppm caused the highest significant fruit weight (137 g) (Suliman et al., 2020). Helaly (2022) also reported that the best results for tomato yield were recorded when using magnetic water (MW) combined with 3 g/L of humic acid, 1 g/L of humic acid, and 2 g/L of humic acid. Humic acid doses showed significant effects on flowering (8 ml/L) and fruit set (4 ml/L) (Yildiz et al., 2023).

Humic Acid (700 ppm) also increased tomato flower number (48.1), fruit number (35.1), and fruit weight (64.0 g). Maximum tomato yield per plant (6 kg) was obtained with the application of 20 L/ha humic acid (Asri, 2021). Foliar application of Ca (15 mM) + HA (30 ppm) resulted in a high yield of tomato (25.36 t/ha) (Kazemi, 2014). Yildimir (2007) reported that foliar application of 20 ml/L of humic acid has better fruit diameter, fruit length, mean fruit weight, fruit number per plant, yield, and early yield in tomato. Padem and Ocal (1999) determined that humic acid application at different concentrations improved tomato yield. The humic acid applications caused a significant increase in yield, fruit weight, and fruit diameter of tomato (Asri et al., 2015). Humic acid treatment (50 mg/L HA + 100 mg/L GA) increased Chlorophyll content and improved photosynthesis, thus enhancing the yield (Haghighi, 2013).

The application of Grow Plex (a water-soluble fertilizer containing humic acid) at 90 g/L, combined with 75% of the recommended NPK dose, has been shown to maintain tomato yield while improving fruit quality, particularly in terms of average fruit weight. This approach also allows a 25% reduction in fertilizer use, contributing to reduced environmental pollution (Abdel-Mawgoud et al., 2007). Moreover, the application of humic acid at 14.4 $kg \cdot ha^{-1}$ significantly enhanced the reproductive performance and yield of tomato plants. The treatment increased the number of flower clusters and flowers per plant, as well as the number and weight of fruits, leading to improved early and total yields across both growing seasons (Abdellatif et al., 2017).

Effects of Humic Acid on The Quality of Tomato

Application of humic acid at the recommended dose significantly increased tomato and quality parameters such as skin colour, lycopene content, acidity, and pH of fruit juice, ascorbic acid, and total soluble solids (Rajendiran & Purakayastha, 2014). Application of humic acid at the rate of 500 ppm also improved tomato fruit quality via enhancing the concentrations of ascorbic acid, the level of vitamin C, and carotenoid content (Suliman et al., 2020). Demirtas et al. (2014) revealed that humic acid increases N, P, K, Fe, and Cu plant nutrients in tomato plants and significantly affects fruit quality. It also improved tomato fruit quality by enhancing the level of dry matter (7.6 %), sugar contents (5.8 °Brix), Ascorbic Acid (26.9 mg/100g), Maturity Index (12.61), Taste Index (1.09), and level of Nitrate (22.0 mg/kg) obtained from Ener-700. In comparison, Humic acid at the rate of 500 ppm gave the maximum Titratable Acidity (0.48%) and Carotenoids contents (4.89 mg/100g) (Abdelkader et al., 2019). Helaly (2022) found that the best results for tomato yield and quality were recorded when using magnetic water (MW) combined with 3 g/L of humic acid and 1 and 2 g/L of humic acid.

Humic acid doses showed significant effects on fruit phosphorus content (4 ml/L) and fruit potassium content (8 ml/L) (Yildiz et al., 2023). Soil application of HA at a higher dose, 1.5 g L^{-1}, exhibited better results in all three tested tomato cultivars (Luanova, Savarona, and Tessera), significantly improving the physicochemical quality of their fruits under a protected environment (Alenazi & Khandaker, 2021). Humic Acid (20 L^{-1}) also increased TSS (4.62%) and Titratable acidity in tomato (0.38%) (Asri, 2021). Foliar application of Ca (15 mM) + HA (30 ppm) resulted in the maximum TSS (5.14 °Brix), vitamin C (25.14), nitrate reductase activity (6.4), fruit firmness (3.91 kg/cm2), fruit lycopene content (2.14), and the lowest blossom end rot incidence (5%) (Kazemi, 2014). The study of Yildirim (2007) showed that foliar application of 20 ml/L of humic acid resulted in better TSS and ascorbic acid in tomato.

DISCUSSION

The application of Humic acid significantly increased tomato growth parameters, including plant height, number of branches, number of leaves per plant, stem diameter, shoot and root weight, fresh weight, and plant dry weight. Thus, it is explored that the growth of tomato was significantly and positively affected by Humic acid. Similar findings were also reported by Kazemi et al (2014), Abdelkader et al (2019), and Sulaiman et al (2020), who observed that the growth parameters of tomato increased with the application of humic acid. The observed increases in tomato growth parameters may be attributed to enhanced nutrient absorption, improved uptake of essential elements, and increased permeability of root cell membranes facilitated by humic acid. As well as, Humic acid application may also improve cell division, cellular nitrate uptake, and cell elongation, which causes fast cell division. Moreover, the increase in tomato growth may be attributed to higher chlorophyll content, which enhances photosynthesis, producing more carbohydrates that promote faster growth and development of the tomato plant.

Furthermore, tomato yield parameters, for instance, fruit weight, number of flowers, number, fruit weight, fruit diameter, fruit length, fruit number per plant, and yield increased with Humic acid. Sri (2021), Sulaiman et al (2020), Kazemi (2014), and Padem and Ocal (1999) also reported similar findings that the application of humic acid improved tomato yield. These increases can be attributed to enhanced photosynthesis activity and better allocation of assimilates toward the reproductive organs of the tomato plant. Increases the yield and yield attributes of tomato using humic acid, maybe also due to enhancement in physiological activities of the tomato plant, such as increment of cell metabolism, and improvement of enzyme activity, which are stimulated by the application of Humic acid and resulted in an increase in productivity.

Moreover, application of humic acid treatments also increased tomato quality parameters such as skin color, lycopene content, acidity, pH of fruit juice, ascorbic acid, total soluble solids, and level of vitamin C. Thus, it is stated that not only did the growth and yield of tomato increase by using Humic acid application, but also the quality of tomato. Similar findings were also reported by Rajendiran and Purakaystha (2014) and Demiratas et al (2024) that the quality of tomato increased by the application of Humic acid. The improvement in biochemical composition of fruits may be linked to enhanced nutrient uptake and metabolism, particularly of K, Ca, and Mg, which are vital for fruit development and quality. As well as the increases in tomato quality parameters, the increases are also attributed to the effective uptake of mineral nutrients, the efficiency of nitrogen in the presence of humic acid, and the improvements of roots and root hairs by Humic acid, which causes effective absorption of nutrients in tomato, improving the growth, yield, and quality.

While the application of Humic acid is one of the sustainable practices that reduces the amount of mineral fertilizer, it also improves farmers' expenses of mineral fertilizer, improves soil structure and fertility, which causes an increase in the absorption of available nutrients in the soil. This increases the growth, yield, and quality of the tomato. Despite this, it is crucial to consider that the effectiveness of Humic acid depends on soil type, application rate, application method, concentration of Humic acid products, source of Humic acid, and environmental conditions.

CONCLUSION

Humic acids have great potential in terms of tomato production. Various agronomical (growth, development, and yield), and quality (protein, ascorbic acid, TSS) properties have been improved by the application of humic acid. Humic acids have also been found effective in abiotic stress management and the production of secondary metabolites. The application of humic acids leads to a reduction in the use of recommended fertilizer doses, which eventually reduces the cultivation cost for farmers. Furthermore, various parameters such as root growth, shoot growth, and plant height are enhanced with the application of humic acid. Moreover, the application of humic acid in tomato production has not only positively affected the growth of tomatoes but also increased yield and improved tomato quality. For instance, both foliar and soil Humic acid treatments positively affected fruit characteristics, including fruit diameter, fruit length, mean fruit weight, and fruit number per plant. In addition, application of humic acid significantly increased tomato quality parameters such as skin color, lycopene content, acidity, and pH of fruit juice, ascorbic acid, and total soluble solids. Application of Humic acid along with the recommended doses of mineral fertilizer in order to improve growth, yield, and quality of tomato is recommended. It is also recommended that further research should be conducted on the effects of different types and application methods of Humic acid on the growth, yield, and quality of tomato in specific areas, as the narrative review did not follow the strict protocol of a systematic review. Thus, there were limitations in publication bias, language bias, and subjectivity involved in article selection and interpretation.

AUTHORS CONTRIBUTIONS

R.H. and M.S.S. conceptualized the review topic, conducted the literature review, and were responsible for writing and editing the original manuscript. M.F. provided technical guidance, critical review, and suggestions for manuscript improvement. M.K.Assisted in literature collection, formatting, and reference management. All authors reviewed and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

This manuscript is a narrative review and does not involve the generation or analysis of primary data. All data supporting the findings and discussions presented in this review are derived from previously published literature, which is appropriately cited throughout the manuscript. No new datasets were created or analyzed during the current study.

REFERNCES

Abdelkader, M. M., Puchkov, M. Y., Lysakov, M. A., Loktionova, E. G., & Suliman, A. A. (2019). Effect Of Crezacin And Humic Acid On Growth And Physiological Aspects Of Tomato Plants (*Lycopersicon esculentum*). *Journal of Applied Horticulture*, 21(1), 1. https://doi.org/10.37855/jah.2019.v21i01.11.

Abdellatif, I., Abdel-Ati, Y. Y., Abdel-Mageed, Y. T., & Hassan, M. A. M. M. (2017). Effect of humic acid on growth and productivity of tomato plants under heat stress. *Journal of Horticultural Research*, 25(2), 45–54. https:// doi.org/45–54. 10.1515/johr-2017-0022.

Abdel-Mawgoud, A. M. R., El-Greadly, N. H. M., Helmy, Y. I., & Singer, S. M. (2007). Responses of tomato plants to different rates of humic-based fertilizer and NPK fertilization. *Journal of Applied Sciences Research*, 3(2), 169–174. Link

Adani F., Sepagnol, M. & Nierop, K.G.J. (2006). Biochemical Origin And Refractory Properties Of Humic Acid Extracted From Maize Plants. *Biogeochemistry*, 82(1), 55-65.. https:// doi.org/ 10.1007/s10533-005-2902-7.

Alenazi, M.M. & Khandaker, M.M. (2021). Responses Of Tomato Hybrid Cultivars To Soil Application Of Humic Acid Under Greenhouse Conditions. *Brazilian Journal of Biology*, 84, 1-11. https:// doi.org/10.1590/1519-6984.252573.

Ampong, K., Thilakaranthna, M. S., & Gorim, L. Y. (2022). Understanding The Role Of Humic Acids On Crop Performance And Soil Health. *Front. Agron*., 4, 848621, 1-12. https:// doi.org/10.3389/fagro.2022.848621.

Asri, F.O, Demirtas, E.I. & Ari, N. (2015). Changes In Fruit Yield, Quality And Nutrient Concentrations In Response To Soil Humic Acid Applications In Processing Tomato. *Bulg. J. Agric. Sci*., 21, 585-591. Link

Asri, F.O. (2021). The Importance of Humic Substances in Tomato Production. *Freseniuce Environmetal bulletin*, 30, 4155-4162 Link

Canellas, L. P., Canellas, N. O., da S. Irineu, L. E. S., Olivares, F. L., & Piccolo, A. (2020). Plant Chemical Priming By Humic Acids. *Chemical and Biological Technologies in Agriculture*, 7, 1-17. https:// doi.org/10.1186/s40538-020-00178-4.

Canellas, L. P., Piccolo, A., Dobbss, L. B., Spaccini, R., Olivares, F. L., Zandonadi, D. B.,. (2010). Chemical Composition And Bioactivity Properties Of Size-Fractions Separated From A Vermicompost Humic Acid. *Chemosphere*, 78, 457-466. https:// doi.org/10.1016/j.chemosphere.2009.10.018.

Cimrin, K. M., Turkmen, O., Turan, M., & Tuncer, B. (2010). Phosphorus and humic acid application alleviate salinity stress of pepper seedling. *African Journal of Biotechnology*, 9(36), 5845–5851. Link

Davies, G., Ghabbour, E. A., & Steelink, C. (2001). Humic acids: Marvelous products of soil chemistry. *Journal of Chemical Education*, 78(12), 1609. https://doi.org/pubs.acs.org/doi/abs/10.1021/ed078p1609.

De Melo, B. A. G., Motta, F. L., & Santana, M. H. A. (2016). Humic Acids: Structural Properties And Multiple Functionalities For Novel Technological Developments. *Mater. Sci. Eng. C.*, 62, 967-974. https:// doi.org/10.1016/j.msec.2015.12.001.

Demirtaş, E., Öktüren Asri, F., & Arı, N. (2014). The Effects Of Humic Acid On Nutrient Status Yield And Quality Of Tomato. *Derim*, 31(1), 1-16. Link

Dunoyer, A. A. T., Castillo, F. C., & Camargo, J. M. (2022). Effect Of Humic Acid On The Growth Of Seedling Tomato (*Solanum lycopersicum*) And Melon (*Cucumis melo*). *Revista Ambiente & Água*, 17(4), 1-11. https:// doi.org/10.4136/ambi-agua.2808.

Dursun, A., Güvenç, I., & Turan, M. (2002). Effects of different levels of humic acid on seedling growth and macro and micronutrient contents of tomato and eggplant. *Acta Agrobotanica*, 55(2), 81-88. Link

Elankavi, S., Nambi, J., Ramesh, S., Jawahar, S., & Lavanya, K. (2020). Influence Of Different Doses Of Fertilizers And Foliar Spray Of Nutrients On Yield And Yield Attributes Of Rice. *Annals of the Romanian Society for Cell Biology*, 1127-1134. Link

FAOSTAT. (2023). Production: Crops and livestock products. Accessed on 26th June 2023. Link

Friedman, M. (2013). Anticarcinogenic, Cardioprotective, And Other Health Benefits Of Tomato Compounds Lycopene, A-Tomatine, And Tomatidine In Pure Form And In Fresh And Processed Tomatoes. *Journal of Agricultural and Food Chemistry*, 61(40), 9534-9550. https://doi.org/ 10.1021/jf402654e.

Garciá, A. C., De Souza, L. G. A., Pereira, M. G., Castro, R. N., Garciá-Mina, J. M., Zonta, E., et al. (2016). Structure-Property-Function Relationship In Humic Substances To Explain The Biological Activity In Plants. *Sci. Rep*., 6, 20798. https:// doi.org/10.1038/srep20798.

García, A. C., van Tol de Castro, T. A., Santos, L. A., Tavares, O. C. H., Castro, R. N., Berbara, R. L. L., et al. (2019). Structure-Property-Function Relationship Of Humic Substances In Modulating The Root Growth Of Plants: A Review. *J. Environ. Qual*., 48, 1622-1632. https:// doi.org/10.2134/jeq2019.01.0027.

Haghighi, M., & Teixeira Da Silva, J. A. (2013). Amendment Of Hydroponic Nutrient Solution With Humic Acid And Glutamic Acid In Tomato (*Lycopersicon esculentum* Mill.) Culture. *Soil Science and Plant Nutrition*, 59(4), 642-648. https:// doi.org/10.1080/00380768.2013.809599.

Helaly, A. A. (2021). Enhancing the Productivity and Quality of Tomato using Magnetized Water and Humic Acid as Bio-stimulant Agents. *Indian Journal of Agricultural Research*, 55(6), 645. https:// doi.org/10.18805/IJARe.A-616.

Ilodibia, C. V., & Chukwuma, M. U. (2015). Effects Of Application Of Different Rates Of Poultry Manure On The Growth And Yield Of Tomato (*Lycopersicum esculentum* Mill.). *Journal of Agronomy*, 14(4), 251-253. https:// doi.org/10.3923/ja.2015.251.253.

Jindo, K., Canellas, L. P., Albacete, A., Figueiredo dos Santos, L., Frinhani Rocha, R. L., Carvalho Baia, D., ... & Olivares, F. L. (2020). Interaction Between Humic Substances And Plant Hormones For Phosphorous Acquisition. *Agronomy*, 10(5), 640. https:// doi.org/10.3390/agronomy10050640.

Kazemi, M. (2014). Effect of foliar application of humic acid and calcium chloride on tomato growth. *Bulletin of Environment, Pharmacology and Life Sciences*, 3(3), 41-46. Link

Khaled, H., & Fawy, H. A. (2011). Effect Of Different Levels Of Humic Acids On The Nutrient Content, Plant Growth, And Soil Properties Under Conditions Of Salinity. *Soil and Water Research*, 6(1), 21-29. https:// doi.org/21. 10.17221/4/2010-.

Kumar, R., Srivastava, K., Singh, N. P., Vasistha, N. K., Singh, R. K., & Singh, M. K. (2013). Combining Ability Analysis For Yield And Quality Traits In Tomato (*Solanum lycopersicum* L.). *Journal of Agricultural Science*, 5(2), 213. https:// doi.org/10.5539/jas.v5n2p213.

Mallick, P. K. (2021). Medicinal values of tomato (Lycopersicon esculentum Mill.–Solanaceae). *International Journal of Applied Sciences and Biotechnology*, 9(3), 166-168. https://10.3126/ijasbt.v9i3.39789.

Mirza, M. A., Agarwal, S. P., Rahman, M. A., Rauf, A., Ahmad, N., Alam, A., ….. (2011). Role Of Humic Acid On Oral Drug Delivery Of An Antiepileptic Drug. *Drug Dev. Ind. Pharm*., 37, 310-319. https:// doi.org/10.3109/03639045.2010.512011.

Nardi, S., Schiavon, M., & Francioso, O. (2021). Chemical Structure And Biological Activity Of Humic Substances Define Their Role As Plant Growth Promoters. *Molecules*, 26(8), 2256. https://doi.org/10.3390/ molecules26082256.

Ola, O. S. (2024). Effect of Poultry Manure and NPK (15: 15: 15) Fertilizer on The Growth and Yield of Tomato (*Lycopersicon esculentum* L.). *American Journal of BioScience*, 9(3), 133-138. https:// doi.org/10.11648/j.ajbio.20241204.15.

Olaetxea, M., Mora, V., Baigorri, R., Zamarreño, A. M., & García-Mina, J. M. (2020). The Singular Molecular Conformation Of Humic Acids In Solution Influences Their Ability To Enhance Root Hydraulic Conductivity And Plant Growth. *Molecules*, 26(1), 1-12. https:// doi.org/10.3390/molecules26010003.

Osman, A. S., & Rady, M. M. (2014). Effect Of Humic Acid As An Additive To Growing Media To Enhance The Production Of Eggplant And Tomato Transplants. *The Journal of Horticultural Science and Biotechnology*, 89(3), 237-244. https:// doi.org/10.1080/14620316.2014.11513074.

Padem, H. & Ocal, A. (1999). Effects Of Humic Acid Applications On Yield And Some Characteristics Of Processing Tomato. *Acta Hortic*., 487, 159-164. https:// doi.org/10.17660/ActaHortic.1999.487.20.

Rajendiran, S. & Purakayastha, T.J. (2014). Effect Of Humic Acid Multinutrient Complex Fertilizers On Yield And Quality Of Tomato And Potato. *Vegetable Science*, 41(2), 155-159. Link

Rose, M. T., Patti, A. F., Little, K. R., Brown, A. L., Jackson, W. R., & Cavagnaro, T. R. (2014). A Meta-Analysis And Review Of Plant-Growth Response To Humic Substances: Practical Implications For Agriculture. *Advances in agronomy*, 124, 37-89. https:// doi.org/10.1016/B978-0-12-800138-7.00002-4.

Rupiasih, N. N. (2005). A Review: Compositions, Structures, Properties And Applications Of Humic Substances. *J. Adv. Sci. Technol*., 8, 16-25. Link

Salihi, M. S., Hamim, H., & Serat, S. M. (2024). Impacts of Humic Acid on Growth and Yield of Wheat A Review. *Journal of Natural Science Review*, 2(3), 87–96. https://doi.org/1062810/jnsr.v2i3.81.

Shah, Z. H., Rehman, H. M., Akhtar, T., Alsamadany, H., Hamooh, B. T., Mujtaba, T., ... & Chung, G. (2018). Humic Substances: Determining Potential Molecular Regulatory Processes In Plants. *Frontiers in plant science*, 9, 263. https:// doi.org/10.3389/fpls.2018.00263.

Stevenson, F.J. (1994). Humus Chemistry: Genesis, Composition, Reactions. John Wiley & Sons.Link

Suliman, A.A., Abramov A.G., Shalamova A.A., Badran A.M. (2020). Effect Of Humic Acid And Naphthalene Acetic Acid On Vegetative Growth And Fruit Quality Of Tomato Plants *Lycopersicon esculentum*. *Journal of Agronomy and Animal Industries*, 15(1), 30-39. https:// doi.org/10.22363/2312-797X-2020-15-1-30-39.

Ural, C., Halime Özdamar Ünlü, Erkan, İ. E., & Ufuk Çelikkol Akçay. (2023). Influence of Humic Acid on Some Physiological Characteristics and Antioxidant Enzyme Genes Expression in Tomato (*Solanum lycopersicum*) Grown under Salt Stress Conditions. *Alatarim*, 22(2), 86-97.Link

Usman, M. (2015). Cow Dung, Goat And Poultry Manure And Their Effects On The Average Yields And Growth Parameters Of Tomato Crop. *Journal of Biology, Agriculture and Healthcare*, 5(5), 7-11. Link van Tol de Castro, T. A., Berbara, R. L. L., Tavares, O. C. H., Mello, D. F., & da, G., Pereira, E. G. (2021). Humic Acids Induce A Eustress State Via Photosynthesis And Nitrogen Metabolism Leading To A Root Growth Improvement In Rice Plants. *Plant Physiol. Biochem*., 162, 171-184. https:// doi.org/10.1016/j.plaphy.2021.02.043.

Wu, S., Li, R., Peng, S., Liu, Q., & Zhu, X. (2017). Effect Of Humic Acid On Transformation Of Soil Heavy Metals. IOP Conference Series: *Materials Science and Engineering*, 207, 012089. https:// doi.org/10.1088/1757-899X/207/1/012089.

Yang, F., & Antonietti, M. (2020). The Sleeping Giant: A Polymer View On Humic Matter In Synthesis And Applications. *Prog. Polym. Sci*., 100, 101182. https:// doi.org/10.1016/j.progpolymsci.2019.101182.

Yang, F., Tang, C., & Antonietti, M. (2021). Natural And Artificial Humic Substances To Manage Minerals, Ions, Water, And Soil Microorganisms. *Chemical Society Reviews*, 50(10), 6221-6239. https:// doi.org/10.1039/D0CS01363C.

Yildirim, E. (2007). Foliar And Soil Fertilization Of Humic Acid Affect Productivity And Quality Of Tomato. *Acta Agriculturae Scandinavica Section B-Soil and Plant Science*, 57(2), 182-186. https:// doi.org/10.1080/09064710600813107.