*University of Thi-Qar Journal of agricultural research*
*Thi-Qar Journal of agricultural research*
*ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 13, Issue 1 (2024) PP 176-184*
*https://jam.utq.edu.iq/index.php/main* *https://doi.org/10.54174/szm42027*

# Impact of Humic Substances on Alleviation of Soil Salinity and the Enhancement of Plant Productivity: a review

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## Abstract

Humic substances (HS) are a major component of organic matter in soil, and they have long been recognized for their ability to promote plant growth in a sustainable manner. Recently, there has been a lot of effort put into using multiple approaches to study the connection between the chemical structure of HS compounds and their effect on plant biological processes. Positive physiological responses at the local and systemic levels have been linked to the presence of specific functional groups in HS. Hormone-like signaling pathways are responsible for eliciting these reactions. This review was written with one goal in mind: to help readers gain a firm grasp on the research surrounding the application of HSs. The spatial arrangement of hydrophilic and hydrophobic regions, as well as the dosage, source, molecular size, degree of hydrophobicity, and aromaticity, all contribute significantly to HS's biological efficacy. Therefore, our hypothesis explains the beneficial effect of HS in salt-affected rhizospheres, likely attributed to both direct and indirect influences on plant metabolism, soil microorganism metabolism, soil nutrient uptake dynamics, and soil physical conditions.

***Keywords: Humic substance, germination, salinity, plant growth***

## I. INTRODUCTION

Worldwide, arid and semi-arid regions face a significant challenge from soil salinity, which reduces crop yields across the board. In order to improve salt-affected soil, it is necessary to increase its physical, chemical, and biological qualities. Dead plants and animals decompose biologically, and microbes produce humic substances like fulvic acid and humic acid (HA) for use in soil. The percentage of organic matter in soil that is made up of these components is relatively high, hovering around 65%-70% (El Hasini et al., 2020). There has been an increasing scholarly focus on the potential application of HS for the purpose of augmenting plant growth (Gouda et al., 2018). The utilization of these technologies also presents a multitude of benefits to agricultural soil. Increases in microbial activity, water retention, nutrient retention, and soil structure are just some of the benefits that have resulted from these changes (Shah et al., 2022). Humic substances are naturally occurring, complex, and heterogeneous mixtures of organic compounds with diverse molecular sizes. Humic substances is produced via the process of humification, which is regarded as the second most prominent organic process on Earth, subsequent to Photosynthesis is a fundamental biological process wherein plants convert light energy into chemical energy (Yang et al., 2021). The biochemical and chemical reactions involved in the breakdown and transformation of organic matter from plants and microorganisms are the focus of this investigation. These compounds have a relatively high molecular weight and exhibit a range of colors from yellow to black (Boumya et al., 2021). Within the framework of this discourse, it is imperative to acknowledge that fulvic acid

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possesses the ability to undergo dissolution in water, irrespective of the prevailing pH level (Ohno et al., 2019). In contrast, HA exhibits insolubility in water under highly acidic conditions (pH < 2), but it demonstrates solubility at elevated pH levels (Jimtaisong and Saewan, 2014). Moreover, hymatomelanic acid is the term used to describe the soluble component of humic acid in alcohol, whereas humin refers to the insoluble fraction of HS in water (Zavarzina et al., 2021). When taken into account as a whole, the two distinct categories of acids, namely FA and HA, are frequently denoted as HA. The physiological impact of drought is a well-established phenomenon that manifests when plants are subjected to soil salinity. The presence of elevated salt levels in the soil results in a reduction in the osmotic potential of the soil water, consequently diminishing the accessibility of soil water for plant uptake. In summary, elevated levels of sodium (Na) and chloride (Cl) ions have a constraining effect on the water absorption capacity of plant roots (Wasim et al., 2021). The detrimental impact of elevated salt concentrations in the soil on soil fertility arises from their gradual inhibition of plant nutrient uptake, thereby impeding the absorption of vital elements. The main objective of this review was to evaluate the effectiveness of these compounds in improving the physical and chemical characteristics of soil affected by high salt content, with the ultimate aim of reducing soil salinity. Additionally, this study aims to examine the specific effects of HS on plant growth, their hormone-like activities, and their interactions with heavy metals.

## The influence of salinity on soil and water

Presently, Iraq is confronted with a shortage of freshwater resources, which are of utmost importance for sustaining agricultural endeavors. The scarcity observed in Iraq can be ascribed to a confluence of factors, encompassing extended periods of drought in recent times and the continued retention of water by neighboring nations, who exercise authority over the river origins that provide Iraq with its water supply. The rise in population, extensive expansion of agricultural land, and escalating food requirements have resulted in a heightened demand for water. As a consequence, there has been a reliance on subpar alternative water sources, such as punctured water, in order to mitigate the scarcity of potable water (VS and Jacob, 2023). The uncontrolled application of saline water has detrimental effects on both soil and crop health. The accumulation of salts in the soil results in elevated osmotic pressure and disrupts nutrient balance, leading to adverse consequences. Hence, it is imperative to explore strategies and methods for the effective utilization of said water while mitigating any potential negative impacts on soil productivity and environmental contamination (Sarwar et al., 2017). In Iraq, salinity is a major problem that has serious consequences for soil quality and the development of a wide variety of crops (Hossain et al., 2020). Salinity is a major hindrance to agricultural development because increasing salinity levels in irrigation water deteriorates farmland. Increasingly rapid temperature increases compound the harm caused by salinity (Kumar et al., 2022). In order to achieve a successful yield of a crop cultivated in saline soils or irrigated with salt water, it is imperative to undertake soil reclamation or supply fresh water (Hussain et al., 2020). The researchers proposed exploring novel mechanisms that are suitable for addressing the challenges posed by saline stress in both soil and plants, such as strategies for coexisting with salinity (Gregorio et al., 2013, Fang et al., 2021). Breeding and improvement initiatives as well as the development of genetic compositions that exhibit salinity tolerance are two ways to achieve saline tolerance in plant varieties (Fageria et al., 2012). The impact of saline stress on plants leads to a variety of developmental impairments, triggering a range of intricate biochemical and physiological alterations (Ma et al., 2020). In contemporary times, the concept of alleviation is employed to refer to the process of mitigating or diminishing the adverse consequences of salt stress while simultaneously enhancing the adaptive capacity of plants to withstand such stressors. This is achieved through the implementation of various strategies, such as biofertilization programs, paper fertilization, and the utilization of growth regulators, among others. These interventions aim to ameliorate the detrimental effects of saline stress on plants (Rose et al., 2014). Negative effects on plant growth, development, and yield have been linked to saline stress, which is caused by factors such as variations in water availability and the occurrence of seismic voltage. Due to their ability to draw moisture from the soil and affect metabolic processes, wheat plants are known to have a detrimental effect on salinity levels (EL Sabagh et al., 2021). The utilization of

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saltwater can occasionally lead to unfavorable conditions for plant growth due to its influence on the soil and plant characteristics, particularly in terms of physical and chemical aspects.

## How much salt is in irrigation water and how it affects seedling development?

Salinity exerts a significant influence on numerous physiological and metabolic processes within plants, spanning from water absorption in seeds to photosynthesis and the accumulation of dry matter. Consequently, salinity has a profound impact on both vegetative and root development. Salinity is a significant factor contributing to the non-germination of a considerable proportion of seeds. In a study was observed that the introduction of varying concentrations of NaCl and potassium chloride resulted in a decrease in the velocity and frequency of bursting of the cells, as well as a diminution in cucumber plants' overall size, root mass, and stem lengths (Raza et al., 2022). However, delayed or failed germination in the high-saline medium was attributed to the toxic effects of a salt-causing ion, specifically sodium (Helmey, 2021). The presence of this ion within the seed has the potential to impact the essential functions of both the fetus and the seed. The elevated salinity levels in the central region of plant growth are associated with a decreased rate of germination. The presence of salinity in the growth medium elevates the osmotic pressure, resulting in a decrease in the plant's ability to readily absorb water (Heuer, 2010). Regarding, the utilization of irrigation water with varying salt concentrations resulted in desalination levels of 4.85, 6.60, and 8.86 desimens (Doornbusch et al., 2019). The study found that the germination rate of wheat seeds decreased as the salinity concentrations of irrigation water increased (Francois et al., 1984), as compared to the control group irrigated with water of 0.43 desimensities. In regards, it was observed that the utilization of brackish irrigation water resulted in electrical conductivity values of 3, 6, 9, and 15 decisiemens (Gkiougkis et al., 2015). The salinity levels of irrigation water were found to have a negative impact on various aspects of barley seed growth, including germination rates, leg lengths, and dry matter. This resulted in decreased germination and overall growth when compared to seeds irrigated with distilled water. The salinity exerts a negative impact on germination indicators, particularly in terms of speed, as observed in the plant species *Oryza sativa* L (El-Katony et al., 2021). Furthermore, the study revealed that the extent of this reduction becomes more pronounced under conditions of elevated salinity levels (El-Hendawy et al., 2017). In their study, demonstrated the utilization of saltwater irrigation, which involved two distinct concentrations of sodium chloride (NaCl) salt and calcium sulfate ($CaSO_4$) at concentrations of 4 and 6 desimens. The application of these salts has resulted in a notable decrease in the germination rate of three distinct cultivars of wheat plants in comparison to the utilization of river water (Leogrande and Vitti, 2019). The effects of utilizing irrigation water with two distinct saline concentrations, specifically 5.8 and 9.3 desimens (Wu et al., 2001). Treatment resulted in a notable reduction in both germination rates and the relative production of dry matter in maize plants when compared to the control group treated with river water (0.48 desismens). The effects of irrigation water with varying levels of NaCl concentration (0, 50, 100, 150, and 200 mM) on the germination percentage, as well as the length of roots and peduncles, were investigated for two soybean plant varieties (172 and 44 sd) (Leogrande and Vitti, 2019). The results indicated a decrease in these parameters as the concentration of NaCl increased, with the highest impact observed at intermediate concentrations. The application of a milliliter of substance led to a decrease in the germination ratio, germination speed, stem length, spruce, and overall vegetative length of the plant. In a laboratory experiment stated the utilization of brackish water containing varying concentrations of NaCl (ranging from 25 to 200 mmol/L) was found to have a detrimental effect on the germination percentage, shoot growth, and biomass of yellow maize plants (*Zea mays* L.) (Sahle-Demessie et al., 2019). The negative impact on these parameters was observed to increase with higher concentrations of NaCl in the water, as compared to the use of distilled water. This study examines the impact of saltwater irrigation on the germination of lettuce seeds. The experimental setup involved the application of NaCl at a concentration of 100 mmol/L. The findings revealed a notable decrease in both the root height and wet weight of the seeds from two different lettuce varieties (Nasri et al., 2015).

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## Indicators of plant health and their response to salinity

The measurement of carbohydrate levels serves as a significant functional parameter for assessing plant health, as it provides insights into plant growth and efficiency. Numerous studies have explored the impact of salinity on plants, further highlighting its influence. Hameed et al. (2021) have demonstrated the presence of salinity-induced effects that exhibit a higher degree of specialization within this particular region. These changes have a direct impact on the activity of a number of crucial enzymes, including those responsible for breaking down starch into soluble carbohydrates and those responsible for inhibiting amylase and invertase. Heidari and Jamshid (2010) observed that the elevated levels of dissolved carbohydrates in the salt medium of the growing wheat plant, specifically their starch content, decreased. They attributed this phenomenon to the disruption of metabolic processes caused by high salinity. The presence of elevated salinity levels hinders the process of converting simple sugars, such as fructose and glucose, into more complex sugars, such as starch (EL Sabagh et al., 2021). Consequently, the concentration of starch diminishes as a result of the higher concentration of simple sugars. Chlorophyll, a vital plant pigment found within chloroplasts, possesses the capacity to absorb light within the visible spectrum. Solar energy is used to create energy-rich compounds that are then used in the construction of organic materials (Aresta et al., 2013). It has been observed that salt stress causes a drop in photosynthetic pigment levels. The decrease is a result of less cytochrome being produced in the roots and less of it being transported to vegetative aggregates. On the other hand, there is a notable rise in the production of a hormone that inhibits the synthesis of chlorophyll, namely abscisic acid. This hormone initiates the degradation of chlorophyll, resulting in the onset of leaf senescence. The diminished presence of chlorophyll pigments can be attributed primarily to the adverse impact of reduced water absorption resulting from negative salinity effects (Sofy et al., 2020). This leads to alterations in the internal structure of chloroplasts, including the membranes that bear photosynthetic pigments. Additionally, the presence of sodium and chlorine ions affects crucial enzymes involved in the synthesis of chlorophyll, which is responsible for the production of chlorophyll chloropheld, the immediate precursor in chlorophyll construction.

## Humic acid's function in plant biology

Humic acid is a constituent of the HA that arise from the decomposition of organic matter. It exhibits a dark color ranging from brown to black and displays solubility in bases while precipitating when exposed to acid at a pH level below 2 (FitzGerald et al., 2006). Humic acid, a hydrophilic organic chemical complex, is present in both liquid and powder states and has a molecular weight of 1680 (Avramenko et al., 2012). The substance exhibits a composition consisting of carbon, oxygen, hydrogen, and nitrogen in varying ratios, resulting in the formation of compounds with diverse molecular weights. The inclusion of these substances in the overall composition of plants plays a significant role in their nutritional requirements, resulting in enhanced growth through the modulation of photosynthesis and respiration (Detmann et al., 2012). A wide variety of nutrients, including phosphorus, nitrogen, and potassium, are stored in organic residues. These nutrients are essential for plant growth and development, and they increase crop yields in general. Increased plant growth and the ability of plant roots to take in soil moisture and nutrients are two of humic acid's most important functions (Liu et al., 2019). Additionally, HA is also recognized for its significant contribution to soil microbiology activity. Humic acid exerts dual effects on plant productivity and growth, manifesting both directly and indirectly. The direct effect occurs within the plant cells upon the absorption of HA. The application of this substance induces a range of chemical modifications and promotes an augmentation in the overall root mass of the plant (Etesami and Maheshwari, 2018). The positive impact of HA on plant growth is evident in various aspects of vegetative development, including increased plant height, branch quantity, leaf count, and leaf area (Hameed et al., 2018). Plant growth stimulant, has been extensively utilized in contemporary agriculture due to its remarkable capacity to enhance biochemical reactions and promote phytoplasty growth within plant cells, thereby augmenting productivity.

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https://jam.utq.edu.iq/index.php/main https://doi.org/10.54174/szm42027

## Significance of humic acid in plant growth

It was found that adding HA to the soil at different levels (2.5, 5.0, and 10.0 g/kg soil) made tobacco plants taller and their leaves heavier when they were dry (Baligar and Fageria, 2007). The observed enhancement can be ascribed to the capacity of HA to augment the chemical properties of the soil and promote the accessibility of vital nutrients for plant growth. In a field experiment, applying HA through leaf spraying to yellow corn plants at concentrations of 150, 300, and 450 mg/L significantly improved a number of growth parameters (Al-Bayati and Ali, 2019). These parameters included plant height, juniper count, grain yield, weight of 1000 tablets, and dry weight. In two consecutive field trials, it was observed that the application of HA at a concentration of 17 mg/liter through foliar spraying on wheat plants grown in sandy soil resulted in a notable enhancement in both plant height and yield (Sabah et al., 2023). The principal biological role of roots encompasses the release of root exudates and the discharge of root border cells into the rhizosphere. Root exudates consist of various substances, including ions and compounds with both low and high molecular weights. These substances have the ability to modify the characteristics of the soil. The significance of organic acids in soil formation and evolution has been widely recognized. Organic acids possess the capacity to alter mineral weathering conditions through their influence on the soil's complexation capacity, pH level, and mineral element concentration. (Nardi et al., 2021). The manipulation of the macrostructure of the hypothalamus can induce the liberation of minute portions. The fractions mentioned above have the ability to selectively attach to cell receptors located on the surface of the root, or alternatively, they can enter the root cells and elicit various biological reactions (see Figure 1). The present study aimed to investigate the impact of HA on plant growth, with a specific focus on hormone and enzyme production. This investigation was conducted within the context of the biology of grain harvesters and hayholders. The study examined the impact of HA on spike length and the number of nabels, comparing these variables to a control group without HA supplementation. A hypothesis was formulated suggesting that HA has the potential to induce the production of growth-promoting hormones, specifically auxins, and enzymes, thereby exerting an influence on the growth and development of plants (Numan et al., 2018). A statistically significant increase in various plant growth parameters was observed when HA was applied to the soil after being dissolved in water at a concentration of 1 kg/dunm. The parameters considered in this study encompassed plant height, leaf area, dry weight, and grain yield. The comparative analysis of the weight of 100 maize grains in relation to the non-addition treatment in their study, Al-Barakat et al. (2021) conducted a three-year field experiment to investigate the effects of adding HA at a concentration of 15 kg/ha to clay sand blending soil. The researchers observed notable improvements in various growth parameters of wheat plants, including plant height, number of charred grains, weight of 1,000 grains, grain harvester, and straw harvester. These positive outcomes were attributed to the capacity of HA to enhance nutrient availability, which is crucial for promoting plant growth.

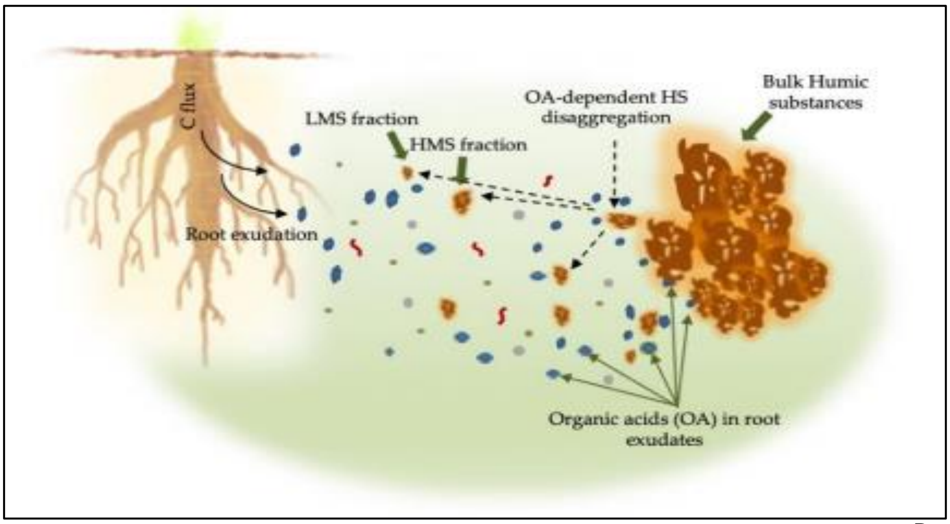

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**Figure 1.** Root exudates' low molecular weight organic acids may affect soil HS (bulk HS) solubility by disaggregating them into LMS and HMS fractions (Nardi et al., 2021).

Humic acid is a significant soil component that mitigates the negative effects of salinity on plant growth. It achieves this by containing various effective aggregates, such as carboxylic, hydroxylated, and carbonyl (C=O) groups, among others. These aggregates ionize and serve as a vital source of negative charge, attracting positively charged ions in a chelating and complex manner. The salts present in the root zone exhibit increased susceptibility to leaching due to their diminished impact on plant health (Corwin, 2021). Researchers have found that HA lowers the reaction and osmotic stress in soil solutions. This makes it easier for soil colloids to spread out during the inter-ion exchange process involving HA and ions like hydrogen or potassium, especially when sodium ions are present. There is empirical evidence that substantiates the aforementioned characteristic of HA, which concurrently enhances the permeability of soil (Corwin, 2021, Darusman et al., 2018, Zhang et al., 2020).

## II. Conclusion

This review examines the impact of HS on soils affected by high salinity. Initially, we presented an account of the mechanisms by which HS is formed, highlighting the four prevailing theories that have been put forth thus far: lignin, amino compounds, polyphenols, and aminosaccharidic condensation. The ensuing discourse underscored the importance of both direct and indirect impacts of hypersalinity on the plant-soil system in the amelioration of salinity. The indirect effects of high school (HS) are linked to the improvement of soil properties, including physical, chemical, and microbiological attributes. The effects on plants arise from the direct interventions exerted upon them, which influence multiple facets including germination, root and shoot growth, and demonstrate hormone-like behavior. When exposed to salt stress, the initial administration of HS, whether applied through the soil or foliage, led to an augmentation in nutrient absorption.

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*ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 13, Issue 1 (2024) PP 176-184*
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