AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 02 (February, 2026)
Available online at http://www.agrimagazine.in
©Agri Magazine, ISSN: 3048-8656

Natural Crop Growth Regulators for Climate-Smart Agriculture: Role of Humic and Fulvic Acids in Improving Yield, Soil Health and Carbon Farming

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Agriculture today is facing a critical challenge: producing more food while conserving soil and protecting the environment. Continuous use of chemical fertilizers has increased crop productivity in the past, but it has also led to soil degradation, reduced organic matter, declining microbial activity, and increased greenhouse gas emissions. These issues have created the need for eco-friendly solutions that can sustain productivity without harming natural resources. Natural crop growth regulators, also called biostimulants, are emerging as an important solution in sustainable agriculture. Among these, humic acid and fulvic acid are gaining global importance because they improve plant growth, soil fertility and nutrient efficiency without directly supplying nutrients. Studies show that humic substances can increase crop yield by about 12% and nitrogen use efficiency by 27%, highlighting their potential for climate-smart agriculture (Ma et al., 2024). A global analysis also reported nearly 18% yield improvement with biostimulant use in open-field agriculture (Li et al., 2022).

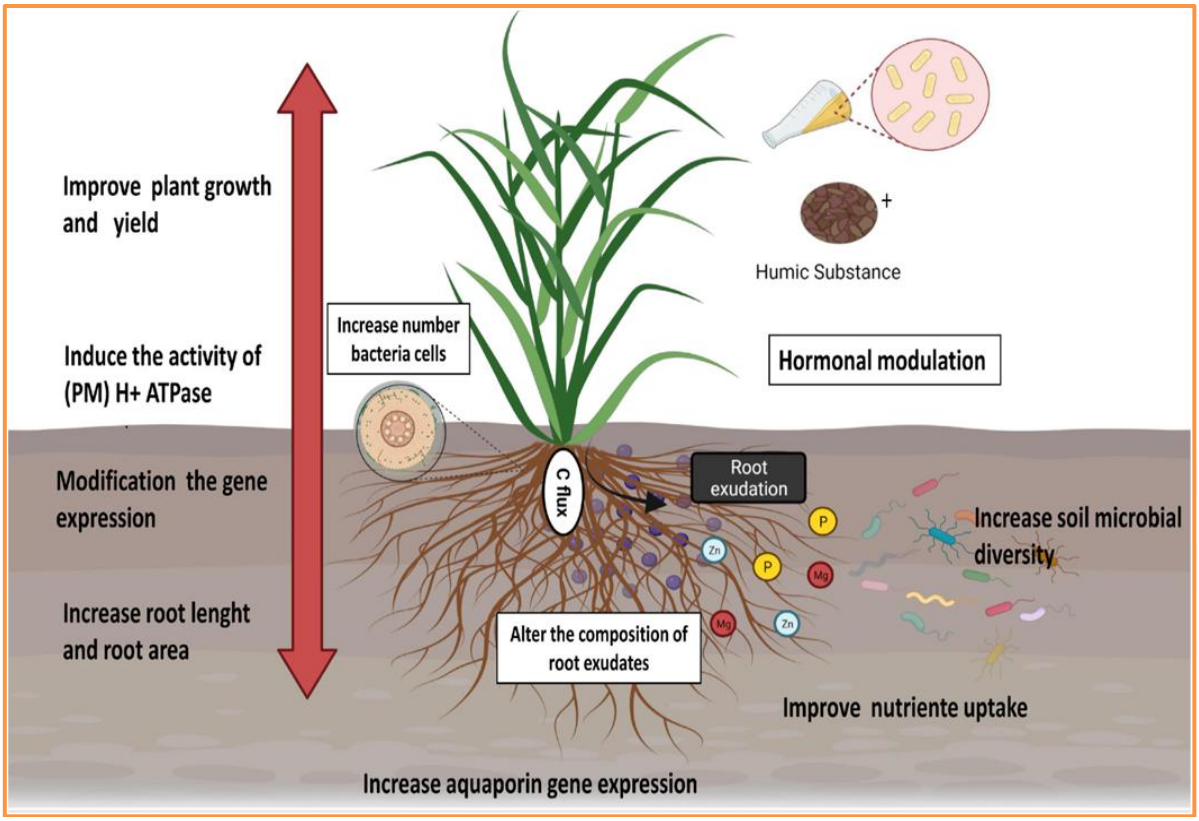
What Are Humic and Fulvic Acids: Humic substances are natural organic compounds formed during the decomposition of plant and animal residues. They are commonly found in soil organic matter, compost, manure, peat, lignite and biochar. These substances are grouped into humic acid, fulvic acid and humin based on their solubility and molecular size. Unlike fertilizers, humic substances act as plant growth stimulants that improve nutrient uptake, enhance soil structure and stimulate beneficial microbial activity (Ampong et al., 2022). Their multifunctional nature makes them valuable tools for sustainable farming.

Role in Improving Soil Health: Healthy soil is the foundation of sustainable agriculture. Humic substances improve soil structure by enhancing aggregation and increasing water-holding capacity. They also improve soil fertility by increasing cation exchange capacity and reducing nutrient losses (Guo et al., 2025). Research shows that humic substances help rebuild soil organic carbon and stabilize carbon in the soil, making them important inputs in regenerative agriculture and carbon farming (Maffia et al., 2025). Their ability to improve microbial biomass further enhances soil biological health (Xu et al., 2025).

Role in Plant Growth and Metabolism: Humic and fulvic acids act like natural plant hormones. They stimulate root growth, increase root hair development and improve nutrient

absorption. Research has shown that humic substances activate plant enzymes and increase chlorophyll content, leading to improved photosynthesis and plant growth (Canellas et al., 2015). Fulvic acid plays a special role in transporting nutrients within the plant and improving phosphorus uptake (Zhang et al., 2025). These benefits result in stronger plants and higher productivity.

Impact on Crop Yield: Field studies across various crops confirm the positive effects of humic substances. Application in wheat and maize increased yield by 8–12% and improved grain quality (Ren et al., 2024). In tomato, humic acid combined with soil aeration significantly increased yield due to improved microbial diversity (Ma et al., 2025). Studies in triticale and canola also reported improved growth and fertilizer use efficiency (Mosaad et al., 2024; Rathor et al., 2025). These findings show that humic substances can benefit a wide range of crops under different growing conditions.



Role in Climate-Smart Agriculture: Climate change is increasing the frequency of drought, salinity and heat stress in agriculture. Humic substances improve plant tolerance to these stresses by enhancing water retention, improving antioxidant activity and supporting better nutrient use efficiency (Antunes et al., 2025). Their role in soil carbon sequestration makes them valuable inputs in carbon credit and regenerative agriculture programs (Meng et al., 2025).

Advantages for Farmers: Use of humic and fulvic acids provides several benefits: Improved crop yield and quality, Reduced fertilizer requirement, Better soil health and water retention, Increased tolerance to drought and stress, Support for carbon farming and sustainable agriculture. However, their effectiveness depends on proper dosage, product quality and farmer awareness (Ren et al., 2024).

Conclusion

Humic and fulvic acids are powerful natural crop growth regulators that improve soil health, enhance plant metabolism, increase crop yield and support climate-smart agriculture. Their adoption can help farmers reduce chemical inputs while maintaining productivity and protecting natural resources. Promoting awareness and proper use of humic substances will play a key role in achieving sustainable agriculture in the future.

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