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Editorial

Humic Substances: A Novel Eco-Friendly Fertilizer

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Humic substances (HS) are macromolecular organic materials ubiquitous in both aquatic and terrestrial systems, effective electron shuttling compounds providing macro- and microelements in organochelate form, and play an important role in determining the mobility and bioavailability of organic/inorganic nutrients and mineral fertilizers. HS enhance soil biological life by boosting highly concentrated populations of soil microorganisms, regulate mechanisms involved in plant growth stimulation and ecofriendly waste management processes, enable moisture retention and soil aeration, are recognized for their positive effects on plant physiology, root architecture, and soil structure.

Humic substances and phenolic compounds, the main constituents and active fractions of soil organic matter (SOM), impact plant-soil relationship. In "*Effectiveness of Humic Substances and Phenolic Compounds in Regulating Plant-Biological Functionality*" [1] by A. Muscolo, D. Pizzeghello, O. Francioso, S. Sanchez-Cortes and S. Nardi, the biological effects of HS and the soil water soluble phenols on *Pinus laricio* callus were compared; the results show that humic substances produce a better callus growth.

"*Foliar Application of Humic-Stabilized Nanoferrihydrite Resulted in an Increase in the Content of Iron in Wheat Leaves*". M. M. Zimbovskaya, A. Yu. Polyakov, D. S. Volkov, N. A. Kulikova, V. A. Lebedev, D. A. Pankratov, A. I. Konstantinov, A. M. Parfenova, O. T. Zhilkibaev and I. V. Perminova [2] synthesized iron (hydr) oxide nanoparticles (IONPs) stabilized by humic substances, via rapid hydrolysis of iron (III) nitrate in a solution of potassium humate, to estimate the feasibility of their use for foliar application on iron deficient plants. Wheat plants (*Triticum aestivum* L. cv. L15) were used for the iron uptake test; it was concluded that humic-stabilized IONPs are much better suited to foliar application as compared to soil amendment when applied as a source of iron for plants.

The paper "*Modified Humic Substances as Soil Conditioners: Laboratory and Field Trials*" by N. A. Kulikova, A. B. Volikov, O. I. Filippova, V. A. Kholodov, N. V. Yaroslavtseva, Y. R. Farkhodov, A. V. Yudina, V. A. Roznyatovsky, Y. K. Grishin, O. T. Zhilkibayev and I. V. Perminova is devoted to the development and performance testing of a soil conditioner [3] based on leonardite humic substances modified with 3-aminopropyltriethoxysilane (APTES). APTES-modified HS can be successfully used as a soil conditioner. The formation of extended siloxane networks was suggested as the main mechanism of the observed improvement in the structure of the amended soils.

In the review article "*Direct and Indirect Detoxification Effects of Humic Substances*" by L. Bondareva and N. Kudryasheva [4] studies on the detoxification effects of water-soluble HS are summarized. HS neutralize free pollutants (indirect bioeffects) and also stimulate the protective response of organisms (direct bioeffects). The detoxification efficiency of HS in different pollutant solutions was evaluated, and the detoxification mechanisms were discussed. The review focuses on the protective function of HS in solutions of radionuclides and salts of stable metals, with special consideration of the antioxidant properties of HS.

The article by V. Enev, P. Sedláček, L. Kubíková, Š. Sovová, L. Doskočil, M. Klučáková and M. Pekař titled "*Polarity-Based Sequential Extraction as a Simple Tool to Reveal the Structural Complexity of Humic Acids*" [5] describes the sequential chemical extraction with a defined series of eluotropic organic solvents with an increasing polarity performed on peat-bog

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humic acid. The extraction procedure is suggested for further studies as a simple and effective way to decrease the structural complexity of a humic material enabling its detail and more conclusive compositional characterization.

"*The Soil Organic Matter in Connection with Soil Properties and Soil Inputs*" by V. Voltr, L. Menšík, L. Hlisnikovský, M. Hruška, E. Pokorný and L. Pospíšilová [6] is focused on the evaluation of soil organic carbon (SOC) and hot water extractable carbon (HWEC) changes. Results showed an increase in the SOC and a decrease in the HWEC contents; it was confirmed that SOM plays an important role in soil physical, biochemical and biological properties, which is particularly important to ensure the productivity of agroecosystems (soil quality and health) and to future food security.

The sorption of three herbicides [7] on samples from peats of progressive degree of maturity and soil samples, amended with the peats, was determined in "*Organo-Mineral Interactions Involved in Herbicide Sorption on Soil Amended with Peats of Different Maturity Degree*" by J. Dorado and G. Almendros. A sorption enhancement effect was observed in the peat–soil system compared with the sum of the sorption in peat and soil alone. Different characteristics of peats (maturity, colloidal properties, oxygen-containing functional groups) played a distinct role in the herbicide–peat or in the soil–peat–herbicide sorption systems.

The purpose of "*Use of the pK Spectroscopy Method in the Study of Protolytic Properties of Humic Substances and Other Soil Polyelectrolytes*" [8] by E. Lodygin and E. Shamrikova is to test the possibility of using pK spectroscopy (an approach that opens up wide possibilities for the potentiometric analysis of complex protolytic systems) for assessing the acid-base properties of fulvic acids, water-soluble fraction, and soils. The results showed that this method is expressive and more informative than the traditional continuous potentiometric titration and significantly expands understanding of the physicochemical properties of humic substances and soil organic matter.

The objective of the paper "Characterization of Soil Organic Matter Individual Fractions (Fulvic Acids, Humic Acids, and Humins) by Spectroscopic and Electrochemical Techniques in Agricultural Soils" by A. Ukalska-Jaruga, R. Bejger, G. Debaene and B. Smreczak [9] was the molecular characterization of soil organic matter fractions. Differences in behavior, formation, composition, and sorption properties of HS fractions derived from various soils were examined. The study revealed significant differences in the molecular structure of fulvic acids (FAs), humic acids (HAs), and humins (HNs). Molecules of HAs and HNs exhibited an abundance of acidic, phenolic, and amine functional groups at the aromatic ring and aliphatic chain while FAs showed the presence of methyl, methylene, ethenyl, and carboxyl reactive groups.

"*One Step Bioremediation of Olive-Oil-Mill Waste by Organoinorganic Catalyst for Humics-Rich Soil Conditioner Production*" by M. Roulia, E. Kontezaki, N. Kalogeropoulos and K. Chassapis involves the innovative application of microaerobic composting for olive oil mill waste (OMW) bioremediation [10] with the addition of a zeolite and a tailor-made biocatalyst extremely rich in soil microorganisms that operates at a wide pH range, provides acceleration of biochemical reactions, enhancement to the bio-oxidative phase and nutrients to the OMW compost obtained. The product is stable, free of toxic compounds and pathogens, rich in cenose with a high humic substances content, and it was identified as a first-class soil conditioner for organic farming.

There is a growing demand for the advancement of new biological technologies in agriculture, especially in order to restore the soil organic matter and soil fertility. The "*Comparative Study of Biostimulant Properties of Industrially and Experimentally Produced Humic Substances*" [11] by M. Klavins, S. Grandovska, V. Obuka and G. Ievinsh analyzes the impact of eight different HS (four extracted from various materials and four commercially available) on plant development. Three species of plants (*Triticum aestivum*, *Sinapis alba*, *Lepidum sativum*) were used to evaluate the stimulating effect of HS that depends on their origin. Tests showed growth-stimulating activity and sensitivity of different plants to different HS-containing products.

Basic dye retention experiments in "*Water Purification by Potassium Humate–C.I. Basic Blue 3 Adsorption-Based Interactions*" by M. Roulia and A. A. Vassiliadis demonstrated that potassium humate is an exceptionally efficient adsorbent in aqueous systems [12]. The effect of both pH and temperature on the adsorption was investigated. Under mildly acidic conditions, interactions between the positively charged dye and the dissociated carboxyl groups of humic substances are encountered and the quantity of dye adsorbed was doubled on standing. Temperature proved to only slightly influence the extent of dye sorption while the heterogeneities of humic substances were attributed to their colloidal behavior.

In all the above mentioned articles, both the advanced scientific progress and the recently explored developments are presented. Therefore, I believe that this issue will serve as a highly useful reference material for humic substances researchers.

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