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Humus, A Complex and Stable Macromolecular Organic Compound

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Abstract

Humus is a brown to black dark substance, which is a stable organic matter synthesized by condensation of aromatic compounds (polyphenols and polyquinones) and nitrogen-containing compounds. in nature, it is generally formed by microbial decomposition of the remains of animals and plants. it widely exists in soil, water and other ecological environment, soil humus can provide rich nutrients and energy for plants and microorganisms. Stimulating the growth and development of plants plays an important role in repairing soil function, restoring ecosystem and reshaping soil microbial structure.

Keywords

Soil; Humus; Repair Soil; Provide Nutrients.

1. Formation of Humus

Humus is a brown to black dark substance, which is a stable organic matter synthesized by Polycondensation of aromatic compounds (polyphenols and polyquinones) and nitrogen-containing compounds [1]. Its formation is affected by many environmental factors. The specific way of humus formation has not been clearly determined, but at present, there are mainly the following mainstream theories on the formation of humus: Maillard reaction theory, polyphenol theory. Sugar-amine condensation theory, polyphenol-Maillard theory, lignin polyphenol theory, cell autolysis theory, microbial synthesis theory and lignin theory, etc.[2-3].

These theories can be divided into three categories, including Maillard reaction, sugar-amine condensation theory and polyphenol-Maillard theory. These three theories have something in common. It is considered that amino acids, reducing sugars, polyphenols and amines are raw materials for the formation of humus. The second category includes polyphenol theory, lignin theory and lignin polyphenol theory, which holds that polyphenols can be decomposed into phenols and quinones, which are precursors for the synthesis of humus. The last category is the theory of cell autolysis and microbial synthesis, both of which are closely related to the role of microorganisms. Humus is formed by the condensation of reducing sugars, phenolic compounds, amino acids, carboxyl compounds and polysaccharides as precursors produced by microbial metabolism [4].

In fact, these pathways may not occur alone, the diversity of composting raw materials and types make these pathways may act together in the humization process, and the formation of multiple theories may be due to the humization raw materials used in the study. research methods and humification research directions are different, a certain theory plays a leading role in the process of humization and needs to be studied together with the structure of humus.

2. Summary of Humus Structure

Humus is a complex polymer structure, but it is not a single substance, but mainly composed of humic acid (humic acid, HA), fulvic acid (fulvic acid, FA) and insoluble humin (HM). Among them, the content of humin is very small, and the property is not active, it is difficult to decompose,

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insoluble in dilute acid, and the aromatization is high and the degree of dissociation is small, so the concentration of humin is usually not considered [5]. In terms of molecular weight, FA is a small molecular form of HA, and the main difference lies in the molecular weight formed. The molecular weight of humus is generally between 0.5-1000 KDa, HA is the larger part, generally between 10-100 KDa, while the molecular weight of FA is concentrated between 0.5-1.5 KDa. In terms of chemical structure, humus is composed of several functional groups of the same type. As shown in figure 1, small molecular substances and other types of polymers are connected to each other by intermolecular forces such as π-π, CH- π, van der Waals force, Coulomb force and hydrogen bond [6]. They mainly contain elements such as C, H, O, N, P, S, and some contain trace amounts of Fe, Mg, Ca and Si plasma. The elements that make up humus are not fixed. It is internationally believed that the average carbon content of humus is about 58%, and the nitrogen content is about 5.6%. The range of C hand N is between 10 and 12 FA [7-8]. HA has a higher degree of condensation and more complex molecular structure than FA, but the degree of oxidation is lower than that of FA [9].

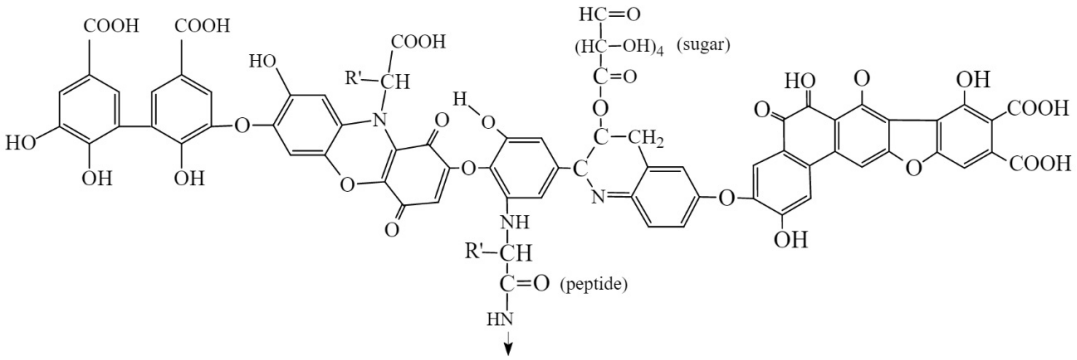

Figure 1. Predictive structure model of humic acid [10]

According to the study on the structure of humus, [11-12], humus contains a large number of hydroxyl, carboxyl, quinone, amino, methoxy, alcohol hydroxyl, sugar, carbonyl and phenolic hydroxyl groups. These functional groups are mainly based on aromatic benzene rings and are connected by chemical bonds and intermolecular interactions.It makes humus show many chemical properties, such as stable chemical structure, ion exchange, coordination, redox, physiological activity and so on. The predicted structure model of humic acid is shown in figure 2.

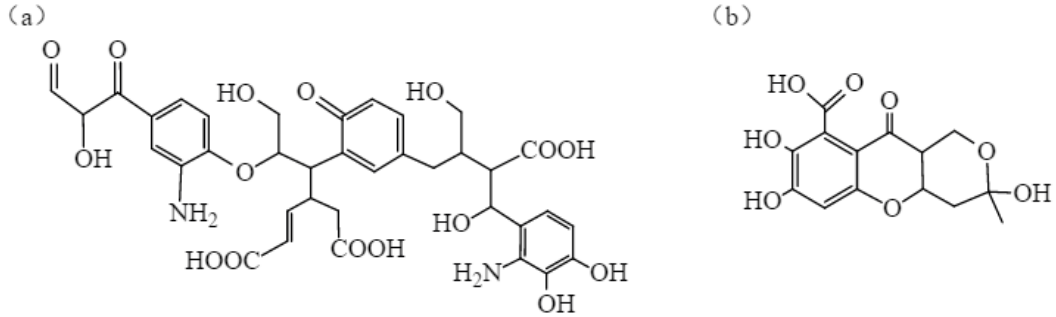

Figure 2. HA[13] monomer and FA[14] monomer structure prediction model

Alvarez-Puebla [13] and Paj czkowska J [14] have predicted the structural model of HA and FA. As shown in Fig 2 (a) and (b), in the structural prediction model of HA and FA, carboxyl, phenolic and amino groups are the most common functional groups in HA and FA. The hydrophilic groups are mainly carboxyl and phenolic groups located outside the unsaturated aromatic benzene ring, and the hydrophobic groups are mainly aliphatic chains and aromatic rings. HA has more aromatic benzene rings than FA.

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The content of carboxyl and phenolic groups in FA is higher than that in HA. Carboxyl and phenolic groups determine the acidity of HA and FA. HA is soluble in alkaline solution, but not in acidic solution, while FA is soluble in both alkaline solution and acidic solution [15].

3. Overview of Humus Function

The process of humus formation is called humization process, which widely exists in soil, water and other ecological environment. Soil humus can provide rich nutrients and energy for plants and microorganisms and stimulate the growth and development of plants [16].

Humus also has a certain degree of cohesiveness, which can make clay loose and sand bond, which is a binder to form aggregate structure and improve the looseness and ventilation of soil.

The functional groups of humus can capture water to a certain extent, enhance the ability of soil to retain water, resist drought and protect fertilizer, and mature humus also has a certain ability to inhibit plant pathogenic microorganisms [17].

The results show that humus can reduce the toxicity of heavy metals in the environment to some extent. Humic acid extracted from peat has certain adsorption properties for Cr6+, macromolecular HA can passivate a variety of heavy metal ions [18], humus also has the ability to reduce Fe_3^+ [19], composting humus has high remediation efficiency for soil heavy metal and arsenic content [20].

Song Zhengguo [21] and others applied compost humus to reduce the toxic effect of cadmium on maize, reduce the absorption of cadmium by corn tissue, and promote the growth of maize. Zhao Junchao [22] and others showed that pig manure composting reduced the exchangeable content of Cu and Zn, and increased the yield of Chinese cabbage. In summary, humus has many excellent functions, such as repairing and improving soil, stimulating crop growth, preserving water and fertilizer, reducing the availability of heavy metals and so on.

4. Summary

Humus is an aromatic compound formed by a series of complex biochemical reactions. Its structure is complex, but it is a mixture of a series of organic compounds with similarities and differences in composition, structure and properties. It is a mixture of small molecules and other types of polymers connected by π-π, CH- π, van der Waals force, Coulomb force and hydrogen bond to form humic substances. The carboxyl, hydroxyl, quinone, amino, methoxy, alcohol hydroxyl, sugar, carbonyl and phenolic hydroxyl groups on the molecule endow humus with chemical properties such as ion exchange, coordination, redox and so on. It has a wide application prospect in the field of agriculture.

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