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Soil Science

Potassium Humate: A Potential Soil Conditioner and Plant Growth Promoter

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Abstract

There is no better way to enhance the economics of farming, than to build soil humus and enhance the natural processes, such as microbial activity, which can be sustained over a long period of life. Potassium humates derived from lignite brown coal are alkaline, rich in carboxylic and phenolic groups, aromatic in nature and provide favourable conditions for biological activity, chemical reactions and physical improvement of soil. Accumulation level of natural humic acids like potassium humate has shown to reduce the need for commercial fertilizers because it improves fertilizer efficiency. The utilization of humic acid has been found to reduce the leaching of fertilizers and pesticides into aquifer and surface waters. By using humic acids, growers will gradually reduce application macro and micronutrients fertilizers application with addition to the improvement of overall crop yields and quality.

Highlights

- Potassium humate is the salt of humic acid, derived from lignite brown coal and rich in carboxylic and phenolic groups
- Humic acid influence the plant growth both directly and indirectly. The indirect effect of humic acid improves physical, chemical and biological condition of soil
- Its direct effects attributed due to its metabolic activity in plant growth
- Potassium humate enhance soil health as well as environment quality during crop cultivation

Keywords: humate, fertilizer efficiency, soil properties, sustainability

Introduction

Humic substances (HS) are the most widely spread natural complexing ligands occurring in soil. The presence of HS in soils has also been detected, even in the Antarctic continent where the humification process is very specific and different from the other ecosystems. The term “humus” originates from the Roman civilization, when it was familiarly used to signify the entire soil. Later the term was used to denominate soil organic matter and compost. The first relevant study of the origin and chemical nature of humic acid was worked out by Sprengel in 1839. His comprehensive study on the acidic nature of humic acid is thought to be his most important benefit to humus chemistry. Research on the chemical properties of humic acid was extended by the Swedish researcher Berzelius who isolated two light-yellow coloured HS from mineral water and slimy mud rich in iron oxides.

Potassium humate is a very concentrated form of humus in the naturally occurring lignite which is the brown coal that accompanies coal deposits. It is a peat material that has not been subjected to high pressure to turn it into coal, and from this originated potassium humate, a pure humic product with potassium. It provides a viable alternative to the use of synthetic polymers in amelioration of poor structure stability and disaggregation in soil. This is because of the refractory nature of their chemical structures which render them more resistant to degradation by soil micro-organisms. Researchers have shown that it is the humic fraction (humic acid, fulvic acid and humin) of the soil organic matter that is responsible for the improvement of soil aggregate stability. The typical potassium humate coal deposits was characterized (Table 1) by Sellamuthu and Govindaswamy (2003).

Table 1: Characteristics of potassium humate

Parameters	Values
pH	8.0
EC (dSm^{-1})	0.04
Organic matter ($g\ kg^{-1}$)	215
Total nutrients	
Nitrogen (%)	3.71
Phosphorous (%)	Nil
Potassium (%)	6.25
Calcium (%)	0.80
Magnesium (%)	0.024
Sulphur (%)	0.55
Zinc ($mg\ g^{-1}$)	100
Copper ($mg\ g^{-1}$)	20
Iron ($mg\ g^{-1}$)	2406
Manganese ($mg\ g^{-1}$)	1700

Sources of humic substances and their value as nutrient ingredients for crop

Humic substances usually occur in soils, waters, compost, peat and in carbon containing minerals such as brown coal, low grade lignites and leonaedites (Table2). Almost all soils and carbonacious natural substances on the earth surface contain some humic substances in the form of humin, humic acid and fulvic acid (Ravichandran, 2011). However, the concentration of humic substances in agricultural soils has reached at abnormally low levels. In general soils contain higher concentration of humin and humic acid. Being water soluble fulvic acid occurs at relatively high concentration in water. Soil humic substances consist of a higher percentage of aromatic compounds compared to humic substances in natural water.

Table 2. Humic and fulvic acid content of various materials from the natural sources

Natural sources	Humic acid (%)	Fulvic acid (%)
Leonardite	40	85
Black peat	10	40
Sapropel peat	10	20
Brown coal	10	30
Dung	5	15
Compost	2	5
Soil	1	5
Sludge	1	5
Hard coal	0	1

Fertilizer grade humic substances can be obtained from carbon containing mineral deposits in many parts of the world (Ravichandran, 2011). Naturally occurring humic substances from low grade lignites and leonardites (nature's soil conditioners) are superior fertilizer ingradientets (Ravichandran, 2011). The best source of humic substances for use as fertilizer is leonardite, which is highly oxidized low grade lignite that contains a relatively high concentration of the smaller molecular unit. In India lignite mined at Neyveli (Tamil Nadu) contains suitable good agricultural grade humic substances.

Humification

Humification is the natural process of changing organic matters viz. microorganisms and plant and animal residues into humic substances by geo-microbiological mechanisms. Compost is an intermediate product consisting of humic substances and partially decomposed organic matter. As the conversion process continues, different secondary bimoleccules dominate at different times.

Types of Humic Substances

Humic substances can be divided (Pena-Mendez, *et al.*, 2005) into three components: fulvic acids (FAs), humic acids (HAs) and humin (Fig 1).These three fractions are separated from various materials by using "classical" extraction techniques with aqueous solutions. First, the humic material is treated with a strong alkali (base), and then an acid is added. The acid caused a coagulated, black, sludge-like material to precipitate out of solution. The precipitate was named "humic acid." The remaining mixture that survived the base/acid treatment consisted of an acidic

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liquid and a solid. The liquid is named "fulvic acid," and the solid that is unaffected by the treatments was named "humin. Potassium hydroxide is the typical alkali used by manufacturers to extract humic acid from leonardite. Since the remaining liquid solution is very alkaline, in the range of pH 8 to 12, the product of adding acid to an alkaline solution, it is a salt, therefore the word "humate" may be more appropriate

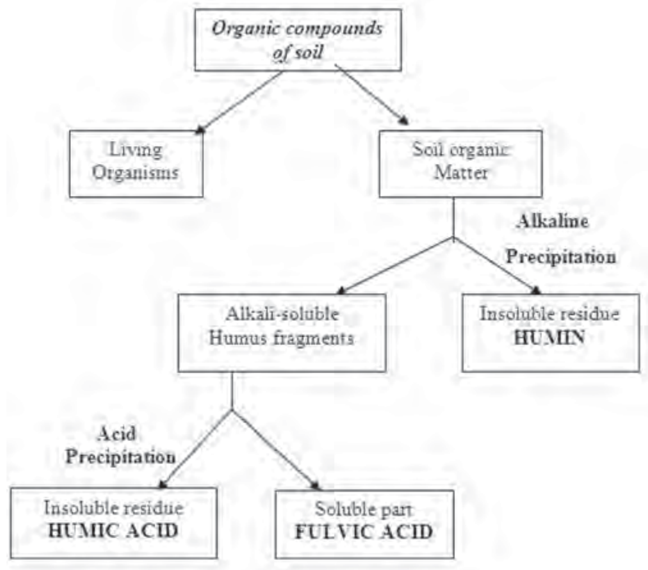

Fig 1: Division of humic substances in dependence of their solubility

Commercial use of potassium humate

Agriculture

Now a days, humic materials are used as additives in fertilizers (Albiach *et al.*, 2001, Arancon *et al.*, 2004). Different salts of humic substances, such as potassium and calcium humate were used to increase soil fertility (Buckau *et al.*, 2000). The fertilizing effect of sodium humate on plant leaves has also been noticed. Ammonium humate was also found to have a significant growth-stimulating effect (Lotosh, 1991).

The exact role of humic acid in promoting plant growth is not completely known, but several explanations have been proposed by researchers such as increasing cell membrane permeability, the transport and availability of micronutrients, nutrient uptake, stimulation of seed germination and viability, respiration and photosynthesis and root cell elongation (Mishra and Srivastava, 1988).

The growth-promoting effect of humic substances has been observed by many investigators and humates are often part of different preparations for growth-improvement of plants. Productivity of soil is increased by different ways in the presence of humic materials. One of the important roles of humic substances lies in the enhancement of the quality of soils when they are very poor in organic matter (Pena-Mendez, *et al*., 2005). Significant role of humic acid in any agricultural system is its ability to complex metal ions (Stevenson 1982). Humic acid forms complex with micronutrient ions, though not to be of the same extent as of many synthetic chelating agents can do (Aiken *et al.*, 1985, Pinheiro *et al.*, 2007). Since humic acid binds to soil colloidal surface, it is not easily leached (Jardine, 1989, Mackowiak *et al.*, 2001) and soil humic acid promotes heavy metal (i.e. copper and zinc) sorption to minerals such as goethite and silica (Spark *et al.*, 1976). Synthetic chelate availability can decrease by as much as 50% through soil sorption processes and this can make field application costly. The humic acids on the other hand can be inexpensively incorporated into soils through biowastes such as manure and the resulting organic matter has the added benefit of improving soil physical properties (Mackowiak *et al.*, 2001; Prakash *et al*., 2002).

The effect of humic substances on anion uptake (nitrate, sulphate and phosphate) has been noticed by many workers (Vaughan *et al.*, 1985; Clopp *et al.*, 2001) and it appears to be selective and quantitatively related to the concentration of humic substances and to the pH of the medium. Humic acid derived from lignite was found to increase growth and yield of crops because of its high ion exchange capacity and their by preventing nutrient loss. Since humic acid frequently behaves as one of the major components of soil and sediment, they may form an enzymatically active complex which can carry on reactions that are usually assigned to the metabolic activity of living organisms (Serbon and Nissenbaun, 1986).

Table3: Effect of humic acid on biometric factors of maize

	Control	Humic acid	% of control
Fresh weight (g)			
Roots	94	139.9	48.8
Shoots	297	475	60
Leaves	98	154.2	57.3
Total	489	813.8	65.8
Dry weight (g)			
Roots	15.9	21.6	35.8
Shoots	54.5	109.1	100.2
Leaves	25.2	38.6	53.2
Total	95.6	176.1	84.2
Length (cm)			
Roots	63.1	77.6	23
shoots	102	176.6	72.5

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Humic acid stimulates (Eyheraguibel, Silvestre and Morard, 2008) plant growth (Table 3) and (Fig 2) and alter the soil microflora (Chizevsky and Dikusar, 1955). The study on physiological effect of humic substances on micro-organism by Visser (1985) elucidated that the additional presence of humic matter in selective culture media can result in much increased counts of micro-organism per gram of soil, which enhanced plant growth due to the changes in microbial activity.

The structure of humic substances is not completely understood (Avena *et al*., 1998) and over the last few decades nuclear magnetic resonance spectroscopy has provided key insight into structural details of humic substances (Hertkorn *et al*., 2002). However, humic acids are made up of complicated mixtures which are linked together in no specific order. The result of this is extraordinary complex materials and no two molecules are exactly the same (Mikkelsen, 2005). Thus, humic acids have a highly heterogeneous structure, functionalities and varied elemental composition (Li *et al*., 2003; Mikkelsen, 2005). However Model structure of humic acid according to Stevenson (1982) is given in Fig 3.

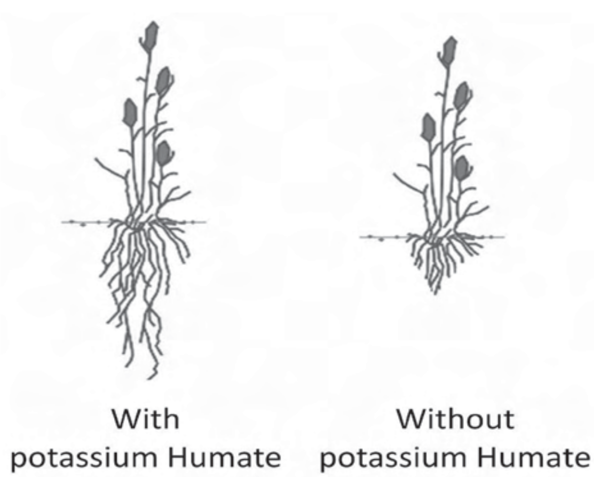

Fig 2: Effect of Humic acid (left) on lateral root emergence in comparison with control (right) of maize (Eyheraguibel, Silvestre and Morard, 2008)

Environment

Humic and fulvic acids are important as radionuclide transport agents through the environment. It is known that the presence of humic substances in natural waters can influence the uptake of radio nuclides by natural solids and thus their migration to surface and ground waters (Samanidou *et al*., 1991). The benefit of humic substances in environment is to remove toxic metals, anthropogenic organic chemicals and other pollutants from water. Ion-exchange materials based on calcium humate were found suitable for the removal of such heavy metals as iron, nickel, mercury, cadmium and copper from water and also to remove radioactive elements from water discharges from nuclear power plants (Pena-Mendez, *et al.,* 2005). Now a days humus-based filter have been developed to remove pesticides from sewage and to remove phenol from water. Many types of compounds such as herbicides, fungicides, insecticides, nematicides, dioxins and some pharmaceutical products like estrogenic compounds were determined as possible environmental endocrine disruptors. Humic substances were found to be useful to remove those contaminants from water, soil and sewage sludges (Shin *et al.,* 1999, Lofredo *et al.,* 2000).

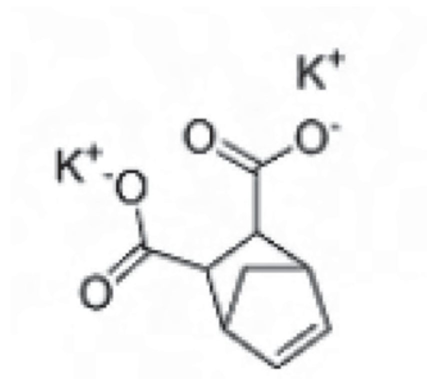

Fig. 3. Model structure of humic acid according to Stevenson (1982)

Industries

Humic substances have been used in large-scale building, for instance, as additives to control the setting rate of concrete. Humic materials found use in the preparation of leather. Initially, they were used as a leather dye, later on as an agent for tanning leather and, finally, as an ingredient of a solution to finish leather (Pena-Mendez *et al.,* 2005). It is also used in wood working industry. They were used to prepare a natural indigo, to dye wood veneer. Humic materials appeared to be suitable agents as a component of water-soluble stains for wood furniture (Pena-Mendez *et al.,* 2005). Other industrial application included: as an ion exchanger, as a source of synthetic hydrocarbons and fuel oils (Duncan *et al.,* 1981), in food processing and to enhance the extraction of uranium from its ores (Schmeide *et al.,* 2000) and in the production of plastics, especially as dyes for coloring Nylon 6 or PVC plastics, hardeners of polyurethane foams or as plasticizer ingredients for PVC (Majakova and Proskurjakov, 1972).

Conclusion

Humic acid offers an economical and effective solution to environmental problems. It decreases the toxicity of liquid fertilizers in food crops and prevents the problem of soil erosion. Humic acid increases plant production and enables plants to absorb more nutrients and vitamins. It strengthens crop resistance to disease and pests. Also, crops treated with humic matter have a higher nutritional value for humans. Application of humic acid improves soil structure and increases the yield of crops planted in the soil. It is particularly important in drought conditions as it helps soil to retain water. It increases the soil's absorption of solar energy and boosts aeration of the soil, making it easier to work with.

The natural process of the formation of humic substance in soil is very slow, particularly in high intensive farming system. Moreover, for improving the soil health (Rakshit and Das, 2011), better efficiency of synthetic fertilizer (Rakshit *et al*., 2010) and for maintaining sustainable cultivation practices without deterioration of the ground water and atmosphere, we need to enhance the accumulation of humic substance in soil. But it is not practically possible in intensive farming system in India, China, Bangladesh, Pakistan, and Srilanka. Thus, improvement in the soil health as well as in environment quality can be achieved by using potassium humate during crop cultivation.

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