Dr. Mir-M Seyedbagheri, Director of Research and Development
Professor Emeritus/Soil Agronomist

Humic substances such as humic acid, fulvic acid, and humin possess complex chemical dynamics *(super mixtures)*. These dynamic groups are comprised of a mélange of different structural makeups. The high molecular-weight humic substances influence soil's physical and chemical characteristics. On the other hand, low molecular-weight humic substances, such as fulvic acid and fulvates, can create high chemical reactions in the soil, which in turn impact plants' metabolic processes.

Fulvic acids:

Fulvic acids are a member of the humic substances family. They are akin to humic acids, *with key differences being reflected in their carbon and oxygen content, acidity, degree of polymerization, molecular weight, and color*. Fulvic acids remain in solution following the removal of humic acid from humin by acidification. *Its name is derived from the Latin fulvus, meaning yellow color*.

Many research findings demonstrate that fulvic acid possesses less carbon and more oxygen than humic acid. Schneider reported that fulvic acids can form via enzymatic or chemical oxidation of humic acid. *In general, the concentration of acidic functional groups in fulvic acids are higher than any other organic polyelectrolyte*. Schneider et al also noted that fulvic acids are assembled in parts of phenolic and benzene carboxylic acid *and are held together by hydrogen bonds, thus forming a polymerasic structure with stronger stability*.

In terms of chemical weathering, the Soviet biochemist Pono Marerva *(et al)* reported fulvic and humic acids influence silicate mineral decomposition. Their findings also signify that fulvic acid possess several interesting and important features in decomposition of silicate minerals. *This study indicates that fulvic's singular absorption abilities, complex bonds, and chemical affinities were maintained over 200 days of experiments*. Fulvic acid shows a marked capacity to enter into complex bonds with many dissolved minerals. The total mineralization of the fulvic and humic acid solution, interacting with soil minerals, increased in all facets of this experiment. *In terms of chronological development, this ranged from the first 5 days of the decomposition to the 200th day of the experiment*.

As per Kodama's studies (et al), fulvic acids in water solution can penetrate micaceous minerals and solubilize substantial amounts of iron, potassium, magnesium, aluminum and silicon, contingent upon the types of minerala.

Organomineral complexes:

Fulvic acids can interact with clay minerals, especially with polyvalent metals at the soil clay surfaces.

Chelation of metals:

Research conducted by Christman et al shows fulvic acids are capable of chelation that enhance the availability of important trace elements, and synergize and prolong the residence time of macro and micronutrients in soil solution chemistry. *Christman also proved that fulvic acids enhance the permeability of cell membranes, increased metabolism of proteins (RNA & DNA)*. Fulvic acids increase the overall activity of numbers of enzymes, including respiratory catalysts. Fulvic acids activate favorable physiological effects in cell division and cell elongation.

Solubilizing agents:
Ong et al reported that fulvic and humic acids are good solubilizing agents for metals and minerals.

Physical, chemical and biological properties of soil:
Schneider's studies demonstrate that fulvic acid is highly oxidized, water soluble, biologically sustainable and possesses chelating and complexing agents that can complex divalent and trivalent metal ions and hydroxylated metal compounds that form organo-mineral complexes in soil.

Molecular oxygen, aerobic respiration, and microbial activity:
Rashid reported that fulvic acid's molecular oxygen is an active terminal acceptor and the aerobic respiration is the most efficient energy yielding metabolic process for microbial growth and activity. During this aerobic respiration the organic carbon is converted to carbon dioxide, sulfur to sulfates, nitrogen to nitrates, and phosphorus to phosphates. This aerobic environment impacts the activities of different aerobic microorganisms in the soil.

Oxygen-Hydrogen groups:
There are plenty of oxygen-hydrogen groups in fulvic acid samples. These electron-donor groups are important in the overall electron-transfer balance which may impact the generation and survival of free radicals in humic substances.

pH relations:
The pH in fulvic acid solution influences the extent and rates of fulvic acid's free radical response to induced changes in the solution's redox potential.

Reduction of Ions:
Stevenson reported that humic substances, especially fulvic acid, have the capability to reduce oxidize forms *(redox)* of certain metal ions. *Example: reduction of* Fe^{3+} *(iron).* This reduction of ionic species is vital in soil and water systems because of solubility characteristics of metal ions and their inherent mobility.

Biological activity:
According to Senesi, increased biological activities, photosensitization action, and involvement in photodegradation processes of organic chemicals have resulted from the free radical enrichment of fulvic acids caused by irradiation.

Photochemical processes, electron production, and radiant energy:
Zalflrou et al documented that light absorption by humic substances creates a plethora of photochemical processes, comprised of solvent stimulated electron production. These photochemical processes influence the oxidizing and reduction of radicals, while creating triple sensitizers. *In other words, these processes form a radiant energy.*

Enzyme activation and plant respiration:
Studies documented that small concentration of fulvic acids are capable of activating enzymatic systems within the plants. The studies documented the plant's respiratory effects. According to

Konova*, oxygen absorbs more intensely in the treated plants that contained fulvic acid, as opposed to untreated controlled plants*. We must note that during the initial growth period and formation of reproductive organs, biochemical processes are most active. *The catalytic activity of fulvic acids in respiration helps plants t better withstand drought conditions.*

Increase cell permeability:

Prakash and other researchers' findings concluded that fulvic acid and low molecular weight humic compounds create specific cell sensitizing chemicals. These enhance permeability of the cell membranes.

Soluble sugars:

Research reveals that the quinones and hydroxyl quinones present in the fulvic acid are responsible for the metamorphosis of metabolisms in carbohydrates. This metamorphosis results in an accumulation of soluble sugars. *These soluble sugars increase osmotic pressure inside the cell wall and help the cells withstand wilting, if the relative humidity of atmosphere is low.*

Plant metabolisms:

According to studies by Vaughn, et al, small amounts of humic substances, especially fulvic acids, increase the activity of several enzymes. *These include alkaline phosphates, transaminase, and invertase.* According to khristeva et al these humic substances also enhance the metabolism of proteins, RNA and DNA.

Seed stimulation:

Succinic and fumaric acid compounds found within fulvic acids are the results of humification. They act as biological stimuli. R*esearch shows that these compounds enhance seed germination, influence development of roots, shoots, and overall crop yield and quality.*

Oxidation-reduction, electron transfer, and catalytic reaction:

Fulvic acids are involve in many oxidation-reduction, electron transfer and catalytic reactions. As a result, the production and consumption of oxygen and carbon dioxides are related to the quantitative and qualitative distribution of humic substances. *These compounds also have pH buffering capacities.*

Influence on physics, chemistry, and biology of soil:

There is much evidence based on an array of experiments, *which indicates the fulvic acid fraction of humic substances directly or indirectly impacts the overall chemistry, physics, and biological dynamics of soil and plants.*

Summary

Functions of fulvic acids:

- *Enhances seed germination and growth.*
- *Enhances development of roots and shoots.*
- *Influences metal complexation and nutritional physiology.*
- *Enhances the uptake of macro and micronutrients.*
- *Is an excellent carrier for nutrient translocation from roots and as a foliar means of application.*
- *Stimulates plant metabolisms.*

- *Possesses strong chelating capacities and overall effects on the plant growth cycle.*
- *Exerts a positive influence on plant's RNA and DNA.*
- *Act as catalysts in plant respiration.*
- *Increases metabolism of proteins.*
- *Enhances enzymatic activities.*
- *Enhances permeability of cell membranes.*
- *Assists in cell division and cell elongation.*
- *Positively influences chlorophyll synthesis.*
- *Increases overall growth, yield, and quality of crops.*
- *Has a unique affinity for chemical balance.*
- *Possesses high cation exchange capacity (CEC).*