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Innovations in Biological Agriculture Systems

OroGro 307

Organic matter, compost, humus, Humates, humic acid, and fulvic acid are all related to, and parts of, decaying plant and animal materials. It is food for soil life and a storehouse for minerals, energy, and water. The biological/organic farming system is based on balanced minerals and lots of soil life in terms of diversity and volume.

So where do humic substances fit in farming systems? The objective of this article is to clarify the role of humic substances, update and review the scientific research and provide guidelines for use of the OroGro 307 product.

Research is proving what farmers have known since Roman times: humic substances stimulate plant roots, stimulate soil life (mostly fungal populations), chelate minerals (increasing their bio-availability), improve absorption of minerals for root and plant use, improve the effectiveness of herbicides and more.

In the first section of this paper I will explain our OroGro 307 product and the benefits to plant life. The last section is a scientific review of recent humate research.

EXTRACTION OF CHEMICALS

Humates are derived from Leonhardites or oxidized Lignite's. Our OroGro 307 Liquid Humates are composed of humic and Fulvic Acid.

Most of the Humate industry obtains their humic and Fulvic Acids by mixing a strong base liquid material like sodium hydroxide or more commonly potassium hydroxide with a dry humate material. This process introduces foreign chemicals to extract the Humates, results in large, coarse particles, disqualification as an Organic substance, low bioavailability and generally results in low quality product.

Our OroGro 307 is made from pure Leonardite, and reverse osmosis purified water with no extracting chemicals agents at all. Our process is a breakthrough innovation in our industry, a completely mechanical, non-chemical extraction technology. Our OroGro 307 is completely natural and organic.

MIXING WITH FERTILIZERS

Our OroGro 307 Humates work very well when mixed with liquid fertilizer; it serves to buffer the soluble fertilizer and can dramatically improve the effectiveness of the fertilizer. Farmers and consultants have good success blending liquid Humates with natural phosphates, calcium, sulfur, and trace mineral materials, inoculates with beneficial organisms, adding molasses, and brewing the batch: just like making compost. The natural humic material has a low pH, large nutrient holding capacity and feeds microbes.

CHELATION

Chelation: The root structures of plants are semi-permeable membranes, whose job it is to identify minerals, vitamins, phosphates, nitrogen, and other beneficial compounds, and let them through the membrane so the plants can use them. Unfortunately, many of the most beneficial compounds in the soil are not readily recognized by the root membrane and are prevented from being absorbed. Essentially, this is an error where the plant misidentifies beneficial compounds.

Chelation is a process whereby the humates attach themselves to the beneficial vitamins, minerals and other nutrients already present in the soil, and the “couple” are easily recognized by the root membrane and are readily absorbed. Essentially, chelated nutrients have a much higher chance of being successfully absorbed into the plant and providing nutrition. When we say that the humates allow better nutrient uptake, a major reason is the benefit derived from the chelation process.

ACIDITY

The acidity of our humates also plays an important role. Many farms are considered “overworked” or not fertile due to over farming. Often this is not an accurate description of the issue. Frequently, we find huge clusters of nutrients, vitamins, minerals, and other beneficial compounds bound together in a single large molecule which is far too large to be utilized by the plant's root system. The nutrients are in the soil; however, the huge molecular size prevents the plant from accessing them.

A property common to all acids is the ability to explode these large molecules into hundreds or thousands of component pieces. Our humic and fulvic acids are particularly adept at **exploding large molecules of nutrients**. These smaller components then become highly available to the plants. Therefore, it is often inaccurate to say that the land is infertile, rather, the land has substantial fertility that is not available to the plants.

PH BUFFERING

The root structures of plants can best absorb nutrients that are free-floating and in solution (not bonded to other compounds). If the nutrients are attached to larger molecules, the plant has a difficult time absorbing them and these bound-up nutrients cannot contribute to the nutrition of the plant. Most nutrients are released from their molecular bonds and become free-floating nutrients only in the presence of a favorable pH level. Our OroGro 307 humates do an excellent job of buffering the pH of the soil. Therefore, helping to release the nutrients into the soil, releasing them from their molecular bonds.

ADDITIONAL NUTRIENTS

In addition to the nutrient-freeing action from pH buffering, and the molecule exploding action from the acidity, the humates themselves bring a rich array of complex molecules including nitrogen, calcium, trace elements and rare earths, minerals, vitamins, hormones and other unknown compounds.

Liquid fertilizers are water soluble, can leach, tie-up in the soil, cause short term nutrient imbalances, and don't provide continuous nutrients over the plant's life. They have their place as a pop-up to get the crop out of the ground or as a foliar to give a boost, but not as a complete fertilizer program. Humates, on the other hand, provide solid, long term nutrition that progressively rebuilds the fundamental humus in the soil.

ANION & CATION EXCHANGE

Most nutrients carry a positive charge, called cations. The clay, humus, and other soil particles typically carry a negative charge. The nutrients (positively charged cations) typically bond with the clay and humus particles (negatively charged anions). These magnetic bonds help to prevent the nutrients from washing away with the water. **Our catalytic water has both cation and anions, offering both a positive and negative charge for magnetic bonding.**

For the plant root system to adsorb the positively charged nutrients, the roots must sometimes exchange another positively charged element to replace the nutrient absorbed. The humates facilitate this exchange of positively charged (cation) nutrients (called Cation Exchange).

In addition, when the humates are introduced into the soil, they often have the impact of displacing the positively charged nutrients that are bonded to the clay particles, forcing those nutrients to move into solution making them available at the roots.

MICROSCOPIC PARTICLE SIZE

Our OroGRo 307 is the finest ground humate product on the market, our production process is expensive and difficult to manufacture using cutting edge technologies originally invented for the gold mining industry. The particles are so fine, we have eliminated the old problems such as: plugged or clogged spray nozzles and/or necessity to constantly stir the tanks.

However, the microscopic particle size of our humates has an enormous impact on the effectiveness of our product. As an example:

Imagine that I am holding a whole beet and I wish to stain your white shirt. I would not be particularly successful … staining only a half-dollar size portion of your shirt. Most of the beet material is trapped on the inside and only the outer surfaces can be used to stain your shirt. Now, imagine that I grind the beet up into a puree. I can now slather the puree all over your shirt, *and probably the guy standing next to you also.* By exposing all the inside of the material, we exponentially increase the surface area and therefore the effectiveness of the product.

The microscopic particle size of our product is much more important than just our ability to fit through spray nozzles.

WATER RETENTION

Humates improve the general structure of the soil and thus directly improve the soil's ability to retain moisture at the root level. However, humates have an additional feature that directly aids in the retention of water.

Silica wafers are ubiquitous in all soils. They are microscopically thin components of the soil. In the presence of humates, these ultrathin wafers become three-dimensional sponges than can absorb a tremendous amount of water, and then they slowly disperse that water over the next days or weeks.

To give an everyday illustration of the water absorption and retention capability of silica and gel packs that accompany most shipped goods. They typically bear a notice "Do Not Eat – Silica Gel". These shipping packets are designed to absorb any moisture that may collect in the shipping box. The humates activate the moisture retention potential of the silica wafers already existing in the soil.

LOWEST LEVELS OF UNDESIREABLE COMPOUNDS

Many humate products on the market contain high levels of lead, mercury, and other undesirable compounds. These are toxic to the plants. We know of no other product on the market with lower levels of undesirable metal compounds than our OroGro 307. Some of the humates that are imported from China have unacceptably high levels of contaminants and sometimes do more damage than good. The sand and ash have also been mostly removed by our manufacturing process.

TOXIN SEQUESTRATION

Most farmland suffers from some level of toxicity either naturally occurring, introduced by pesticides or other sources. These toxic substances in the soil can cause tremendous damage to the plant's health. The humate molecules have receptor sites that are extremely attractive to toxins, pesticides, and other negative elements in the soil. The receptor sites on the humates capture and bind these negative elements and render them unavailable to the plant. Humates are so effective at capturing toxins that the EPA recommends use of the humates in every toxic cleanup project. By sequestering the toxins, humates can dramatically improve the health of the soil and plants.

CONVIENCE

Some humate products are distributed as dry powder which is: dusty, hard to handle, suffer from low bioavailability and have substantially inferior actual results. The black dusty humic material is unworkable for most fertilizer blenders. Our OroGro 307 is distributed in liquid form, as a colloidal suspension making it far more flexible and available for use with spray rigs as well as convenient and effective for application and mixing.

COST EFFECTIVENESS

With all these features and benefits, one might think that humates are quite expensive. Fact is, it takes a small amount of humates (ten parts per million) to get the job done. Roughly one pint per acre is sufficient to get all the benefits described above. Application of higher concentrations has no additional effect; it is simply wasted. In addition, humates need only be applied once or twice each season for maximum effect. At a retail price of approximately $100 per gallon, the cost of the humates virtually disappears in all the other costs of farming.

SCIENTIFIC RESEARCH

In our effort to help farmers, consultants, and agricultural researchers to better understand humic substances, we have included a review of current scientific research about the humates.

Humic Substances as Agronomic Inputs in Biological Agricultural Systems: A Review

Background

Humankind has realized for thousands of years that dark-colored soils with high humus content are more fertile than light-colored soils. It has long been recognized that humic substances have many beneficial effects on soils and consequently on plant growth (Mulller-Wegener, 1988). Anywhere on the globe, where there is soil or water associated with organic matter, humic substances are present. They are the brownish tint often seen in natural streams, the darkness of dark soils and the dark brown color of weathered lignite coal.

Humic substances are the most widely distributed organic products of biosynthesis on the face the earth (Tan, 2003), exceeding the amount of carbon contained in all living organisms by approximately one order of magnitude (Steinberg, 2003).

Soil organic matter is defined as the total of all naturally occurring organic (carbon based) substances that are found in soils, which have come from living things. The process of changing from recognizable bits and pieces of plants (or animals) to an amorphous, “rotted” dark mass is called **humification**. **Humus** is defined as the organic matter in soil that is a mixture of partially and totally humified substances. Most humic substances come from the natural process of decaying plant matter. (Hayes, 1998) Humic substances make up about 80% of the soil organic matter in dark soils. (Schnitzer, 1986)

Humic substances in soil are the dark brown, fully decomposed (humified) remains of plant or animal organic matter. They are the most chemically active compounds in soils (Tan, 2003) with cation and anion exchange capacities far exceeding clays. They are long lasting critical components of natural soil systems, persisting for hundreds to thousands of years, which can be destroyed in less than fifty years by some agricultural practices.

The interest surrounding the use of humic substances comes forth from the necessity to understand an essential component of the most complex ecosystem on the globe … soils! The global movement away from chemical to biological agriculture is encouraging some of the best minds in scientific world to solve the great mystery of how these substances operate in the environment.

As information-agriculture moves towards organic methods, the world is compelled to reconsider the post-World War II paradigm of indiscriminate use of high-energy input, high solubility, and toxic chemical resources. (Nardi, et al, 1996) Natural humic substances are destroyed by conventional practices but can be replaced by proper management practices. Humic substances are the most widely distributed products of biosynthesis on the face of the earth (Tan, 2003). Besides soils, they can be found in varying concentrations in several different sources: rivers, lakes, oceans, compost, sediments, soils, peat bogs, and soft coal. As the use of humic substances in agriculture grows, the number of vendors of humic products is also growing. Historically, the typical supplier has been a small, privately owned operation located where the materials can be easily removed with basic equipment. Because humic substances are typically associated with coal deposits, the large coal mining companies are beginning to realize that the market for these materials may be attractive.

There are several theories that attempt to explain how coal is converted to humic matter. All of them agree that “younger” deposits of organic matter have lower concentrations of humic acid (Tan, 2003). The concentration of humic substances in the converted coal can be as high as 80% by weight.

Although humic substances can be found in every scoop of soil and almost every drop of water on the earth, no one has succeeded in 200 years at describing their structure. (Steelink, 1999) Behaving more like chameleons, humic substances rapidly rearrange their molecular structure as the surrounding conditions change (Tombacz and Rice, 1999).

The worldwide usage of humic substances is extensive (Fataftah, et al, 2001) The benefits of humic substances in agriculture soils are well established (MacCarthy, 2003), especially in soils with low organic matter. (Chen and Aviad, 1990) They are an integral part of all ecosystems and play an important role in global cycling of nutrients and carbon ((MacCarthy, 2003).

Humic substances are extremely versatile. They provide a concentrated and economical form of organic matter that can replace humus depletion caused by conventional fertilization methods as well as being used in biological programs. (Burdick, 1965) The addition if humic substances to soils, including calcareous soils, can stimulate growth beyond the effects of mineral nutrients alone. (Chen, et al, 1999)

Humification

Humification is the natural process of changing organic matter, such as leaves, 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 chemicals dominate at different points in time (Ziechmann, et al, 2000). Complete conversion to humic substances will eventually occur.

Unlike most other biosynthetic processes, humification occurs in a complex, chaotic "open" system where there is no "closed" control of the process by enzymes, cell structures, membranes, or cellular transport systems. With the infinite variety of plant materials that exist in nature and with the infinite access to chemical radicals, humification should produce humic substances that are infinitely variable (Ziechmann, et al, 2000). It would seem impossible to find two humic molecules with the same structure.

Confusion and Non-Standardization

Humic substances have been a matter of scientific controversy for over 200 years. They are incredibly complex colloidal super mixtures (MacCarthy, 2001) that have never been separated into pure components (Steelink, 1999; MacCarthy, 2001). Inconsistent use of terminology and the previous lack of standard materials for comparison purposes have compromised the ability to translate the sparse amount of scientific knowledge to practical applications in soil environments. Traditionally, humic substances have been defined by their solubility in aqueous (water) solution at arbitrary pH levels and molecular weighs.

The use of numerous names to describe commercially available humic materials has contributed to the confusion. Humates, humic acid, Leonardite, brown coal, lignite, slack lignite, oxidized lignite, weathered lignite, humalite, fulvic acid, fulvates, ulmic acid, humic shale, carbonaceous shale, colloidal minerals, humin, concentrated humus, soil organic matter, peat, humus acid, humus coal and dead organic matter are some of the terms that are used to describe and/or market humic substances.

Non-standardization and confusion are not limited to humic substances. For example: many labs are using soil tests that may not accurately determine soil organic matter content due to oversimplification. There are numerous tests for soil organic matter (Tabatabai, 1996), but there is no standardized test protocol for all soils. Some of the tests for soil organic matter must be interpreted with much caution (Magdoff, 1996). Additionally, conventional analyses do not predict possible adverse interactions of trace elements (Olness et al, 2002).

The establishment of standard reference material by the International Humic Substances Society http://www.ihss.gatech.edu/ has helped to remedy some of the communication problems. The society is composed of scientists from all over the world who are striving to understand the structures and functions of humic substances. The north-central United States contact is Dr. Alan E. Olness, USDA-ARS, North Central Soil Conservation Research Laboratory, Morris, MN 56267, 320-589-3411 x 131.

The Benefits of Humic Substances

While the complete structure of humic substances has eluded scientists, their effects on everything from apples to zucchini have been extensively studied.

Humic substances are renowned for their ability to:

- Chelate soil nutrients
- Improve nutrient uptake (especially phosphorous, sulfur and nitrogen)
- Reduce the need for nitrogen fertilization
- Remove toxins from both soils and animals
- Stimulate soil biological activity
- Solubilize minerals
- Improve soil structure
- Act as a storehouse of nitrogen, phosphorus, Sulphur, and zinc (Frank and Roeth, 1996)
- Improve water holding capacity for better drought resistance and reduction in water usage (Russo and Berlyn, 1990)

Extensive research on the stimulatory effects of humic substances has been conducted by the USDA-ARS soil lab in Minneapolis (Clap et al, 2001; Chen et al, 2001; Chen et al, 1999) and worldwide (Karr, 2001). Most of the research conducted in Eastern Europe on improving nitrogen utilization has not been translated into English (Clapp et al, 2001).

Depending on the form of fertilization applied, nitrogen may become a structural component of humic substances as a stable organic material, preventing it from leaching through the soil (Haworth, 1971; Stevenson, 1982; Haynes and Swift, 1990; Kelly and Stevenson, 1996). In their natural state, humic substances contain anywhere from 1% to 5% nitrogen.

Nitrogen Management

Other effects of humic substances include increased CEC (cation exchange capacity), stabilization of soil structure (Piccolo et al, 1999) and the reduced need for nitrogen and phosphorus fertilizers (Day, et al, 2000; Fataftah, et al, 2001). The importance of humic substances on the fertility of soils and the stabilization of nitrogen has been well documented (Thorn, 2000; Kelly and Stevenson, 1996; Nardi, et al, 1996).

If there are sufficient humic substances present, up to 35% of the soluble nitrogen applied to soils as fertilizers can be retained in the soil in organic forms at the end of the first growing season (Stevenson and Xin-Tao He, 1990), thus converting the N to a stable, yet bioavailable, form.

The ecological impact of nitrogen applied to turf grass is increasingly coming under the scrutiny of the public sector and the federal government. Because of this pressure, humic substances have become the most commonly used organic materials in golf course turf management (Clapp et al, 1998). After 45 years of research, C. Edward Clapp of the USDA-ARS, Department of Soil, Water & Climate in Minneapolis, Minnesota is recommending humic substances be used to prevent nitrogen leaching on golf courses (Clapp, 2001).

An exhaustive review of the scientific literature has revealed very little regarding the practical application of humic substances in agriculture. There are numerous references to a large body of research in Russia that has not been translated into English. A recent reference (Steinberg, 2003) states that most of the information is buried as internal reports within universities.

Benefits for Livestock Management

One study done by a science team from west Texas A&M University and the USDA-ARS (Shi et al, 2001) demonstrated the potential of humic substances in reducing ammonia emissions from feed lots.

Barley Test

There was over a 12% increase in yield in the barley test plot even though the Leonardite treated crops had relatively low nitrate nitrogen. The significant yield advantage was partially attributable to increased tilling.

Potato Test

The potato test plots reveal how a 95% increase in plant tissue uptake of nitrogen was possible while 35% less nitrogen was applied with the Leonardite fertilizer combination.

Sugar Beet Test

Sugar beets treated with the fertilizer- Leonardite combination yielded 23% more tonnage per acre and 15% more sugar per acre.

Despite the fact that the above report from the US Bureau of Mines concentrated primarily on yield, which is typical of conventional NPK fertilization programs, the report underscores how humic substances can improve nitrogen utilization and impact overall crop quality by increasing the efficiency of fertilizers. Additionally, the reduction in nitrogen usage demonstrates the environmental significance of using humic substances blended directly with fertilizers.

Carbon Cycling

The carbon held in soil humic substances is so stable it may be retained in soils for thousands of years, depending on conditions (Miller and Gardiner, 1998). The shear complexity of the materials may explain why they are not broken down by microbial action for thousands of years (Schnitzer and Khan, 1972). It is possible that the surfaces of humic substances are unrecognizable by microbes (Orlov et al, 1994).

Conventional fertilizers rapidly age soil components, resulting in acidification of soils (Burdick, 1965; Barak, 1999) and by dissolving the humic materials with soluble nitrogen. Urea is so effective at dissolving humic substances, it is used in some laboratory extraction procedures (Pokorna et al, 1999). A typical Iowa soil under conventional agriculture management retains its carbon for as little as 90 years (miller and Gardiner, 1998).

The negative effects of high soil acidity have been extensively researched. “Liming”, which is the use of dolomitic limestone (calcium magnesium carbonate) improves soil productivity by providing cations of calcium (Ca2+) and magnesium (Mg+). The carbonate ions raise the pH by combining with the excessive hydrogen protons.

The ability of humic substances to complex with cations, such as calcium, is decreased as the bulk pH of soils goes down (more acid) due to aggregation of the humic molecules. The aggregation reduces the exposure of functional groups, cutting off the access of nutrients to the molecules (Liu and Huang, 1999). Functional groups attached to carbon chains are primarily responsible for the biochemical characteristics of organic compounds.

Humic Acid, Fulvic Acid and Humin

The humin fraction gets little attention. It may seem to be somewhat inert, but it has been described as acting like a sponge, soaking up nutrients (Karr, 2002). Hayes and Graham (2000) report the composition of humin to be the same as humic acid and fulvic acid. They say that humin may be a humic substance in association with mineral oxides or hydroxides (from the reaction), Alternatively, humin may be coated with hydrocarbons or lipids (fats) that were stripped during the reaction, making them insoluble to aqueous solvents. Nobody really knows for sure.

Some people think that fulvic acid is more biologically active than humic acid because of its smaller molecular size. There is some truth in these representations as there is evidence that the lower weight fractions can cross plant membranes and approve permeability of cell walls. It is true that fulvic acids have a higher "total acidity" than humic acids (Tan, 1986), however the chemical reactivity and chelating ability of humic acids is equal to or greater than fulvic acid (Tan, 2003) making them very bioactive substances. The humic acid fraction may be more effective than fulvic acid at solubilizing extremely stable aluminum and iron phosphates (Lobartini et al, 1998).

In one case reviewed by Chen and Aviad (1990), the young age of the humic materials were suspect because humification is a time dependent process. As the material ages, more bioactive ingredients become incorporated into the humic complex (Ziechmann et al, 2000). Old age is good.

Wet Chemistry vs. Complex Geobiological Systems

The lower molecular weight (the mass of a substance expressed in a gram equivalents of its atomic mass) of fulvic acid is sometimes said to account for its greater biological availability. That is somewhat correct (Chen and Aviad, 1990), but very vague because the industry has not agreed on standardized molecular weights for fulvic acid. Defining humic acid, fulvic acid, and humin by their molecular weights is a controversial concept.

Some wet chemistry techniques can be used to characterize different humic materials. For example: the carbon/oxygen ratio is used by some to determine the presence of functional groups.

There may be some merit to this as functional groups are high in oxygen content. The difficulty with wet chemistry techniques is that it rarely mimics the real environment in which these materials are expected to perform.

Humic substances change their structure depending on pH and the type of metals present (Kolla, 1998; Piccolo et al, 2000). High pH (or the presence of multivalent ions such as calcium Ca^{2+}) makes humic substances open their long chain polymers and low pH makes them close. In the presence of toxic metals, humic substances remove the metals from the surrounding environment by forming insoluble aggregated spheres around them (Liu and Huang, 1999).

Humic substances are "polymer-like" molecules that demonstrate self-organization (Hayes, 1998; Cook and Lanford, 1999; Piccolo, et al, 2000). The bilayers formed by humic substances to surround otherwise insoluble minerals (Tombacs and Rice, 1999) are reminiscent of the way all living things utilize biochemical reactions to carry on life in general. The self-organized (micellular) colloidal phases act like biological molecules in cellular systems, showing a strong resemblance to the biological mechanisms of living membranes, as described in college textbooks such as Voet and Voet, 1995. Humic substances are more like living creatures than chemical entities, but they don't reproduce.

Slight changes in pH will cause the humic polymers to fracture, breaking up the original molecules (Tombacz and Rice, 1999; Piccolo et al, 2000). The fractured molecules are then free to associate with numerous other free radicals. Metals, or impurities. Humic substances are made up of hundreds of different molecules of many different sizes (polydispersity) with many ways to orient themselves by twisting, bending, compressing, and expanding (conformational changes). They are held together very loosely by weak forces (Piccolo, et al, 2000) in a colloidal state. Any change in solution pH, concentration, or the presence of metal ions (especially calcium ions) will cause huge changes in the physical makeup of the humic molecules. Even slight changes will cause the molecules to change in orders of magnitude (Tombacz and Rice, 1999). Rapid changes in molecular structures are not peculiar to just humic substances. Water molecules change their structure 10,000,000,000,000 times a second (Voet and Voet, 1995). Although water is an extremely simple molecule, the determination of its structure at any given instant is still somewhat unknown. The amazing complexity of humic substances may forever keep their structures a secret.

Fulvic Acid

The primary reason why there is so much confusion about humic substances is the fact that the same procedures used to describe them are based on "classical" aqueous extraction. If minerals are present in the parent material, they become complexed by humic substances. This allows more humic and non-humic material to be solubilized during extraction (Ozdoba, et al, 2001) by breaking down ion bridges that would normally hold the molecules together in higher purity materials. Unless the supernatant is separated by special procedures (such as passing over XAD-8 resin) to isolate the fulvic portion, the extracted substances may contain anything from amino acids, proteins, sugars, or fatty acids in addition to the fulvic acid (Hayes and Graham, 2000).

In biological molecules, it is an established fact that the presence of functional groups, such as carboxyl, phenol, quinone, and hydroxyl groups are responsible for the activity of these molecules. There is some evidence that there are more functional groups in fulvic than humic acid. The effectiveness of fulvic extracts may be influenced by the way they are synthesized during chemical processing. The fulvic fraction of humic substances in undoubtedly a beneficial part of oxidized lignites.

Analysis of Humic Substances: In search of a Standard

It is important to know the Cation Exchange Capacity (CEC) since these materials are renowned for that characteristic. It should be in the range of 100 to 200 (on a dry matter basis) as analyzed by the ammonium saturation method. Low pH is especially important because the acidity initiates the dissolution of rock minerals. Low pH may be a broad indicator for open sites for chelating or complexing reactions to take place and an indicator of the relative concentration of functional groups. A pH of about 3.8 is acceptable. An ash content over 10% is not unusual, indicating the degree of association with clay minerals or other contaminants (Ozdoba, et al, 2001). CEC, pH, and ash analysis can be performed by many laboratories. **OUR OROGRO 307 is .01% ASH.**

Humic Substances Enhance Nutrient Bioavailability

Studies of the direct and indirect effects of humic substances on plant growth have repeatedly shown positive effects on plant biomass if there is sufficient mineral nutrition. Stimulation of root growth is generally more apparent than stimulation of shoot growth (Chen and Aviad, 1990; Nardi, et al, 1996; Abad et al, 1991).

For many years, the stimulatory effects of humic substances were attributed to hormone-like activity because the action of humic substances were like auxins, cytokinin's and absisic acid. This is no longer the case (Clapp et al, 2001). The stimulation effects of humic substances have been directly correlated with enhanced uptake of macronutrients, such as: nitrogen, phosphorus, sulfur (Chen and Aviad, 1990) and micronutrients, i.e. Fe, Zn, Cu, and Mn (Chen et al, 1999).

Humic substances enhance the uptake of minerals through the stimulation of microbiological activity (Albuzio et al, 1994; Figliolia et al, 1994; Visser, 1995; Nardi et al, 1996; Paciolla et al, 1998; Day et al, 2000). Humic substances coat mineral surfaces with a membrane-like bi-layer which aids in the solubilization of otherwise insoluble compounds (Tombacz and Rice, 1999) by dissolving, complexing, and chelating the dissolved nutrients.

The bioavailability of nutrients released from rock minerals by biological activity is enhanced in the presence of humic substances (Chen and Avaid, 1990). Geo-microbiologists have reported that organic acids generated by microbial activity directly influence the rate of dissolution (release of nutrients) from rock minerals (Barker et al, 1997; Welch et al, 2002).

The implications of this research are astonishing. While conventional farmers are faced with the mandated reduction of soluble fertilizers, sustainable, biological, and organic farmers can take advantage of the microbiological release of nutrients from insoluble minerals while the humic substances stabilize and improve the bioavailability of the minerals that are in soil solution.

Calcium

Humic substances are becoming renowned throughout the world for their importance in agriculture (Fataftah et al, 2000; Tan 2003), especially their ability to chelate nutrient minerals (Chen et al, 2001) and increase root mass (Amarasiriwardena et al, 2000; MacCarthy et al, 1990; Chen and Aviad, 1990).

The benefits to soils and plants are extensive and correlate well with the benefits of humus, organic matter, and calcium.

It seems reasonable to conclude that humic substances saturated with unwanted cations and heavy metal contaminants may lower bioavailability and the efficacy of the product. Therefore, it must be important to seek out a high-grade uncontaminated source. Since there are many sites on a humic molecule for acceptance of cations (Tan, 1986), it seems reasonable that calcium in combination with humic substances should make a powerful combination.

Many of the benefits of calcium overlap with the benefits of humic substances. Also, the low pH of humic substances along with their biological stimulation and chelating capacity combined with the right dry calcium source may perform as well as, if not better than, chelated liquid products and calcium chloride (Tan, 2003). Furthermore, because humic substances are known to complex both cations and anions (Huang and Violante, 1986) creating a synergistic effect (Clapp et al, 2001), the combined benefits should be greater than the individual ingredients.

In theory, the enhanced benefits should result in greater:

- Biological release of nutrients from otherwise insoluble materials (Tan, 1986; Chen and Aviad, 1990; Banfield and Hamers, 1997; Barker et al, 1997)
- Root growth (Chen and Aviad, 1990; Chen et al, 2001)
- Nutrient uptake from the larger root mass (Kapulnik, 1996)
- Respiration (Nardi et al, 1996; Marschner, 1999; Chen et al, 2001)
- Photosynthesis (Marschner, 1999; Chen et al, 2001)
- Mineral bioavailability and stabilization (Banfield and Hamers, 1997)
- Nitrogen stabilization and fertilizer efficiency (Fenn et al, 1995; Clapp, 2001)
- Disease resistance (Marschner, 1999)

Indeed, recent research has demonstrated how the combination of dry calcium with oxidize lignite performed as well as calcium chloride and EDTA, a popular synthetic chelating agent (Pare' et al, 2001).

The Effect of Humic Substances on Rock Phosphates

The ability of humic substances to solubilize and complex with natural minerals, such as rock phosphates, is well documented (Chen et al, 1999; Burdick, 1965; Banfield and Hamers, 1997; Schnitzer, 1986; Martinez et al, 1984; Tan, 1986). The bioavailability of nutrients released from rock minerals by microbiological activity is enhanced in the presence of humic substances (Chen and Aviad, 1990).

Humic substances can improve the effectiveness of rock phosphates by causing the release of (PO4)3-anions and (Ca)2+cations from hardly-soluble rock minerals (Sinha, 1971; Lobartini et al, 1994) because of high total acidity (Tan, 1986), ability to complex and chelate the resulting solutions (Tan, 1986; Chen et al, 1999; Clapp et al, 1999) and stimulate microbial metabolism (Albuzio et al, 1994; Figliolia et al, 1994; Nardi et al, 1996; Paciolla et al, 1998; Day et al, 2000; Chen et al, 1999; Visser, 1985).

Natural Leonardite or oxidized lignite is a complex super mixture of high and low molecular weight humic substances. The lower molecular weight constituents (fulvic acids) are primarily responsible for the solubilization of phosphate minerals (Levesque and Schnitzer, 1967; Weir and Soper, 1963). Just like the fulvic acid fractions, the higher molecular weight components (humic acids) also engage in solubilizing minerals, have a high capacity for stimulating biological activity and greater potential for chelation (Tan, 2003). In natural soil systems, the two components may act synergistically by complementing each other.

Humic substances also chelate iron, zinc, copper, and complex with many other trace elements (Clapp, 2001). Elements typically found in natural phosphate minerals, such as zinc and copper, are known to suppress pathogens and encourage the growth of beneficial organisms (Duffy and Defago, 1999).

These phenomena have environmental implications as well because the solubilization of rock phosphates by humic substances can reduce the need for industrial acidification of rock phosphate used to produce phosphatic fertilizers. Industrial production of phosphate fertilizers is extremely inefficient and creates enormous waste piles that are burdened with contaminants. Additionally, 60 to 80% of all highly soluble phosphate fertilizer applied to soils is lost to the environment (Griffin et al, 2003).

Colloidal humic substances are part of natural soils and help retain nutrients in the soil system through soil stabilization (Piccolo et al, 1999) and the stabilization of nitrogen (Day et al, 2000). Furthermore, the complexing action keeps the minerals in solution instead of precipitating (locking up) with soil iron, aluminum (Tan, 1986; Banfield and Hamers, 1997; Schnitzer, 1986) and rare earth elements (Banfield and Hamers, 1997).

Applying Theory to Practice

Because of their ability to improve fertilizer efficiency, humic substances are best utilized as part of a total fertility program blended into the fertilizer. Programs that include rotations, green manures, cover crops, livestock manure, and compost are the best methods to derive the full effect of humic substances. **However, the most effective form, dry Leonardite or oxidized lignite, is an extremely dusty material.**

The release of nutrients from insoluble minerals has been confirmed also. By combing rock phosphate with Leonardite (oxidized lignite), the available phosphate analysis (AOAC, 1999) can increase from near zero to over 10%. When considering that the total P205 content of the rock phosphate was 20%, that means that over 50% of the total phosphorus was released from the rock. The released minerals may exist in a chelated form, providing an environmentally safe, bioavailable form of calcium and phosphorus while avoiding the industrial pollution, energy waste and ground water contamination created by highly soluble phosphate fertilizers.

Summary and Discussion

Humic substances are formed by a process called humification. The humification process is chaotic, with innumerable reactions occurring under countless conditions. The process occurs over geological time, therefore younger deposits of humic materials generally have lower concentrations of humic acid.

Humic substances are critical components of water and soil ecosystems, which are essential to soil genesis and the global cycling of carbon and nutrients. The interactions among microbes, clays and minerals are dependent upon humic substances. The vast agronomic and environmental importance of these materials is just beginning to be appreciated.

Distinction based on molecular mass (weight) or the quantity of functional groups and fulvic acid content are useless if there is no argument regarding the methods used to evaluate the materials. The quality of natural humic materials can be assessed by pH, CEC, total carbon, total organic carbon, and association with calcium, silicon, sulfur, iron, aluminum, and toxic contaminants. The concentration of humic and fulvic acid can be analyzed by some labs because standard reference materials and procedures for the extraction and analysis of humic substances are available from the International Humic Substances Society.

The agronomic effectiveness of humic materials to may be influenced by the presence of metals associated with the natural ores. Because humic substances are powerful complexing and chelating entities, association with silicon, aluminum, or iron (typically found in clays) may influence the materials in soil systems. Research based on the agronomic effectiveness of humic materials (oxidized lignites) from different sources has not been performed.

Conclusion

The conventional tools of chemistry cannot be applied to these materials to explain why they work in complex soil ecosystems. They have all the qualities of humus in a compact convenient package.

Although the microscopic detail and structure of humic substances is currently not achievable, their beneficial properties are evident. The ecological and plant nutritional benefits provide sufficient justification for using these extraordinarily complex Eco-minerals. If the supply side of the industry so chooses, a set of standards could be adopted by professional society or trade group representing the industry. AN independent laboratory could monitor the standards. Some of the best and brightest professionals in the industry are working toward that goal.

Standardization of materials may also provide a basis for acceptance by state fertilizer regulators. Anyone in the supply industry should seriously consider joining the International Humic Substances Society (IHSS) to communicate the industry's needs to the scientific community. Besides, scientists need to be reminded sometimes that there are many good people who can benefit from their knowledge. That knowledge needs to be communicated to everyone, not just other scientists.

For the consumer, there is an endless variety of applications for humic substances, both as agronomic inputs and as human health aids. Humic substances are part of an environmental engineer's toolbox for the bioremediation of toxic contaminants. Humic substances are possibly the most versatile natural substances ever known.

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