Comparing Organic and Inorganic Fertilizers

Roger C. Funk, Ph.D., The Davey Tree Expert Company©

According to sales psychologists, people do not buy a product for its features; they buy a product for its benefits. A feature is something that remains true about the product whether the person buys it or not. For example, "organic" is a feature of fertilizers that have a carbon source. A benefit is personalized to the person's needs or wants, and usually involves saving time, money, or worry. Yet because of *perception,* a certain segment of society will buy the feature "organic" without understanding the benefits, or for that matter, understanding organic.

Organic is widely perceived to be of natural origin, yet organic compounds can be synthesized, often with characteristics superior to those which are natural. Organic is the chemistry of carbon, not the chemistry of natural. An organic compound that occurs naturally in urine, urea $(NH_2)_2CO$, was first synthesized from inorganic components in 1828 by Fredrich Wohler. His work disproved the theory that organic compounds could only be synthesized in living organisms through a vital "life force," a mystic philosophy known as Vitalism. According to the official publication of the Association of American Plant Food Control Officials (AAPFCO), the officials responsible for registering fertilizers in each state, the definition of organic is "*a material containing carbon and one or more elements other than hydrogen and oxygen essential for plant growth*." The USDA's National Organic Program definition of organic fertilizer is, *With the exception of synthetic substances included in the National List of Allowed and Prohibited Substances, all organic fertilizers allowed in the Program are naturally derived; that is, of plant or animal origin. Sewage sludge is not allowed and no synthetic organic fertilizers are included on the allowed list*. And, the U.S. Environmental Protection Agency defines it as, "*Organic material such as manure or compost, applied to cropland as a source of plant nutrients*."

The belief that the carbon used by plants and animals to synthesize chemicals is somehow different from the carbon used to make synthetic organic chemicals is also unfounded. All carbon on Earth was produced in the cauldrons of stars larger than our sun and captured during the formation of our solar system. With the exception of "seeding" from occasional meteors, the amount of carbon on Earth is fixed. It can neither be created nor destroyed; only recycled. Strictly speaking, organic is the chemistry of the carbon-hydrogen linkage, since carbon alone cannot catenate; that is, form chains or polymers, which are the basis for organic chemistry and life on Earth.

Carbon has the unique ability to form covalent bonds with other carbon and other elements at temperatures and conditions that are common on Earth, a characteristic that allows the formation of complex chemicals and structures such as cells. In a process called photosynthesis, green plants combine inorganic carbon dioxide with inorganic water to form sugar, an organic polymer with carbon-hydrogen linkages. All other organisms are dependent upon green plants to form this carbon-hydrogen linkage from which other organic compounds are made. Plants synthesize many of the other compounds they need to complete their life cycle by combining the sugar manufactured during photosynthesis with other elements absorbed from the soil.

Humans and other animals consume the carbon-based compounds synthesized by plants (or other organisms that have) and recycle the carbon by synthesizing chemicals necessary for animal life. This process of recycling is called biosynthesis.

The recycling of natural carbon compounds is also the basis of synthetic organic chemistry. Petroleum ($>C_5H_{12}$) and natural gas ($<C_5H_{12}$) are natural hydrocarbons often used to synthesize other organic compounds such as plastics and fabrics, including polyethylene, nylon and polyester. Synthetic organic fertilizers are also made from hydrocarbons. Ethanol and a more advanced biofuel, butanol, can be synthesized from renewable carbohydrates such as sugar $(CH_2O)_n$ and cellulose $(C_6H_{10}O_5)_n$. Biodegradable plastics and synthetic fabrics can also be made from plant residues rather than petroleum, as can fertilizer supplements.

By itself, carbon is considered "inorganic," that is, not organic, as are other carbon-containing compounds without a carbon-hydrogen linkage, such as carbonates (limestone, $CaCO_3$) and carbon oxides (carbon dioxide, CO_2). In addition, compounds that do not contain carbon such as table salt (sodium chloride, NaCl) are inorganic.

All fertilizers can be grouped into those that are **organic** or those that are **inorganic**. As stated previously, organic fertilizers contain carbon, and more specifically, a carbon-hydrogen linkage. Those that do not – inorganic – are typically the mineral fertilizers such as potassium nitrate (KNO_3), which are commonly referred to as chemical fertilizers. In reality, all fertilizers are chemicals and all can cause adverse reactions in plants and the environment when used improperly.

Organic fertilizers, whether natural or synthetic, have nutrient elements such as nitrogen, phosphorus or potassium attached to carbon. Because of the *covalent bonding* that shares electrons, the structures are quite stable. As the carbon structure is decomposed or hydrolyzed over time, the nutrient elements are released as ions such as ammonium (NH_4^+), which carry a positive or negative charge. It is in this form that nutrients are absorbed by plants since plants have no mechanism to attract uncharged nutrient sources including organic compounds.

The nutrient ions are also responsible for water flow across the root membrane in response to a concentration gradient (osmosis). Plant roots expend energy to absorb the nutrient ions and, under normal conditions, have a greater concentration of salts (lower osmotic potential) than does the soil solution. Water flows across the membrane toward the side with the highest concentration of salts (lowest osmotic potential). Should the concentration of salts become greater in soil solution, water will flow outside the root cell. This is called plant "burn", which is a form of physiological drought. The tendency for fertilizers to release the nutrient ions in water is called the *salt index*, and the more quickly the ions are released, the higher the salt index.

Leaching is the removal of nutrients in solution from the soil and the nutrient ions increase susceptibility. Nitrogen, in the form of the nitrate ion (NO_3^-), is particularly susceptible since the mineral components of soil carry a net negative charge, which repel similarly charged ions.

The typical qualities of an organic fertilizer are *slow release*, *low burn potential,* and *low leach potential* to reflect the sustained release of nutrients as the carbon structure is decomposed or hydrolyzed over time.

In addition, the carbon in some organics may provide an *energy source for microorganisms* in the soil. It is important to note that not all natural or synthetic organic fertilizers are decomposed by microorganisms. Those that are not are hydrolyzed by water. Basically, any fertilizer that is readily soluble in water will be hydrolyzed, but exceptions do occur. Microbial activity in the soil releases nutrients and enzymes that are beneficial to plants and also secretes "glue-like" substances that aggregate soil particles, improving soil structure. Organic fertilizers that stimulate microbial activity are said to "feed the plant and feed the soil."

Inorganic fertilizers contain no carbon-hydrogen linkage and, thus, are not used as an energy source by soil microorganisms. Although many inorganic fertilizers are naturally occurring as minerals such as potassium nitrate (KNO_3), they are often synthesized to reduce costs and contaminants. Like organic fertilizers, inorganic fertilizers are either natural or synthetic. However, unlike organic fertilizers, the nutrient elements in inorganic fertilizers are attached directly together with *ionic bonding*, which separates or dissociates readily in water. For example, potassium nitrate dissociates into the potassium ion (K^+) and the nitrate ion (NO_3^-) when dissolved in water. Thus, inorganic fertilizers are typically *quick release*, and have a *high burn and leach potential* compared to organic fertilizers. However, the same nutrient ions are released as with organics. Because of the lack of carbon, inorganic fertilizers "feed the plant but not the soil."

Inorganic or soluble organic fertilizers may be coated with impermeable sulfur, waxes or plastics to slow their release, emulating the release characteristics of an insoluble organic fertilizer. However, they will not be used as an energy source by soil microorganisms.

In summary, organic fertilizers may be natural or synthetic and inorganic fertilizers may be natural or synthetic. The difference is the carbon, and more specifically the carbon-hydrogen, linkage in organic fertilizers, which slows the release of the nutrient ions. A slower nutrient release results in more sustained availability of the nutrients, and a lower "burn" and leach potential compared to their inorganic counterparts. In addition organic fertilizers *may* act as an energy source for microorganisms in the soil, which can improve soil structure and plant growth.