



## Plant Health Care Inc.

440 William Pitt Way  
Pittsburgh, PA 15238

# Technical Bulletin

063 01/28/03

## THE NATURE OF SOIL FERTILITY

Soil is considered fertile if it is productive, that is, if it can support lush healthy growth of desirable plants, whether they be garden plants, landscape plants, or crops. But what makes soil fertile? What characteristics of soil determine whether it will be productive or not? This question has been asked repeatedly for many years. Here is a summary of our current understanding on this topic.

### ***Three Aspects of Soil Fertility***

Soil fertility is determined by three different aspects: chemical, biological and structural (i.e., physical). While these can be viewed separately, they are in fact interconnected.

#### The Chemical Aspect

For the last 100 years or so, agronomists have understood that the chemical makeup of soil is a very significant aspect of fertility. Soils that are rich in important plant nutrients will be fertile, as long as those nutrients are soluble or can become soluble. The most important elements that plants require in significant amounts are nitrogen (N), typically in the forms of nitrates or ammonia, and the minerals phosphorus (P), preferably as soluble phosphates, and potassium (K). Most commercial fertilizers are formulated to supply these three essential elements. Other nutrients important in lesser quantities for plant growth include the minerals iron, magnesium, manganese, zinc, boron, copper, and even silicon. The latter are often included in some commercial fertilizers. The chemical aspect of soil fertility essentially involves the availability of these essential nutrients in the soil. Other important chemical features include soil salinity, soil pH, and organic content.

#### The Biological Aspect

While farmers are busy applying chemical fertilizers to their crops, Nature has been steadily overseeing prolific growth in natural forests and prairies around the world without direct application of minerals. Instead, myriad populations of microbes, including both bacteria and fungi, perform important tasks that improve soil fertility. These fertilizing tasks are typically performed in the root zone of host plants, which make sugar available to fuel the process. Such tasks include nitrogen fixation. That is, nitrogen gas from the air is chemically bound into soluble compounds (like nitrates) or is bound into insoluble organic compounds that biodegrade in time, releasing soluble nitrogen compounds (like ammonia) which plants use. Another important fertilizing task is the conversion of insoluble mineral phosphorus into soluble phosphates, which plants can readily absorb and use. Finally, the ongoing biodegradation of dead organic matter continually releases soluble nitrogen compounds and various minerals for recycling by plants as nutrients. Nitrogen fixation is commonly performed by various rhizosphere bacteria, including the *Rhizobium* species that are symbiotic with legumes, as well as various free living bacteria which proliferate in the soil of the root zone. Phosphorus solubilization is carried out by both bacteria and fungi, including mycorrhizal fungi and decomposing fungi like *Trichoderma*. Biodegradation and recycling of organic matter is carried out by various bacteria and decomposing fungi, and is assisted by other life forms like protozoa, insects and earthworms.

#### The Structural Aspect

The physical structure of soil also has a big effect on its productivity. To be fertile, soil must be fairly porous. This allows it to hold water and air in sufficient quantities to support plants. Sandy soil can be too porous if rain or irrigation water immediately leaches away, and the topsoil quickly dries.

Clay soil is often too compact, so water pools on the surface and cannot penetrate downward. Good soil structure exists when soil is comprised of particles of varying sizes. There are some natural materials which bind small soil particles into aggregates of varying sizes, thereby increasing porosity and improving soil structure or "tilth". Bacteria and mycorrhizal fungi both exude such glue-like materials that produce particle aggregates and contribute to good soil structure. This reduces compaction and increases porosity, as well as the soil's capacity to hold air and water. In addition, various microbes produce natural surfactants which promote water infiltration through the soil.

### ***Manipulating Soil Fertility***

Soil fertility can be improved by addressing deficiencies in each of these three aspects. A huge fertilizer industry has developed to supply products that improve the chemical makeup of soils by supplying N,P, K, and other minerals needed by plants. Products of this type are known collectively as chemical fertilizers. Other treatments, like liming, can address problems with acidity, while soluble calcium additives can address problems of high salinity. Applying mineral additives to soil is the most common method currently in use to improve soil fertility. While this method is very effective, it lacks sustainability. Applied fertilizers eventually are used up or leach away, and must be reapplied to maintain productivity. In addition, the uncontrolled leaching of fertilizers into the ground water has created major pollution problems in catch basins and waterways.

In recent years, science and industry have teamed up to develop products that improve the biological aspect of soil fertility. These products contain mycorrhizal fungi and/or beneficial rhizosphere bacteria that can be added to soil before or at planting time to provide the microbial activities that create sustainable soil fertility. (Such products are called "biofertilizers.") Once introduced, these microbes can colonize the root zone and establish self-sustaining populations that continually improve the mineral content of soil (through N-fixation, P-solubilization, and nutrient recycling).

Soil structure can be manipulated in various ways. In addition to their affects on soil chemistry, microbes can also improve soil structure by promoting the aggregation of soil particles, and through the production of natural surfactants that improve water penetration. However, the structural improvements by microbes are slow and gradual. More immediate improvements can be made directly. For example, farmers have tilled soil regularly to reduce compaction. In urban settings, landscapers will decompact soil beneath trees by means of vertimulching, radial trenching, or by injecting compressed air in a process known as "fracturing". Commercial surfactants are employed to improve water penetration, especially when irrigating turf or when applying soluble fertilizers by spray, drench or soil injection. Superabsorbent materials (hydrogels) are tilled into soil to increase its water holding capacity. All of these treatments are intended to improve fertility by addressing one or more aspects of the soil structure.

### ***The 3-Pronged Approach***

Plant Health Care, Inc. had set out to study the nature of soil fertility, only to discover "Nature in soil fertility." Armed with this understanding, Plant Health Care, Inc. has developed the biological approach to soil fertility, and has married that approach with both classical and modern methods for improving soil chemistry and soil structure. PHC products provide immediate mineral supplements in chemical form, and sustainable fertility in biological form. Surfactants and hydrogels are added where needed to address structural considerations in the short term. The result is a new line of products that provide a comprehensive approach to soil fertility: biological, chemical, and physical (structural). No other company has viewed the big picture. No other company has a more advanced or comprehensive approach to soil fertility.