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The Science of Humus

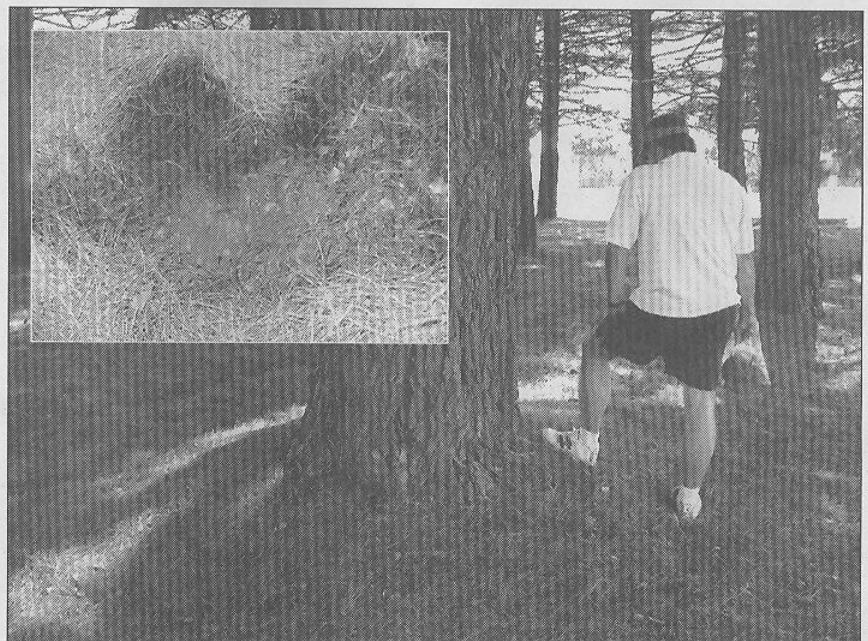
Case Studies in Soil-Building

by Michael Martin Meléndrez

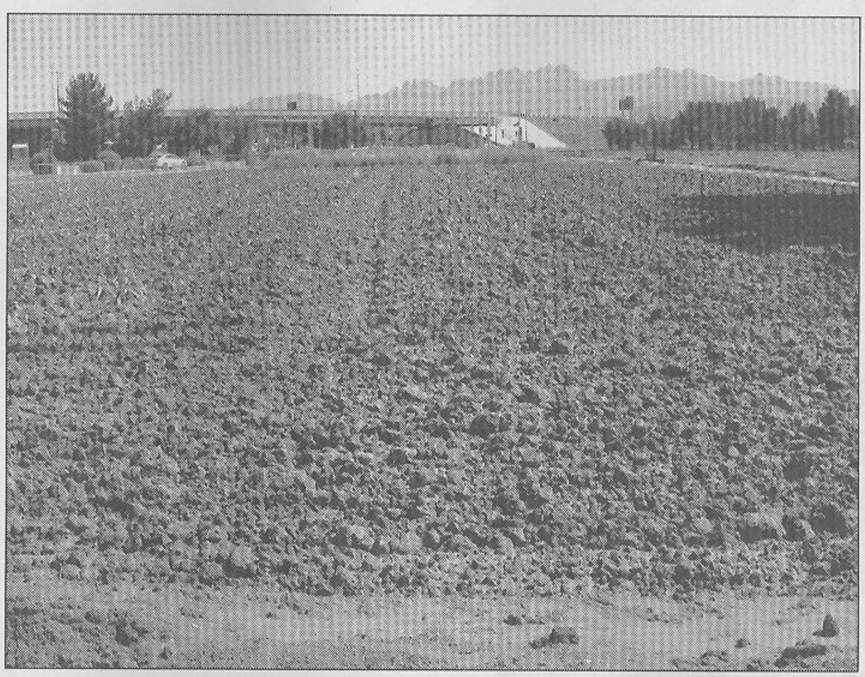
In my previous article on the science of humus, "How Humic Substances Benefit Soil & Landscapes" (*Acres U.S.A.*, August 2009), I defined what humus is and how that term was derived from and related to the more technical term — *humic acids* — as it's a common mistake to associate *humus* with *soil organic matter*. In this article we'll carry that point a little further, addressing more of the benefits that humus provides a soil, and we'll examine some case studies we performed to help us with our own learning curve at our soil consulting business.

Numerous observations and the results of accurate laboratory experiments have proved the positive effect of humus on the growth and metabolism of plants. The benefits of having a humic substance in a natural soil, or a manufactured soil such as in a potting mix are many and are as follows but not limited to: increased growth, increased crop yield, improved water use or plant available water (PAW), improving soil tilth, improving soil porosity, improving drainage and percolation of water and more. Rather then bore the reader with endless studies and quotations, I'll list the benefits, with the corresponding studies that support the claims made in what is called a meta-analysis of studies relating to humic acids, humic substances and humus. The accompanying table titled "Humic Acid Benefits" is a short list of a compendium of studies and could easily be expanded with thousands of published research papers.

In farming and in landscaping we have tried for generations to heal a soil by adding amendments such as compost, green manures, bio-char and even compost tea. This supplemented organic matter is legally defined and regulated by many state government entities as a "Soil Amendment." The idea was that the soil amendment would improve the soil, allowing it



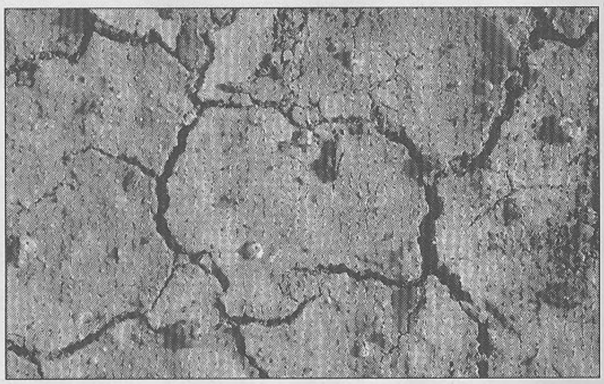
Pinus eldarica *grove at NMSU planted 1971. Pine needle mulch in the grove is at least 12 inches deep.*



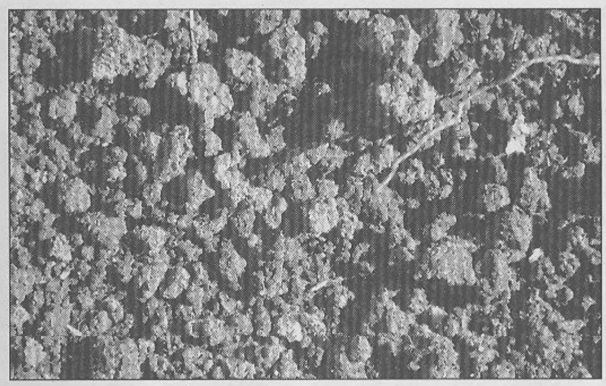
NMSU farm field next to the Pinus eldarica *grove. The shadow on the right is from the 80-foot-tall pine trees.*

Humic Acid Benefits (Selected Studies)

Researcher	Plant Benefit	Plant Studied	Soil Benefit
Smidova (1962)	increased water absorption	Wheat	
Dixit and Kishore (1967)	improved germination rate	Barley	
Ivanova ,1965; Alexandrova (1977)	increased root growth & mass	Corn	
Reynolds et al. (1995)	increased root growth & mass	Grapes	
Sanchez-Conde and Ortega (1968)	increased root growth & mass	Capsicum - pepper	
Sanchez-Conde et al. (1972)	increased root growth & mass	Sugar Beets	
Sladky (1959a); Lineham (1976); Adani et al. (1998)	increased root growth & mass	Tomato	
Piccolo et al. (1993)	more efficient water uptake	Lettuce & Tomato	
Adani et al. (1998)	increased both shoots & root growth	Tomato	
Lee and Bartlett (1976)	increased seedling growth	Corn	
Kelting et al. 1998b	increased post planting growth	Washington hawthorn	
Martin and Senn (1967)	greater number of fruits and quality	Tomato	
Brownell et al. (1987)	greater then 11% yield increase	Cotton	
Wang et al. (1995)	increased yield by 25%	Wheat	increased P availability by 25%
Jelenic et al. (1966)		Corn	increased uptake of soil-P & superphosphate-P
Dormaar (1975)	improved nitrogen uptake	Fescue grass	
Lobartini et al. (1998)	improved phosphate uptake	Corn	
Rauthan and Schnitzer (1981)	uptake of N, P, K, Ca, and Mg increased	Cucumber	
Dekock (1955)	increased Fe uptake		increased the solubility of Fe
Bar-Tal et al. (1988)	increased zinc availability at high pH		
Sladky (1959a)	increased respiration rate	Tomato	oxygen consumption increased by 23%
Sladky (1959a)	Chlorophyll density increase of 63%	Tomato	
Mato et al. (1971, 1972a, 1972b)	Hormonal benefits		
Nardi et al. (2000)	positive effect on protein synthesis	Maize	
Xudan (1986)		Wheat	drought tolerance and water use efficiency
Bkardwaj and Gaur (1972)		Soil microbes	stimulating effect on microbial activity
Bkardwaj and Gaur (1972)		Soil microbes	increase in microbial membrane permeability
Piccolo and Mbagwu (1989)			improved soil aggregation
Piccolo and Mbagwu (1989)			reduced runoff
Piccolo and Mbagwu (1989)			improved water inflitration & retention
Piccolo and Mbagwu (1989)			increased aeration
Piccolo and Mbagwu (1989)			decreased soil erosion
Piccolo et al. (1997)			reducing runoff erosion
Piccolo et al. (1997)			increased moisture retained at field capacity increased
Stevenson (1994)			increase water retention of soils



Arizona desert soil and lack of vegetation on the control site that was not primed.



A site a few feet away from the non-primed site, showing a 3-inch humic acid topsoil layer. At the time of these photos, only three years of protocol had taken place, but the soil tests described in the text were done at five years.

to mimic a natural environment rich in topsoil — retaining moisture and providing fertility for the plants being installed on the site. We felt we were building a better ecosystem than current soil conditions could sustain — in essence, we were trying to build a topsoil!

Over the past few years a huge learning curve has taken place in the understanding of soil science, soil ecology and the soil "food web," and with this knowledge a better understanding of topsoil has made it clear that soil organic matter (SOM) is not necessarily the substance that defines an optimum topsoil. The decomposition of dead roots, green manures, grass clippings, leaves and so forth does not necessarily yield the correct biochemical properties to result in the formation of humus, as the only precursors of the humic acids are amino acids, which must come from a source of protein. Amino acids are the building blocks of protein, and most of the bulk of the dead roots, grass clippings, green manure, leaves and most ingredients of compost are made up of carbohydrates — therefore compost alone is normally a poor source of the humic acids.

To prove this point, analyze any finished compost that fulfills the standards of maturity, stability and carbon-to-nitrogen ratio — unless extraordinary ingredients were used to make the compost, you will find that it has a low percentage of humic acids. The mistake of lumping soil organic matter with humus is made even by the experts — for example, a recent article by the Missouri Extension specialist (High Plains Journal, Oct 19, 2009) states, "The three main chemical and physical properties that influence topsoil quality are pH, texture, and organic matter content." The single most important ingredient that defines a topsoil was completely left out in this statement — humic acids.

THE CHEMISTRY OF HUMUS

To get to the point as to the significance of humic acids, I will quote from Geoffrey Davies and Elham A. Ghabbour's paper "Humic Acids: Marvelous Products of Soil Chemistry" (*Journal of Chemical Education,* December 2001). The abstract reads: "Humic Acids (HAs) are remarkable brown to black products of soil chemistry that are essential for healthy and productive soils. Current HA models help to explain HAs' origins and behavior as flexible, aliphatic-aromatic, highly functionalized molecules that can act as photosensitizers, retain water, bind to clays, act as plant growth stimulants, and scavenge toxic pollutants. No synthetic material can match HAs' physical and chemical versatility. HAs can bind soil toxins along with plant nutrients and they strongly stabilize soils. For these reasons more widespread HA production and future applications of humic acids will help to combat water and soil pollution, fight soil erosion, and lessen our dependence on chemical fertilizers."

First Case Study: To demonstrate my point that adding organic matter is not a guarantee of adding humic acids, I did a test on the soils of a pine grove planted in 1971 at New Mexico State University. For at least the last 25 years the needles under this grove have not been picked up and have layered and sheet-composted to a depth of over 12 inches, and for the first 3 inches of soil a rich mixture of decomposing organic matter with the mineral soil had accumulated. I tested this 3-inch layer for its humic acid content and compared it to a farm field a few dozen feet away that's been under cultivation for over 100 years with insignificant organic matter contributions.

Here's what I found:

Pine grove — Humic acids, 1,633 pounds per acre to a depth of 3 inches; organic matter, 9.5 percent; pH = 7.7.

Farm field — Humic acids, 1,198 pounds per acre to a depth of 3 inches; organic matter, 2.6 percent; pH = 8.4.

The simple act of sheet composting pine needles had thus failed to increase the humus content on this site to a significant level as compared to a traditionally farmed field. We also checked the pH, and while it did drop in the pine grove soils, considering the fact that there had been at least 25 years of a huge volume of pine needle decay on the site, the drop in pH was minor. Therefore with alkaline soils, as we often have in the Southwest, I'd say that adding pine needles to acidify a soil is not a logical way to go.

Second Case Study: To demonstrate a successful effort at priming a soil's ability to produce humic acids and consequently sequester atmospheric carbon into biological carbon, this case study involves an arid Northern Arizona site that has been primed with our protocol and shows a better humic acid accumulation in a few short years than the pine grove could do in several decades. The property is owned and operated as a CSA farm. We measured the soil for its humic acid content, percent organic matter and pH, just as I did with the pine grove site at New Mexico State University. In this case we have soil that is undisturbed and has not benefited from our priming protocol compared to soil that has been primed with mycorrhizal products and fortified with a dry humic acid formula (76 percent humic acid).

It has been our belief for over 20 years that mycorrhizae are the factors producing the humic acid precursors of amino acids, and recent research done by us and our associates at the National Labs of the DOE on soil carbon sequestering have proven that this in fact is true. While we supplemented the equivalent of 2,940 pounds of humic acid over the course of five years, the total quantity of humus accumulation is much greater, which the analysis demonstrates. In both cases we tested the top 3 inches of soil, which also happens to be the zone of soil on the primed site that appears to be developing into a humic acid-rich soil.

Here's what we found:

Arizona site, before priming — Humic acids, 435 pounds per acre to a depth of 3 inches; organic matter, 2.2 percent; pH = 8.6.

Arizona site, after priming — Humic acids = 20,000 pounds per acre to a depth of 3 inches; organic matter, 7.3 percent; pH = 7.4.

In summary, the percentage of humic acid on the primed site is better than most, if not all, compost products on the market. While we added about 2,940 pounds of humic acid to the primed site, the net gain was in excess of 16,600 pounds (the pine grove had a net gain of only 435 pounds). The drop in pH was greater on the Arizona site in five years then it was in over 25 years in the pine grove. The total amount of organic matter added to the Arizona site in five years (in the form of mulch to protect the soil from weeds and evaporation) was a tiny fraction compared to what the pine trees had added in three decades, yet the total percent of soil organic matter was comparable. Soil carbon sequestering on the primed site was very successful.

After several decades of learning how to rehabilitate a soil, prime pedogenesis, and manufacture and use mycorrhizae, I believe that the key to mycorrhizal success in accumulating humic acids and sequestering soil carbon lies in fortifying the soil with a chemically viable and liberated humic acid material. The combination of humic acids with a quality mycorrhizal product as a soil supplement is analogous to using a starter to make sourdough bread — and while it's necessary to supplement the humus material to jump-start this process, if done correctly, the soil's chemistry and biological transmutation of amino acids into humic acids will soon result in substantial accumulation of humus.

In our business, we are involved with the process of soil erosion control, mine reclamation, farm soil rehabilitation, and more recently LEED Green Building landscape construction — and in every case we are concerned about trying to sequester carbon into the soil in the form of humic acids, because it's humic acids that benefit the soil by improving its chemical, physical and biological condition. Nothing else in nature or in science can do what the humic acids can do!

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