Sentinels of the Soil

Harness the Amazing Power of Earthworms

by PAUL REED HEPPERLY, PH.D.

When moist, practically all soils from tundra to lowland tropics support earthworm activity. Largely unseen, earthworms are a diverse, powerful workforce with the capacity to transform soil into fertile ground. Found in 27 families, more than 700 genera and greater than 7,000 species, they vary from about 1 inch to 2 yards long. Their living mass outweighs all other animal life forms in global soils.

Although we may view earthworms as being both prolific and productive, do we fully appreciate our human capability to favor their beneficial efforts as allies allowing farms and gardens to flourish? I think not. Earthworms not only play productive roles in sustainable agriculture, but they have enormous capacity to help mitigate our elevated atmospheric greenhouse gas content by reducing carbon and nitrogen gas.

Earthworms' powerful activities include promoting favorable soil structure, increasing biological diversity, improving soil function, balancing nutrients needed by plants and animals and optimizing living soil.

Vermicastings, or worm manure, are rich in carbon, calcium, nitrogen and other important elements.

SYMBIOSIS

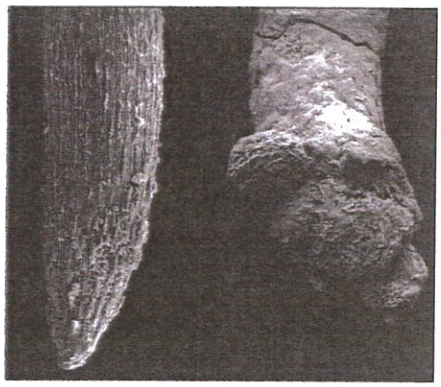
In commercial vermicompost, earthworm production is favored by a brief compost cycle to produce earthworm diet. Because earthworms derive their nutrition from fungi, bacteria, protozoa and nematodes, their lives and those of teeming masses of micro-organisms and microbes are closely interlinked. Trained as a plant pathologist, I marvel at the unseen microscopic realm and its power to transform. Scientists have found that microbes break down plant and animal debris. This process promotes the nutrition and health of earthworms, microbes, soil and everything that depends on the soil.

As earthworms turn and churn, they function as effective premier plant residue shredders. Their work helps liberate plant nutrients into the digestive tract by microbe activity while the earthworms themselves are favored.

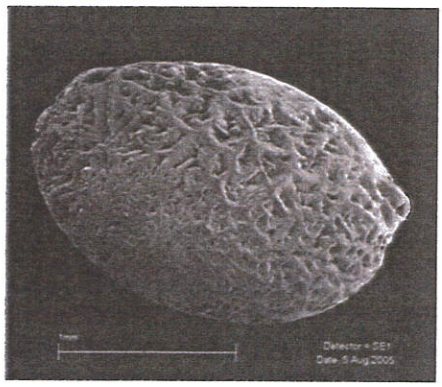
We are asked by some great thinkers to ponder on the earthworm and its significance. Charles Darwin referred to earthworms as "the intestines of the soil." Rudolf Steiner, originator of biodynamic agriculture, referred to them as the "stomach of the earth."

EARTH MOTOR

Earthworms play a critical role in improving and enriching soil. Through their tunnel networks they create air channels, optimizing aeration and providing conduits for watering the soil. By allowing water and air to channel through the soil they promote rooting. Roots and plant residue feed the rich microflora that feeds the worms. Worms feed the earth that nourishes the plants. This is a productive interdependent life cycle. The ability to maximize water percolation also minimizes runoff,



On the left see a healthy root tip from a neutral pH balanced soil, at right the necrotic root tip from acid soil infertility associated with low calcium and ammonium-toxic environment.

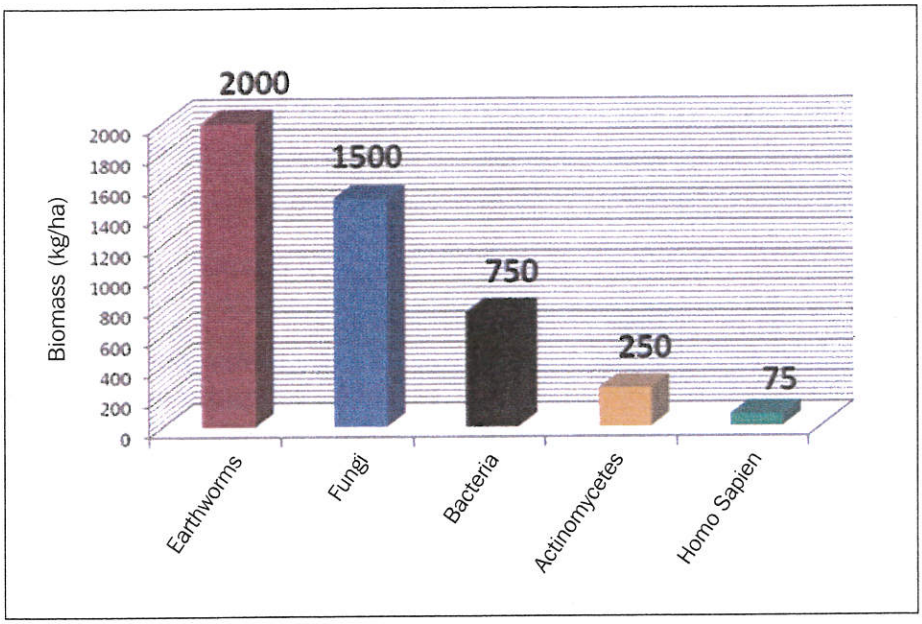


Electron micrograph of lead.

and reduced runoff greatly reduces soil erosion.

Together earthworms and microbes are the great digestive fermenters. They join together in shared shredding/digesting. As digestion results from joint effort, insoluble plant materials are solubilized. In the alimentary tract, what was waste is consolidated into value-added packets known as castings. Earthworm castings are an ideal organic amendment/fertilizer with greatly increased nutrient solubility compared to the organic materials they originated from.

Relative Biomass of Biological Components on a Hectare of Land



Castings are particularly rich in phosphorus which stimulates seedling and root growth and extension. Unlike most synthetic fertilizers, they are well balanced in macronutrients, secondary and micro-nutrients. The humic substances in earthworm castings support the foundational physiological processes of plants such as photosynthesis and respiration. Their growth regulation properties include the ability to stimulate defensive reactions in plants, allowing them to deal with stress and adapt to difficult conditions.

Scientists have compared the earthworm tunnel system to a motor with pistons – the muscular earthworms are the piston drivers of the soil pump. Plant materials fuel the living soil machine with microbial-aided decomposition working together with the worms deriving their energy through the plant remains. The earthworms drive plant material into the ground, infusing life into the whole system.

NO EVERYDAY COMPOST

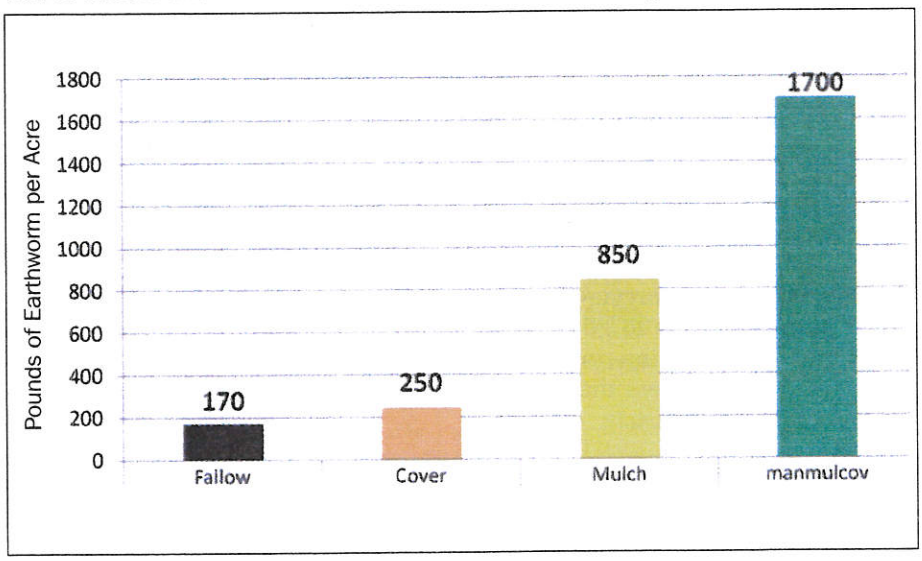
In a strict sense, worm castings are not vermicompost at all. They are really earthworm manure. Unlike many other animal manures, however, casting are not laden with toxic ammonia. Earthworm castings are rich in organic nitrogen. This critical difference gives unique advantages over other animal manures. Earthworm castings are also distinctive in being rich in carbon and calcium.

Calcium, carbon and nitrate constitute a trifecta. They avoid the ammonia toxicity and salt issues common in ammonia-rich manures and fertilizers. Because of the organic nature and low ammonia, earthworm castings can be used in close proximity to seedlings without plant toxicity.

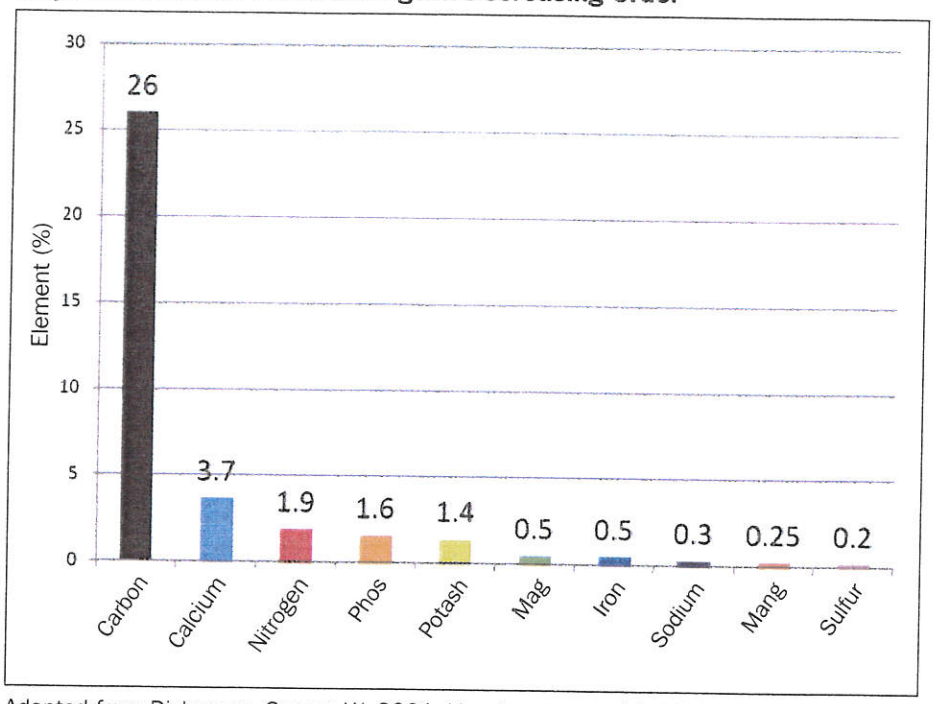
Besides calcium, red earthworm castings are exceedingly rich in iron. Copious calcium excretion is critical to the metabolism and digestion of earthworms, and earthworms can be greatly restricted in acid soils. Where soils are high in alkalinity, the ability of plants which originally adapted to more acid environments, show inability to absorb and utilize iron. This results in plants yellowing due to iron deficiency or chlorosis. The organic, chelated form of iron from castings is ideal for such situations because they are readily soluble and rich in iron. Humic materials from the earthworm microbial combo are champion chelators. Earthworm castings have a 6.9 pH, neither highly acid nor alkaline. This neutral, slightly acid pH is friendly to both earthworms and most plants they depend upon.

Besides the castings, the earthworm ejects granules akin to miniature lime stones. The fine structure of earthworm granules is both beautiful and well organized. Like castings these granule outputs are dispersed into the soil, where they act to benefit soil fertility, biology and structure. In its composition, the earthworm granule is mostly mineral. Although calcium is its biggest component it usually features a silica center clear in electron micrographic analysis. The granule is a rich source of a diverse variety of micronutrients. Under the scanning microscope, these little gems resemble mineral snowflakes.

Cover Mulch and Manure Increase Earthworm Activity



Major Elements of Vermicastings in Decreasing Order



Adapted from Dickerson, George W. 2001. Vermicompost guide H164, New Mexico State University.

An abundant earthworm population will produce about a ton of these per acre every year under good conditions. As such, the earthworm-tilled soil becomes limed with calcium carbonate quartz granules besides being enriched with a critical spectrum of major, secondary and micronutrients.

These granules take carbon dioxide that was in our atmosphere as greenhouse gas and trap it as insoluble carbonate. The little lime stones neutralize the soil, preventing it from becoming overly acidic. Calcium also serves as a mortar for cementing soil aggregates together, conserving both carbon and soil structure.

ON THE FARM

In upstate New York, longtime organic farmers Klaas and Mary Howell Martens were asked to review my work on worms. Upon reviewing this article, they urged me to go beyond the living soil machine metaphor. They asked me to stress the cycling and mineralization capacity of earthworms.

On their farm, in their personal witness, they testify to cover crops of over 3 tons of fall dry matter residue being cleaned up by early spring by the worms. They were amazed when they analyzed the soil that same spring. The soil analysis showed 360 pounds of N, 40 pounds of phosphate and 160 pounds of potash per acre available, more than sufficient for an optimum maize crop. This was without any application of synthetic chemical fertilizer. Relying on the legumes and worms to till and feed, Klaas reported, "Earthworm recycling and mineralization occurs sometimes overnight. I have seen large clumps of leaves fall from my spreader in the spring and days later I went back and nothing was there. Yet, upon looking closer at the soil surface it was covered with worm castings ... amazing."

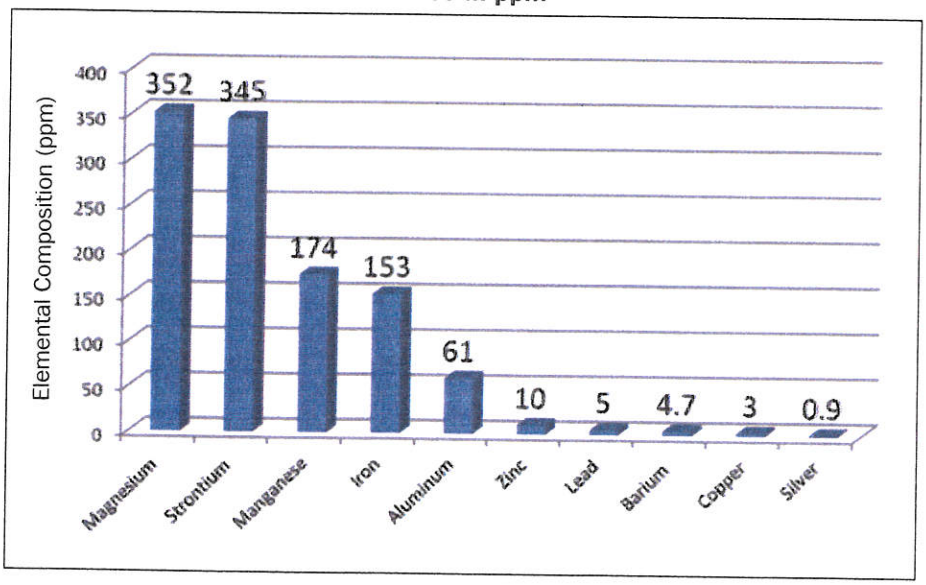
A DEADLY TRIO

In conventionally farmed and tilled fields it is common to find few or no active earthworms. Toxicity of pesticides commonly used in the field crops, the destruction of their habitat by excessive tilling, and acidity and toxicity of fertilizers constitute a deadly trinity for earthworms. When appropriate worm environment is produced all of these constraints are eliminated and the need for synthetic fertilizer is reduced or eliminated.

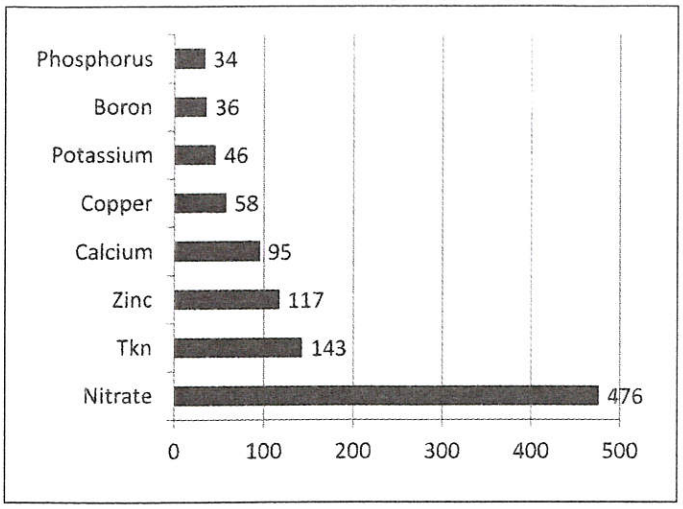
Soil acidity is the mortal enemy of earthworms, and the use of ammoniated fertilizers and tillage can largely stymie their beneficial natural soil-building potential. Earthworms are well known as premier bio-indicator organisms, revealing soil potential and overall environmental health. In a mechanized agriculture vast mines of calcium carbonate rock are crushed into fine powders and transported to depots and then to farms where massive spreader trucks lime the fields.

Can we be more thoughtful in promoting natural earthworm popu-

Composition of Earthworm Granules in ppm



Percentage Increase of Vermicasts Relative to Turned Compost



lations? Yes, let us begin as farmers and gardeners by identifying acidic, low calcium soils and spread lime to remediate this common condition. Let us also incorporate manure, compost, cover crops, rotation and other sustainable practices.

Synthetic nitrogen fertilizer is directly toxic due to ammonia content and indirectly by its effect on acidifying the soil. When fertility is largely based on ammonia, the absorption of the ammonium ion causes the plant to release hydrogen ions to maintain electro-neutrality. This causes an acid release that first invades the root zone and continues to expand into the soil profile itself.

Earthworms promote a natural liming and are favored by liming. Calcium, I believe, is used by the earthworm to lime the soil as they themselves are sensitive to heavy metals such as aluminum which abound in soil. When these are soluble as in an acid environment, they are deadly, but when acidity is buffered they are harmless.

The only nutrients available to plants are those that become soluble. Carbon is the primary element in earthworm castings. This high carbon content demonstrates the organic nature of this amendment and organic nature is key for solubility of difficult-to-dissolve minerals. Tests show copper, manganese and zinc have water solubility of 15 percent or less without humic substances. On the other hand, when using organic chelation with soluble organic material, water solubility increases to over 85 percent, more than five times solubility in water alone. Fulvic and humic acids are champion organic chelators.

CARBON & CALCIUM

Professor Albrecht was a well-known proponent of the role of calcium. He envisioned calcium as the key to unlocking soil fertility. After carbon, calcium is second in abundance in earthworm castings. Unlike synthetic amendments that do not address secondary nutrients, earthworm castings do just that.

Castings have abundant nutrients in balanced rations. Calcium provides a key not only to structure and nutritional aspects for the plant but also acts as mortar in the formation of soil structure or aggregation. It helps granulate or aggregate the particles and stabilizes them from erosive force by its cementing action, which helps water and nutrients flow through the soil system. When earthworms build their soil profiles, they need mortar to be master builders.

Since the 1980s more and more research has shown calcium has some amazing capabilities. In humans, calcium is involved in the structure and function of our bones. As calcium granulates and coagulates soil aggregates, the serum calcium is critical in this defensive blood clotting in animals and humans. As calcium is lost in membranes the defensive reactions of plants are triggered. When calcium is low in plant cell walls and membranes, they become very susceptible to soft rot by fungi and bacteria.

TOO GOOD TO BE CAST OFF

Turned, high-temperature compost is well documented as an excellent organic input. Yet, the value of earthworm castings is less recognized and cooler in temperature and impact. In this respect, castings not only have excellent value, but exceed those present in turned hot compost – in the total and range of macronutrients, secondary and micronutrients, they beat the turned hot compost hands down.

Hot composts can pasteurize the substrate yet the beneficial microbes need a cooler ambient temperature which is found in the earthworm environment. In the story of Old John Henry, the mythic miner challenged the mining machine and died trying to defeat it. Our subterranean earthworm hero "John Henry Earthworm" meets the challenge of tilling soil and liming it. However, he is not beaten by the machine. In fact, the biological force of earthworms can prevail over the machine in this contest when the emphasis is on the potential of that force and they stay healthy and alive.

Earthworm Anatomy

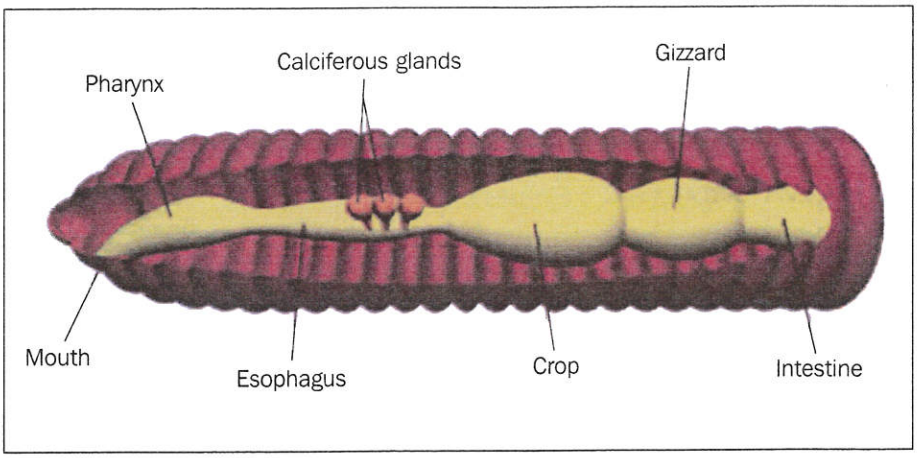


Diagram shows the position and morphology of the calcium glands of the earthworm. These glands secrete a milky, calcium-rich concoction.

GLOBAL OPPORTUNITIES

Many of us in the center parts of North America are spoiled by being blessed with wonderful, comparatively young prairie soils founded on limestone parent materials. These soils may have fewer concerns about acid soil infertility compared to the vast majority of tropical soils in the developing nations. This tropical problem can be found in rich red clay soils in the southeast United States. Few peoples in Central and South America, Africa and tropical Southeast Asia are so well blessed as we, the people from the North American maize and soybean belt.

Tropical areas are notably plagued by possessing the majority of soils which are old, degraded and suffer from acidity, toxicity and deficiencies. Consider that even commercial North American farmers using synthetic fertilizer typically add up to 1 ton of lime each corn crop to neutralize their heavy ammonia dependence and use. There is much untapped value in earthworms and they make sense in a wide range of areas, both tropical and temperate. An agriculture which will flourish for millennia will need to take earthworms into account not only as the prime soil health bio-indicators but also as the master engineer and builders of the soil machine.

Certain areas in the eastern half of the United States, tropical South America, Africa and Southeast Asia are dominated by acid, infertile soils. The use of synthetic ammoniated fertilizers will worsen this all-too-common condition. Fortunately, nutrients from earthworms are ideal based on nitrate nitrogen form and its liming effect based on calcium in the worms' metabolism. In addition, in countries throughout the world there is no shortage of limestone for agricultural use.

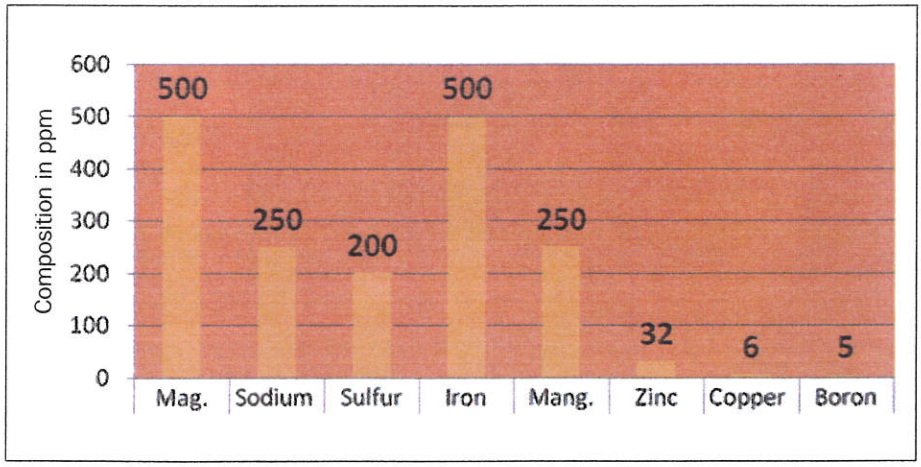
Many organic farmers have noticed slow initial nutrient release response from organic amendment. This can constrain high yields because of the low solubility of nitrogen and other critical nutrients. This is avoided with the earthworm castings which are rich in soluble nitrogen as

nitrate and soluble phosphorus for pop-up growth needs. They have available humates from soil organic matter and complete secondary and micronutrients to overcome an array of issues. The best point is that their nitrogen as nitrate does not acidify the soil as common ammoniated synthetic nitrogen does.

While synthetic fertilizers are classified based on nitrogen, phosphate potassium salt contents alone, this reliance can easily lead to nutritional gaps in the supplies of essential secondary and micronutrients which are not considered. More importantly their use and dependence does not avoid soil acidity issues over the long term but rather will generate them.

In contrast, the worm castings provide a full complement of essential micronutrients playing critical roles in plant health and the secondary nutrients essential to plants and animals. Because these are needed in relatively small quantities, and organic products have better solubility and retention characteristics, these can be utilized efficiently and economically with better environmental and energetic footprints. When the best natural production systems are used, earthworms are favored and do not need continual application and re-application.

Micronutrient Composition of Earthworm Castings



While the earthworm casting has significant nitrogen, it is in nitrate rather than ammonium form. Nitrate, when absorbed by plants, causes release of hydroxyl ions, working together with the calcium carbonate granules to lime the soil, not to acidify it. One negative nitrate in the plant, leads to one negative hydroxyl out of the plant. This conservation of charges results in liming the root zone or rhizo-sphere. This in turn helps the rhizo-sphere and earth-worm to create favorable environments for the plants and themselves in the virtuous cycle. This working together is especially important for the problematic, acid, infertile soils in the majority of struggling areas in the global tropics. Our tropical agricultural resource is our ace in the hole in globally regenerating the world environment and reversing greenhouse gas issues.

PHOTO BY ROB LORBER

Putting green at Bryan Park Golf Course in Greensboro, North Carolina, after applications of kelp.

Research shows not only can worm castings stimulate yields over that of an optimum rate of synthetic fertilizer inputs but indeed exceed them substantially. This is related to not having the high salt index of synthetic fertilizer and being a complete nutrition. We have shown that castings have primary, secondary and micronutrients at ideal levels. Humic materials, that are produced by the microbial and worm tag team, are able to stimulate plants as growth regulators at parts per million dosages. Finally, the rich microbial population has been associated with pathogenic fungi and bacteria suppression. In addition they possess the ability to stimulate the signal active defensive actions of plants to insect pests and adverse environmental conditions.

After seven years working with worms, I have come to the conclusion that my earth-changing ability is exceedingly small compared to my underground friends, the earthworms. For this reason I ask us to transform our intention in regards to the unseen and unheralded worm that works tirelessly and constantly for our benefit and that of the environment. Give them a chance and they will reward you with their endless, tireless efforts.

Paul Reed Hepperly, scientist, consultant, educator and advisor, previously served as the research director for Rodale Institute, 2002-2009. His son Reed Paul Hepperly is CEO of Hepperly Enterprises, a premium compost supplier and developer of tropical root crops in Mayaguez, Puerto Rico. Paul currently resides in Maryville, Tennessee. Contact him at *paul.hepperly@gmail.com*.