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Only where you find earthworms will you find rich, healthy soil with high amounts of organic matter and vice versa. Earthworms simply cannot proliferate and flourish in areas where chemical fertilizers and pesticides are paramount. Earthworms, actually, act as a barometer for soil health.

Many agriculture oriented people still do not understand or appreciate the tremendous enriching value that earthworms have on our soils.

It took a French scientist and ecologist, André Voisin, author of the insightful *Soil, Grass and Cancer*, to point out that the earthworm, and in particular the slippery lumbricid, most common in the United States and Europe, is not only essential to good agriculture but is the very foundation of all civilization. In *Better Grassland Sward*, Voisin traces man's civilizations in relation to the distribution of active earthworms, of which he lists some three thousand species.

Among the most ancient of terrestrial animal groups, several hundred million years old, they come in various colors and sizes: brown, purple, red, pink, blue, green and light tan, the smallest barely an inch long, the largest a ten-foot giant in Australia, though South African newspapers reported a boa-constrictor-sized monster twenty feet long, a yard wide through the middle. The most common European and American earthworm, *Lumbricus terrestris*, grows barely longer than six inches.

Ten thousand years ago, immediately after the last ice age, the lumbricid earthworms were to be found only in certain restricted areas of the planet, such as in the valleys of three great civilizations - the Indus, the Euphrates, and the Nile - where crops grew almost without cultivation in a soil of immensely fruitful richness.

As Jerry Minnich points out in *The Earthworm Book*, other areas of the earth offered ideal climates and rich soils, but produced, with the exception of China, no such civilizations. The Egyptian experience alone, says Minnich, is strong indication that a complex civilization cannot develop until the basic agricultural needs of its people are met, and that requires the earthworm.

Not that the point was entirely overlooked by the USDA. an agricultural report on investigations carried out in the valley of the Nile in 1949, before the folly of the Aswan Dam, indicated that the great fertility of the soil was due in large part the work of earthworms. It was estimated that during the six months of active growing season each year the castings of earthworms on these soils amounted to a stunning 120 tons per acre, and in each handful of that soil are more microorganisms than there are humans on the planet.

Thirty years before the birth of Darwin, as the American colonists were breaking away from the mother country, an English naturalist, Gilbert White, was writing:

> Worms seem to be the great promoters of vegetation, perforating and loosening the soil, rendering it pervious to rains and the fibers of plants by drawing straws and stalks of leaves and twigs into it; and, most of all, by throwing up such infinite numbers of lumps of earth called worm-casts, which being their excrement, is a fine manure for grain and grass. . . . The earth without worms would soon become cold, hard-bound, and void of fermentation, and consequently sterile.

That the phenomenon was understood before the time of Christ is clear from Cleopatra's decree that the earthworm be revered and protected by all her subjects as a sacred animal. Egyptians were forbidden to remove it from the land, and farmers were not to trouble the worms for fear of stunting the renowned fertility of the Nilotic valley's soil.

In the northern part of North America the last ice age so stripped the country bare of earthworms that in very few areas of what is now the United States were agricultural lands rich enough to support even moderately large populations of native American Indians. As Minnich says: "Before European contact, the only lumbricids native to the United States were some lacy species of *Bismatus* and *Eisenia*, essentially worthless as soil builders."

But wedged in the shoes of the colonists' horses were tiny lumbricid egg capsules, and in the root balls of European plants immigrant earthworms arrived to remedy the situation. In no time a rich but dormant soil was transformed into one of high fertility. The lush meadows of New England, the vast farmlands of the upper Midwest, the great wheat fields of Canada are all attributed to the introduction of the earthworm.

By the early part of the twentieth century, says Minnich, New Zealand soil scientists observed that European lumbricids were making vigorous inroads into the island's previously wormless soils. Hill pastures that could barely support a stand of grass were gradually becoming lush and green even though no fertilizer was applied. Counts of earthworms ran as high as over four million per acre, more than three times the maximum populations of the same species in their Old World habitats. The source of all this fertility was what the worms excreted in the form of castings, compost of the highest grade, containing mineral and organic matter in a soluble form, excellent as both a fertilizer and as a soil conditioner.

Earthworms can produce more compost, in a shorter time, with less effort, than any other method. As they burrow, they are constantly bathed in mucus, which helps them through the roughest ground. Continually rubbed off, this mucus helps cement the walls of their tunnels. And, while it helps a worm worm its way out of a predator's grasp, it also helps hold the soil firm, retaining moisture as it hardens.

In classical Greek times, Aristotle called the earthworm "the guts of the soil" because it produces particles that are smaller than when they enter, held together by the intestinal fluid that makes for a finer-structured earth. An omnivorous and unfinicky eater, the eyeless earthworm ingests whatever appears before it in morsels fit for its toothless gums.

Muscularly pumping through the soil, it ingests not only organic matter but the raw earth itself, using sand and other mineral particles as grinding stones in its gizzard. Mixed in the crop with digestive chemicals and disintegrator bacteria, the elements come out in different combinations, more easily taken up by plants.

Worm castings, neutralized by constant additions of carbonate of lime from three pairs of calciferous glands near the worm's gizzard, and finely ground prior to digestion, are five times as rich in available *nitrogen*, seven times as rich in available *phosphates*, and eleven times as rich in available *potash* as anything else in the upper six inches of the soil, producing a nutrient in just the right condition for the plant to absorb. Real organic NPK! What's more, the castings are always more acidically neutral than the soil from which they were formed, naturally improving the local pH factor as armies of earthworms work to keep the soil in balance, neither too acid nor too alkaline for the growth of plants.

Could it be that these great sinusoid fertilizers actually transmute elements, as the French savant Louis Karvran would have it, or are they merely collecting, distilling, and rearranging them to fertilize the soil? The former would appear to be more likely.

Castings, usually deposited in old burrows, or by night crawlers on the surface when they come up to mate or draw leaves into their burrows, consist of about one-third of the contents of the worm's intestines, in pelletlike form, and have a third more bacteria than the surrounding soil.

Even when ample organic matter is available, earthworms consume large amounts of soil, and by mixing the two produce a rich humus, perfect in texture, with more plant nutrients than in the material from which it was derived. Castings contain a higher percentage of aggregates than is found in the surrounding soil - aggregates being the formations of individual particles of sand, clay, and silt, grouped into larger units, which help make a crumblike structure of the soil.

An earthworm is said to produce its own weight in castings each day it is on the prowl. Henry Hopp of the USDA estimates that one acre of good agricultural land can produce well over five tons of castings in a year, or more than 5 percent of the total soil volume to plow depth. In the process of producing its castings, on even an ordinary agricultural soil, earthworms are credited with turning more than fifty tons of soil per acre, and in the Nile Valley as many as two hundred tons, into a fructifying base.

Earthworms are prodigious diggers and earth movers, capable of burrowing down as deep as fifteen feet. They can squeeze between and push apart the soil crumbs, and one worm alone can move a stone fifty times its own weight. As they burrow, earthworms mix and sift the soils, breaking up clods and burying stones. Some carry down leaves and other organic matter; others bring nutrients and humus to the top. Tunnels held together by their mucus afford planted roots quicker avenues into the soil. And the mucus, forming humus, prevents erosion. Henry Hopp says these materials, once dried, do not dissolve again in water. Yet, while the soil thus treated holds the required moisture, the burrows drain superfluous water. Experiments have shown that soils with earthworms drain from four to ten times faster than those without. Conversely, in light sandy soils, where water tends to run straight through to the subsoil, the aggregates produced by earthworm castings act to improve the retention of water.

By digging into the subsoil, loosening it, and threading it with tunnels, earthworms gradually deepen the topsoil layer. by ripping up fine mineral particles and depositing them as castings on or near the surface of the soil, they constantly adding nutrients to the zone in which plant roots feed, delivering mineral substances that would otherwise remain largely unavailable to most plants.

With their mixing, digging, burrowing, fertilizing, and humus-making activities, the worms have an immense impact on the soil, its texture, its fertility, and its ability to support everything that lives in or on it, especially plants that form the basis of our food supply. But the worms must be fed, proliferating in direct proportion to the amount of organic matter incorporated into the soil, a supply which must be kept up so long as one wishes to retain the earthworms. *Eisenia foetida*, a red manure worm that inhabits compost heaps, turning animal manure into sweet-smelling humus, grows to five inches, but cannot live without copious amounts of decaying organic matter.

Night crawlers, so named because they creep about at night on the surface of the earth, feed on leaves, which they drag down into their burrows, and even with their pinhead brains they have the wit to pull them by the narrow end - which shows more wit than the leaf-gathering suburbanite who regularly spends a fortune to deprive the earthworm of his autumnal fare.

In an orchard, during the three months of autumn, earthworms can dispose of 90 percent of the fallen leaves, dissolving even tough material such as stems and roots. Darwin, who reported seeing burrows plugged with twigs, bits of paper, feathers, tufts of wool, or horsehair, claims that worms, though congenital scatophages, showed a predilection for celery, carrot leaves, wild cherry leaves, and especially raw meat, including fat. Minnich reports that one Wisconsin commercial raiser of earthworms even chose to feed his charges ice cream as a treat on Saturday nights.

More surprising still is his report that a German researcher, C. Merker, writing in the 1940's, astounded fellow scientists by asserting that earthworms have voices, and can actually sing, their faint sound being "rarely in a solo number, but generally in series marked by a definity and changing rhythm." Dr. Merker claimed to be able to hear the sounds when within twelve feet of the worms, sounds produced not by chance but by the deliberate opening and closing of the earthworms' mouths.

How this could be, when earthworms have no lungs - breathing through the whole surface of their skin, moistened to dissolve oxygen, which is pumped through the bloodstream by five sets of double hearts in rings or segments close to the head - is all the more amazing.

A cleric contemporary of Darwin complained that earthworms are also "much addicted to venery." In suitable weather, night crawlers can spend a goodly portion of their nocturnal activities in the pursuit of sex, even an entire night coupled to a willing hermaphroditic mate, each possessing both male and female organs. With the undersides of their bodies held firmly together by tiny bristles, or setae, they lie with their heads pointing in opposite directions, touching in the region of the spermathecal openings, where the clitter - a white band a third of the way down their bodies - touches the surface of its mate.

They Copulate by exchanging sperm cells stored in cuplike hollows in the ninth and tenth segments, excluding a special mucus from the sexual region to protect the spermatozoa being mutually exchanged. More mucus secreted by the clitellum forms a jellylike ring, which picks up the worm eggs from ovaries and sperm cells from testes, slipping the ring off the body, to form a tiny yellow cocoon. Greatly enlarged, it looks like a lemon and contains scores of fertilized eggs, which can be found in the soil during the warmer months of winter. Under good conditions, an average red worm can produce from 150 to more than 200 young ones annually.

One of the principal functions of the earthworm is to consume available mineral nutrients, and, by actions of enzymes in their digestive tract, render them water soluble, easily absorbable by the root hairs of plants, to be made available in turn to the cells of plants, animals, and man.

As Voisin points out, without earthworms there would be no civilization. But Minnich complains that with the single exception of Dr. Henry Hopp, the attitude of USDA scientists, along with that of many of their associated colleagues in subsidized state universities, has traditionally been negative toward the earthworm.

> They have long begun with the assumption that earthworms are just one more facet of the "unscientific" cult of organic gardening and farming, and that this method of growing crops is antithetical to the "modern" methods of agriculture, including its principles of heavy chemical treatment, monocropping, and other facets of maximum-profit agribusiness. The earthworm, thus judged guilty by reason of association (with organic methods), the USDA has long discouraged serious investigation into the possible benefits of earthworms in agriculture, and has even gone so far as to denigrate or ignore the work of other researchers who have revealed such benefits. Since the USDA has either conducted or influenced the great bulk of agricultural research in this country during the present century, its position on any facet of agriculture or horticulture has broad, far-reaching, and determining effects on both scientific direction and public attitudes. . . . The USDA will sponsor no significant earthworm research, and its long tradition of ignorance is the chief reason why we know so little about earthworms, and why we have failed to utilize their power throughout the present century.

The seriousness of the situation was recently emphasized by Marcel B. Bouche, Secretary of the Soil Zoology Committee of the International Society of Soil Science, in his foreword to Dr. Kenneth E. Lee's last word on Earthworms, a book published in 1985 by Academic Press, which for the first time places the worm on a world-wide scale in the economy of nature.

> Humanity (writes Bouche) knows little about its most important commensals. We are unaware of the nocturnal, hidden, subterranean activity of the most important animal biomass that shares with us the earth's land surface. . . . Using increasingly powerful physical and chemical methods, we decide to remodel the landscape, to disturb the soils, to pulverize chemicals, to release fumes and waste water. . . ignoring the principal animal that inhabits the environments we alter. . . . If we compare, for example, the significance accorded to ornithology and the multitude of birdwatchers studying about one kilogram of birds per hectare, with the extremely limited number of research workers' interest in the hundreds of kilograms or tons per hectare of earthworms, we must conclude that our knowledge of ecosystems of fundamentally distorted by our above-ground, visual perception of nature and our ignorance of life below-ground.

Normally healthy and long-lived, earthworms are discouraged if not killed outright by many pesticides and most chemical fertilizers. Copper sulfate, in concentrations near the surface of the soil, even in only 260 parts per million, can drastically reduce the worm population, and any nitrogenous fertilizer will quickly wipe them out. Nearly all commercial brands contain high levels of nitrogen in the form of ammonia, which destroys earthworms by creating intolerably high acidic soil.

Yet the more organic material they receive the faster they proliferate. And, as they proliferate, so do their symbiotic progenitors, the microorganisms, manufacturers of humus, the basis for a fertile soil. Steiner's premise was basic: that his biodynamic preps create the ambience for the infusion of the essential cosmic and telluric forces that generate this metabolic miracle.

(**Reference:** Secrets of the Soil / Peter Tompkin & Christopher Bird)

Recommended reading regarding Earthworms:

1. **Darwin on Humus and the Earthworm / Charles Darwin**
2. **Earthworms / Kenneth Ernest Lee**
3. **Microcosmos / Lynn Margulis**
4. **The Earthworm Book / Jerry Minnich**
5. **The Earthworm Book / Alicia Previn**