# Degraded Soils, Food Shortages & Eating Oil

## Restoring Soil Life through Biological Agriculture

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*Worn-out soils are less productive, less resilient and more dependent upon intensive inputs.*

The global urgency to produce food is not expected to lessen. By 2030 our planet is expected to support 8.3 billion people. The United Nations Food and Agriculture Organization has stated that by then, farmers will have to produce 30 percent more grain than they do now to keep pace with hunger. How do we increase agricultural production while fossil fuel supplies decline and costs escalate, restricting their use on the farm? And how do we expand production when desertification, soil erosion, organic matter and nutrient loss are on the increase? It is a paradox: precisely as we are increasing our demands on soil, we are losing it at an unprecedented rate.

The so-called Green Revolution has been anything but green. Initially, through intensive chemical inputs and monocultural cropping practices, the Green Revolution greatly increased the production of chosen commodity grain crops such as wheat, corn, soybeans and rice — but it also greatly broadened the use of weed control, chemical fertilizers and pesticides, thus increasing toxicity levels in the environment and widely impacting the planet's precious soil and water resources. In fact, agricultural production has not increased in several decades and high levels of chemical inputs have been needed just to sustain current levels of production. In addition, the escalated use of chemical fertilizers, pesticides, erosion, land clearing, and compaction has had a devastating effect on beneficial living organisms in the soil. Globally, 1.9 billion hectares are significantly degraded.

Now more than ever, we need a real paradigm shift rather than mere incremental changes in the way we grow, buy, and eat our food — and an organic, biological approach to managing the world's soil provides that much-needed shift. According to a recently released UN Environment Programme report (*www.unctad.org/en/docs/ditcted200715_en.pdf*), this may be the only way we can solve the growing problem of hunger in developing countries. UNEP reports that organic and biological practices in Africa outperformed industrial, chemical-intensive conventional farming, while also proving environmental benefits such as improved soil fertility, better water retention and drought resistance. This analysis of 114 farming projects in 24 African countries found that organic or near-organic practices resulted in significant yield increases.

### NOT-SO-GREEN REVOLUTION

Chemically based conventional agricultural practices lead to increased risks to human health. Pesticides have poisoned farm workers and wildlife and created public health problems including cancers and birth defects. The impacts reach both rich and poor countries. In the United States, over 50 percent of the nation's drinking water wells contained detectable amounts of nitrate and 7 percent have detectable amounts of pesticides.

The United States is burdened with an estimated $12 billion annual health and environmental cost associated with pesticide use, and estimated annual public and environmental health costs related to soil erosion of about $45 billion. But the damage transcends environmental soil loss — the cost of destroying future generations' ability to produce enough food for their survival cannot be calculated.

### INOCULANTS

Soil loss, compaction and the use of chemical fertilizers and pesticides have caused tremendous harm to the environment and life in the soil. Part of our strategy to combat this degradation is to reestablish beneficial life in the soil using biological inoculants. Biological inoculants contain organisms that enrich the nutrient and water-holding capacity of soil. The main types of inoculants are nitrogen-fixing bacteria and mycorrhizal fungi. These groups of organisms have a special, mutually beneficial, or symbiotic, relationship with plants in which the partners derive life-sustaining benefits from each other. These symbiotic organisms deliver multiple benefits to the plant host, including improved nutrition, disease resistance, and tolerance to adverse soil and climatic conditions. Techniques to reestablish beneficial soil organisms have proved to be successful in countries all over the world, and biological inoculants have been used to reduce problems associated with erosion, drought, decreased fertility and increased salinity of the soil.

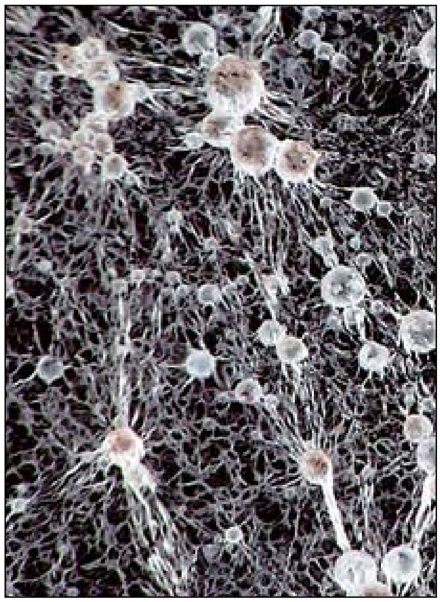
## MYCORRHIZAE

Mycorrhizae literally means "fungus roots." In this association, fungal filaments extend into the soil and help the plant by gathering water and nutrients and transporting these materials back to the roots. These beneficial fungi grow on the roots of most plants, and plants that have mycorrhizal fungi growing on their roots survive better after transplantation and grow faster. The fungal symbiont receives shelter and food from the plant, which in turn acquires an array of benefits such as improved uptake of nitrogen, phosphorus and most micronutrients, drought and salt tolerance, and an overall increase in plant growth and development.

Most plants, including more that 90 percent of all agricultural crops, form a root association with these specialized fungi. Miles of fungal filaments can be present in a tiny fraction of healthy soil. The crop's association with mycorrhizal fungi increases the effective surface absorbing area of roots by several hundred to several thousand times.

Mycorrhizal fungi can increase the yield of an area of land by 30 percent or more. They can readily absorb nitrogen and phosphorus from the soil and pass them on to the plant. Mycorrhizal plants show higher tolerance to elevated soil temperatures, various soil- and root-borne pathogens, and heavy metal toxicity.

Recent research published in the journal *Nature* (M. Govindarajulu et al., "Nitrogen Transfer in the Arbuscular Mycorrhizal Symbiosis," 2005) has emphasized the important role mycorrhizal fungi play in delivering nitrogen to crop plants, thus lowering the need for excessive amounts of synthetic fertilizers. With this in mind, farmers may benefit from promoting the proliferation of mycorrhizal fungi through diminished fertilizer input, thereby making more efficient use of the nitrogen stores in agricultural soils. The authors found that beneficial mycorrhizal fungi transfer substantial amounts of nitrogen to their plant hosts. The researchers also discovered a novel metabolic pathway in which the ammonium form of nitrogen (less subject to leaching losses compared to nitrates) in soils is absorbed by the fungi.



*Mycorrhizal fungal hyphae.*

There are well-documented research trials also available on the important role of mycorrhizal fungi with most legume crops. The rhizobia bacteria that form with important legume crops have a high phosphorus requirement to optimize their level of nitrogen-fixation. Mycorrhizal fungi produce specific enzymes to extract phosphorus from the soil and make it available to nitrogen-fixing bacteria. The synergy effect of a combined treatment with nitrogen-fixers and mycorrhizae can increase yield. In soybeans, inoculation with mycorrhizal fungi has been shown to increase the amount of biological-fixed nitrogen and stimulated phosphorous uptake, soybean growth and yield, and other studies have shown mycorrhizal inoculation improve rates of nitrogen-fixation for other species. Yield increases of up to 30 percent have been realized for corn and soybeans, with phosphorus savings of 160 and 213 pounds per acre, respectively.

Mycorrhizae perform many functions related to plant establishment that fertilizers do not. Fertilizers cannot maintain healthy roots, improve soil structure, increase water uptake, or promote other beneficial microbes. In fact, chemical fertilizers often negatively affect these factors. Fertilizers can lead to other side effects, such as deteriorated water quality, soil structure and excess soil salinity. The mycorrhizal relationship improves feeder-root production, allowing a mycorrhizal plant to better utilize added fertilizer.

## LEGUME-RHIZOBIUM RELATIONSHIP

Nitrogen is plentiful in the atmosphere (air is 80 percent nitrogen), but plants can't use it in the gas form. Nitrogen uptake is possible in a fixed form, which is facilitated by the rhizobium bacteria present in nodules located on the root systems of certain plants. The bacterium lives in the soil to form root nodules (*i.e.* outgrowth on roots) in plants such as beans, groundnut and soybean. In agriculture settings, it is commonly added as a powder or liquid biological seed inoculant.

In the "old" days, farmers were careful to rotate crops and incorporate nitrogen-fixing legumes into management practices which added organic matter and fertility into soil. An excellent example is the use of rhizobia inoculant when growing beans, alfalfa, clover and other nitrogen-fixing legume crops on farmland. Symbiotic nitrogen-fixing bacteria associated with the roots of legumes are capable of converting substantial quantities of the vast pool of atmospheric nitrogen and converting it to an organic form usable by plants. A good cover crop can add 200-300 pounds of nitrogen per acre to the soil.

These nitrogen-fixing organisms evolved millions of years ago and helped pioneer plants to colonize the land. As these early plants gained a foothold on rocky ledges surrounding primordial seas, they helped build soil on the land surface. From ancient times until recent decades, these soil organisms were essential partners in building soil productivity. Until recently, these organisms were among the most important tools in maintaining the productivity of the farm. Now, the escalating monetary and environmental costs of chemical-based nitrogen fertilizer are making biological or "symbiotic" approaches increasingly attractive to farmers.

### CARBON SEQUESTRATION

Soils are also a potentially powerful sink for accumulating carbon in the form of organic matter. Atmospheric $CO_2$ can be recaptured by the soil under a variety of conditions, including activities that slow soil decomposition rates, introduce greater amounts of plant biomass, reduce soil erosion, and produce glomalin derived from mycorhizal activity. Land management practices such as no-till, winter cover crops, biological inoculants, perennial crops, manure and compost inputs are being studied for their ability to increase soil-stored carbon.

Of recent interest has been the discovery of glomalin in 1996 by Agricultural Research Service scientist Sarah Wright. Produced by arbuscular mycorrhizal fungi, glomalin permeates organic matter, binding together silt, sand, and clay particles. Not only does glomalin contain 30 to 40 percent carbon, but it also forms aggregates that create soil structure and keep other stored soil carbon from escaping. Studies have shown glomalin can represent up to 30 percent of the total carbon in soil and can last 40 years.

The only sources of glomalin are arbuscular mycorrhizal fungi, found living on plant roots around the world. Wright named glomalin after *Glomales*, the taxonomic order to which arbuscular mycorrhizal fungi belong. Unfortunately, numerous factors such as erosion, organic matter removal, compaction, cultivation, fallow, and the use of certain chemical fertilizers and pesticides have reduced or eliminated these glomalin-producing mycorrhizal fungi from large expanses of managed lands.

### A BETTER WAY

Over the last few decades we have learned much about how soils in natural areas remain extremely productive without inputs of chemical fertilizers, pesticides and irrigation. The system can work. The use of organic amendments and biological inoculants such as mycorrhizal fungi has been proved in thousands of University studies. Quality mycorrhizal inoculum is now available at a fraction of the pre-acre cost farmers typically pay for chemical soil supplements.

For millions of years the powerful combination of organic amendments and soil biology has demonstrated its natural success and today we are beginning to see these benefits on large-scale farming. In North America both large-scale conventional and organic farmers are applying mycorrhizal fungi to wheat, corn, flax and soybean. Many will also use fish fertilizers, compost and compost tea to stimulate and inoculate their soils with beneficial biology, improving nutrient retention and uptake. In India, farmers are using mycorrhizal inoculation to decrease their fertilizer use by 50 percent without any loss of yields. Large U.S. companies such as Pennington Seed are using mycorrhizal fungi to coat millions of pounds of grass seed to save water and fertilizer.

*Inoculated (left) and non-inoculated oats subjected to drought in Australia.*

Clearly, we stand at a crossroads. We must feed the world today without destroying future generations' ability to produce enough food. To do this we need to launch an organic, biologically sound strategy to manage the world's soils — a strategy that makes basic changes to the way we grow our food. We need an approach that maximizes agricultural production while restoring clean water, protecting the environment, building soils, and sustaining soil resources. Such a strategy marks a dramatic change from reliance on unsustainable, energy-intensive, potentially toxic fertilizers and pesticides to benign, organic farming systems. This new paradigm utilizes proven agricultural practices developed over thousands of years and age-old natural relationships within the living soil to sustain and improve the health and survival of our soil, environmental and world population.

Our approach is an organic, biologically based strategy for managing soils. It is an approach that improves rather than degrades the productive capital of soil. Scientific studies substantiate that the use of organic fertilizers, biological inoculants, such as nitrogen-fixing bacteria and mycorrhizal fungi, appropriate cover crops, green manures, compost and compost tea, can maintain or increase crop yields with reduced chemical inputs. Furthermore, yields can continue to increase over time in stressed agricultural environments without the detrimental effects of soil erosion, loss of organic matter and environmental degradation.

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