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A Brief Sketch of the Soil Food Web

Organic *Cannabis sativa* growers seek purity, quality and taste in their products – buds that are free of harsh chemicals and are ideal for the medical or connoisseur user. Ecological methods produce this quality and minimize the expensive chemical inputs and fixes necessary to grow with conventional methods.

A key fundamental difference between conventional growing techniques and organic, ecological techniques is that conventional techniques feed the plant, while ecological techniques feed the soil organisms, which in turn make nutrients available for plants to feed themselves. These soil organisms function in a biological system we call the *soil food web*. In this Green Paper, I briefly describe the soil food web (SFW), mention some ways to apply this knowledge to growing Cannabis, and highlight some problems to avoid.

Plants are active feeders that obtain food by growing roots towards food sources (expanding the *rhizosphere*, or root zone) and by feeding and hosting a system of microbes that in turn provides food to the plants. Plants feed this system by secreting *root exudates,* complex mixes of sugars, carbohydrates and proteins, to bacteria and fungi, which in turn provide the roots with water and nutrients in plant-available form (K, Ca, Mg, P, N, and others). These micro-organisms create *biofilms*, which are cohesive communities of organisms that often include a variety bacteria, fungi, viruses and other lifeforms living in an adhesive matrix of carbohydrates and sugars – *exopolysacchrides* (a sticky goo). Biofilms offer the communities and their hosts protection from pathogens, drought, and food scarcity while creating channels for efficiently transporting nutrients. These biofilms generally cover the entire surface of a plant. (While biofilms are generally transparent, they are visible using electron-scanning microscopes.)

Within the rhizosphere and amidst its biofilms, fungi play many important roles, including important functions in the nutrient cycle. The fungi that exchange nutrients with plant roots (and confer resistance to pathogens) are called *mycorrhizal* fungi (MR fungi). MR fungi exchange minerals (including nitrogen and phosphorous), water, and sugars for carbohydrates, sugars and amino acids – a mutualistic relationship. Some MR fungi can transfer sugars from one plant to other plants in the mycorrhizal network – and to other plant species. These *mycelial* networks grow throughout the soil, intensively and extensively; their complex form creates large surface-area per soil-volume, and mycelium can grow over a large area. (*Mycelium* is the living mass of a fungus, made up of networks of *hyphae*, the fungal growing points.) Thus, mycorrhizal mycelium vastly increases the effective surface-area of plant roots, while effectively connecting plants with neighboring plants in a large, mycelial network. This increased surface-area proportionately increases the plant's ability to obtain nutrients and water from its environment, effectively expanding the plant's rhizosphere and growing space. Many MR fungi can obtain nutrients such as phosphorous (anion) and potassium (cation) from organic sources like decaying plant or animal material, or inorganic sources like clay, sand, or even bare rock in a process called *weathering*. Mycelia apply bending-force to the rock, creating stress on the crystal-structure, while secreting acids at the stress point in a sophisticated, gradual system. Most MR fungi seem to weather rock symbiotically with bacteria; however, because the biofilms within rhizospheres are difficult to observe and are amazingly complex, definitive scientific conclusions are yet elusive on this mechanism.

Mycologists have named seven MR fungal types, but the two most common types are (a) *Ectomycorrhizal* fungi, which form mycelium sheathes around the root cortical cells (just inside the epidermis, or skin), and (b) *Endomycorrhizal* fungi, which penetrate the cortical cells with hyphae. Cannabis growers, especially those growing indoors, are concerned with Endomycorrhizal fungi – specifically the *arbuscular* mycorrhizal fungi (Glomeromycota phylum), whose hyphae form arbuscular structures (vein-like branched hyphae) within the host cell. This phylum is the most widespread of the seven mycorrhizal types and benefits most annual-cycle plants.

In addition to their roles in nutrient-cycling, Arbuscular hyphae secrete *glomalin* – a glycoprotein that constitutes a large percentage of soil carbon (c. 25%) in temperate zones. Because of its stickiness, glomalin is an important contributor to soil *aggregation*. We'll discuss aggregation in another Green Paper.

Within the soil food web, bacteria also play key roles in nutrient-cycling, interacting directly with the root or, more commonly, in association with MR fungi to decompose rocks, obtain nutrients (minerals in soluble form) and deliver them to roots. Often bacteria will provide the acids for rock weathering, which fungi metabolize and transport to fine root-hairs.

However, bacteria play another highly important role – concentrating nitrogen from low-nitrogen organic structures. Because bacterial C: N ratio is so low (4–6) compared to the organic compounds that they consume (from root exudates and dead tissue mass), they must consume more carbon than they need in order to gain enough nitrogen. They release this carbon to the atmosphere as CO2 and fix the nitrogen into their cell mass. When bacteria predators – protozoa and bacteria-feeding nematodes – consume the high-N bacteria – they must release the extra nitrogen to the rhizosphere in soluble form (ammonium, NH4) where it becomes immediately available to plant roots and other organisms.

Another important type of bacteria transforms atmospheric nitrogen (N2) into plant soluble form (ammonia, or NH3 or its conjugate acid, NH4); these *nitrogen-fixing bacteria* are the main source of nitrogen available to the living world. Nitrogen-fixers form nodules within plant-roots to create the anaerobic conditions necessary for the transformation. In exchange for ammonia, plant roots feed the bacteria sugars, carbs, and proteins via root exudates.

Many organisms in the rhizosphere (in addition to plants) consume NH4 from nitrogen fixers and other ammonium sources. The ubiquitous *nitrifying bacteria* transform NH4 to NO2 (nitrite) and then to NO3 (nitrate), another plant-available form of nitrogen. Further, under anaerobic conditions (which we seek to avoid), *denitrifying bacteria* complete the cycle, converting nitrates to N2 or N2O, both gaseous forms that enter the atmosphere.

Beneficial bacteria play other roles, as well. Insofar as they occupy plant surface area (below- and above-ground), they block pathogenic and parasitic colonization. Further, compounds from the cell-walls of decomposed gram-negative bacteria are a significant source of humic and fulvic acids. These carboxylic acids comprise the R-groups in the lipid bi-layer structures of the outer membrane of gram-negative bacteria.) In this way, natural humus derives from gram-negative bacteria.

In turn, protozoa eat bacteria, thereby releasing nitrogen, phosphorous, and other nutrients. Protozoa feed mostly on bacteria, though some species feed on fungi, other protozoa, and even nematodes (microscopic worms), thereby releasing nutrients. However, more often, nematodes prey upon protozoa, as well as on bacteria, fungi, and other nematodes – and on weakened plant roots under anaerobic conditions. In turn, a variety of organisms prey upon the nematodes, including collembola (six-legged micro-arthropods, also known as spring-tails), tardigrades (eight-legged micro-arthropods), turbellarians (flat worms) and mites (arthropods), as well as predatory nematodes, large protozoa, obligate bacterial parasites, rhizobacteria, and several types of fungi.

A grower can devise a wide-variety of methods for working with the soil food web, depending upon one's objectives, resource limitations and imagination. For instance, to build an indoor, container garden, the grower might use a favorite bulk soil mix or recipe in combination with worm-castings, spikes and layers and a diet of compost tea and herbal extracts. Into this mix one could drop the starts or seeds inoculated with mycorrhizal and bacterial inoculant. In this scenario, the soil food web is short-lived and simplified, but it would still offer some significant productive benefits.

Or, to build an outdoor, no-til garden for long-term use, one might build SFW-promoting structures deep into the soil, fill beds with diverse and biology-promoting materials (fungal composts, worm composts, thermophilic compost, bokashi, etc.) and plant the growing space with *support plants* for the Cannabis. (Support plants are perennial plants arranged in *polycultures* that, in combination, confer multiple effects on soil and contributing diverse exudates that fuel the SFW.) The grower would plant the inoculated clone or seed into this polyculture.

On the other hand, some caution is in order. One of the grower's worst scenarios is arthropod infestation, whether spider mites, thrips, fungus gnats, or any number of problem creatures – all creatures that can hide or lay eggs into composts. But, as mentioned above, mites are a common predator in SFW systems, and though most species are predators and beneficial to Cannabis growing, a parasitic mite infestation can completely ruin a crop. So, when using composts, the grower must be highly conscious of quality control, for example combining highly-controlled worm composts to thermophilic composts that have maintained constant temperatures over 140°F. And, the grower might even consider this procedure too risky; some growers might prefer to avoid all unpasteurized composts, depending upon their own objectives and situation.

Similarly, the container grower must be careful not to exhaust the SFW with too many short-term resources and too few long-term resources, such that soil organism populations grow quickly, deplete stores in the rhizosphere, and plummet, becoming food for a different set of organisms. Similarly, one must be careful not to over-saturate soils and create anaerobic conditions at the bottom of the container. And, after mixing a biologically-rich soil, one should always let the soil "cook" for a few weeks before planting into it, as it will become quite hot during the initial build-up.

The individual grower will have to decide how to apply knowledge of the Soil Food Web, depending upon economic circumstances, current resources and facilities, strains and their soil demands, and any number of possible factors. But, caution is always in order when trying unfamiliar systems. One might consider a test plot or two to compare results and gradually expand into a full-scale project. Imagination is the limit in this enterprise. We'll keep you posted as we learn more. We appreciate all your comments and insight.