©Parker Forsell

The Microbiology of Biodynamic Preparations

Elaine Ingham

A central point in Steiner's teachings is that soil life is critical for a healthy system. Because plants and soil life both take nutrients from the soil, it may seem to be an impossible task to maintain both soil health and good plant yields. By adding organic matter with biologically held nutrients to the soil, one can keep the nutrients in soil organisms such as bacteria, fungi, protozoa and nematodes. Feed the microbes and they will feed your plant. Animals, including humans, eat plants, and animal waste products are then used to make properly processed compost so weed seed, human pathogens, most plant pathogens, and root-feeding nematodes aren't present. Compost, with all its nutrients, is added back to the soil to balance what was taken out by the plants.

Leaching of nutrients from compost or soil to ground and surface waters is a big problem. The problem is not only environmental. If one loses the nutrients meant to feed the plants, nutrient deficiencies will occur. Lack of the right biology causes the leaching of nutrients from the soil. Anaerobic metabolism results in nitrogen being lost as ammonia, sulfur being lost as hydrogen sulfide and the production of toxic materials like alcohol and low pH organic acids. So even if some anaerobic microorganisms are able to produce antibiotics that harm disease organisms, anaerobic conditions also mean loss of nutrients.

Initial studies suggest that it is the aerobic fungi that hold many of our nutrients in the soil, when those nutrients are added as inorganic forms. Without aerobic fungi, one's nutrients end up in the "drink", lost as leaching occurs and moves inorganic nutrients beyond the root zone.

It is the biology in soil that converts nutrients held in plant material into forms of nitrogen, phosphorous, sulfur and a host of other micronutrients. Organisms perform the balancing act between organic and inorganic forms of nutrients. The balance is maintained through the right number and kinds of organisms immobilizing nutrients in their bodies and in organic matter. Part of the balancing act also involves the right number and kind of organisms consuming nutrient-retaining organisms, and therefore releasing nutrients in a plant available form.

This balancing act must happen in the root zone in order for the plant to benefit. The reason why this happens, and why the majority of these nutrient cycling interactions occur in the root zone can be found in several scientific papers. The benefits that can occur if the soil food web is in a healthy condition have also been documented (Ingham et al., 1985; Coleman et al., 1988; Ingham et al., 1986). *Applied Soil Ecology* and *Biology and Fertility of Soils* also publish papers concerning the soil food web. The Soil Ecology Society (<www.soilecology.org>) is a scientific organization comprised of researchers in this area of work and their investigations leave little doubt that nutrient cycling occurs through the actions and functions of the soil food web.

Benefits of a healthy soil food web

The documented benefits of having a healthy soil food web are:

- Protect against disease organisms through competition and consumption without the use of toxic chemicals.
- Retention of nutrients in the soil through biological cycling, which prevents nutrients from leaching, eroding, or otherwise being lost from the soil. These are nutrients not in a plant-available form.
- Nutrient availability to plants through different sets of organisms.
- Decomposition of toxic material.
- Building of soil structure, which reduces water loss from the soil, increases oxygen movement into the soil, and prevents toxic conditions from developing and suppressing plant growth. Erosion and loss of nutrients is also reduced as soil structure is improved.
- Production of plant growth promoting compounds.

Soil ecology supports Steiner's ideas and it is critical to return life in the soil to normal functioning levels. We have been documenting that the life needed varies from plant to plant, soil type, climate, and time of year.

Do soils maintained with biodynamic approaches have healthy soil food webs? If not, how do you get the right biology back? How did those organisms get lost? One loses the right sets of organisms by plowing too much, and not putting the right organic material back into the soil to feed the biology. When one drives over the soil with heavy equipment, he or she may compact the soil and destroy the organisms the plants need. While pesticides and inorganic fertilizers are not a part of biodynamic methods, many other people use materials that harm the normal life in the soil. Air pollution and drift from toxics applied elsewhere harm life in fields where toxics may not be applied. The damage caused by these toxics still has to be remediated.

One is required to replace the biology damaged by other people's waste products, by plowing, harvesting and using heavy equipment. Some knowledge of the biology required by different plants is needed, but really the most important thing growers can do is to provide a diversity of organisms and the foods to keep those organisms active throughout the year.

In properly made compost, organisms grow, out-compete disease-organisms, and build good aggregate structure. Whether compost is made by putting plant residues on the soil in the fall, by thermal composting, or worm composting, the compost needs to be aerobic in order to compost fully. The process of composting needs to take place without loss of nitrogen, sulfur or phosphorus, and without the production of plant toxic compounds like alcohol or low pH organic acids.

Anaerobic organisms are the ones that produce these problems. But it isn't all anaerobic organisms that are "bad"; it is only a certain set of anaerobic organisms that cause problems. It may be possible to add a community of fermentative lactic acid bacteria without a loss of nutrients. The organic acids produced by fermentative organisms may not be beneficial for plants, but more work is needed to understand the interaction between highly acidic organic acids produced in putrefactive conditions, the fermentative organic acids produced by lactic acid bacteria, and the alkaline organic acids and glues produced by aerobic bacteria. The other complication involves the fact that different beneficial biology is necessary for different plants.

So, aerobically composted material is important. Just as in sewage treatment, maintenance of aerobic conditions selects against the growth of human pathogens. Of course, having many species of aerobic bacteria and fungi that compete with the human pathogens for foods and many protozoa and beneficial nematodes that consume the human pathogens, means multiple mechanisms to reduce human pathogens.

But even if the data exists showing that in sewage treatment human pathogens are reduced by aerobic competition and consumption, apparently this work needs to be repeated when applying it to compost or compost tea.

Biodynamic preparations are another way to inoculate beneficial organisms into different materials. Some preliminary data about the biology in different biodynamic preparations, and in one type of flow form are shown in this report (Table 1, 2, 3). While interesting, this work isn't fully replicated, so the data are only an indication. Variability can't be fully assessed with just one or two samples. The data we do have shows that preparations made by different people result in differing soil food webs. The reasons for the differences should be quite apparent, given different soil types, weather conditions, water quality, and so forth.

How were the preparations obtained?

The fresh preparations (Table 1) were obtained from a vineyard on the East coast of the U.S. in the spring of 2001. The preparations were made by an established New York grower using biodynamic methods. The preparations were stored and then used to make tea in late summer (Table 2). Water was placed in a barrel, and stirred compost tea was prepared (one hour of stirring each day). Preparations were added in appropriate amounts to portions of the compost tea. Samples were taken several days after the preparations were added to the tea in order to allow adequate incubation of the preparations in the tea.

Fresh biodynamic preparations were obtained from an established grower in Oregon in October 2003 in order to have a comparison to the New York preparations (Table 3).

Microbial assessment

All samples were tested using standard direct count activity and total biomass methods described on the SFI website. All organism numbers and biomass were observed using DIC-epifluorescent microscopy. There is no requirement for growth of the organisms in media. Bacteria and fungi are stained and ready to be observed within a few minutes of receipt of samples within the lab, and all counts were performed by direct microscopy.

Data

The purpose of this investigation was to assess different preparations made by different growers, fresh versus dried, for their biology. More testing is needed to assess how variable preparations may be when prepared by other growers in other places. All preparations need to be assessed for their ability to affect plant growth. Some plants may be affected positively, while other plants may be affected negatively.

The desired ranges listed on the bottom row of the tables are based upon the testing of many different soils and composts at Soil Foodweb Inc. We can demonstrate that the biology between different preparations varies, and suggest that based on this biology, the preparations would have very different effects on different plants. But that plant effect needs to be confirmed by testing. In addition, if the important parameters that Steiner defined are maintained, will most biodynamic preparations have similar microbial deficiencies, or can preparations have above the minimum levels of beneficial organisms?

Barrel compost and dandelion preparation 506 (Table 1) had the highest biomass of active bacteria (typically variance is within 1.5), while oak bark preparation 505 contained less than the desired level of total bacterial biomass (variance is 25). Horn manure 500, chamomile preparation 503 and oak bark preparation 505 were low for active fungi while dandelion preparation 506 contained high levels of total fungi (variance is 3.1). Total fungal biomass was low in all these preparations, although of these preparations dandelion preparation 506 had the highest total fungal biomass, while horn manure and barrel compost had the lowest (variance 5.9). Horn manure and barrel compost had mostly actinobacterial (*actinomycetes,* except they actually are bacteria) populations, while the other preparations contained mostly *ascomycete* fungi. Actinobacteria can be detrimental to fungi, especially the beneficial fungi.

All of the fresh preparations (Table 1) were low in active bacteria (suggesting quite mature composts), as well as being low in active and total fungi. Possibly the soil in which materials were incubated did not contain the desired ranges of fungal biomass. Even though the barrel compost was buried in woodlot soil, it was at the edge of the forest, near the road and the soil may have been too disturbed. The horn manure and barrel compost were both high in actinobacterial biomass, suggesting a similar source of material high in actinobacteria, but low in fungal biomass.

Storing and allowing the preparations to dry, and then adding the preparations to compost tea made by stirring (several day brew), resulted in a drastic reduction of fungi, but a significant increase in bacteria in these preparations (Table 2). [Note: the fact that these preparations were dry is due to the transport between farm and lab and it was an unintentional consequence.] If the preps are not maintained in conditions that help the microbes stay alive, they may lose the important biology that Steiner desired. Alternatively, addition of preparations to stirred compost tea may not benefit the tea, especially if conditions in the tea are not conducive to the growth of the beneficial organisms.

The teas made without any preparation added (Control and No Yarrow) contained the highest levels of active bacteria and total bacteria. The oak bark preparation addition contained organism biomass similar to the higher levels observed in the no-preparation addition. Barrel compost and nettle leaf addition had total bacterial biomass in the range of the no-addition teas, but active bacterial biomass was lower. The other preparations resulted in lower active bacteria, and lower total bacterial biomass than the non-preparation additions.

All of the teas contained active bacteria far above the desired range of active bacteria based on actively aerated compost teas, but total bacterial biomass was extremely high in all the teas, suggesting that for some time during the brew, the brew was in anaerobic ranges.

Both active fungal and total fungal biomass were uniformly low in all the teas. In other work, both total and active fungal biomass has been lost when oxygen concentration dropped below 5.5 to 6 mg oxygen per L. All of the brews most likely lost quite a bit of the nutrients from the tea through volatilization of ammonia. Ammonia is produced only under anaerobic conditions, and could be

Table 1. Fresh biodynamic preparations from New York, sampled May 10, 2002

Sample	Moisture (g water per g fresh material)	AB	TB	AF	TF	Hyphal diameter (μg)
		μg/g dry weight				
Horn (500)	0.55	**7.1**	130	**1.0**	**16.4**	**2.0**
Barrel	0.56	**11.0**	128	**5.0**	**16.8**	**2.0**
503	0.63	**6.8**	123	**1.9**	**23.7**	2.5
504	0.56	**7.3**	136	**3.9**	**25.5**	2.5
505	0.60	**7.0**	109	**2.6**	**23.3**	2.5
506	0.59	**12.0**	142	**11.0**	**29.9**	2.5
Desired range		15–25	100–300	15–25	100–300	2.5–>3.0

Bold values indicate below desired range

AB = Active Bacterial Biomass; TB = Total Bacterial Biomass; AF = Active Fungal Biomass; TF = Total Fungal Biomass. Activity is a measure of those organisms performing metabolic functions, growing, respiring, and reproducing, while total biomass is a measure of the whole diversity of organisms present.

smelled from most of the brews, regardless of preparation addition. Hydrogen sulfide was detected from the 503 and the horn manure 500 brew, while organic acid production (vinegar smell) was detected from 506, barrel compost tea.

The very high total bacterial biomass, the low relative-to-total value for active bacteria, and the lack of fungal biomass suggests that the tea brews went anaerobic for a significant period. Beneficial fungi cannot tolerate lack of oxygen for more than and hour or two. Some spores of the fungi probably started to regrow after the anaerobic conditions were alleviated, giving the low fungal activity and total biomass seen here.

Another consideration is that these preparations were added when temperatures were quite warm, in late August, in New York. Oxygen could easily have been limiting strictly because little oxygen is dissolved in water when temperatures are near 100° F, such as they were when these teas were tested. Therefore, it is critical to maintain teas in cooler conditions in the hot summer period, while keeping teas in warmer conditions in late fall and early spring may be necessary to allow microbial growth to occur in a reasonable period of time.

An important parameter here appears to be the method of making the compost tea. Reasonably similar teas were produced, even when teas were made in different containers, although using similar starting materials. Slight variation in

Table 2. Teas made from the preparations tested in Table 1, August 15, 2002

Sample	AB	TB	AF	TF	Hyphal diameter (μg)
	μg/g dry weight				
Control (no preparations)	57.3	7680	**0.30**	**0.46**	2.5
Horn	37.1	3072	**0.10**	**0.23**	2.5
502 (yarrow)	55.6	2253	**0.13**	**0.55**	2.5
no yarrow	46.1	7664	**0.06**	**0.96**	2.5
503 (chamomile)	39.4	1669	**0.00**	**0.25**	2.5
504 (nettle)	28.7	1754	**0.00**	**0.84**	2.5
506 (dandelion)	40.7	2304	**0.02**	**0.29**	2.5
505 (oak bark)	53.8	7424	**0.57**	**0.57**	2.5
Barrel	34.0	6400	**0.07**	**0.44**	2.5
Nettle leaves	29.5	5184	**0.04**	**0.21**	2.5
Desired range	2–20	100–300	2–25	2–10	2.5–>3.0

Bold values indicate below desired range

AB = Active Bacterial Biomass; TB = Total Bacterial Biomass; AF = Active Fungal Biomass; TF = Total Fungal Biomass. Activity is a measure of those organisms performing metabolic functions, growing, respiring, and reproducing, while total biomass is a measure of the whole diversity of organisms present. The values for desired organisms are based on actively aerated compost tea, which may not be what would be desired for stirred compost tea. Additional testing is needed to demonstrate what the effects would be on plant performance.

Table 3. Biodynamic preparations from Oregon, October 12, 2003

Sample	AB	TB	AF	TF	Hyphal diameter (µg)
	µg/g dry weight				
Horn	25.9	**66.4**	19.2	227	2.5
Barrel	65.6	241	35.0	364	3.0
Desired range	15–25	100–300	15–25	100–300	2.5–>3.0

Bold values indicate below desired range

AB = Active Bacterial Biomass; TB = Total Bacterial Biomass; AF = Active Fungal Biomass; TF = Total Fungal Biomass. Activity is a measure of those organisms performing metabolic functions, growing, respiring, and reproducing, while total biomass is a measure of the whole diversity of organisms present.

bacterial biomass occurred as a result of the addition of different preparations. Actively aerated compost tea machines typically contain much higher biomass of active and total fungi, but this could be the effect of the high temperatures during the brewing period that resulted in anaerobic conditions in the brews.

Aeration as described by Steiner should maintain aeration in the vessel. The tea should be stirred first one way and then the other. The chaotic step of reversing the direction of stirring is very important when stirring by hand, as the infusion of oxygen is critical for maintaining aerobic conditions during stirring events. Care must be taken to maintain cool water temperatures, to not to add too much additional food to the tea, and to use mature compost so excess oxygen demand is not generated.

The Oregon preparations contained a great deal more biology than the ones from the East Coast, but the time of year for sampling was very different. The appearance of the Oregon preparations was quite different from the East Coast preparations. The East Coast composts were more clearly plant material, while the West Coast composts seemed to be more earthy, with a higher clay content.

These results are the barest beginning of a database that needs to be developed to guide what biology can be evidenced in a good preparation. "Good" is likely to be relative as well, depending on whether one is trying to grow broccoli, strawberries, bananas or cucumbers. We just need to know what biologically active life is present, and what life is needed in order to promote the plants we want and select against the plants we don't want. For example, time and again we have shown that strawberries grow without disease (and thus no pesticide requirement) in a fungal-dominated soil. A tea that improves the diversity of fungi in the soil, and contains fungal foods, may result in a soil habitat that allows strawberries to grow abundantly, without the need for amendments or other improvements.

Clearly, a great deal more work is needed. We need to recognize, however, the need to understand the biology present in soil and the biology required by different plants. We need to know how to place that biology back into the soil if it has been lost, or modify it if the biology is not quite balanced correctly. Steiner was most likely trying to teach people how to make these adjustments and changes with the different preparations. We just need to "fine-tune" our biological understanding of the preparations and soils to which we add those preparations.

Flow forms

Flow form testing was performed in Lismore, New South Wales, Australia. Oxygen was measured every five hours through a twenty-four-hour brewing cycle. Worm compost was used as the source of compost, and the testing done in late fall; warm during the day (up to 80° F), and cool at night (down to near 45 degrees during the night). Water was from Lismore municipal supply and degassed by starting the water flow about a half-hour before adding the compost. Chlorine rapidly dispersed as no smell could be detected within a half hour of aeration. Approximately 250 ml of molasses and 500 g of kelp were added to 50 gallons (200 L) of water.

The flow form arrangement had three different forms, with a child's wading pool at the bottom to hold the water. The compost was in a basket at the bottom of the forms, so the water passed through the compost after each trip through the flow forms. Water was pumped out of the wading pool back to the top of the three flow forms.

Aeration clearly occurred routinely through the flow form (Figure 1). Aerobic microbial activity increased when aeration was maintained, but decreased when oxygen was lost.

The "waterfall" from one flow form to the next increased oxygen content by 0.5 mg oxygen per L. Oxygen rapidly became limiting in the wading pool. Only when the compost was removed at eight hours did oxygen increase to above problematic levels. Clearly, the biological growth on the surfaces of the compost was so great that oxygen was rapidly depleted in the compost. Removal of the compost removed the bacteria and fungi that were rapidly growing and depleting oxygen.

Figure 1. Flow form oxygen levels

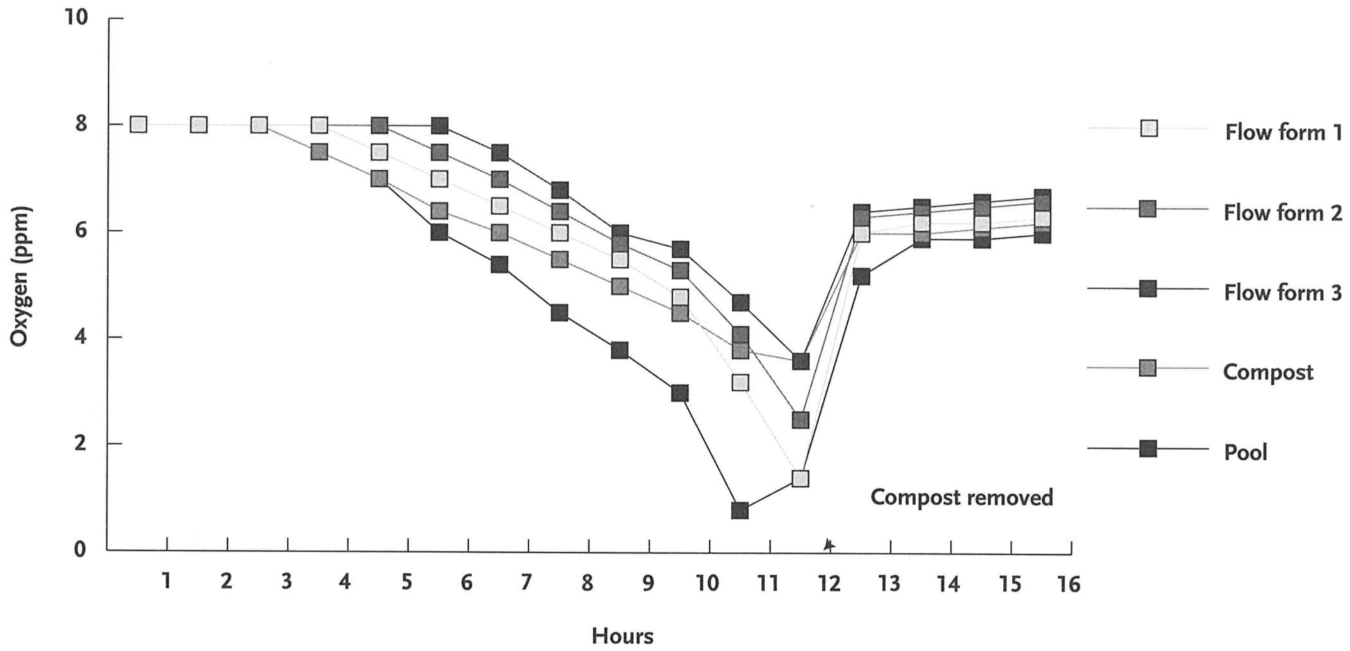
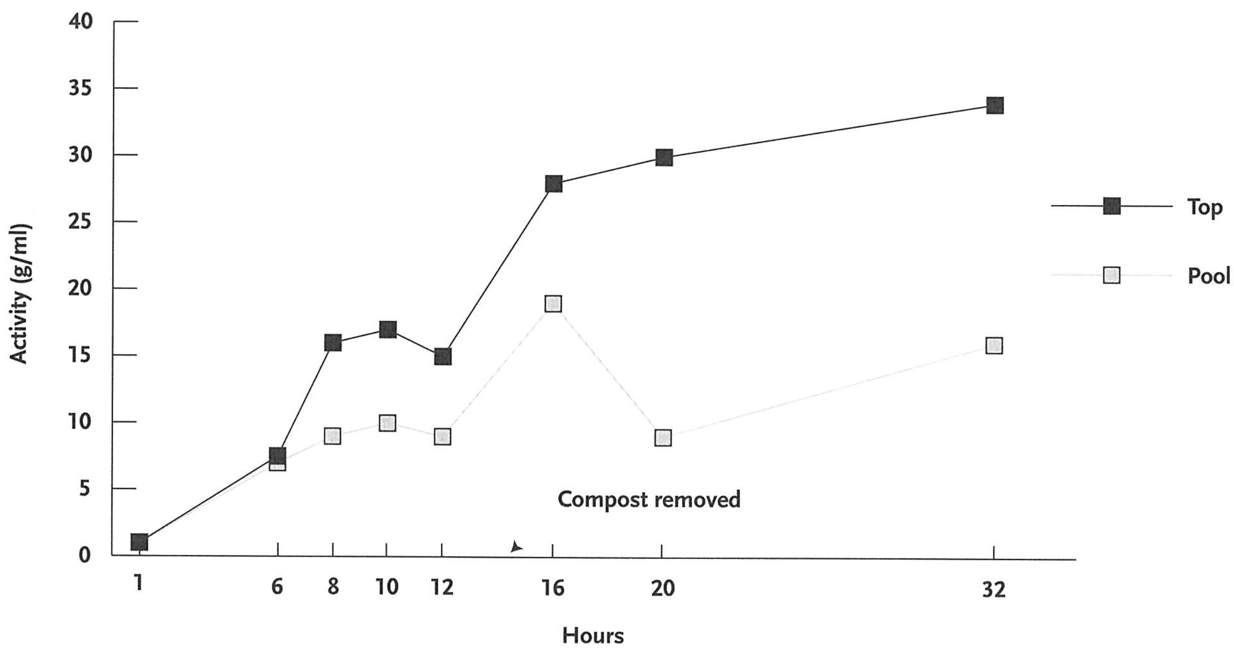


Figure 2 Flow form microbial activity levels



Does this happen with all flow forms? Are there differences in different designs?

The pool at the bottom of the flow forms needed to be kept better aerated, or the compost basket needed to be removed at six to eight hours, to prevent the pool of tea from becoming anaerobic. The smell coming from the system made it clear that nutrients were being lost by anaerobic gas production. If the biological oxygen demand had been removed by taking the compost away, then the flow forms would most likely have stayed above anaerobic levels, and loss of nutrients would have been prevented.

Conclusions

Given that the work on the preparations was not fully replicated, and that sampling may not have been at optimal times of the year (or under optimum storage conditions) for full potency, these findings need to be properly supported by further work. Different growers make their preparations somewhat differently. What difference does that make?

What difference does it make that preparations are made in Florida, Virginia, New Jersey, California, or Washington? Indigenous organisms survive and grow in the conditions unique to each climate. There are even papers that suggest that an east-facing slope will have different species of microbes as compared to a south-facing slope. Likewise with a north or west slope, because the climate is different with hot sun on western or southern-facing slopes versus cooler morning sun on northern or eastern-facing slopes. Frost is less prevalent on upper slopes than on lower pockets where cold air pools. Species differences can be demonstrated in the soil in these different areas. How important are those differences? Are regional preparation preparers needed? How precise do the methods of preparation production have to be? There are things yet to learn, but it is the biology in the preparations that will help teach us how important different climate conditions may be.

Steiner was concerned with the influence of processes beyond the physical realm, and so it is quite interesting to consider microbiological activity in preparations produced by different individuals. Using methods that have been developed since the time that Steiner lived, can we begin to quantify some of the things he knew were important, but for which there were then no methods to measure? What is the effect of different communities of bacteria, fungi, protozoa, nematodes, microarthropods? Did Steiner suggest different food resources in the different preparations because he recognized the different microbial communities that would result given different plant materials treated in different ways?

Managing biology appropriately will improve soil health more rapidly than the addition of minerals. Minerals alone, without the biology to process them and convert them into biologically active forms, do not improve soil fertility. One needs to know, therefore, what impact human management strategies have on soil biology, on cycling processes carried out by different organisms, and on biological interactions. Before we manage something, we have to be able to measure the effects of our management. We have recently developed the tools to measure the activity of soil life. We need to use those tools to understand boot-strapping processes in the soil.

References

Coleman, D.C. and E.R. Ingham. 1988. Carbon, nitrogen, phosphorus and sulfur cycling in terrestrial ecosystems. *Biogeochemistry* 5: 3–6.

Coleman, D.C., E.R. Ingham and J.C. Moore. 1990. An across ecosystem analysis of seasonal effects and faunal reduction on decomposition in a semiarid prairie, meadow, and lodgepole pine forest. *Pedobiologia* 34: 207–219.

Ingham, E.R., J.A. Trofymow, R.N. Ames, H.W. Hunt, C.R. Morley, J.C. Moore and D.C. Coleman. 1986. Trophic interactions and nitrogen cycling in a semiarid grassland soil. Part 1. Seasonal dynamics of the natural populations, their interactions and effects on nitrogen cycling. *J. Applied Ecology* 23: 597–614.

Ingham, R.E., J.A. Trofymow, E.R. Ingham and D.C. Coleman. 1985. Interactions of bacteria, fungi and their nematode grazers: Effects on nutrient cycling and plant growth. *Ecological Monographs* 55: 119–140.

Dr. Elaine Ingham is the president of Soil Foodweb, Inc. in Corvalis, Oregon. She can be contacted at Soil Foodweb, Inc., 1128 NE 2nd St., Suite 120, Corvalis, OR 97330; phone: (541)752-5066, fax: (541)752-5142; <info@soilfoodweb.com>; <www.soilfoodweb.com>.