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Bionomics for Woody and Herbaceous Perennial Plant Production©

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INTRODUCTION

Until recently chemistry was seen as the best way to understand and work with crop production, turning it into an industrial process: seeds and chemicals are the inputs and the crop is the end product. But what happens in the middle is biology — and bionomics is about looking at soil chemistry from a biological standpoint.

Biology is mostly about organic molecules rather than inorganic chemical salts or ions. Nitrogen, phosphorus, potassium, and the trace elements are important for the crop's nutrition. From these elements plants can synthesize all they need. It is the soil's organic compounds however that determine the availability of these nutrients to a crop.

Soil bionomics is about the soil economy and the maintenance of soil organisms, which in turn maintain the nutritional quality of the soil. Bacteria and fungi prepare the nutrients in a form suitable for everything else living in and from the soil. Economics is based on numbers and counting to measure financial health and you can also keep an account of the health of your soil by measuring the amount of fungal or bacterial biomass in the soil and counting the number of different species present. Dr. Elaine Ingham from Soil Foodweb Inc., Oregon, U.S.A. has researched the soil economy and how to manage it in agricultural practice around the world. The soil foodweb analysis she designed, based on the most accurate microbial biomass assessments available, shows us a collection of numbers crucial for soil foodweb management. Her desired ranges make soil life evaluation easy.

Most nutrients needed by living cells are universal; bacteria need them and plants need them. Hunting the soil for what they need, soil microbes find food for plants as well. Some bacteria can take in nitrogen from the air. Some fungi can make phosphate soluble where plants cannot. Protozoa and nematodes predate bacteria and fungi — like can openers they unlock the rich nutrients stored in bacterial cells. These predators excrete surpluses like all animals do, which make excellent plant nutrients, easily absorbed by the roots. The amounts of protozoa and nematodes are directly indicative of the amount of plant nutrients that are made available for the crop.

As an adviser I have helped many growers manage the foodweb in their soils. Some of the results they report include:

- Greater yields and improved uniformity.
- Grading time shortened from 12 to 7 h a day in cut flowers.
- Grafting take increased by 20%.
- Crops less susceptible to stress.
- Pot plants less susceptible to over- or under-watering.
- Improved soil structure.

CONSTITUENTS OF A HEALTHY SOIL FOODWEB

Bacteria and fungi are the primary organisms in the soil food chain as they degrade all material that falls on or in the soil. The number of different bacterium species in the soil is expressed in millions and the number of fungal species in thousands. The more different species that are living in a soil, the more tasks can be performed by the different specialists and the better the soil ecosystem is protected against disruption — either by an incoming pest or pathogen or an environmental change such as drought or waterlogging. Hardly any erosion occurs where a good soil foodweb is established. Root exudates from plants provide the microorganisms with food they can't make themselves, so there is mutual dependence in a healthy foodweb.

The oldest fossils from plants living on land contain mycorrhizal fungi, showing that as soon as plants evolved to live on dry land, they began to use the microorganisms that already lived there. And by the same token, microbes in the soil immediately started to make use of all the opportunities plant life brought to their habitat. This mutual dependence evolved over the last 450 million years into a sophisticated system that can survive almost everywhere to produce biomass in a highly efficient manner using water, air, and sunlight.

Processes That Damage the Foodweb.

When the ionic concentration outside a microorganism is higher than its internal ionic concentration, the microorganism dries out and dies. Chemical fertilizers add ions into the soil and kill microorganisms when applied in dosages higher than 200 $kg \cdot ha^{-1}$. Chemical pesticides and herbicides kill many nontarget beneficial organisms. Fungi consist of threads that are rather brittle and break when the soil they live in is cultivated.

When Dutch researchers started to monitor microbial life in the soil they did not include an assay for fungi because they did not find any in Dutch agricultural soils. It took some time before the absence of fungi was recognized as a result of agricultural practice and probably the cause of many disease problems. When a healthy soil foodweb is established, there is less need to work the soil structure mechanically. Soil life can break hard pans, keep air in the soil, and regulate moisture. A spading machine works the soil more gently than normal tilling and therefore is kinder to soil life.

THE ROLE OF SOIL ORGANISMS IN CROP NUTRITION

Chemistry turned agriculture into an industrial process, but this in turn has reduced the amount of life in agricultural soils. More chemistry has been needed to replace functions that were once the beneficial result of soil biological activity. It is possible to manage the soil to repair what has been lost but without turning back time and losing the benefits of a scientific approach to agricultural and horticultural production.

Soil microbes can replace much of the chemical fertilizer now used. This is achieved by feeding the microbes really well in order to make them very productive. The microbes will then make available a wide range of nutrients and stimulants around the plant roots — both mineral nutrients and more complex bioactive molecules. Such bioactive substances stimulate the roots and many can be used by the plants as nutrients.

The best crop performance occurs with a good foodweb in the soil rather than when they are grown with large amounts of mineral nutrient. Plants can respond to nutrient deficiency by releasing exudates from their roots into the soil to stimulate the growth of certain microbes that release the required nutrients.

There is still a place for additional chemical fertilizers. But small doses of chemical fertilizers in a rich soil foodweb will be utilized very efficiently. Feeding the soil foodweb and letting that feed the crop is more cost effective than supplying chemical fertilizers to try to feed the plants. In addition this approach will reduce leaching of fertilizer nutrients, which not only reduces fertilizer cost, as less has to be applied, but reduces the costs associated with prevention or repair of environmental damage caused by leaching.

Plants need so much more than NPK and trace elements. They respond very positively to vitamins and amino acids, but such nutrients are hardly considered in industrial agriculture today. When nitrogen is available as amino acids, the plants can use more energy for growth and development instead of to make their own amino acids.

Fertilizer salts do not contain all mineral nutrients plants need nor the agents that make trace elements available to plants. Plant health and development is stimulated when nutrients are contained in organic molecules. Humus and microbes make taking in nutrients so much easier for plants. Although a plant can live on mineral nutrients alone, this is not the optimum situation. A nutrition source based on organic molecules demands less energy of the plant.

THE ROLE OF SOIL ORGANISMS IN CROP HEALTH

When crop plants are well fed and grow in soil rich with microbial life, they have optimum natural resistance against disease. For example, bacteria taken up from the soil into the plant's vascular system help to induce resistance. Also, a highly diverse population of bacteria and fungi in the soil makes it more difficult for individual plant pathogenic species to establish large populations above infection thresholds. They are eaten, barriers are formed against their entering plant tissue, and their nutrients and environmental niches are taken up by other species.

Chemical fungicides, apart from killing pathogens, also attack the organisms that help the crop resist diseases. By optimizing natural defence mechanisms the use of chemical pesticides can be reduced.

There is still a place for the use of chemical fungicides and pesticides but if they are used then the soil foodweb should be re-established afterwards. This can be done with applications of compost or compost tea. Good composts, and the teas brewed from them, contain replacement organisms and nutrients for them.

Compost applied to the soil contains biochemical molecules, which are a source of nutrition for bacteria and fungi. The nutrients provided to the microorganisms, will end up in the crop. As they grow the microorganisms make something else that's very important for a healthy soil: humus.

This is the fraction of the soil that consists mainly of humic and fulvic acids, and it plays a central role in nutrient exchange between soil, microbes, and plants.

Its electro-chemical properties enable nutrients to be dissolved and taken in by plants. At the same time it is beneficial to microbes and the soil structure.

HOW TO MANAGE SOIL BIOLOGY

The first step is to know what you are starting with. Find a laboratory able to undertake a soil foodweb analysis and send a sample. Developed in the U.S.A. the results apply universally because microbial degraders and their predators operate in basically the same way all over the world.

The analysis looks at:

- Total and active bacterial biomass (direct counting through microscope).
- Total and active fungal biomass (direct counting using microscopy).
- Hyphal diameters (mean hyphal diameter as met during total fungal biomass assessment).
- Protozoa numbers and community structure (different dilutions of the sample are incubated on soil agar and checked for presence of flagellates, amoebae and/or ciliates and from these results their numbers are calculated).
- Nematode numbers and community structure (nematodes are extracted from the sample, counted, and identified with microscopy).
- Mycorrhizal colonization of roots.

Each parameter has an optimum range of numbers or measurements so the assays can be used to diagnose and monitor the soil foodweb and predict its functions. Once an analysis has been performed the laboratory should be able to suggest what can be done to improve the situation when a parameter is outside the desired range.

Good compost can be used either to adjust the soil ecology to address problems identified by the analysis or to maintain the soil. Compost can be made to contain more bacteria or more fungi, depending on requirements identified by the analysis report.

How to Identify a Good Compost. First look for a good crumb structure. The microorganisms that establish this crumb structure will also give your soil the required structure. If the compost does not have a good structure it means it does not contain the right balance of organisms.

Looking at compost, it should not be possible to identify the original material it is made off. That should be really well digested by the microbes.

Moisture content is important. Too much water often makes compost anaerobic. Too little makes it hard for the microbes to survive. Aim for a moisture content of 55% to 65% — this can be estimated by hard squeezing, which will release just a drop of water when the moisture is right.

Good compost will smell of forest soil, sweet and pleasurable. An unpleasant smell means the compost has the wrong balance of microorganisms. The unpleasant smell indicates toxics formed by anaerobic processes.

When temperatures have been high during composting, the materials become “burned.” Black compost means charcoal has been formed when the temperature was too high.

The carbon found here as charcoal would have been incorporated into organic molecules if it was in good compost.

When you buy compost you should ask for laboratory test results. Compost can be analysed at by the same assays as the soil foodweb analysis, except for mycorrhizal colonization, and the results should fall within optimum ranges for compost.

Some laboratories grow microbes and sell them in packages, but in this author's opinion this is not as beneficial to soil as good compost. The number of different microorganisms is what matters: enough species to undertake all the different tasks and to ensure a functioning ecosystem survives any changes in the soil environment. Not all commercially available microbes are as well equipped for soil survival in a competitive situation as compost microbes are.

Making your own compost has many advantages, the main one being that you are in control of the raw material, the process and therefore the quality of the end product.

Collecting raw materials to make compost will get easier the more you do it. Most materials are delivered to you free because others consider it waste. The composting process takes 6 to 8 weeks.

If using solid compost is a problem, for example in container growing, it is possible to apply your microbes and the nutrients they need in liquid form through a sprayer, as compost tea.

Brewing compost tea takes about 20 h. The resulting liquid is a living material and should be used as soon as it is ready. It is made in a container with water and compost. It should be well oxygenated by blowing air through the water as the tea is brewing. Like compost, compost tea is rich in microorganisms and nutrients. The organisms in the tea will cover your crop with a layer of micro-life to protect it against diseases.