Your Living Environment

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MICROBES, SOIL & MAN

"For the microbiologist, the soil environment is unique in several ways: it contains a vast population of bacteria, actinomycetes, fungi, algae, and protozoa; it is one of the most dynamic sites of biochemical reactions concerned in the destruction of organic matter, in the weathering of rocks, and in the nutrition of agricultural crops" (*Introduction to Soil Microbiology,* M. Alexander, p. 3.).

Is it not a sad thing that this uniqueness of the soil environment continues to escape all but a few microbiologists? Especially as most of them miss the point as to who created it anyway!

Surely *WE* above all others, should increase in our knowledge and understanding of our magnificently designed environment. We know it is *magnificent* in concept and we know who *created* it, but our specific knowledge tends to be very limited.

All life nourished directly from the soil, must depend upon a highly complex system for nutrients. But man either takes this system for granted, or attempts to dispense with it! In the January issue, we saw something of these *"attempts"*. And last month we looked at the operation and advantages of the legume/rhizobium partnership.

It was shown how perfectly and miraculously these two work to each other's mutual advantage, in the fixation of atmospheric nitrogen for plant protein. This time we will have a much wider look at the whole scheme of life in the soil.

With what other living forms are rhizobium bacteria associated? Are they classified as *animal* or *plant*? What physical characteristics of soil affect the life within it? And does that life affect the soil?

These are just some of the questions we will answer in this issue. You will see that there is much more to biological plant nutrition than supplying nitrogen via root nodules.

THE SOIL ENVIRONMENT

Minerals, water, air, dead organic matter and *soil life* are the five components that go to make up the total soil environment. Each of these components has its own particular physical and chemical properties and may be present in almost innumerable combinations. These five parts will each be in a constant state of change, thereby multiplying the possibilities for environmental variation, beyond human comprehension!

Those physical and chemical properties are important to microbial action, but conversely microbial actions exercise great changes in the soil's physical and chemical properties. In other words, these effects work in both directions at once! It is only as we begin to appreciate these facts that we can understand the dynamism that exists in a fertile soil.

THE INORGANIC CONSTITUENTS

Those parts of the total soil mass which have not lived, are termed the *INORGANIC* portion. They are *THREE* in number — *minerals, water* and *air.*

The mineral portion may vary infinitely in chemical composition and at the same time the physical size of those tiny rock particles may vary. Furthermore the actual ratio of these different sizes may also vary extensively. Each of these factors has an important bearing on the composition of nutrients released and their *rate* of availability.

Particle size relates to the external surface area of the *"rocks"* forming the mineral portion of the soil. (It does consist of *"ROCKS"* — a *pinch* of the finest textured soil looks like a rock quarry under low power with a microscope!)

The total surface area of the mineral particles in a gram of *silt* has been estimated at *450 sq. cm.* But a sample of *medium sand* comes out at only *45 sq. cm.* — just one tenth the surface area! *Clay* on the other hand is assigned a figure of *11,300 sq. cm. per gram!* When it is realized that biological and chemical breakdown can proceed only on the total surface area it is easier to explain why sandy soils are potentially the least productive.

MOISTURE, AIR AND TEMPERATURE!

Together, *moisture* and *air* can approach half of the total soil volume! Each plays a significant role in productivity, not only by their direct effect on the soil but also by their effects on each other.

For example, under limited *moisture* conditions, little or no biological action takes place. A rising level of *moisture* not only increases biological action, it also forces *air* from the soil into the atmosphere and at the same time reduces soil temperature.

If however, soil *moisture* continues to rise, *air* will decrease to the point where lack of oxygen severely affects the rate and type of microbial decomposition. Soil *temperature* will usually fall as rising *moisture* levels continue to exclude most of the air. Then instead of a rapid aerobic decomposition of organic material, a slower anaerobic putrefaction sets in, resulting in a slower turn-around of nutrients and the giving off of offensive gases.

There is no single optimum within the soil for these three: *"Moisture" "Air"* and *"Temperature"*, because of complicating factors, such as multiplicity of microbial species and the variable nature of organic residues. 30-40°C does appear to be the soil temperature range within which maximum rates of organic decomposition are obtained.

It is commonly accepted, for example, that:

> "A change in temperature will alter the species composition of the active flora [*within the soil*] and at the same time have a direct influence upon each organism within the population. Microbial metabolism and hence carbon mineralization is slower at low than elevated temperatures and warming is associated with greater CO_2 release. Appreciable organic matter breakdown occurs at 5°C and probably at cooler values, but plant tissue rotting is increased with progressively warmer conditions ... Above about 40°C the rapidity of decomposition declines" (*Soil Microbiology*, M. Alexander, pp. 148, 149).

THE HUMUS FRACTION

The organic content of any soil may be adequately described as a combination of *the living* and *the dead.* That which lives, or has lived, may easily range from 6% to 12% of the total soil mass. The lower figure seems to be eminently suitable for most agricultural purposes. 9% dead organic matter would therefore be a fair average to maintain and this may consist of any admixture of dead plants, animals and insects. It may include anything from a dead cow, above ground, to dead bacteria down below and a variety of worms and insects at or near the surface.

Complexity of the soil environment is enhanced by the fact that each of these organic residues will vary in mineral composition, pH, date of death and rate of decomposition. The latter of course, being affected by all of the variables mentioned earlier in this article!

With which of us is it not a problem, to come to a realization of just how little we know about the wonderfully complex creation around us? God may have had this in mind when He said to Job: *"Have you perceived the breadth of the earth? Declare if you know it all"* (Job 38:8).

THE LIVING PORTION

We can divide the living portion of the soil into *TWO* parts — *MACRO* and *MICRO-organisms;* those which we can see with the naked eye and those which we cannot. Taken together, they represent about 1% of the total mass in a fertile soil *(see last issue for diagram).*

In spite of this tiny percentage, the total weight of *macro*-organisms can easily run as high as 4,000 lbs. per acre, in a well managed pasture.

These creatures play an important role in organic decomposition by chewing plant and animal residues (and each other) into fine particles. As with earthworms, the end product emerges as a mixture of their digestive juices and soil.

We now come to the *MICRO-organic* portion of life in the soil. Though it represents considerably less than 1% of the soil mass, it is upon this tiny fraction that the continued re-cycling of nutrients mainly depends! It appears that God has balanced the entire physical terrestrial world on this pin-point of naturally invisible life!! It is as though this living microscopic fraction is at the apex of a giant inverted pyramid, which spreads upward and outward from its base, to encompass man's entire ecological system.

Micro-organic soil life is so vital to man and yet he is often unaware of what is going on 24 hours a day below ground. Take this example:

"Leaf and branch fall in a forest contributes five tons per acre in a cool temperate forest and up to thirty tons per acre a year in a tropical rain-forest. Yet by the following year the surface litter left differs little in amount from that present before the annual fall". (*Micro-organisms in the Soil*, Alan Burges, p.159).

Examples like this show us what a real blessing God's laws are — how they direct man into activities that preserve and promote this essential microbial action in all forms of agricultural production! We learn via obedience, that God protects us, through His law, against our own ignorance of His complex creation.

SOIL MICROBES

MAN has divided soil microbes into *FIVE* main types: *Bacteria, Actinomycetes, Fungi, Algae* and *Protozoa!* His efforts beyond this point range from most impressive to utter confusion. This is the self-confessed opinion of microbiologists themselves. The literature, though very erudite on some points is liberally sprinkled with such phrases as:

"Bergey's classification contains six species", "Dorosinskii distinguished eleven groups of the genus", "Several investigators have tended to enlarge the groups", "There are some other groupings", "By this criterion the genus ... divides into two species", "... a classification ... now being developed", etc., etc. *(Biological Fixation of Atmospheric Nitrogen* Mishustin & Shil'nikova, pp.19, 20). These examples, taken from just *ONE AND A HALF PAGES,* are typical of the literature!

BACTERIA

"The Bacteria form a very heterogeneous group of organisms which are difficult to classify. [You can believe it, after reading the above paragraph.] Their small size coupled with lack of morphological characteristics, usually makes it impossible to identify the organisms in direct observation of the soil" (*Micro-organisms in the Soil,* Burges p.30).

Bacteria, along with *Actinomycetes, Fungi* and *Algae,* are classified as part of the *"plant kingdom,"* but as *Alexander* states:

"... keep in mind the fact that the microscopic inhabitants do not exist in an isolated state, but rather as just a part of a highly complex environment regulated by natural forces and, to a lesser extent, by man's activities. An appreciation of soil microbiology can only be gained by viewing the soil system as a dynamic whole, as a natural environment in which micro-organisms play an essential and often poorly understood role" (*Soil Microbiology,* M. Alexander, p. 17).

ACTINOMYCETES

This organism is said to be intermediate in appearance and activity between *Bacteria* and *Fungi.* One reason for its coming into prominence within recent years has been man's interest in the chemotherapeutic use of the antibiotics produced by *Actinomycetes.*

In abundance they are second only to *Bacteria* and flourish in composts and various soil levels. Alkaline pH appears to be especially favourable to the production of large populations of *Actinomycetes.*

Populations of this micro-organism are said to be greater in dry areas and in grassland, than in cultivated land. Peats, water-logged areas and a pH less than 5, are all unfavourable. Russian sources indicate that their scientists have found many species of *Actinomycetes* that evince the capacity to fix some nitrogen!

FUNGI

Similar nitrogen-fixing functions have also been attributed to numerous species of fungi. Characteristically *Fungi* possess a filamentous micelium, or white thread-like network of individual strands. They contain no chlorophyll, and must therefore obtain carbon for cell synthesis from other preformed organic molecules.

One of the most spectacular functions yet noted of this micro-organism is its ability to trap eelworms in a noose of filament. The thread then begins to swell rapidly and the outgrowths from the *"noose"* penetrate the eelworm, breaking down the internal contents of the animal. This is just one of many forms of predacious activity of *Fungi.*

Some *Fungi* form a structure called *"mycorrhiza",* by a symbiotic union with roots of plants. *Burges* states that the general consensus of opinion is that mycorrhizal infection assists in the absorption of mineral salts, especially in soils low in available minerals.

Sir Albert Howard (nighted for his work in soil research) described this mycorrhizal association as *"the living fungous bridge which connects soil and sap ..." (An Agricultural Testament,* Howard, p. 37).

ALGAE

This form of microscopic life is mostly photosynthetic and therefore needs sunlight. But *Burges* states that there is no universally-accepted classification for them. They appear to be yet another form of soil life critically affected by pH. And experimental results show that most types fail to multiply significantly in pH 5 or less. In a sample of English soils, *three* important types have been shown to be most abundant in the *7.6 to 8.2 pH range.*

Algae are few in number compared to *Bacteria* and *Fungi,* but there is one form that is especially important to world agriculture. It is called *"Blue-green" Algae* and is responsible for fixing most of the nitrogen utilized in rice production world-wide!

Mishustin quotes sources who claim that *36 lbs. of fixed nitrogen per acre* is not uncommon and estimates range as high as *50 lbs. per acre per year!* This amount would be ample to account for *all* the nitrogen used in the production of rice in most areas!

PROTOZOA

Man has classified this form of life as part of the *"ANIMAL KINGDOM"* and the terrestrial forms are apparently all microscopic. *Amoeba* are the most important "Order" of the "Phylum" *Protozoa* and they live mostly on bacteria.

> "It has been estimated that one species . . . requires approximately 40,000 bacteria per cell division. Consequently, bacteria must reproduce at a rapid rate merely to keep pace with their predators" (*Soil Microbiology,* Alexander, p.105).

Not *all Bacteria* are prey to Protozoa, but the reason is unknown. (It could prove to be interesting and quite important!) Populations of *100,000 to 300,000 cells per gram of soil* are not uncommon. The extra size of these cells offsets their numerical insignificance and so they often equal the total mass of soil bacteria.

Alexander quotes six readings that show on average, that the number of *Protozoa* in the soil increased by 500%, following the addition of *farmyard manure!*And this is not the full story of these results. In unfavourable soil conditions *Protozoa* change into an inactive cystic form, which enables them to survive for years. And in the *unmanured* soil, only 53% of the *lesser* number of *Protozoa* were *active.* On the *manured* section however, numbers not only increased by *500%,* but those in the *active* group rose to *82%* of the population!

CARBON/NITROGEN RATIO

It is not only the addition of organic residues that increases microbial population and the turn-around of nutrients, but the *composition* of those residues. A ratio high in carbon and low in nitrogen will cause microbes to draw on soil nitrogen. The result of this will be temporary nitrogen starvation of plants.

Soil microbes use carbon as a source of energy and *nitrogen* for tissue building. Ideally these two elements need to be in a ratio of around *10 to 1.* Herein lies one of the great advantages of humus over other organic residues. It averages 50%C. and 5% N. or a ratio of *10 to 1.*

Organic decomposition dissipates carbon at a much faster rate than nitrogen and this results in a narrowing of the ratio as decomposition proceeds. With humus applications, the C/N ratio will be *spot-on,* but the following table will show the need for care in applying other residues:

Material	*C/N Ratio (approx.)*
Saw-dust	400 - 1
Cornstalks	60 -1
Straw	80 - 1
Sugarcane Trash	50 - 1
Rotted Manure	20 - 1
Lucerne	12 - 1
Humus	10 - 1
Bacteria & Fungi	7 - 1

(*Organic Gardening & Farming",* J. I. Rodale, March, 1967, pp.128-131).

MICROBES IN MAN'S FUTURE!

Perhaps in the future when we read such scriptures as: *"I am come down to deliver them unto . . . a good land and a large, unto a land flowing with milk and honey"* (Ex. 3:8), we will better appreciate just what is involved in making a land flow *"with milk and honey".*

Now we may stop and reflect a little on some of the myriad of activities that God has designed into our soil system in order to make it *"flow with milk and honey".*

We may reflect more effectively and with awe, on what is involved when God states that: *"the desert shall rejoice, and blossom as the rose. It shall blossom abundantly, and rejoice even with joy and singing"* (Isa. 35: 1,2). Along with rain in due season, the entire complex structure of *micro-* and *macro-organic* life must first spring back into action!

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