

THE LIVING SOIL – ITS CONTROL FOR BETTER PLANT GROWTH

By

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The various organisms that inhabit the soil, both macro (big) and micro (small), form one of the important components of all soils. Though the presence of microbial population in soil was suspected for a long time it was not known whether and in what way the micro organisms were responsible for the various changes and transformations that took place in the soil. It is only during the last 100 years, since the epoch-making discoveries of Pasteur, that the part played by microorganisms in these changes and their role in plant nutrition and maintenance of soil fertility has been explained. The pioneering investigations of a number of early bacteriologists showed for the first time that the soil was not an inert static material but a medium pulsating with life. The soil is now believed to be a dynamic or rather a living system in which not only physical and chemical but biological changes as well take place continuously.

The microflora of a soil is an intimate part of soil organic matter; in fact, much of the colloidal portion of humus consist of living and dead microbial cells or their disintegrating residues. The remaining portion, consisting of residual decomposition products of plant and animal tissues, owes its properties primarily to the activities of the microflora. The quantity and characteristics of organic matter in any given soil are therefore, so dependent on the nature of the microflora and their biochemical transformations that no discussion of the role of soil organic matter in plant growth would be complete without a consideration of its microbial population. The lesser part played by the micro-and macro-fauna in the formation of soil organic matter has also to be considered.

Four groups of organisms constitute the microflora population of the soil. These are bacteria, actinomycetes, fungi and algae. Each of these groups is made up of many genera and hundreds of species. New species are still being described from time to time.

Bacteria are one celled organisms and constitute the most numerous group of micro organisms in soil and they are the smallest living organisms, apart from the viruses that live in the cells of other organisms. Bacteria may be of various shapes, including round, rod shaped, spiral and filamentous. In size they commonly range between 0.5 - 5.0 microns in diameter but most of them are within the 1 - 2 micron range. The number of bacteria per gram of soil varies greatly and the population curve can go up or down very strikingly within a period of a few days or even hours. Most uncropped soils of average fertility that have received no recent additions of organic matter are likely to contain 10 - 100 million bacteria per g as determined by plate counts. Where abundant supplies of organic matter have been added recently, it is not unusual to find as many as one or more billions of active bacteria per gm. Estimates of the weight of bacteria in soil vary from about 300 to 6400 lb per acre in the first 6 inches, with the higher values applying to soils cropped to legumes.

Bacteria can be of two general types: heterotrophic (that depend on organic compounds synthesized by chlorophyll containing plants for their nutrition) and autotrophic (that are either able to oxidize inorganic compounds or which contain chlorophyll and can utilize sunlight as their energy source). This type is not an important factor in soil while the former type is dominant.

Bacteria bring about a number of changes and transformations in the soil. Some of the changes are very rapid and extensive. These are decompositions of cellulose and other carbohydrates, decomposition of proteins with the liberation of ammonia (ammonification) formation of nitrites and nitrates (nitrification), transformation of combined nitrogen compounds into free elemental nitrogen (de-nitrification), fixation and oxidation and reduction of sulphur and iron compounds.

Nitrogen-fixing bacteria are present in most cultivated soils but not in large numbers. These include the non-symbiotic bacteria or free living bacteria, and the symbiotic forms that live in nodules on the roots of leguminous plants.

Denitrifying bacteria deserve special mention because of their practical importance. These commonly grow aerobically (in the presence of oxygen) on various carbon sources but can also grow anaerobically (without O_2) if supplied with nitrates that serve as a hydrogen acceptor in place of oxygen. They reduce nitrate to nitrite and then to free nitrogen gas. Under field conditions this process is slow, as the soil is usually not completely free of oxygen even under conditions of excess water, unless permanently submerged. An abundance of readily available carbon sources favours de-nitrification greatly, since the bacterial population is increased following their addition.

The actinomycetes constitute a group of organisms that morphologically and physiologically fall between the true bacteria and the fungi. These occur in soils in numbers ranging up to about 200 millions per g, which makes them second only to the true bacteria. In manure piles and similar environments their numbers may be 10 to 20 times this value. They have a unicellular mycelium with long branching hyphae. The aerial mycelium, is usually 0.5 - 1.2 in diameter and some of these hyphae bear sexual spores, called conidia.

The ability to produce antibiotics is common among the actinomycetes and much of the interest in these in recent years may be attributed to this fact. Many species and strains of actinomycetes have been found to synthesize a number of antibiotics of which streptomycin, terramycin, aureomycin etc. are some of the important anti-microbial agents. Actinomycetes play a very important role in humus formation largely because of their ability to attack a variety of comparatively resistant substances such as cellulose, polysaccharides, hemicellulose and Keratin.

Fungi usually constitute the third most numerous group of microflora in the cultivated soil, but the fungal mass is likely to be greater than the mass of either the bacteria or actinomycetes. Fungi, known to occur in soil, cover the range from chytrids to agarics, from saprophytes to plant parasites and from parasites of amoebae to parasites of man. Fungi exist in soil in the form of masses of branching filaments which may or may not be separated into cells. These filaments are commonly about 5 μ in diameter but the size varies with the species and the length is indefinite. In addition, masses of sexual and asexual spores are formed which may remain in soil in a dormant condition for months or years.

The chief activity of fungi is the decomposition of organic compounds, both nitrogenous and non-nitrogenous, that are added to the soil in the form of plant residues and manures. They also bring about the decomposition of proteins and convert them into amino-acids and ammonia. The ammonifying power of soil fungi is greater than that of many bacteria. There are some fungi that readily attack fats and fatty acids. Even some of the more resistant constituents like lignin, resin, tannins etc. succumbed to their activity. Thus fungi on the whole are far more active than bacteria in decomposing organic substances.

Another important activity of the fungi is humus formation. While decomposing the complex organic substances they give rise to a number of intermediate products which on condensation form humus. Many fungi produce pigments of various colours. It is believed that the brown and dark brown pigments produced by some fungi especially the cellulose - decomposing fungi, are responsible for imparting the black colour to humus.

Some of the soil fungi are parasitic and are responsible for causing a number of plant diseases. They enter the tissues of the host plant from which they absorb the nutrients

and thus bring about the degradation of their tissue cells. As a result of this the development of the host plant is considerably disturbed. In some cases they even cause the death of the host plant. Fortunately, only a very small proportion of the fungal flora is parasitic. The saprophytic fungi on the other hand are quite beneficial. While trying to obtain their food nutrients from the organic matter present in or added to the soil, they liberate a good proportion of the plant food elements in an available form for the use of higher plants. They thus help to increase soil fertility.

Certain fungi of the Phycomycetes and fungi imperfecti groups possess predatory habits. They attack certain Protozoa and nematodes present in the soil. On the other hand, certain bacteria have been found to parasitise some of the soil fungi.

Certain fungi have the ability to establish a relationship with many higher plants that seems to be mutually beneficial in most instances. These organisms are known as mycorrhizal fungi. There are two kinds of mycorrhizae, endotrophic and ectotrophic. The former penetrates into and continue to live in the plant root cells, whereas the latter form a mat around the roots with minimum cell penetration. In some cases the higher plants require these organism for normal growth. The mycelia of the ectotrophic mycorrhizae often largely replace the root hairs and seems to act as their substitute in nutrient uptake.

Algae are found in nearly all cultivated soils in numbers that vary from a few hundred to several millions per g. Many species are commonly 2-5 μ in diameter. Other species are filamentous. Soil algae comprise the blue-green Chlorophyceae, the blue-green Cyanophyceae, and the diatoms or Bacillariophyceae.

Some algae possess great water absorbing and water retaining capacities. Thus they increase the power of the soil to retain moisture for a long period. One of the most important roles of algae is the fixation of elemental nitrogen. Some of the blue-green algae fix relatively large amounts of atmospheric nitrogen. Laboratory experiments have shown that as much as 1.0 mg of nitrogen per g of soil is fixed in 2 to 3 months in this way. The predominance of blue-green algae in the tropics is therefore, of considerable importance in maintaining soil fertility in these regions. Some of the algae take part in the nitrogen economy of the soil indirectly, by supplying available carbohydrates, especially starch, which they build up photosynthetically, to Azotobacter as a source of energy necessary for the nitrogen fixing process. Mixtures of nitrogen fixing bacteria and certain algae have been shown to fix greater quantities of nitrogen than bacteria alone. Algae add organic matter to the soil, when they die and help to bind soil particles. Specially the blue-green algae have this capability, due to the presence of an outer coating of gelatinous mucous material.

A great diversity of animals, having few morphological features in common exist in the soil and the litter above it. Some of these are permanent soil inhabitants, whereas others are temporary. In size the individuals vary from the microscopic Protozoa and nematodes to mammals such as rabbits. There are about 10,000 species of nematodes alone, half of which are free-living. About 1800 species of earthworms are known and the arthropod species (principally insects) that spend a part of their lives in soils are even more numerous. The most important kinds of animals constituting the soil and litter fauna, are the Protozoa, nematodes, segmented worms and the great Phylum of arthropods. Recent work has shown that Protozoa are of minor importance in the large majority of soils. This applies to their contribution to organic matter breakdown and the overall effects on crop production. Nematodes are widely distributed as parasites of plants but most nematodes are not parasitic. As the weight of the nematodes is small, it is doubtful whether they play an important role in the transformation of soil organic matter.

Earthworms are found widely distributed in soils, frequently comprising more than half the biomass present. Earthworms swallow great quantities of earth, from which they digest much of the organic matter and discard the mineral matter and undigested organic residues as casts on the soil surface. Some species discard below ground most or all of the soil that they ingest. There is little or no evidence that they are responsible for any appreciable

injury to garden crops, except possibly to an occasional seedling. The quantity of soil ingested by earthworms in a year may be surprisingly large. It was Darwin in 1881 who first called attention to this fact. He observed that in some fields worms bring 0.2 inches (about 30 tons per acre) of soil to the surface per year over a 25 year period and in the process bury stones, cinders and other foreign bodies.

Later scientists observed that in a 4-year rotation of ; 2 years of grass, one of fallow and one of wheat, the weight of worms after the fallow and crop years was only a quarter of that found on permanent pasture, but after the grass the weight almost equalled that of permanent pasture. This emphasizes that they can often be of major importance in the consumption of organic matter, in its mixing with soil, in soil aggregation, and in fact in almost all phases of humus formation and interactions in soil.

The most important living organisms in soil are the higher plants. The cooperation of higher plants with living micro-organisms, occurs most intensively and strikingly in the root zone. The area immediately surrounding a root commonly referred to as the rhizosphere, is the seat of intense biological activity. The products produced may be either beneficial or directly toxic. The organism themselves may have little or no effect or they may be parasitic in or on the roots.

Certain American scientists, who pioneered studies in rhizosphere affects observed that bacteria from the rhizosphere of beans produced an antibiotic that was selectively inactive against bacteria. This suggests that these bacteria by means of the antibiotic play a role in the suppression of root infecting fungi in soil. Present information indicates that the concentration of the microbiologically - synthesized substances are low and hence are more likely to be stimulating to plant growth than to be toxic to plants.

The amount and type of organic matter in soils play a role in the extent to which a crop is affected by certain plant diseases. In some cases, organic matter may increase the incidence or severity of diseases but under proper management beneficial effects can usually be realised. This applies particularly to diseases produced by fungi but also to those caused by bacteria, actinomycetes and possibly nematodes.

In controlling diseases biological control is of utmost importance. Biological control of a plant disease has been defined by Garrett as any condition under which or practice whereby, survival or activity of a pathogen is reduced though the agency of any other living organism (except man himself) with the result that there is a reduction in incidence of the disease caused by the pathogen. Biological control can be brought about either by introduction or by augmentation in numbers of one or more species of controlling organisms, or by a change in environmental conditions designed to favour the multiplication and activity of such organisms, or by a combination of both procedures.

There is probably no other constituent or factor in cultivated soils that is more important than organic matter in favouring the development of organisms that suppressing the multiplication and activity of soil-borne pathogen. The form of organic matter that is most active in this respect is green manures, crop residues, animal residues and growing plants. Hence, crop rotation is a major factor in the biological control of plant disease organisms present in the soil. Addition of green manures and crop residue has controlled root rot of cotton, root and foot-rot diseases of beans, and take all disease of cereals. Addition of oat straw, and straw with a small amount of ammonium nitrate, increased the numbers of rhizosphere micro-organisms antagonistic to several root disease causing fungi. The addition of a small quantity of sulphur round the plant at the time of planting of *Hevea* budded stumps is a classic example in altering the micro organic organism in the soil in the vicinity of the plant thus bringing about an increase in fungi causing antagonistic activity towards the causal fungus of white root disease.

By making use of green crop residues and crop rotation much can be done towards the control of many, but not all, of the more troublesome diseases. It is now firmly established

that a number of diseases can be controlled by the ploughing in of fresh organic material of suitable composition into the soil. The successful control depends on the right choice of amendments and the degree of control varies from one soil to another.

The discussion of the microflora and microfauna of soils serves to emphasize their extreme importance in almost every phase of soil organic matter formation and transformation as well as directly or indirectly in crop production. Soil that appears to the naked eye to be inert is actually at all times a beehive of activity and the nature of the activity can markedly affect the plant that has its roots imbedded in the soil.