



# Biodiversity of the soil life in support of coconut production at optimum levels

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**Biodiversity in soils is composed of multitudes of organisms. The basic requirement for the soil life to flourish is regular availability of fresh organic residues. Integration of woody species, arable crops and livestock components in coconut holdings, regular recycling of organic wastes, soil and water conservation measures and need-based use of organic amendments provide congenial conditions for an active soil life.**

## Introduction

The biosphere or the part of the earth and its atmosphere where life is found is made up of small and big ecosystems powered by solar energy. Ecosystems have both biotic and abiotic components. The biotic component comprises closely interacting groups of flora and fauna covering autotrophic, heterotrophic and decomposing organisms. Biodiversity refers to the richness of life as manifested by the size and diversity of the biotic components and their interdependence in a habitat. It is because of the biodiversity that each ecosystem functions as the basic life support system of the planet earth. Biodiversity sustains the food and nutrition security of human beings and regulates ecosystem processes by resisting environmental perturbations under given soil and climatic conditions.

In the present day discussion on biodiversity greater emphasis is being given on the above ground biotic components. The size and diversity of living communities in soil and their contribution to sustainable agriculture often do not receive adequate mention. This

makes the discussion and understanding of global biodiversity fragmentary since it is known that the total biomass of soil life is more or less equal to the above ground biomass.

## 2. Biodiversity of the Soil Life

Soil is the natural habitat of a vast number of diverse organisms belonging to the plant and animal kingdom. They range in size from microscopic bodies to large representatives of flora and fauna. All these organisms exert direct and/or indirect influence on soil properties and plant growth. While the activities of most of the soil organisms are crucial in sustaining the desirable biochemical transformations in soil, some are damaging to agricultural crops.

Decomposition of plant and animal residues in soil, mineralization of plant nutrients present in organic combinations, solubilization of unavailable forms of nutrients, biological nitrogen fixation, sustainment of natural energy cycles etc. are mediated by diverse communities of soil life. In the absence of soil organisms all biological processes will come to a standstill making the life of higher

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plants and animals impossible on earth. The diversity and activities of soil organism communities are related to the availability of organic matter which in turn is influenced by the cultivation methods practised. Conventional farming characterized by monocropping, continued use of chemical inputs without organic replenishment, frequent tillage and improper soil and water management is not conducive to the multiplication of a vibrant soil life. On the other hand, multispecies cropping, crop rotations, mixed farming, less reliance on chemical inputs, organic recycling and water and soil conservation measures create congenial conditions for enhanced biological activity and biodiversity of soil organism communities. Coconut holdings are amenable to the introduction of diverse cropping/farming models that are capable of stimulating soil life, improving soil health and supporting sustainable production of coconut and companion crops in the system.

### 2.1. Soil Fauna

Soil fauna or soil animals comprise a large variety of organisms with differing sizes and adaptive strategies. Though their proportion in soil life is smaller than that of soil flora, their functional role in the early stages of organic decomposition and other soil properties is no less important. Based on their sizes and adaptive strategies they are classified as microfauna, mesofauna and macrofauna.

#### *Microfauna*

Organisms belonging to this group are very small with an average

size of less than 0.2 mm. They are found in soil pores and water films that cover soil particles and feed on microflora and other microfauna. Many are parasitic on higher plants and some subsist on plant residues. Nematodes and protozoa are the main representatives of this group.

Nematodes are present in almost all soil types and are among the most abundant soil fauna. Their numbers are the highest in cultivated soils showing a range from 10,000 to 10 million per square metre. Nematodes are composed of those that are predatory on bacteria, fungi and protozoa, parasitic on higher plants and those that feed on decaying organic matter. In undisturbed soils where fungal population is high fungivorous nematodes will proliferate whereas in soils under cultivation where bacterial population predominates bacterivorous nematodes will be present in large numbers. Nematodes often cause serious damage to crop plants. Over 500 species of plant parasitic nematodes are known to exist in soils. These round and spindle shaped organisms have adaptable mouth parts and pointed form. As such, it is easy for them to penetrate plant tissues. Though a major crop pest, nematodes also possess the potential to suppress the population of disease causing fungi and bacteria in the root zone.

Protozoa are one celled organisms confined mostly to the surface horizons of soils. They are slightly bigger than bacteria and usually the most varied in the microfauna population of soils. Flagellates, amoeba and ciliates are

the three groups of protozoa. Aeration and availability of food sources are the factors influencing the population density. In normal soils the population varies between 10,000 and 100,000 per g of dry soil. Protozoa are important predators of bacteria and, thus, exercise regulatory control on the bacterial population of soils. The indirect effects of such control may be reflected on the nitrogen transformations. As the area of dominance of protozoa is confined to the rhizosphere, the effect of bacterivorous population is likely to prove beneficial in controlling pathogenic bacteria present in the root zone.

#### *Mesofauna*

Organisms of the group range in length from 0.2 to 2.0 mm. Population densities in favourable soil conditions reach upto 10 million per square metre of soil surface. Mites and collembola are the most abundant of the soil mesofauna. The organisms comprise feeders of plant litter and predators of other mesofauna and fungi. In undisturbed soils or in soils under conservation tillage, the population of fungi is usually more than that of bacteria and in such situations the populations of collembola and mites tend to increase. These organisms are known to survive on external rumen feeding strategy in which their faecal matter which supports intense microbial activity is reingested to serve as a source of microbial biomass. Although present in all soil layers, the concentration is high in the rhizosphere or in the zone of maximum root activity of plants.



### Macrofauna

To this group is included organisms comprising small mammals, insects, mites, centipedes, millipedes, slugs and snails, spiders, earthworms etc. They exceed 10 mm in size and include predators and feeders of plant materials. Most of the macrofauna contribute to soil fertility by incorporating organic residues in the soil, improving soil granulation and by facilitating better aeration and drainage, though some cause damage to agricultural crops. Their contribution at death to the total biomass becoming available in the soil is also substantial. Among the members of soil macrofauna the more important from the angle of soil fertility management are termites, ants and earthworms.

Termites and ants are very common in the soils of tropical, subtropical and warm temperate regions. Through their activities they modify the organic constituents of soil either by digestion or translocation. These organisms especially termites utilize undecomposed organic matter as food and serve a very useful purpose in the organic transformations in soil. Their biomass is, however, much less than that of earthworms. Termites sometimes cause damage to growing plants and when present in large numbers leave the soil depleted of all organic residues on the surface making it vulnerable to different forms of erosion.

Earthworms form the major representative of soil macrofauna having the maximum influence on the physical and biological properties of the soil. They are found

in large numbers in soils which are moist and rich in organic matter and exchangeable calcium. Their population will be low in dry soils deficient in organic matter. Though the population density in cultivated soils receiving regular additions of organic manures and residues is variously estimated, the generally accepted range is between 0.6 and 2.5 million per ha with a live weight ranging between 300 kg and 1.25 tonnes. In unfavourable soil types the population density may drop to even less than 30,000 per ha with a biomass of only 15 kg or less.

Earthworms are generally classified into detritivores and geophages. The former group includes epigeic and anecic forms and the latter group comprises the endogeic earthworms. The epigeics bring about the comminution and fragmentation of plant litter, but have no effect on soil structure as they restrict their feeding on the soil surface. The anecics feed on the litter mixed with the mineral particles of the soil and produce surface casts. The endogeic earthworms live within the soil deriving nutrition from the organically rich soil they ingest. The common examples of detritivores which are also known as humus formers are *Perionyx excavatus*, *Eisenia foetida*, *Eudrilus eugineae*, *Lampito mauritii*, *Octochaetona serrata* and *Octochaetona surensis*. The common example of the geophages or humus feeders is *Octochaetona thurstoni*.

While feeding on organic debris earthworms also ingest substantial amounts of mineral particles. The ingested food is subjected to digestive enzymes and to a grinding

action before excretion as casts. As undecomposed organic debris is dragged by earthworms into their burrows, the casts are found both within the burrows and on the soil surface. In arable fields with a flourishing earthworm population, the casts may amount to more than 15 tonnes per ha. In such fields the amount of soil that these organisms pass through their bodies annually has been estimated to be around 40 tonnes per ha. Same level of earthworm activity takes place in coconut holdings devoted to organically managed integrated cropping/farming system.

Earthworm casts are richer than the original soil in organic matter, available plant nutrients, base status and microbial population. They serve as excellent medium for the proliferation of diverse groups of soil flora. The enhanced microbial activities especially of the heterotrophic microflora minimize leaching loss of nitrogen by transforming soluble nitrogen into microbial protein. Vermicast also harbour a high population of nitrogen fixers. By sustaining enhanced population and activities of soil microflora earthworms promote soil granulation and the production of water soluble macro aggregates. In earthworm worked soils the water holding capacity as well as the infiltration rate of water will be high. In such soils the macroaggregates exhibit higher resistance to the erosive effects of rain drops than those formed in the absence of earthworms.

### 2.2. Soil Flora

Soil flora is represented by diverse communities of organisms



comprising algae, fungi, actinomycetes and bacteria. To this is also included the roots of higher plants. These organisms account for a higher proportion of soil life than fauna and perform very useful functions such as soil granulation, mineralization of nutrients present in organic combinations, fixation of atmospheric nitrogen etc. The organic transformations initiated by the soil fauna are carried forward by the microflora and the polysaccharides produced in the process together with the binding effect of filamental organisms and plant roots on soil particles bring about significant improvement in the structural properties of soil. During the decomposition process soil flora are known to produce vitamins, amino acids, hormones and other growth regulating substances. Soil enzymes such as dehydrogenase are known to be the products of microbial activities in the soil.

### *Algae*

Algae are present in diverse locations such as land, fresh water and sea. The organisms present in the upper layers of soil are chlorophyll bearing and derive their energy from photosynthesis. Algae are also found in subsoils as resting spores or cysts or as vegetative forms that do not depend on photosynthesis. These forms, however, represent only a small fraction of the total algal biomass of the soil. The algal population of soil has been estimated to range between 10 and one million per g of dry soil with 100,000 being the average in favourable locations. Algae contribute to soil structure,

erosion control and nitrogen fixation. Blue green algae fix atmospheric nitrogen both asymbiotically and symbiotically.

Blue green algae found in rice fields comprise unicellular, colonial and filamental forms. They fix atmospheric nitrogen asymbiotically in the heterocysts possessed by them which are large, thick walled empty cells. Blue green algae also form symbiotic association with fungi, liverworts, ferns and flowering plants and fix atmospheric nitrogen. A typical example is the symbiosis between heterocystous nitrogen fixing blue green algae *Anabaena azollae* and the aquatic fern *Azolla*.

### *Fungi*

Different groups of fungal organisms are present in soil. They are active in the presence of plenty of organic debris and are tolerant to such soil reactions that are not favoured by bacteria and other groups of soil microorganisms. Though fungi are less abundant than bacteria in soil the weight of their biomass is more than that of bacteria. They are mainly responsible for the degradation of cellulose, lignins, starch, gums etc. in soil. They convert most of the carbon and nitrogen present in the organic residues being decomposed into fungal tissue which serve as the source of energy and nutrients for bacteria and other microflora to carry forward the biochemical transformations. As fungi can tolerate low soil pH, dry soil conditions and can tide over unfavourable conditions by forming resistant spores, their role in the pre-humus formation stages is more

important than bacteria especially in acid forest soils and in mulched soils. In cultivated soils the estimated population of fungi ranges from 10,000 to 10 million per square metre of soil surface which may amount to 1 to 1.5 tonnes per ha.

Certain fungi form symbiotic associations with the feeder roots of higher plants. These associations, known as mycorrhizae, cause an increase in the absorptive area of the root system. Mycorrhizae are beneficial to higher plants as they are conducive to the enhanced availability of phosphorus, zinc, copper and molybdenum, increased uptake of moisture, enhanced nitrogen fixation by *Rhizobium* and *Frankia* in association with leguminous and non-leguminous plants and better resistance to diseases by inhibiting root pathogens. Among the different types of mycorrhizal fungi, ectomycorrhiza and vesicular arbuscular mycorrhiza (VAM) have been found to have the maximum potential in forestry and agriculture. Ectomycorrhizae are found associated only with tree roots with their mycelia developing on the surface of the roots to form a sheath. On the other hand, the occurrence of VAM fungi has been found in a wide range of trees and cultivated plants where the mycelia do not form a sheath on the root surface but penetrate into the roots. While various groups of fungi perform useful functions in soil, some of them cause diseases in arable crops as well as tree species. Root rot, damping off, wilt, blight etc. are some of the common diseases of fungal origin.



### **Actinomycetes**

Actinomycetes are unicellular, filamentous organisms. In size they are closer to bacteria. They are present in large numbers in well aerated moist soils, rich in organic matter. They are highly sensitive to acidic conditions and do not function at a soil pH of 5 or below.

Actinomycetes are more numerous in soils than fungi, but the weight of their biomass is comparatively much less. Their population density is estimated to range from 10 to 2 million per g of dry soil accounting for a biomass weight of around 650 kg per ha in favourable locations. These organisms are active in the degradation of soil organic matter and can bring about the dissolution of lignin and other resistant compounds. *Frankia*, an actinomycete, is also known to possess the ability to fix nitrogen in association with many non-leguminous plants. *Frankia* is widely distributed in soils and cause nodulation in different species of *Casuarina*, *Alnus rubra*, *Myrica faya* etc. The quantity of nitrogen fixed has been found to vary from as low as 12 kg to as high as 320 kg per ha per year.

### **Bacteria**

Soil bacteria are the most abundant of all microflora present in soil. They are the simplest and smallest forms of life and are present in soils as bacterial colonies. These organisms are active under diverse soil conditions and comprise the heterotrophic or general purpose decay organisms and the autotrophic or special purpose organisms.

Though most soil bacteria are heterotrophic, the autotrophic organisms have a special significance as they support nitrification and sulphur oxidation, the two vital processes that provide sustenance to higher plants. Soil bacteria are responsible for the cycling of many inorganic compounds such as nitrogen, sulphur and phosphorus. Heterotrophic bacteria along with fungi and actinomycetes cause the dissolution of organic matter and the formation of humus besides many organic acids. These products of decomposition by forming complexes with iron and aluminium compounds present in soil reduce fixation of inorganic phosphorus.

Besides the enzymic processes of nitrification and sulphur oxidation, some groups of soil bacteria have the ability to fix molecular nitrogen into forms utilizable by higher plants. Nitrogen fixing bacteria form either asymbiotic, associative symbiotic or symbiotic associations with higher plants. The asymbiotic and associative symbiotic organisms are categorized into aerobic, microaerophilic, facultative and anaerobic. These organisms fix nitrogen in the soil and the typical examples are *Azotobacter*, *Azospirillum* and *Beijerinckia* besides many other bacteria. The symbiotic bacteria form associations with higher plants of the leguminous group and fix nitrogen in the nodules formed on the roots. The organisms involved comprise different species of *Rhizobia*. In some leguminous plants nodules are formed on the stem as well. Substantial amounts of nitrogen are fixed by nitrogen fixing

bacteria in the different farming systems especially when leguminous trees and pulses are included.

The population of bacteria is influenced by soil conditions and farming methods. Higher organic matter content and exchangeable calcium, moderate temperature without extremes and soil moisture considered optimum for higher plants favour the growth and functioning of an active bacterial population. In cultivated soils where there is regular incorporation of organic residues, bacterial population will predominate in comparison with that of fungi or actinomycetes. In regularly tilled soils bacterial population multiplies rapidly leading to enhanced rates of decomposition and nitrification. Under such conditions the depletion of soil organic matter and the leaching loss of nitrate nitrogen will be higher than that from soils under conservation tillage. Bacteria though are regarded as a valuable biological input in agriculture; some of them are also responsible for a number of plant diseases.

### **Roots of higher plants**

Roots of higher plants are also regarded as soil organisms in consideration of their large biomass that provide sustenance to the soil fauna and flora leading to improvement in soil properties. The regular availability of root exudates and sloughages stimulate soil life especially in the zone of effective root growth. The elongation of roots coupled with the constant addition of dead root tissues bring about improvements in soil granulation,



drainage and aeration. In the effective root zone the availability of plant nutrients is also more than that in other parts of the soil.

### 3. Conclusion

Biodiversity in soils is composed of multitudes of organisms. As the richness of soil life is the key to soil health and sustainable agriculture, biodiversity of soil life has to be

conserved and protected from depletion. The basic requirement for the soil life to flourish is regular availability of fresh organic residues. The soil and climatic conditions considered optimum for healthy plant growth are also favourable for a vibrant soil life. Integration of woody species, arable crops and livestock components in coconut holdings, regular recycling

of organic wastes, soil and water conservation measures and need-based use of organic amendments provide congenial conditions for an active soil life. In the presence of a rich biodiversity, optimum levels of productivity of coconut and other component crops in the system could be sustained on an enduring basis without recourse to the use of chemical inputs.

## COCONUT DEVELOPMENT BOARD

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