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Soil biota and decomposition of organic residues

Introduction

Soil biota, the biologically active powerhouse of soil, includes an incredible diversity of organisms. Tons of soil biota, including micro-organisms (bacteria, fungi, and algae) and soil "animals" (protozoa, nematodes, mites, springtails, spiders, insects, and earthworms), can live in an acre of soil and are more diverse than the community of plants and animals above ground. Soil biota is concentrated in plant litter, the upper few inchesof soil, and along roots. Soil organisms interact with one another, with plant roots, and with their environment, forming the soil food web.

Roles of soil biota

As soil organisms consume organic matter and each other, nutrients and energy are exchanged through the food web and are made available to plants. Each soil organism plays a role in the decomposition of plant residue, dead roots, and animal remains. The larger soil organisms, such as millipedes and earthworms, shreddead leaves and residue, mix them with the soil, and make organic material more accessible to immobile bacteria. Earthworms can completely mix the top 6 inches of a humid grassland soil in 10 to 20 years. Ants and termites mix and tunnel through soils in areas of arid and semiarid rangeland.

Predators in the soil food web include scorpions, centipedes, spiders, mites, some ants, insects, and beetles. They control the population of soil biota. The smaller organisms, including mites, springtails, nematodes, and one-celled protozoa, graze on bacteria and fungi. Other organisms feed on dead roots, shredded residue, and the fecal by-products of the larger organisms. The smallest soil organisms, microscopic bacteria and fungi, make up the bulk of the biota in the soil. They finish the process of decomposition by breaking down the remaining material and storing its energy and nutrients in their cells. Algae and fungi are the first organisms tocolonize rock and form "new soil" by releasing substances that disintegrate rock

Importance of soil biota

Through their interactions in the soil food web, the activities of soil biota link soil with the plants and animalsabove ground. Soil organisms perform essential functions that allow soil to resist degradation and provide benefits to all living things.

1. **Residue decomposition**.—without the soil food web, the remains of dead plants and animals would accumulate on the earth's surface, making nutrients unavailable to plants. Soil biota decompose these organic residues and some forms of organic matter in the soil. They convert these materials into new forms of organic matter and release carbon dioxide into the air. Many of the biota can break down pesticides and pollutants.

2. **Nutrient storage and release**.—Most of the annual nutrient needs of rangeland plants are supplied through decomposition of organic matter in the soil. As soil organisms consume organic materials, they retain (immobilize) nutrients in their cells. This process prevents the loss of nutrients, such as nitrogen, from the root zone. When fungi and bacteria die or are eaten by other organisms, nutrients are mineralized, that is, slowly released to the soil in plant-available forms. Nutrient immobilization and mineralization occur continuously throughout the year. Some bacteria and fungi provide nutrients to plants in exchange for carbon. Special types of bacteria, called nitrogen fixers infect the roots of clover and other legumes, forming visible nodules. The bacteria convert nitrogen from the air in the soil into a form that the plant host can use.

3. **Water storage, infiltration, and resistance to erosion**. — Soil biota form water-stable aggregates that store water and are more resistant to water erosion and wind erosion than individual soil particles. Threads of fungal hyphae bind soil particles together. Bacteria and algae excrete material that "glues" soil into aggregates. As they tunnel through the soil, the larger soil biota form channels and large pores between aggregates, increasing the water infiltration rate and reducing the runoff rate. and fungi become less active or temporarily shut down, protozoa form dormant cysts, and the number of most other organisms declines. When the soil is saturated and anaerobic, the number of denitrifying bacteria increases. Organisms affect each other through predation and competition for food and space. Small soil pores can restrict the movement of large soil organisms.

Management considerations

1. Grazing.—Proper management of the plant community is the best strategy for maintaining the benefits of the soil food web. Plant production and the supply of organic matter can be maintained or enhanced by timely grazing, the proper frequency of grazing, and control of the amount of vegetation removed. If the plant community is overgrazed, a reduction in the amount of surface plant material and roots will result in less food for soil organisms.
2. Erosion.—Erosion removes or redistributes the surface layer of the soil, the layer with the greatest concentration of soil organisms, organic matter, and plant nutrients. Runoff and wind erosion redistribute litter from one area of rangeland to a surrounding area. The loss of organic matter reduces the activity of soil biota in the areas from which the litter has been removed.
3. Compaction by grazing animals and vehicles.—Soil compaction reduces the larger pores and pathways, thus reducing the amount of habitat for nematodes and the larger soil organisms. Compaction can also cause the soil to become anaerobic, increasing losses of nitrogen to the atmosphere.
4. Fire and pest control.—Fire can kill some soil organisms and reduce their food source while also increasing the availability of some nutrients. Pesticides that kill above-ground insects can also kill beneficial soil insects. Herbicides and foliar insecticides applied at recommended rates have a smaller impact on soil organisms.

Soil biota and decomposition of organic residues

- Soil biota, soil life, soil fauna, or edaphon is a collective term that encompasses all organisms in soil.
- The soil organisms include earthworms, nematodes, protozoa, fungi, bacteria, different arthropods, as well as some reptiles (such as snakes), and species of burrowing mammals like gophers, moles and prairie dogs. Soil biology plays a vital role in determining soil characteristics.

The soil biota includes:

- **Megafauna:** size range - 20 mm upward, e.g. moles, rabbits, and rodents.
- **Macrofauna**: size range - 2 to 20 mm, e.g. woodlice, earthworms, beetles, centipedes, slugs, snails, ants,

and harvestmen.

- **Mesofauna**: size range - 100 micrometres to 2 mm, e.g. tardigrades, mites and springtails.
- **Microfauna and Microflora**: size range - 1 to 100 micrometres, e.g. yeasts, bacteria (commonly actinobacteria), fungi, protozoa, roundworms, and rotifers.
- Of these, bacteria and fungi play key roles in maintaining a healthy soil. They act as decomposers that break down organic materials to produce detritus and other breakdown products. Soil detritivores, like earthworms,

ingest detritus and decompose it. Saprotrophs, well represented by fungi and bacteria, extract soluble nutrientsfrom delitro. The ants (macro faunas) help by breaking down in the same way but they also provide the motion part as they move in their armies. Also the rodents, wood eaters help the soil to be more absorbent.

Nitrification

- Nitrification is a vital part of the nitrogen cycle, wherein certain bacteria (which manufacture their own carbohydrate supply without using the process of photosynthesis) are able to transform nitrogen in the form of ammonium, ammonium, which is produced by the decomposition of proteins, into nitrates, which are available to growing plants, and once again converted to proteins.

Nitrogen fixation

- This is carried out by free-living nitrogen-fixing bacteria in the soil or water such as Azotobacter, or by those that live in close symbiosis with leguminous plants, such as rhizobia. These bacteria form colonies in nodules nodules they create on the roots of peas, beans, and related species.

Denitrification

- Denitrifying bacteria tend to be anaerobes, or facultatively anaerobes (can alter between the oxygen dependent and oxygen independent types of metabolisms), including Achromobacter and Pseudomonas. The purification process caused by oxygen-free conditions converts nitrates and nitrites in soil into nitrogen gas or into gaseous compounds such as nitrous oxide or nitric oxide. In excess, denitrification can lead to overall losses of available soil nitrogen and subsequent loss of soil fertility.

Actinobacteria

- Actinobacteria are critical in the decomposition of organic matter and in humus formation. They specialize in breaking down cellulose and lignin along with the tough chitin found on the exoskeletons of insects. Their presence is responsible for the sweet "earthy" aroma associated with a good healthy soil. They require plenty of air and a pH between 6.0 and 7.5, but are more tolerant of dry conditions than most other bacteria and fungi.

Fungi

- In terms of soil and humus creation, the most important fungi tend to be saprotrophic; that is, they live on dead or decaying organic matter, thus breaking it down and converting it to forms that are available to the higher plants. A succession of fungi species will colonise the dead matter, beginning with those that use sugars and starches, which are succeeded by those that are able to break down cellulose and lignins.
- Fungi spread underground by sending long thin threads known as mycelium throughout the soil and compost heaps. From the mycelia the fungi is able to throw up its fruiting bodies, the visible part above the soil (e.g., mushrooms, toadstools, and puffballs), which may contain millions of spores.

Mycorrhizae

- The Fungi that are able to live symbiotically with living plants and create a relationship that is beneficial to both, are known as Mycorrhizae (from myco meaning fungal and rhiza meaning root). Plant root hairs are invaded by the mycelia mycelia of the mycorrhiza mycorrhiza, which lives partly in the soil and partly in the root, and may either cover the length of the root hair as a sheath or be concentrated around its tip. The mycorrhiza obtains the carbohydrates that it requires from the root, in return providing the plant with nutrientsincluding nitrogen and moisture. Later the plant roots will also absorb the mycelium into its own tissues.

- Beneficial mycorrhizal associations are to be found in many of our edible and flowering crops. Recent research has shown that arbuscular mycorrhizal fungi produce glomalin, a protein that binds soil particles andstores both carbon and nitrogen. These glomalin-related soil proteins are an important part of soil organic matter.

Insects and Mammals in soil

- Earthworms, ants and termites mix the soil as they burrow, significantly affecting soil formation. Earthwormsingest soil particles and organic residues, enhancing the availability of plant nutrients in the material that passes through and out of their bodies.
- Ants and termites are often referred to as "**Soil engineers"** as when they create their nests there are severalchemical and physical changes that become present. Such as increasing the presence of the most essential elements like C, N and P.

Soil populations, processes and fertility

- Symbionts such as rhizobia and mycorrhiza increase the efficiency of nutrient acquisition by plants.
- A wide range of fungi, bacteria and animals participate in the process of decomposition, mineralization andnutrient immobilization and therefore influence the efficiency of nutrient cycles.
- Soil organisms mediate both the synthesis and decomposition of soil organic matter (SOM) and thereforeinfluence cation exchange capacity; the soil N, S and P reserve; soil acidity and toxicity; and soil water holding capacity.
- The burrowing and particle transport activities of soil fauna and soil particle aggregation by fungi andbacteria, influence soil structure and soil water regimes.

Microbiology of residue decomposition

- Decomposition of farm residue involves the action of wide variety of microorganisms like bacteria, fungi,actinomycetes.
- The bacteria are first to act followed by fungi and actinomycetes with ultimate stabilization of populationequivalent to initial population.
- As the residue carbon decreases, microbial biomass C increases at initial stage followed by decrease inbiomass C and ultimately both reach to the same level.
- During this cycle, there is exchange of carbon from residue carbon to biomass-C, soil humus carbon andgaseous carbon.
- When a residue is incorporated having constituents of different degradability, the rate of decomposition isfast for easily decomposable constituents like hemicelluloses followed by cellulose and lignin
- The initial step in cellulose destruction is enzymatic hydrolysis of the polymer:

Cellulase extra cellular
enzymesCellulose ----------→Cellobiose
→ 2 glucose

- More microbial species are active in destroying hemicelluloses than celluloses
- Hemicellulose → Shorter carbohydrate fragments
- Lignin is probably depolymerized to give simple aromatic substances such as vanillic acid or methoxylatedaromatic structures under extra cellular enzymes system

Principles of composting

- Composting is a self heating thermophilic and aerobic biological process which occurs naturally in heaps ofbiodegradable organic matter such as manure, crop residues, moist hay etc.
- Major reactions occurring aerobically are: (CH O) + nO CO + nH O + energy
- $(CH_2O)_n + nO_2 \rightarrow CO_2 + nH_2O$ + energy
- Organic N $\rightarrow NH_3 \rightarrow NO_2 \rightarrow NO_3$
- Organic S + $2nO_2 \rightarrow nSO_4$
- Organic P $\rightarrow H_3PO_4 \rightarrow Ca(HPO_4)_2$
- Under anaerobic conditions the reactions are:
- $(CH_2O)_n + nO_2 \rightarrow CH_3COOH \rightarrow CH_4 + CO_2$
- Organic N $\rightarrow NH_3$

Use of organic wastes

- The organic sources are carbonaceous materials having great variation in C:N ratio which determines:
- The rate of decomposition, release of nutrients and also the duration for completion of composting process.
- The decomposition rate also depends on temperature; soil conditions, moisture, supplementation, inoculationetc.
- Basically there are two processes of narrowing the C: N ratio:
- First is → in situ as in case of green manuring, fallen leaves and twigs etc.
- and second is → in vitro in pits or trenches following different procedures as Bangalore, Indore, NADEP,vermicompost, mechanical compost etc.
- The rate of composting can be accelerated by supplementing with chemicals and / or inoculums.

❖ Other methods of composting

- Vermi-composting
- Synthetic composting
- Accelerated composting and enrichment
- Oil palm waste composting
- Phosphocompost
- Reinforced compost from sugarcane trash and press mud
- Enriched FYM (EFYM)
- Weed composting
- PROM etc

Sugarcane trash composting

- One tonne of Sugarcane trash chopped into pieces (8-10 cm size) and divided into 10 lots (100 kg each)
- Spread First lot of 100 kg trash in a raised shady place on an area of 5x3 sq m.
- Sprinkle uniformly (a bottle) Pleurotus sojor- caju spawn on the bed
- Water to obtain a moisture % = 60
- Spread second lot of 100 kg chopped sugarcane trash over this followed by sprinkling of 1 kg urea uniformlyover the bed followed by watering
- Then spread third lot followed by sprinkling of a bottle of Trichoderma viridie followed by watering.
- Repeat this type of sandwiching until entire lots of sugarcane trash are utilized
- Spread 250 kg tank silt on top most layer to give a compaction to the bed
- Water once in four days.

Composting Farm wastes/crop residues

- Fill uniformly the farm wastes /crop residues to a thickness of about 15 cm in pits of 4x2x1 m^3

- Sprinkle a layer of cow dung slurry to thickness of about 5 cm.
- Above this layer, bone meal / rock phosphate @ 1 kg can be spread to conserve N loss and add P to thecompost
- Repeat the process of residue-cow dung-bone meal till the height reaches 50 cm above the ground level

Cover the material with mud

- plaster and turn it after 1 month for an aerobic process