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ROLE OF SOIL BIOLOGY IN LIFE: ACHIEVEMENTS AND CHALLENGES

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Soil plays a vital role in sustaining life on the Earth. It is a non-renewable dynamic natural resource that is essential to life. Soil is a critical component of nearly every ecosystem provides a home for organisms. Soil biota plays an integral role in soil ecosystems by decomposing leaves, downed logs, and animals, and providing the primary nutrient source for vegetation. Soil biota includes both flora (plants) and fauna (animals). Soil flora includes organisms as small as diatoms and algae up to the size of tree roots. An important member of soil flora is mycorrhizae, fungi that form a symbiotic (mutually beneficial) relationship with plant roots. Most plants contain roots infected with mycorrhizal fungi. Mycorrhizae enhance water and nutrient absorption by increasing root surface area and accelerate mineral weathering which releases nutrients to the soil Water movement; water quality, land use, and vegetation productivity all have relationships with soil. Nearly all of the food that humans consume, except for what is harvested from marine environments, is grown in the Earth's soils. Other obvious functions that soils provide humans include fiber for paper and clothing, fuel-wood production, and foundations for roads and buildings. Less obvious functions that soils serve are providing a medium to attenuate pollutants and excess water, groundwater recharge, nutrient cycling, and habitat for microorganisms and biota. Soils have many secondary uses such as ingredients in confectionaries, insecticides, inks, paints, makeup, and medicines; uses of clays range from drilling muds, pottery, and artwork, to providing glossy finishes on various paper products. This study introduces many important soil concepts including development, classification, properties (physical, chemical, and biological), quality, and conservation. A general understanding of soil concepts and these interwoven relationships is essential to making sound land management decisions. Soil acts as the basis of the ecosystem foundation, as soil productivity determines what an ecosystem will look like in terms of the plant and animal life it can support. For example, in forest ecosystems, soils can determine species composition, timber productivity, and wildlife habitat, richness, and diversity. The role soil plays in forests is critical to maintaining water quality and long-term site productivity. In cultivated fields, soil quality plays a significant role in crop productivity since soil nutrients and soil physical properties can directly impact yields Collectively, soil biota carries out enzymatic and physical processes that decompose organic matter, build soil humus, and make nutrients available for plants. Decomposition is one of the most critical roles that soil biota play in an ecosystem. Without efficient decomposition, organic material would accumulate on the soil surface and nutrients would be bound within the material. Decomposition is initiated immediately when a leaf, twig, or fruit hits the ground. Once on the ground surface, biota begins to physically break down the material, creating more surface area to which flora can adhere.

***Keywords**: soil life, soil properties, soil microbiomes, soil biology*

INTRODUCTION

Soil is an essential resource for human societies and ecosystems, and it is subjected to permanent and increasing constraints and pressures. Animals and plants each have evolved specialized organs dedicated to nutrient acquisition, and these harbor specific bacterial communities that extend the host's metabolic repertoire. Similar forces driving microbial community establishment in the gut and plant roots include diet/soil-type, host genotype, and immune system as well as microbe-microbe interactions.

Life on Planet Earth is sustained by a small volume of soil surrounding roots, called the rhizosphere. Soil is where most of the biodiversity on Earth exists, and the rhizosphere probably represents the most dynamic habitat on Earth; and certainly is the most important zone in terms of defining the quality and quantity of the Human terrestrial food resource. Despite its central importance to all life, very little is known about rhizosphere functioning. A major issue in research on rhizosphere processes is the intimate connection between the biology, physics, and chemistry of the system which exhibits astonishing spatial and temporal heterogeneities.

Soil is the largest reservoir of biodiversity on Planet Earth. It is important habitat for Prokaryotes and a diversity of Eukaryotes, which comprise fungi among soil microbiomes, and large variety of invertebrates (from protozoa and nematodes to mites, collembola, insects and earthworms). The diversity of Prokaryotes in soil has been estimated to be about three orders of magnitude larger than in all other environmental compartments of the Earth's ecosystems combined (Crawford et al. 2005; Curtis and Sloan 2005).

Rhizosphere ecology is driven by a combination of the physical architecture of the soil matrix, coupled with the spatial and temporal distribution of rhizodeposits, protons, gases, and the role of roots as sinks for water and nutrients. Consequences for plant growth.

Soil health and soil quality are defined as the capacity of soil to function as a vital living system within land use boundaries. This function which sustains biological productivity of soil also maintains the quality of surrounding environment and human health. Thus the two terms are used interchangeably although it is important to distinguish that, soil quality is related to soil function, whereas soil health presents the soil as a finite non-renewable and dynamic living resource. In this review, we deal with soil health concept which includes interactions between plant inputs and soil in creating a healthy environment.

Through many studies it is clear that biological activity may increase the stability of soil within and outwith the rhizosphere. What is evident is the importance of wet~dry cycles to 'lock-in' that stability. Clearly a combination of biophysical factors, the exact nature dependent on a wide range of conditions, impacts on the stability of soil at the root-soil interface. Another important factor relates to the chemical make-up of the carbon involved.

Adverse effects on soil health and soil quality arise from nutrient imbalance in soil, excessive fertilization, soil pollution and soil loss processes that are increasingly becoming common in developing countries. Studies of the biological processes which take place in a soil have been based on the measurement of several variables: microbial biomass (Jenkinson and Ladd, 1981), respiration (Nannipieri et al., 1979), ATP (Brookes et al., 1983) and enzymatic activities (Frankenberger and Dick, 1983). However, the idea of microbiological activity has recently been revised by Nannipieri et al. (1990), who suggest that problems exist if variables such as biomass-C, CO_2 emission or dehydrogenase are to be considered as indices of microbiological activity; these problems are even greater when such complex ecosystems as the soils of arid zones are considered, since they are subject to such enormous imbalances.

Soil is a non-renewable dynamic natural resource that is essential to life. Water movement, water quality, land use, and vegetation productivity all have relationships with soil. **S**oil plays a vital role in sustaining life on the planet. Nearly all of the food that humans consume, except for what is harvested from marine environments, is grown in the Earth's soils. Other obvious functions that soils provide humans include fiber for paper and clothing, fuelwood production, and foundations for roads and buildings. Less obvious functions that soils serve are providing a medium to attenuate pollutants and excess water, groundwater recharge, nutrient cycling, and habitat for microorganisms and biota. Soils also have many secondary uses such as ingredients in confectionaries, insecticides, inks, paints, makeup, and medicines; uses of clays range from drilling muds, pottery, and artwork, to providing glossy finishes on various paper products.

Soil is a critical component of nearly every ecosystem, but is often taken for granted. Soil can be thought of as the ecosystem foundation, as soil productivity determines what an ecosystem will look like in terms of the plant and animal life it can support. For example, in forest ecosystems, soils can determine species composition, timber productivity, and wildlife habitat, richness, and diversity. The role soil plays in forests is also critical to maintaining water quality and long-term site productivity.

In cultivated fields, soil quality plays a significant role in crop productivity since soil nutrients and soil physical properties can directly impact yields. In urbanized areas, soil plays a vital role in reducing runoff through infiltration and nutrient attenuation. The value of soil is easily overlooked until soil quality becomes degraded and the critical services the soil once provided are diminished.

Human activities frequently cause a degradation of soil environment which leads to a reduction in the abundance and to a simplification of animal and plant communities, where species able to bear stress predominate and rare taxa decrease in abundance or disappear. The result of this biodiversity reduction is an artificial ecosystem that requires constant human intervention and extra running costs, whereas natural ecosystems are regulated by biotic communities through flows of energy and nutrients, a form of control progressively being lost with agricultural intensification.

For these reasons the identification of agricultural systems which allow the combination of production targets and environmentally friendly management practices, protecting both soil and biodiversity, is essential in order to prevent the decline of soil fauna and microbiomes communities in agricultural soil.

Soil is the third most important element of the environment. It plays a central role in the physical, chemical and biological processes taking place on Earth in the biogeocycle of elements, but the classification of the biological state is a significantly more complicated task. One of the most important tasks of the soil is to store plant nutrients and make them available to the plants at the right time and in the right form.

Soil is fundamental and irreplaceable; it governs plant productivity of terrestrial ecosystems and it maintains biogeochemical cycles because microorganisms in the soil degrade, sooner or later, virtually all organic compounds including persistent xenobiotics and naturally occurring polyphenolic compounds.

The living population inhabiting soil includes fauna (macro-, meso-, and microfauna) and microflora. This property is due to the complicated physico-chemical-biological role of the soil, the complex system consisting of organic and inorganic substances, to which nutrients, water and soil microorganisms can be connected by physical or chemical bonds of varying strength.

Soil fauna and soil microorganisms, i.e. fungi, bacteria and actinomycetes (actinobacteria), yeasts and algae, etc. they contribute to soil fertility in many ways. The presence and activity of microbiomes are therefore of fundamental importance from the point of view of the fertility of agricultural soils. The beneficial effect of fertilization on soil productivity has been known for a long time. Microbiomes are the largest fraction of the soil biota in terms of mass and number. These miniature "factories" are the driving forces behind many processes of decisive importance in nature, such as the C, N and P recycles.

Microbes ensure the decomposition of organic materials, they play a huge role in plant nutrition (biological nitrogen fixation, mobilization of micro- and macro-elements, nutrient absorption, etc.) and in the formation of soil structure. The functioning of the soil-plant system is unthinkable without billions of microorganisms.

Soil fauna subsists on a wide variety of energy sources, including: living plant material (herbivores), animals (carnivores), dead material (detritivores), fungi (fungivores), and bacteria (bacterivores). Soil fauna and microbiomes are an important reservoir of soil biodiversity and play an essential role in several soil functions; furthermore, it is often used to provide soil quality indicators. Although soil biodiversity was one of the focal points of the Rio conference, in the 1990s virtually no attention was paid to activities for the conservation of soil communities. However, with the new millennium, the conservation of soil biodiversity has become an important aim in international environmental policies, as highlighted in the Planet.

Soil fauna are highly variable and the majority are also highly adaptable with regard to their feeding strategies, ranging from herbivores to omnivores and including carnivores. Depending on the available food sources many soil fauna are able to change their feeding strategies to a greater or lesser extent with many carnivorous species able to feed on dead organic matter in times of low food availability. The interactions between soil fauna are numerous, complex and varied. As well as the predator / prey relationships and in some instances parasitism, commensalism also occurs.

Soil fauna includes earthworms, collembolans, mites, nematodes, and protozoa. These are eukaryotic, heterotrophic, motile organisms that require oxygen for metabolism. There are many evidences on

how the role of soil fauna in food webs will respond to environmental change and influence aboveground processes has advanced considerably.
Loss of species due to varying management practices, erosion, pollution, urbanization, and resulting effects on ecosystem function and services are becoming widely recognized and related to larger issues of biodiversity loss, desertification, and elevated greenhouse gas concentrations.
Microfauna: organisms whose body size is between 20 µm and 200 µm. Just one group, protozoa, is found wholly within this category; among the others, small mites, nematodes, rotifers, tardigrades and copepod crustaceans all fall within the upper limit. Mesofauna: organisms whose body size is between 200 µm and 2 mm.
Microarthropods such as mites and springtails are the main representatives of this group, which also includes nematodes, rotifers, tardigrades, small araneidae, pseudoscorpions, opiliones, enchytraeids, insect larvae, small isopods and myriapods. Macrofauna: organisms whose size is between 2 mm and 20 mm. This category includes certain earthworms, gastropods, isopods, myriapods, some araneidae and the majority of insects. Megafauna: organisms whose size exceeds 20 mm. The members of this category include large size invertebrates (earthworms, snails, myriapods) and vertebrates (insectivores, small rodents, reptiles and amphibians).
The degree of interaction between soil organisms and the soil itself can be highly variable among taxa and dependent on the part of the life cycle that is spent in the soil [2].
In particular, in this regard, combined with the morphological adaptations and the ecological functions of organisms, it is possible to classify soil fauna into four main groups: temporarily inactive geophiles, temporarily active geophiles, periodical geophiles, and geobionts (Figure 1).

Figure 1. The main four grouping that can be individualized between soil invertebrates, depending on their life strategies and how closely they are linked with soil
Source: Menta Cristina (2012). DOI: 10.5772/51091

Many studies have reported increased microbial activities during the passage of food through the gut in earthworms and higher numbers of fungi, bacteria and actinomycetes in vermicasts showed enhanced microbial populations and activity in the freshly deposited pressmud vermicasts in relation to nutrient rich substrate concentrations, multiplication of microbes after passing through the gut, optimal moisture level and large surface areas of vermicasts ideally suited for better feeding and multiplication of microbes. It is important to note that often worm casts are not released in the same layer in which the earthworm fed; in effect the components of the anecic group live at depth and release their mineral-rich faeces on the surface. In contrast the endogeic live at the surface and release their faeces, once again rich in organic matter, at lower depths. These forms of behaviour together with the direct action due to the burrowing, ensure that the soil is mixed, thereby increasing its fertility. The burrowing of the earthworms is also essential for increasing the aeration of the soil and for improving the circulation of water since their tunnels increase the porosity of the ground by 20-30%, enabling those organisms that are not good burrowers to move around easily even at lower depths of the soil. Other than with their worm casts, earthworms contribute to the increase in the amount of N present in the ground through the excretion of NH_3 and urea, forms that are directly useable by plants; furthermore a sizeable quantity of N is returned to the soil on the death of animals, which have 72% protein content.

Within the context of edaphic fauna it is possible to identify, based on the type of locomotion, swimming organisms, capable of moving around in capillary or gravitational water, reptants that move by taking advantage of natural porosity or cavities produced by other organisms and burrowing organisms. The last-mentioned can open up cavities in the ground in various ways; for example, earthworms compress the ground outside their bodies, diplopods use their legs and backs to push the sediment upwards, the larvae of click beetles use their mandibles, while moles, scarabs and mole-crickets have specialised legs for burrowing. This continual burrowing activity contributes to the creation of spaces within the soil with the resultant increase in its porosity; the increase of the pores between the particles in turn increases the aerobic bacterial activity and the consequent speed of demolition of organic substances. This bioturbation also has positive effects on water retention, percolation processes and the development of the rhizosphere. The burrowing activity also enables the soil to be mixed and organic matter from the surface layers to be incorporated into the lower layers, while mineral substances are brought towards the surface. This process is carried out in a very evident way by the anecic earthworms discussed a little earlier, which moves vertically in the ground even reaching depths of several metres.

According to an ecological and functional classification it is possible to identify three groups of earthworms that differ in size, burrowing capability, type of food and habitat: epigeic, endogeic and anecic. The epigeic, whose sizes ranges from 0.5 to 5 cm, have a red coloured body, are poorly adapted to burrowing and have a good tolerance to low pH values. They inhabit the superficial organic layers where they feed on litter. The endogeic, whose sizes range from 1 to 8 cm, have a non-pigmented body; exposure to soil with pH values below 5 restricts their activity. They live in the first few centimetres of mineral soil, feeding on humic compost and dead roots, they are capable burrowers and they make tunnels that extend mainly horizontally. Earthworms defined as anecic, whose sizes generally are in excess of 5 cm and have a reddish-brown body, are excellent burrowers, making vertical tunnels that can reach several metres in depth; they tend to avoid soil that is asphyxiated or lacking in moisture. They live in the mineral layer of the soil but rise to the surface, mainly at night, to feed on litter. The activity of earthworms produces a significant effect, not just on the structure, but also on the chemical composition of the soil, since a large part of the organic matter ingested by earthworms is returned to the soil in a form easily used by plants. While they are feeding, earthworms also ingest large quantities of mineral substances (minimally so in the case of the epigeic), that are then mixed with the organic matter ingested and, after having been cemented with a little mucous protein, are expelled in piles called worm casts. In addition to being rich in nitrogen and other nutritive substances such as calcium, magnesium and potassium, worm casts also contain a large quantity of non-digested bacteria which proliferate easily in this sub-stratum and contribute to the humification and mineralisation of organic matter. Vermicasts have more favourable physico-chemical properties, increased microbial population, enzyme activities and nutrient mineralization that support plant growth and yeld.

Soil bacteria belong to different taxonomic classes; from the point of view of soil life, species that bind N from the air, nitrify, are very active in breaking down proteins, and convert NO_2 into free N. Ray fungi are important in breaking down cyclic compounds that are difficult to break down such as humus, lignin, etc. Figure 2 represent the soil food web.

Soil microflora includes living organisms as small as diatoms and algae up to the size of tree roots. An important member of soil microflora is mycorrhizae, fungi that form a symbiotic (mutually beneficial) relationship with plant roots. Most plants contain roots infected with mycorrhizal fungi. Mycorrhizae enhance water and nutrient absorption by increasing root surface area and accelerate mineral weathering which releases nutrients to the soil (Fisher and Binkley, 2000). Collectively, soil biota carries out enzymatic and physical processes that decompose organic matter, build soil humus, and make nutrients available for plants.

Algae occur mainly in the surface layers of the soil, where they photosynthesize with the energy of sunlight (photosynthesis), but there are also heterotrophic organisms among them. Some of the fungi are important in the breakdown of manure, in the discovery of raw phosphates, and in the transformation of toxic substances that have entered the soil, but the fungi that live together with individual plants also play a significant role, helping the higher plant to absorb nutrients.

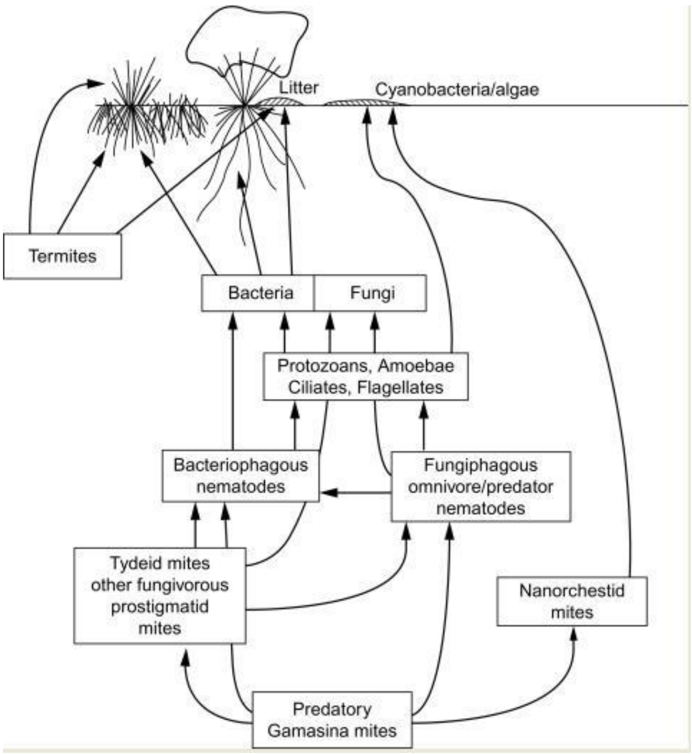

Figure 2. Diagrammatic representation of a soil food web

Microorganisms that cause plant diseases also live in the soil, they infect the soils under agricultural cultivation, and the degree of infection can increase with incorrect agrotechnical procedures and a poorly chosen crop rotation, which can lead to a decrease in crop yield and, in the case of severe infection, to the soil becoming unproductive. The proliferation of saprobiont microorganisms and the increase in their activity reduces the number of pathogenic microbes, also the reduction of pathogens, or its destruction can be achieved by using various biocides and pesticides.

THE ROLE OF SOIL FAUNA IN SOIL ECOSYSTEM PROCESSES

Some researchers have defined edaphic fauna as a “super organism” that assumes a crucial significance due to the chemico-physical and biological processes that are rooted in the soil. Soil biota play an essential role in soil functions as they are involved in processes such as the decomposition of organic matter, the formation of humus and the nutrient cycling of many elements (N, S, C). Moreover, edaphic fauna affect the porosity and aeration of, as well as the infiltration and distribution of organic matter within soil horizons. The ecosystem services provided by soil fauna are one of the most powerful arguments for the conservation of edaphic biodiversity. Decomposition of organic matter by soil organisms is crucial for the functioning of an ecosystem because of its substantial role in providing ecosystem services for plant growth and primary productivity (Maharning et al., 2008).
Due to the absence of light, which makes photosynthesis unfeasible, among the organisms populating the soil it was found very few real phytophages, unless the extend the definition of soil animals to surface organisms, or if it was considered as the pests also include fungivorous microarthropods (Wallwork, 1970).
The activity of animals, among them typically protozoa, nematodes, rotifers, certain springtails and mites, which feed on microflora, consisting of bacteria, actinomycetes and fungi (both hyphae and spores) is of crucial importance both for regulating the density and for diffusing these micro-

organisms. For example, through their faeces, springtails, which feed on fungi, can spread fungal spores that are still viable to areas as far as a few metres away from their point of origin.
The detritus food chain takes on an essential role within the soil, as it becomes the basis of the hypogean food web; in fact, many organisms such as isopods, certain myriapods, earthworms, and springtails, many species of mites, and the larvae and adults of many insects feed on the vegetable and animal detritus that is deposited on the soil. For example in the soil of a temperate forest, in which the contribution of litter each year can amount to 400 g/m^2, about 250 g/m^2 are ingested by earthworms and enchytraeids, 30-40 g/m^2 by mites and 50-60 g/m^2 by springtails.
Soil fauna performs a mainly mechanical action, whereas chemical degradation is essentially performed by fungi and bacteria, both free and intestinal symbionts of other organisms; furthermore during digestion, organic substances are enriched by enzymes that are dispersed in the soil along with the faeces, contributing to humification. Earthworms are among the most important organisms in many of the soils of the world (Figure 3).

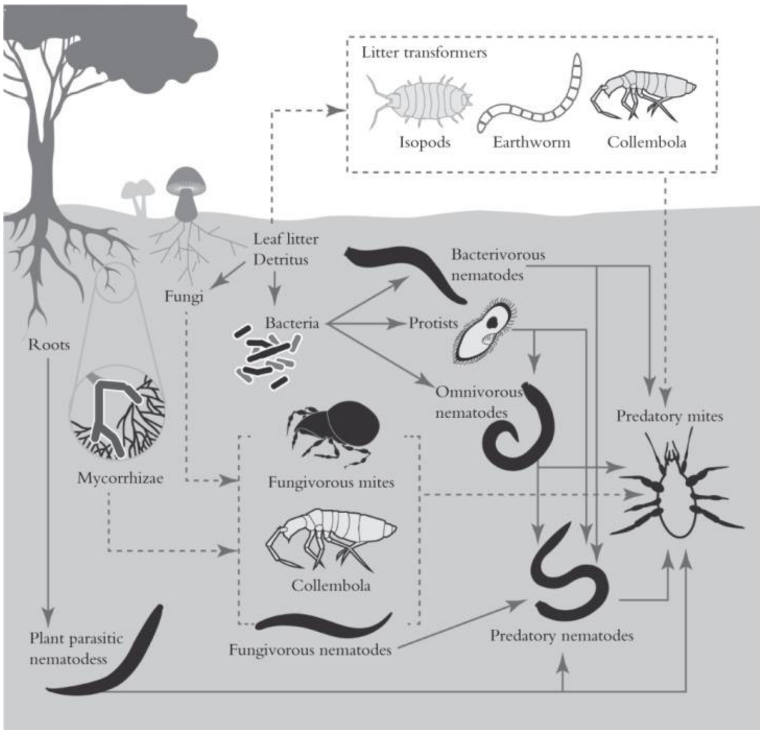

Figure 3. Functional Roles of Soil Fauna

DECOMPOSING PROCESSES AND MINERAL CIRCULATION

Decomposition is one of the most critical roles that soil biota play in an ecosystem. Without efficient decomposition, organic material would accumulate on the soil surface and nutrients would be bound within the material. Decomposition is initiated immediately when a leaf, twig, or fruit hits the ground. Once on the ground surface, biotas begin to physically break down the material, creating more surface area to which microflora can adhere.
Microbial decomposition is favored by an adequate supply of N and P, neutral to alkaline conditions, good aeration, and adequate moisture. Physical breakdown of materials by insects, earthworms, and other animals favors decomposition by exposing more surface area to microbial attack. Good soil quality and structure is extremely important for plant growth, water penetration, gas exchange, and resistance to erosion. Organic matter is also produced within the soil by plant roots. In 1 ha of a 50 year old pine forest, the soil to a depth of 200 cm may contain about 4 tones of living roots less than 0.3 mm in diameter, about 50% of which are replaced each year.

Decomposing processes and mineral circulation are of outstanding agricultural importance, because they influence the nutrient supply capacity of the soil, and can cover a significant part of the nutrient needs of plants. The release of soil organic matter, plant residues, and organic soil conditioners, as well as the breakdown of their nutrients, are processes almost entirely dependent on the activity of microorganisms. From this point of view, N is particularly unique, since the soil reserves of this macro-nutrient occur almost exclusively in organic form. The biological activity of soils is determined by several microbiological soil characteristics together, and can be inferred based on numerous microbiological soil tests. Actual soil biological activity is measured in open field conditions, while potential activity is usually measured in a laboratory, where environmental conditions (temperature, moisture content, aeration, etc.) are controlled. Human intervention, such as different farming methods, different agrotechnical factors, such as monoculture cultivation or even crop rotation, soil cultivation, fertilization, has a great impact on the number, composition, and life activity of the microorganisms living in the soil, and thus on the activity and fertility of the soil, and more safety than the use of chemicals for soil improvement. It is not only the quantification of microbiomes that are important, but also how the microbial composition of the soil, the diversity of species, i.e. biodiversity, changes as a result of cultivation. As a result of one-sided tillage and the excessive use of chemicals, diversity decreases, and thanks to this, the processes taking place in the soil also decrease. All of this leads to the deterioration of the soil structure and a greater leaching of nutrients, possibly erosion.

The most frequently occurring bacteria belonged to the following genera: *Bacillus, Brevundimonas, Cellulomonas, Enterobacter, Micrococcus, Pseudomonas* and *Streptomyces.* The most common isolates were representatives of the genera *Alternaria, Aspergillus, Geotrichum, Penicillium, Rhizopus and Trichoderma and Saccharomyces*.

Many soil microbiotas produce enzymes (phosphatases) that decompose various organic P compounds (nucleoproteins and leciteins) in the soil. In this decomposition organic P is converted into phosphoric acid which combines with the soil bases to produce salts of calcium (Ca^{2+}), magnesium (Mg^{2+}) and iron (Fe^{2+}).

SOIL AND RHIZOSPHERIC MICROFLORA

Globally, an increasing population needs a high yield of crops to compete for this competition, but it must be achieved without, or by minimizing, the application of synthetic products due to high concern about environmental protection. Still, the main source of crop improvement in the agriculture sector is the practice of applying synthetic products, such as commercial fertilizers, nutrient supplements, and pesticides. This action has hazardous effects on the environment and human and livestock health. The farmer communities are convinced to change their old practices by using alternative products that could be environmentally friendly. The biofertilizers and pesticides consist of non-pathogenic microbiomes; this uniqueness in nature facilitates attaining sustainable agriculture and environmental protection from chemical hazards. Additionally, bioformulations might be the best alternative option to reduce environmental degradation and the threat to human health.

Soil and rhizospheric microbiomes especially plant growth-promoting rhizomicrobes (PGPR) have especial roles for promoting the soil quality. In the PGPR tests, the pathogenic opposition of the roots, the production of phytohormones, cyan, siderophores, their ability to dissolve phosphate, and their sensitivity to antibiotics were assessed. The ability to suppress disease was generally greater when more time passed between soil treatments and planting. Increasing the microbiological activity of the soil and the targeted use of microorganisms that compete with pathogenic organisms in the soil are tools that can be used to induce the occurrence of plant diseases less frequently by introducing organic substances into the soil. The specificity of the host plant is clarified during the purchase. If possible, apply the inoculants in spring and autumn, when it is not too hot and dry. Heat and dryness damage microbes. In order to optimize soil life, it is recommended to use broad-spectrum inoculants, because then we can expect good crop results with greater certainty. There is only one known vaccine (EM1 activated) that has been consciously designed in such a way that the microorganisms contained in it multiply and live side by side.

Nitrogen and phosphorus are critical for the vegetation ecosystem and two of the most insufficient nutrients in the soil. In agriculture practice, many chemical fertilizers are being applied to soil to improve soil nutrients and yield. This farming procedure poses considerable environmental risks which affect agricultural sustainability. As robust soil microbiomes, PGPR have emerged as an environmentally friendly way of maintaining and improving the soil's available nitrogen and phosphorus. As a special PGPR, rhizospheric diazotrophs can fix N in the rhizosphere and promote plant growth. However, the mechanisms and influences of rhizospheric N_2-fixation (NF) are not well researched as symbiotic NF lacks summarizing. Phosphate-solubilizing bacteria (PSB) are important members of PGPR. They can dissolve both insoluble mineral and organic phosphate in soil and enhance the P uptake of plants. The application of PSB can significantly increase plant biomass and yield. Co-inoculating PSB with other PGPR shows better performance in plant growth promotion, and the mechanisms are more complicated.

SOIL ENZYMATIC ACTIVITIES

In addition to the physico-chemical parameters, plant cover and microbial activity, the nutrient circulation of the soil are also determined by the activity of the free, even more, the accumulated enzyme fractions. It retains the activity of the accumulated enzyme fraction even if the microbial activity of the soil has ceased or the plant remains have decomposed. Within the accumulated fraction, the immobilized enzymes are chemically bound and protected against denaturation, which is carried out in a model experiment. The maintenance of soil fertility depends on the activity of the microbial biomass present in it. This biomass is a relatively small fraction (1–3%) of the soil's organic matter stock, which, in turn, plays a fundamentally important role in the biological cycle of all the main nutrients required by plants. The activity of hydrolytic enzymes in the soil serves as an indicator of changes in soil fertility, as it is related to C-, N- and P mineralization. Dehydrogenase activity is also closely related to soil microbial activity. Protease activity plays a significant role in the breakdown of N-containing organic materials, during which NH_4 is formed. Urease, on the other hand, can directly break down N-containing urea and produce NH_4. Several enzymes are involved in the breakdown of complex organic-P and -C-containing materials in the soil: acid and alkaline phosphatases stimulate the hydrolysis of organic P-containing parts into phosphates, and β-glucosidase stimulates the hydrolysis of glucose-containing parts. Soil enzymatic activities are involved in soil nutrient recycling dynamics and can catalyze the conversion of nutrient from unavailable to forms readily assimilable by plants and microorganisms. Soil enzymatic activities are believed to be able to discriminate between soil management treatments probably because they are related to microbial biomass, which is sensitive to such treatments. The enzymatic activity was stimulated by increasing organic matter content (Pathak and Rao, 1998). Enzymatic activity is generally higher in rhizosphere than in bulk soil, as a result of a greater microbial activity sustained by exudates, actively or passively released by roots, or due to the release of enzymes from plant roots (Pinton et al., 2001). Among soil enzymatic activities, hydrolase activities of rhizosphere are supposed to play an important role in plant nutrition. For example, the hydrolysis of organic phosphate monoesters by phosphomonoesterases can account for 30-80% of P taken up by plants in agricultural soils (Gilbert at al., 1999). Enzymes are potential indicators of the extent to which soil disturbance by a given activity may affect the immediate environment (Pascual et al., 2000).
Dehydrogenase activity has correlated well with other measures of microbial activity in some studies but has been poorly correlated in others. Enzymes are potential indicators of the extent to which soil disturbance by a given activity may affect the immediate environment (Pascual et al., 2000). Hydrolase activities in the soil can be quantitatively important for plant nutrition; Measurement of soil hydrolases provides an early indication of changes in soil fertility, since they are related to the mineralization of such important nutrients elements as N, P, C (Ceccanti and Garcia, 1994). Protease activity is involved in the hydrolysis of N compounds to NH_4, using low-molecular-weight protein

substrates and urease is responsible for breaking down urea into ammonium. Phosphotases catalyse the hydrolysis of organic phosphorus compounds to phosphates and ß-glucosidase catalyses the hydrolysis of the ends unreduced chains of b-D-glucoside to form ß-D-glucose, and indicates the potential for soil organic matter decomposition

SOIL MICROBIAL ACTIVITIES

In general, the microbial biomass of the soil is recorded as a decomposing agent of the organic substances that have entered the soil, apart from this, the importance of its mass in terms of nutrient recycling and degradation processes is little recognized. Soil biomass is the regulator of virtually all nutrient circulation and organic matter storage cycles, as well as the formation of micro-aggregates, which is an essential process in terms of water movement in the soil and soil aeration. Studies investigating the relationship between tillage methods and procedures and soil microbial biomass mostly report on changes in population density and, as a result, soil fertility, while less attention has been paid to the use of biomass as an indicator of soil pollution. The abiotic stress effects caused by heavy metals and various inorganic and organic substances can cause the functional disturbance of soil microorganisms, the denaturation of their proteins, and the disintegration of cell membranes, thus having a harmful effect on the reproduction, morphology and metabolism of microbes. As a result, the contamination of soils with heavy metals can significantly reduce the size and activity of the microbial biomass occurring there. When the mentioned microbial preparations are used, living organisms enter the soil which, through their life processes, promote N, P, K, various micro- (e.g. Zn, Cu, Fe, Mn, Mo, etc.) and macro- (e.g. (S, Ca, Mg, etc.) elements, they bind N and help break down plant residues. All natural biologically active soil conditioners and soil improvers increase the resistance of plants to various pathogens and abiotic stress factors (drought, frost). Only plants with sufficient immunity can deal with the various harmful effects of the environment naturally.

Soil microorganisms are important components in the natural soil sub-ecosystem because not only can they contribute to nutrient availability in the soil, but also bind soil particles into stable aggregates, which improve soil structure and reduce erosion potential (Shetty et al., 1994). Studies of soil microbiota enabled soil biologist to set up a new understanding of soil as a combination of various ecological microenvironments. This concept explains the unique character of soil as a specific biotope, possessing the highest life density and diversity of all environments of the earth. The free – living components of the soil biota are the bacteria, fungi, algae and the fauna. Within each of the free living components, there exist a broad range of morphological and physiological characteristics that has led tom the naming of a large number of taxa for each group (Paul and Clark, 1988).

Microbial activity in soil is controlled by several environmental factors, such as availability of C, mineral nutrients and growth factors, availability water, favourable temperature and pH, composition of soil microflora and ecological interactions between microorganisms (Nannipieri et al., 2003). Microorganisms play an important role in soil fertility because they oxidise organic matter and promote the biogeochemical cycles of C, N, P, and S. Soil enzymatic activities are involved in soil nutrient recycling, dynamics and can catalyze the conversion of nutrient from unavailable to forms readily assimilable by plants and microorganisms. Soil enzymatic activities are believed to be able to discriminate between soil management treatments (Dick, 1993) probably because they are related to microbial biomass, which is sensitive to such treatments.

Indeed, rhizosphere microorganisms can both mobilise and immobilise plant nutrients (C, N and S) and can produce growth promoting substances, such as phytohormones, as well as phytotoxins. Beneficial bacteria such *Pseudomonas, Bacillus, Arthrobacter, etc.* are major component of the microbial flora which live in close association with various types of plants. Their association with plant materials has been related both to their antagonistic activities towards pathogens and to their ability to colonise and produce plant growth promoting compounds within the rhizosphere (Cook et al., 1995). In order to understand microbial behaviour in a certain habitat, it is necessary to know their physiological characterisation. It is important to measure the soil biochemical and biological parameters related to microbial activity in order to evaluate soil quality and productivity (Garcia et al., 1997). Because microorganisms play an important role in establishing biogeochemical cycles and facilitate the development of plant cover and has been assessed frequently through biological and biochemical parameters such as biomass C and enzymatic activities (Caravaca et al., 2005).

In the great majority of natural communities, the primary producers depend heavily on microbiomes. These include the organisms that decompose and mineralize organic detritus, others that promote plant growth and suppress plant pathogens and some that build soil structure. They help the roots take up nutrients, brings nutrient elements into the ecosystems from atmosphere or mineral reserves, break down detritus, release mineral elements in soluble forms and protect the roots from pathogens. They also hold soil aggregates together, creating channels through which roots grow, soil animals move and water percolates. Bacteria occupy a wide variety of habitats and perform many ecological functions. They produce a vast array of chemical metabolites, many of which affect other organisms. Some fix carbon dioxide (CO_2) into organic compounds and are part of the primary level of the food chain. Many are extremely important in cycling nutrients in the soil and in water, making the nutrients more or less available to plants and other organisms.

Air, water, and soil quality can be altered by the activities of bacteria. Soil microbiomes play important roles in maintaining soil quality and plant production, and they have a great influence on soil hydrolysis reactions and these in turn reflected in the natural recycles of C, N, P and other elements. 80-90% of the bioprocesses in soil are reactions mediated by microbiomes.

The study of diversity, distribution, and behaviour of microbiotas in soil habitats is essential for a broad understanding of soil health. The physiological response of bacterial populations following introduction into the natural soil environment is poorly understood. Yet information on the physiology of bacteria in soil in relation to their resistance to soil factors is required to obtain a better in their survival strategies so that effectiveness of bacterial releases can be predicted (Overbeek et al., 2006). Bacteria exhibit many ways of exploiting their environments. Species differ greatly in their biochemical capabilities and utilize many different substrates. Some form mutualistic associations with other bacterial species or other organisms. Most bacteria are exposed to gradients either of substances such as nutrients or of physical factors such as temperature and radiation, and they often have adaptations which allow them to find or remain in the location in these gradients which best meets their needs. Bacterial cells introduced into soil should be able to rapidly adapt to soil conditions in order to persist and reproduce. Survival strategies depend on the physiological adaptation in the introduced cells, such as adaptation to nutrient-limited conditions and/or other physical chemical conditions, efficient utilization of root-released compounds or specific interactions with plants. Therefore bacteria which are well adapted to the soil environment, i.e. that survive and persist, probably have an efficient response to stressful soil conditions, activating molecular mechanisms necessary for their adaptation and survival (Overbeek and elsas, 1997). Soil contains a high number and diversity of microbiomes withy a wide range of metabolic activities and physiological properties. The distribution of bacteria is governed by limiting factors, and each species will exist where levels of factors such as temperature, moisture, nutrient availability, and pH fall within its specific range of tolerance. Because soil is a complex system, the determination of where a soil microorganisms would be found based on limiting factors must take into account interactions between environmental factors, alterations of the organism's range of tolerance by other factors, and variations of environmental factors in both time and space. The range of environmental conditions over which micro organisms can maintain growth and activity increases their importance. Extreme conditions may reduce the activity of some microbiomes but will stimulate that of others, and in many extreme environments microbes are the only contributors to nutrient recycling. Two conditions stressful to bacteria in soil are nutrient (mainly C) starvation and low water activity. The availability of organic nutrients in soil largely depends on the soil sites occupied by the bacterial cells or microcolonies.

Oligotrophy is probably locally dispersed through most soils. Therefore, soil in general can be regarded as a grossly oligotrophic environment (Morita and Moyer 1989). Both starvation and low water activity represent typical stress conditions general in most soil. Other stress conditions like extreme temperatures and pH values or toxic compounds may be more specifically related to the climate geographic location or soil type and site (Overbeeek and Elsas, 1997). The majority of known bacterial species re chemoorganotrophic and are commponly referred to as heterotrophs. Both energy source and C sources are useful for describing basic physiological differences among bacteria as well as among biotic organisms generally. Some functional groups of microbiomes are as following:(1) heterotrophs, (2) N_2-fixers, (3) nitrifyers, (4) denitrifyers, (6) phosphorus, calcium, and potassium solubilizers. These biochemical changes that take place in the soil prove that microorganisms perform numerous essential functions that contribute to the productivity of soil.

Heterotrophs

Heterotrophic bacteria have been assumed to be the dominant types among soil bacteria, since the consumption and mineralization of organic materials represent most of the energy flux though the soil biota. For this reason, all attemptsto culture the majority of soil bacteria has concentrated on the heterotrophic bacteria (Bakken, 1988). For heterotrophic bacteria, it is the distribution of their organic substrates which primarily determines the occurrence of pockets of activity, sometimes referred to as microhabitats. The majority of the organic substrates entering soil are either insoluble or are soluble but packaged in cells. Nevertheless, some soluble materials will diffuse into the soil water and be leached out of the surface horizons (Nedwell and Grey, 1987).

The other components of the microbial C cycle are the conversion of organic compounds into other organic compounds, and the breakdown of organic compounds with the accompanying release of energy and CO_2. Those bacteria that fix CO_2 will also break down organic matter in respiration (Atlas and Bartha 1987). Many bacteria are able to grow heterotrophically, obtaining all their energy and cellular C from pre-existing organic material. They are extremely important in the formation of humus in soil, the cycling of other minerals tied up in organic matter, and the prevention of buildup of dead organic materials.

Heterotrophic bacteria are found in many diverse groups, can be aerobic or anaerobic, and are capable of utilizing a broad array of organic compounds. Microbiomes are unique in their ability to carry out anaerobic or fermentative degradation of organic matter, although C turnover is greater under aerobic conditions. They are responsible for the digestion of polymers such as cellulose and lignin, which multicellular organisms are unable to utilize. Some are able to break down man-made synthetic materials (Atlas and Bartha 1987).

Heterotrophic bacteria play an important role in maintaining soil structure by their involvement in the formation and stabilization of water-stable soil aggregates. Polysaccharides are one of the major agents of soil aggregation, and it is thought that the soil polysaccharides are likely to be of microbial origin and are more resistant to breakdown than animal and plant polysaccharides. Bacteria also release other organic compounds which affect aggregate structure and other soil properties such as water holding capacity. Bacterial cells themselves can hold soil particles together by adhesion or mechanical binding, and even after the bacteria die, their remains continue to bind the particles (Tisdall and Oades 1982). Many heterotrophic bacteria are specialized to the environmental conditions under which they are found. Plant species had strong influence on soil microbial organisms and their activity. According to Merckx et al. (1987), obviously the input of nutrient by the roots into surrounding soil as well as the mineral nutrients levels in the soil are of considerable importance. It was mentioned that root exudates play a key role in the selective stimulation of microbiomes and the plants have an important effect on soil microbiology, due releasing different nutrients and organic compounds into the soil (Grayston et al., 1998).

Oligotrophic bacteria

By general definition, an oligotrophic bacteria predominate in a nutrient poor environment, is isolated using a low nutrient medium and shows relatively high growth rates in cultures at low concentrations of energy yielding substrates (Hirsch et al., 1979). One of the earliest attempts to relate the growth and substrate utilization of soil microbiomes was made by Winogradskiy (1924). The author distinguished between the "zymogenous" microorganisms, which existed mainly in a resting phase with brief periods of activity in the presence of available substrates, and the "autochtonous" microbiomes, which were more or less continually and slowly active. Despite the current paucity for the occurrence of strictly oligotrophic bacteria in soil, it is often regarded as a nutrient poor environment. Oligotrophic bacteria (oligotrophs) are microbiomes that grow in extremely nutritionally deficient conditions in which the concentrations of organic substances are low.

Nitrogen fixers

Nitrogen (N) is an extremely important element to all forms of life. It is found in amino acids and many other organic compounds. It exists in stable valence states from -3 to +5. Large amounts of N are in N_2 gas in the atmosphere, but utilizable combined forms are limiting in many ecosystems. Ammonium (NH_4^+) and nitrate (NO_3^-), inorganic salts of N, are water-soluble, and are the main forms used by living organisms.

Nitrogen-Fixation (N_2 – NH_3) is carried out only by prokaryotes which may be symbiotic or free living. N_2-fixation requires a considerable amount of energy and it has been calculated that in bulk soil there is not enough available C. However round the roots there may be sufficient exudates to allow some N_2-fixation, the production of which could be available to the plant. Most of oligonitrophilic bacteria have ability to fix N_2. In N poor soils they are widely distributed to compare to other soil.

Biological N_2-fixation is a sensitive indicator of soil contamination with heavy metals. The N_2-fixation of freely pre-heterotrophic microbes, the reproduction and N_2-fixation of cyanobacteria (formerly blue-green algae), and the efficiency of the symbiont nitrogen-fixing *Rhizobium* can decrease in the case of high heavy metal content in soils. The contribution of the activity of free-living soil microorganisms to the available N stock of the soil is relatively small and its agricultural importance is probably small.

For example, free-living heterotrophic bacteria can fix less than 5 kg/ha/year of N, while N_2-fixation by cyanobacteria can reach 10–50 kg N/ha/year. However, symbiont N_2-fixation provides a significant amount of nitrogen to the soil and is of outstanding importance for agricultural production. For example, the amount of N bound by white clover can reach 100-200 kg N/ha/year.

Nitrifying bacteria

In nitrification process, the NH_3 or NH_4^+ is oxidized to NO_2^- and then to NO_3^-. Nitrate is readily taken up by plants and because of its negative charge, moves freely through soil. Both NO_3^- and NO_2^- are also more susceptible to leaching than is NH_4^+. They can become a health hazard when they reach groundwater. Nitrification can also prevent N losses in soils where NH_3 volatilization is a major factor. Nitrification is limited to species of a few genera of aerobic autotrophic bacteria.

Nitrifies are found in most aerobic environments where organic matter is mineralized, and on rocks where NH_4^+ is liberated through weathering. Many are restricted to specific environments. The oxidation of NH_3^- and NH_4^+ to NO_2^- is carried out in most soils by species of *Nitrosomonas*, while the oxidation of NO_2^- to NO_3^- is carried out by *Nitrobacter* (Bock et al., 1990). Species of *Nitrosospira*, *Nitrosococcus*, and *Nitrosolobus* can also be involved in the former oxidation, while species of *Nitrospira*. and *Nitrococcus* can be involved in the latter. The two processes are usually closely coupled. Both oxidations are energy yielding, and the bacteria involved are chemolithotrophic, utilizing the energy to fix CO_2. Because the energy yields of the oxidations are small, large amounts of N are turned over for relatively small cell yields. Nitrification is inhibited by anaerobic conditions or high acidity.

PLANT RHIZOSPHERE

Rhizosphere is a wealthy location of microbes, ecological niche and should be explored for potential plant growth promoting rhizomicrobiomes (PGPR), which developing as bio inoculants for interact with plant roots and enhancement of yield of crop plants. There are several PGPR inoculants that seems to promote plant growth through different mechanism such as plant growth hormone production, nutrient acquisition and plant disease suppression. PGPR are inhabiting rhizosphere are capable of producing plant growth regulators such as auxin, gibberellins and ethylene. Indole acetic acid is a naturally occurring auxin which involves in cellular development and physiological processes in plants. Different soil microorganisms including bacteria (Stein et al., 1990), fungi (Finnie and Van Staden, 1985) and algae (Rifat Hayat et al., 2010) are capable of producing physiologically active quantities of auxins, which may exert prominent effects on plant growth and development. The application of single and combined application of microbes could increase plant growth of cotton due to result of slightly deleterious effect of strain causing increased root leakage/damage, which allows a greater population of aggressive rhizosphere and root colonizers such as Trichoderma viride and Pseudomonas fluorescence (Shanmugaiah et al., 2009)

Hiltner in 1904 recognised the potential importance of microbial activities associated with root systems in plant nutrition and coined the term "rhizosphere"to describe the zone of intense microbial activity around roots of the leguminousae. This term is now used in a more general sense to describe soil influenced physically and or chemically by any root system (Chanway, 2002). The rhizosphere is first of all an unique hot spot in the soil at the viewpoint of microbial ecology as soil microbiomes are considerably stimulated in the vicinity of the roots, as a consequence of the release by roots of a range of C compounds (Hinsinger and Marschner, 2006, Hinsenger et al., 2009). The region of soil surrounding and including the plant root (the rhizosphere) is of crucial importance for plant health and nutrition. It has a high level of microbial activity, particularly because of nutrients secreted by plant roots in the form of soluble exudates as amino acids, organic acids and other photosynthates. The rhizosphere is relatively nutrient rich because 40 % of the photosynthates moving into roots are lost to the soil in the form of soluble exudates, mucilage, and shed. It is a habitat for a vast interactive community of rhizotrophic microorganisms whose activities largely determine the physico-chemical properties of the rhizosphere soil. Exudates from roots have long been recognised as a major potential source of energy for many saprophytic bacteria in soil, being the prime cause of the rhizosphere effect. There is considerable amount of evidence suggesting that loss of soluble organic substances from roots is significantly stimulated by the presence of microbes around them.

Understanding the complexity of this environment and how the microbial community adapts and responds to alterations in the physical, chemical and biological properties of the rhizosphere remains a significant challenge for plant and microbial biologists (Rainey, 1999). The interactions between microbiomes and roots are now considered to occur in the outer, invaded cortical layer, on the rhizoplane when this can be distinguished and also in the surrounding soil, the rhizosphere. Because all soil borne nutrients obtained by the plant rot must pass through the rhizosphere, the potential for microbes to alter these compounds in a way that will affect plant growth is great (Chanway, 2002).

The term "endorhizosphere" may now appropriately be used to describe the multilayered microenvironment, which includes a mucoid layer of plant or microbe derived polysaccharide, the epidermal layer including the root hairs, and the cortical layer. The rhizoplane (root) surface should be defined as the epidermal layer, including its associated polysaccharide matrix.

By comparison ectorhizosphere comprises the rhizosphere soil, which usually extends a few millimetres from the root surface (Sorensen, 1997). The important role of the root cap is its production of mucilage (polysaccharide), which covers epidermal cells and acts as a lubricant while the root advances through soil. It is interesting that the mucilage layer on the young root may contain the chemical components of importance in host-pathogen or host symbiont recognition system. In the young plant root, the uptake of nutrients and water occurs through an intact epidermal layer including the root hairs. Normally, this layer is quite short-lived as a result of the mechanical tension or desiccation of the rhizosphere (Christensen 1995). Living epidermal cells and root hairs become densely colonised by micro organisms, notably bacteria, which depend completely on simple organic molecules exuded from the plant cells (Sorensen, 1997). The exudates are typically carbohydrate monomers (sugars), amino acids, and organic acids, which are suitable substrates for a wide range of rhizobacteria. Roots form an unstable habitat for micro-organisms for the interfaces between the root, soil and microbes are continually changing. Healthy, vigorous root tip elongate so rapidly that bacteria and fungi cannot grow fast enough to colonize them from pre-existing root parts and they are colonized from the soil. The rhizosphere soil contains more soluble sugars but less insoluble material than the surrounding soil and there is less nitrogen but more polyphenols (Campbell, 1985).

RHIZOSPHERE MICROBIOMES

Soil Microbiomes are important for agriculture in rder to promote the recycling the plant nutrients and reduce the need for chemical fertilisers. Plant growth promoting rhizomicrobiomes (PGPR) are able to exert a beneficial effect upon plant growth. Biological N_2- fixation (BNF) provides a major source of N for plants as a part of environmentally friendly agricultural practices. Apart from fixing N_2, PGPR can affect plant growth directly by the synthesis of phytohormones and vitamins, inhibiting plant ethylene synthesis, enhancing stress resistance, improving nutrient uptake, solubilising inorganic phosphate, and mineralising organic phosphate.

In early work on the rhizosphere research the ratio of organism count in rhizosphere soil to count in root-free soil were determined for different plant species and for single species in different soils, under differing climatic regimes and at different stages of phenology. Total microbial counts were commonly found to be increased 10 to 50 fold in the rhizosphere. The rhizosphere harbours a large and diverse community of prokaryotic and eukaryotic microbiomes that interact and compete with each other and with the plant root. The concentration of bacteria that is found around the roots of plants is generally much greater than the bacterial density, or concentration, that is found in the rest of the soil (Lynch 1990). Many bacteria are intimately associated with plants roots. In a zone surrounding the root known as the rhizosphere, the populations of microorganisms differ from those in the surrounding soil both in total number and in species distribution (Atlas and Bartha 1987). The plant alters rhizosphere populations through root exudation and the sloughing of root cells. Most plants interact with specific fungi to form associations known as mycorrhizae, and these have considerable effects on populations of rhizosphere bacteria (Meyer and Linderman 1984).

The rhizosphere is known to harbour proportionately more Gve- bacteria *Pseudomonas*, *Achromobacter* and denitrifiers and fewer Gve+ and Gram variable forms (*Bacillus*, *Arthrobacter*). Increases in the rhizosphere microbiomes are accompanied by heightened faunal activity, especially in those groups that are grazers on the microflora or on roots (Paul and Clark, 1988).

The rhizosphere harbours a large and diverse community of prokaryotic and eukaryotic microbes that interact and compete with each other and with the plant root. Activity of any one member of this community affects the growth and the physiology of the others, and also affects the physical and chemical properties of the soil.

A continuous interaction exists between the plant roots and the rhizotrophic microbiomes and within the various groups of these microbiotas which have an important influences on plant growth. The microbial composition in the rhizosphere often differs greatly from that of the surrounding soil and from one plant species to another, as a result of diverse plant microbe interactions. There are different groups of microbiomes playing in the rhizosphere. Some of them may be deleterious (causing diseases, -) and others may be supporting the plant growth (stimulating the growth, +) and some others may not affect the plant developments (neutral, 0) at all. They are mainly bacteria, fungi, and actinobacteria.

The microbial composition in the rhizosphere often varies greatly from that of the surrounding soil and from one plant species to another, as a result of diverse plant microbe interactions. Some bacteria, such as *Pseudomonas* and *Flavobacterium* spp. tend to be more predominant in the rhizosphere than others, such as *Arthrobacter* and *Bacillus* spp. (Alexander, 1977).

Because of the wide range of microbiomes that is stimulated in the rhizosphere, it is difficult to assess the influence of rhizosphere microbial activity on plant growth. The interaction between bacteria and the roots of plants may be beneficial, harmful, or neutral for the plant. Rhizosphere microbes can both mobilise and immobilise plant nutrients, and can produce growth promoting substances, such as gibberellins, as well as phytotoxins. Rhizosphere microbes, such as species of the fungi *Fusarium*, *Gaeumannomyces* and *Rhizoctonia* can be plant pathogens, as well as antagonist against those pathogens.

The challenges for the next decades include understanding of the behaviour of microbiomes in their natural and often complex habitats, such as the rhizosphere (Lugtenberg et al., 2002). The overall in the rhizosphere, that is on the plant root or its close vicinity, bacteria are abundantly present, most often organized in microcolonies. Some of these rhizobacteria not only benefit from the nutrients secreted by the plant root but also beneficially influence the plant in a direct or indirect way, resulting in a stimulation of its growth (Bloemberg and Lugtenberg 2001).

Rhizosphere bacteria depend on plant root exudates- which are low molecular weight, easily oxidizable compounds – for much of their nutrition (Rovira, 1965). Microbial processes in the rhizosphere of different crop plants are crucial to agriculture. Many rhizosphere colonizing bacteria, including *Bacillus, Azospirillum, Pseudomonas*, etc., typically produce substances that stimulate plant growth or inhibit root pathogens (Glick, 1995). Previous studies of bacteria in salt-affected soils lies behind those on halophiles in extremely saline soils and some bacterial groups related to the nitrogen cycle. Culturability of micro organisms on laboratory media has been the basis for the majority of studies on microbial populations in the rhizosphere. Even cell viability has often determined from estimates of colony forming units (CFU) as percentage of total counts. This figure is variable, but estimate of 10% viability of bacterial population in rhizosphere soil are common (Rovira et al., 1965).

PLANT GROWTH PROMOTING RHIZMICROBIOMES

Plant growth promoting rhizomicrobiomes (PGPR) are the living microbiomes which colonise the rhizosphere or the interior of the plant or promotes growth by increasing the supply or availability of primary nutrients to the host plant when applied to the seed, plant surface, or soil. Bacteria having growth promoting property in plants through the control of deleterious organisms have been categorized as biopesticides and are different from biofertlizers. However, some PGPR promote growth of plants by acting both as biofertilizer and biopesticides. PGPR can be Rhizospheric or Endophytic in nature depending upon their relationship with their hosts. The solubilization of ‘P’ in the rhizosphere is the most common mode of action that increases nutrient availability to host plants. Insoluble inorganic ‘P’ associated with the solid phase can be adsorbed to the surface of soil constituents which occur as Ca, Fe or Al minerals. Mineral ‘P’ is further released and made available to plant mostly by the action of phosphate solubilizing microorganisms. The addition of rock phosphate significantly increased N, P and total plant biomass by arbuscular mycorrhizal infection. P-solubilization ability of the microorganisms is considered to be one of the most important traits associated with plant phosphate nutrition.

Phosphate solubilizing microorganisms (PSM) includes bacteria including symbiotic N_2-fixers like *Rhizobium* as well as fungi. Among bacteria most efficient phosphate solubilizers belong to genera *Bacillus* and *Pseudomonas*. Cultures isolated from rhizospheric and non-rhizospheric soils solubilize phosphate with a fall in pH due to the production of organic acids but no correlation could be established between acidic pH and quantity of P_2O_5 liberated. Rise in pH observed later, may be due to organic acid produced by the organisms.

Many soil bacteria e.g., *Pseudomonas*, *Rhizobium*, *Enterobactor*, *Bacillus Clostridium*, etc possess the ability to solubilize insoluble inorganic phosphates and make them available to the plants. Production of organic acids i.e. lactic, gluconic, fumeric, succinic & acetic acid by these microorganisms results in the solubilizing effect. Also, these microrganisms are also known to produce amino acids, vitamins and growth promoting substances like Indole Acetic Acid (IAA) and Gibberellic Acid (GA), which results in better growth of plants.

There are evidences that show that many PGPR increase the availability of nutrients for the plants in the rhizosphere. The mode of action of the PGPR involves solubilization of available forms of nutrients and/or siderophore production which helps in facilitating the transport of certain nutrients.

Heavy metal toxicity to plants can be reduced by the use of PGPR, e.g., free living soil bacteria, these exert beneficial effects on plant development when they are applied to seed or incorporated in the soil. There has been a tremendous work on P-solubilizing, metal resistant, siderophore producing and PGPR and their mutants.

Phosphate Solubilizing Bacteria

Phosphorus (P) is one of the major nutrients to plants and microorganisms second to N in requirement. It is involved in several physiological processes; approximately 95–99% of phosphorus is present in the soil as insoluble phosphates (PO_4^{3-}) and cannot be utilized by the plants. Organic phosphorus constitutes a large proportion of the total phosphorus in several soils

Mineralization of most organic P compound is carried out by means of phosphatase enzymes. The major source of phosphatase activity in soil is considered to be of the microbial origin. To increase the availability of P for plants, it was found that large numbers of soil microbes including bacteria which are known as ‘Phosphate Solubilizing Bacteria (PSB).’ These kind of bacteria are used for the conversion of soil organic P in to the soluble inorganic forms.

The solubility of P is mobilized by phosphoric acids. This is done by different microorganisms such as *Pseudomonas*, *Mycobacterium*, *Micrococcus* etc. These microorganisms produce acids like sulphuric acid and nitric acid which ultimately help in mobilizing P. The process of conversion of insoluble phosphates into soluble once is known as ‘solubilization’.

Some PSB can accumulate heavy metals and are thus beneficial in eradicating heavy metal Phytotoxicity and promoting growth in plants. Out of added P fertilizer only 10-20% is available for the plants. The rest remains in the soil as insoluble PO_4^{3-} in the form of rock phosphate and tri-calcium phosphate. The PSB significantly convert this insoluble inorganic phosphate and makes it available to the plants. PSB are a group of beneficial bacteria capable of hydrolysing organic and inorganic P from insoluble compounds.

Generally the mechanism of mineral phosphate solubilization by PSB strains is associated with the release of low molecular weight organic acids through which their hydroxyl and carboxyl groups chelate the cations bound to phosphate, thereby converting it into soluble forms. In addition, some PSB produce phosphatase like phytase that hydrolyse organic forms of phosphate compounds efficiently. One or both types of PSB have been introduced to agricultural community as phosphate 'Biofertilizer'.

Role of PSMs in plant disease managemen

Disease causing plant microorganisms adversely affect the crop yields by significantly reducing plant performance and crop quality. The usual method for the control of such phytopathogens is to apply chemical pesticides, but this strategy has led to increased concerns over environmental contamination and has also resulted in the development of resistance against the individual chemical over the time. This needs a constant development of new pesticides77. In this context, rhizobacteria that can provide biocontrol of disease or insect pests (biopesticides) are considered an effective alternative to chemical pesticides (Zahir et al., 2004). A large number of mechanisms are involved in the biocontrol and can involve direct antagonism via production of antibiotics, siderophores, HCN, hydrolytic enzymes (chitinases, proteases, lipases, etc.), or indirect mechanisms in which the biocontrol organisms act as a probiotic by competing with the pathogen for a niche (infection and nutrient sites).

Biocontrol can also be mediated by activation of the acquired systemic resistance (SAR), induced systemic resistance (ISR) responses in plants, and by modification of hormonal levels in the plant tissues (van Loon, 2007; Martínez-Viveros, et al., 2010)

Amendment of soil with decomposable organic matter or plant growth promoting microorganisms is one of the cheapest, hazard-free and environmental-friendly effective methods of modifying soil environment. It was observed that continuous extensive agricultural practices that depend heavily on use of chemical fertilizers have resulted in loss of organic matter, an increase in acidity, and accumulation of toxic elements in cultivated soils creating an environment favorable for development of certain soil-born pathogens. The reduction in common scab of potato (S. scabies) by green manuring through prevention of the buildup of inoculums was the first report of organic amendments as a means of disease suppression. Since this observation of Sanford (1926), numerous reports have appeared regarding the beneficial effects of organic and inorganic amendments of soil

DIVERSITY OF RHIZOBACTERIA

Microbial diversity studies are important in order to understand the microbial ecology in soil and other ecosystems (Garland, and Mills, 1994). Diversity can be regarded as the amount and distribution of genetic information in a natural community. A representative estimate of microbial diversity is a prerequisite for understanding the functional activity of microbiomes in such ecosystems (Simon, et al., 1991). Studies in microbial diversity are important in order to understand the role of microbiomes in the ecology of soil and also in other ecosystems. Analysis of the genotypic and phenotypic characteristics of indigenous rhizobacteria can help to clarify the mechanism of interactions between them and plant roots (Tripathi, et al. 2002).

Alexandre (1977) has made a brave attempt to summarise a great number of classic taxonomical studies of bacteria prevalent in soil and presents the following ranges (%): *Arthrobacter* 5 – 60%, *Bacillus* 7-67%, *Pseudomonas* 3-15%, *Agrobacterium* up to 20%, *Alcaligenes* 2-12%. *Flavobacterium* 2-10%. The arid and semi arid ecosystems may provide an excellent natural research field and information on microbial physiology, diversity and their role in the ecology of soil as affected by gradients of environmental conditions combined with anthropogenic activities (Atlas et al., 1984).

Microbial diversity is a general term used to include genetic diversity, that is, the amount and distribution of genetic information, within microbial species; diversity of bacterial and fungal species in microbial communities; and ecological diversity, that is, variation in community structure, complexity of interactions, number of trophic levels, and number of guilds (Nannipieri et al., 2003). The microbial population in soil is very diverse. Torsvik et al., (1996) calculated the presence of about 6000 different bacterial genomes per gram of soil by taking the genome size of *Esherichia coli* as a unit. Microbial diversity is a general term used to inclue genetic diversity, that is, the amount and distribution of genetic information, within microbial species, diversity of bacterial and fungal species in microbial communities; and ecological diversity, that is, variation in community structure, complexity of interactions (Nannipieri, 2003).

Determining the presence and abundance of specific groups of bacteria can provide useful insight into ecosystem functions. Identification of which species representing a functional group is/are present could enable the choice of indicator species to be monitored during ecosystem disturbances. Species diversity can also be an indicator of soil quality because of its obvious relationship to functional diversity (Visser and Parkinson 1992).

SECONDARY METABOLITES

The research on natural products may offer substantial advantages, like discovery of new drugs with a new mode of action, high selectivity and activity. It is clear that from all microbiomes the procaryotes whose secondary metabolism shows the highest flexibility, are the most suitable. Many bacteria are synthesis secondary metabolites such as certain extracellular enzymes and other bioactive compounds. A diverse group of soil microbes are capable of producing physiologically active compunds that may have pronounced effects on plant growth and development. According scientific reports 86% of the bacterial isolates from the rhizosphere of various plants produced phytohormones, and also different vitamins. Rhizospheral bacteria produce growth promoting substances in culture media, in the rhizosphere and in the rhizoplane of forage grasses and many economically important cereals like wheat, barley and vegetables, tomato and bean plants under cultural conditions (Frankenberger and Arshad, 1990). The study of microbial populations and their biochemical activities associated with herbal plants growth in such unique environment may thus provide valuable information on microbial distribution, their biochemical activities and their role in plant establish and development.

CONCLUSION

The review reflecs the fact that soil is the foundation upon which society is sustained and evolves, that it is a vital component of ecological processes and recycles, as well as the basis on which earthr infrastructure rests. Often not enough importance is given to the fact that soil quality and its protection contribute significantly to preserving the quality of life, and that the nutrition and health of humans and animals cannot be separated from the quality of the soil. Growing pressures from an ever increasing global population, as well as threats such as climate change and soil erosion, are placing increasing stresses on the ability of soil to sustain its important role in the planet's survival. Evidence suggests that soil is one of the fundamental components for supporting life on Earth. It is the processes that occur within soil, which drive ecosystem and global functions and thus help maintain life above ground. Soil performs numerous ecosystem functions and services, ranging from providing the food that biotics eat to filtering and cleaning the water that biotics drink. It is used as a platform for building and provides vital products such as antibiotics, as well as containing an archive of ecosystem cultural heritage in the form of archeological sites. Life within the soil is hidden and so often suffers from being 'out of sight and out of mind. A more complete knowledge of soil biotics is needed for biodiversity conservation. Only by knowing soil in all its complexity, while maintaining its functionality and quality through actions aimed at protecting its properties, and acknowledging the importance it assumes in the quality of life worldwide, can human beings embark on a truly sustainable use of soil perceived as a resource and build a proper man-soil relationship to be left to future generations.

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