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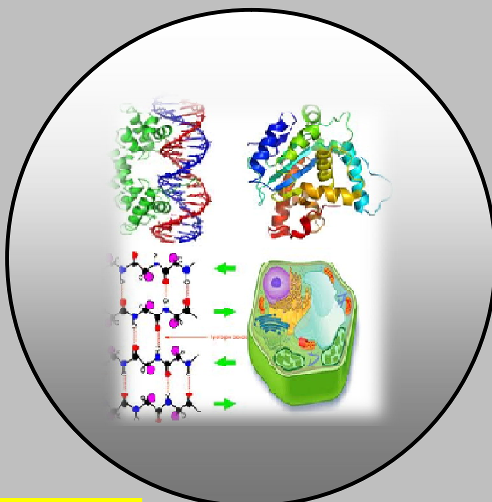

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RESEARCH PAPER

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Relationship between Management Practices such as Irrigation, Tillage, Cropping, Fertilizer and Soil Microbial Diversity

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ABSTRACT

Soil microorganisms, such as bacteria and fungi, play central roles in soil fertility and promoting plant health. Soil bacteria and fungi play pivotal roles in various biogeochemical cycles. The extent of the diversity of microorganisms in soil is seen to be critical to the maintenance of soil health and quality, as a wide range of microorganisms is involved in important soil functions. Diversity of microbial population in soil in relation to various agricultural practices was evaluated. In the soil profile, the microbial population mostly occurs within 40 cm of top soil. Bacteria are predominant followed by actinomycetes and fungi. Management practices such as irrigation, tillage, cropping, fertilizer application, residue incorporation, manuring and microbial inoculation have major impact on diversity of biological population in soil. Diversity index was much higher in Alfisols than Vertisols under different crop management practices. In both the soils, addition of organic manure (FYM) showed greater species diversity over control and inorganic fertilizer application. Continuous monoculture had a negative impact on species diversity as compared to crop rotations.

Key words:Soil Microbial Diversity, Agricultural Function and Soil.

INTRODUCTION

Microorganisms form a vibrant living community in the soil contributing to a number of nutrient transformations. They are involved in organic matter decomposition, N2-fixation, solubilization and immobilization of several major and minor nutrients (Alexander, 1971).

Microbes also play an important role in soil structure maintenance, soil borne disease control and plant growth promotion through secretion of hormones. The diversity and richness of soil microorganisms has been a fascinating subject for scientists over the years, but till today relatively little is known on the complex living biota in the soil and their biophysical and biochemical functions in the soil ecosystem. But during the last 50 years, many beneficial effects of microbes in soil have been discovered (Alexander, 1971; SubbaRao and Gaur, 2000) and we have been making use of microorganisms for improving productivity in agriculture, industry and pharmaceuticals. With growing awareness on agro biodiversity conservation and management during the last decade, a parallel interest has been generated on understanding soil microbial biodiversity (SMD) as well. SMD is a vast frontier of potential gold mine for the biotechnology industry as it offers countless new genes and biochemical pathways (Tilak, 2000). This paper summarizes the recent advances in understanding soil microbial diversity, its functional significance and the impact of agricultural practices with particular reference to semi-arid tropics.

Significance of microbial diversity in soil

One cubic meter of soil may house many hundreds of species of bacteria, actinomycetes, fungi and algae. The distribution of microorganisms in a typical soil profile has been described by Alexander (1971). The numerical dominance of bacteria and its significance, each group has its unique contribution to the nutrient cycles and as source of useful chemicals like antibiotics, vitamins and enzymes. Although extensive information has been generated on plant and animal biodiversity, little is known on microbial diversity and our knowledge on soil biodiversity is still a miniscule. About 45,000 species of plants, 67,000 species of insects and 61,000 of invertebrates have been described in India. No specific information on bacteria is available for the country but an estimated 50 percent of all living population on earth is microbial. There may be 1.5 million species of fungi but only 5 percent are described and as many as one million species of bacteria but only about 5,000 have been described (Tilak, 2000). The estimated and the actually described number of species of bacteria, fungi, algae and viruses are compared with the culture collections of Hawksworth (1991). Compared to number of species estimated, the described ones are few and those actually cultured in the laboratory are still fewer. The data indicate the dominance of fungi in the estimated species but very small percentage of them had been cultured. Two parameters become important while evaluating the significance of microorganisms in soil i.e., abundance and diversity. While abundance may increase or decrease over short periods of time in response to management practices and inputs, diversity is a more complex and stable attribute and reflects a state of near equilibrium. The latter is more important to understand the functional significance of microorganisms at a given site. High variation can be found for abundance between different soil types, seasons and land uses. In view of the large fluctuations and the undependability of numbers, microbial biomass is often used as a more reliable parameter to assess the abundance. The populations and biomass levels of major groups of organisms in a typical soil profile (0-25cm) has already been described by Miller (1990). In terms of biomass, fungi dominate in the soil followed by bacteria and actinomycetes.

The total populations and live biomass are only reflections of the status of the soil at a given point of time, but do not give a clear picture of the living diversity as influenced by different land use practices over time. The greatest uncertainty in population counts is our inability in recovering all the organisms in the culture. Generally only about 5-10 percent of the organisms in the soil can be recovered through normal viable counts. Even direct counting methods do not reflect the true composition of the population in the soil. Therefore in most studies, what is being determined is only the cultureable biodiversity.

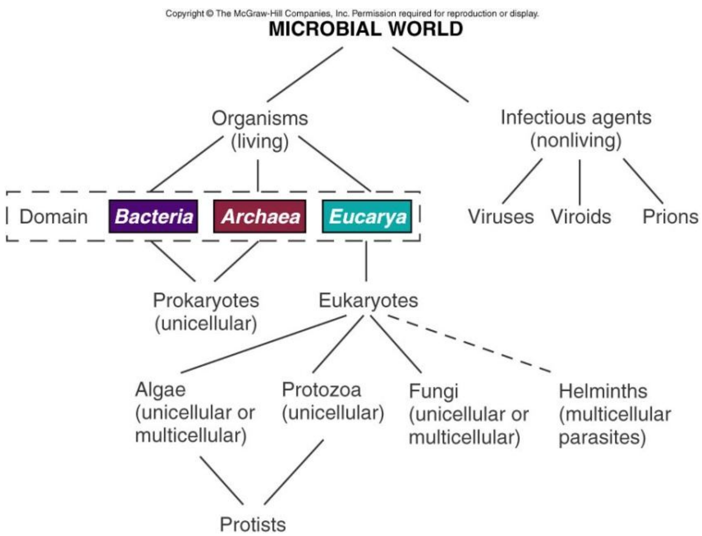

Figure 1. Show microbial diversity in world.

Despite these limitations, conventional studies on soil microbiology have always relied on total population counts, enrichment and isolation of pure cultures to study their practical significance, estimation of microbial biomass and carbon dioxide evolution (Alexander, 1971). Only recently, studies on soil microbial diversity have been initiated using the standard methods developed for eukaryotes. Kennedy and Smith (1995) reviewed the various components of microbial diversity and the different indices normally used for its measurement. Although diversity can be studied at the level of genera, species, community and ecosystem, species diversity is the most commonly studied parameter in the soil. Many indices have been described for assessing the species richness and evenness (Kennedy and Smith, 1995). More recently molecular genetics tools have also been used to study microbial diversity in soil (Ogram, 2000).

Agricultural practices and soil biodiversity

Microorganisms are involved in a number of biochemical processes that contribute to improved plant nutrient availability. These include 1) mineralization 2) nitrogen fixation 3) nitrification/denitrification 4) phosphate solubilization 5) antibiosis 6) siderophores production 7) plant growth regulation and 8) induced resistance.

Several groups of organisms act both competitively and synergistically to mediate the above processes. Soil and crop management research over the years has helped in understanding the impact of various natural factors and agricultural practices on the population and diversity of microorganisms in soil. Soil management practices in general and those that influence the fertility in particular have an immediate impact on microbial population. Swift et al. (1996) has summarized the general typical soil management practices and their impact on biotic activity. In view of the practical importance, most of the studies have been focused on agriculturally useful organisms like nitrogen fixers and phosphate solubilizers. Tillage, soil erosion, crop rotations, manuring, burning and pesticide application were the major agricultural practices whose impact has been studied in detail. However, most studies focused on the population and activities of individual organisms of specific physiological significance are not on the diversity per se.

Species diversity at a particular site is not always related with the microbial biomass or carbon dioxide evolution, which indicates the total microbial activity. In general, cultivated soils have greater diversity than fallow lands (Kennedy and Smith, 1995). The impact of land use is highly variable. Each kind of vegetation (natural or crop) provides a particular substrate, which encourages some microbial species over others in the rhizosphere. Although several studies indicate that cultivation increases the population and diversity in soils, there have been few reports of increased population under minimum tillage with residue incorporation as compared to conventional tillage (Linn and Doran, 1984). However, this superiority was restricted to surface soil (0-75mm) and in deeper layers conventional tillage caused more population build up. Soil biota influence soil properties through the formation of stable aggregates, bonding through fungal hyphae and polysaccharides, but accelerated erosion and loss of clay and organic carbon fractions can cause significant decline in microbial population and diversity (Venkateswarlu, 1998). In a comprehensive study in Alfisols and Vertisols in peninsular India, Venkateswarlu (2000) observed a considerable decline in population and diversity as a result of top soil erosion. (Table 1).

Table 1. Population and diversity indices (DI) of bacteria, fungi, actinomycetes and nitrifying bacteria in control and eroded sites of Hayatnagar Research Farm near Hyderabad (Population of bacteria, fungi and actinomycetes by plate counts, while Nitrosomonas and Nitrobactor by MPN method. Ten randomly collected samples (0-30 cm) were analysed twice during July and October for each treatment).

Organism	Control site		eroded site	
	population	DI	Population	DI
Bacteria	51.21×10^4	0.48±0.04	13.5×10^4	0.42±0.03
Fungi	62.51×10^3	0.31±0.02	9.62×10^4	0.27±0.03
Actinomycetes	17.12×10^4	0.39±0.02	4.82×10^4	0.36±0.01
Nitrosomonas	16.55×10^4	**	10.12×10^3	**
Nitrobacter	12.65×10^4	**	1.62×10^3	**

DI was determined based on operational taxonomic unit (OTU); ** Not applicable

Manuring and fertilizer application also have a significant impact on the species diversity of bacteria and fungi. They cause significant changes in the microbial populations which are largely mediated through changes in soil pH. Sharma et al. (1983) reported that application of nitrogen fertilizers like ammonium sulfate increase the fungal population whereas FYM and NPK application increased the population of fungi, bacteria and actinomycetes. Certain species of microorganisms like Azotobacter are very sensitive to soil acidity while others like Nitrosomonas and Nitrobacter are more sensitive to erosion of top soil (Venkateswarlu, 2000). Such organisms can be used as indicators of degradative processes in soil or the extent of degradation of given soil.

Samples analyzed from long term fertilizer trial plots in Alfisols at Bangalore revealed greater species diversity in FYM plots as compared to chemical fertilizer and control plots. While organic manured plots showed greater population and species richness, continuous application of NPK did not cause any significant change in the diversity of fungi or bacteria as compared to control plots (Table 2).

Table 2. Microbial populations and diversity indices (Mean ± SD) in long term experimental plots receiving only chemical fertilisers or FYM at (Alfisols) and (Vertisols).

Site	Crop/cropping system	Treatment	Population g dry soil			
			Bacteria (× 10^4)	Fungi (× 10^4)	Actinomycetes (× 10^3)	Nitrosomonase
Site I	Ragi	Control	74	32	6	18
		Fertilizer	86	48	8	28
		FYM	101	55	19	27
Site II	Soybean	Control	32	28	8	5
		Fertilizer	41	34	10	14
		FYM	62	40	18	18

A critical analysis of the qualitative composition of the microflora indicated that certain species like *Chaetomium, Monilia, Trichoderma* and *Spicaria*were more frequently isolated in FYM plots than control or chemical fertilizer plots. In Vertisols, few species not found in chemical fertilizer or control plots could be isolated from FYM plots. Similar trend was noted with *Nocardia* and *Streptomyces*. *Actinoplanes* could be detected only in FYM plots of Alfisols. *Aspergillus* and *Penicillium* together constituted 80% of the total colonies in control and chemical fertilizer plots while in FYM plots it did not exceed 65%. Similarly, *Streptomyces* comprised 60% of the total actinomycete colonies in control and chemical fertilizer plots, but in FYM plots this did not exceed 50%.

The crops and cropping systems grown on cultivated fields over a period of time also significantly influence their population and diversity. Certain crops encourage a particular group of genera of fungi and actinomycetes in rhizosphere while others do not exhibit any specific effect.

For example, in a study of two sites near Hyderabad under sorghum - castor - sorghum rotation for twelve years and continuous castor for ten years, a differential distribution of fungal genera was noted. More diversity was recorded in rotation plots as compared to monoculture. In monoculture plots, there was a predominance of one or two genera (mostly *Streptomyces*) representing 80% of the actinomycetes. These preliminary studies indicate the negative effects of monoculture, over crop rotations on the soil biota, but more detailed studies are required to understand the cropping system effect by not only studying the effect of root exudates, leaf leachates from standing biomass but also of the residues after the crop harvest. Allelopathic effect of crops on soil microbes is yet another area very little understood.

CONCLUSIONS

The available information on changes in soil microbial diversity in response to agricultural practices is quite scanty. However even this limited data indicate that significant changes occur in the diversity of important microorganisms involved in nutrient transformations, antibiosis, plant disease control and growth promotion in response to various soil managing practices which are part of intensive agriculture. Therefore, there is need to understand the following aspects of microbial diversity in order to sustain the soil productivity on a long term basis, particularly in tropical soils.

What are the changes in rhizosphere biology under continuous monocropping? Are there any microbial factors involved in yield declines under continuous cropping?

What are the impacts of long term use of agrochemicals like fertilizers and pesticides on the diversity of important functional groups?

Do the soil management practices cause selective stimulation of particular species of microbes. If so, can it be used to suppress pathogenic organisms in soil?

What are the microbial indicators of sustainable soil fertility? Can particular species of microbe be used as early indicators of land degradation?

What are the best biological indicators of soil quality?

The future research on soil microbiology particularly using the frontier techniques like molecular biology including PCR, 16S rRNA study and gene tagging might provide answers to some of the above questions. Species diversity studies on unique habitats might inadvertently show up useful gene products, which can be used outside the agriculture. Thus soil microbial diversity studies in future might transcend beyond the academic level and prove to be a source of large economic gains in agriculture, bio-pharmaceuticals and environmental management.

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