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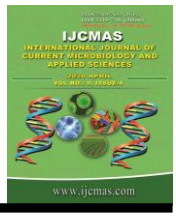

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Microbial Population and Beneficial Properties of Rhizospheric Soil as Influenced by Different Amendments in Various Land Use Systems: A Review

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A B S T R A C T

Plant roots, soil and microbial interactions result in alteration of soil physical and chemical properties that in turn affect the micro-biological properties in the rhizosphere region. The growth and productivity of plant depends upon the diversity and composition of soil microflora present near rhizosphere zone. The aim of this study is to review the effect of organic, inorganic and integrated use of nutrients on soil properties under different land use systems in rhizospheric region. The studies highlight positive as well as negative influence of organic, inorganic and integrated use of fertilizers on the rhizosphere population. As the addition of above material influence physical and chemical properties of soil, they have a direct influence on soil microbial properties. Studies evident deteriorated soil quality as well as health as we follow intensive chemical fertilizers application. Therefore, various researches suggested an improvement in soil health and crop productivity on sustainable basis through conjoint usage of different package of nutrient sources.

Introduction

Rhizosphere is the vital soil microenvironment where the plant roots, soil properties and microbial activity are interconnected. Rhizosphere microorganisms have direct as well as indirect impact on composition and biomass of natural plant populations (Van der Heijden *et al.*, 1998, 2006, 2008; Schnitzer *et al.*, 2011). Therefore, microbial species abundance in rhizosphere can therefore be used as indicator of aboveground plant diversity and productivity. Plant roots, soil and microbial interactions results in alteration of soil physical, chemical properties that in turn affect the

microbiological properties in the rhizosphere region (Nihorimbere *et al.,* 2011). The beneficial rhizosphere microorganisms can help in maintenance of ecosystem balance through organic matter decomposition and cycling of nutrients that serves as an indicator of land use changes and ecosystem sustainability (Ros *et al.,* 2006; Balser *et al.,* 2010).

The soil physico-chemical properties strongly influence the microbial properties such as (bacteria, fungi and actinomycetes), basal soil respiration, enzymatic activity, microbial biomass carbon, mineralizable carbon, nitrogen, phosphorus, sulphur etc. Such intense microbial properties occur in rhizosphere zone due to presence of several nutrient rich exudates.

Land-use activities specifically related to agricultural practices can have a significant impact on the quantity and activity of soil microbial community and biological health of soil (Das *et al.,* 2011). Joanisse *et al.,* (2007) and Liu *et al.,* (2002) also stated that anthropogenic activities and various soil physico-chemical properties such as soil pH, soil organic matter, texture etc have great influence on soil microbial activity.

Intensive utilization of inorganic fertilizers without organic manures are responsible for deterioration in soil health in terms of soil physical and chemical properties, lowers soil microbial activity as well as soil humus (Anjanappa *et al.,* 2012).

Nambiar (1997) stated that the integrated use of chemical and organic fertilizers is more effective, not only providing greater stability but also maintains a better soil health. The purpose of this study is to review the impact of different soil amendments on rhizosphere microbial communities and soil physico-chemical properties under different land use systems.

Soil properties in relation to different soil amendments

Various soil amendments have greater impact on soil microbiological properties that are also responsible for the maintenance and determination of soil physico-chemical properties such as soil pH, EC, soil organic matter, nutrient availability in soil that effect crop yield.

Organic mulches are widely used for soil surface application in order to suppress weeds and diseases, control soil temperature and conserve soil moisture conditions (Robinson, 1988; Hoitink and Boehm, 1999).

It has also been recognised that mulches have greater potential to improve soil structure, increase in soil organic matter content and create nutrient cycling patterns more similar to natural ecosystems (Tukey and Schoff, 1963; Roe, 1998).

On the other hand, plant health and soil sustainability could be maintained by liquid organic fertilizers due to availability of soluble nutrients and abundant soil organic matter (Hou *et al.,* 2017 and Dordas *et al.,* 2007). The integration of watering and fertilizer patterns may be attributed to increase in nutrient use efficiency and decrease in nutrient loss risk (Toonsiri *et al.,* 2016 and Ceretta *et al.,* 2010).

Additionally, suitable vermicompost application along with chemical fertilizer could also be result in inhibition of soil pests and soil-borne diseases (Edwards and Norman,2004) and also causes reduction in plant parasitic nematodes and infection rates in plants (Arancon *et al.,* 2002). Brussard *et al.,* (2007) suggested that application of organic amendments is the most effective way of managing biodiversity in the soils (Table 1).

Table.1 The various favourable and unfavourable influences of different soil amendments on soil properties in rhizospheric soil in different land use systems

Sr.	Land use/ plant rhizosphere	Soil amendment		Physico chemical properties of soil/ plant characteristics/yield attributes		Microbial properties/ enzymatic activities		Place of study	Reference
				Positive	Negative	Positive	Negative		
Field crops									
1.	Rice rhizosphere	Integrated	50% Nitrogen (recommended) through urea + compost/bhattian sludge	Nil	Nil	Maximum count of fungi, bacteria, diazotroph, PSB, actinomycetes and enzymatic activities such as dehydrogenase, alkaline phosphatase and urease activity were also increased	Nil	Punjab, India	Gill *et al.*, 2016
		Chemical	100% Nitrogen (recommended)through urea	Nil	Decrease in soil pH and increase in soil EC	Nil	Suppressed microbial activity		
2.	Wheat rhizosphere	Integrated	Chemical nitrogen (^{15}N-labeled urea) + swine manure	Nitrogen rate was two times faster than inorganic fertilizer application.		Increased microbial biomass carbon and increased enzymatic activities such as invertase, urease and protease	Nil	China	Yuan *et al.*, 2011
		Inorganic	Chemical nitrogen (^{15}N-labeled urea)	Nil	No changes	Increased urease activity	Nil		
3.	Wheat rhizosphere	Organic	Farm yard manure and organic liquid booster like Jeevamruth and Beejamruth	Nil	Nil	Enhances rhizosphere mycoflora population and diversity of species- *Acremonium sp.*,	Nil	India	Shaikh and Gachand, 2013

			(Palekar, 2006)			*Trichoderma pseudokonigii, Glomus sp., Cladosporium herbarum and Curvularia lunata* (increases soil fertility), *Aspergillus, Penicillium, Trichoderma, Fusarium, Rhizopus and Cladosporium*			
		Inorganic	Chemical fertilizers	Nil	Nil	Isolated mycoflora *Aspergillus, Penicillium, Trichoderma, Fusarium, Rhizopus and Cladosporium*	Lowers the rhizosphere mycoflora population as compared to organic		
4.	Wheat	Integrated	Fertilizers level+FYM+ bioinoculants (Azotobactor chroococum, Cd, Pseudomonas fluorescens BHU PSB06, acillus megaterium BHU PSB14)	Increase in water holding capacity, organic carbon, available N, P and K and decreased bulk density	Nil	Increased dehydrogenase, phosphatase enzyme activity, soil microbial biomass carbon and microbial properties of soil.	Nil	India	Parewa *et al.*, 2014
		Inorganic	100% NPK (Recommended) basic fertilizers	Decrease in nutrient availability	Nil	Nil	Lower microbial as well as enzymatic activity		
5.	Maize	Different coated urea	Neem coated urea, Pongamia oil coated urea and Castor oil coated urea	Higher NPK content when 100% rec N applied through Neem Coated Urea.	Lower availability of nutrients	Nil	Nil	India	Shilpha *et al.*, 2017
6.	Maize	Integrated	Biochar addition and nitrogen reduction	Nil	Nil	Influences rhizosphere metabolome, quality and quantity of root exudates	Nil	China	Cheng *et al.*, 2018

						i.e. Increases the levels of amino acids and organic acids.			
		Inorganic	Nitrogen addition through urea	Nil	Nil	Nil	Decreases the rhizosphere microbial communities and quantity and quality of root exudates also lesser.		
7.	Sugarcane	Inorganic	High dose of nitrogen (200 kg N/ha/year)	Nil	Nil	Nil	Ascomycetes fungi (pathogenic fungi)	Australia	Paungfoo-Lonhienne *et al.*, 2017
			Low dose of nitrogen (40 kg N/ha/year)	Nil	Nil	Basidiomycetes fungi (lignin decomposer, helps in carbon cycling), lesser abundance of ascomycetes	Nil		
8.	Maize-cabbage	Bioorganic fertilizers	Soil amended with organic fertilizer + *Trichoderma guizhouense* NJAU 4742	Higher levels of soil pH, the concentrations of total organic carbon, Total N, total P, total K, NH_4-N, avail P and avail K	Decrease in NO_3-N	Fungus genera: *Humicola, Derxomyces, Rhizophydium* and *Trichoderma* were significantly higher	Bacterial genera *Zavarzinella, Rubritepida* And *Bdellovibrio,* were significantly depleted	Jiangsu province, China	Qiao *et al.*, 2019
		Organic	Chicken manure	-do-	-do-	Bacterial genus abundance: *Massilia, Zavarzinella* and Rubritepida Fungus genus abundance: *Massaria, Naumovozyma, Cladorrhinum*	-nil-		
9.	Soybean rhizosphere	Organic	Plant compost (PC), vermicompost (VC),	Ph, moisture content, Total N,	Available phosphorus	Greater microbial population of fungi and	Nil	India	*Das and Dkhar,*

			Farmyard manure (FYM) and integrated plant compost (IPC).	exch K (FYM)	(PC).	bacteria, Soil respiration, Microbial biomass carbon			*2011*
		Inorganic	Nitrogen, phosphorus and potassium thru' fertilizers	Soil available phosphorus	pH, moisture content	Nil	Lesser bacteria and fungi population, Microbial biomass carbon.		
10	Soybean rhizosphere	Organic	Nitrophospho-Sulphocompost, Phosphocompost	Nil	Nil	Significantly higher enzymatic activities like urease, DHA, alkaline Phosphatase, aryl sulphatase.	Nil	India	Souza *et al.*, 2017
		Inorganic	Urea, MOP, DAP	Nil	Nil	Nil	Lower enzymatic activities		
11	Chickpea	Integrated	Inoculation with *Trichoderma koningiopsis* strain (NBRI-PR5)+FYM+NPK (different doses)	Enhanced plant growth parameters, soil pH	Nil	Phosphorus solubilization, modifying the rhizosphere microbial quantity and quality as well as enzymatic activities.	Nil	India	Tandon *et al.*, 2018
		Inorganic	Commercially available fertilizers NPK	Nil	Less beneficial without inoculation	Nil	Lesser as compared to bio-inoculation		
12	Red Amaranth	Organic	Different leaf litter (acacia, eucalyptus, teak, Sal)	Highest Organic matter, total nitrogen, available phosphorus, exchangeable available calcium and available magnesium.	Nil	Nil	Nil	Bangladesh	Sarkar *et al.*, 2010
		Inorganic	Chemical fertilizers	Nil	The lower level of	Nil	Nil		

					nutrients was observed				
13	*Sitanion Hystrix* and *Agropyron smithii*	Fertilized	Chemical fertilizers	Nil	Decreased organic matter and organic carbon,	Nil	Decreases in fungal hyphae length of rhizosphere of both grasses, decreased microbial biomass (*S. Hystrix,)*	USA	Klein & Frederick, 1989
		Control	no treatment	Higher amount of soil organic matter and organic carbon were observed	Nil	Increased fungal length, more microbial biomass.	Nil		
Forest crops									
14	Poplar	Integrated (inorganic + biofertilizers)	Urea and DAP (100% rec) fertilizer + Consortium biofertilizer/azotobacter/PSB	Nil	Nil	Highest Fungi, bacteria, diazotroph, PSB, Plant growth promoting bacteria, Maximum enzymatic activities such as DHA, alkaline phosphatase and urease enzyme.	Actinomycetes	India	Khipla *et al.*, 2017
15	*Eucalyptus camaldulensis*	Organics	Mixture of biofertilizers (Azotobacter chroococcum, Bacillus circulans and Arbuscular mycorrhizal fungi AMF)	Highest content of chemical constituents (chlorophylls a, b, carotenoids content, total Carbohydrates, N, P and K %)	-	Mixture treatment recorded higher microbial population, mycorrhizal colonization (%) and Inoculation with mixture of microorganisms including Enzymatic activities, inc nitrogenase activity.	Nil	Egypt	Kh *et al.*, 2014
		Control	Without treatments	Nil	Lesser content of	Nil	Nil		

					chemical constituents				
16	**Red oak, Sugar maple, Yellow birch.**	Inorganic	Fertilized with solid fertilizer like nitrogen, phosphorus, potassium, calcium and magnesium.	Nil	Nil	Nil	Reduction in carbon dioxide flux from soil, suppression of fungal activity due to decreased decomposition rate, reduction in microbial respiration and fine root biomass (except no changes observe in case of red oak in fine root biomass)	USA	Phillips and Fahey, 2008
		Control	No treatment	Nil	Nil	More activity of rhizosphere microbial activity occurs as compare to fertilized soil.	Nil		
17	**Pine forest**	Inorganic	Fertilized with ammonium nitrate/urea for 10 years	Increase in soil carbon content	Nil	Nil	Reduction in respiration rate of microbes, ATP and microbial biomass carbon.	Sweden	Arne brant *et al.*, 1988
		Control	No fertilizers added	Nil	Decrease in carbon content	Increased respiration rate, ATP, Microbial biomass carbon.	Nil		
Horticultural crops									
18	**Banana**	Organic	Compost prepared from the mixture of filter mud from sugar factory, plant residues and conc. Molasses solution.	Higher concentrations Of calcium, magnesium,	Nil	Enzymes like urease, catalase, alkaline Phosphatase, acid phosphatase and invertase	Nil	Guangxi province, South China	Zhang *et al.*, 2019

				available nitrogen, available potassium, Fe, Zn, soil organic carbon and exchangeable cation exchange capacity.		were significantly higher than lime			
		Inorganic	Lime @ 3.1 t ha-1	Nil	Significantly lesser nutrient levels than organic.	Nil	Significantly decrease in enzymes, liming alone was not a viable approach to fight against diseases and acid soils.		
19	*Citrus Grandis* var. *Longanyou* rhizosphere	Organic / Integrated	All applied organic fertilizers/ organic fertilizers + chemical fertilizers like N P K	Total N, available N, available Fe, available Mn and exchangeable Mg and organic matter was significantly higher than chemical fertilizers/ organics were significantly at par with integrated system but higher than chemical fertilizers.	Nil	Nil	Nil	China	Li *et al.*, 2017

		Inorganic	Chemical fertilizers (N P K)	Nil	Significantly lower values				
20	Pomegranate rhizosphere	Organic	Biofertilizers (A. Chroococcum + G. Mosseae)	Maximum uptake of N, P, K, Ca, Mg and micronutrients.	Nil	Dehydrogenase, alkaline phosphatase and nitrogenase, hydrolysis of fluorescein diacetate in rhizosphere Soils	Nil	India	Aseri *at al.*, 2008
		Control	Without any treatments	Nil	Nil	Infected with native AM fungi	Nil		
21	Guava	Organic	Biofertilizers (Kotengin, Biomagic, Hummer, phosphorine, Rhizobacterin, Biovit solution	Increased vegetative growth measurements (stem height, stem diameter, number of shoots per plant, number Of leaves per plant and leaf area), leaf photosynthetic Pigments content (chlorophyll A, B and carotenoids) were increased as well as leaf mineral contents (N, P, K, Ca, Mg, Fe, Mn and Zn)	Nil	Nil	Nil	Egypt	Khamis *et al.*, 2014
		Control	Superphosphate, $(NH_4)_2SO_4$, K_2SO_4	Nil					
22	Tomato	Organic	Chicken manure	Higher plant height and higher	Nil	Nil	Nil	West Africa	Agyematn *et al.*, 2014

				fruit yield					
		Inorganic	Unik 15 + Urea, Winner + winner, Winner + Sulfan, (Unik 15 - 15:15:15 (N:P: K), Sulphan: 24 % N, 6% S (12NO3, 12 NH4), Winner: 15:9:20 + 1.8 mgo + 3S + 0.02 Z + 0.15 B + 0.02Mn)	Higher plant height, highest fruit yield (Winner + Sulfan) than control	Nil	Nil	Nil		
23	Tomato	Organic	Vermicompost, compost, Integrated plant nutrient system (IPNS).	Improved soil pH and EC. Highest number of flower clusters, fruit clusters, fruit yield and plant height (IPNS)	Nil	Nil	Nil	Bangladesh	Islam *et al.*, 2017
		Inorganic	Urea, MOP, TSP, borax and Zn fertilizers	Nil	Comparatively lesser yield attributes were recorded				
24	Cucumber	Integrated	50% (recommended) through inorganic + 50% (recommended) through poultry manure	Positive effects on soil pH, electrical conductivity, organic carbon and available nitrogen, phosphorus and potassium.	Nil	Nil	Nil	Maharashtra, India	Ghayal *et al.*, 2017

		Inorganic	Chemical fertilizers	Nil					
25	Cucumber rhizosphere	Organic	Mulches such as recycled, groundwood pallets and composted yard waste	Soil mulched with compost yard increases the CEC, OM, P, K, Calcium and total N	Nil	Significantly higher microbial respiration and microbial nitrogen, higher population of fluorescent *Pseudomonas*	Nil	USA	Tiquia *at al*., 2002
		Inorganic	Chemical fertilizers	Nil	Nil	Nil	Nil		
26	Cucumber rhizosphere	Integrated	Inorganic compound fertilizer + Vermicompost	Increase in soil EC, total nitrogen, total and available phosphorus, available potassium and total carbon content and Decrease in soil pH and bulk density	Nil	Increased the relative abundance of beneficial fungi (*Ascomycota, Chytridiomycota, Sordariomycetes, Eurotiomycetes*, and *Saccharomycetes*) and decreased those of pathogenic fungi (*Glomeromycota, Zygomycota, Dothideomycetes Agaricomycetes* and *Incertae sedis*)	Nil	China	Zhao *et al.*, 2017
		Inorganic	Chemical compound fertilizer	Nil	Lower availability of nutrients and carbon content	Nil	Lowers the beneficial fungi and promote harmful pathogens.		
27	Spinach rhizosphere	Organic	Biochar	Higher values of pH, Eh, total nitrogen, total	Nil	Higher abundance of bacteria, fungi and actinomycetes,	Nil	Liaoning,China	Han *et al.*, 2013

				phosphorus, total potassium, total carbon, total sulphur, C/N ratio and total carbon were recorded		ammonifying bacteria, azotobacter and denitrifying bacteria			
		Control	Without biochar	Higher total sulphur, C/N ratio, and total sodium content	Nil	Nil	Nil		
28	Chrysanthemum rhizosphere	Liquid organic fertilizers	Shrimp extract, plant decomposition, vermicompost, seaweed extracts and fish extracts.	Increase in nutrient levels (mineral nitrogen, available phosphorus and potassium)	Nil	Stimulate microbial activity and functional diversity	Nil	Jiangsu, China	Ji, 2017
		Chemical fertilizers	Nitrogen, phosphorus and potassium fertilizers	Nil	Decreased nutrient levels	Nil			
29	Arecanut palm rhizosphere	Organic	Farmyard manure, green leaf, bone meal and wood ash	Soil organic carbon and soil pH showed significant results	Nil	Higher microbial population (bacteria, fungi, actinomycetes) and *Trichoderma sp*. and *Aspergillus sp.* were dominated.	Nil	Karnataka, India	Bopaiah and Bhat,1981
		Inorganic	Nitrogen, phosphorus and potassic fertilizers.	Nil	Nil	Nil	Lesser microbial population as compared to organic		

Biochar as one of the organic amendments may affect the microbial biomass in many ways as it provides habitat for microflora, protect against hazards and serves as a substrate for microbes (Thies and Rillig, 2011 and Lehmann and Joseph, 2009). Warnock *et al.,* (2007) observed that addition of biochar resulted in promotion of colonization and abundance of mycorrhizal fungi on plant roots.

The studies highlight that integrated use of different organic and inorganic nutrition package may offer feasible and friendly approach towards soil health maintenance and sustainability. As evident by various studies continuous and sole application of inorganic fertilizers resulted in soil quality deterioration, however, combined use of organic and inorganic sources not only contributes significantly to soil health and productivity, but also increase crop productivity and quality on long term sustainable basis.

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