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.

Keywords
Land use systems, Microflora, Rhizosphere, Soil amendments and Physico-chemical properties

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 |                                 |                | Positive | Negative | Positive | Negative |                               |                               |                               |            |           |
| 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 |
| 4. Wheat | Integrated fertilizers | 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 |
|---|---|---|---|---|---|---|---|
| 5. Maize | Different coated urea | Higher NPK content when 100% rec N applied through Neem Coated Urea. | Nil | Lower availability of nutrients | Nil | India | Shilpha et al., 2017 |
| 6. Maize | Integrated | Biochar addition and nitrogen reduction | Nil | Influences rhizosphere metabolome, quality and quantity of root exudates | Nil | China | Cheng et al., 2018 |
### 7. Sugarcane

| Type      | Description                                                          | pH | Organic Carbon | N | P | K | Decrease in NO\textsubscript{3}\textsuperscript{-N} |
|-----------|----------------------------------------------------------------------|----|----------------|---|---|---|------------------|
| Inorganic | Nitrogen addition through urea                                        | Nil| Nil            | Nil| Nil| Nil            | Decreases the rhizosphere microbial communities and quantity and quality of root exudates also lesser. |
|           | High dose of nitrogen (200 kg N/ha/year)                             | Nil| Nil            | Nil| Nil| Nil            | Ascomycetes fungi (pathogenic fungi) Australia Paungfoo-Lonhienne et al., 2017 |
|           | Low dose of nitrogen (40 kg N/ha/year)                               | Nil| Nil            | Nil| Nil| Nil            | Basidiomycetes fungi (lignin decomposer, helps in carbon cycling), lesser abundance of ascomycetes Nil |

### 8. Maize-cabbage

| Type                   | Description                                                                 | pH | Organic Carbon | N | P | K | Fungus genera:  |
|------------------------|-----------------------------------------------------------------------------|----|----------------|---|---|---|-----------------|
| 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\textsubscript{4}-N, avail P and avail K | Decrease in NO\textsubscript{3}\textsuperscript{-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 |
| Chicken manure         | -do-                                                                        | -do-                       | Bacterial genus abundance: *Massilia*, *Zavarzinella* and *Rubritepida* Fungus genus abundance: *Massaria*, *Naumovozyma*, *Cladorhinum* | -nil-         | |

### 9. Soybean rhizosphere

| Type              | Description                                                                 | Available phosphorus | Greater microbial population of fungi and Nil |
|-------------------|-----------------------------------------------------------------------------|----------------------|-------------------------------------------|
| Organic           | Plant compost (PC), vermicompost (VC), Ph, moisture content, Total N,       | Available phosphorus | Nil                                        | India Das and Dkhar, |
|                   |                                                                             |          |                                           | |

i.e. Increases the levels of amino acids and organic acids.
| Plant Species | Type of Fertilizer | Treatment | Soil Parameters | Microbial Parameters | Notes |
|---------------|-------------------|-----------|-----------------|----------------------|-------|
| Soybean       | Organic           | Nitrophospha- | Nil              | Nil                  | Significant higher enzymatic activities like urease, DHA, alkaline phosphatase, aryl sulphatase. |
|               |                   | Sulphocompost, Phosphocompost |                  |                      | Nil |
| 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. |
|               |                   | Commercially available fertilizers NPK | Nil | Less beneficial without inoculation | Nil |
| Red Amaranth  | Organic           | Different leaf litter (acacia, eucalyptus, teak, Sal) | Highest Organic matter, total nitrogen, available phosphorus, exchangeable available calcium and available magnesium. | Nil | Lower level of beneficial without inoculation |
|               |                   | Chemical fertilizers | Nil | The lower level of beneficial without inoculation | Nil |
| # | Crop/Species | Treatment | Fertilizer | Soil Characteristics | Soil Microbiota | Origin |
|---|-------------|-----------|------------|---------------------|-----------------|--------|
| 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 + biofertilizer s) | 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, including 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.

| Method                          | Treatment                        | Result                                      | Country       |
|---------------------------------|----------------------------------|---------------------------------------------|---------------|
| Inorganic                       | Lime @ 3.1 t ha⁻¹                | Nil                                         | China         |
|                                 |                                  | Significantly lesser nutrient levels than organic. | Li et al., 2017 |
| 19 Citrus Grandis var. Longanyou rhizosphere | Organic / Integrated fertilizer | All applied organic fertilizers/organic fertilizers + chemical fertilizers like N P K | Nil | China | Li et al., 2017 |
|                                 |                                  | 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 | China | Li et al., 2017 |
| No. | Plant          | Type     | Treatment                                                                 | Effect                                                                 | Control                                                                 | Method                                                                 |
|-----|----------------|----------|---------------------------------------------------------------------------|----------------------------------------------------------------------| ------------------------------------------------------------------------|------------------------------------------------------------------------|
| 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 | India Aseri et al., 2008                                              |
|     |                |          |                                                                           |                                                                         |                                                                         |                                                                        |                                                                        |
|     |                |          | Control Without any treatments                                           |                                                                         |                                                                         |                                                                        |                                                                        |
|     |                |          |                                                                           |                                                                         |                                                                         |                                                                        |                                                                        |
| 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                                                                     | Infected with native AM fungi                                         | Nil                                                                     | Egypt Khamis et al., 2014                                             |
|     |                |          |                                                                           |                                                                         |                                                                         |                                                                        |                                                                        |
|     |                |          | Control Superphosphate, (NH₄)₂SO₄, K₂SO₄                                  |                                                                         |                                                                         |                                                                        |                                                                        |
| 22  | Tomato         | Organic  | Chicken manure                                                            | Higher plant height and higher                                         | Nil                                                                     | Nil                                                                     | Nil                                                                     | West Africa Agyematn et al., 2014                                     |
| 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 |
| 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 et al., 2002 |
| Inorganic | Chemical fertilizers | Nil | 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

| 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 |
| 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 |
| Inorganic | Nitrogen, phosphorus and potassic fertilizers. | Nil | Nil | Nil | Lesser microbial population as compared to organic |

Jiangsu, China
Ji, 2017

Karnataka, India
Bopaiah and Bhat, 1981
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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