

ROLE OF FUNGI IN SOIL HEALTH

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Abstract: Healthy soil is a fundamental necessity of increased food because soil health is directly connected with the production of healthy food which impacts public and animal health. Dynamic nature of soil organism makes them sensitive to natural or management related soil changes and thus make excellent assessors of soil quantity. Microorganism in the soil contributes to the enhancement and preservation of soil quality controls the decomposition of plant and animal materials and it also controls organic chemical in the soil. Soil microorganisms such as bacteria, fungus play a central role in soil fertility, processing, promoting crops health and also involves in protecting the soil organic matter. Fungi play important role in stabilization of soil organic matter, immobilizing, retaining nutrients, and decomposition of residues in the soil, so it is also very essential to maintain fungal biodiversity in soil. Fungi have a profound influence on biogeochemical cycles through their growth habits, which include external digestion of food resources by their digestive enzymes, and secondary metabolites. The rate of turnover of fungal biomass has significant consequences for the C cycle and long-term sequestration in soil. Fungi dominate microbial biomass and activity in soil organic horizons mainly in the forest, and they are mainly influenced by N and P. This review focus on the fungal biodiversity and its role in soil health.

Keywords: Decomposition, Soil dynamics, Arbuscular mycorrhizal fungi, Parasites, Saprophytes, Secondary metabolites.

1. Introduction

Soil organic matter is the key relevance in maintaining soil resistance and stability. Soil health will determine the sustainable agriculture especially in the content of soil dynamics, microorganisms so when there is a change in fungal communities it will affect the functional stability of soils (Treseder and Lennon, 2015). Microbial biomass maintains the soil pH neutral, high clay content, sufficient nutrient availability. The productivity of soil biomass by optimizing microbial substrate is efficiency by keeping the soil pH neutral. The composition of soil is essential it is maintained by all microorganisms because the physical and chemical composition of the soil will determine the generic composition and size of the mycoflora (van der Heijden, 1998). Many microorganisms can also grow outside the soil so it is important to preserve healthy soil and deserve ecosystem (Pankhurst, 1997). Whereas soil fungi do important functions within the soil such as nutrient recycling, disease suppression, water dynamics and important role in the metabolic process occurring in the environment (L.Y. Kutateladze, 2016). Fungi can be originating in almost every environment and can live in a wide range of pH and temperature (Frac et al., 2015). Due to their high plasticity and their capacity to adopt various forms in response to adverse or unfavorable conditions, fungi are very successful inhabitants (Sun et al., 2005).

Soil fungi are an important component of soil due to their biochemical activity and engagement in nutrient cycling can also be influenced by human activities and the components of long-term fertilization and other treatments. Nearly 70,000 distinct species of soil fungi are identified were as 1.5 million species were found worldwide (Hawksworth, 2001). Ecosystem regulators like living microorganisms are also responsible for soil structure formation, modification of habitats for other organisms and principle decomposers which release carbon, nitrogen and other elements. (Carlile, 2001), whereas fungi are known to increase the soil structure by promoting the soil aggregates and spores within especially some fungi react directly with the plants by associating with them as pathogens and mutualist (Degens, 1997; Miller and Jastrow, 2000).

2. Fungal communities

Fungal communities in the soil are species-rich and patchy at small spatial scales. In soil fungal communities are influenced by climatic conditions on both geographic and temporal scales. Soil fungi were grouped into three general functional groups depending on how they obtain their energy. Decomposers which is saprophytic fungi they convert dead organic material into fungal biomass, carbon dioxide (CO₂), and small molecules, such as organic acids. The Saprophytic fungus is the major agents of decomposition (Boddy., et al 2008) because they are commonly active around woody plant residue. They decompose cellulose and lignin found in the soil for energy. The metabolic byproducts of this process include carbon dioxide, Co₂ and smaller molecules such as organic acids; some of these metabolites remain in the soil surroundings for thousands of year in right conditions. Saprophytic fungi use complex substrates, such as the cellulose and lignin, in wood which is essential in decomposing the carbon ring structures in pollutants and some fungi use simple substrates which are called as sugar fungi

The second type is Mutualist, the fungi which develop a mutually beneficial relationship with plants namely mycorrhizal fungi (Ingham, 2009). They are commonly associated with grasses and crops. These fungi are a very important part of the soil system; many fungi in the forest are mycorrhizal (Alexander, 1961). Mycorrhizal fungi are plant growth promoting fungi, it decomposes the litter on the floor, they dominate in low pH and slightly acidic soil, one major group of mycorrhizae is

ectomycorrhizae that grow on the surface layer of the roots, actually does not invade the root cells but forms the sheath. Another type is endomycorrhiza which grows on shrubs. Arbuscular mycorrhizal (AM) fungi are these type of endomycorrhiza. Mycorrhizal roots are penetrated by hyphae, due to the presences of roots it forms a link between forest litter and plant root and all nutrients are observed by mycorrhiza. Most of these fungi decompose lignin and digest the soil organic matter (Sylvia, 2005). Exchange of carbon atoms from plants occurs which helps mycorrhizal fungi to make phosphorus that is easier for plants to draw in and they also bring soil nutrients, including nitrogen, micronutrients, and water to the plants (Wilson, 2009). Mycorrhizal fungi directly or indirectly involved in the stabilization of carbon in the soil. By the symbiosis plant directly transfer a larger amount of assimilates from the soil (Schweigert, 2015). Plant growth is increased by mycorrhizal fungi by nutrients enrichment approximately 90 % of plants form symbiotic mycorrhizae fungal relationship by forming hyphae networks (Meeting, 1993)

The third group of fungi are pathogens or parasites, they root pathogenic fungi which includes *Verticillium*, *Pythium*, and *Rhizoctonia*, Some species also act as decomposers which are called as saprophytic fungi which decompose chitin and lignin in the soil (Owen, 2015). Some fungi in return it also affect plant growth through mutualism, pathogenicity and their effect on nutrient availability and cycling (Wardle, 2002; Wagg et al., 2014; Hannula et al., 2017). Pathogenic fungi cause many agriculture root disease including *Phytophthora*, *Rhizoctonia*, *Pythium*, *Verticillium*. *Ascomycetes* fungi are mainly dominated in the agriculture soil and grassland, whereas basidiomycetes have larger fruiting body or mushroom that dominate in high residue and forest soil (Dick 2009). Some fungi help to control disease and predators including nematode-trapping fungi that feed on insects and can be used as biological control (Scholer et al., 2017). These fungi have the ability to produce a huge variety of extracellular enzymes which helps in a break down all kinds of organic matter and involves in regulating the balance of carbon and all kinds of nutrients (Zifcakova et al., 2016). The chitin addition to the soil increase fungi that can degrade the pathogenic fungal cell walls and can thus increase the soil suppressiveness against plant pathogen *Trichoderma harzianum* species was often used for biological control against soil-borne pathogenic fungi (Nguyen and Bruns, 2015). *Trichoderma koningii* helps to increase the soil nutrients it was added to the soil for seed treatment, significantly increased the percentage and spread of the soil germination (Kutateladze, 2014).

3. Arbuscular mycorrhizal fungi (AMF)

Arbuscular mycorrhizal fungi (AMF) are the most important class of beneficial microorganisms in agriculture and horticultural soils. Significant increases in the yield of crop plants following inoculation with AMF (Thilagar and Bagyaraj, 2015). AMF is required for soil aggregate stability, whilst the contribution of roots to soil structure is further stabilized by AMF (Daynes, 2013). The key effect of AMF symbiosis includes improvement of rooting and plant establishment, stimulation of nutrient cycle, improvement of soil structure, enhancement of plant tolerances to stresses to increase uptake of low mobility irons and enhancement of plant community diversity (Azcon, 1997). The positive effect of the fungi in soil and plant growth was increased by a microbial consortium of AMF with plant growth promoting rhizobacteria (PGPR) (Lindahl et al., 2013).

4. Microbial biomass and activity

The important roles of fungi are a synthesis of a growth factor such as vitamins and auxins, fixing of atmospheric nitrogen and production of soil aggregating substances (Glick, 2012). Many plants depend on fungi to extract nutrients from the soil mainly phosphate, *Penicillium radicum* a phosphate solubilizing fungi which are isolated from the rhizosphere of wheat roots are involved in solubilizing phosphate which is essential in plant growth promotion this helps to improve the P nutrition of plants and thus stimulate plant growth (Whitelaw, 1999). Microorganisms increase the nutrient bioavailability through nitrogen fixation and mobilization (Muhammad, 2015). Soil fungi help in mobilization and solubilizing insoluble form and structural unavailable form of K compounds (Abou-el-Seoud 2012). Soil fungi increase the organic matter which also boosts the availability on N, P, K and Fe (Egamberdiyeva and Höflich, 2004, Caesar-Tonthat et al., 2014, Leifheit et al., 2015). The basic mechanisms through which bacteria and fungi promote nutrients bioavailability include N fixation, P, K and Fe mobilization through production of organic acids and siderophores (Mortimer, 2008) In addition to this, organo-polysaccharides and proteins (glomalin, mucilages, and hydrophobins) are also produced that help to promote soil aggregate stability (Caesar-Tonthat 2014).

Recently, it has been shown that fungal biodiversity in soils is strongly affected by plant community due to the fertilizers (Yang, 2017) so organic manure usage has a strong influence on soil health by an alteration in physical, chemical characteristic and availability of soil fungal communities (Goldstein, 1994). Soil micro-organisms have already been identified as essential players in carbon, nitrogen and phosphorus cycling, and consequently in soil fertility (Whitman et al., 1998; Yang et al. 2014), which is also involved in the degradation and recycling of organic matter (Johnson et al., 2013). Interaction of microbes with soil organic matter is a key constraint limiting soil organic matter decomposition, affecting cycling and storage of carbon (C) and nitrogen (N) (Schimel and Schaeffer, 2012; Lehmann and Kleber, 2015). The basic mechanism through which fungi promotes nutrient bioavailability includes N fixation, P, K, Fe mobilization through the production of organic acids this helps to promote soil aggregate stability (Mortimer, 2008).

5. Fungal functions in soil health

Fungal diversity determines the plant biodiversity, ecosystem variability, and productivity in forest area and also in cultivation lands (Wagg et al., 2014). Degradation of soil properties leads to deforestation mainly affects soil fungal diversity and

functional stability (Chaer et al., 2009). During the process of thinning, the transfer of nutrients from aboveground biomass to forest soil takes place (Tian et al., 2010). It had been shown that the number of fungal species and colonies in the profile fall down with depth. Few species of fungi are found abundant on the surface layer, few species are found in chalky boulder clay of the C horizons (Warcup, 1951). Soil organism's influences above ground ecosystem by contributing to plant nutrients (George, 1995). Fungi play important role in decomposing the forest litter or dung, or other organic matter (Campbell and Reece, 2002). During the winter season, the microbial community of Arctic soil is dominated by saprotrophic fungi (Schimel and Mikan 2005), but fungal activity during the growing season cannot be neglected because of its important role in supplying arctic plants with minerals and nutrients (Schmidt and Bolter 2002). Strong linkage was proved between functional soil biodiversity and the function of the soil ecosystem (Wagg et al., 2014; Delgado-Baquerizo et al., 2017; Morrien et al., 2017). Later on, there is an overall shift in fungal assemblages along environmental gradients could be determined by changes in specific groups with specific functions, for instance, some fungi are tightly linked with plants through symbiotic and parasitic relationship (L.Pellissier 2014).

6. Fungal pigments

The application of soil fungal pigments are in dyeing cotton, silk and wood have been already reported (De Santie et al., 2005). Fungal pigments provide a readily unavailable alternative source of naturally derived pigments which is used worldwide. Filamentous fungi are known to produce an extraordinary range of pigments such as carotenoids, melanins, flavins, phenazines, quinines, monascin, violacein, and indigo (Dufosse et al., 2014). Nearly 200 fungal species have been reported for the pigment production which has antimicrobial, antimutagenic anticancer and antiobesity property (Feng et al., 2012). Fungal pigments should satisfy several criteria such as toxicity, regulatory approval, and stability. Now a day's natural pigments are widely used in foodstuff. Normally all fungi have the potential to produce secondary metabolites even pathogenic fungi have the probability of producing one or more range of secondary metabolites such as gibberellins (GAs) which explained by Tudzynski, 2005. The functions of secondary metabolites generally recognized that pigment materials are likely product fungi from exposure to environmental stress like UV light.

7. Conclusion

Soil health condition has a remarkable impact on environmental sustainability which is directly connected with the production of healthy food. Fungi is the important source to maintain the soil health so it's important to maintain the fungal communities in soil because fungi mediate all the aspects of organic matter production and structuring the communities. Rates of turnover of fungal biomass have significant consequences for long-term sequestration in soil. A fungus was profound influences on biogeochemical cycles through their growth habits, which includes digestion of food resources by a prevailing arsenal of degradative enzymes and secondary metabolites. Fungi are considered as the principle degraders of plant cell wall materials and drive the bulk of primary litter decomposition in most soils. The soil food web is a significant complex food web on earth with fungi plays a central role as both specialized consumers and specific prey.

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