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Potentiality of mycorrhizal fungi in Indian ecosystem: A study

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Abstract
Mycorrhiza is a mutualistic symbiosis between plants and fungi localized in roots or root like structures in which energy moves primarily from plants to fungi and inorganic resources move from fungi to plants. Mycorrhizal fungi may play important roles in nature. Findings of many researches are helpful in understanding the role of mycorrhizal fungi in the structure and functioning of ecosystems. In this review article, the following aspects of mycorrhizal fungi research have been found as an important part of ecosystems, mycorrhizal fungi consume a great deal of photosynthate and are parts of food chains They have a great effect on the biogeochemical cycling .They have an interaction with microbes in the soil and thus may have an influence on the composition of soil microbes. They influence the inter or intra-specific interactions of plants through having beneficial effects on host plants or connecting different plants with mycorrhizal networks. The magnitude and species composition of mycorrhizal fungi may indicate the changes of an ecosystem and mycorrhizal fungi can also be used in the conservation of natural ecosystems. The focuses of mycorrhizal fungi researches and a brief perspective have also discussed in this review study.

Keywords: mycorrhiza, ectomycorrhizal fungi, endomycorrhizal fungi, functioning

Introduction

The word mycorrhiza is derived from the Classical Greek words for 'mushroom' and 'root'. Certain fungi are capable of infecting roots and forming a symbiotic relationship with them. The resulting structure is called a mycorrhiza, or literally fungus-root. In a mycorrhizal association the fungal hyphae of an underground mycelium are in contact with plant roots, but without the fungus parasitizing the plant. In fact the association is commonly (but by no means always) mutually beneficial. Through photosynthesis a chlorophyll-containing plant makes simple carbohydrates (using carbon dioxide, water and sunlight). While it is clear that the majority of plants form mycorrhizas, the exact percentage is uncertain, but it is likely to lie somewhere between 80% to 90%. In many of these associations between 10% to 30% of the food produced by the plant moves through to the fungi. The benefits of mycorrhizas to plants are well documented and include efficient nutrient uptake, especially phosphorus; enhanced resistance to drought stress; and direct and indirect protection against some pathogens. From an ecosystem standpoint, Mycorrhizal benefits extend much further in space and time. In addition to participation in nutrient cycling and food web processes, Mycorrhizal fungi provide linkages among plants that affect plant community development and resiliency. Indeed, many fungi can form mycorrhizas with diverse plant species, including across plant families (Rajak, 2004). Under field conditions a new flow of carbon can move from a donor plant to shaded recipient plant via Mycorrhizal fungus linkages. Thus, understorey plants many receive partial nourishment from overstorey plants via a shared Mycorrhizal fungus net work Mycorrhizas are mutualistic associations between fungi and plant roots. They are described as symbiotic because the fungus receives photosynthetically derived carbon compounds from green plant and the plant increase access to mineral nutrients and sometimes water**.** The two most common associations are the arbuscular endomycorrhizas (AM) formed by Zygomycete fungi, and the ectomycorrhizas (ECM) formed by Basidiomycetes, Ascomycetes and a few Zygomycetes. Other mycorrhizal associations include the Orchid, Ericoid, Arbutoid, Monotropoid and ectendo- mycorrhizas (Brundrett *et al*., 1996). Mycorrhizal associations predominate in most natural terrestrial ecosystems (Brundrett, 1991). Whereas the endomycorrhizas fungi are widespread geographically and have a very extensive host range, the ectomycorrhizal fungi are more restricted, forming associations predominantly with genera of important woody plants. Nevertheless endomycorrhizas fungi are dominant components of the ground-dwelling macro-fungi in ecosystems of the following plant families: Betulaceae, Dipterocarpaceae, Fagaceae, Myrtaceae, Pinaceae, Ulmaceae, Salicaceae. Ectomycorrhizas fungi are common in tropical and sub tropical forests of Asia but are uncommon in many forests like China, India and Nepal. The number of host species tends to increase with altitude and at higher latitudes.

Positive Aspects for Plants

The experiments have shown that mycorrhizal fungi can overcome nutrient limitation to plant growth by enhancing nutrient acquisition, especially phosphorus (Marschner and Dell, 1994; Clark and Zeto, 2000). A notable exception is the element boron which is often the main micronutrient limiting growth in Asia (Dell and Malajczuk, 2000).

According to the plant species and to the growing practices and conditions, mycorrhizae provide different benefits to the plants and to the environment:

Increase yields and crop quality

Reduce disease occurrence

Enhance flowering and fruiting

1. Increase plant establishment and survival at seedling or transplanting
2. Produce more vigorous and healthy plants
3. Improve drought tolerance, allowing watering reduction
4. Optimize fertilizers use, especially phosphorus
5. Increase tolerance to soil salinity
6. Contribute to maintain soil quality and nutrient cycling
7. Contribute to control soil erosion

Although many mycorrhizal fungi can access inorganic forms of N (Chalot and Brun, 1998) and P (Koide and Kabir, 2000), some litter-inhabiting Ectomycorrhiza fungi produce proteases and distribute soluble amino compounds through proposed mechanisms include the production of antibiotic or antifungal compounds by mycorrhizal fungi, and the activation of plant defence genes. Further, mycorrhizal plants may be less impacted by pathogenic nematodes than nonmycorrhizal plants (Smith, 1987; Pinochet *et al*., 1996), An increasing number of studies indicate the importance of mycorrhizal fungi for the survival of plants in places with problem soils or regions with extreme climate. The topic has been reviewed (Haselwandter and Bowen, 1996). Often, growth stimulation through the supply of essential nutrients dilutes the potential impact of damaging ions in the shoot. **1**)The capacity of plants to colonise soils containing high levels of heavy metals (such as Zn, Cu, Mn, Ni, Cr) is enhanced by their colonisation by mycorrhizal fungi (Galli *et al*., 1994; Hartley *et al*., 1997; Leyval *et al*., 1997). Possible mechanisms by which mycorrhizas deal with excess metals include the immobilisation of metals in the fungal hyphae or in root tissue (Hildebrandt et *al*., 1999).

Ectomycorrhizas plants in alkaline soils may be advantaged by the capacity of fungal hyphaeto access limiting nutrients such as P and Zn. Some ectomycorrhizas fungi produce oxalic acid which dissolves sparingly soluble calcium phosphates. Iron uptake may be enhanced by the release of siderophores (Marschner, 1995).

Endomycorrhizas fungi can protect some non-halophytic plants against yield losses in moderately saline soils. Possible mechanisms include the stimulation of root growth (Ruiz-Lozano and Azcon, 2000), improved plant nutrition (Al-Karaki, 2000) and increased synthesis of plant polyols (Juniper and Abbott 1993) in mycorrhizal plants. The incidence of Mycorrhizal and halophytes association is generally quite low (Brundrett, 1991). Little information is available for ectomycorrhizas associations (Dixon et al., 1993).

Ecological Management

The ecology of mycorrhizal fungi is not well documented (Abbott and Gazey, 1994; Francis and Read, 1995). Hence, conclusions are mostly drawn from short-term studies with a small range of partnerships. In nature, the situation is far more complex as a single tree may have fungal partners which can vary in time and space. The study by Moyersoen *et al*., (1998), on the co-occurrence of endomycorrhizas and ectomycorrhizas fungi in rainforest in Cameroon, provides a CMU.

The fungal/plant interface provides a conduit for the movement of carbon from the plant to the fungus, and for movement between plants linked by mycelia (Francis and Read, 1984; Wu *et al*., 2001). The nature of the interface and its mode of regulation are still being elucidated (Hall and Williams, 2000). It is generally believed that mycorrhizal plants direct more of their photosynthates into the soil than nonmycorrhizal plants. This extra carbon accumulates in patches and at the edge of hyphal mats (Finlay and Read, 1986), and boosts the energy supply to the detrital food web, benefiting saprohytic microbes and other soil organisms (Barea, 2000). Because the chemical (Dieffenbach and Matzner, 2000) and physical environment around mycorrhizas (the mycorrhizosphere) differs from nonmycorrhizas, presumably it provides microhabitats for soil biota that are not present in the rhizospere of nonmycorrhizal roots. Mycorrhizal fungi are estimated to consume from 15 to 50% of net primary production (Fogel and Hunt, 1979).

The main constraint to productivity appears to be low soil fertility (Dell and Malajczuk, 1994; Xu and Dell, 1998). Most of the land available for plantation forestry have been degraded over recent centuries with extensive loss of the A horizon caused by population pressure, inadequate management and over-harvesting (Xu, 1996). Top soil crusting is common, contributing to enhanced erosion, reduced soil water storage, compaction and poor root development. Low soil organic matter (SOM) content (<2%) Also restrains productivity. Significant effects of ectomycorrhizas fungal inoculation on growth of plantation eucalyptus were obtained at two sites in southern China (Xu *et al*., 2001). Effects were isolates stimulating tree growth and some isolates depressing tree growth. Similar results were obtained in a trial in the Philippines where two isolates increased survival while one isolate decreased survival of *Eucalyptus urophylla* Ectomycorrhizas fungi can mobilise P, N and other nutrients from litter to tree roots (Attiwill and Adams, 1993; Perez-Moreno and Read, 2000). Fogel (1980) estimated that ECMs account for 43% of the annual turnover of N in a *Pseudotsuga menziesii* forest in Oregon. Litter type can affect the diversity and function of ECMs (Conn and Dighton, 2000). Buscot *et al.*, (2000) propose that the high diversity of fungal partners that a tree may have allows optimal foraging and mobilization of various N and P forms.

Long-distance dispersal of spores from ectomycorrhizas fungi with hypogeal (truffle-like) sporocarps depends largely on mammal mycophagy (Kotter and Farentinos; Claridge and May, 1994). Mycophagy is widespread and has been demonstrated in Europe, Australia, Asia and North America. Mycophagy serves to maintain populations of ectomycorrhizas fungi and provides nourishment to small mammals (Malajczuk et *al*., 1987). Sporocarps are good sources of water, protein, carbohydrates and minerals (Johnson, 1994; Claridge et *al*., 1999). The tripartite relationship between truffles/truffle-like fungi, vertebrates such as squirrels and many ground-dwelling marsupials, and the host trees, are well known. Less well known is the role that mycorrhizal fungi play as a food source for invertebrates and the role of invertebrates in dispersal of ectomycorrhizas and endomycorrhizas fungal spores.

Use for People

In many upland forest regions of South Asia like Nepal, India and China, sporocarps of fungi, mostly basidiomycetes, have traditionally been collected for local consumption and trade (Dell *et al*., 2000). Many of these fungi, especially members of the Amanitaceae, Boletaceae, Russulaceae, and Tricholomataceae, form ectomycorrhizal associations with trees in the families Dipterocarpaceae, Fagaceae and Pinaceae are important for maintaining ecosystem function. The highest diversity of edible fungi is collected from mixed forests in China and the lowest diversity from areas of tropical pine and dipterocarps. In general, traded fresh sporocarps are 2 to 20 times more valuable, by weight, than local seasonal fruits and vegetables.

Soil versus Mycorrhizal Fungi

Any form of soil management that involves tillage, timber harvesting, vegetation clearing or other forms of disturbance can affect mycorrhizal populations. Severe soil disturbance, such as fallowing agricultural soils (Thomson, 1987), crop rotation, top soil stripping and storage during mining (Jasper et *al*., 1987; Gardner and Malajczuk, 1988; Bellgard, 1993), markedly reduces populations of mycorrhizal fungi. Unlike Endomycorrhizal fungi, Ectomycorrhizas fungi may be able to quickly invade disturbed soils (Jasper, 1994). This is often the case for what have been termed "early colonising" genera such as Laccaria, *Pisolithus, Rhizopogon, Scleroderma* and *Thelephora*. Recolonisation mostly results from spore dispersal by wind and animal vectors from sporocarps in adjacent vegetation. The mycelial network appears to be an important component of the inoculums potential of an undisturbed soil (Evans and Miller, 1990). Even minor soil disturbance can impact on the function of mycorrhizas. Several myceliums reduce the extent of inter-root and inter-plant connections, thus reducing access to existing and new food bases (Read and Birch, 1988).

Studies in a number of ecosystems (Reeves *et al*., 1979; Janos, 1980; Allen *et al.*, 1987; Siqueira *et al*., 1988) show that in climax communities, normally dominated by species heavily colonised by mycorrhizal fungi, disturbance leads to a successional sequence in which re-colonisation is initiated by plant species which are non-mycorrhizal or little infected (Read and Birch, 1988). Gap-preferring species thus may have lower rates of mycorrhizal infection than species preferring undisturbed microsites (Onipchenko and Zobel, 2000). However, It was found that for parts of tropical Australia, the activity of mycorrhizal fungi was higher in patches of early-successional vegetation than in undisturbed habitats. In a study in deciduous tropical forest in Mexico, Allen (1998) concluded that regrowth of vegetation in small gaps was not limited by Mycorrhizal fungi, since they were still abundant after treefalls. However, recovery in pastures could be affected by low fungal diversity and dominance of grasses. Jasper *et al.*, (1991) found that disturbance of forest and heathland soils decreased colonisation of test plants (clover) compared to disturbance of clover soil. They proposed that a larger number of propagules in the pasture soil may have allowed the pasture soil to maintain infectivity after disturbance. There is a suggestion that ecosystems with a high proportion of grasses and high numbers of endomycorrhizas spores may also be be more tolerant of Disturbance (Visser *et al*., 1984). The abandonment of agricultural land in the Italian Alps resulted in succession from nonmycorrhizal ruderal annuals to endomycorrhizas - colonised perennials and an increase in floristic richness (Barbi and Siniscalo, 2000). Over time, Ectomycorrhizas hosts will increasingly dominate if old-field succession is allowed to continue.

Conclusion

Most emphasis on the management of mycorrhizal fungi has focussed on disturbed habitats such as occur in agriculture and forestry; few studies have investigated the ecology of mycorrhizal fungal populations in natural systems. We know relatively little about how perturbations such as fire, flood, drought, volcanism affect the diversity,function and genetic composition of micorrhizal fungal populations. Our knowledge is depauperate concerning seasonal changes in mycorrhizal populations and fungal succession. However, it is clear that Mycorrhizal fungi are an integral part of ecosystems and provide physical links between the primary producers, the consumers and the decomposers. Clearly we need to understand a lot more about the biology and ecology of the mycorrhizal fungi in their natural habitats.

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