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Review of Application and Importance of Ectomycorrhiza Fungi and their Role in the Stability of Ecosystems

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Ectomycorrhiza is a kind of fungus-plant symbiotic that plays an important role in the performance, maintenance, improvement of the situation after the destruction, biodiversity evolution, stability and better and more efficiency from ecosystems. Ectomycorrhiza can be considered as an integral component of the biology and ecology of soil that has a significant impact on the growth and absorption of nutrients and protection against diseases. Given that today's concern of humanity is loss, damage or diminish of important economical species in the environment, ectomycorrhizal identifying is considered as an essential understanding of research in tropical and non-tropical forests. This paper is an overview of the diversity and performance knowledge of ectomycorrhiza and its impact on plant diversity, composition, restoration, dynamism and amount of biomass in the ecosystem. This paper also discussed about ectomycorrhizal effects and tolerance of these fungi in hard environmental conditions and their reflection in this situation such as nutrient deficiency, stress, drought, salinity and ultramafic soils and the effects of these fungi in the stability of ecosystems and climatic diversity of these fungi. This paper shows that ectomycorrhiza fungus is an integral part of plant physiology and also, plays a key role in plant adaptation to specific environmental conditions, but whether the ectomycorrhiza can be a promising tool for biological relationship between soil and plants and a natural and useful program to restore damaged nature?

Key words: Soil biology, mycorrhiza, environmental stresses, ultramafic

Symbiosis between plant roots (micro cement) and fungi (micro cement) was first discovered in plants by Kamienski (1881), Polish mycology and then it was named as mycorrhiza (fungus-root). Fungus-root includes a variety of arbuscular mycorrhiza, ectomycorrhiza, ectendomycorrhiza, ericoid, arbutoid, monotropoid, and orchid mycorrhiza. 80 percent of the species and 92% of plant families are mycorrhiza. This amount is different in angiosperms and gymnosperms and ferns [1].

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Ectomycorrhizal case (EMC) is detected through the hyphae of the fungus in the surface and around the involved roots [2]. There are more than 5000 fungi belonged to basidiomycetes and ascomycetes involved in ectomycorrhizal relation in almost 2000 plants [3]. Tuber fungus (the most popular edible mushrooms) belongs to ectomycorrhiza[4]. Most of the host plants of this group have short deformed and branched secondary roots [5]. Ectomycorrhiza may have an important role in rebuilding after entering the forest [6]. The Hyphae and Rhizomorphs of ectomycorrhiza are high, since, ectomycorrhiza needs more photosynthetic products (carbohydrates) and it has more biomass than other mycorrhiza. Hence, they have carbon costs than other mycorrhiza. Perhaps, this is due to the production of plant hormones by ectomycorrhiza

that impress the carbon transfers and convert the host sugar to the stored carbohydrates [7]. It is estimated that 10-60 thousand plants species are involved in ectomycorrhizal relation [8] in that 25-20 thousand species of ectomycorrhiza fungi are involved [9]. Most of ectomycorrhiza fungi are located in northern temperate forest soils, in contrast, mycorrhiza arbuscular have colonized the tropical forests[10]. In fact, although most plants show the mycorrhizal symbiotic, but temperate zone plants are more likely to involve in ectomycorrhizal relation [3]. Ectomycorrhiza fungi play a key role in the success of large-scale forest destruction, so that the symbiotic of these plants was used to minimize the effects of drought after the great fire of the central Alps [11]. It is difficult to predict the outcome of ectomycorrhiza relation, because sometimes a combination of competitive fungi species may show different results [12]. In the past few decades, different techniques were used to detect and apply these fungi considering the complexity, breadth and importance of ectomycorrhiza. Thus, the purpose of this paper was to refer these cases and their strengths and weaknesses.

Ectomycorrhiza in phytoremediation of contaminated soils

Root surface symbiotic fungi create harttingnet in addition to establishing roots in skin texture that this network in the main location of substances exchange between symbiotic fungi and plants and can create chelate from the heavy elements in its Harting network [13]. Also, it was recently shown that plants in ultramafic soils can have very good growth (soil with higher heavy metals (Ni, Cr, and etc.) compared to other soils) with involvement in an ectomycorrhiza relationship, because ectomycorrhiza gives the best answer in this condition and it will also increase the diversity of fungal [14]. Also, it was reported that with raising the information about adaptation and evolution of fungal species in this soil, better conditions can be provided for better growth of plant species in this environment [15]. Ectomycorrhiza symbiotic cause restricted access of plant to metal and absorbing it by the plant. The presence of heavy metals not only is not harmful, but also is better to fungal growth and fungal diversity and thus, it help to improve plant growth [16]. Jourund et al. showed in a study that plants inoculation with ectomycorrhiza in heavy soil (60 mg per kg of nickel) (high concentrations and toxic) increases root growth up to 20 times and shoot growth up to 30 times compared to the controlled case of ectomycorrhiza [17]. To justify this case, it could be argued that probably, fungal sheath coverage is an effective barrier to limit the transfer of nickel from the soil into the roots and make it available for the plant [17].

Ectomycorrhiza fungus increases the plant resistance to the certain conditions with its physiology and causes the better performance of the plant in this condition. This condition also causes fungal diversity that can be a solution for growth and yield.

Ectomycorrhizalization and salinity and drought

Fungus is important in various aspects such as pharmaceuticals, pathogens, production of specialty chemicals, and crop nutrition. About 5 to 6 thousand fungi species have been reported from different parts of the world which have ectomycorrhizal life with plant roots [18]. Many studies have been conducted in the field of the role of ectomycorrhiza fungi in protecting plants against drought and salinity stress and it was detected that this relation caused to increase nutrients absorption, rate of photosynthesis and water use efficiency of plants [19]. One of the species of ectomycorrhiza (Pisolithus) can protect the plant under drought stress and partly prevent damage in this condition [20]. Bandove et al. (2006) [21] investigated the effect of salinity on Coccoloba plant. They studied this plant in two modes of inoculated and not inoculated with a species of ectomycorrhiza (scleroderma bermudense). The results showed a significant difference in plant growth in two different modes. The following table explains this difference. Also, performed measurements in the amount of proline in the leaves showed that the amount of proline increased proportionally with increasing salinity, but its rate in controlled leaves remained almost constant.

Further studies were done to clarify the physiological mechanisms. For example, stomatal conductance of water, light efficiency and osmoregulation and the events that occur in salinity condition in plant physiology and soil physics in that the toxic effect of NaCl can be minimized. In this case, ectomycorrhiza can somewhat reduce the effects of stressful situations.

Ectomycorrhizalization and rehabilitation in the host

Since 1993, Indonesian used native species in the plantation system to enrich the forests due to declination of forest [20]. After conducting research in this area, they concluded that the best trees to combat this condition is Dipetrocarpaceae (due to soil compaction and excessive heat and intense competition of weeds)[22], because this tree had an intense desire to ectomycorrhizal relation [23] and this relation was essential for initial growth of tree [24]. Two years after a terrible fire in a forest in the eastern of Kalimanian, nothing was found on the floor of the burned forest. However, studies have shown the presence of symbiotic species with ectomycorrhiza and this shows that mycorrhizal inoculum potential of the soil will not remove after a terrible fire. Although, types of ectomycorrhizalize morphology in burned and healthy forests are different, but it can be a good option for reforestation of forest [25]. Ectomycorrhiza community studies on the parvifolia plant roots indicate a greater diversity of mycorrhiza open canopy to close canopy. Given that the environmental conditions were same, this can show a greater tendency to ectomycorrhiza in the sunlight compared to the shade condition [26]. Also, ectomycorrhiza symbiosis with S.lamellata plant during a year was higher than the symbiosis of this plant under the coverage of tree crown. It is remarkable that in the particular condition of Shorea, survival and growth of seedlings and relative growth of the plant, stem height and stem diameter was possible only with ectomycorrhiza insemination[25]. In a comprehensive review [23], it was argued that the inoculation of ectomycorrhiza fungi in the degraded areas likely grow to the favor of plants that grow in those areas. The experiment that was conducted in controlled and non-controlled conditions in Pisolithhus albus strain plant suggests that differences in trees' wood in ectomycorrhizal condition was clearly evident compared to controlled mycorrhizal condition, so that in ectomycorrhizal condition wood growth and its weight were several times further [27]. The results show that the inoculation with ectomycorrhizalize fungi can improve particular species of tropical forest growth and this technique would accelerate the restoration of degraded forests. Therefore, ectomycorrhiza inoculation (at seedling stage) is recommended to rehabilitate degraded areas in that the potential of ectomycorrhiza inoculation is limited.

Becham and Alexander (2012) [28] showed that ectomycorrhizalization lead to increasing the stem length, root length and total dry weight of

Table 1. Effect of inoculation with ectomycorrhiza in three levels of salinity and control within 3 months in Coccoloba uvifera plant

Minimal Leaf Water potential (-bars)	Leaf area (cm^2)	Number of leaves	NaCl levels (mM)	ECM status
9.2^{e}	33.7^{b}	3.60^{e}	0	Non-inoculated
13.4^{bc}	18.7^{a}	2.90^{c}	200	
14.0b	15.6^{a}	2.30^{b}	350	
15.0^{a}	15.7^{a}	1.90^{a}	500	
5.9^{f}	80.9^{e}	4.10^{e}	0	Inoculated
11.1^{d}	76.4^{d}	4.20^{e}	200	
12.2^{cd}	68.9d	3.80^{de}	350	
15.50^{a}	56.05^{c}	3.60^{d}	500	

Vermicompost	Vermicompost +ECM2	Salliter +ECM2	ECM2	Vermicompost +ECM2	Sallitter	Sailitter +ECM1	ECM1	Control	Status
3.03	7.98	4.90	6.99	5.03	4.20	3.44	3.64	2.35	Growth indices

ECM=Russula michiganensis, ECM2 = Lycoperdon compactum

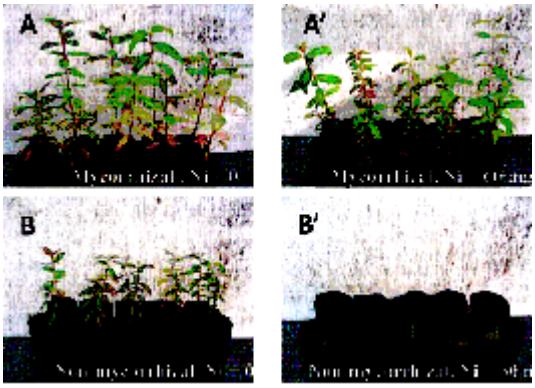
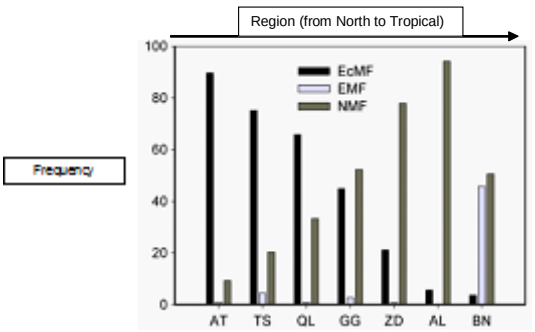


Fig. 1. Symbiotic effect of ectomycorrhiza fungi with eucalyptus plant in nickel and nickel-free environment in the two-week stage of growth by Jourand et al. [17]



plants in ectomycorrhizal plants compared to non-ectomycorrhizal plants. In this study, it was found that ectomycorrhiza allows plant to access to the phosphorus which can lead to better performance of the plant. These tests indicate that Gentumo plant shows a positive response to ectomycorrhiza symbiosis in its growth and this cause an increase in the absorption of nutrients such as P and N, so that their presence in the fields of Gnetum seems to be necessary, because some ectomycorrhiza in tropical area are able to use amino acids and some of proteins are the only resource of nitrogen. This means that this fungus is able to access some of the phosphorus in phosphorus deficiency and these findings can be used as an important strategy used to improve critical situations and this itself is a reason to use these fungi in terms of food shortage.

Ectomycorrhizalization and plant diversity

The following diagram shows a variety of mycorrhiza species in temperate, tropical, and semi-tropical forests. Diversity of ectomycorrhiza in northern areas and diversity of endomycorrhiza in semi-tropical area are further. The lowest diversity was in the tropical areas. It can be said that the diversity of fungus distribution pattern is created depending on regional and plant coverage and this pattern is inversely related to the ectomycorrhiza. However, it can be expressed that temperature is the environmental factors affecting the fungus diversity distribution pattern. This diagram shows the maximum and minimum variation in the different vegetation cover [26].

Effect of ectomycorrhiza was performed on the stability and growth of Sal plant (important species in the wood industry). In this study, different substrates were used for Sal plant. The best growth was related to the condition that substrate was composed of vermicompost and ectomycorrhiza fungi and the lowest growth was related to controlled mode of mycorrhiza and it confirms the usefulness and necessity of these fungi to better and higher growth [29].

Challenges

The reduction in the growth of the involved plants in the ectomycorrhiza relation can be due to the negative response to colonization of the specific root system or high concentration accumulation of available minerals to plants [30]. Some fungi cause the plant death, although they are useful. Some plant species are affected by the fungal parasite, but some are more resistant to diseases and thus the pathogenic type depends on the variety of plant-fungi combination and differences in habitat for seed survival. The studies showed that the effects of fungal pathogenic factors is dependent on the particular combination of plant-fungi [31]. For different plant species in different areas, symbiotic fungus for the same conditions is recommended. For example, in low rainfall areas in which, ectomycorrhiza is scare; scleroderma can be the known fungus partner. This fungus can be better studied by molecular studies in ectomycorrhizal communities by sequencing, sporocarps and ectomycorrhizas using Klasing Sanger method [32].

CONCLUSION

Symbiotic fungus preservation has become important more than ever due to destruction of the ecosystem in recent years, but attention to the climate differences are the best

option to improve conditions in each region for biological relation of plant and fungi. Although, ectomycorrhiza plays an important role in growth and development and soil toxicity tolerance and stressful conditions, their cultivation in each region depends on having a successful ectomycorrhizal relation with the plant and climatic conditions of that region. In general, ectomycorrhiza can be considered as an integral part of some plants' physiology. Ectomycorrhiza with its specific physiology is irreplaceable in northern areas' plants. Perhaps, advanced molecular methods from ectomycorrhizal relation can be used for most areas that this relationship is needed, but is not possible for various reasons. Fungal synthetic program may become necessary in most parts of the world in the future due to deforestation.

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