THE ROLE OF MYCORRHIZAE IN AFFORESTATION

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Abstract

Hungary is facing to perform intensive afforestation on 700 thousand – 1 million hectares during the next 40 years. New forests and wood plantations will be planted mostly on dry, poorly fertile soils nonprofitable for agricultural use to be found firstly on the Great Hungarian Plain. Applying artificially mycorrhized seedlings partly may considerably increase the effectivity of afforestation assuring of more intake of nutrients and water for the seedlings, partly we hope that may decrease the total costs of afforestation.

Keywords
Mycorrhiza, afforestation

1. INTRODUCTION

Hungary had always belong to the European forefront of quantitative afforestation. Therefore after the Second World War the forest area could be increased from 11 % by the present to 19 %. The extent of agricultural territories suitable for afforestation in the country is calculated to be between 700 thousand and 1 million hectares [1,2,3].

The agricultural territories possibly involved in afforestation belong partly to the very dry, sandy areas where the drought is often raised by high lime content. The other part of land potentially usable for afforestation is the steeps of mountains and hills previously covered by woods. These areas have been cultivated for centuries but exhaustion and erosion degraded the soils, so their agricultural use is nonprofitable. The humus content of these soils is very low, usually below 1 %. In additon agricultural soils miss the normal microbiota of forest soils the trees are adapted to and contain higly different microbe communities disadvantageous for the development of planted seedlings.

It can be stated that the roots of tree seedlings planted into agricultural soils get into a hostile environment which a part of the plantlets cannot cope with. That is one reason why new plantations must be planted in average 1,6 – 1,7 times or even twice.

According to our results merely in Bács-Kiskun County there are more than 300 thousand hectares of unpritable agricultural land can be proceeded. In such case afforestation seems to be the most reasonable land use [4].

Rapid ecological changes of the last years (e.g. warming up, drying and sink of underground water level) warn us to look for new ways of afforestation succesful also in disadvantageous circumstances. Establishing artificial mycorrhizae on the roots of seedlings is such a new and in addition a natural method.

2. THE EFFECT OF MYCORRHIZAE ON THE NUTRITION AND WATER UPTAKE OF FOREST TREES

Mycorrhiza, a symbiotic relationship between roots and fungi, is widespread all over the world. Different types of mycorrhizae, characteristic to plant communities having evolveld in different geographical and climatical zones, exist. In the decidous and needle woods under temperate climate trees typically form ectomycorrhizal connections mainly with basidiomycetes, less with some ascomycetes. There are of course some broadleaved species having endomycorrhiza connections (*Fraxinus sp., Acer sp., Prunus sp., Sorbus sp., etc.*)

Diversity of fungal communities in forest ecosystems is determined by the following factors:

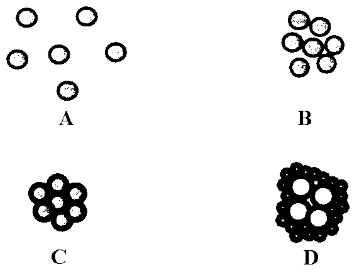
- *age of trees in the stand;*
- *composition of natural plant association, the occurence of host plants, specificity of host-symbiont connection;*
- *soil factors (pH, chemical composition, organic contents, etc.);*
- *climatic and microclimatic factors*

The mycorrhiza fungi have a great influence on the growth, water and mineral uptake of the trees to be as host plants.

According to the findings of several experiments on seedlings, mycorrhizal plants can better take up the water and show more drought-tolerant than non-mycorrhizal trees. Moreover, fungal strains differ widely in this respect. Several mechanisms are involved: a direct effect on water uptake through various strategies of soil exploration by the mycelium, an indirect effect through the modification of water status regulation by the tree and changes in the water-use efficiency of photosynthetic carbon.

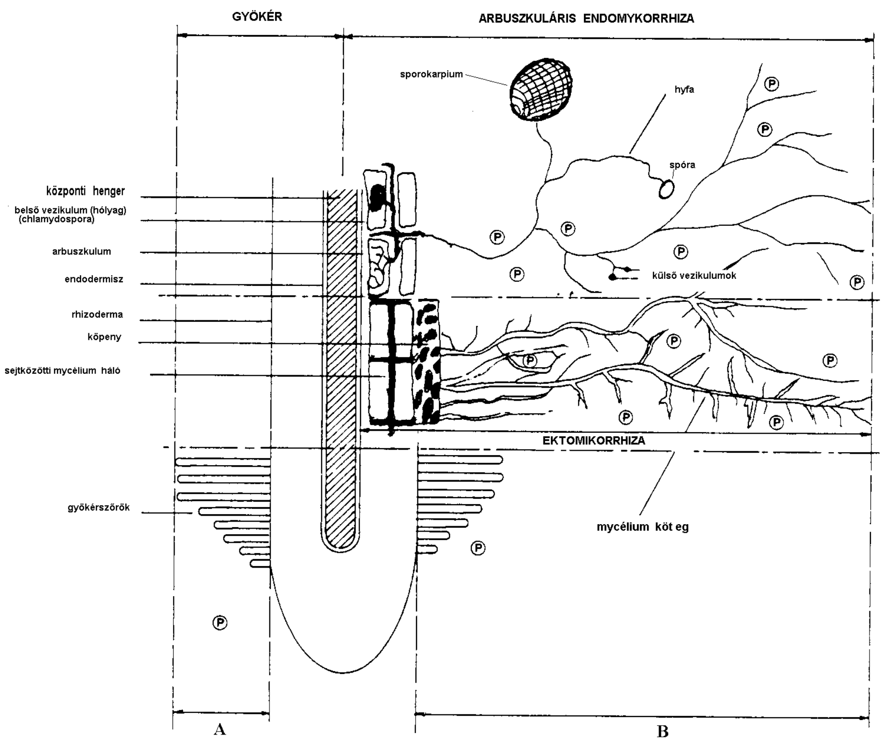
In ectomycorrhizae, a dense sheet of fungal mycelium, the so called *mantle*, is covering the root tips. Emanating hyphae, growing from the mantle into the soil, multiply the covered soil volume, and permit the increased water and mineral uptake. It happens the same way in the case of endomycorrhizae (Fig. 1-2.)

The advantage of mycorrhizae compared to non-mycorrhized plants is more distincly manifested in dry soils, poorly supplied with phosphorous and nitrogen. Mycorrhization increases growth (Table 1.) as well as P ans N content of plants (Table 2.)



A: myceliums consisting dispersed, individual hyphae
B: myceliums organised loose bundle
C: mycelium bundle containing closed connected hyphae
D: complex, water-conduit rhyzomorpha consisting thick, hollow hyphae inside and thin, cortical hyphae outside

Fig. 1. Organization of hyphae bundle [7]



A: the uptake-zone of roots (1 mm)
B: the uptake-zone of mycorrhiza (more than 10 cm)

Fig. 2. The extension of mineral uptake-zone surroundings of mycorrhiza [PLENCHETTE et al. 1982 cited in 10]

Mycorrhiza help plants to survive dry periodes and adapt to limy [8, 9, 13]. Mycorrhizal seedlings can tolerate higher soil temperature and lower pH conditions. Mycorrhizae increase toleance of plants against inorganic and organic toxic substances, protecting them from heavy metal stress [5, 6, 14, 15]. This is extremely significant economically in afforestation and reafforestation of dry, poor and polluted areas.

Table 1. The effect of ectomycorrhiza on overground growth of Pinus pinaster seedlings 10 months after planting out (fresh plant mass in g)

[MOUSSAIN et al. 1979 cited in 10]

Soil	Non-mycorrhized control	Natural mycorrhiza	Pisolithus tinctorius	Hebeloma cylindrosporum
1.	1,4 ± 0,2	3,5 ± 1,2	10,6 ± 1,6	13,5 ± 2,1
2.	0,6 ± 0,3		7,3 ± 2,6	8,9 ± 1,7
3a.	1,4 ± 0,7	3,5 ± 0,5	7,7 ± 0,7	6,9 ± 1,1
3b.	1,5 ± 0,3		4,6 ± 0,8	3,8 ± 0,4

The test was realised partly in controlled conditons. One part of the 3.5 months age seedlings were inoculated with artificialy produced mycelium, the other part of them were inoculated with naturaly mycorrhized root extract.
The soil samples were taken from the A level.
1. humous podzol; 2. eluviated adobed sand; 3a. slightly humous sand (humous content < 0,55 %); 3b. slightly humous sand (humous content = 0,08 %).

Table 2. The effect of mycorrhization on the N and P content on overground parts of Pinus pinaster seedlings 10 months after planting out (expressed in % of dry mass)

***[MOUSSAIN et al. 1979** cited in 10]*

Content	Non-mycorrhized control	Natural mycorrhiza	Pisolithus tinctorius	Hebeloma cylindrosporum
Total P	0,09	0,17	0,21	0,32
Total N	1,79	2,19	2,10	2,77

3. POSSIBILITIES OF APPLICATION OF MYCORRHIZAE

In the nurseries, the underground parts of the plants are often damaged by different root pathogenic fungi belong to the following genera.

- *Phytophtora*
- *Pythium*
- *Fusarium*
- *Rhizoctonia*
- *Cílindrocarpon*

Some of them can cause diseases only when plants are stressed (alcalic pH, bad water draining, too low/high temperature or irradiation). In contrary, *Phytophtora*, *Fusarium* and *Rhizoctonia* are agressive pathogens damaging also healthy plantlets.

The most simple protection methods are the traditional crop-rotation and the soil desinfection. The sensibility of phytopathogenic fungi against chemicals are highly different. Many pathogenic fungi are resistant to commonly used fungicides. Worldwide tendency of decreasing the use of pesticides from human health and environmental protection reasons helps biological control methods to expand.

The plant protection effect of ectomycorrhizal fungi have been demonstrated [14]. These fungi may play a significant role in the biological control of nurseries. The main advantage is that, in contrast of pesticides which must be applied repeatedly, mycorrhizae have to be applied only once. However, it is important that inocula get into the soil before phytopathogens can spread [12].

The protection mechanism of ectomycorrhizal fungi consists of the following elements:

- *fungal mantle itselfs serves as a mechanical defens barrier to root;*
- *the mycorrhizal fungus degrads toxins and enzymes of the pathogens and produce acids and antibiotics inhibiting the enemy;*
- *mycorrhizal fungi compete with pathogenic species for the use of root carbohydrates;*
- *the rhyzosphere of mycorrhized roots are about ten times richer in other microorganisms than non-mycorrhized ones;*
- *some microbes enhance mycorrhization, they are so called Mycorrhiza Helper Bacteria (MHB) and some show an additional inhibition against pathogens*

According to experiments carried out in Germany the sheat volume of beech seedlings mycorrhized with Pisolithus tinctorius was by 72 % higher than that of the non-mycorrhized control. The same value in the case of Paxillus involutus was 58 % [11].

3. CONCLUSIONS

We hope that using mycorrhized plants for the afforestations, we can partly establish healthier forest ecosystems and more productively wood stands, partly may decrease the total costs of afforestations because it will be no need to repeat the plantations.

After some years of preparation, this year we have begun the field trial to produce more and more mycorrhized forest seedlings for the afforestations.

4. REFERENCES

1. Barna, T.: A hosszú távú erdőtelepítési program. (The-long term afforestation program.) Erdészeti Lapok **76**, 168 (1991)
2. Barna, T.: Erdőtelepítések az Alföldön. (Afforestations on the Great Plain). Hidrológiai Közlöny **73**, 34-39 (1993)
3. Barna, T., Király, L., Kőhalmy, T., Varga, F.: Az erdő- és vadgazdálkodás. (Forest and wild economy) AGRO-21. **7**, 5-35 (1995)
4. Barna, T.: A racionális földhasználat lehetőségei erdő- és ültetvénytelepítéssel (Possibility of land use by afforestation and tree plantation) In: Kiút a válságból. MTA RKK Pécs 157-161 (1993)
5. Berry, C.R.: Survival and growth of pine hybrid seedlings with Pisolithus ectomycorrhizae on coual spoils in Alabama and Tennessee. Journal of Environmental Quality **11**, 709-715 (1982)
6. Bradley, R., Burt, A.J., Read, D.J.: The biology of the mycorrhiza in the Ericaceae VIII. The role of mycorrhizal infection in heavy metal resistance. New Phytol. **91**, 197-210 (1982).
7. Garbaye, J – GUEHL, J.-M.: Le rôle des ectomycorrhizes dans l'utilisation de l'eau par les arbres forestiers. Revue Forestière Française XLIX. N° spec. 110-120 (1997).

8. Hocine, H. et al.: Possibilités de mycorrhization de Cedrus atlantica Manetti. Annales de la Recherches Forestières au Maroc. **27**. spéc. Vol. I-XXXVI.: 350-361 (1993).
9. Le Tacon, F.: La mycorrhization contrôlée et ses possibilités d'application (les progres réalisés aux USA). Revue Forestière Française 30, 353-362 (1978).
10. Mousain, D. – Matumoto-Pinto, Paula – Quiquampoix, H.: Le rôle des mycorrhizes dans la nutrition phosphatée des arbres forestiers. Revue Forestière Française XLIX. N^o spec. 67-81 (1997).
11. Scmitz-Zeitz, D.: Mykorrhizaeinsatz im Langzeitversuch. AFZ/Der Wald **23**. 1264-1265 (1995).
12. Stenström, E., Damm, E., Unestam, T.: Le rôle des mycorrhizes dans la protection des arbres forestiers contre les agents pathogènes du sol. Revue Forestière Française XLIX. N^o spec. 121-128. (1997).
13. Theodoru, C., Bowen, G.D.: Mycorrhizal reponses of radiata pine in experiments with different fungi. Austral For. **34**, 183-191 (1970).
14. Trappe, J.M., Molina, R., Castellano, M.: Reaction of mycorrhizal fungi and mycorrhiza formation to pesticides. Ann. Rev. Phytopatol. **22**, 331-359 (1984)
15. Turnau, K., Kottke, I., Oberwinkler, F.: Paxillus involutus – Pinus sylvestris mycorrhizae from heavily polluted forest. Bot. Acta **106**, 213-219 (1993).