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EXPERIMENTAL USE OF CONTROLLED MYCORRHIZATION IN AFFORESTATIONS IN HUNGARY

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SUMMARY
As we indicated above, we are for the time being only at the beginning of our analysis. A conclusive evaluation can only be given in view of data extending over several years. We met namely a number of phenomena concerning the nutrition content of the leaves, which we cannot explain at the moment. It is however obvious in most cases, that the mycorrhized trees are able to build a bigger tree volume, than the control trees. On this basis – as an early evaluation – we can say, that mycorrhizae is indeed a useful method to increase the tree volume production of afforestations realized on dry soils with poor nutrient content.
KEY WORDS:
mykorrhizae, plant nutrients, Populus alba L., Robinia pesudoacacia L., Pinus nigra Arn. forestation

1. INTRODUCTION

The nutrition of woody plants means, that plants absorb the vital materials from the environment by the help of energy and they transform them by assimilation. The energy used during the process comes mainly from sun-rays. (Heinze, M – Fiedler, H-J. in Lyr, H. et al. 1992). Whether a plant is adequately supplied with nutrients, can be estimated from its nutrient content.

Nutrients can be inorganic or organic materials. The autotrophic plants are able to absorb and utilize inorganic materials and produce organic bindings from them during photosynthesis but they can absorb and handle organic materials as well. Organic materials are available in the form of ions and molecules. The plant absorbs these nutrients *mainly from the soil solution through its roots*. (Heinze, M – Fiedler, H-J. in Lyr, H. et al. 1992).

Different kinds of symbionts help plants including woody plants to do it, and make the absorption of nutrients and water possible by an increased extent. Mycorrhizae is also such a symbiosis, which is constituted by vascular plants and different kinds of fungi: *Glomales - endomycorrhizae*, and the different *Asco-* and *Basidiomycota – ectomycorrhizae* (Barna 2003).

In Hungary is proceeded the afforestation of a yearly average of 10.000 hectares of such agricultural land, where the agricultural plantation has already become uneconomical. 15-20% of this tree planting is realized in Bács-Kiskun county. The local dry, sandy soil with poor productivity was extremely affected by the fast ecological changes in latest years (global warming, drying, sinking of soil water).

These phenomena warn us that we have to find new methods of successful tree planting. (Barna 2003).

We wanted to achieve by the artificial mycorrhization carried out in 2004/2005, that we can increase the nutrition and water absorption capability of trees and thereby their organic material production, namely the tree yield. Mycorrhizae is particularly suitable for it among the symbioses of woody plants, because it occurs generally in natural surroundings, it means no dramatically different, artificial intervention into the forest biome, and according to previous foreign experiences it is an effective method of increasing the growth, viability and resistivity of trees.

We will report on hereinafter, how the height and thickness growth, as well as the N, P, K, Ca, Mg, and Zn, Fe, Mn absorption of the most important tree species (*Populus alba* L., *Robinia pesudoacacia* L., *Pinus nigra* Arn.) within the afforestation in this area has changed by the effect of artificial mycorrhization realized in 2004. We compared the nutrition content of the tree leaves with the nutrition supply of the soil and we simultaneously examined the mycorrhization level of the roots.

2. APPRAISAL OF THE MYCORRHIZAE EXPERIMENT 2006. MATERIAL AND METHOD

The climate of the experiment area is extremely dry, the yearly precipitation is around 500 mm, and the calcareous sand soil in general is poor in humus and nutritions. We used the Czech products SYMBIVIT and ECTOVIT as a graft material for mycorrhization.

The examinations were made within afforestations of white poplar (*Populus alba* L.), black locust (*Robinia pseudoacacia* L.), ash (*Fraxinus excelsior* L.), pedunculate oak (*Quercus robur* L.) and black pine (*Pinus nigra* Arn.). We will report however in the present summary about our experiences regarding forestations of Populus alba, Robinia pseudoacacia and Pinus nigra.

We measured the collar diameter and height of at least 30 trees in the afforestations of mycorrhized saplings both in the treated area and the control area; we collected at least 30 leaves from various parts of the trees for studying their nutririon contents, and we collected root samples both in the treated area and the control area from 3 trees each to examine the mycorrhization level. We took the samples at the end of July – beginning of August.

The leaves were analised by the Laboratory of the Research Institute for Viticulture and Oenology (Kecskemét-Miklóstelep), the roots were examined by the OMMI National Institute of Agricultural Quality Control - Laboratory of Phytopathology (Budapest). The tests were realized in three forestries of KEFAG ZRt. – Forestry of Bugac, Forestries of South- and North-Kiskunság. We will publish the test results regarding only the Forestry of Bugac because of the volume limits.

3. RESULTS

3.1. Status of mycorrhyzation

Table 1 shows the variations of the growth of roots and heights, as well as the status of mycorrhization. It can be assessed, that the mycorrhizae inoculation in the Bugac Forestry are well shown in the roots. We could identify ectomycorrhizae primarily, but the occurence of endomycorrhizae was also relatively good compared to the other samples.

There can be several explanations for inefficient mycorrhization:

- The inoculation was not careful enough in every cases;

- The sampling was not perfect, because mycorrhizae can only be found on the slim radicles!
- The root samples – and also the mycorrhizae on them – are extremely sensitive of storing circumstances. It could happen, that between the sampling and the analysing not all samples were kept under ideal circumstances, and as a consequence some samples could become destroyed.

3.2. The effect on tree growth

We measured the collar diameter and the tree height among the growth parameters. The height could not be measured in every case because of the strong animal chewing. We pointed out the results in table 1, which were at least 20% better than the control. It is interesting to mention, that the collar diameter of the 2years old mycorrhized black pines in the Bugac afforestation 24A had a result of 153,04% compared with the control Bugac 16A, but the heights of the saplings were only 87,18% of the control! We had a similar, but inverse result in the white poplar forestation in Solt 16C, where the collar diameter of the mycorrhized trees was less than the control (91,37%), but their height was 119,33% compared with the control.

We measured the best results regarding root diameter in the forest part Bócsa 7C, where we made two various treatments two years ago. In this afforestation we planted such saplings, which we have already mycorrhized in the nursery by soil inoculation, and we planted also such seedlings, which were mycorrhized on the spot by dunking, immersing the root of the seedlings in the inoculum. Just like generally, where we applied these two various methods, the mycorrhization on the spot gave the better results in this case, too. The same is true of both the locust and the white poplar. In the case of Bócsa 7C the collar diameter of the saplings treated on the spot were 250,52%, concerning saplings mycorrhized in the nursery were 188,57% compared with the control.

Regarding height we measured the best results also in Bócsa, in the parcelle 3A, where the heights of the white poplars mycorrhized on the spot were 175,63%, the heights of those mycorrhized in the nursery were 163,45% compared with the control. So the mycorrhization on the spot brought a better result in point of the height growth as well.

3.3. The results of the nutrition content analysis

We examined the nutrition content by analysing the leaves. For the time being there can be made out only some general rules. For example, that the increasing K content effects the decreasing of the Ca and Mg content, and inversely: the decreasing K content accompanies increasing Ca and Mg content (Diagr. 1-2).

In the case of black pine it can be presumed, that the higher N/P/K content of the mycorrhized saplings needles compared with the control has effected the stronger thickness growth of the treated saplings. (Diagram 2). This phenomenon can be judged with safety only on the basis of analysis lasting over several years. Ivanova – Lavricsenko (1980) and Fiedler – Höhne (1984) (quoted Lyr et al 1992) have drawn the conclusions from their studies of analysing scotch pine and spruce needles on the territory of the former GDR and the former Soviet Union, that the optimal macro nutrition element proportion regarding scotch pine is N/P/K 10,04:1:4,34, and regarding spruce is 6,67:1:4,57. I haven't found any data concerning black pine in the literature.

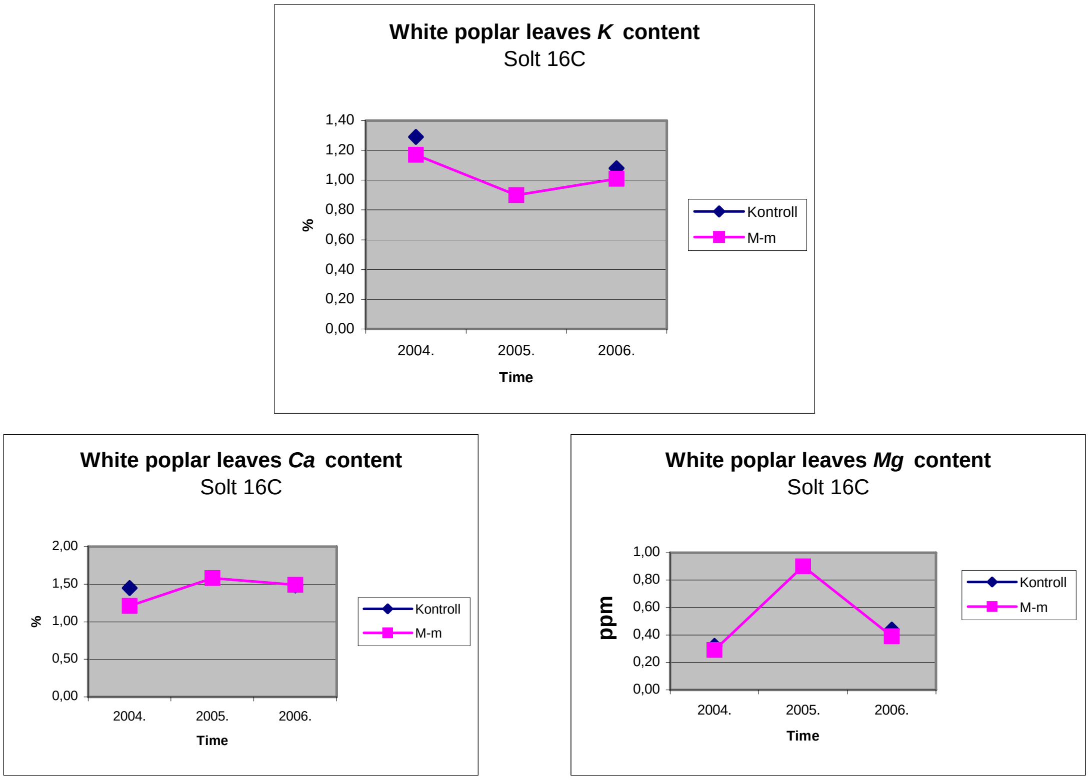


Diagram 1. The decreasing K content effects the increasing of the Ca and Mg content also in case of white poplar (*Populus alba* L.)

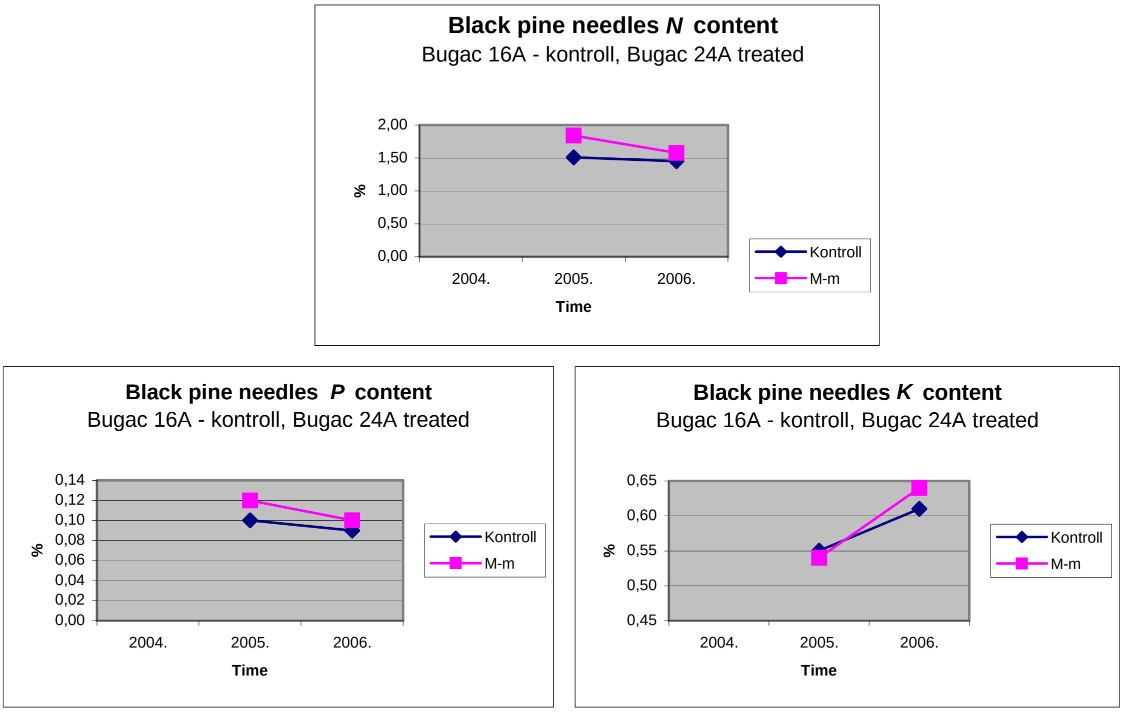
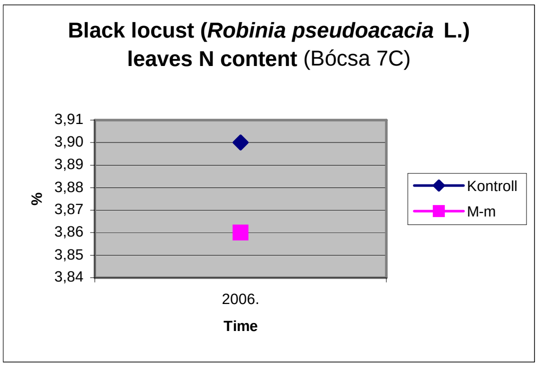


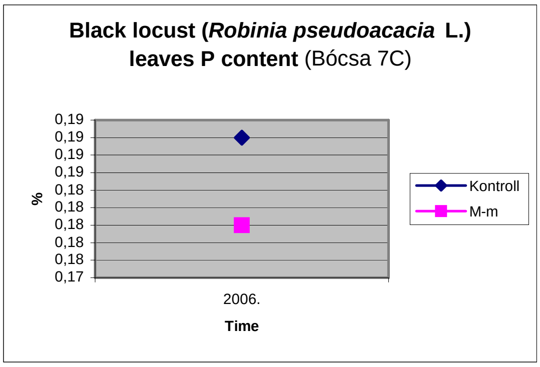
Diagram 2. The higher N/P/K contents effected bigger collar diameters at *Pinus nigra* Arnd. saplings (see table 1)

We can anyhow risk on the basis of the good growth and manifestly good development and health condition of the saplings, that the mycorrhized black pines in the forest part Bugac 24A have an optimal nutrition content (diagram 4 and 5), which values are:

2005. N/P/K 15,3:1:4,5
2006. N/P/K 15,8:1:6,4

These values seem to be relatively close to the values of the above mentioned scotch pine analysis.





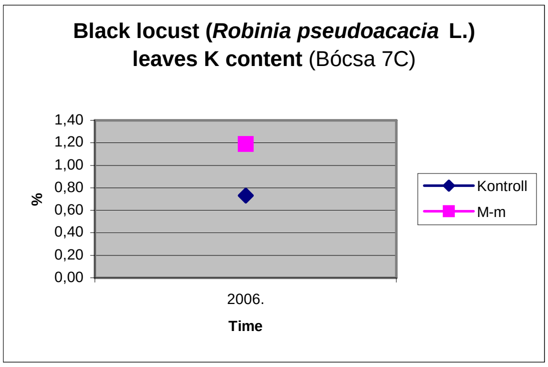
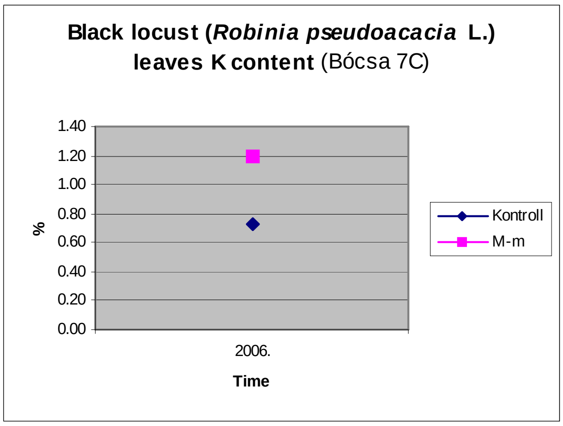
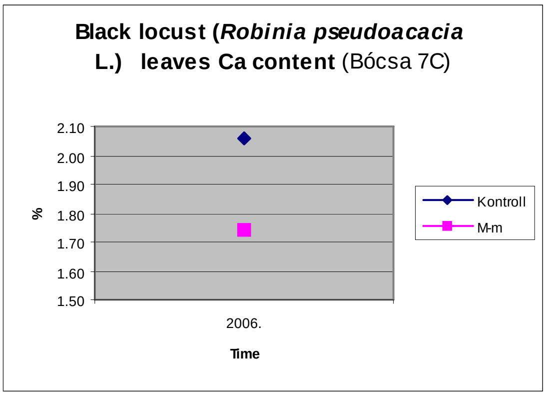


Diagram 3. The N-P-K contents of the Bócsa 7C black locust (*Robinia pseudoacacia* L.) stock





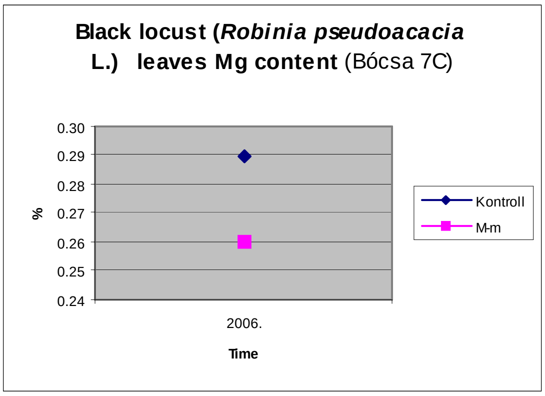


Diagram 4. K, Ca and Mg contents of the Bócsa 7C black locust stock

The leaf analysis of the black locust stock Bócsa 7C has brought astonishing results. However the collar diameter of the mycorrhized trees is in this case the very best compared with the control, it is surprising, that both the N content and the P content is higher in the leaves of the control, though these elements escalate the thickness and height growth, so the vegetative character, the most (diagram 4, table 3).

It can be observed also in the Bócsa 7C black locust stock, that the high K content of the leaves accompanies low Ca and Mg contents (diagram 4 – mycorrhized trees), and inversely: a relatively low K content accompanies relatively higher Ca and Mg contents (diagram 4 – control). There are relatively less data in the literature concerning the average nutrition content of forest trees. The values found in this relation are summarized in table 2.

Table 1. The average nutrient content of some forest trees (Guha-Mitchell 1966; Czerney-Fiedler 1969a, b; Komlenović-Cestar 1984, 1987; Schmalfuss-Schulze 1961; Fiedler-Czerney 1970; Heinsdorf 1987; Heinze-Fiedler 1979; Heinze et al. 1983; Heinsdorf-Krauss 1970 quoted Lyr et al 1992)

Tree species	Nutrition element							
	N	P	K	Ca	Mg	Zn	Fe	Mn
	%					ppm		
Pinus sylvestris	1,35-1,80	0,10-0,30	0,35-0,50	0,15-0,50	0,05-0,15	25-75	40-550	10-100
Pinus nigra	0,84-1,83	0,08-0,19	0,39-1,17	0,15-0,31	0,06-0,16	28-67	50-408	0,5-45,8
Quercus robur	1,32-2,39	0,16-0,36	0,63-1,24	0,81-1,91	0,10-0,31	20-113	124-437	67-2824
Populus sp.	2,27-2,77	0,22-0,23	1,53-2,64	0,91-1,32	0,18-0,26		740	230
Robinia pseudoa.	3,65-3,71	0,18-0,21	1,26-1,95	1,05-2,14	0,16-0,28			

Table 2. The nutrient contents of the leaves of some tree species during the experiment (measurements in the year 2006)

Tree species / experiment area	Treatment	Nutrition element							
		N	P	K	Ca	Mg	Zn	Fe	Mn
		%					ppm		
Pinus nigra/Bugac 24A	Control	1,45	0,09	0,61	0,55	0,18	26	82	41
	M-m	1,58	0,10	0,64	0,61	0,16	41	71	54
Robinia pseudoa./Bócsa 7C	Control	3,90	0,19	0,73	2,06	0,29	27	106	51
	M-cs	3,86	0,18	1,19	1,74	0,26	23	109	49
	M-m	4,13	0,20	0,66	1,87	0,28	30	113	53
Populus alba/Bócsa 7C	Control	2,40	0,14	0,95	1,29	0,31	107	127	55
	M-cs	2,29	0,16	1,13	1,17	0,27	95	147	49
	M-m	1,97	0,13	0,90	1,47	0,33	77	179	81
Populus alba/Bócsa 3A	Control	2,84	0,16	1,42	1,29	0,30	120	106	58
	M-cs	2,52	0,11	1,20	1,07	0,25	90	107	37
	M-m	2,56	0,15	1,15	1,39	0,29	148	149	59

Legend: M-cs – saplings inoculated with mycorrhizae in thenursery
M-m – saplings mycorrhized on the spot of the afforestation

We pointed out some cases among our examinations as an example, which are shown in the table 3.

The nutrient content of the leaves strongly depends on the nutrient supply of the soil. This classification is shown in the table 4. We also examined the nutrient (macro element) content of the experiment territory soil, which is shown in the table 5. It can be seen, that the most of the soils are poor in nutrients. We found however, that the nutrient content of the trees in the experimental territory is satisfactory. If we compare the values in table 4 and 5, it can be seen, that the nutrient content measured in the leaves in the experimental territory corresponds in each case to the average level of harmonically nutrient content, it is either much above or at least near this value.

Table 3. Classification of the macro element content of soils (Tihanyi-Tompa 1985.)

Classification		Absorbable P_2O_5 with 1% citric acid dissolving	Absorbable K_2O n/4 with ammon-chlorid dissolving	Total N
description	symbol			
Poor	gy	0-5	0-5	0-50
Poor-average	gyk	5-10	5-10	50-100
Good-average	jk	10-15	5-10	100-150
Good	j	15-20	10-15	150-200
Rich	g	20-	15-	200-

Table 4. The macro element content of the mycorrhized afforestation soils 2006

Parcelle/ Depth of sampling (cm)	Nutrient								
	Content (mg/100g)			Content (%)			Classification		
	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N
Bócsa 3A 0-50	0,3	33,4	15,9	0,0003	0,0334	0,0159	gy	g	gy
Bócsa 7C 0-50	1	3	18,8	0,001	0,003	0,0188	gy	gy	gy
Jászsztl. 8E 0.50	0,5	2,5	52,4	0,0005	0,0025	0,0524	gy	gy	gyk
Jászsztl.137D 0.50	0,6	2,1	37,4	0,0006	0,0021	0,0374	gy	gy	gy
Jászsztl.142C 0.50	0,8	1,8	39,4	0,0008	0,0018	0,0394	gy	gy	gy
Jászsztl.142D 0.50	0,2	111,2	20,6	0,0002	0,1112	0,0206	gy	g	gy
Bugac 24A 0-50	1,2	7,4	22,9	0,0012	0,0074	0,0229	gy	gy	gy

3.4. The variation of the N content

We achieve a mixed image among identical tree species, if we compare the control and the treated plants. The nutrition element content of the mycorrhized trees, especially concerning N, is not always higher, than the values of the control trees. That is basically against our expectations! This surprising detail is also noticeable concerning the other elements, but the difference is not so considerable, like in the case of N.

It is furthermore noticeable, that the N content of the black locust leaves, which are able to absorb N also by autotrophic way, is considerably higher, than the values of the other tree species.

It is visible from the data, that the N content of Pinus nigra needles is considerably lower, than the values of the other trees, and among this the values of the mycorrhized saplings are higher, than those of the control saplings. These effects have already been analysed above.

3.5. The variation of the P content

The P content of the black locust leaves is also the highest among the examined tree species, just like the N content. The needles of the Pinus nigra have the lowest P content, but these values are also between the international determined average marginal values (table 2). Only the P content of the Populus alba leaves are lower than the above mentioned marginal values, which can have the reason, that the data in the table 2 don't show the details of the possible differences between the different Populus species.

3.6. The variation of the K content

Concerning K content the results are relatively various. It is interesting to observe, that in this case not the Pinus nigra is the last one!

It can be observed in the case of several tree species, that the K content of the mycorrhized tree leaves is considerably higher, than those of the control trees:

- The difference concerning *Pinus nigra* is 104,92 %,
- Concerning *Robinia pseudoacia* M-cs 163,01 %,
- Concerning *Populus alba* M-cs (Bócsa 7C) 118,95 %,

In other cases the K content of the mycorrhized tree leaves is hardly lower, than that of the control, or the values are the same.

3.7. The variation of the Ca content

In the cases of Pinus nigra, Populus alba, Fraxinus and partially Quercus robur the Ca content of the mycorrhized tree leaves is considerably higher, than that of the control.

3.8. The variation of the Mg content

The Mg content of the Pinus nigra needles is outstanding lower, than the Mg content of the other species leaves. There is only a little difference between the Mg content of the mycorrhized and the control tree leaves, and the one of the control is in general higher, except the Quercus robur in Bácsalmás, the Fraxinus and the Kelebia 60 B-C Populus alba.

3.9. The variation of the micro elements (Zn, Fe, Mn) content

The element content of *Pinus nigra* is also in this case considerably lower compared to the other tree species!

With the exception of one case (*Populus alba* – Bócsa 3A) the Fe content is considerably higher compared to the other two elements. It is salient, that the Zn content of the white poplar control saplings leaves are in three cases outstanding high, higher than the ones of the mycorrhized trees treated with *M-cs* method, but in one case among them the Zn content of the tree leaves treated with *M-m* method is still more (Bócsa 3A).

BIBLIOGRAPHY

[1.] BARNA T.: The role of mycorrhizae in afforestation Annals of the Faculty of Engineering Hunedoara. 179-184. (2003)

[2.] CZERNEY, P. és FIEDLER, H-J.: Gefässversuch mit Wermsdorfer Staublehm zum Einfluss der Düngung auf einige Nadel- und Laubhölzer. Arch. Forstwes. **18** (1969a): 133-153.

[3.] FIEDLER, H-J. – CZERNEY, P.: Vergleichende Untersuchungen zum Ernährungszustand junger Eichen (Quercus robur) im Staatlichen Forstwirtschaftsbetrieb Oschatz. Arch. Forstwe. **19** (1970): 963-979

[4.] FIEDLER, H-J. - HÖHNE, H.: Ernährungsphysiologische Untersuchungen an Douglasiensämlingen. Beitr. Forstwirtsch. **19** (1985): 157-162.

[5.] GUHA, M-H. – MITCHELL, R-L.: The trace and major element composition of the leaves of some decidous trees. II. Seasonal changes. Plant and Soil **24** (1966): 90-112.

[6.] HEINSDORF, D.: Ergebnisse eines Nährstoffmangelversuchs zur Robinie (*Robinia pseudoacacia* L.) auf Kipprohboden. Beitr. Forstwirtsch. 21 (1987): 13-17.

[7.] HEINSDORF, D. – KRAUSS, H-H.: Ergebnisse von Düngungsversuchen zu Androscoggin-Pappeln auf einem ziemlich nährstoffarmen Sandboden im Bezirk Potsdam. Arch. Forstwes. **19** (1970): 555-581.

[8.] HEINZE, M. - FIEDLER, H-J.: Versuche zur Begründung von Kalirückstandshalden. 1. Mitteilung: Gefässversuche mit Bäumen und Sträuchern bei unterschiedlichen Wasser- und Nährstoffangebot. Arch. Acker- u. Pflanzenbau u. Bodenkd. **23** (1979): 315-322.

[9.] HEINZE, M. - FIEDLER, H-J. – HÖHNE, H.: Ernährung uns Wachstum der Birke (*Betula pendula* Roth) auf Sulfat-, Karbonat- und Silikatstandorten Thüringens. Flora 173 (1983): 321-334.

[10.] IVANOVA, Z-V. – LAVRIĆENKO, V-M.: Bestimmung des Nährstoffbedarfes eines Bestandes nach der Methode der Pflanzendiagnostik. Lesnoe chozjajstvo. Moskau (1980): 22-24.

[11.] KOMLENOVIĆ, N – CESTAR, D.: Istraživanje stanje ishrane lužnjaka (*Quercus robur* L.) u utvrdenim ekološko-gospodarskim tipovima šuma u SR Hrvatskoj. Radovi Šumarskog instituta, broj 59, XIX (1984): 1-14. Zagreb

[12.] HENZE, M. – FIEDLER, H.-J.: Ernährung der Gehölze. In LYR, H. – FIEDLER, H-J, - TRANQUILINI, W.: Physiologie und Ökologie der Gehölze. Gustav Fischer Verlag (1992) 43-107. Jena

[13.] SCHMALFUSS, K. – SCHULTZE, W.: Über Nährstoffverlagerungen in Holzgewächsen. Flora **150** (1961): 353-371.

[14.] TIHANYI, Z. – TOMPA, K.: Erdészeti nemesítés és szaporítóanyag termesztés. Gyakorlatok. Kézirat. Erdészeti és Faipari Egyetem, Erdőmérnöki Kar, Sopron, 1985.