

INFLUENCE OF SOIL PHOSPHORUS FORMS ON THE VAM FUNGI SPORULATION IN THE CASE OF FIVE DIFFERENT SOIL TYPES

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Introduction

Mycorrhizal associations between a fungus and a plant root are ubiquitous in the natural environment. By far the most common type of association is that of the vesicular-arbuscular mycorrhiza (VAM). The VAM association is the most ancient and probably aided the first land plants to colonise by scavenging for phosphate (Simon *et al.*, 1993). Approximately two-thirds of all land plants form the VAM type of association, in sharp contrast with the relatively small numbers of fungi involved, all of which are members of the order *Glomales* (*Zygomycotina*) comprising only approximately 150 described taxa (Smith and Read, 1997). Phosphorus (P) is one of the most essential plant nutrients. Its availability to plants is controlled mainly by soil pH, soluble Al, Fe and Ca and organic matter content. It is maximal at soil pH between 5.5 and 7.0 (Engelstad and Terman, 1980). It is well established that VAM symbiosis improves phosphorus nutrition, but since the work of Sanders and Tinker (1973), numerous experiments have also shown that increasing phosphate availability decreases the mycorrhization level, suggesting that VAM fungi might play a minor role in natural ecosystems or agriculture fields with high P availability (e.g. Ryan and Graham, 2002). In this study, we analysed the variance and correlation between the abundances of free spores and sporocarps with the contents of plant available phosphorus fraction in five different soils.

Methods

Six topsoil samples were collected from five different soil types in the environs of Debrecen, Hungary. Soils were sampled with a stainless steel cylinder. Topsoils were taken in each case from 0–15 cm. Soil samples were air-dried, sieved through 2 mm, stored at room temperature, and were analysed, following standard methods. Soil pH was determined in distilled water and 1 M KCl solution using a 1:2.5 soil/solution ratio. The plant available soil P was measured after extracting the soil samples with 0.1 M ammonium lactate - acetic acid solution (Egner *et al.*, 1960). The content of orthophosphate ($\text{PO}_4\text{-P}$) of the soil solution was analysed spectrophotometrically using the molybdate blue method of Murphy and Riley (1962).

The free spores and sporocarps of the VAM fungi were extracted from 5 g of soil from each sample at each site ($N = 6$) by sucrose flotation (Allen *et al.*, 1979). Spores and sporocarps were counted under a stereoscopic microscope. Permanent slides in polyvinyl alcohol (PVLG) and PVLG-Meltzer's reagents were made for taxonomic determinations, as described by Schenck and Pérez (1990) and at the INVAM Web site. (The analysis of fungi species diversity is not the subject of this paper). We used a one-way analysis of variance (ANOVA) with Tukey's post test to analyze the potential differences in the measured values in the different soils. We also examined the relations between the contents of phosphorus in the soils on the abundance of the arbuscular morphotypes (spores and sporocarps) by Pearson's correlation analysis.

All analyses were done using SPSS 9.0 and GraphPad Prism 3.0. Means and standard error (S.E.=±) are reported throughout and $P < 0.05$ is considered significant.

Results And Discussion

We summarize the investigated soil types, the mean numbers of intact free spores, the mean P concentration values and the mean values of pH measured in distilled water and in KCl solution in Table 1.

Table 1. General characteristics of the soils; number of spores, mean value of P and pH in distilled water and in KCl solution (N=6)

	Soil types	Spore number as counts per 5g soil	P concentration mg.100g ⁻¹	pH in d.water	pH in KCl
1.	Meadow chernozem soil (Kismacs)	98±32	93.15±2.31	7.36	7.23
2.	Salt-affected solonchak soil (Hortobágy)	351±51	19.87±0.47	9.11	7.98
3.	Acidic sandy brown forest soil (Nagyerdő, Debrecen)	54±30	6.43±0.18	4.76	4.55
4.	Blownsand (Pallag)	61±37	20.19±0.91	6.97	6.73
5.	Calcareous chernozem (Experimental Garden of the University, Debrecen)	319±59	162.83±8.08	7.54	7.43

The abundance of intact free spores ranged from 20 to 431 spores per 5 g of soil. The greatest numbers of spores were counted in the case of Salt-affected solonchak soil (2. soil) and the Calcareous chernozem soil (5. soil). On the basis of ANOVA test it can be concluded that means of the spore numbers in the 2. and the 5.soil were significantly identical. At the same way, the 1., the 3., and the 4. soils were not different. The P concentration was the highest in the 5. soil. The lowest P amounts were measured in the case of the 3. and the 2. soil. Under acidic soil conditions, soluble P reacts with aluminium and iron to form compounds that precipitate out of solution (Lee *et al.*, 1990; Holford, 1997), while in alkaline soil conditions, it reacts with Ca to form insoluble precipitates (Iyamuremye and Dick, 1996) which are less available to plants. The 2. soil was alkaline (pH dw.= 9.11). On the other hand the 3. soil was acidic. The results are perhaps best displayed in graphs such as the examples in Fig. 1 for the contents of phosphorus, spore numbers and pH values.

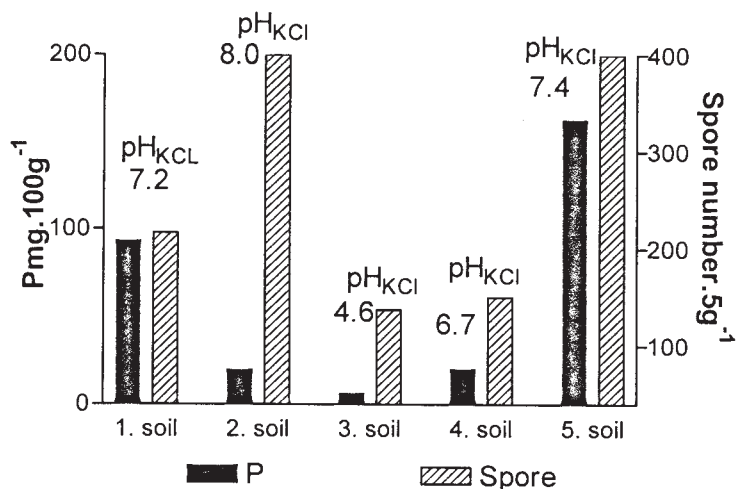


Figure 1. Graphs of counts of VAM spores, concentrations of phosphorus, and pH_{KCl} values. Table 2. shows the correlations between spore numbers and the contents of the phosphorus and pH_{KCl} values. Most of the correlation coefficients (*r*) lay in the

Table 2. Values of the correlation coefficient (*r*)

	Soil types	Values of the correlation coefficient (<i>r</i>)		
		Spore / P	P / pH _{KCl}	Spore / pH _{KCl}
1.	Meadow chernozem soil (Kismacs)	-0,1	-0,3	-0,1
2.	Salt-affected solonchak soil (Hortobágy)	0,1	-0,6	-0,6
3.	Acidic sandy brown forest soil (Nagyerdő, Debrecen)	-0,3	-0,6	0,9
4.	Blownsand (Pallag)	0,5	-0,5	-0,5
5.	Calcareous chernozem (Experimental Garden of the University, Debrecen)	-0,6	0,1	0,2

range -0.6 to 0.2 with no common pattern, and we attribute them to sampling fluctuation. But the correlation among spore numbers and the pH_{KCl} values was strong in the case of the acidic sandy brown forest soil. Read *et al.* (1976) found little variation in mycorrhizal colonisation in natural soils covering a wide range of pH. However, VAM fungal sporulation is influenced by the pH and nutrient status of the soil (Coughlan *et al.*, 2000).

Conclusion

We have demonstrated that VAM sporulation differs in the examined five different soils. The soils with lower concentrations of P have tended to increase mycorrhizal sporulation. Sporulation of VAM fungi may be stimulated by increased or decreased soil pH, whereas others do not respond to soil pH. It is, however, to be expected that each VAM fungal community is adapted to its native soil.

References

- Allen, E.B., Moore, T.S., Christensen, M., (1979): Growth of vesiculararbuscular mycorrhizal and nonmycorrhizal *Bouteloua gracilis* in a defined medium. *Mycologia* 71, 666–669.
- Coughlan, A.P., Dalpe', Y., Lapointe, L., Piche', Y., (2000): Soil pH-induced changes in root colonization, diversity, and reproduction of symbiotic arbuscular mycorrhizal fungi from healthy and declining maple forests. *Canadian Journal of Forestry Research* 30, 1543–1554.
- Egner, H., H. Riehm, and W.R. Domingo, (1960): Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des nah Stoff zu Standes der boden. II. Chemische extraktions-methoden zu Phosphor – and kalim Bestimmung kungle. *Lantbrukshoegsk. Ann.* 26:204-209.
- Engelstad, O.P. and G.L. Terman, (1980): Agronomic effectiveness of phosphate fertilizer. In: F.E. Khasawneh, E.C. Sample and E.J. Kamprath, (Eds): *The Role of Phosphorus in Agriculture*, American Society of Agronomy, Madison, Wisconsin, USA
- Holford, I.C.R., (1997): Soil phosphorus: its measurement, and its uptake by plants. *Aust. J. Soil Res.* 35, 227–239.
- INVAM Web site, <http://invam.caf.wvu.edu>.
- Iyamuremye, F., Dick, R.P., (1996): Organic amendments and phosphorus sorption by soils. *Adv. Agron.* 56, 139–451.
- Lee, D., Han, X.G., Jordan, C.F., (1990): Soil phosphorus fractions, aluminium and water retention as affected by microbial activity in an Ultisol. *Plant Soil* 121, 125–136.
- Murphy, J., Riley, J.P., (1962): A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* 27, 31–36.
- Read, D.J., Koucheki, H.K., Hodgson, J., (1976): Vesicular-arbuscular mycorrhiza in natural vegetation systems. I. The occurrence of infection. *New Phytologist* 76, 415–431.
- Ryan, M.H., Graham, J.H., (2002): Is there a role for arbuscular mycorrhizal fungi in production agriculture? *Plant Soil* 244, 263–271.
- Sanders, F.E., Tinker, P.B., (1973): Phosphate flow into mycorrhizal roots. *Pestic. Sci.* 4, 385–395.
- Schenck, N.C., Pérez, Y., (1990): Manual for the identification of VA mycorrhizal fungi (INVAM). University of Florida, Gainesville, FL.
- Simon, L., Bousquet, J., Levesque, R.C. and Lalonde, M. (1993): Origin and diversification of endomycorrhizal fungi and coincidence with vascular land plants. *Nature* 363, 67–69.
- Smith, S.E. and Read, D.J. (1997): *Mycorrhizal Symbiosis*. Academic Press, London.
- Kádár, I. (2004): Szennyvíziszap-adagok hatása a növény (*Triticum vulgare* L.)-talaj rendszer néhány mikrobiológiai és biokémiai tulajdonságára (Impact of sludge treatments on some microbiological and biochemical properties of plant (*Triticum vulgare* L.)-soil system. – in *Hungarian*). *Agrokémia és Talajtan.* 53. 3-4. 331-342 pp
- Svetková, K.; Henselová, M.; Morvová, M. (2005): Effects of a carbonization product as additive on the germination, growth and yield parameters of agricultural crops. *Acta Agron. Hun.* 53. (3). 241-250 pp
- Tanács, L., Matuz, J., Gerő, L., Petrőczy, I.M. (2005): Effect of NPK Fertilizers and Fungicides on the Quality of Bread Wheat in Different Years. *Cereal Res. Commun.* 33 (2-3): 627-634 pp