Treeline shift under global change – ectomycorrhizas as limiting factor?

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Ecosystems close to arctic or alpine timberlines are sensitive to climate change; they are expected to respond by advancing beyond their current position (Smith et al., 2009; Harsch et al., 2009). This could lead to various changes in ecosystem vitality, species distribution and carbon fluxes.

Ectomycorrhiza plays a crucial role for trees surviving under suboptimal conditions at treeline. Environmental change is supposed to cause migration of ectomycorrhizal (ECM) symbionts and their hosts, modification of interactions between plant and fungal species and changes in the contribution of both partners to global carbon cycle (Courty et al., 2010; Pickles et al., 2012). This could lead to distinct shifts in ECM communities. Absence of appropriate symbionts or a reduced functionality of original ECM communities could be a serious constraint limiting the treeline shift.

Fig. 1. Localization of PRPs in Giant Mts.

Fig. 2. Norway spruce forest – PRP Modrý důl

Fig. 3. Norway spruce forest under treeline – PRP Pašerácký chodníček

Fig. 4. Treeline – Norway spruce/dwarf pine

To find out if the mycorhiza can be a limiting factor of treline shift we ask the following questions:

1. Which ECM fungi are known to grow in mountain spruce forests and which in dwarf pine stands?
2. What is a current state of ectomycorrhizal association of treeline ecosystems?
3. What is the pattern in morphotype diversity and extramatrical mycelium types towards treeline?
4. Can dwarf pine (*Pinus mugo*) and Norway spruce (*Picea abies*) trees share their ECM fungal symbionts?

Methods

The Giant Mts. (Krkonoše) have been selected as a model area for our study.

Mycological studies from mountain spruce forests above 950 m a s.l. and dwarf pine stands on acid bedrock were reviewed to get a list of ECM fungi that can be found in treeline ecosystems similar to those in the Giant Mts.

Permanent research plots (PRP) in mountain spruce forests and mountain spruce forest just under treeline have been studied since 1994. Dwarf pine stands with scattered spruce trees above treeline will be studied in 2013.

Approximately 20 root fragments of mature spruce trees per PRPs (Alžbětinka, Modrý důl, Pašerácký chodníček) were sampled in 2012, 37 root fragments of spruce seedlings in Modrý důl PRP in 2009-2010. Ectomycorrhizas were classified into morphotypes (Agerer & Rambold, 2004-2008), assigned to extramatrical mycelium type (Agerer 2001) and sequenced (ITS rDNA). Identification was made by comparison with sequences from the public databases Unite and Genbank or own sequences from microscopically identified sporocarps.

Spruce trees on each permanent plot were classified into 4 stress categories (resistant, resilient, damaged-weekly transformed, damaged-strongly transformed) based on estimation of defoliation and percentage of secondary shoots (Polák et al., 2007) in order to assess forest health status.

Fig. 5-9. Ectomycorrhizas created by *Tylospora fibrillosa, Russula ochroleuca, Russula emetica, Lactarius lignyotus, Tomentella badia*

Discussion and conclusions

Possible explanation of **disproportion between number of ECM symbionts in mountain spruce forests and dwarf pine stands**:

- reduction of sporocarp production at treeline
- unfavourable conditions for formation of ectomycorrhizas at treeline
- lower genetic diversity of dwarf pine trees in comparison with Norway spruce trees
- lack of mycological studies dealing with dwarf pine stands

Preliminary results indicate a well-balanced ECM community in mountain spruce forests with no distinctly dominant species on roots of mature trees or seedlings (Fig. 12, 13).

- The ECM species composition is in concordance with other studies done in similar biotopes.
- Spruce seedlings host higher proportion of Ascomycetes ECM species than mature trees
- We did not observe a reduced ECM species diversity towards treeline as it was reported by Kernaghan and Harper (2001).
- Low proportion of morphotypes forming rhizomorphs in PRPs resembles ECM communities of boreal forests (Ostonen et al., 2011).

Questions for future research:

1. Are symbionts of both trees at treeline really the same taxon or are there two or more cryptic species associated with different tree species?
2. If it is possible that one individual forms simultaneously ectomycorrhizas with both spruce tree and dwarf pine, what is about nutrient and carbon fluxes and its influence on Norway spruce fitness (nursery effect, nutrients removal)?

Results

Based on a literature review we have found out 226 ECM fungal species occurring in mountain spruce forests on acid bedrocks, 27 of which have been detected in ectomycorrhizas. On the contrary only 54 ECM species were found to be associated with dwarf pine stands, half of them make sporocarps also in mountain spruce forests.

Fig. 10. *Lactarius rufus*. Common ECM species that crate mycorrhiza with both, Norway spruce and dwarf pine (photo L. Zíbarová)

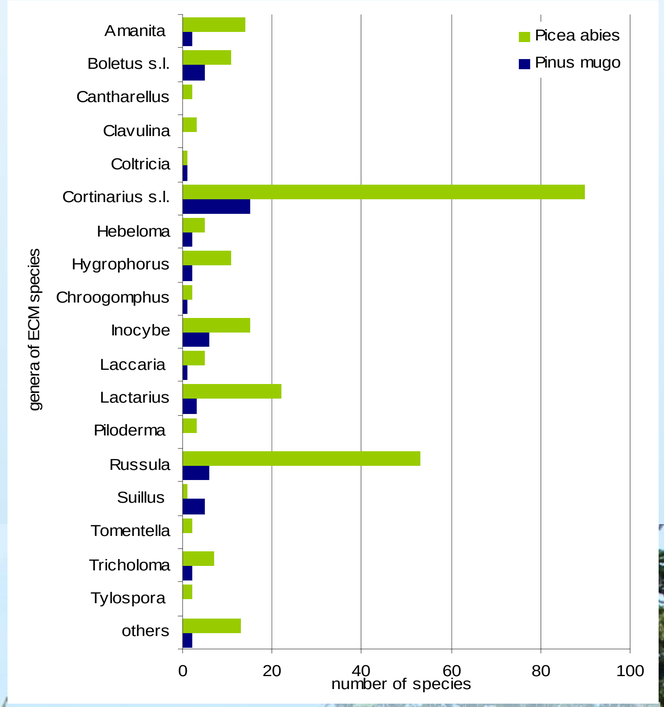

Fig. 11. ECM species known to occur in mountain spruce forests and dwarf pine stands

A total of 30 ECM species was identified from 96 ectomycorrhizas, sampled in PRPs in the Giant Mts. (Fig. 12). There were no two plots considerably similar in terms of ECM species composition. ECM species composition of seedling roots in Modrý důl differed the most evidently. Proportion of taxonomic groups in PRPs in mountain spruce forests (Alžbětinka, Modrý důl) seems to be more similar than Pašerácký chodníček PRP in mountain forest under treeline (Fig. 13). Proportion of ectomycorrhizas forming rhizomorphs was up to 21% per plot.

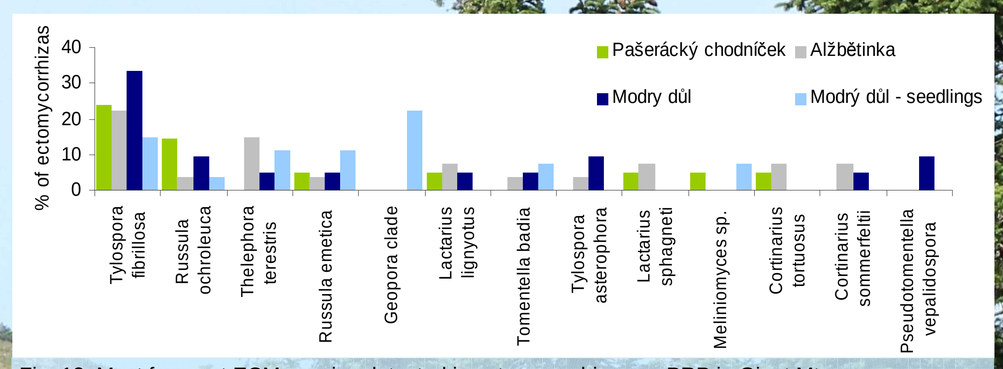

Fig. 12. Most frequent ECM species detected in ectomycorrhizas on PRP in Giant Mts.

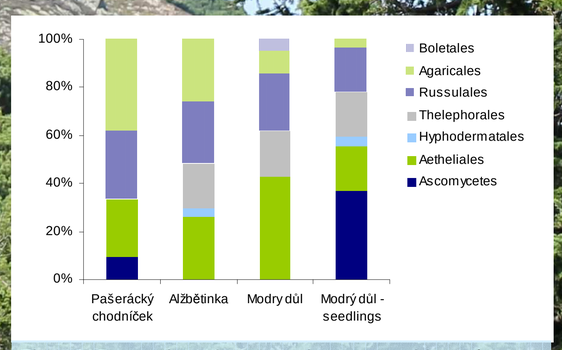

Fig. 13. Proportion of taxonomic groups of fungal symbionts detected in ectomycorrhizas on PRPs in Giant Mts.

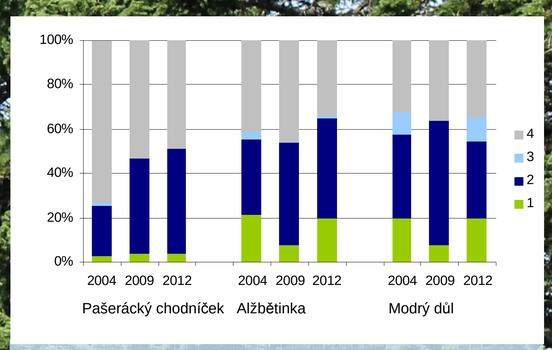

Fig. 14. Proportion of spruce crown transformation categories in last three years on PRPs in Giant Mts. (cathegories: 1 – resistant, 2 – resilient, 3 – damaged-weakly transformed, 4 – damaged-strongly transformed)

Agerer (2001) Mycorrhiza 11, 107-114. ● Agerer, R., & Rambold, G. (2004–2008) http://www.deemy.de ● Courty, P. E. et al. (2010) Soil Biology and Biochemistry, 42, 679-698 ● Harsch, M. A et al. (2009) Ecology Letters, 12, 1040-1049 ● Kernanghan, G., & Harper, K. A. (2001) Ecography, 24, 181-188 ● Ostonen, I. et al. (2011) Global Change Biology, 17, 3620-3632 ● Pickles, B. J. et al. (2012) Fungal Ecology, 5, 73-84 ● Polák T. et al. (2007) Trees, 21, 23-35 ● Smith, W. K. et al. (2009) Botanical Review, 75: 163-190.

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