Excellentia-Center for Climate-Diversity-Pathogen Interactions in Central European Forests

Douglas L. Godbold
Boris Rewald
Mendel University, Brno

Soils and the fungal community

Funded by
the European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N°101087262.

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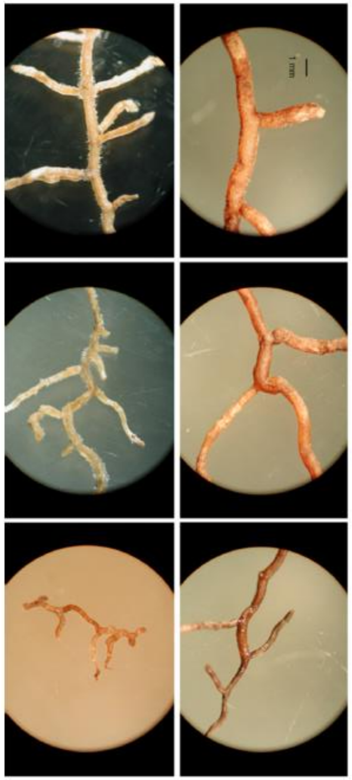
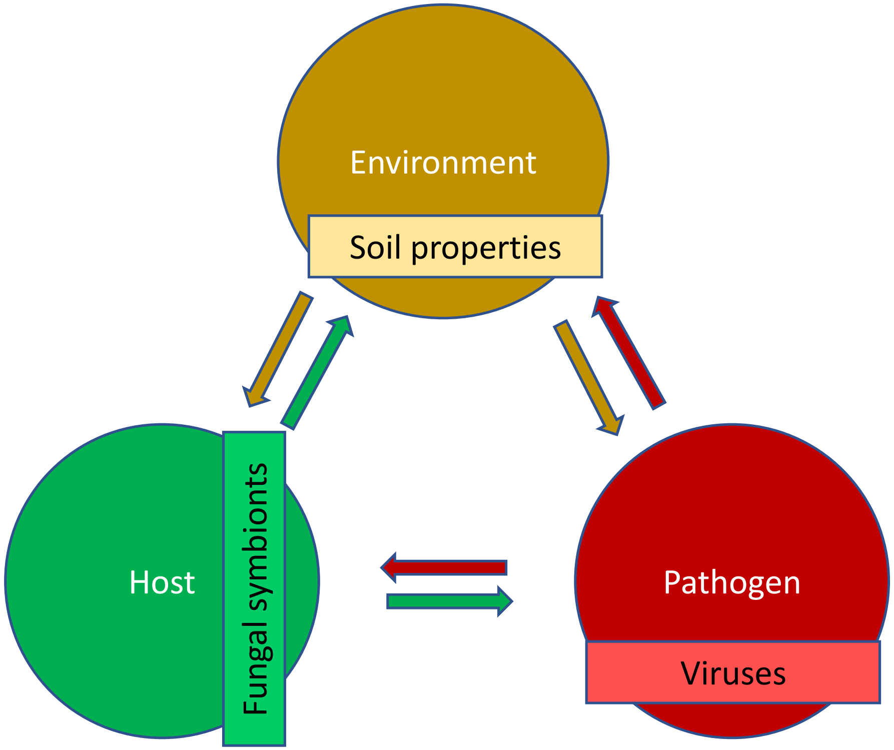
Interactions between tree roots and root pathogens





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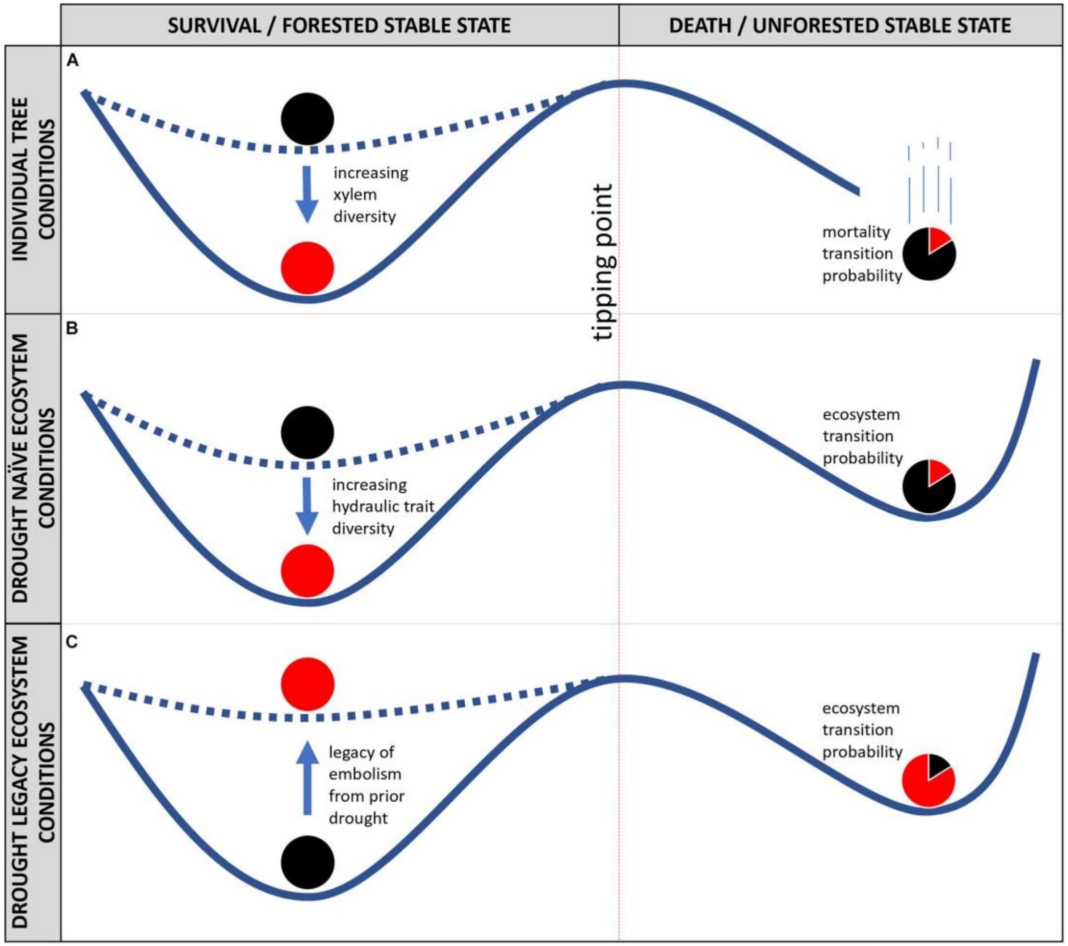
Ecological stability of trees and mixed tree stands



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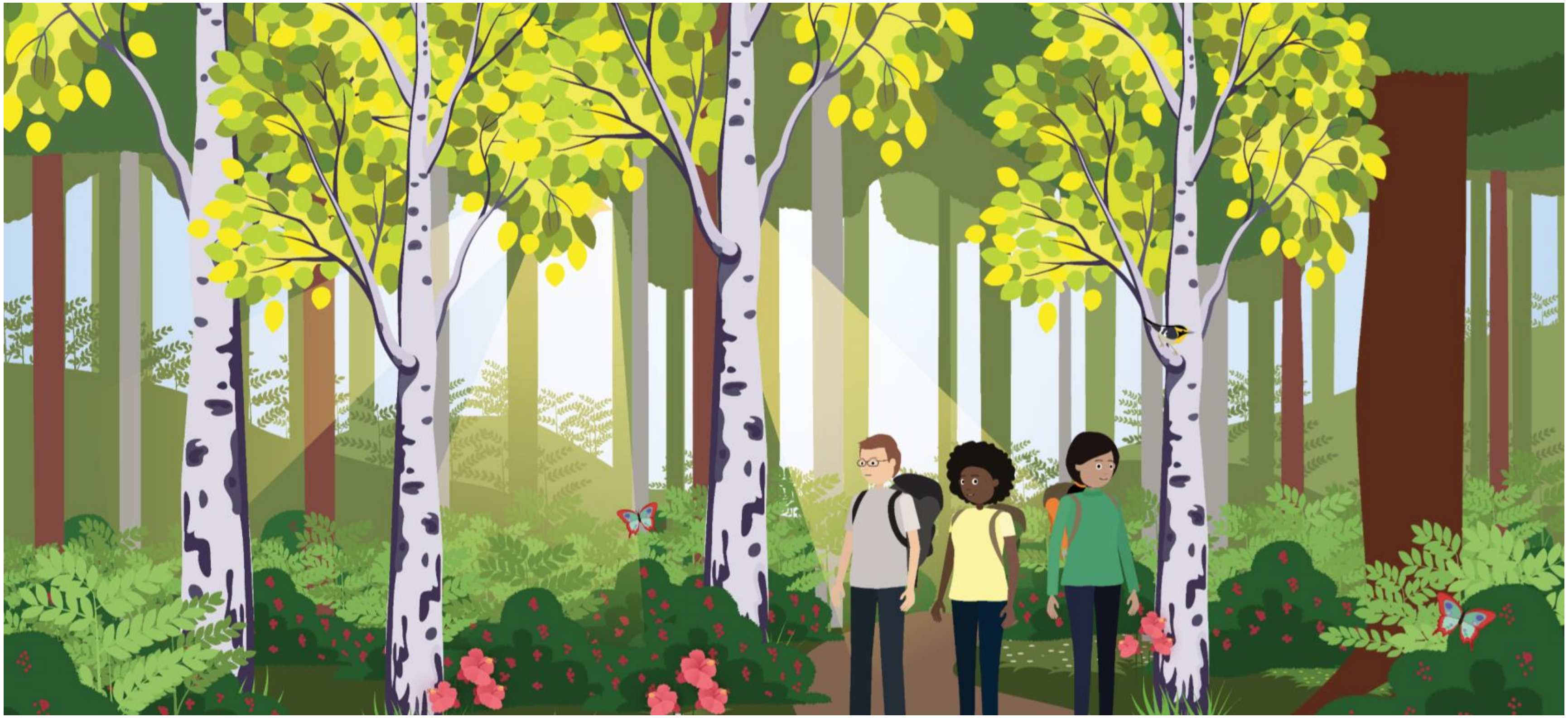
Healthy Forest and society needs

EXCELLENTIA
Forest Ecosystem Research



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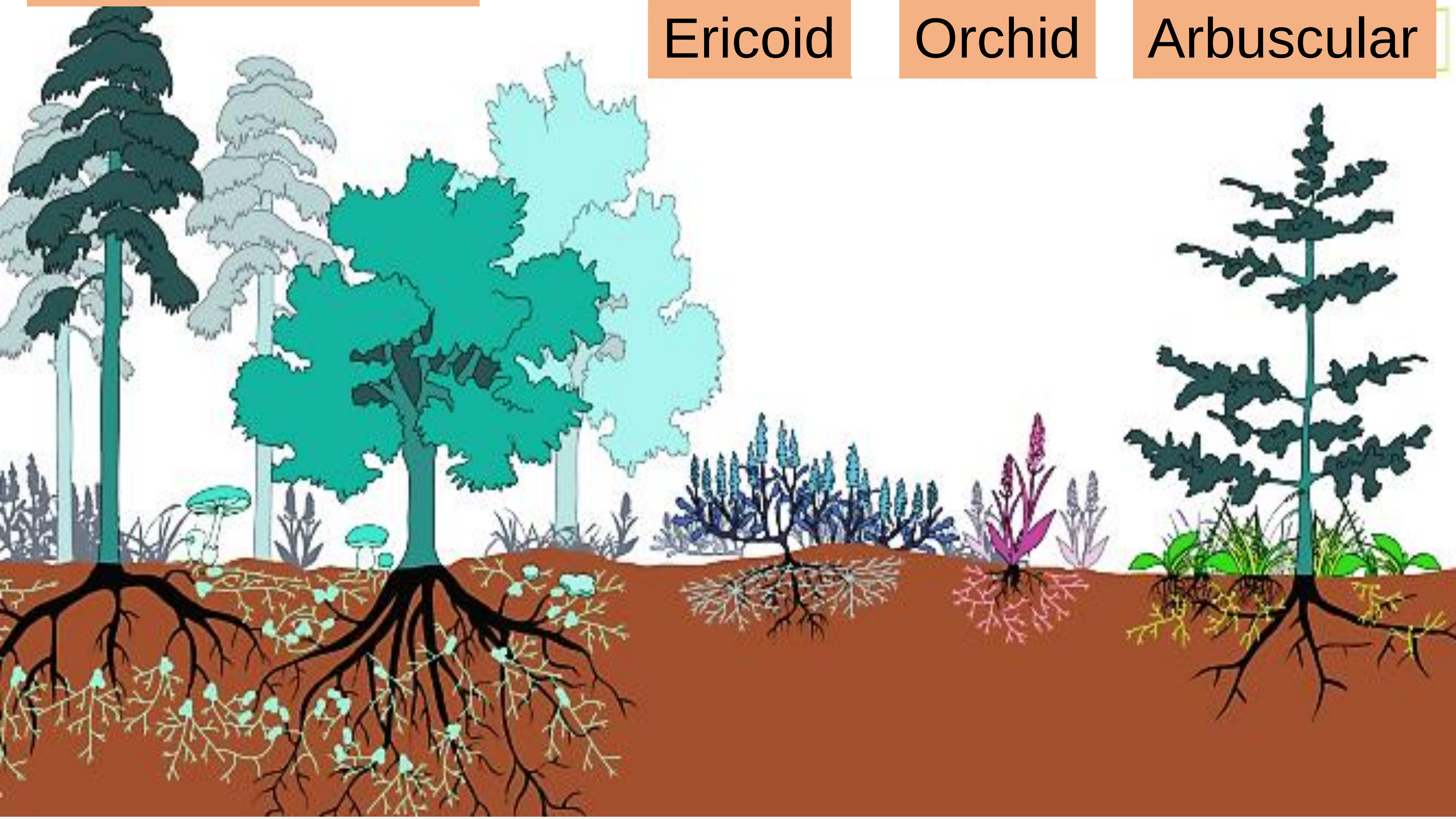
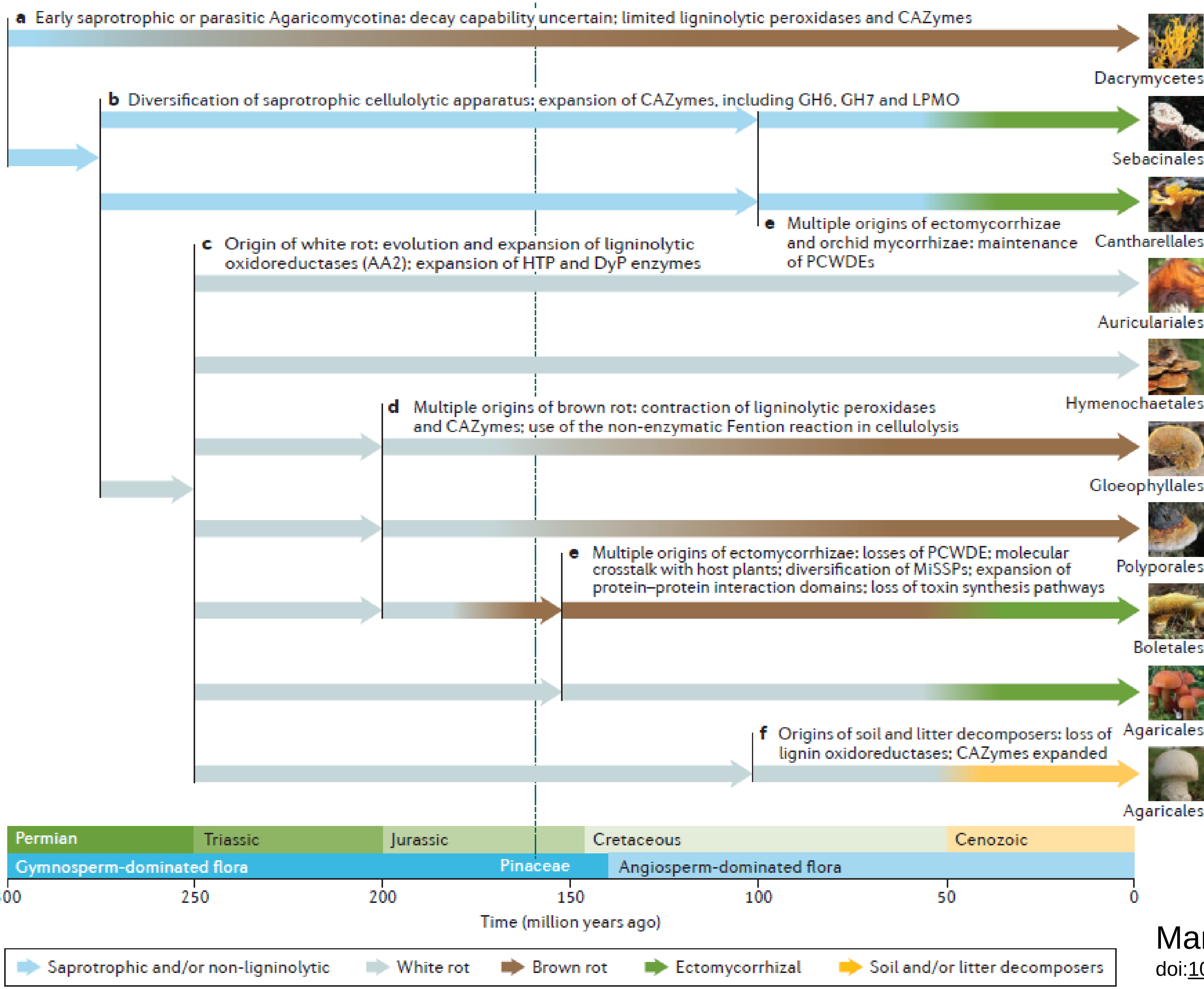
Mycorrhizas



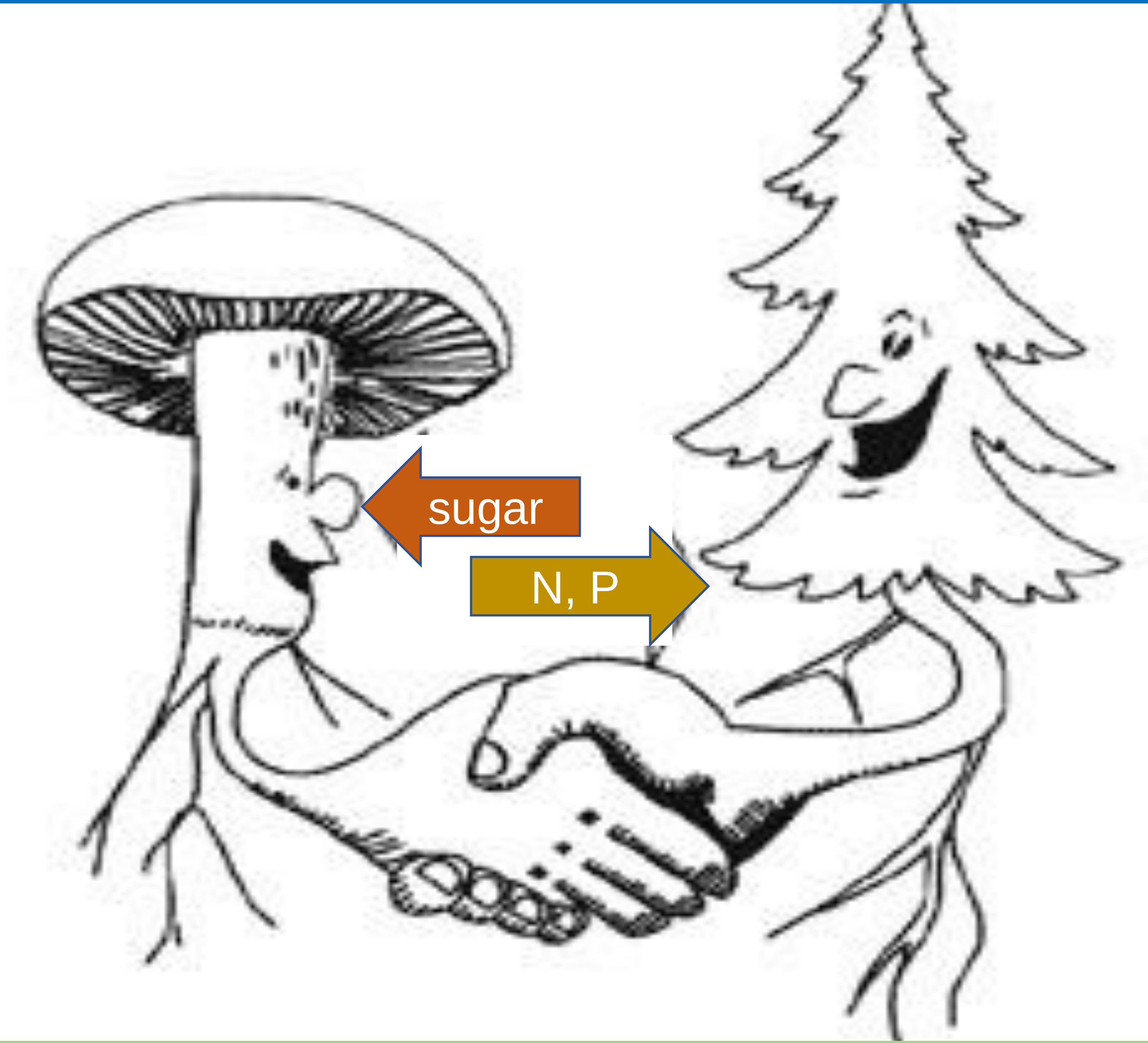
Ectomycorrhizas

Ectomycorrhizal fungi have evolved from saprotrophs

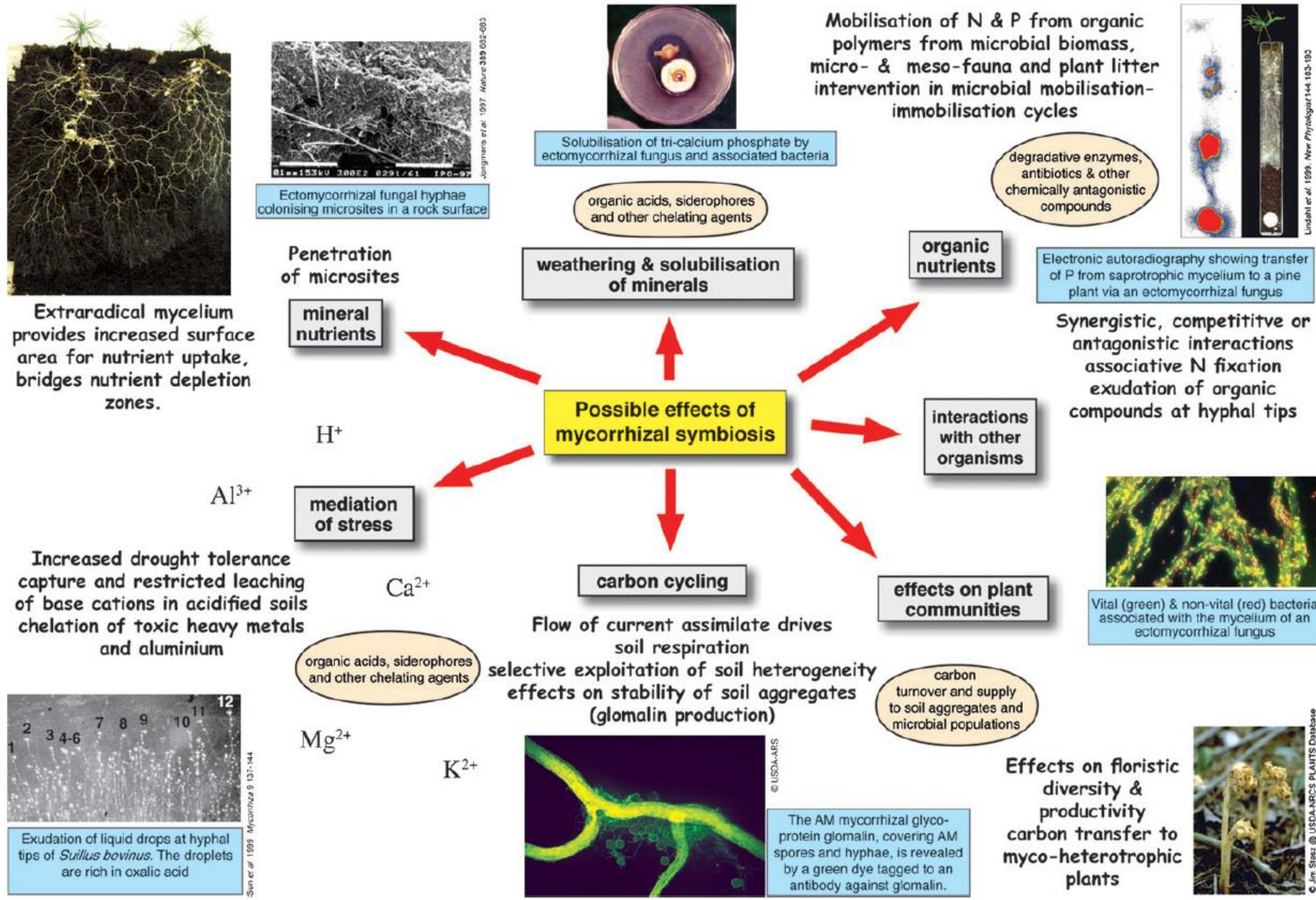


Martin *et al.* 2016
doi:10.1038/nrmicro.2016.149

For trees being ectomycorrhizal can have many benefits



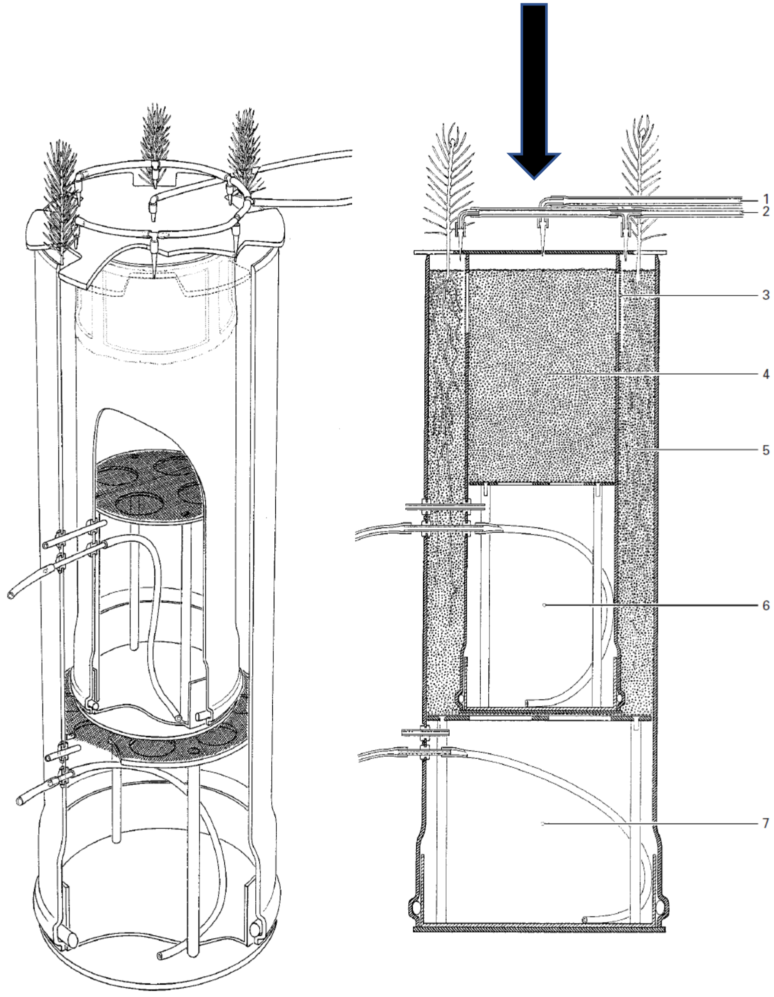
Organic nutrients, mineral nutrients, water, stress, pathogens

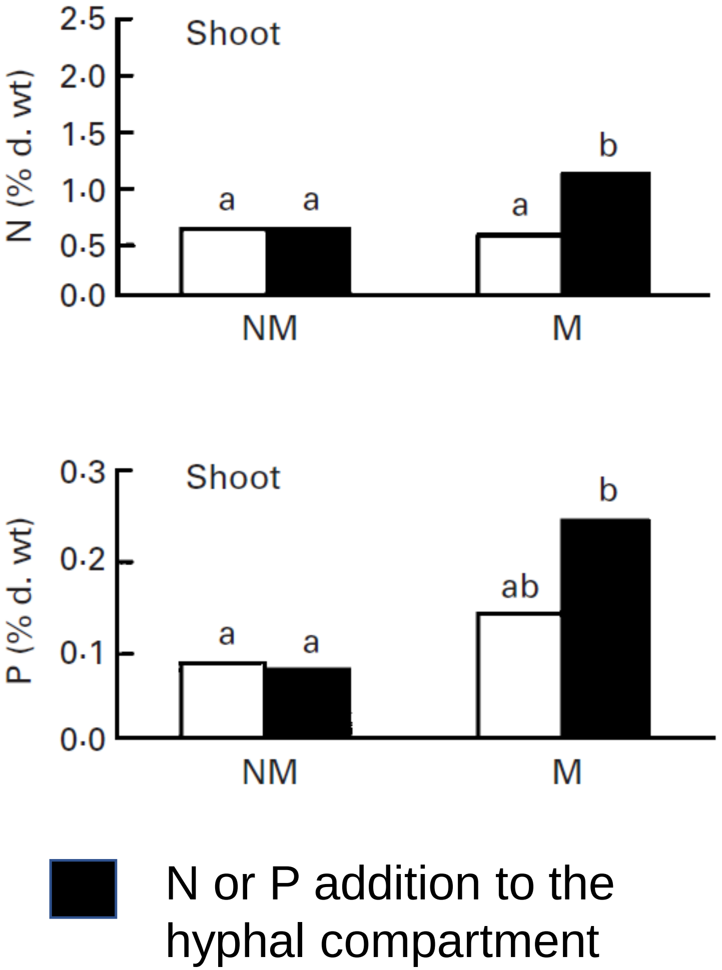


Extraradical mycelium provides increased surface area for nutrient uptake, bridges nutrient depletion zones.
Ectomycorrhizal fungal hyphae colonising microsites in a rock surface
Jongmans et al. 1997 Nature 389 682-683
Penetration of microsites
mineral nutrients
Solubilisation of tri-calcium phosphate by ectomycorrhizal fungus and associated bacteria
organic acids, siderophores and other chelating agents
weathering & solubilisation of minerals
Mobilisation of N & P from organic polymers from microbial biomass, micro- & meso-fauna and plant litter intervention in microbial mobilisation-immobilisation cycles
degradative enzymes, antibiotics & other chemically antagonistic compounds
organic nutrients
Electronic autoradiography showing transfer of P from saprotrophic mycelium to a pine plant via an ectomycorrhizal fungus
Lindahl et al. 1999. New Phytologist 144:183-193
Synergistic, competititve or antagonistic interactions associative N fixation exudation of organic compounds at hyphal tips
Possible effects of mycorrhizal symbiosis
interactions with other organisms
H+
Al3+
Ca2+
Mg2+
K2+
mediation of stress
Increased drought tolerance capture and restricted leaching of base cations in acidified soils chelation of toxic heavy metals and aluminium
organic acids, siderophores and other chelating agents
carbon cycling
Flow of current assimilate drives soil respiration selective exploitation of soil heterogeneity effects on stability of soil aggregates (glomalin production)
carbon turnover and supply to soil aggregates and microbial populations
effects on plant communities
Vital (green) & non-vital (red) bacteria associated with the mycelium of an ectomycorrhizal fungus
1 2 3 4-6 7 8 9 10 11 12
Exudation of liquid drops at hyphal tips of Suillus bovinus. The droplets are rich in oxalic acid
Sun et al 1999 Mycorrhiza 9 137-144
©USDA-ARS
The AM mycorrhizal glycoprotein glomalin, covering AM spores and hyphae, is revealed by a green dye tagged to an antibody against glomalin.
Effects on floristic diversity & productivity carbon transfer to myco-heterotrophic plants
© Jim Stasz @ USDA-NRCS PLANTS Database

Phosphorus and nitrogen is uptaken up by mycorrhizas

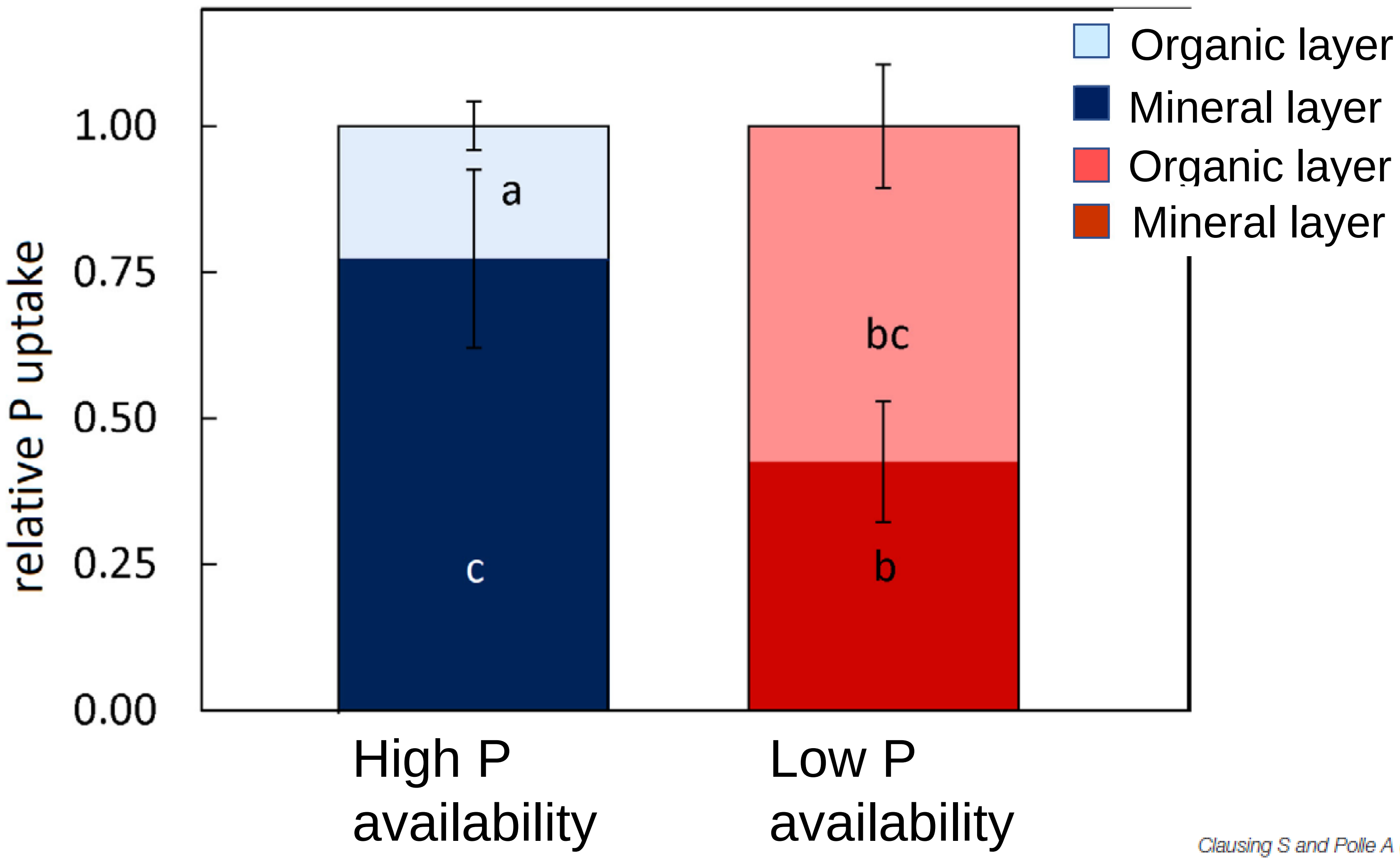
P or N addition to the hyphal compartment





Brandes et al 1991

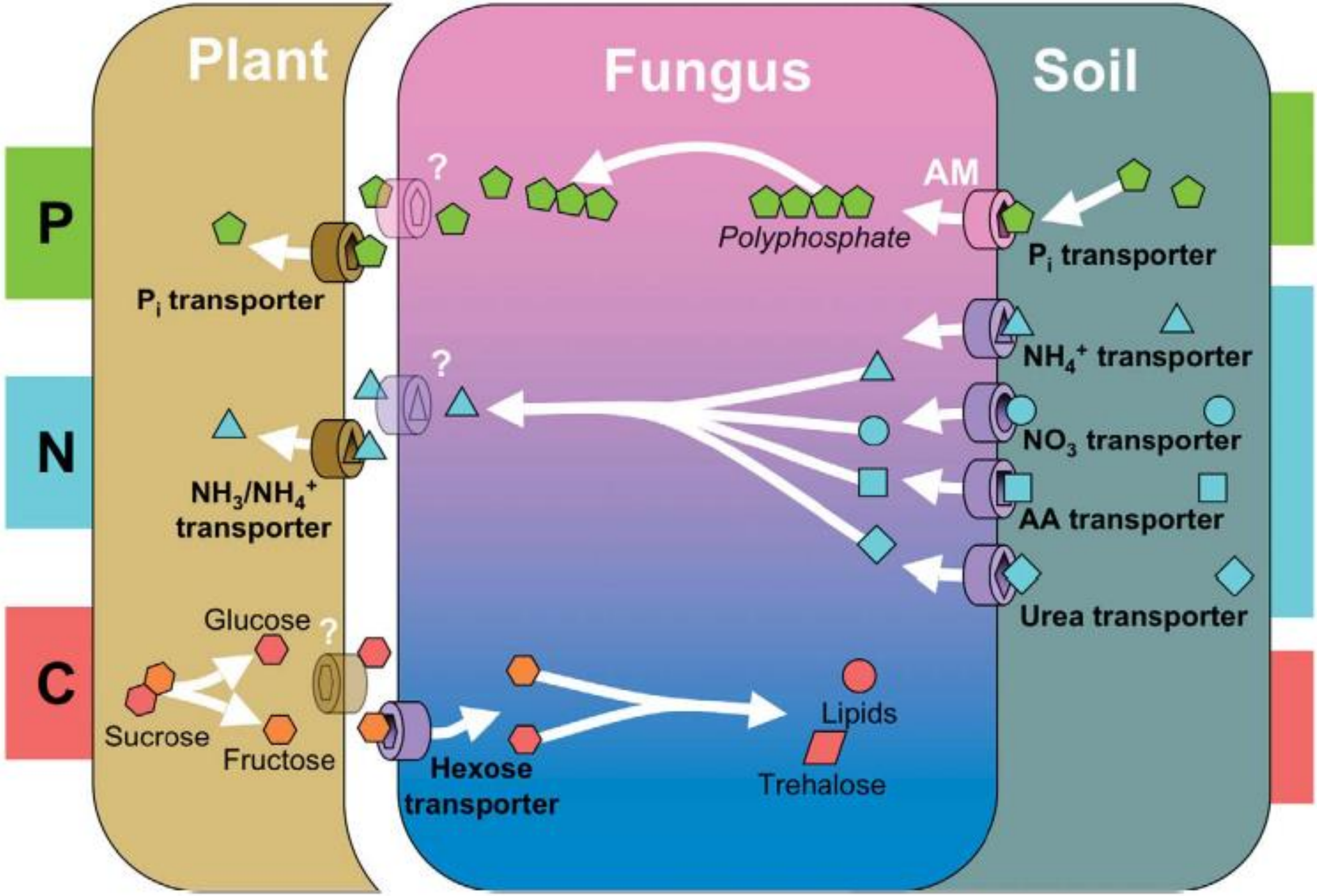
Phosphorus is acquired from organic and mineral soil layers



Clausing S and Polle A (2020) Mycorrhizal Phosphorus Efficiencies and Microbial Competition Drive Root P Uptake. Front. For. Glob. Change 3:54. doi: 10.3389/ffgc.2020.00054

Exchange processes

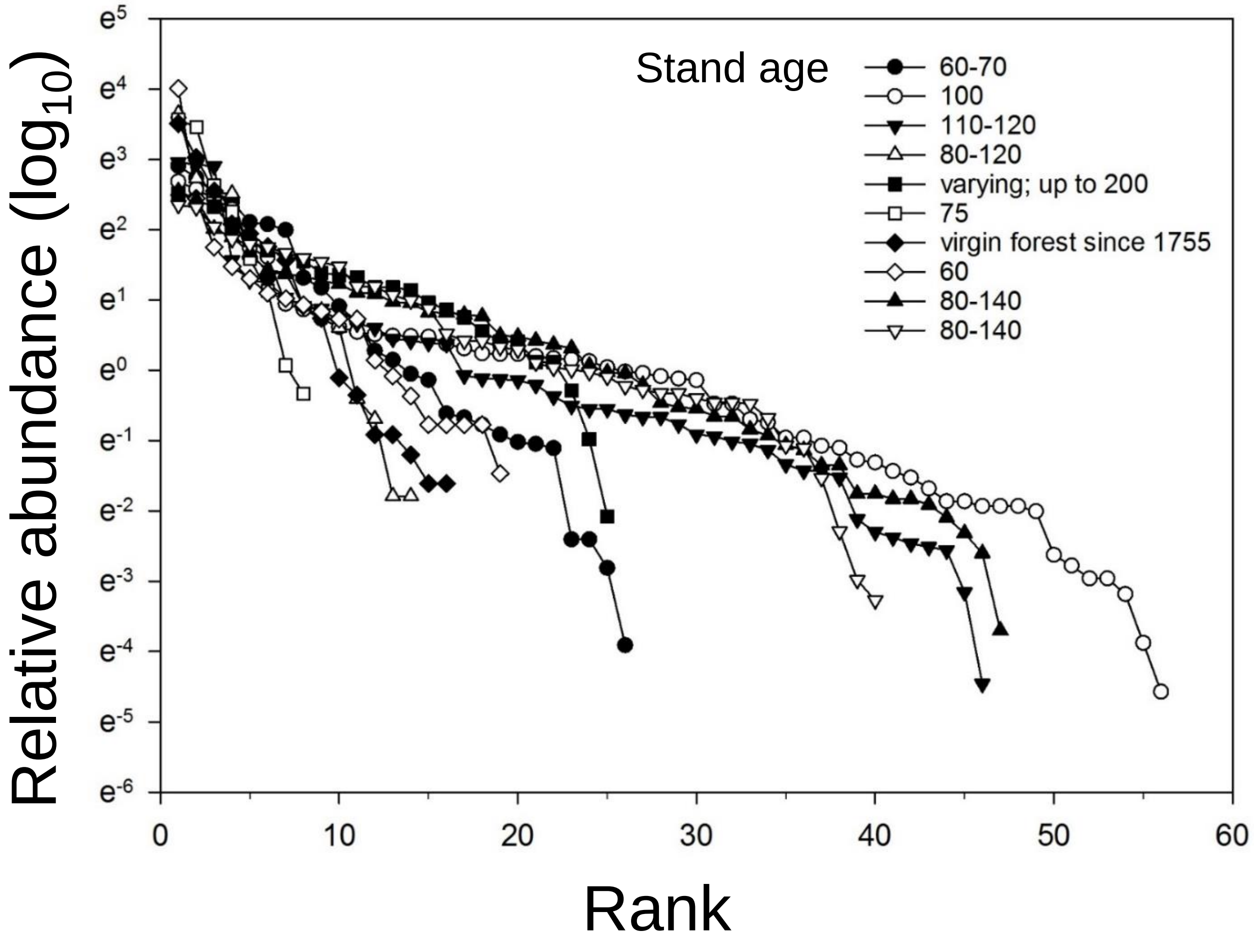
REVIEW Published 27 Jul 2010 | DOI: 10.1038/ncomms1046
Mechanisms underlying beneficial plant–fungus interactions in mycorrhizal symbiosis
Paola Bonfante[1] & Andrea Genre[1]

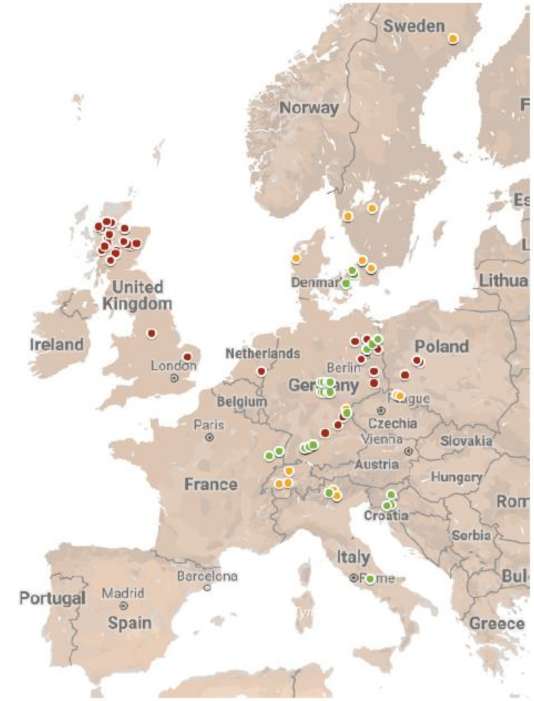



Russula emetica
Paxillus involutus
Thelephoraceae sp.
Lactarius subdulcis
Laccaria laccata
Russula rosea
Cortinarius sp
Cenococcum geophilium
Hydnum rufescens

Ectomycorrhiza communities

Beech (*Fagus sylvatica*) in Europe





A small number of abundant taxa, a large number of low abundance taxa

Rosinger *et al.* 2018 Forests 9, 445

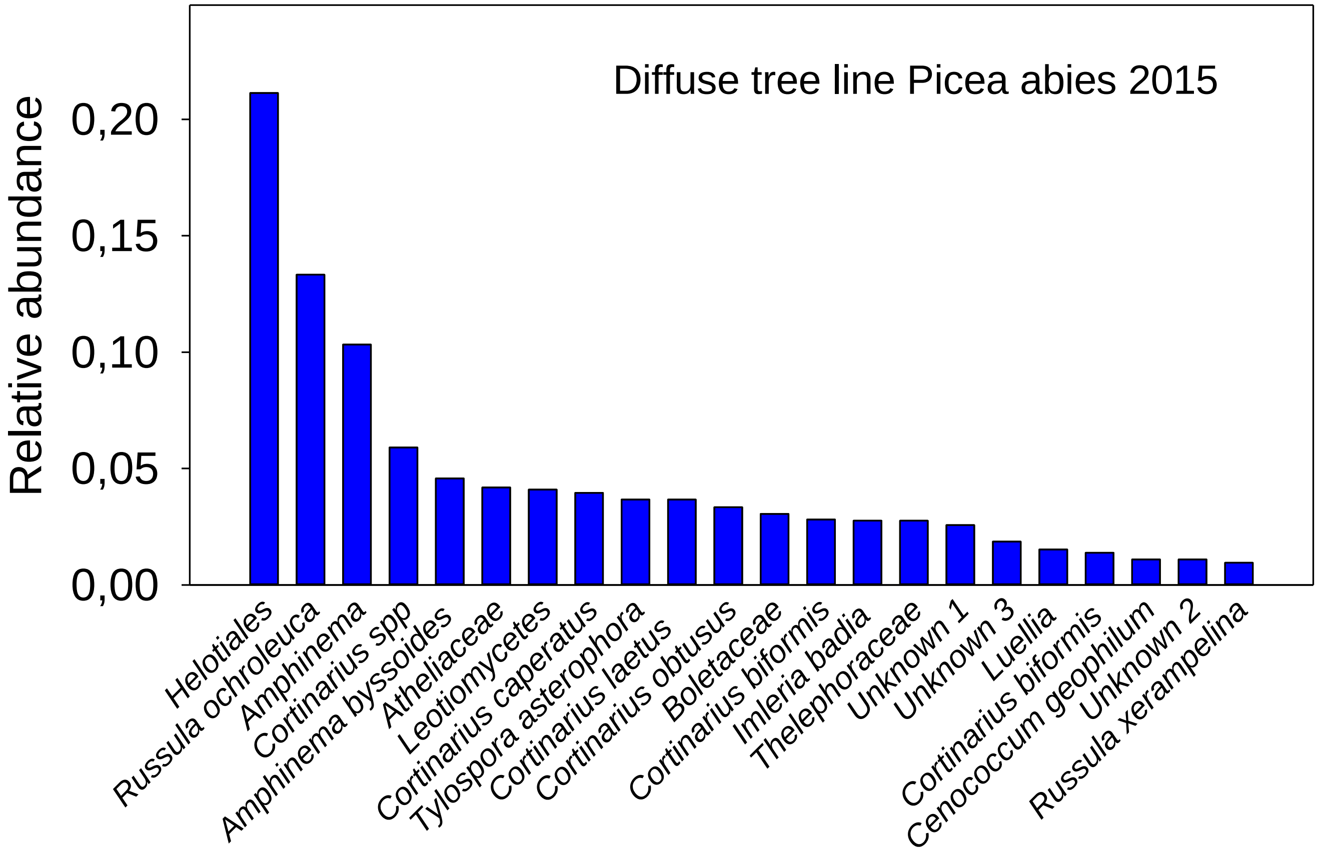
Diffuse tree line Austrian alps

1750- 1800 m

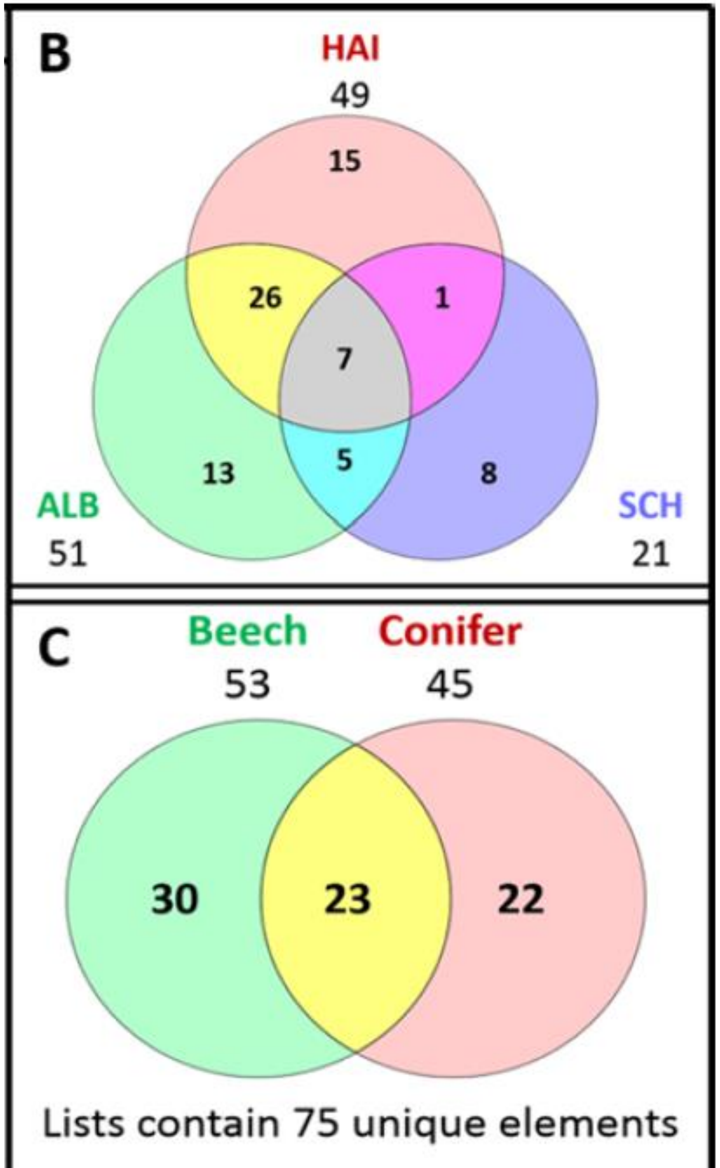
Ectomycorrhiza community

Few dominate species

Many low abundance species



What drives community composition?



Tree host and environment determine ectomycorrhizal community composition

Environment

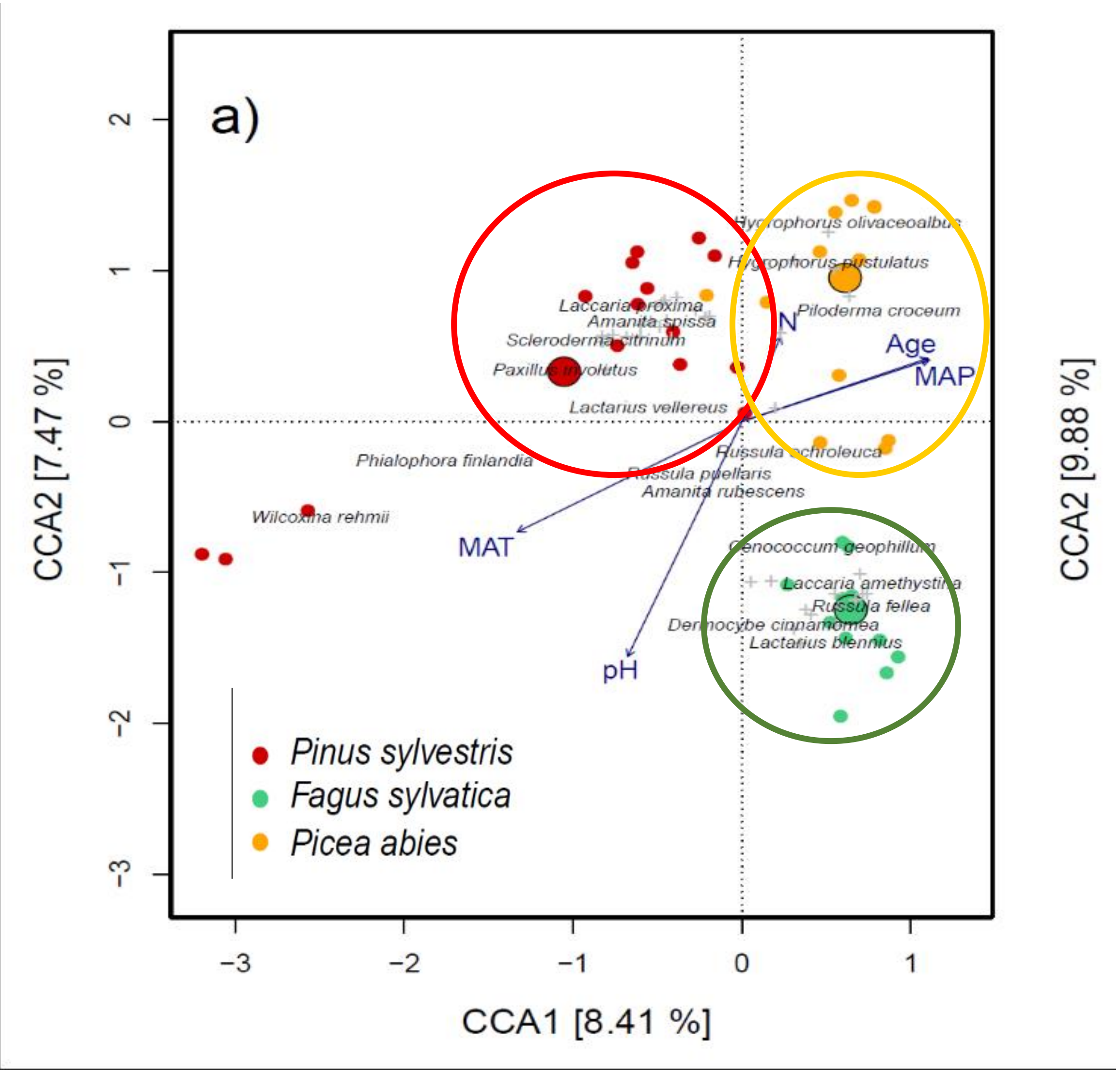
Tree host

Common EM taxa and unique EM taxa

Phylogenetic and functional traits of ectomycorrhizal assemblages in top soil from different biogeographic regions and forest types

Rodica Pena[1] · Christa Lang[1,2] · Gertrud Lohaus[1,3] · Steffen Boch[4] · Peter Schall[5] · Ingo Schöning[6] · Christian Ammer[5] · Markus Fischer[4] · Andrea Polle[1]

What drives community composition?

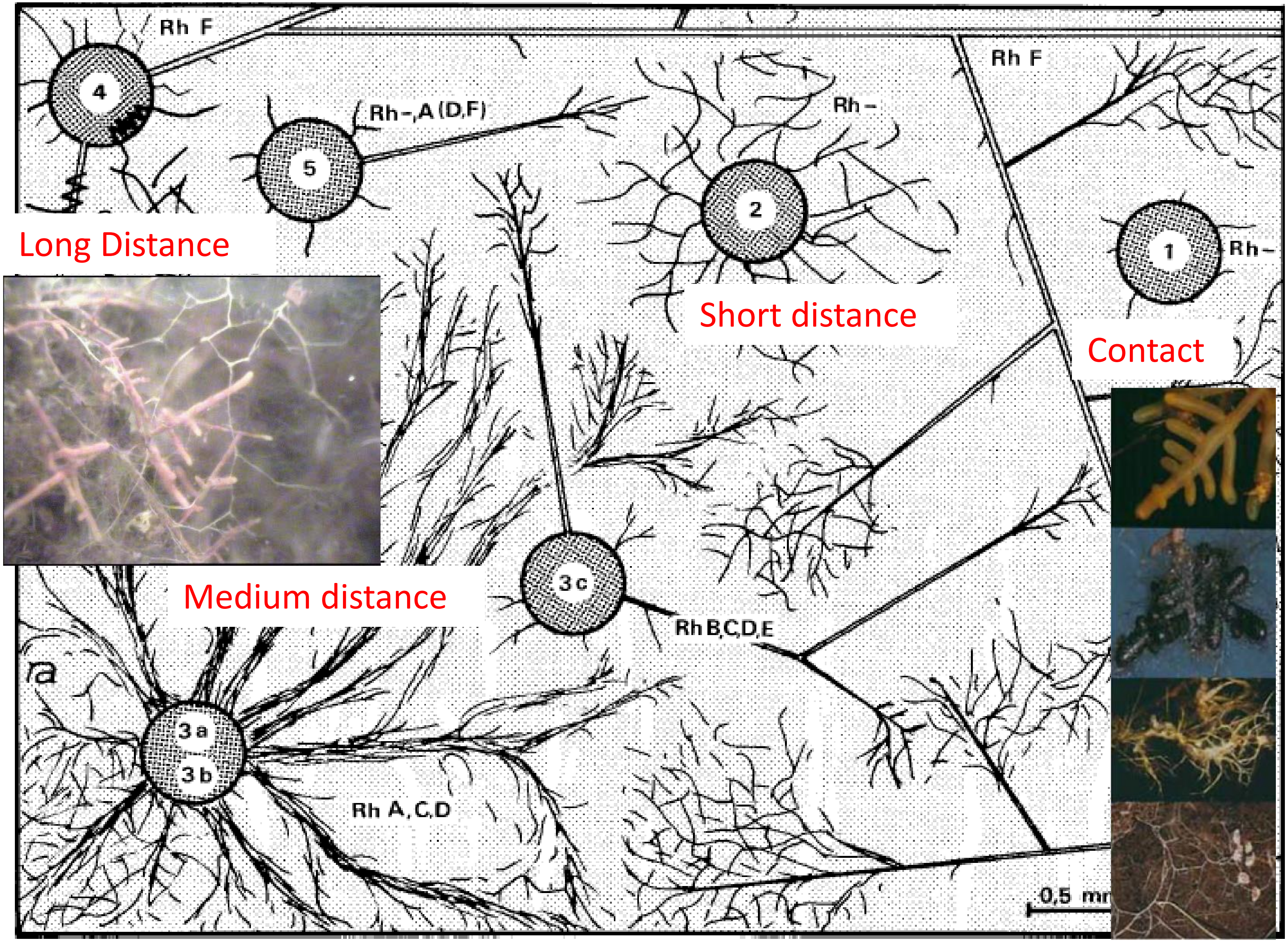


Tree host, soil pH and **nitrogen** control ectomycorrhizal community composition

Rosinger *et al.* 2018 Forests 9, 445

Linking to function

Exploration types – functional traits

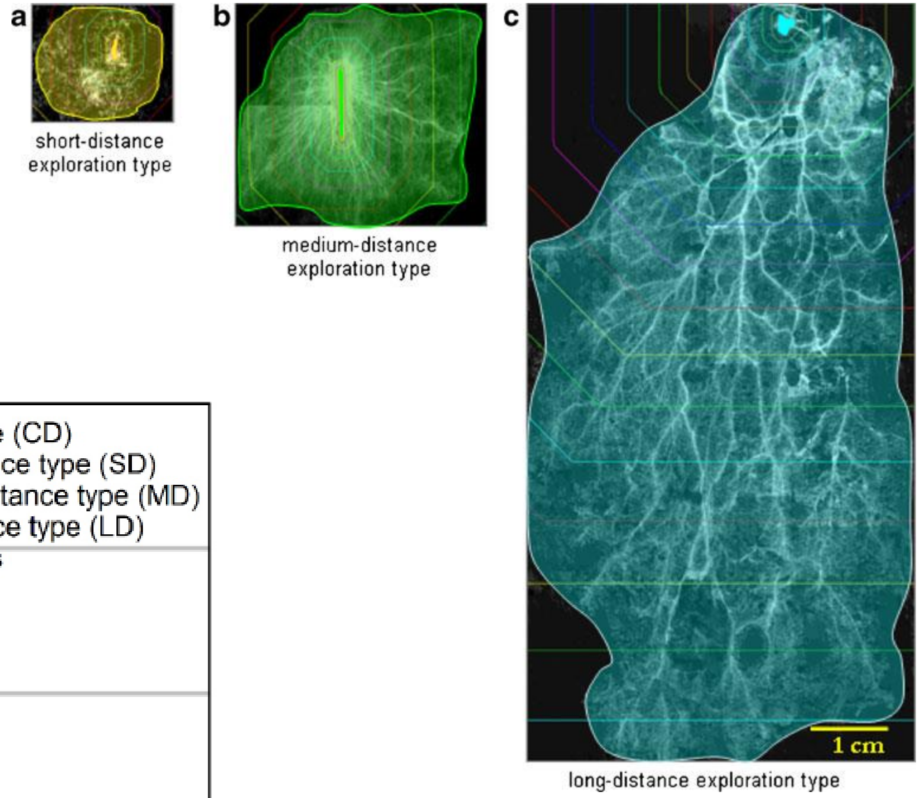


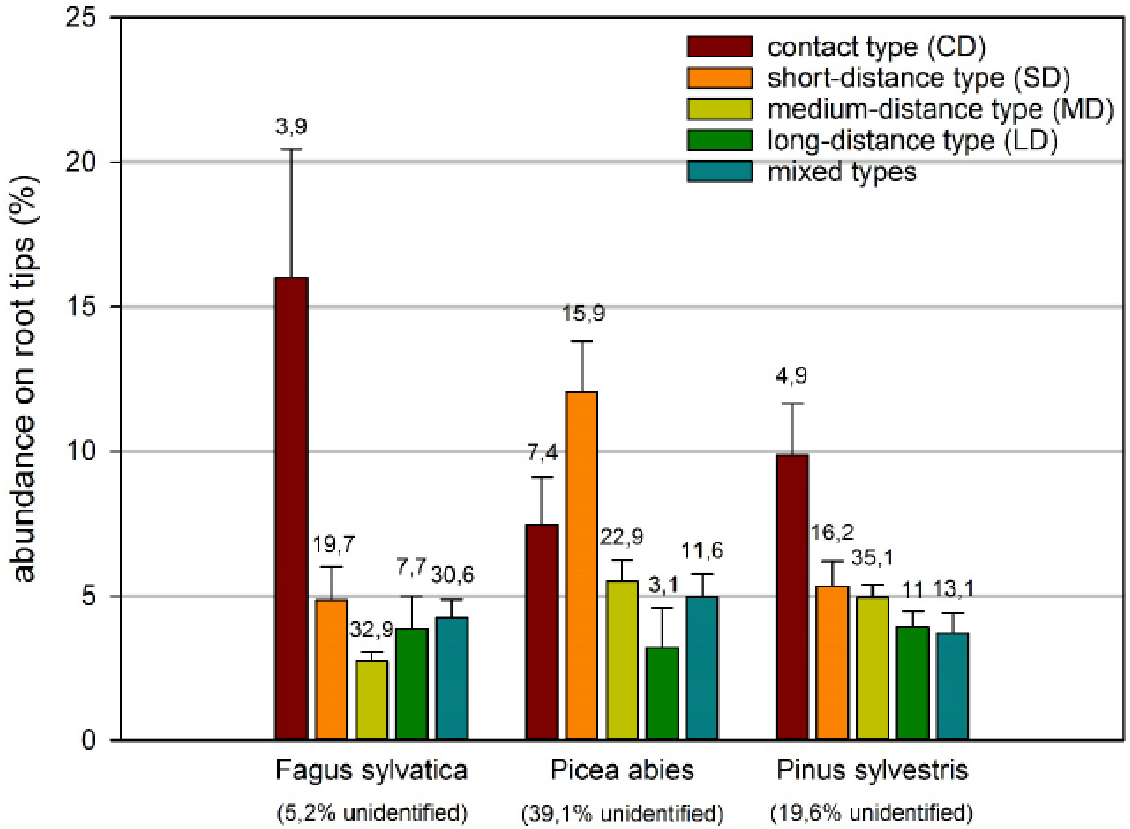
Agerer (2001) Mycorrhiza 11:107–114


Russula emetica
Paxillus involutus
Thelephoraceae sp.
Lactarius subdulcis
Laccaria laccata
Russula rosea
Cortinarius sp
Cenococcum geophilium
Hydnum rufescens

Functional diversity

Exploration types



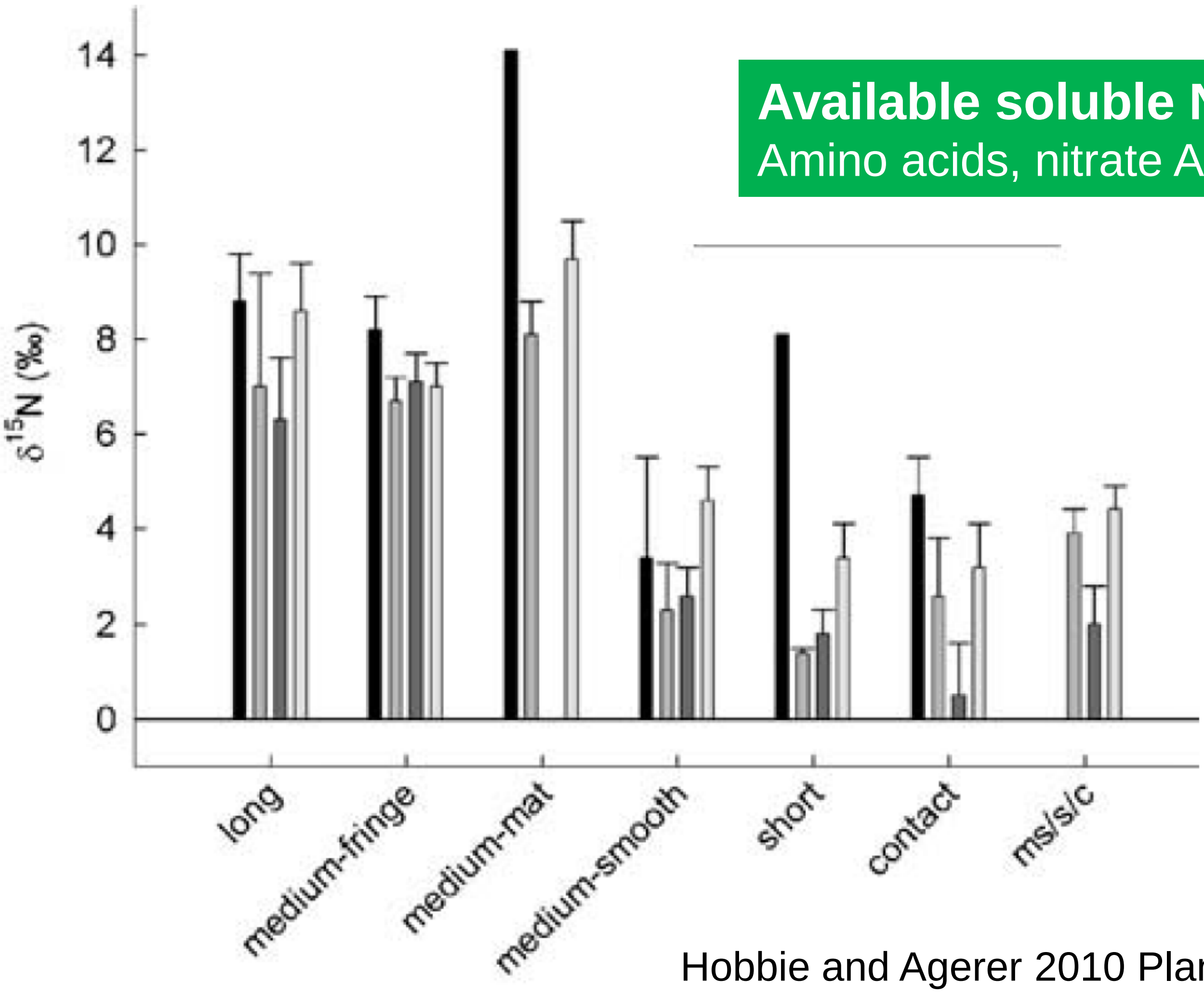


Similar among tree species, contact exploration types tend to dominate

All ETs are composed of many taxa

Different exploration types use different N sources

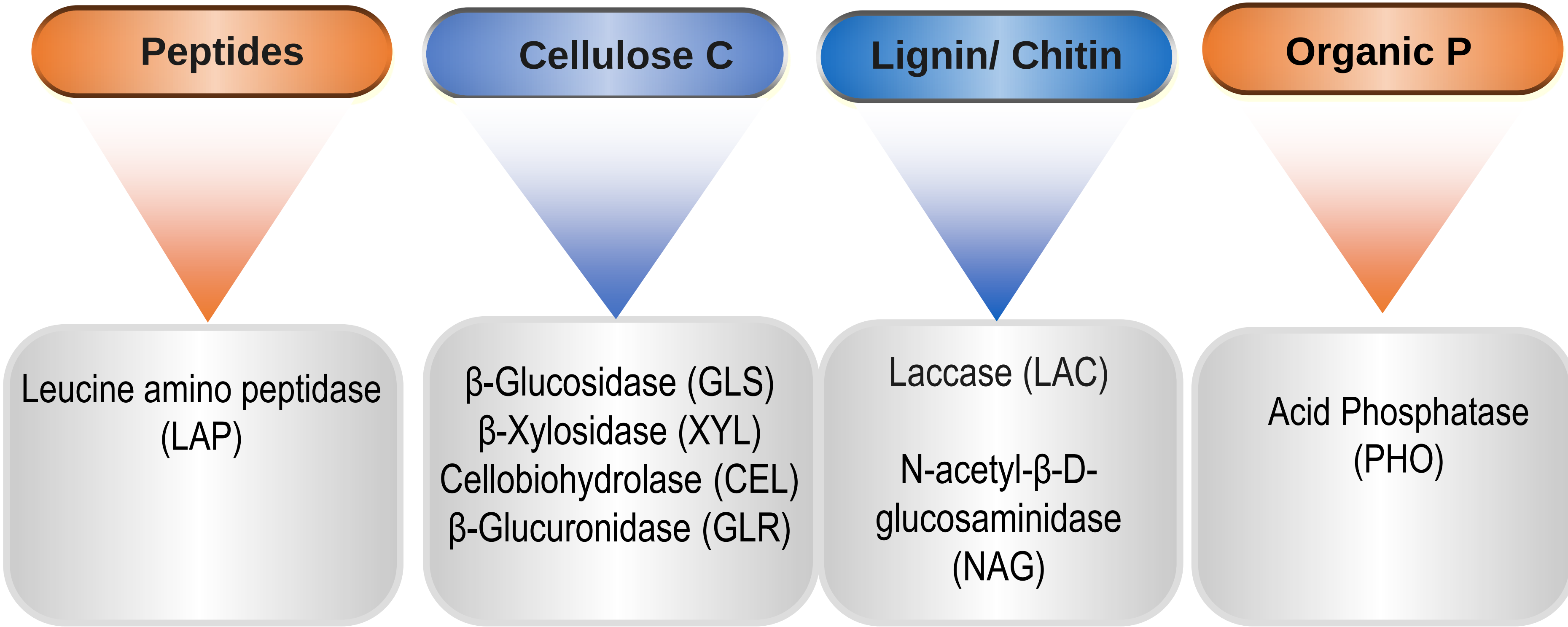
Undissolved N
Soil organic matter
Proteins, peptides



Available soluble N
Amino acids, nitrate Ammonium

Hobbie and Agerer 2010 Plant Soil 327:71–83

Target substrates of root exoenzymes



Nitrogen cycle, decomposition, phosphorus cycle

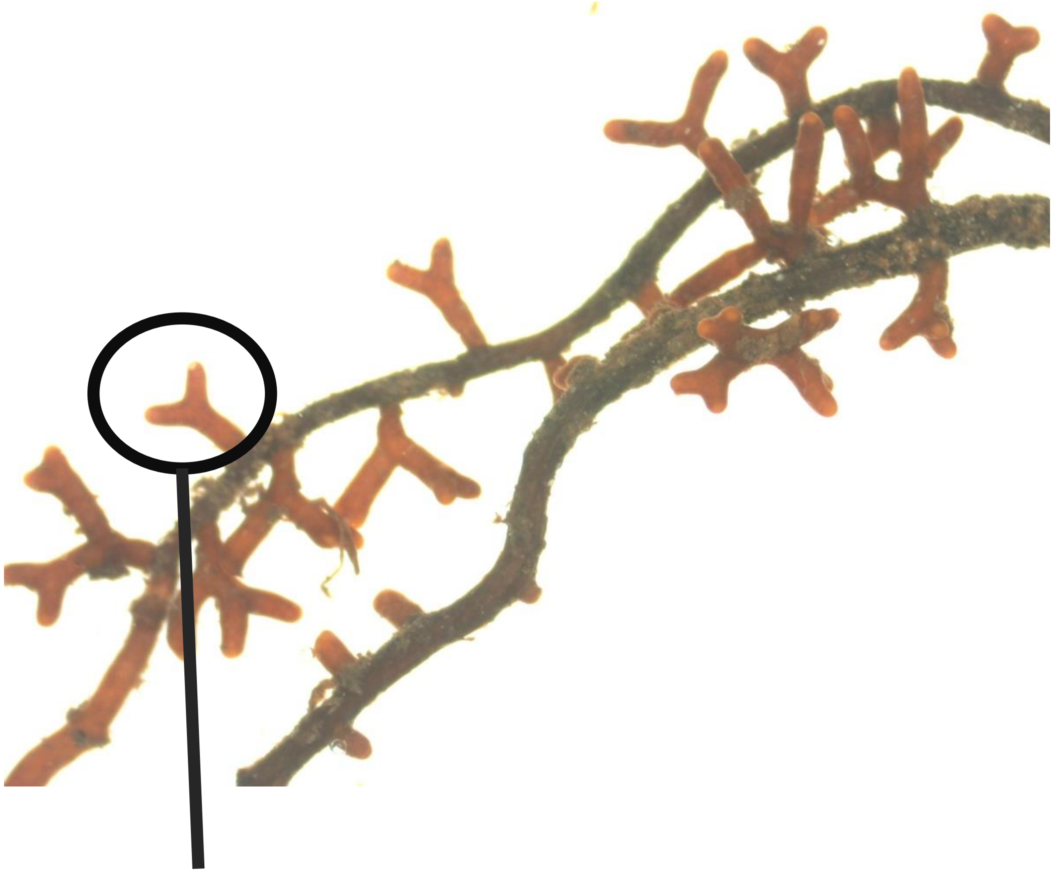
In temperate and boreal soils, N and P availability is dependent upon SOM decomposition

Linking community structure to function

Enzyme activity profiling of ectomycorrhizas

Enzymes measured

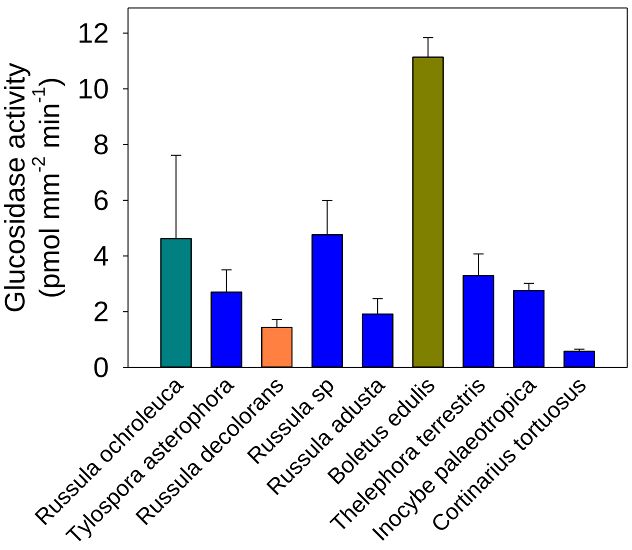
Leucine amino peptidase-LAP
β-Xylosidase-Xyl
β-Glucuronidase-Glr
Cellobiohydrolase –Cel
N-Acetylglucosaminidase-Nag
β-Glucosidase-Gls
Acid phosphatase-Pho
Laccase-Lac



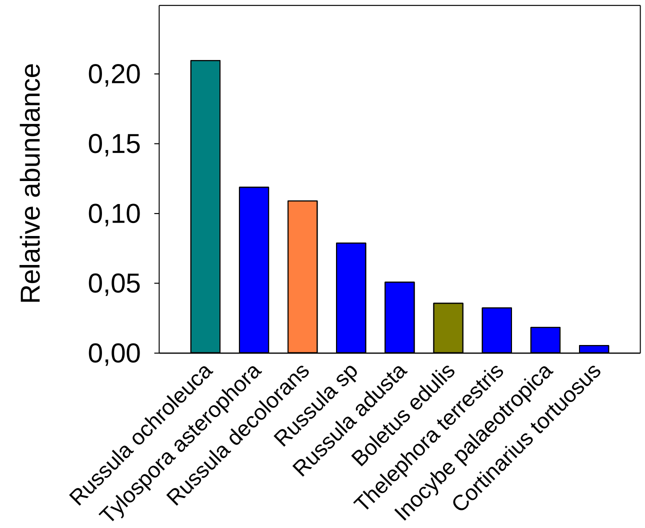
Ectomycorrhizas on roots

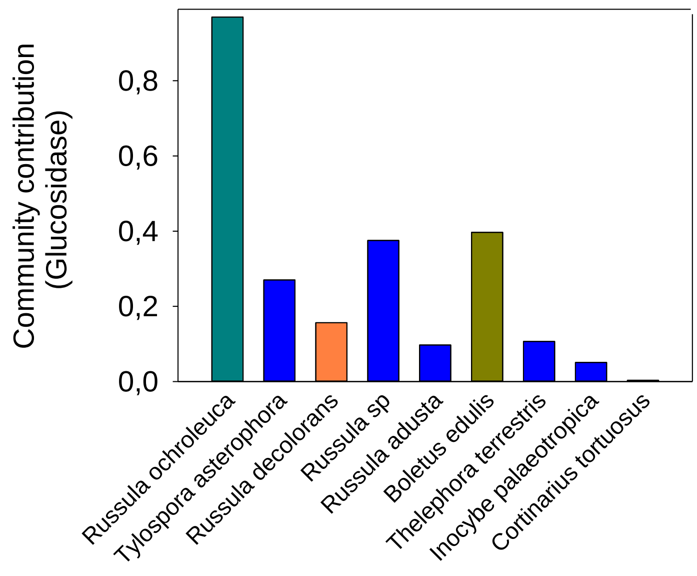
Estimation of the contribution of taxa to the community

Taxa enzyme activity



Relative abundance



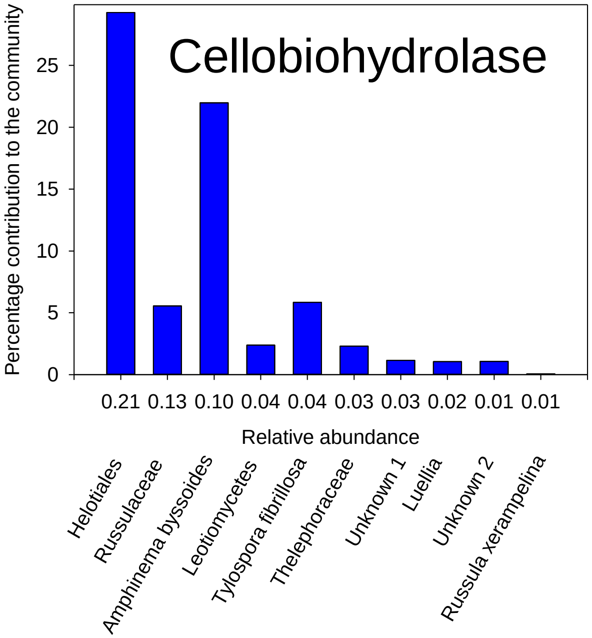


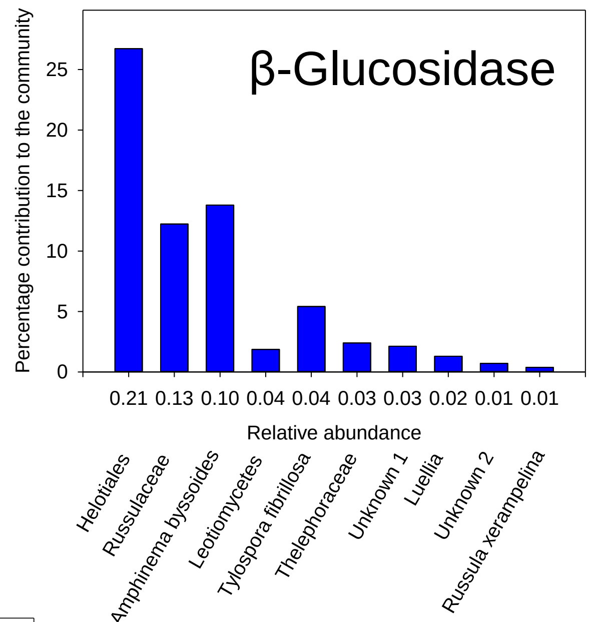
Taxa from ca. 60 % of the relative abundance were measure.
Missing taxa assigned median activity

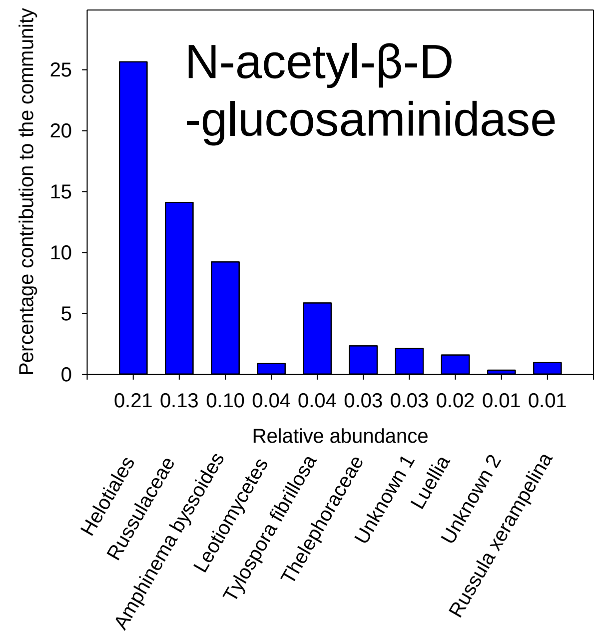
Relative contribution to the community

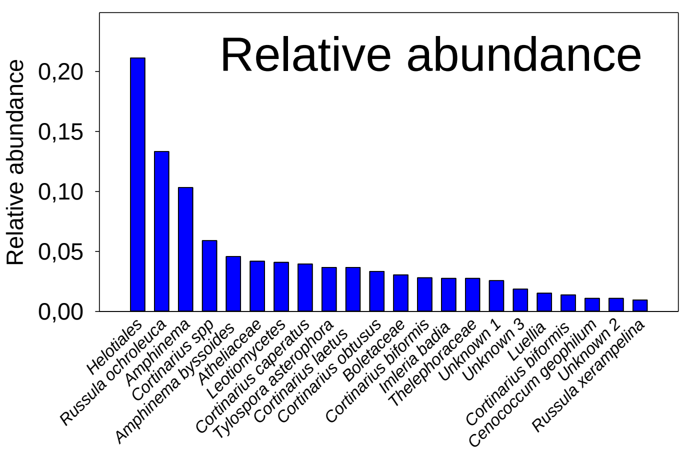
Contribution of taxa to the community

Diffuse tree line *Picea abies*





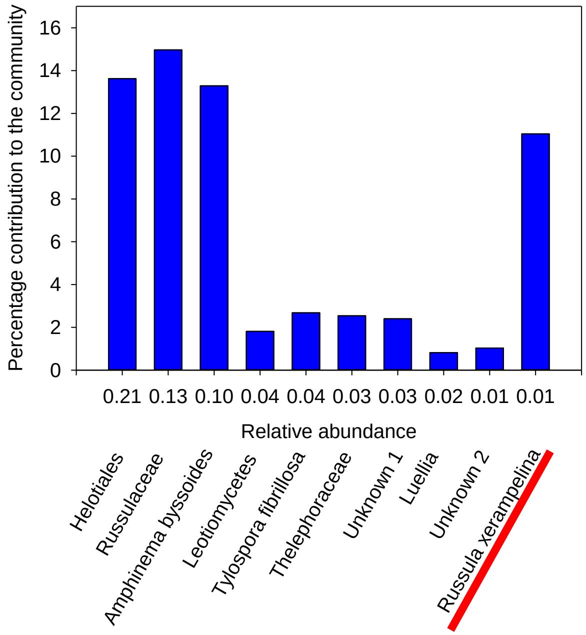


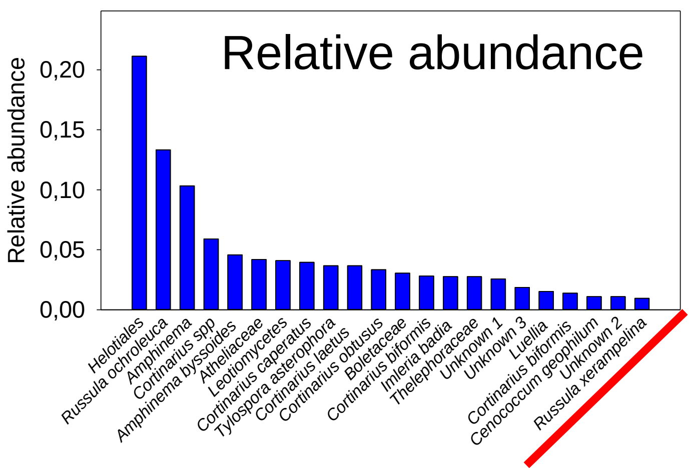


Contribution to the community driven by relative abundance

Contribution of taxa to the community

Leucine amino peptidase

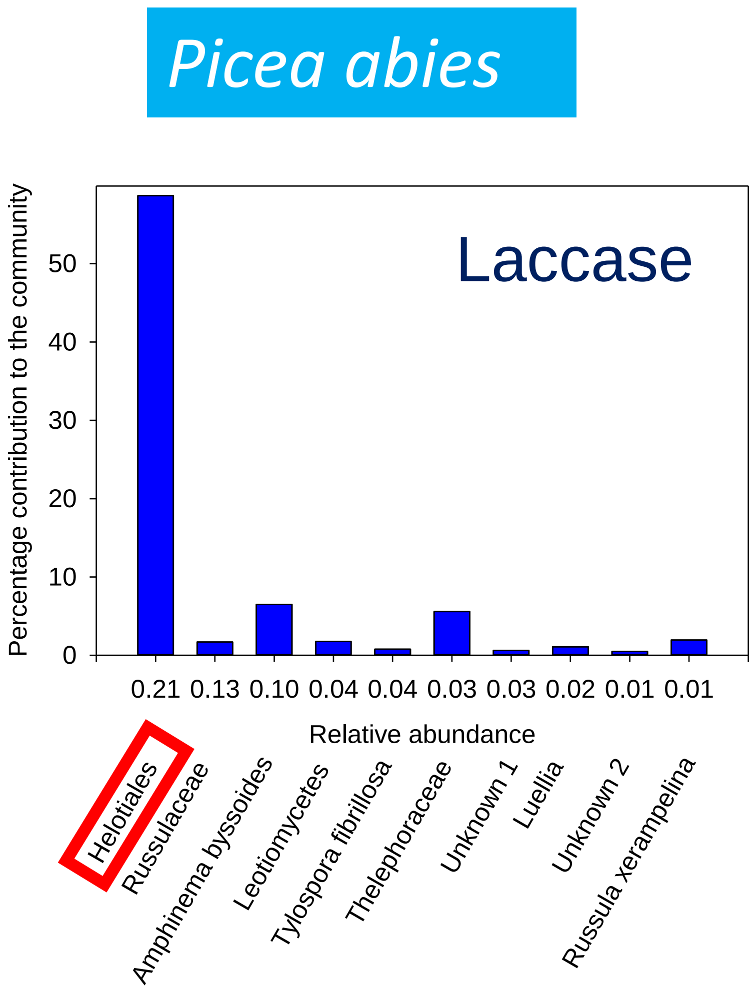


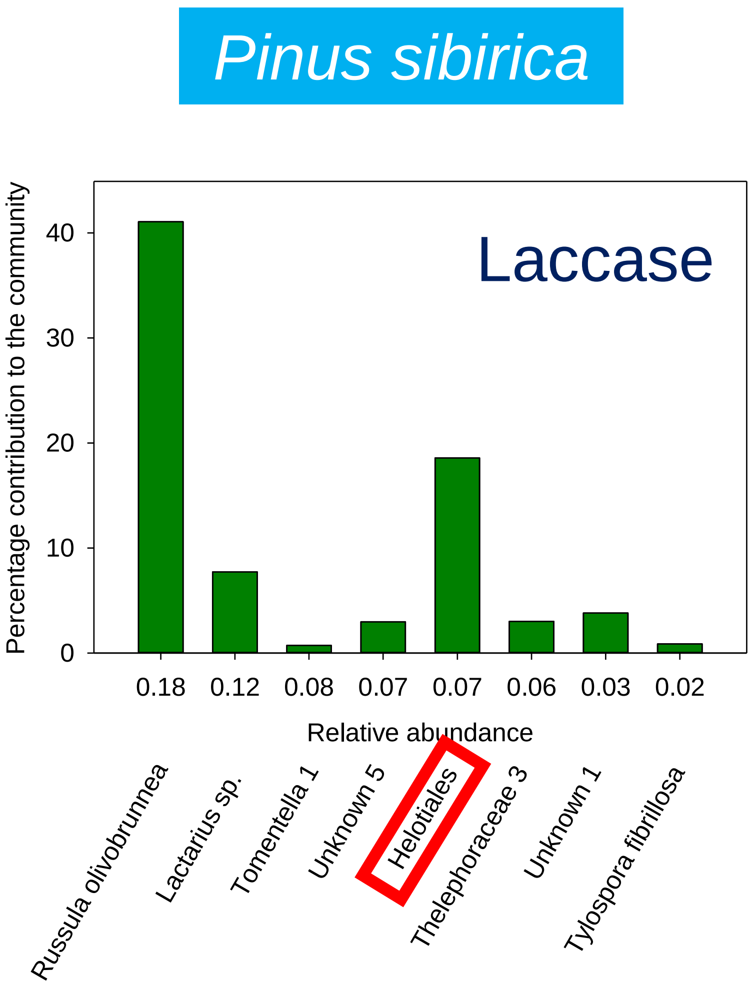


Diffuse tree line *Picea abies*

Contribution to the community driven by enzyme activity

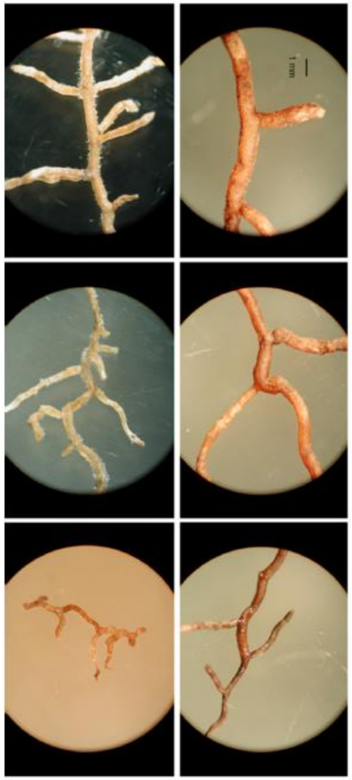
Importance of EM identity

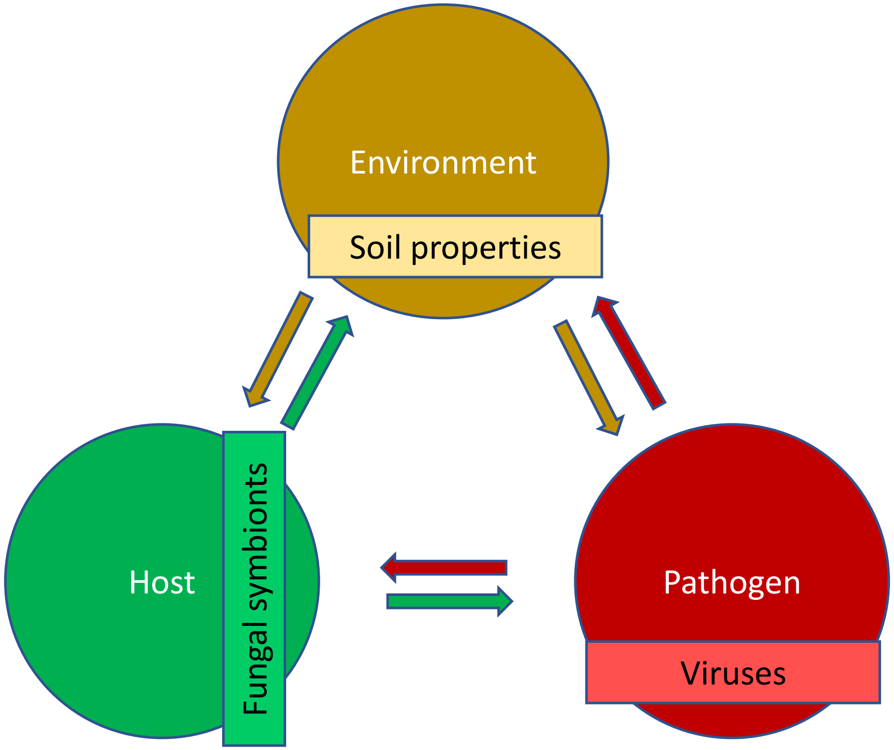




Helotiales has a high contibution to laccase activity independent of tree host

Interactions between tree roots and root pathogens





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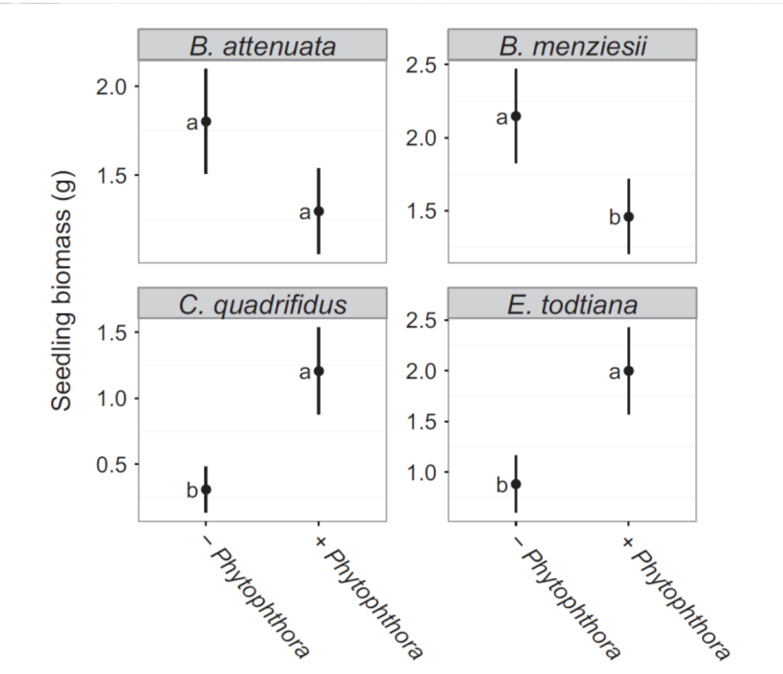
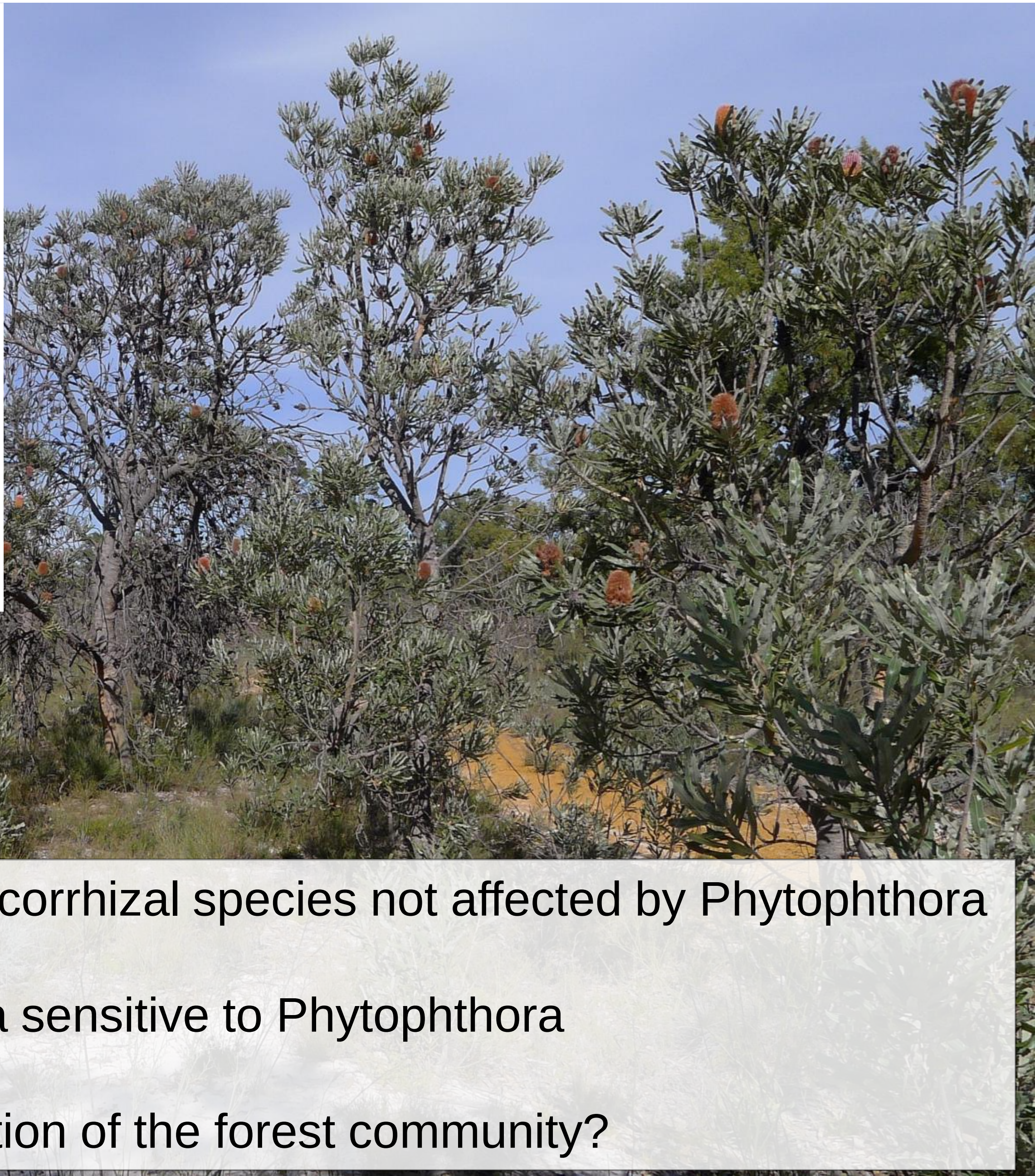
Western Australia Banksia woodlands





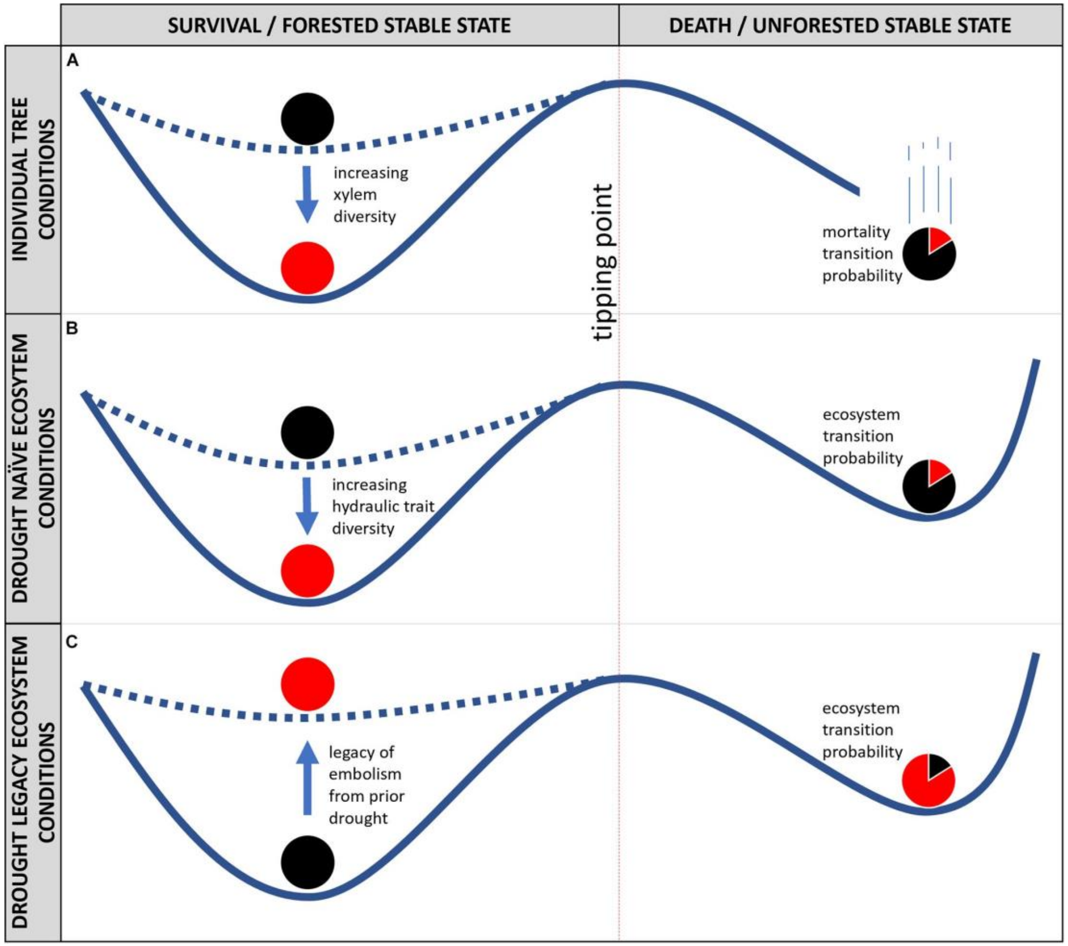
Ectomycorrhizal species not affected by Phytophthora

Banksia sensitive to Phytophthora

Regulation of the forest community?

Albornoz et al, 2017

Ecological stability of trees and mixed tree stands



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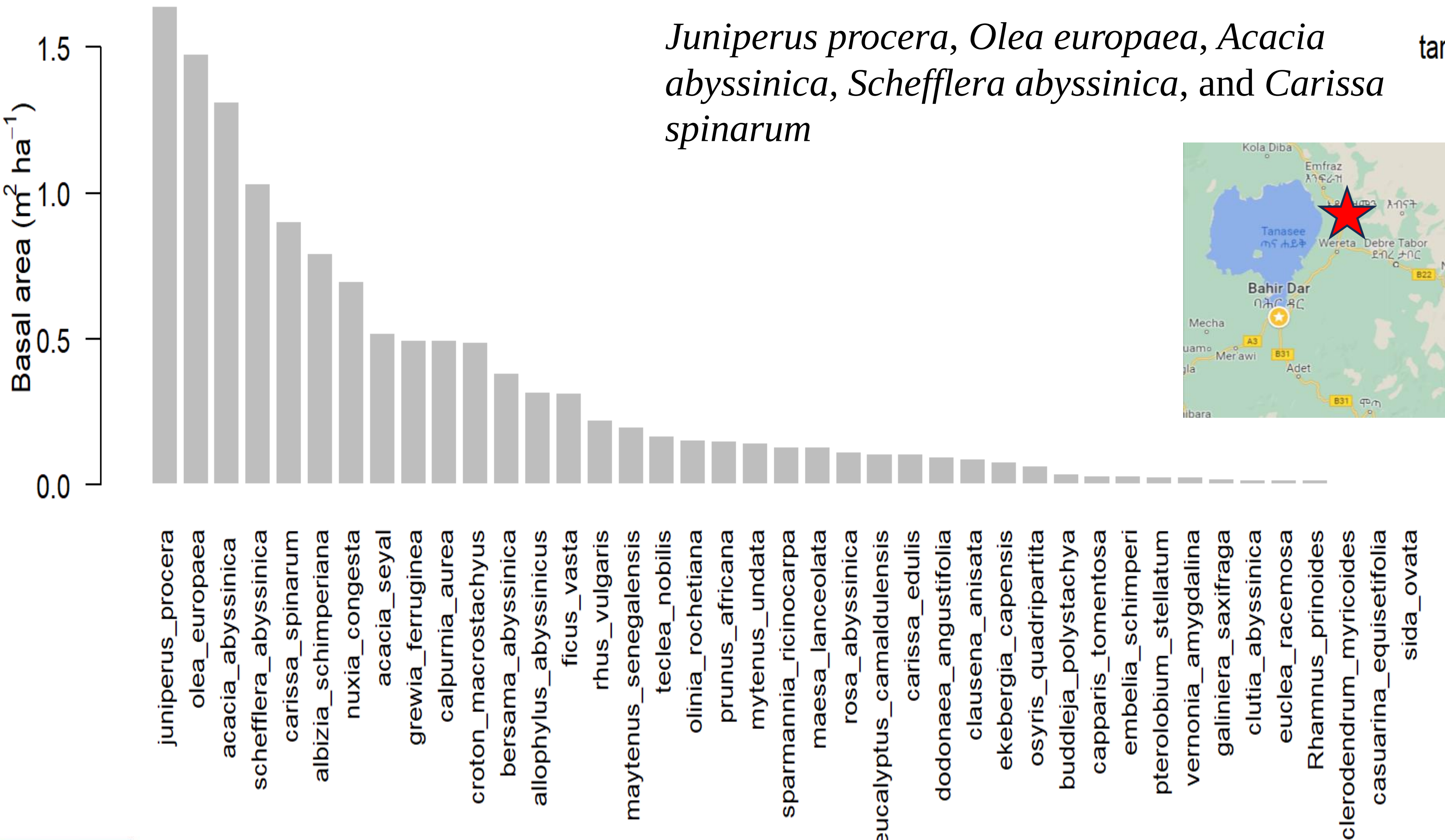
MENDELU Faculty of Forestry and Wood Technology


Tara Gedam
Ethiopia

Tree community composition



Juniperus procera, *Olea europaea*, *Acacia abyssinica*, *Schefflera abyssinica*, and *Carissa spinarum*

tara

Funded by the European Union

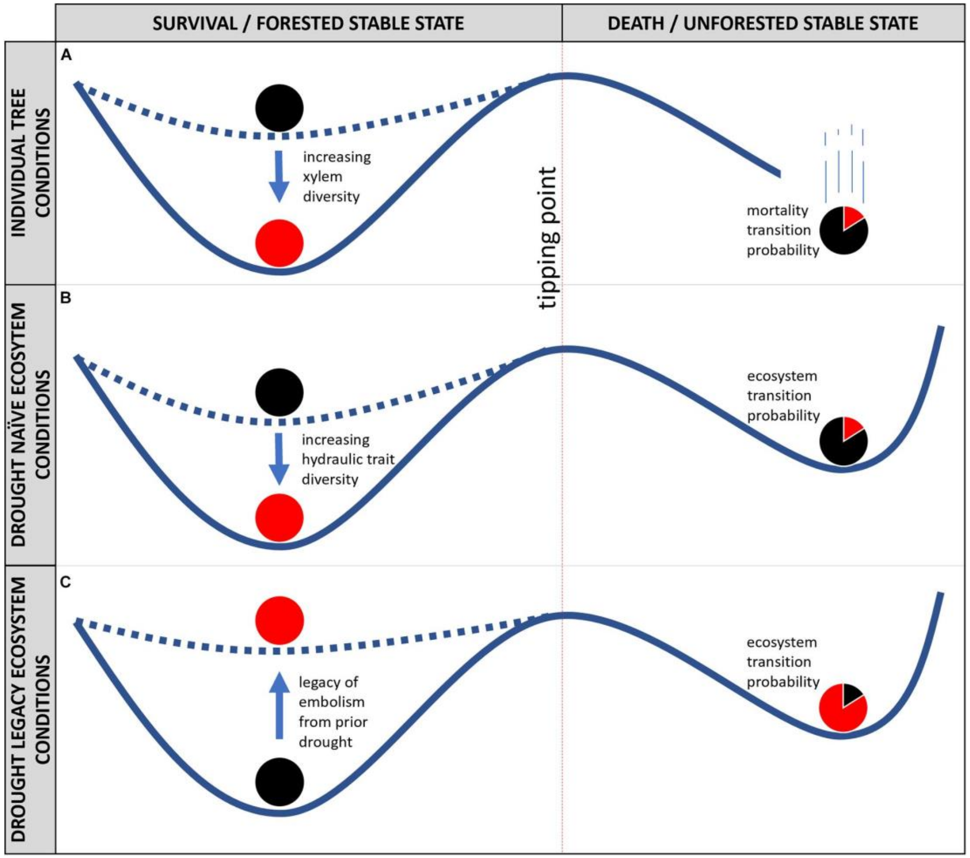
unpublished

Ecological stability of trees and mixed tree stands

If we want to determine the effects of future environments on the stability of (mixed) forests we need to understand:

- **Genotype-specific traits**
- **How species interactions with other species effect traits**

→ **per environment**



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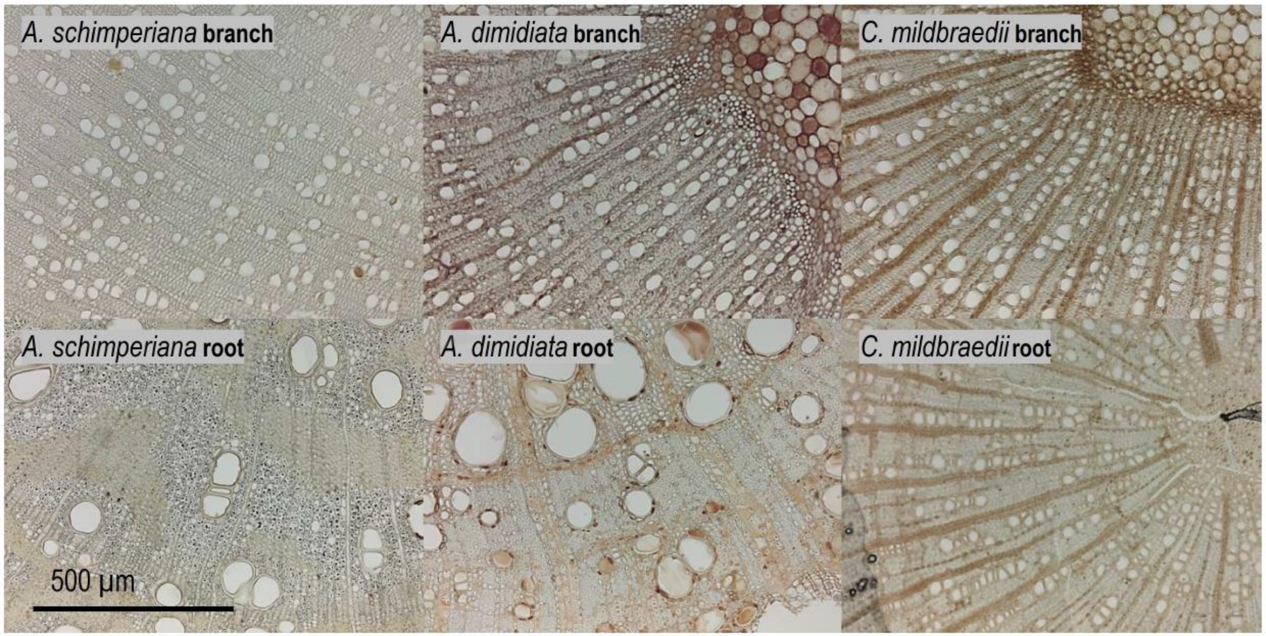
Functional Diversity – above and below ground

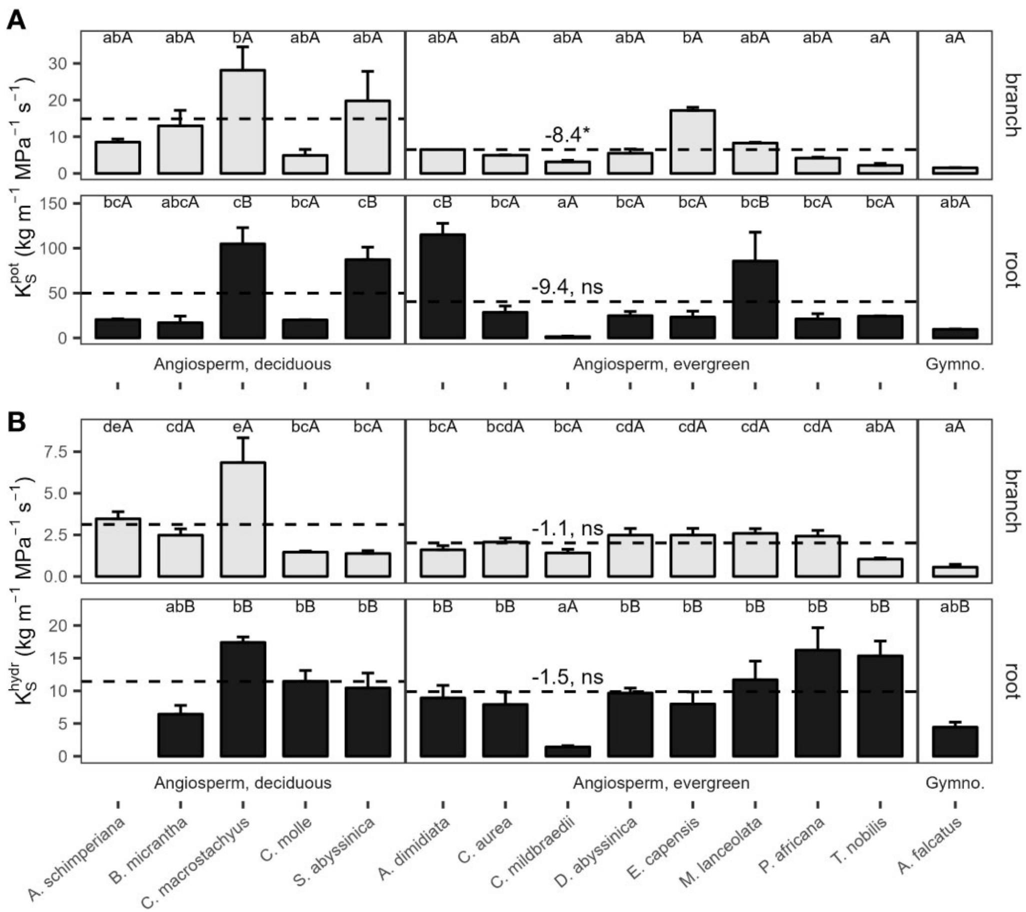


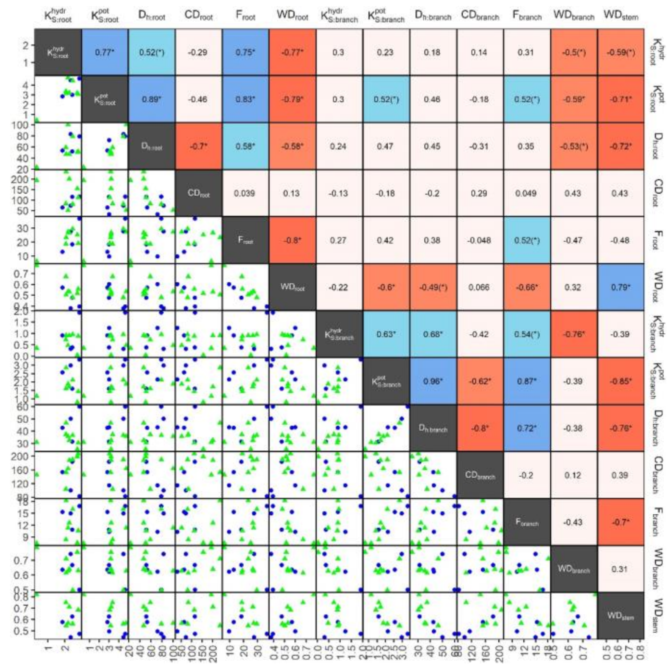
Galowdiwos Church Forest, Ethiopia

Funded by the European Union

Schönauer et al., 2023

Leaf habits and hydraulic parameters as key factors to understand drought tolerance / avoidance strategies

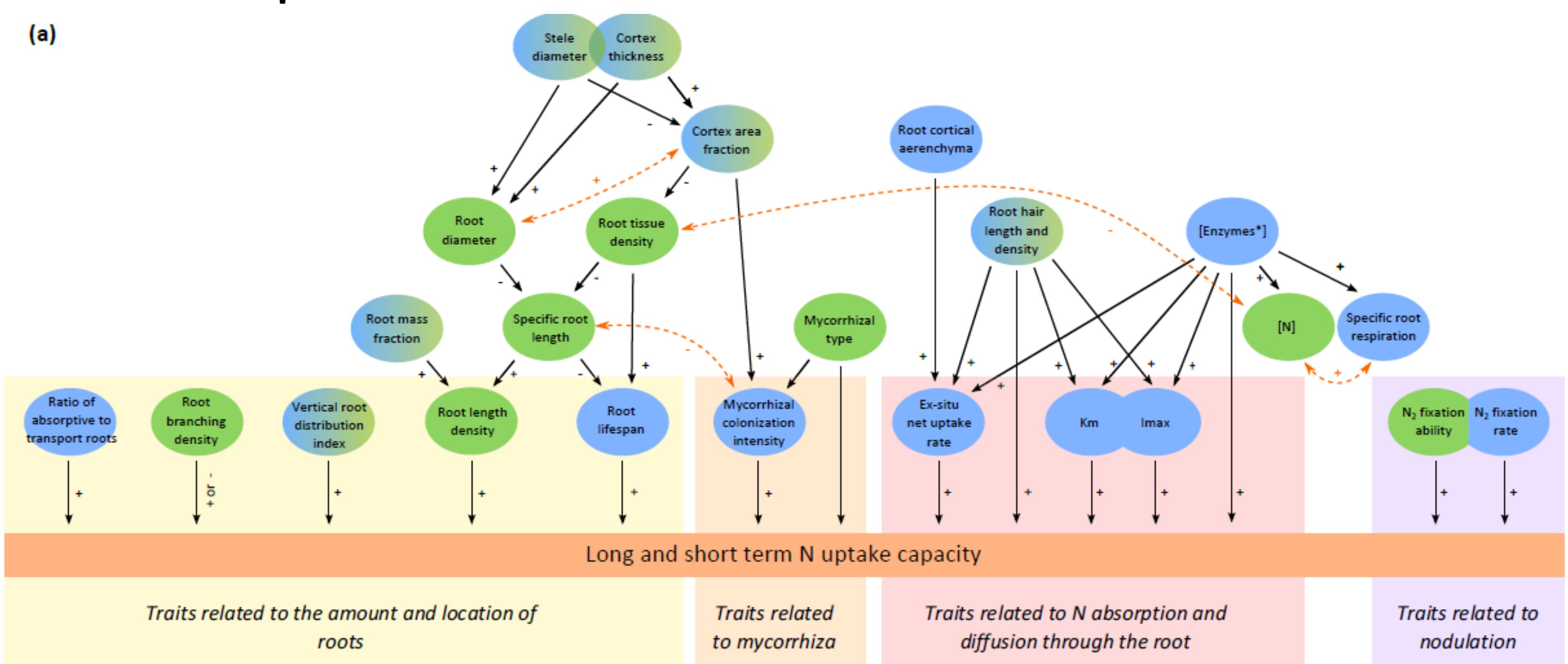




→ Above- : Belowground trait interrelations also unknown for many temperate tree species

A trait-based approach to ecosystem function

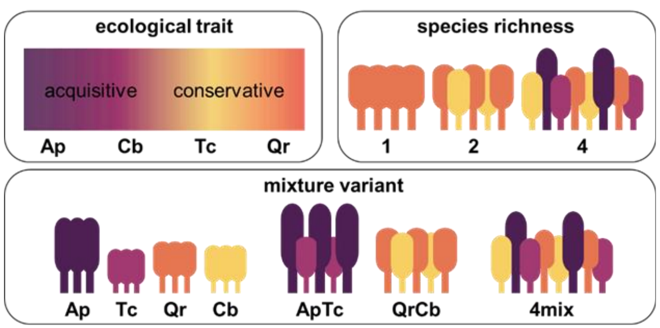
Paradigm: The function of an ecosystem depends on the environmental conditions, on the **traits of the species making up the ecosystem**, and the biomass of those species.

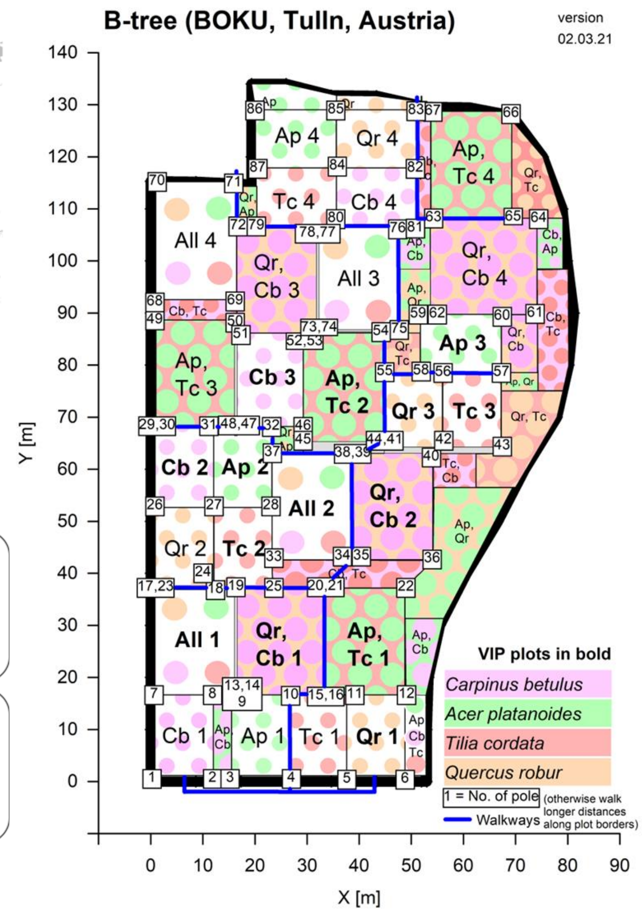


Freschet et al. 2021a

B tree, a TreeDivNet experiment

Tull, Austria





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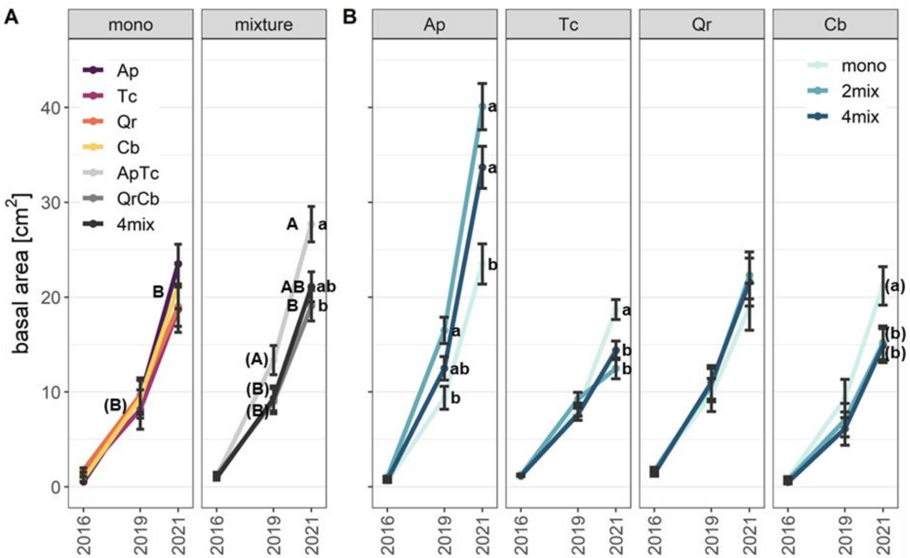
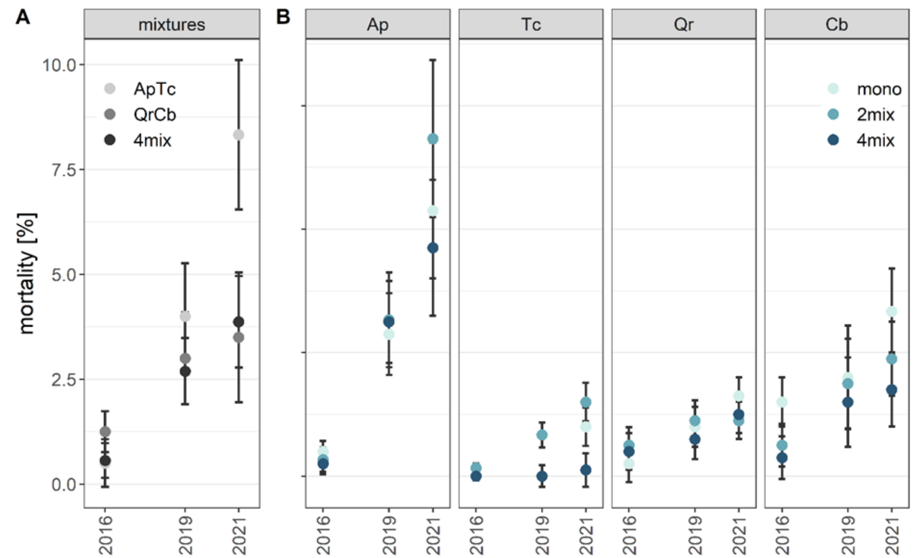
Werner et al., unpublished

Diversity effects “kick in” ~canopy closure and are species specific





Planted 2013, replanted 2014

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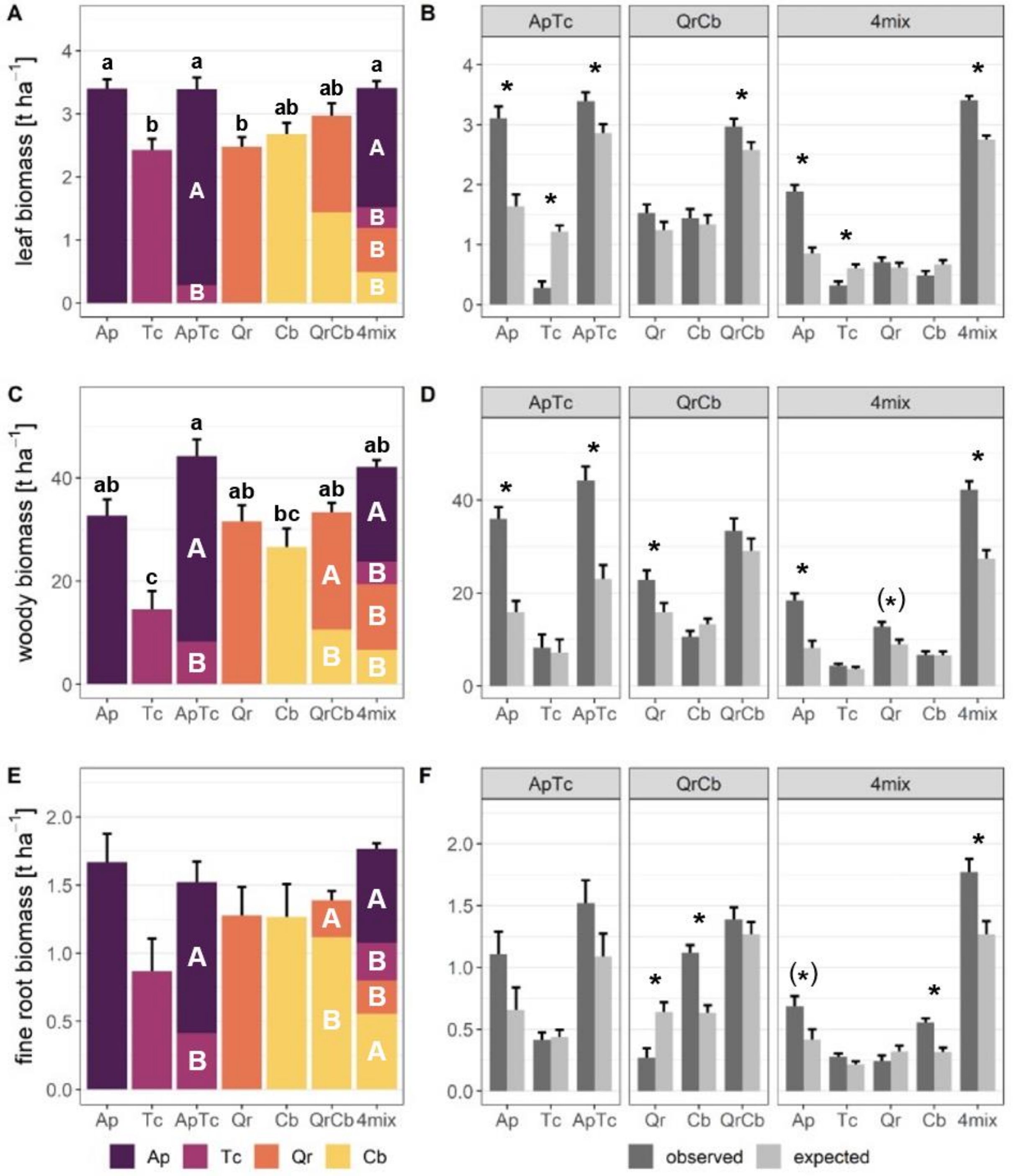
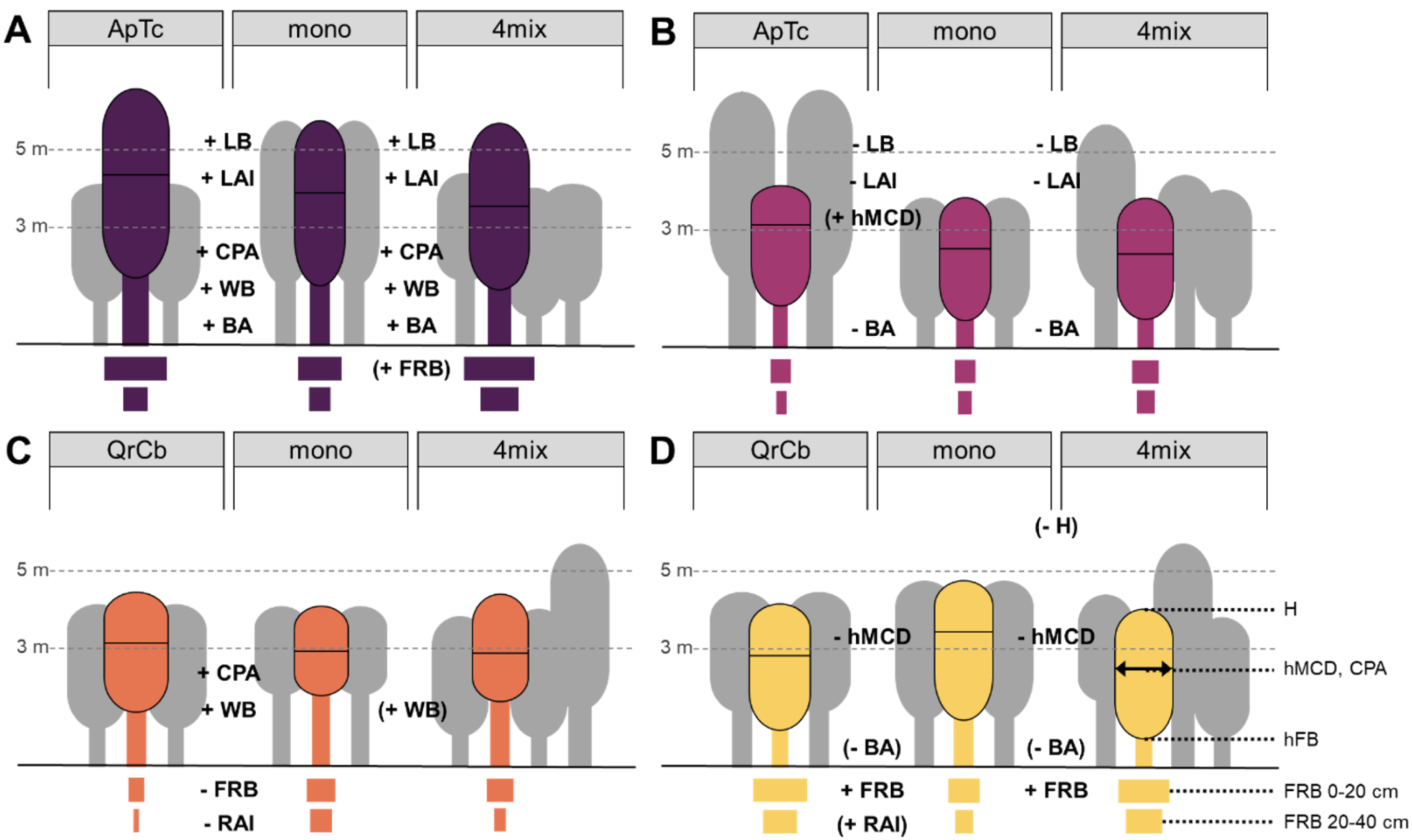
Biomass 2021

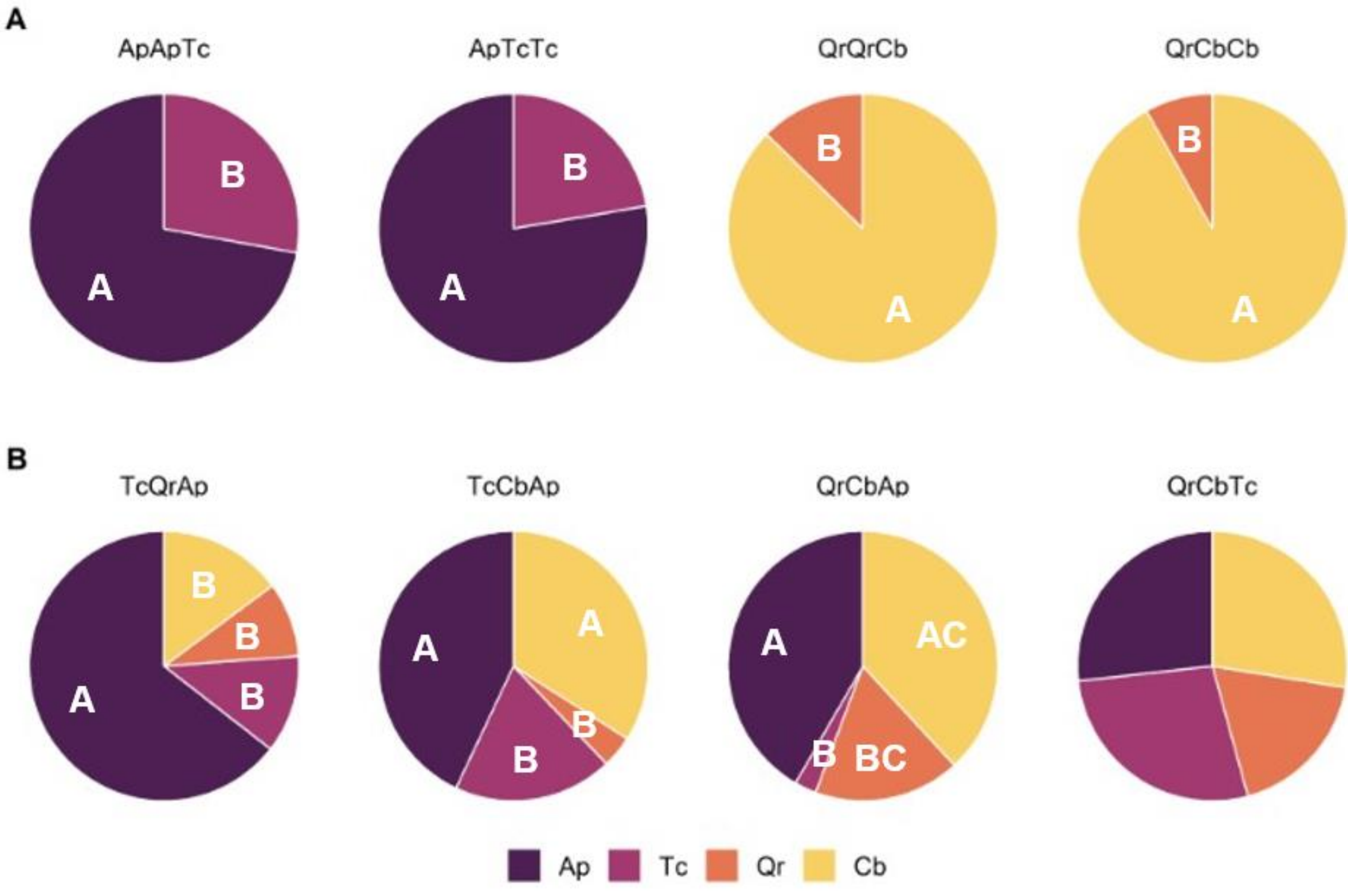


Funded by the European Union

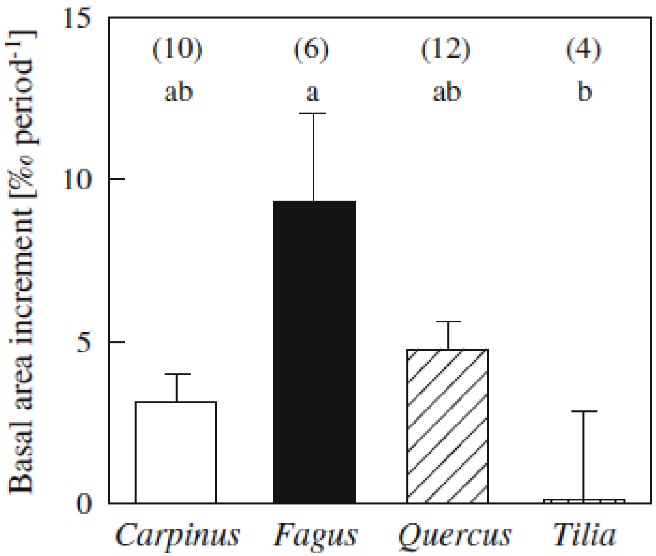
Enhanced structural complexity, trait plasticity of mixed stands



Root system - overlap or segregation?



Root competitive ability – Mature mixed stands Thuringia



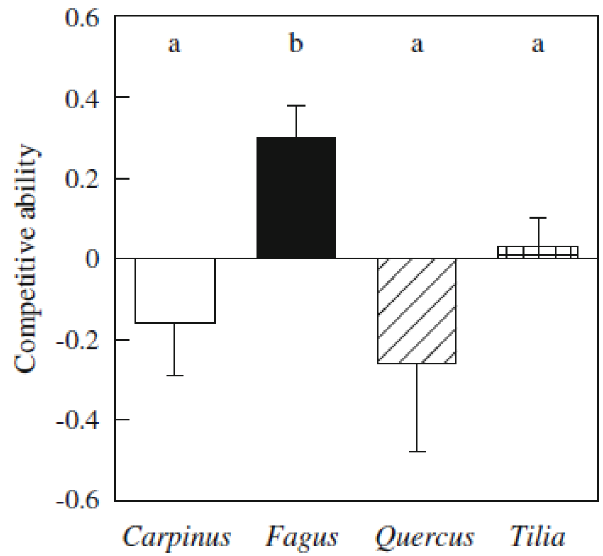
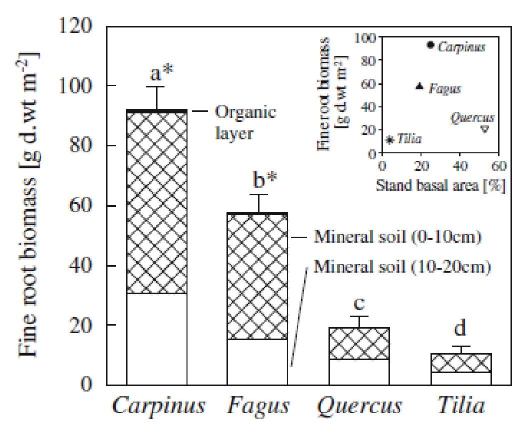


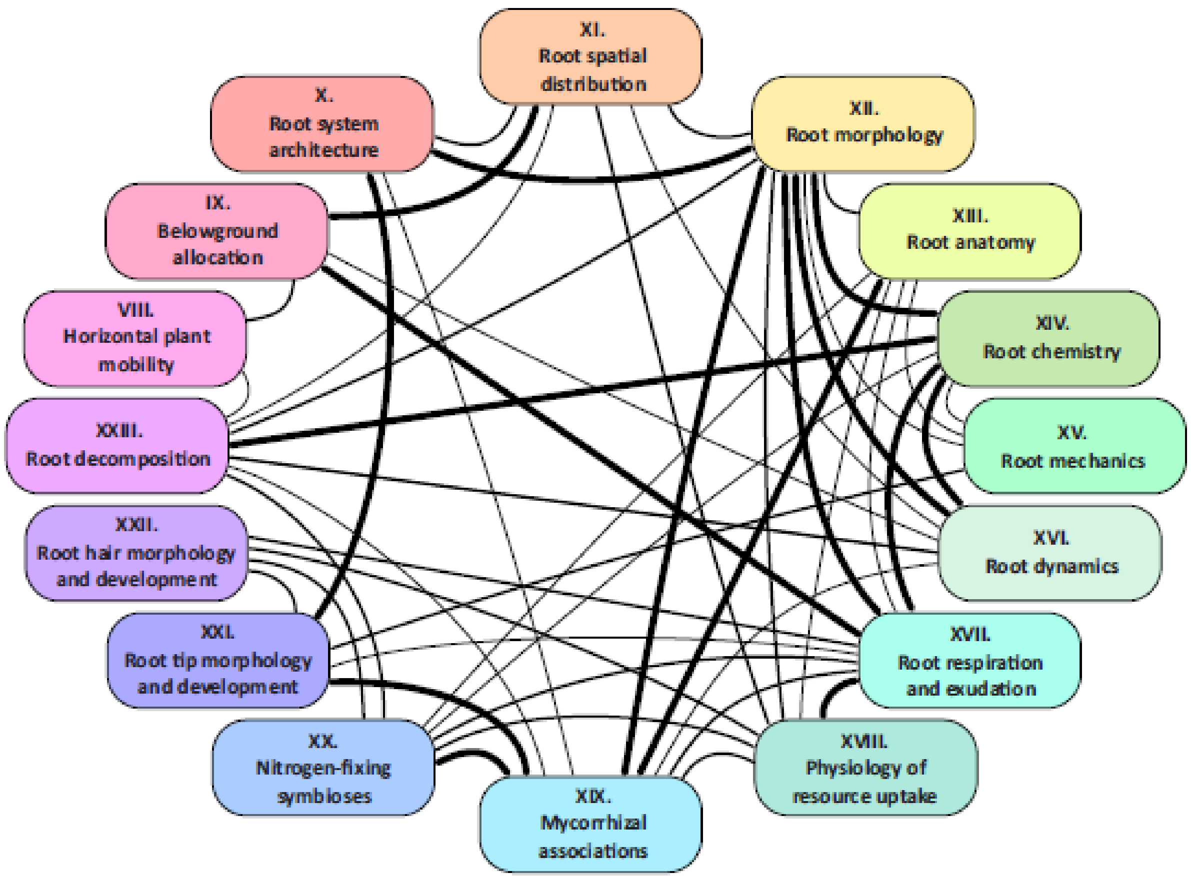
Table 4 Relative frequency of soil samples containing fine roots of 1–4 tree species (or no roots at all) in three soil layers (in per cent; $n = 59$)

No. of tree species present with their fine roots	Organic layer	Mineral soil (0–10 cm)	Mineral soil (10–20 cm)
No fine roots	59.3	0	0
1	33.9	23.4	17.2
2	6.8	48.3	60.3
3	0	23.3	15.6
4	0	5.0	6.9



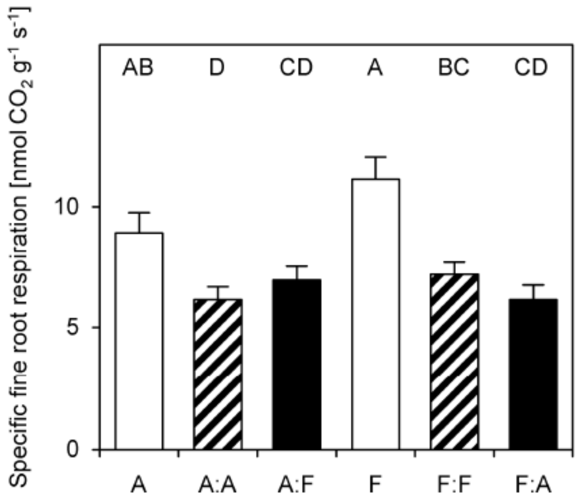
Rewald et al., 2009

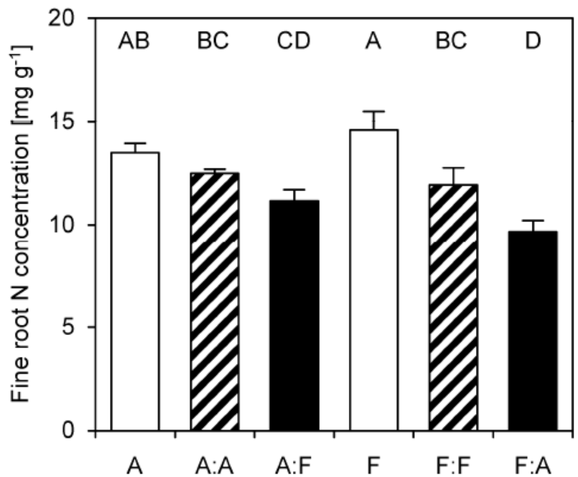
Excursus: Root traits – beyond biomass

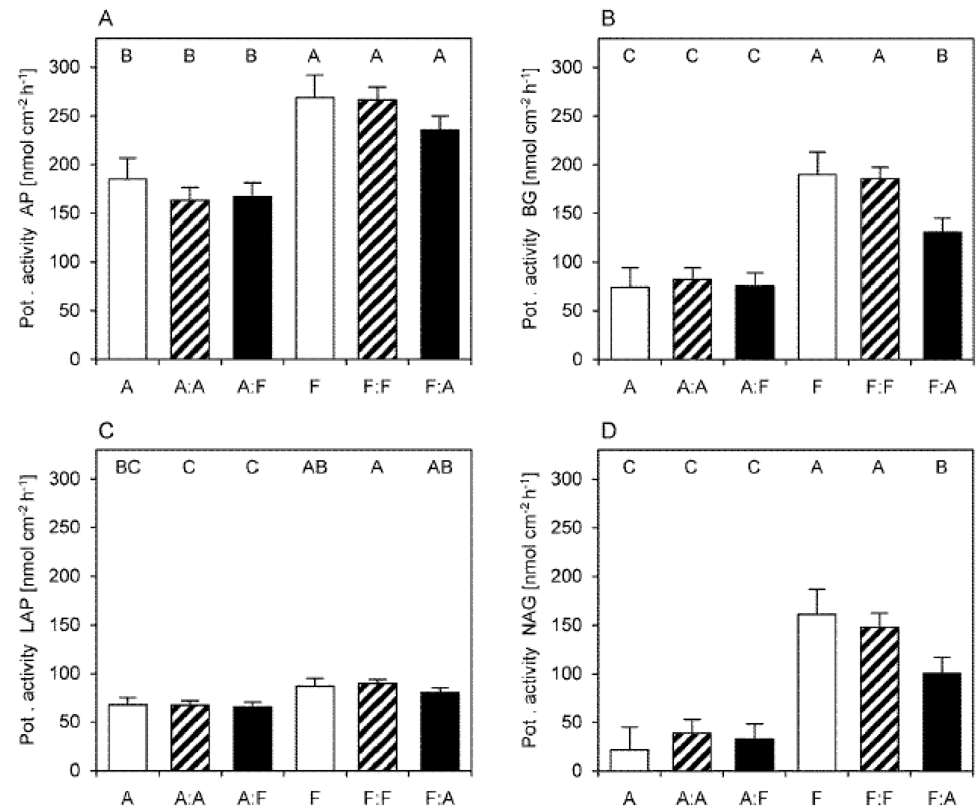


Freschet et al., 2021b

Competition effects on (fine) root traits – Seedlings of *Acer* vs. ***Fagus***



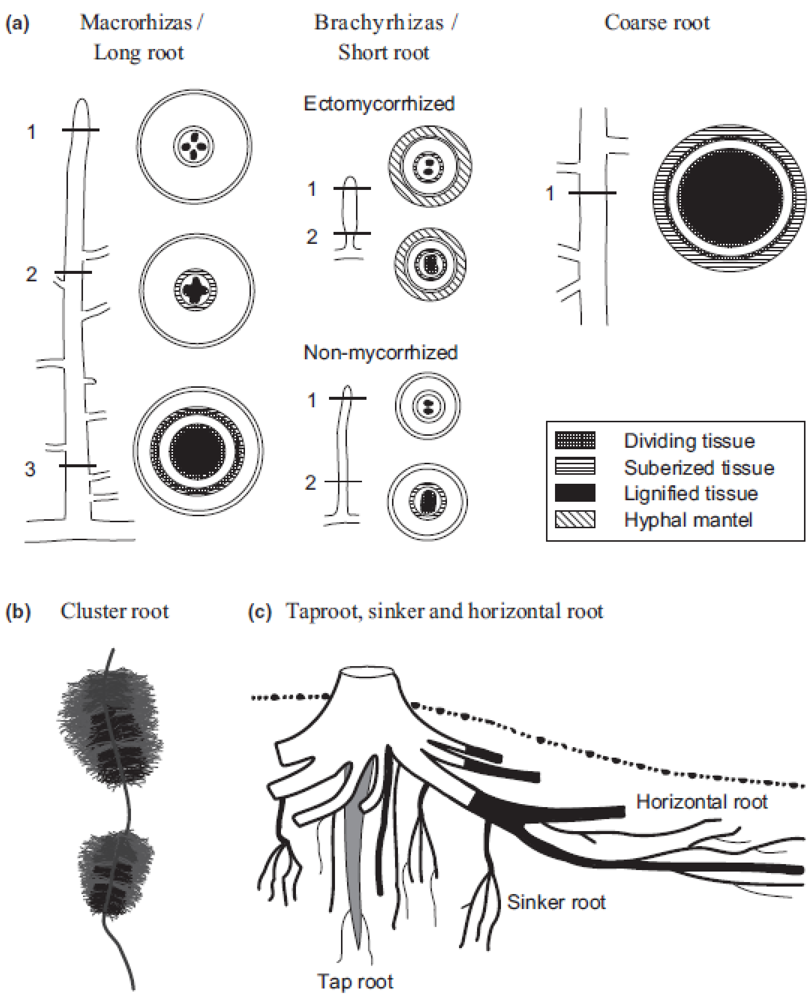


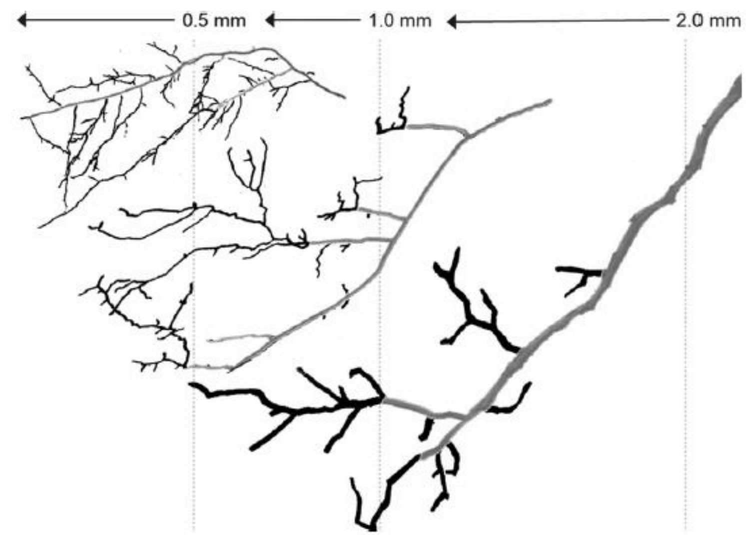


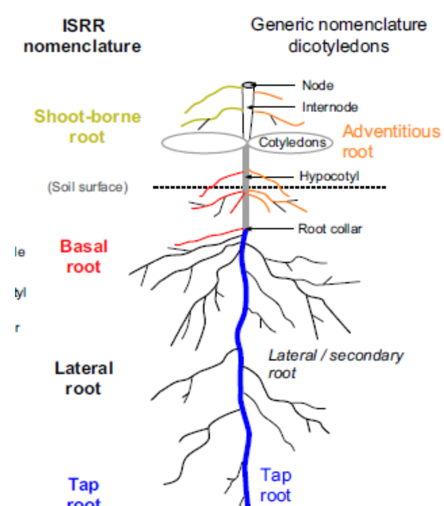
→ We are only starting to understand mixed species effects (belowground) on various root traits

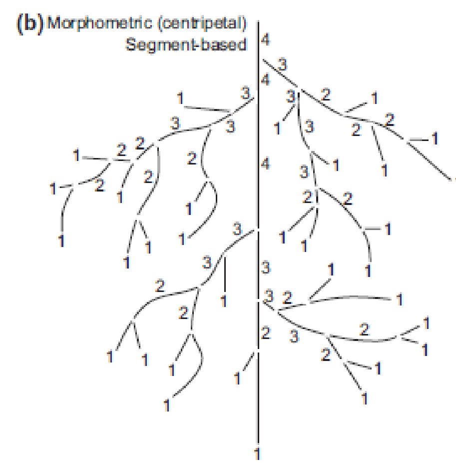
Lak et al., 2020

Excursus: Frontiers of Root Nomenclature – "*Who is who - and how many*?"



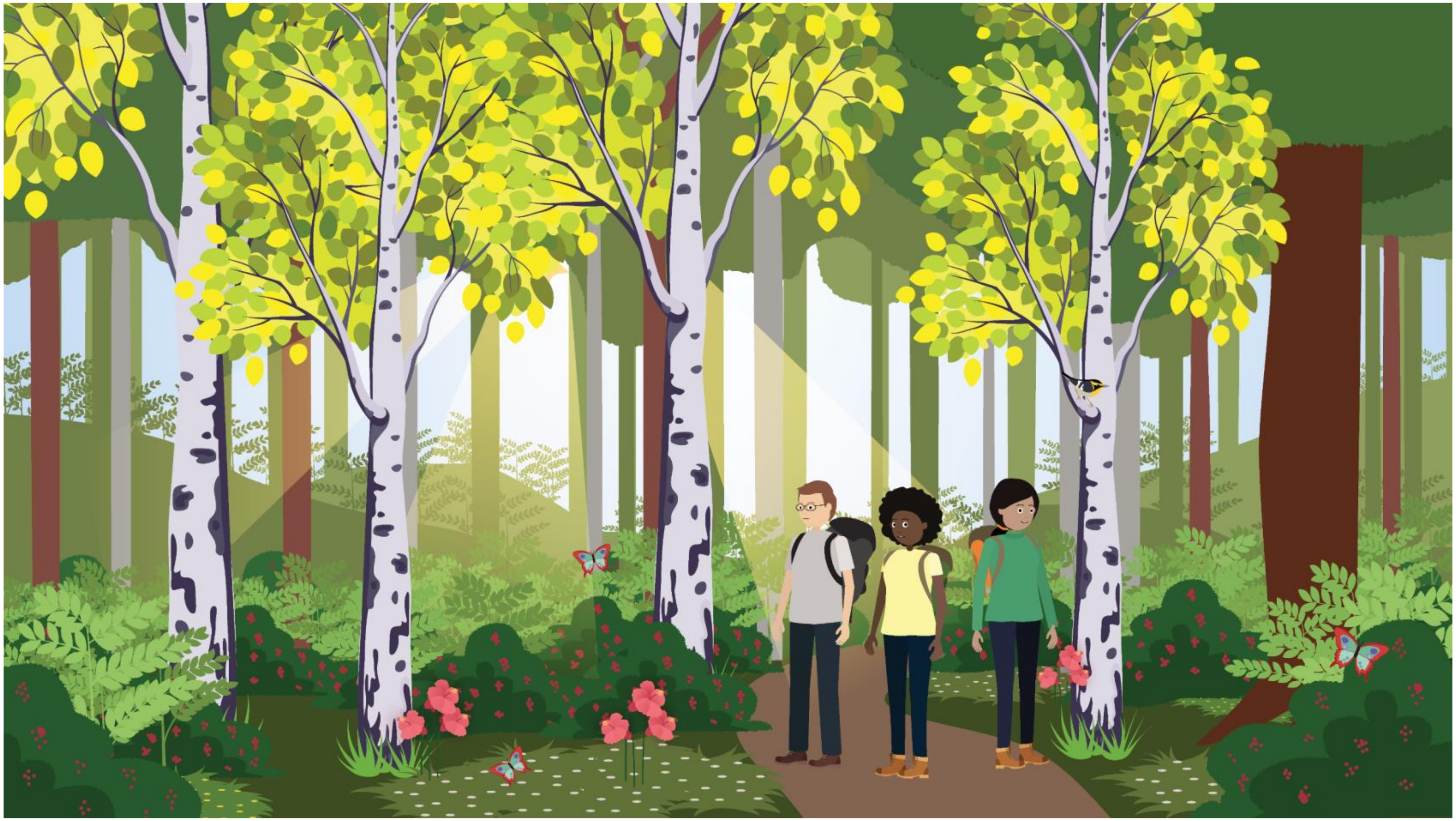






Freschet et al., 2021

Healthy Forest, ecosystem services and society needs



Tree Diversity shapes (insects) habitats

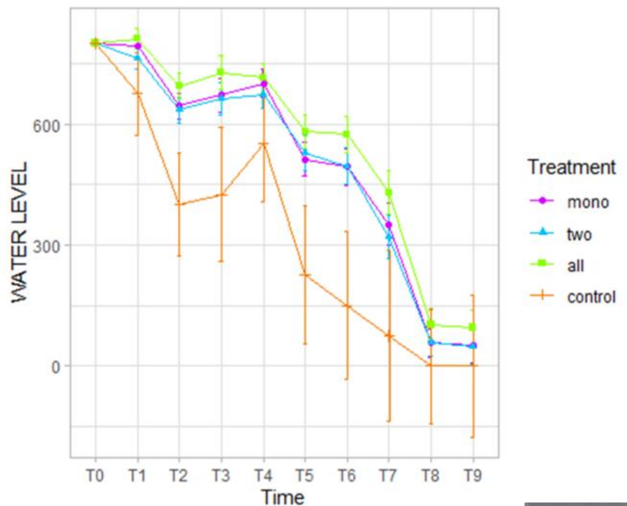
- Aquatic microcosms

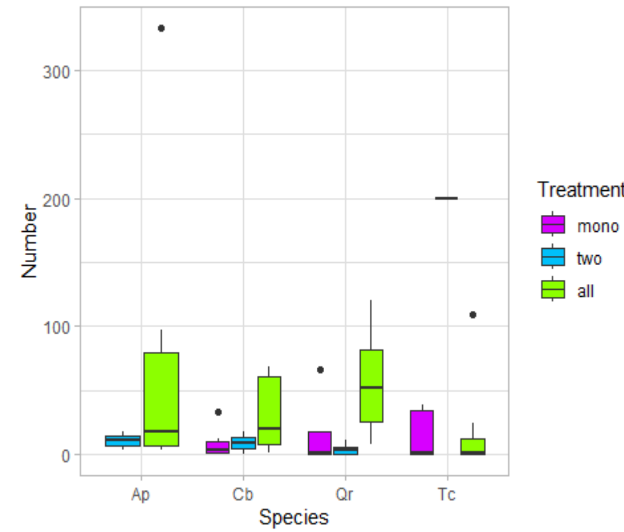
→"Tree holes"

Funded by the European Union

Frottier et al., unpublished

Tree diversity "stabilizes" aquatic habitats – resulting in greater insect numbers and -diversity

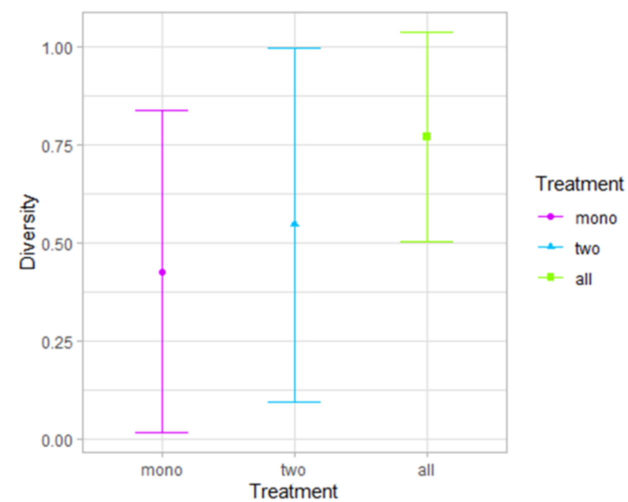




Collembola

Psychodidae

Ceratopogonidae



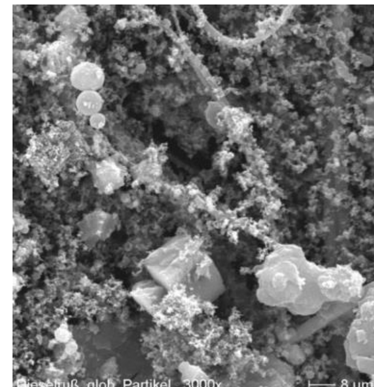
Frottier et al., unpublished

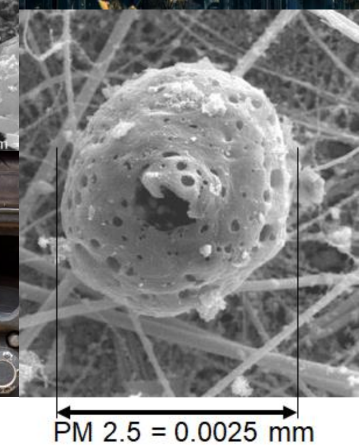
Air Quality - Particulate Matter

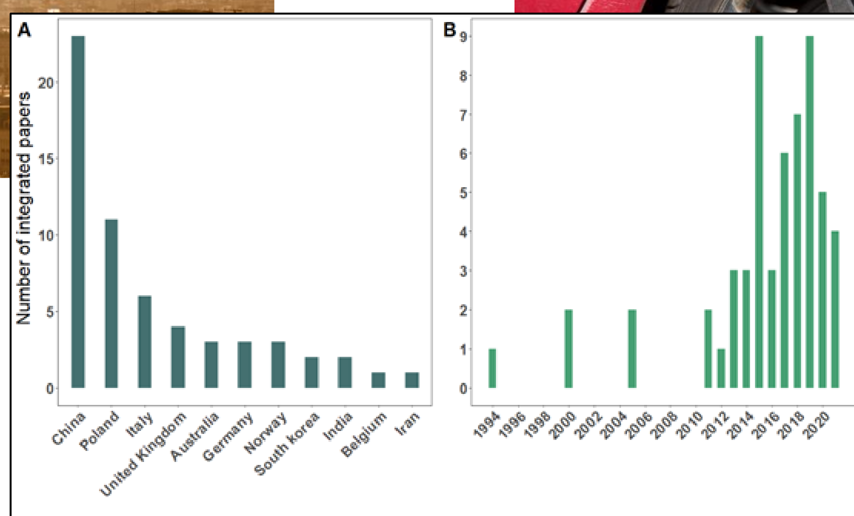
PM_{100} particle size 100-10 µm

PM_{10} particle size 10-2.5 µm

$PM_{2.5}$ particle size 2.5-0.2 µm

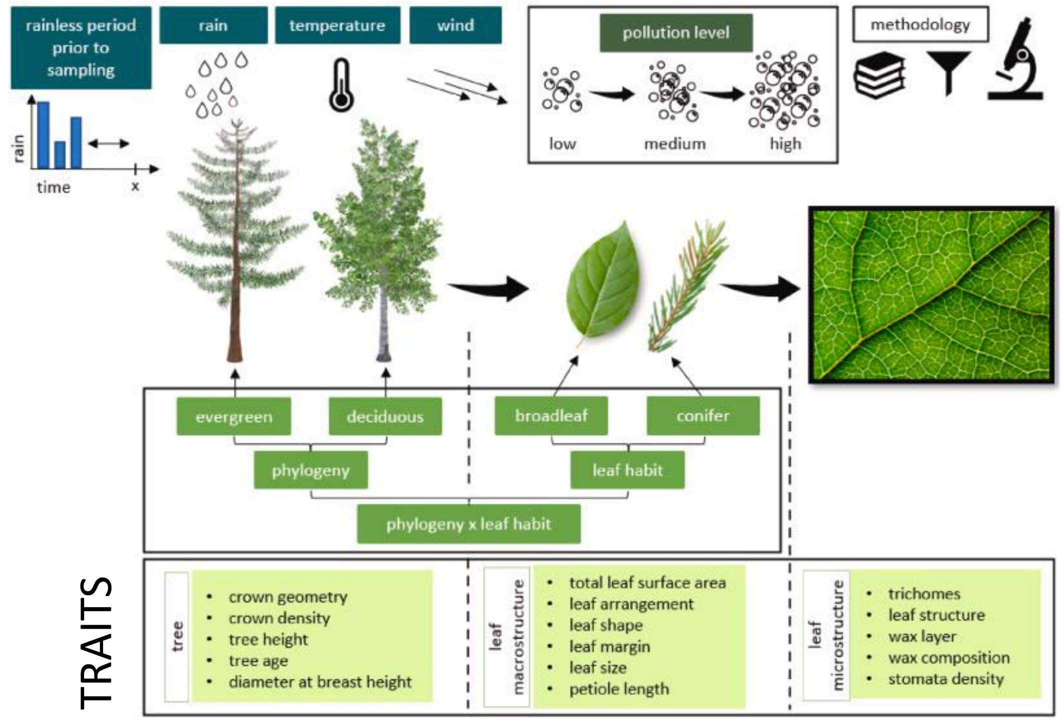






Particulate Matter Removal Capacity – Trait Dependent

- Vegetation can act as natural filters to remove particulate matter from air
- The efficiency of binding of PM to leaves is dependent on **leaf and whole tree <u>traits</u>**, examples being leaf size, leaf roughness, total leaf area



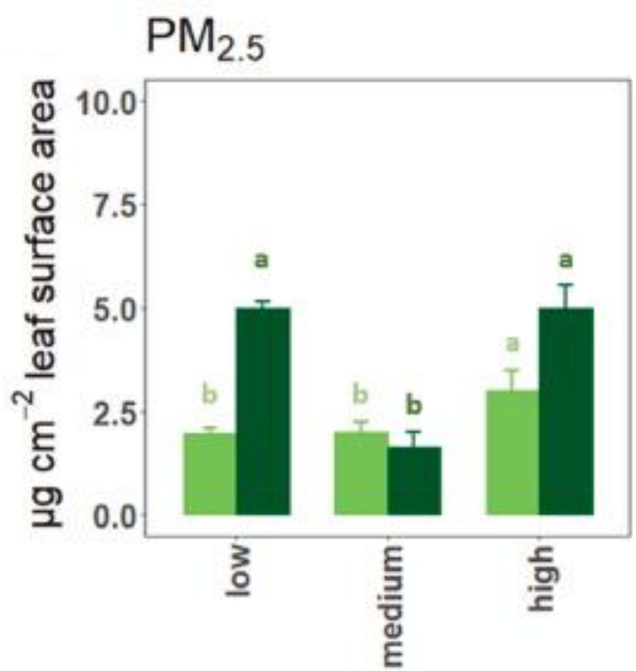
Funded by the European Union

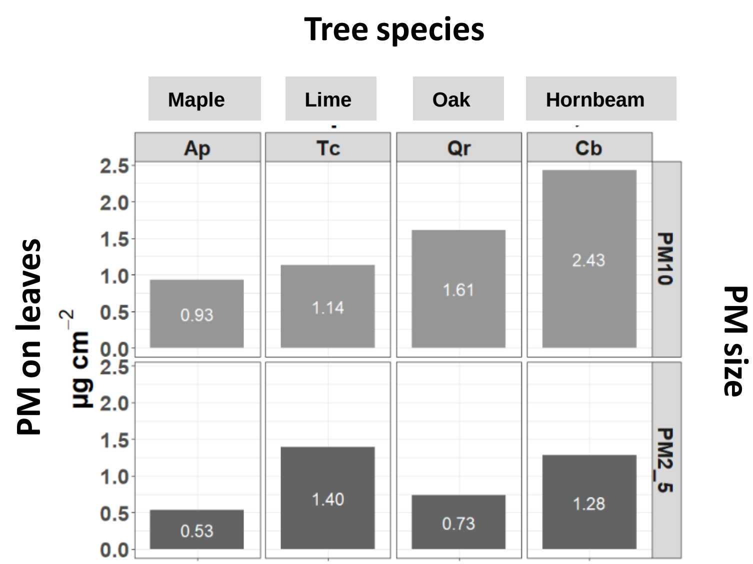
Steinparzer et al., 2023

Does tree identity matter?

Yes.

- Evergreen conifers have a greater PM accumulation than broad-leaves
- Leaf traits influence PM accumulation





Hornbeam binds >2x more PM than maple per cm²

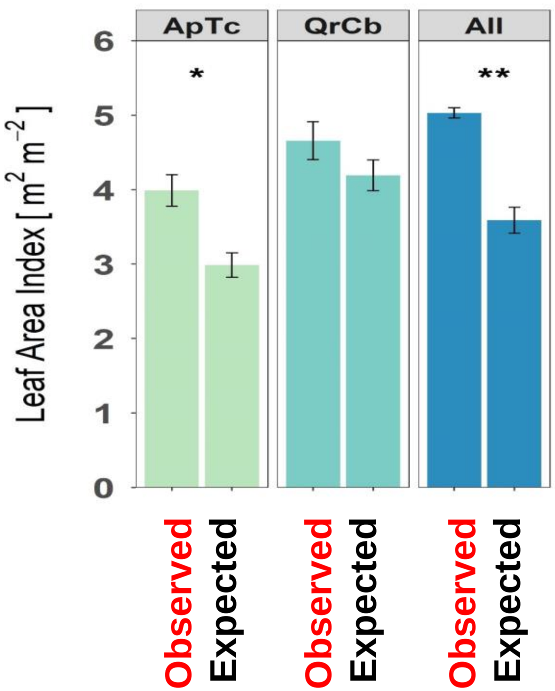
Steinparzer et al., 2022 & 2023

Do tree species mixtures matter?

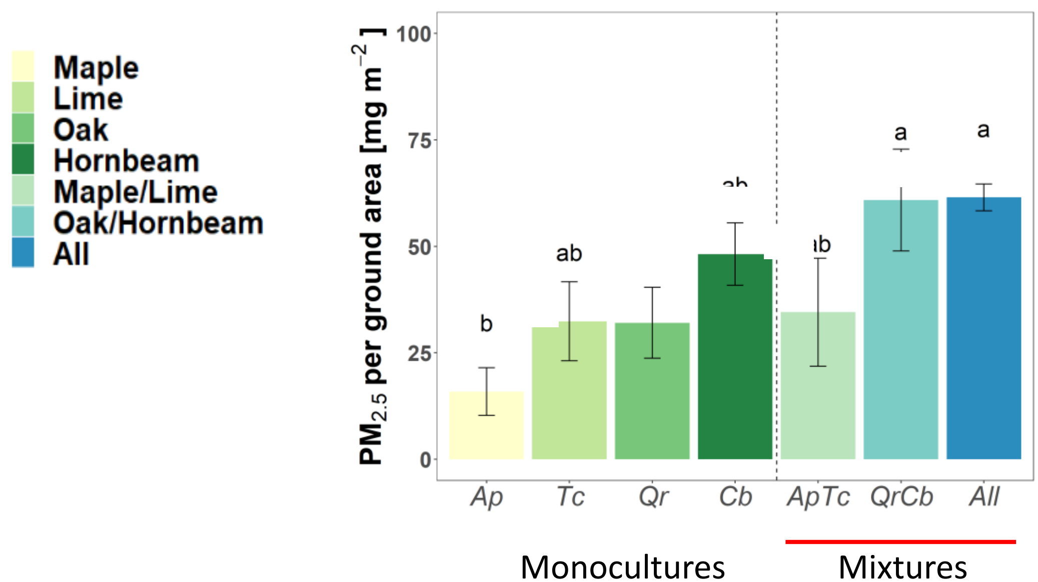
Yes.

Mixing tree species increases stand **leaf area to a level greater than** expected from the component trees, and leads to greater PM accumulation than **in monocultures**

Leaf area



PM accummulation



Steinparzer et al., 2022

Open BSc / MSc theses, selection

Experimental / (Meta-) Reviews

- Ectomycorrhizas of Oaks
- Nitrogen usage by Ectomycorrhizal Fungi
- Grafting in Forest Trees
- Particulate Matter Accumulation in Tree Canopies
- Tree Diversity, Productivity and Ecosystem Services of Riparian Forests
- Effects of Forest Soil Compaction on Roots Traits
- Rooting Depth in Mixed Species Stands
- Leaf to Root Ratios in Beech Regeneration Patches

… and we are happy to discuss ***YOUR*** *ideas!*

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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N°101087262.

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MS TEAMS

douglas.godbold@mendelu.cz

boris.rewald@mendelu.cz, +43 680 2249623

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