Symposium International « *La Biodiversité au service du développement* »
07 octobre 2015. Antananarivo. Madagascar

Valorisation and Management of mycorrhizal fungal communities for a sustainable management of tropical ecoagrosystems

- ✓ **To improve the performance of reafforestation programs**
- ✓ **To mitigate the negative influence of the exotic species on soil native tree species**

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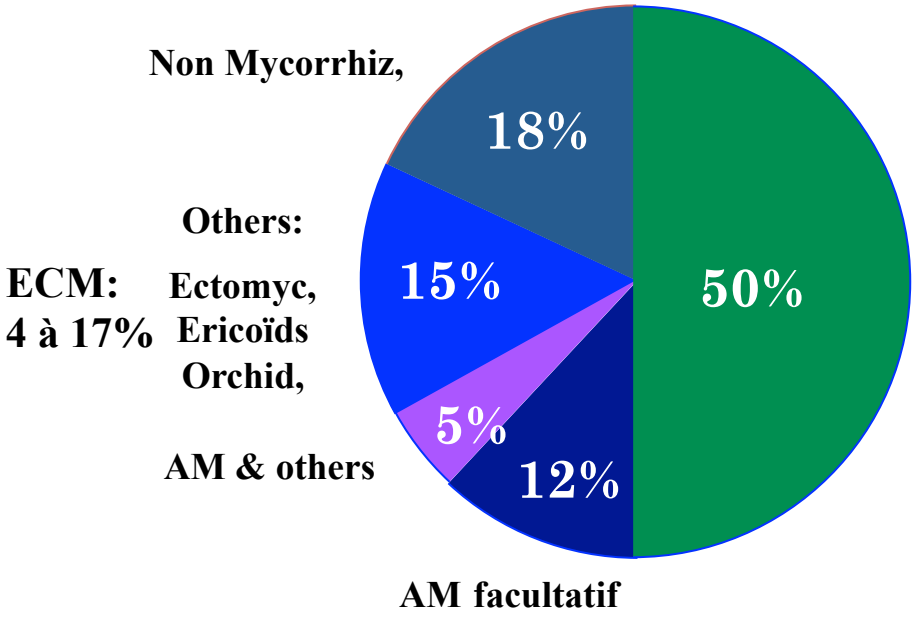
THE MYCORRHIZAL SYMBIOSIS : AN ESSENTIAL COMPONENT OF THE SOIL MICROFLORA



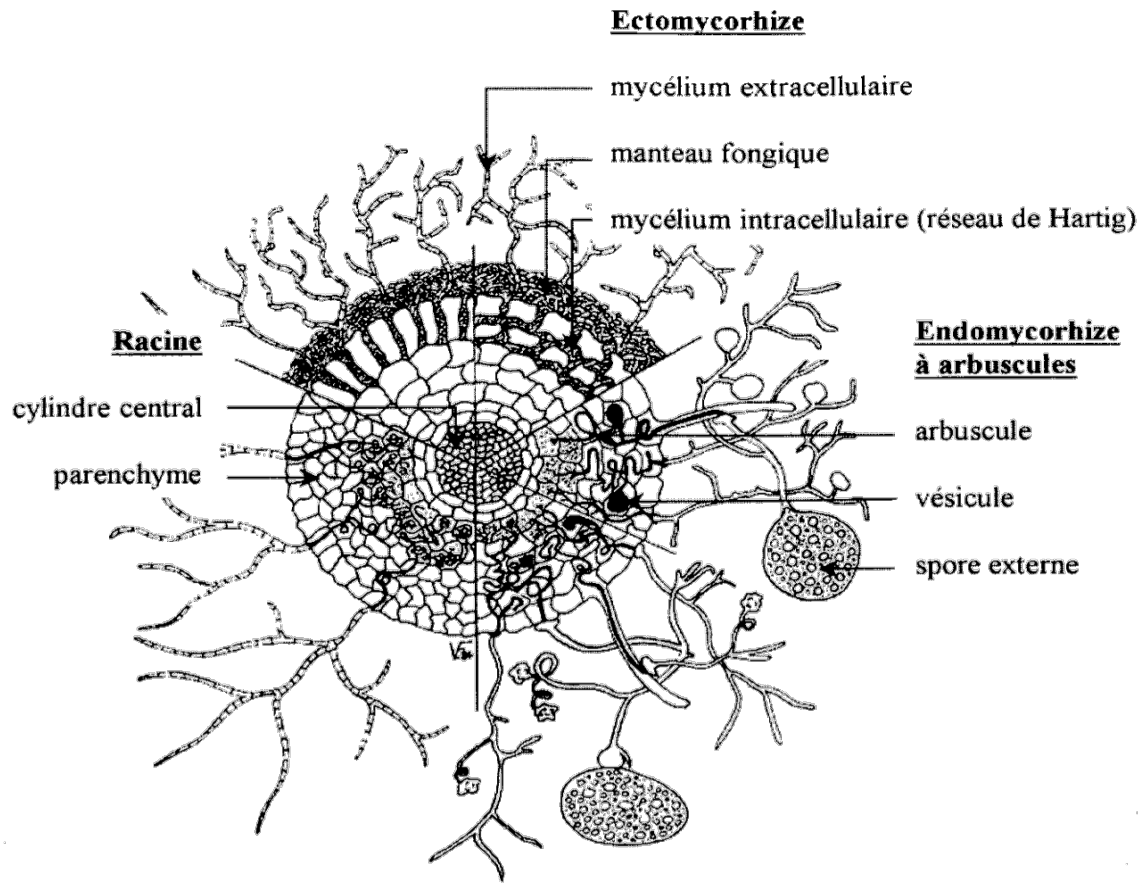
Distribution of the main types of mycorrhizal symbioses among angiosperms

*(**Brundrett, 2002** – New Phytologist)*

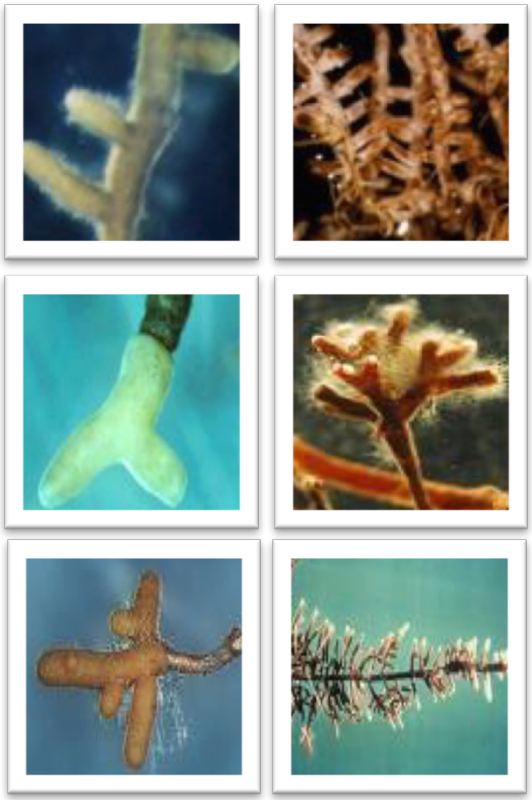
AM : arbuscular mycorhizas

80% of the terrestrial plant species are mycorrhized

MYCORRHIZAL TYPES



ECTOMYCORRHIZAS



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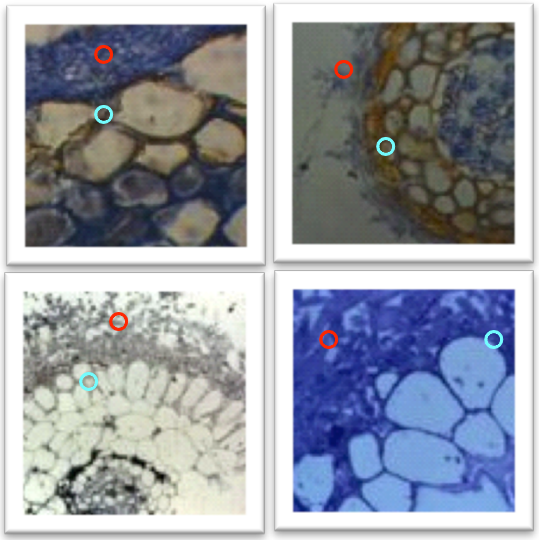

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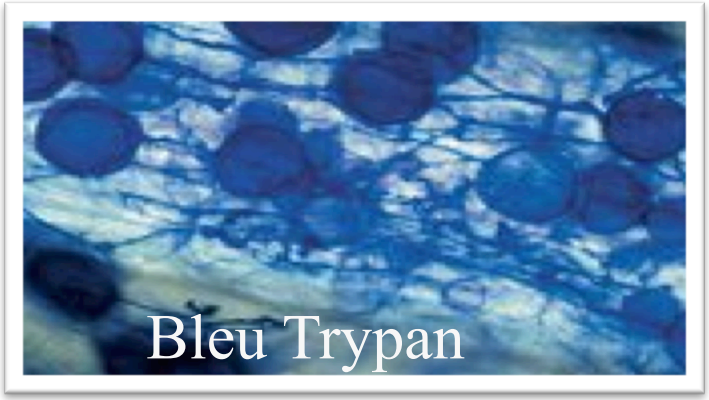
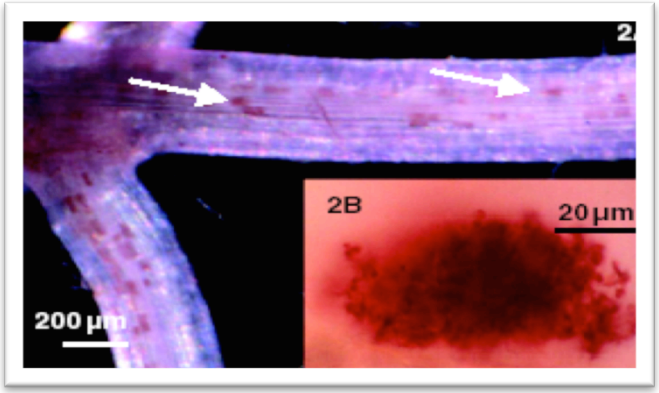
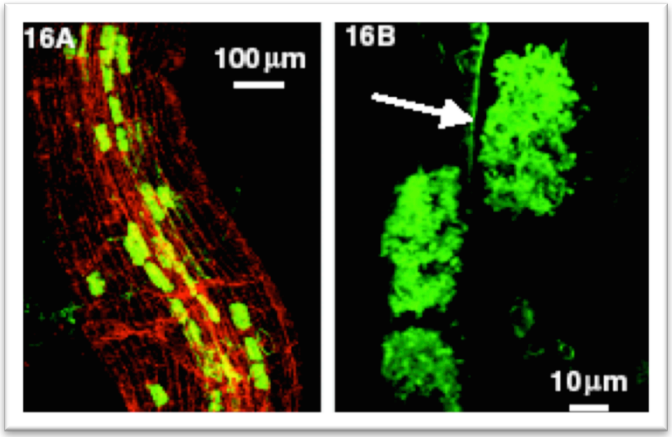
- Hartig net
- Mantle

ARBUSCULAR MYCORRHIZAS





Rouge neutre



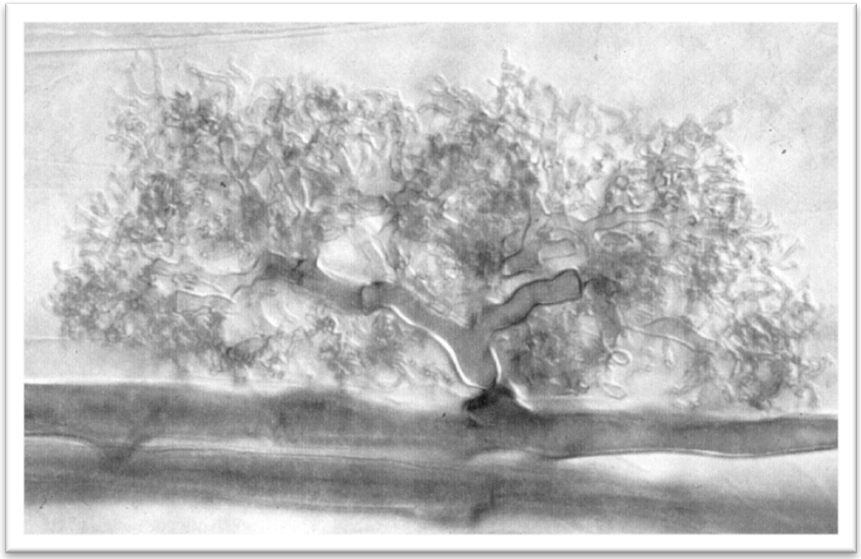
FITC + confocal

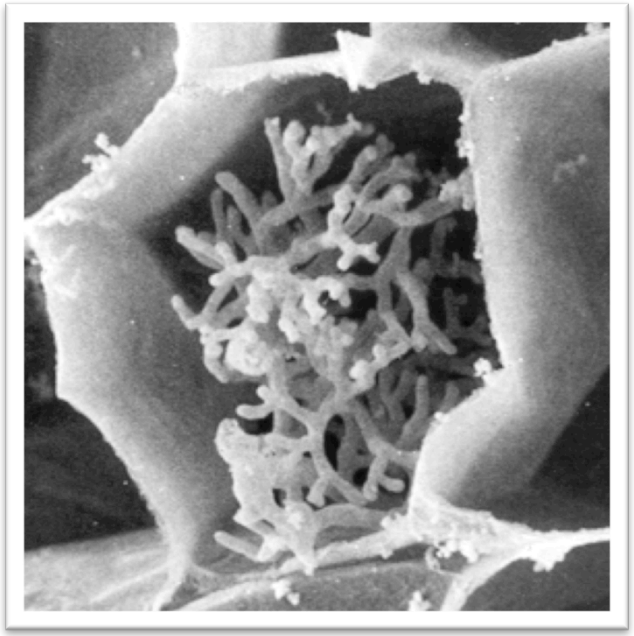
http://www.ffp.csiro.au/research/mycorrhiza/ecm.html

(Vierheiliga et al. 2005, Physiologia Plantarum 125: 393–404)

ARBUSCULAR MYCORRHIZAS

Internal structures



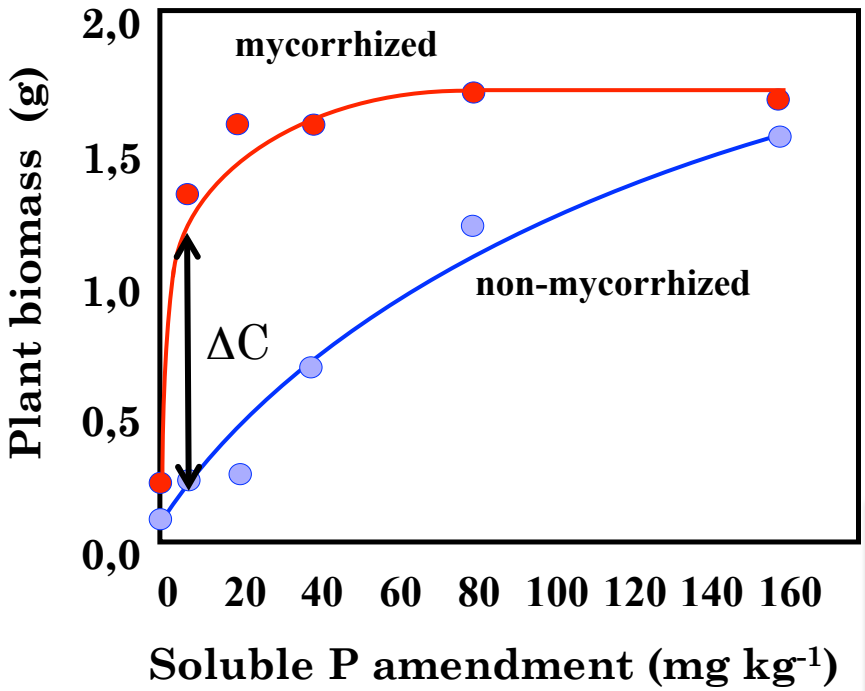


Source http://dmsylvia.ifas.ufl.edu/myc_slides_files/frame.htm

THE BENEFICIAL EFFECTS OF THE MYCORRHIZAL SYMBIOSIS

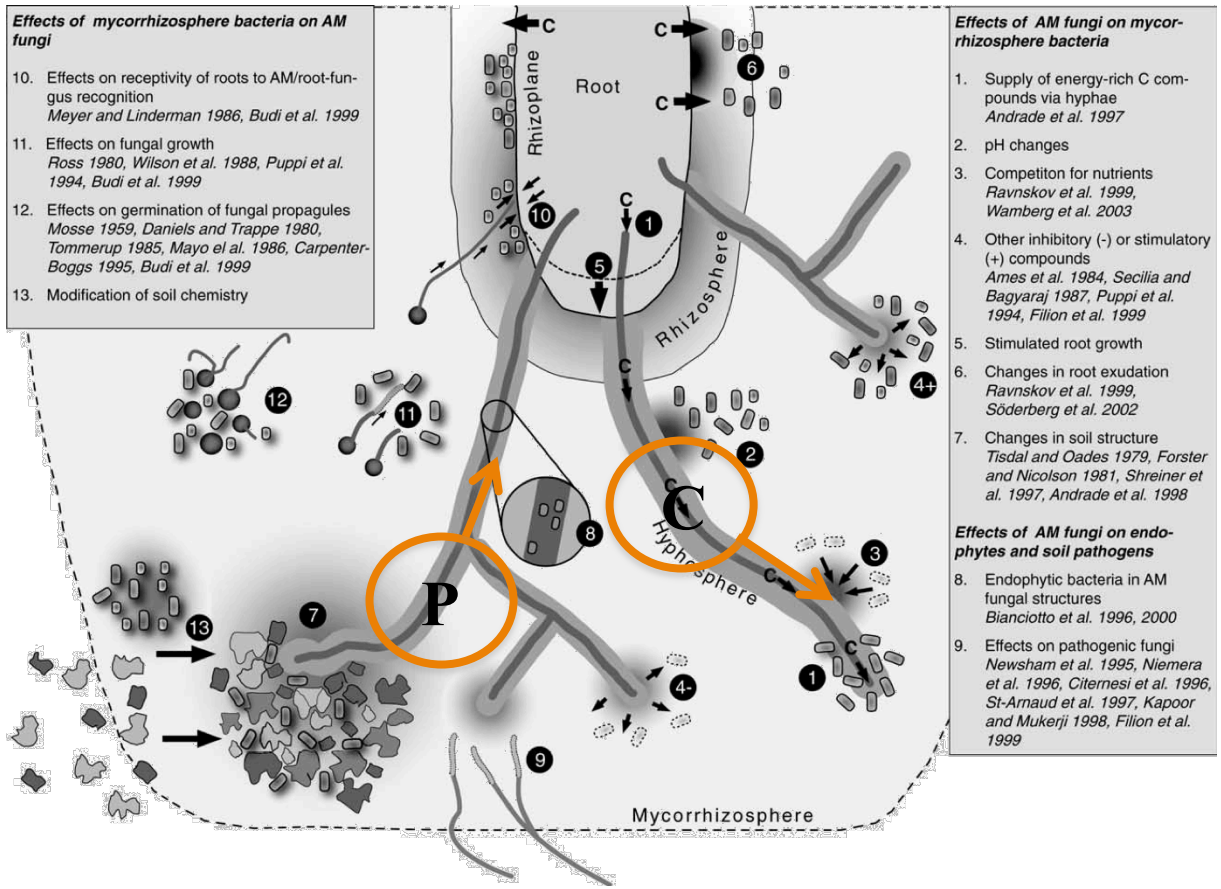
- Water uptake
- Increased tolerance to the plant pathogens
- **Mineral nutrition (N, P, etc)**
- Microbiological remediation

MYCORRHIZAL EFFECT AND PLANT GROWTH



A NEW DIMENSION OF THE MYCORRHIZAL SYMBIOSIS: « THE COMPLEX TROPHIC EFFECT »

Interactions between fungal symbionts and soil microflora



From Johansson et al, 2004, FEMS Microbiology Ecology

THINKING THE MYCORRHIZAL SYMBIOSIS MANAGEMENT IN RELATION WITH ENVIRONMENTAL CHARACTERISTICS

Non anthropized ecosystem

↓

Alternative stable state

↓ Anarchic and extended impacts

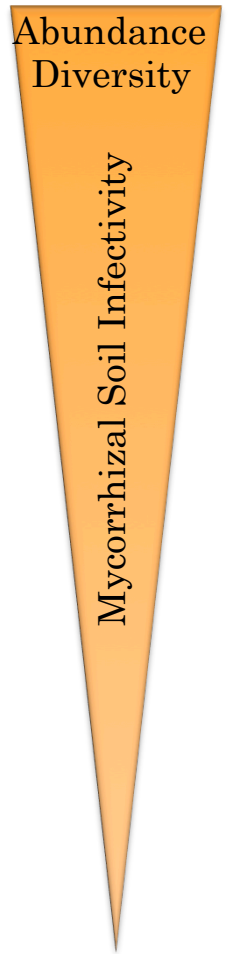
Degraded ecosystems

↓ Irreversible threshold of the degradation

Ecosystem severely degraded

↓ Seuil d'irréversibilité

Ecosystem very severely degraded



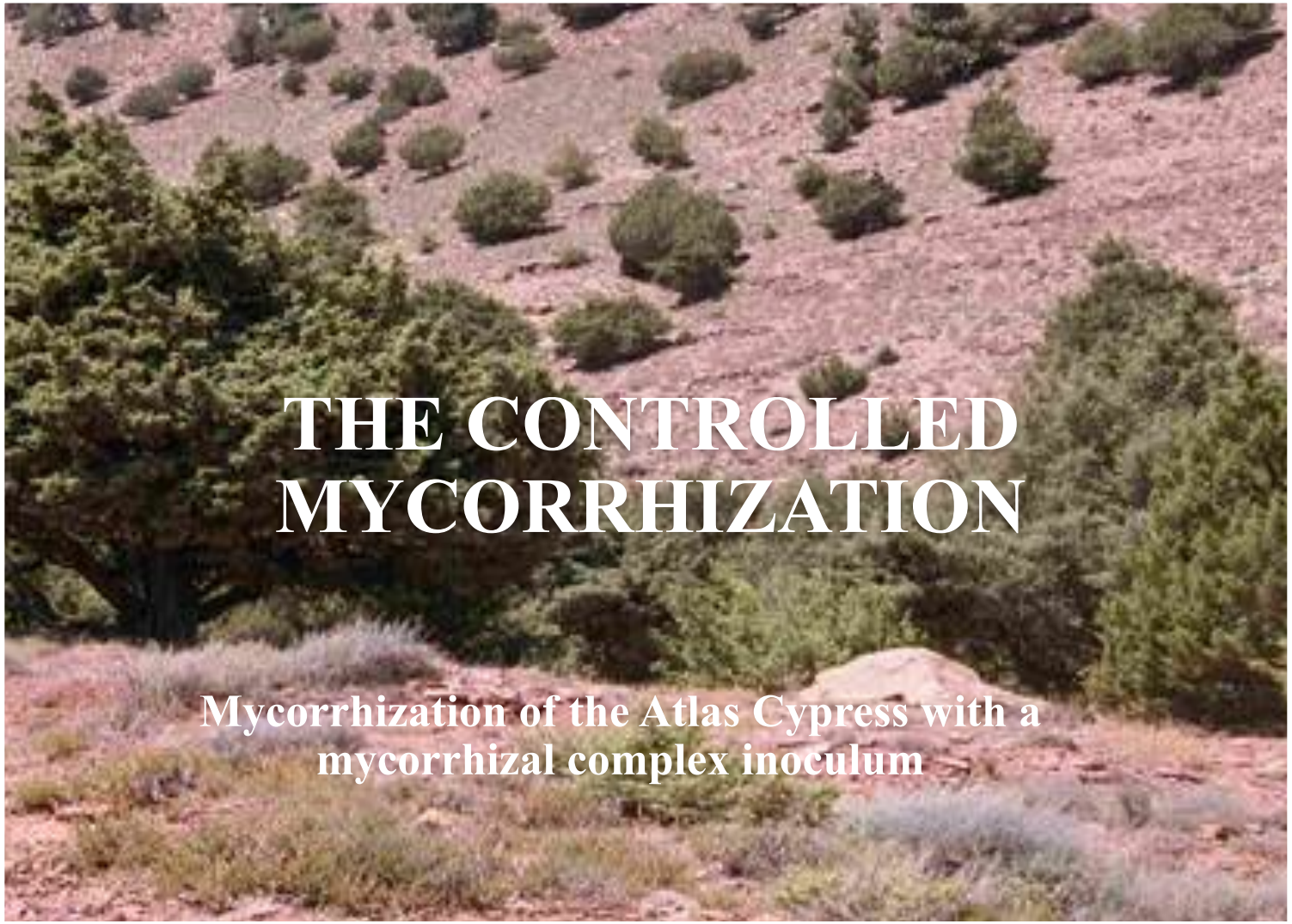
STRATEGIES

Mycorrhizal Soil Infectivity management

- ❖ **Cover plants**
- ❖ **Nurse plants**

Threshold of resilience

Controlled mycorrhization

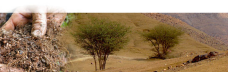


THE CONTROLLED MYCORRHIZATION

Mycorrhization of the Atlas Cypress with a mycorrhizal complex inoculum

GROWTH IN NURSERY CONDITIONS

	Treatments	
	Control	**Mycorrhizal complex**
Height(cm)	12.3 (0.46) a	**16.1 (0.71) b**
Shoot biomass (mg)	1163 (20) a	**1893 (264) b**
Root biomass (mg)	740 (64) a	**1183 (132) b**
Total biomass (mg)	1903 (62) a	**3077 (392) b**
P content (mg g^{-1} MS)	0.09 (0.01) a	**0.167 (0.03) b**
N content (mg g^{-1} MS)	2.23 (0.23) a	**3.50 (0.1) b**
Mycorrhizal rate (%)	-	**41.2 (2.3)**

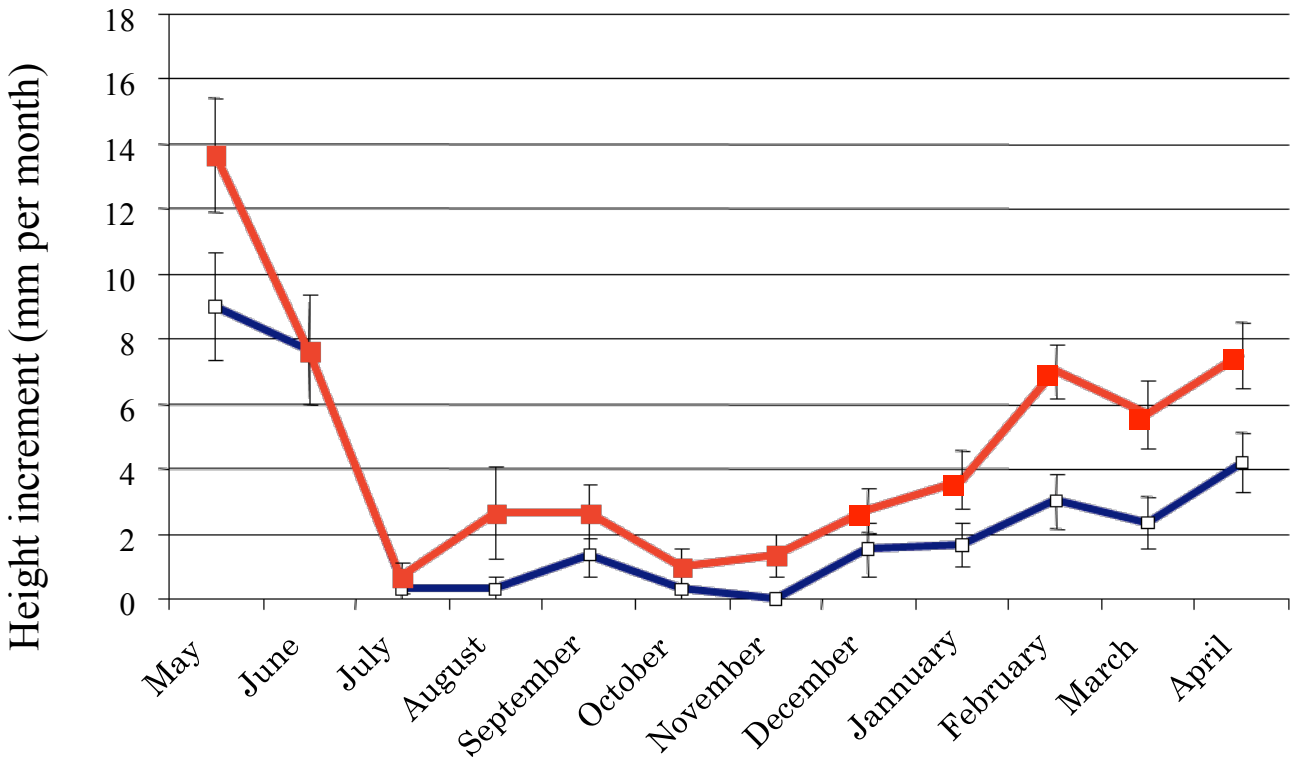


FIELD PLANTATION (1 YEAR)

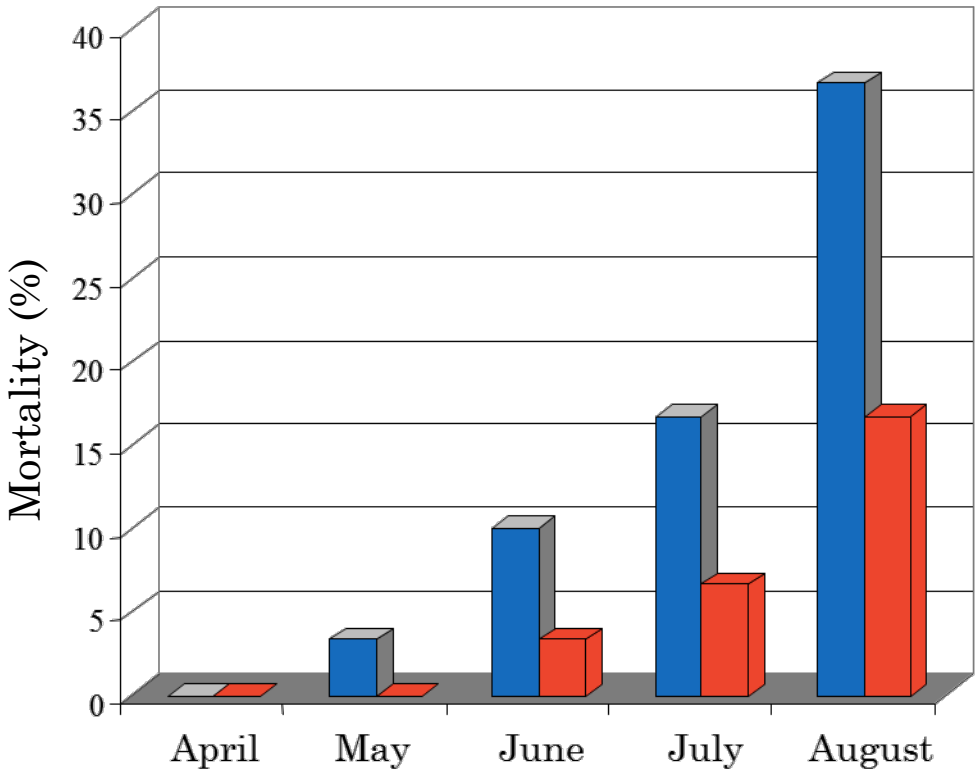
CONTROL

INOCULATED

GROWTH INCREMENT

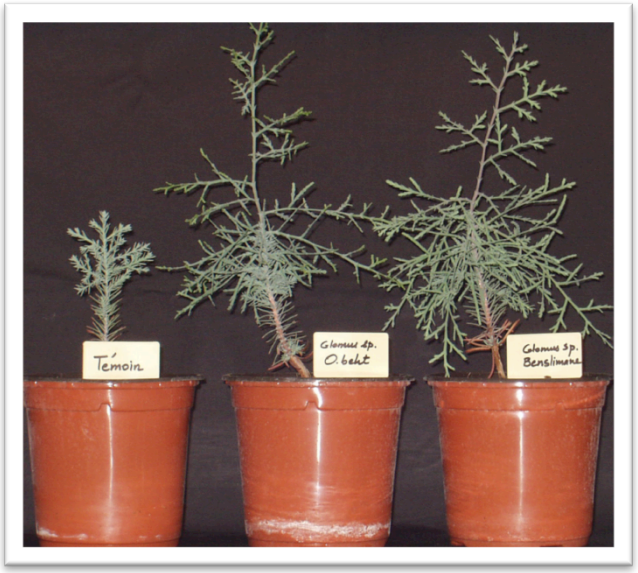


TRANSPLANTATION STRESS EFFECT



OTHER EXEMPLES

Controlled mycorrhization of *T. articulata*



Tetraclinis articulata

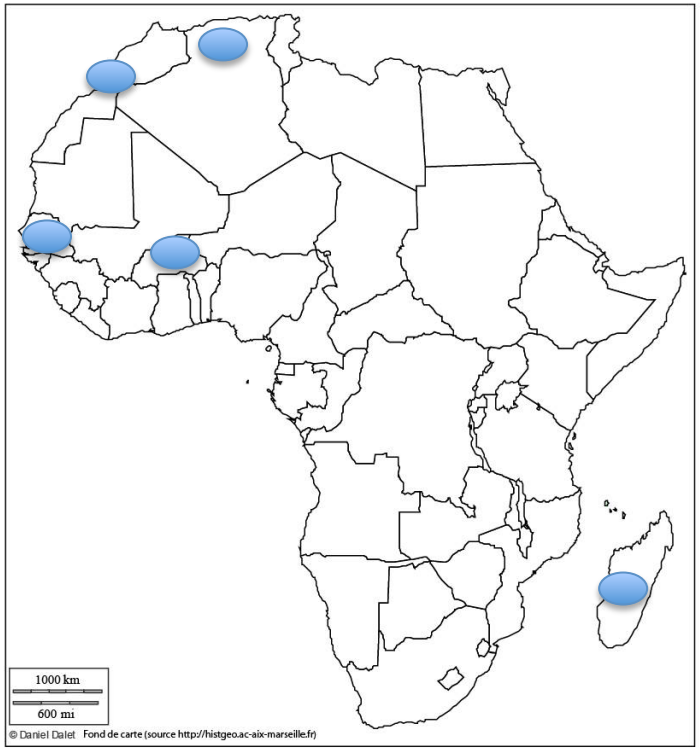
Controlled mycorrhization of *Ceratonia silica*

The management of soil mycorrhizal communities to mitigate the negative influence of exotic species on the early growth of native tree species

IMPACTS OF EXOTIC TREE SPECIES ON SOIL MICROFLORA

CASE STUDIES

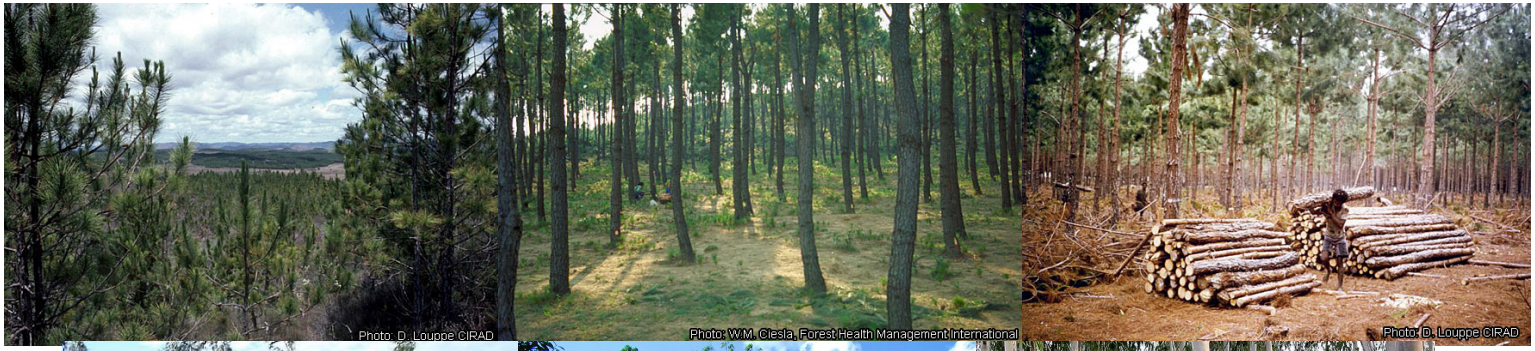
- *Acacia holosericea* (Senegal, Burkina Faso)
- *Acacia saligna* (Algeria, Morocco)
- *Eucalyptus camaldulensis* (Senegal, Burkina Fasc
Madagascar)
- *Pinus patula* (Madagascar)



Impact of *Pinus patula and Eucalyptus camaldulensis* on a native tree species (*Uapaca bojeri*) in Madagascar

CONTEXT

A lot of revegetation programmes have been undertaken in Madagascar using fast-growing exotic trees. Reforestation with eucalyptus (*E. robusta*, *E. rostrata*, *E. camaldulensis*) and later pine (*P. khesya, P. patula*) provided a wood supply mainly for the cooking fires in the region but also for construction timbers, casketts, etc



The native tree species from Madagascar: *Uapaca bojeri* (Tapia)

8 species in Madascar, all of them endemic
Distribution: Trees of open dry forests and savannas of the central plateau

Tapia forests have important ecosystem functions. (Erosion, etc).
The tapia forest also forms a preferred habitat for some animals (silkworms). *Uapaca bojeri* is the main food source for silkworms

From Baohanta *et al.* (2012). *Biological Invasions*, 14:2407–2421

Chemical and biochemical characteristics of rhizosphere soils collected under a native tree species (*Uapaca bojeri*), two exotic tree species (*Pinus patula* and *Eucalyptus camaldulensis*) and from the bare soil (control) in the Arivonimamo forest

	Soil origins				
	Control	*U. bojeri*		*P. patula*	*E. camaldulensis*
pH (H_2O)	5.26 d	4.94 c	-	4.78 b	4.52 a
Total nitrogen (%)	0.09 a	0.19 c	- / +	0.15 b	0.22 d
Soluble P (mg kg^{-1})	1.45 a	2.85 c	- / +	2.14 b	3.09 d
Total organic matter (%)	1.76 a	4.26 d	-	3.23 (b	3.53 c
Total microbial activity (µg of hydrolyzed FDA h^{-1} g^{-1} of soil)	5.61 a	6.69 b	+	11.54 c	15.33 c
Acid phosphatase activity (µg *p*-nitrophenol g^{-1} of soil h^{-1})	130.56 a	314.01 b	+	867.06 c	586.51 c
Alkaline phosphatase activity (µg *p*-nitrophenol g^{-1} of soil h^{-1})	166.51 a	302.54 c	-	170.95 b	82.54 a

(1) Data in the same line followed by the same letter are not significantly different according to the Newman-Keuls test ($p < 0.05$)

Exotic plant impact

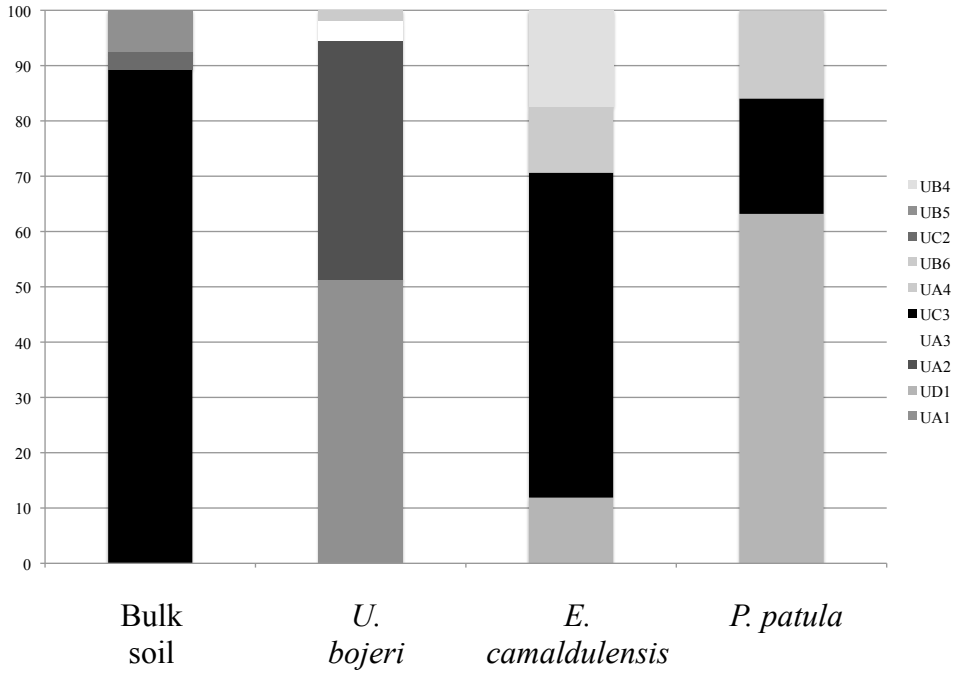
Response of *U. bojeri* seedling growth and ectomycorrhizal colonization in soils from different origins

	Exotic plant impact	Soil origins			
		Control	*U. bojeri*	*P. patula*	*E. camaldulensis*
Shoot biomass (mg dry weight)	↘	131 b	125 b	85 a	83 a
Root biomass (mg dry weight)	↘	113 b	295 c	119 b	27 a
Total biomass (mg dry weight)	↘	244 b	419 c	205 b	110 a
Root : Shoot ratio	↘	0.88 b	2.37 d	1.42 c	0.34 a
N leaf mineral content (mg per plant)	→	0.89 a	0.85 (a	0.65 a	0.65 a
P leaf mineral content (mg per plant)	↘	71.1 ab	94.1 b	58.9 a	62.3 ab
Ectomycorrhizal colonization (%)	↘	36.1 b	73.7 c	29.3 ab	16.3 a

(1) Data in the same line followed by the same letter are not significantly different according to the Newman-Keuls test ($p < 0.05$)

From Baohanta *et al.* (2012). *Biological Invasions*, 14:2407–2421

The impacts of exotic tree species on the ectomycorrhizal communities associated with *U. bojeri* seedling



Similarities in ectomycorrhizal communities between *U. bojeri* seedlings growing in soils collected under *Uapaca bojeri*, *Eucalyptus camaldulensis*, *Pinus patula* and from a bulk soil

Values are expressed by RFLP type percentages with regards to the soil treatments. UA1: *Russula earlei*, UD1: *Bondarcevomyces* taxi, UA2: *Amanita* sp., UA3: Telephoroid mycorrhizal sp., UC3: *Russula exalbicans*, UA4: Uncultured ECM homobasidiomycete Clone E2, UB6: *Boletellus projectellus*, UC2: *Boletus rubropunctus*, UB5: *Coltricia perennis*, UB4: *Xerocomus chrysenteron*

From Baohanta *et al.* (2012). *Biological Invasions*, 14:2407–2421

The positive role of **NURSE PLANTS** to mitigate the negative influence of exotic tree species on soil biological characteristics

- ❖Common plant species of herbaceous and shrub layer in degraded areas
- ❖Chemical fertility « islands »
- ❖Fungal propagule islands
- ❖Potential vectors to facilitate the processes of natural regeneration

VALORIZATION IN FOREST CULTURAL PRACTICES

The potentialities of an early-successional ectomycorrhizal shrub, *Leptolena bojeriana* to provide a **NURSE PLANT EFFECT**

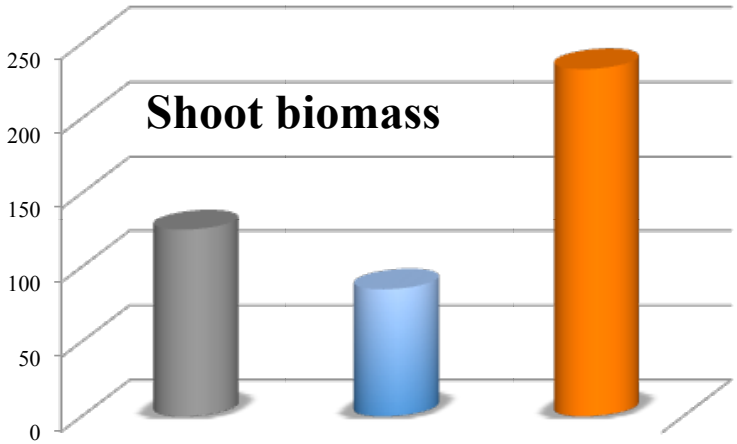
HYPOTHESIS

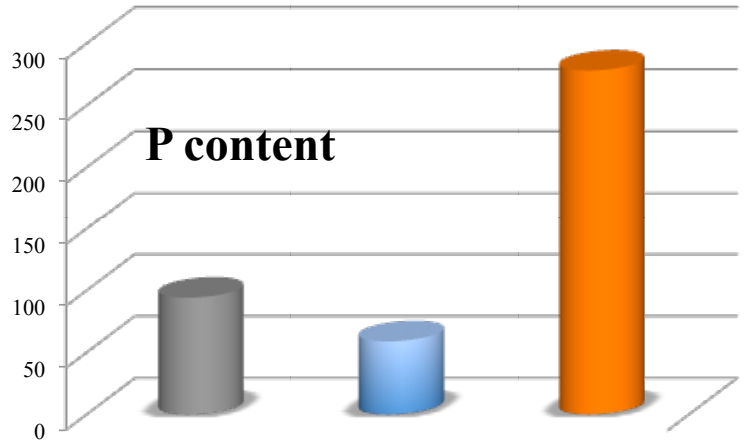
An early-successional ectomycorrhizal shrub, *Leptolena bojeriana*, would minimize the negative effects of these exotic species and consequently improves *U. bojeri* growth through a well-developped ectomycorrhizal root colonization.

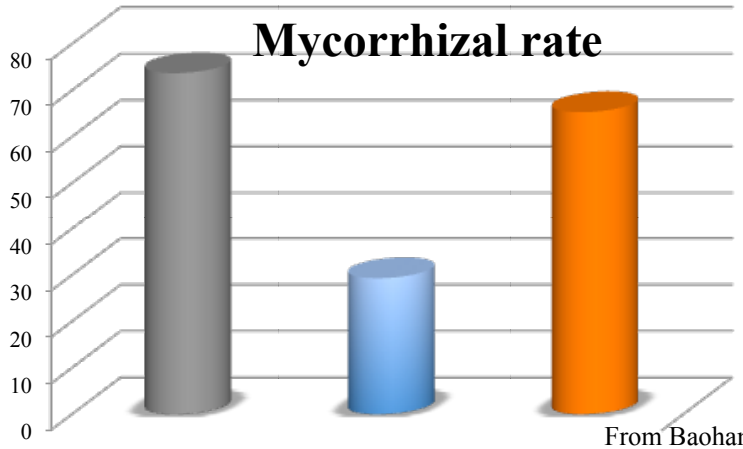
We tested the hypothesis that ***L. bojeriana* could act as a natural provider for ectomycorrhizal propagules** and could preserve the abundance and diversity of ectomycorrhizal fungi in stressfull environments.

From Baohanta *et al.* (2012). *Biological Invasions*, 14:2407–2421

The positive role of nurse plants to mitigate the negative influence of exotic tree species on soil biological characteristics







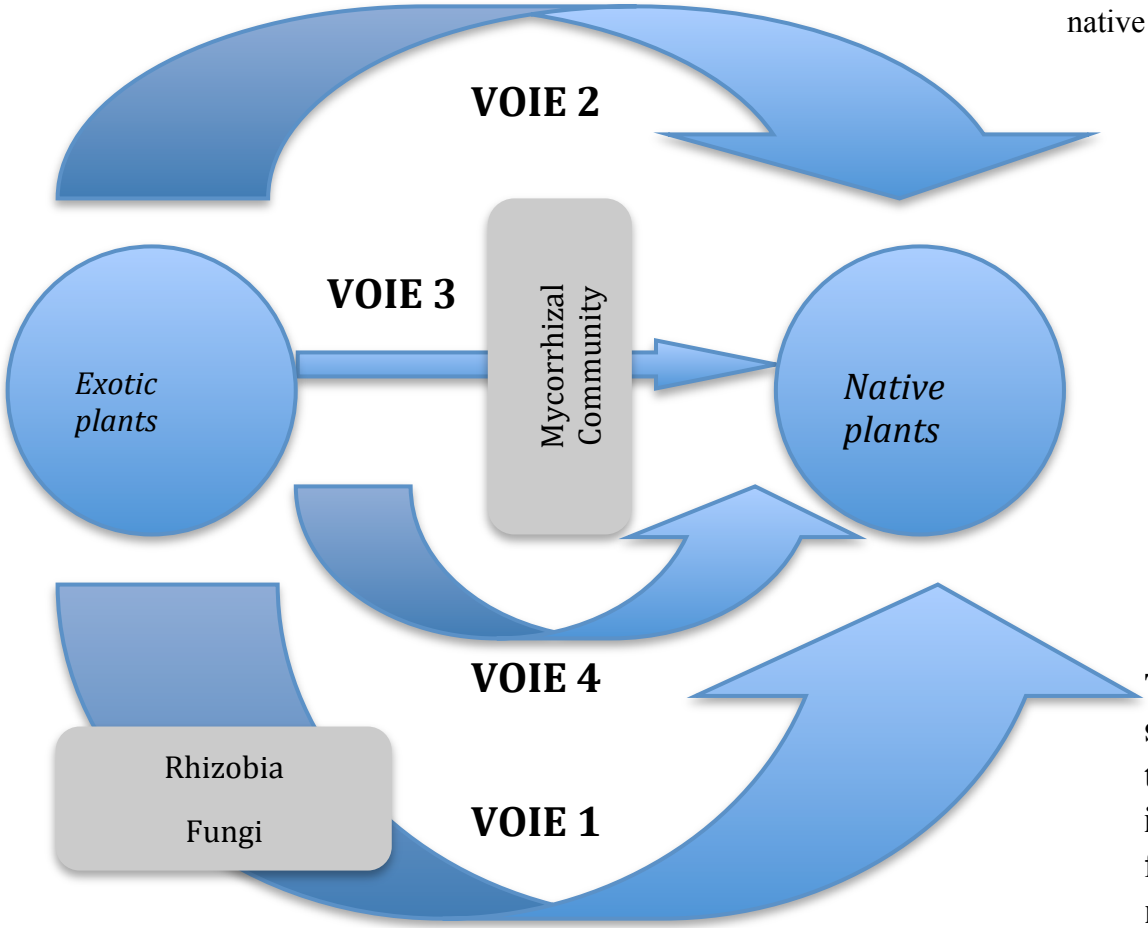
Control

P. patula

L. bojeriana

From Baohanta *et al.* (2012). *Biological Invasions*, 14:2407–2421

CONCLUSION



The invasive species has compatibility with rhizobia and indigenous arbuscular mycorrhizal fungi allowing it to have optimal growth in these soils and thus develop a strategy competitor towards native forest species (**Voie1**)

The invasive species excrete into the soil allelopathic substances which exert an inhibitory action on the development of seedlings of native species (**Voie 2**)

The exotic species induced directly or indirectly through its allelopathic effect, a significant degradation of the fungal communities ectomycorrhizal associated with the native tree species (**Voie 3**)

The ground invasion by the exotic species also leads to weakening of the soil biological functioning with in particular a reduction in the functional diversity of the microflora potentially reducing the resilience of the ecosystem with respect to biotic and / or abiotic stresses (Voie 4)

All these negative effects could be mitigate by enhancing the soil mycorrhizal infectivity

CONCLUSIONS & PERSPECTIVES

- **THE MYCORRHIZAL SYMBIOSIS IS INVOLVED IN THE BIOLOGICAL MECHANISMS GOVERNING THE SPATIO-TEMPORAL EVOLUTION OF MEDITERRANEAN FOREST ECOSYSTEMS**

  - **A major role in the soil biofunctioning (chemical and biological fertility)**
    Main component in the biological processes involved in the resilience capacity, productivity, plant co-existence

- **THE MYCORRHIZAL IMPACT DEPENDS TO THE ABUNDANCE AND DIVERSITY OF THE SOIL MYCORRHIZAL PROPAGULES**

  - **Need to identify the rules of an integrated management of the AM community structure through effective biological vectors (eg: nurse plants)**

    Natural ressource conservation / Socio-economical valorization

THANKS FOR YOUR ATTENTION