Controlling and predicting the spread of Heterobasidion annosum in even-aged Pinus pinaster stands in South-West France

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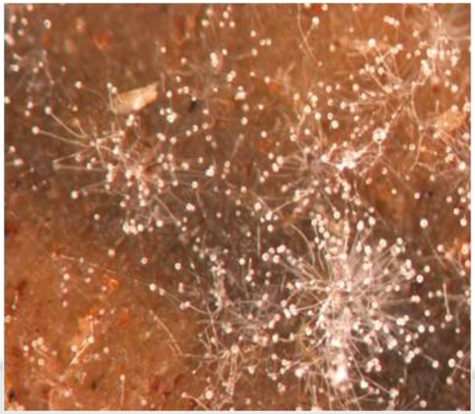
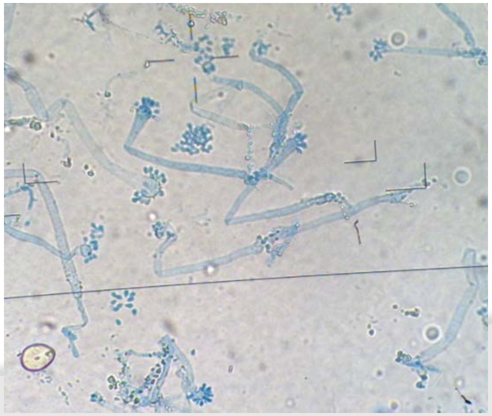
Introduction: Heterobasidion annosum

Pathogenic fungus

Root rot disease of pine forests

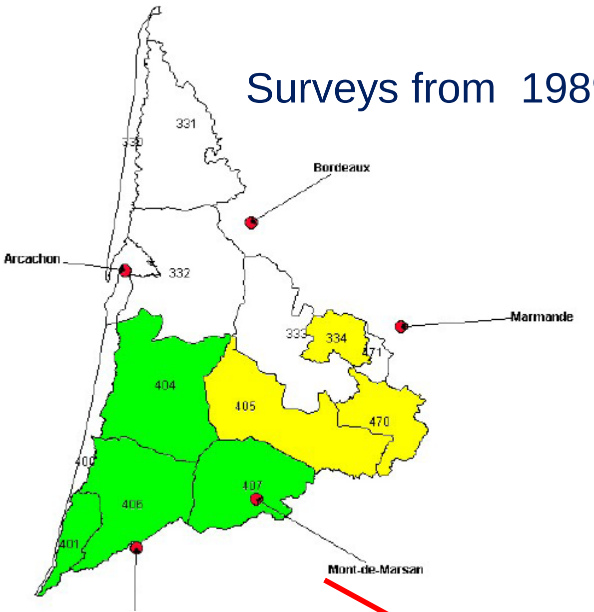
Diagnosis on the field or at laboratory



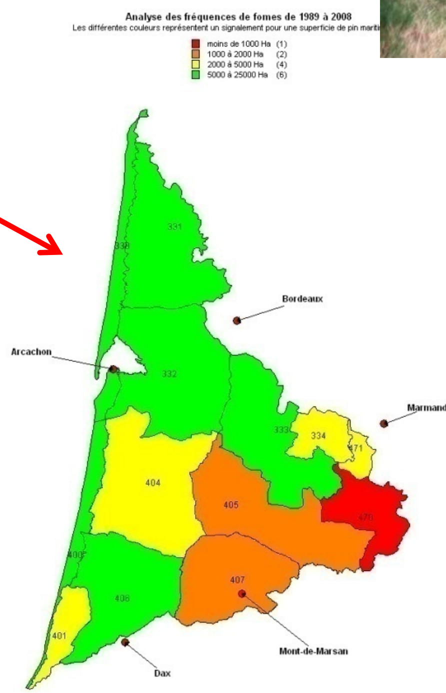


Introduction: More and more severe damages for Maritime pine

Surveys from 1989 to 1997



Campet forest (47)



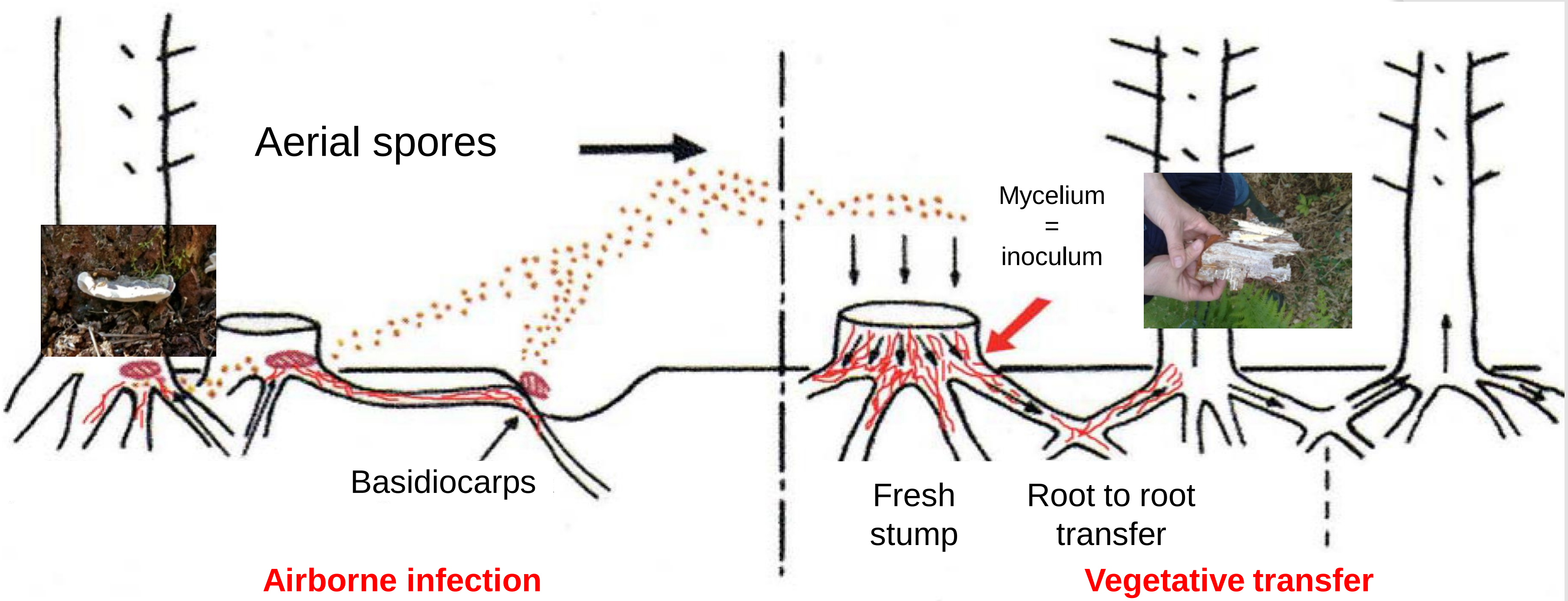
Surveys from 1998 to 2008

- Increase of forest damages in South-West Maritime pine forests between 1997 and 2008

(T. Aumonier – DSF 2008)

Lizay forest (Ile de Ré - 17)

Introduction: Ecology and life cycle



C. Delatour, (Abgrall & Soutrenon, 1991)

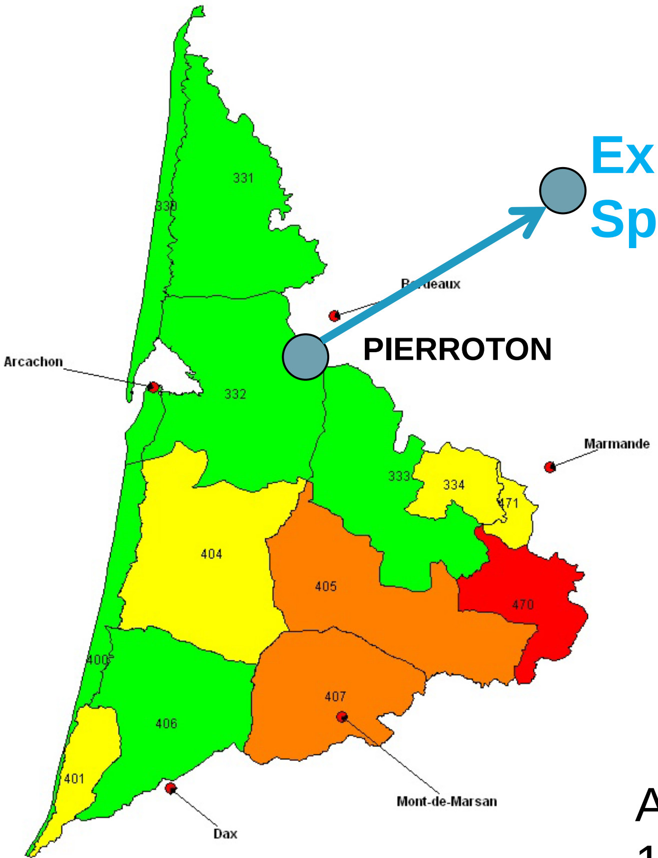
- Perennial basidiocarps → Sexual spore emission→ Spore deposition on freshly thinning stumps → Colonization of stump roots → Vegetative transfer to healthy tree root via root-to-root contacts

How to model the disease dynamics ?

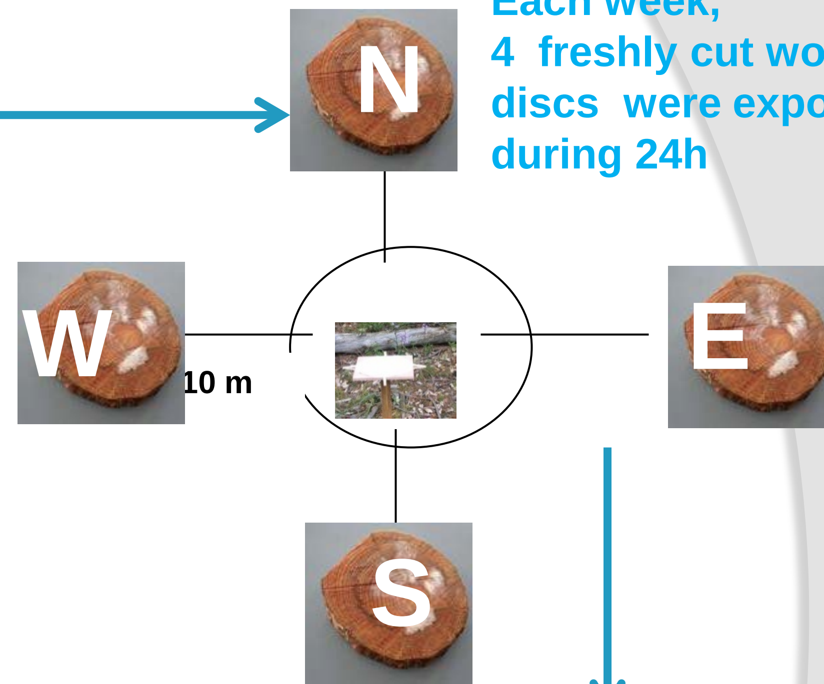
- The root fungus dynamics
  - The seasonal pattern of spore deposition
  - The stump and root colonization of thinning stumps
  - The spread of fungus in roots of healthy tree

- Effect on trees
  - Disease effect on tree growth and survival

Monitoring the aerial spore deposition: wood-disk method



Experiment 1: Spore traps



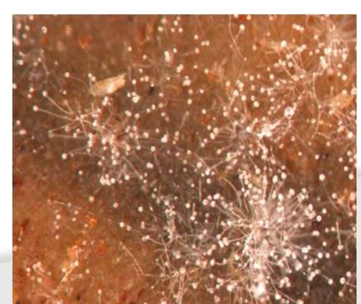
Each week, 4 freshly cut wood discs were exposed during 24h

Experiment 2: Thinning stump disks

In 48 stands, harvest of 50 wood discs of stumps at different seasonal dates and in different soil types (12 stands/season/soil type)

After exposure in humid chamber in darkness at 19 C for 10 days, the wood discs were examined for colonies of the imperfect stage of *H. annosum* (*Spiniger meineckellus*)

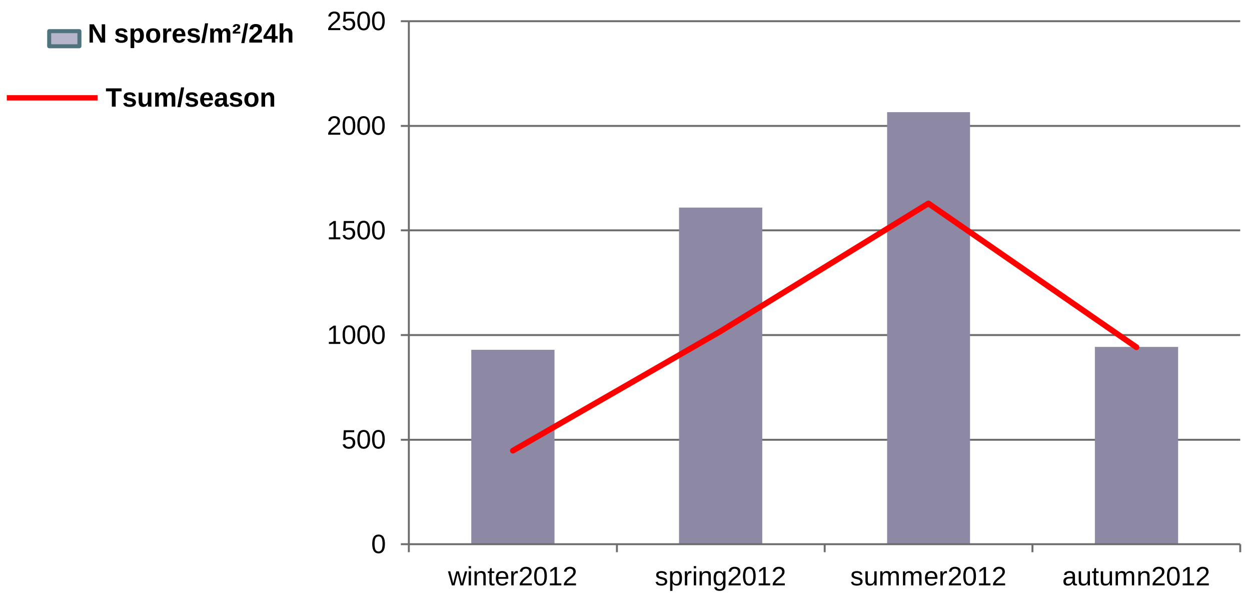
% of stumps infected by H. annosum

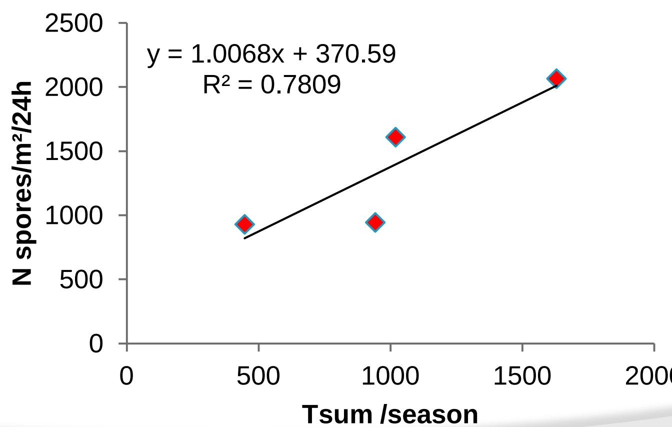


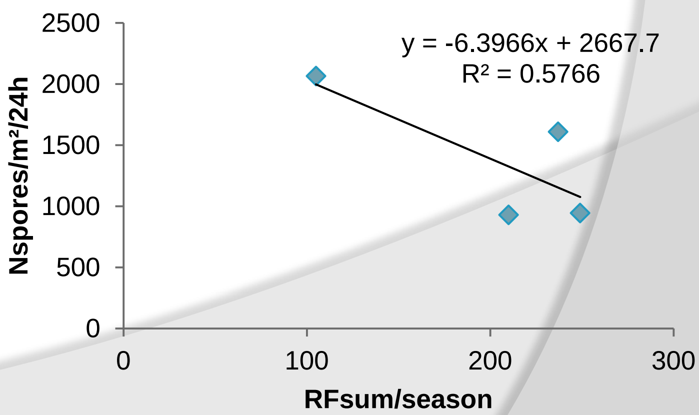
Nb spores/m²/24h (as the result of the germination of one aerial spore)

Experiment 1: Seasonal pattern of spore deposition - Results

Prediction of the probability of a fresh stump becoming infected by spores

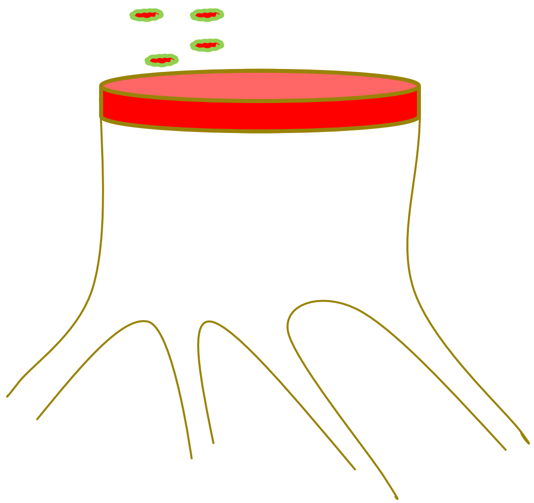


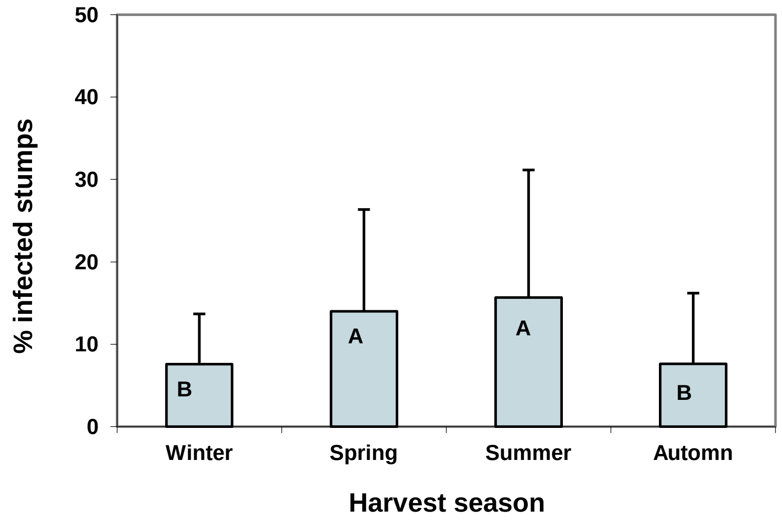




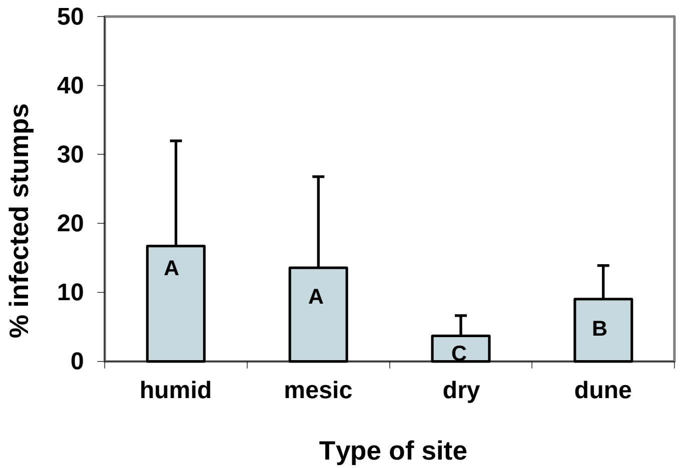
Experiment 2: Infection of thinning stumps - Results

Actual infection probability = f(Season)

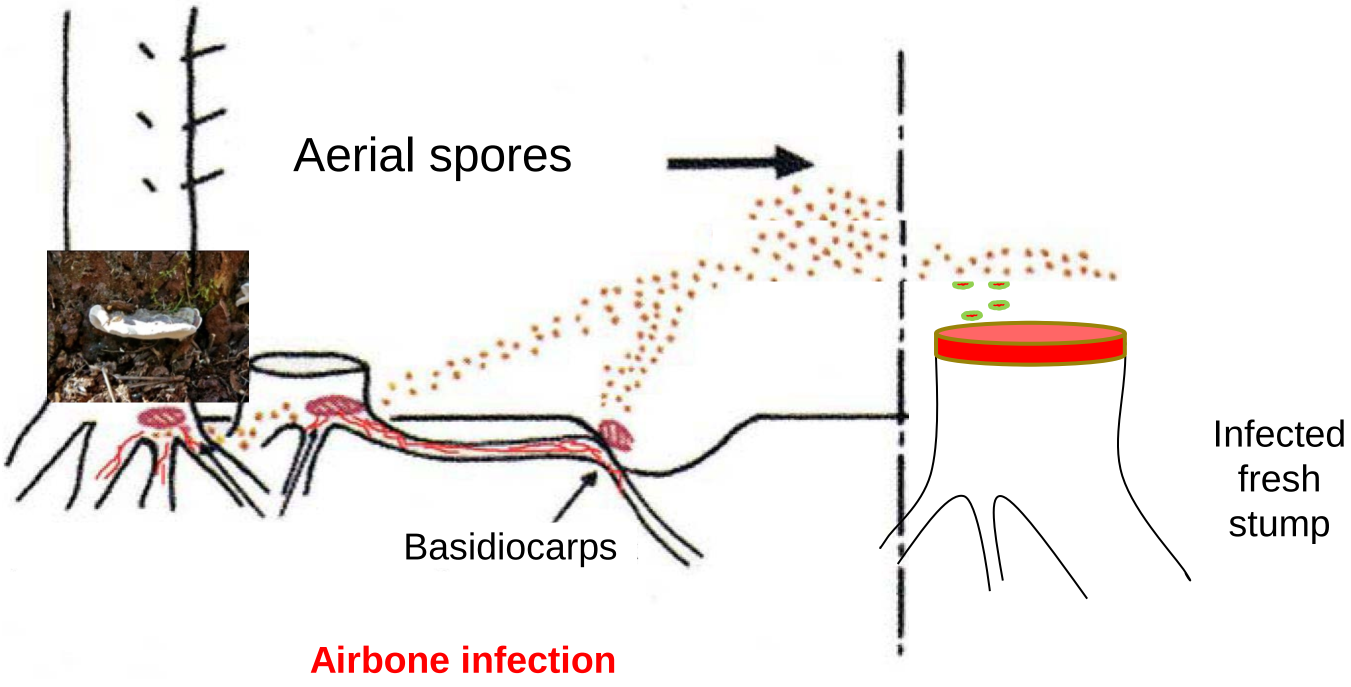




Actual infection probability = f(Type of site)



Model description: root fungus dynamics.1
Air Born infection



Prediction of a fresh stump becoming infected by spores after thinning: Pinf

- Number of aerial spore per m² per season

- Percentage of infected stumps after a thinning according to edaphic factors and combined with thinning season

Stump and root colonization of thinning stumps: parameter calibration

Four years after thinning:

In 6 stands chosen among the 48 above-mentioned stands and selected in 4 types of soil forests

Release of root systems of 49 infected thinning stumps coupled with the two nearest healthy trees

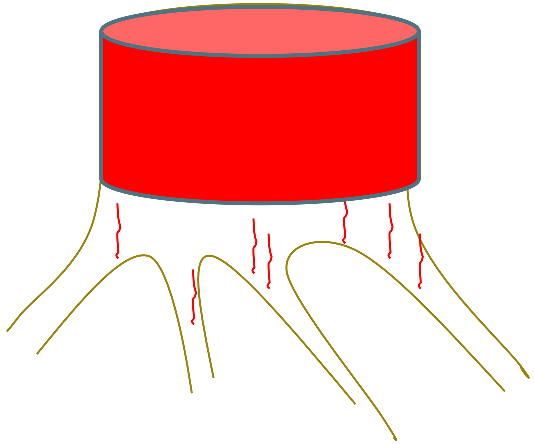
- **One Humid site: 16 root systems at Herm**
- **One Mesic site: 16 root systems at Vieux Boucau**
- **Two Dune sites: 5 root systems at La Teste; 5 at Lit et Mixe**
- **Two Dry sites: 4 root systems at Morcenx; 3 at Argelouse**

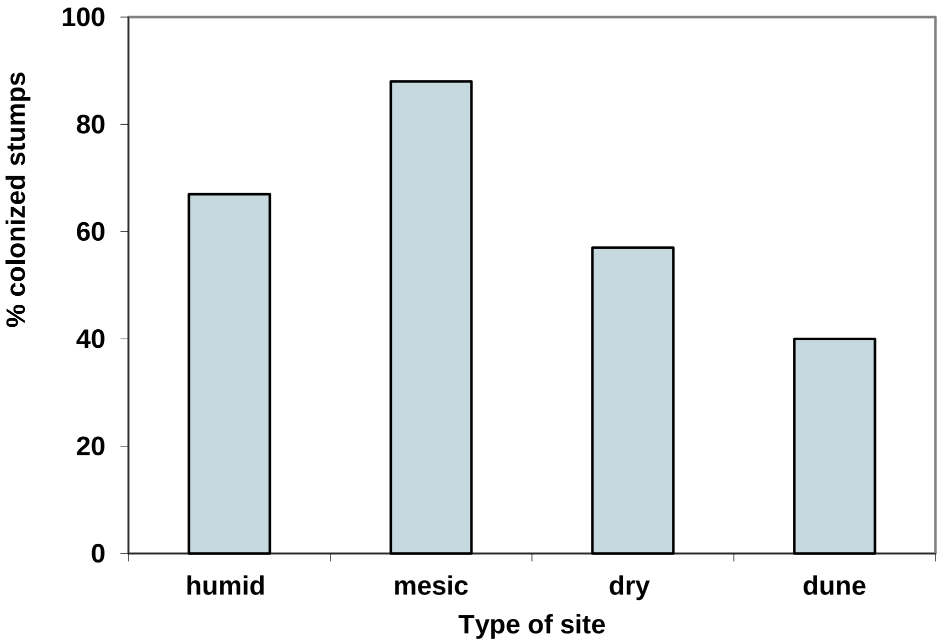
We measured:

- % colonized stumps
- Lengths of colonized roots (mean rate in cm/year)
- % infected root to root contacts

Stump and root colonization of thinning stumps: Results

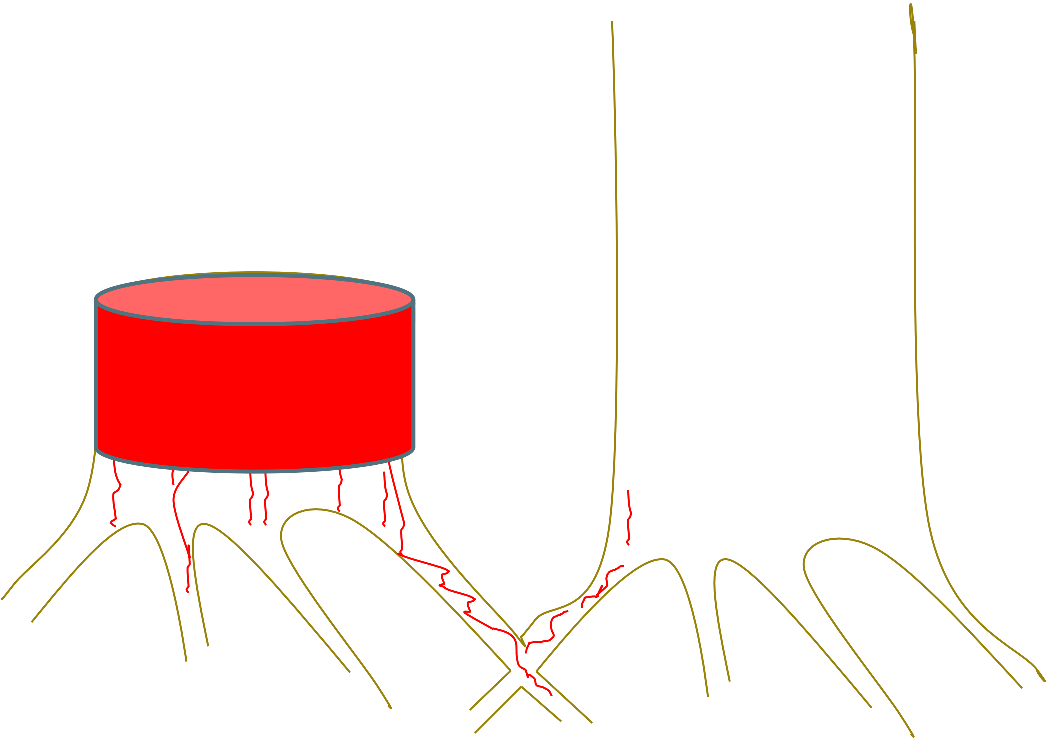
Probability of infected stump to be colonized= f(Type of site)

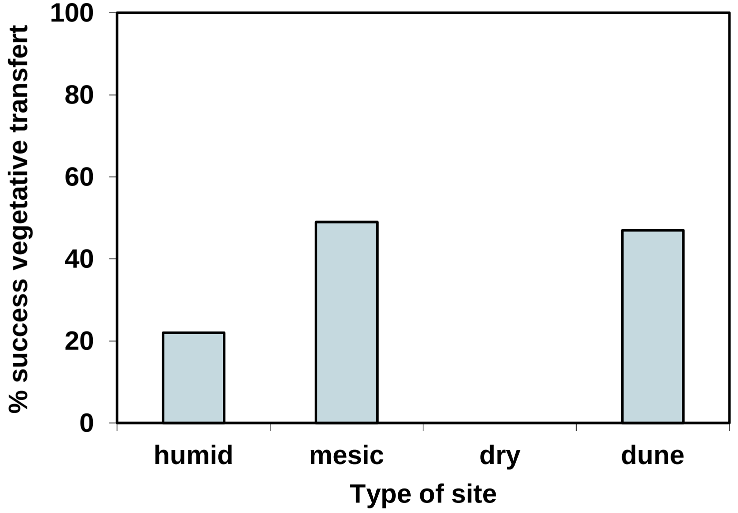




Stump and root colonization of thinning stumps: Results

Probability of transfer from stump to living tree = f(Type of site)





Stump and root colonization of thinning stumps: Results

Rate of mycelial growth in stump roots

Site types	Mean rate of mycelial growth (cm /year)	Max rate of mycelial growth (cm /year)
Humid site	**30**	81
Mesic site	**35**	99
Dune	**25**	37.5
Dry site	**15**	25
Mean (N = 49)	**26.25**	60.62

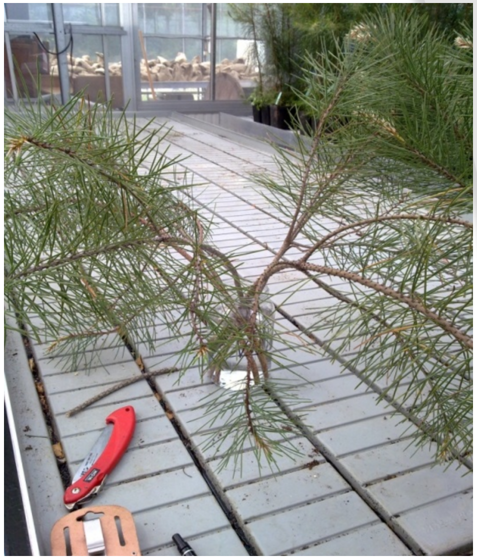
Rate of mycelial growth : artificial inoculations

Inoculation on stems of 2-yrs old trees (N=120)

mycelial growth in leaving tissues

- After 75 or 21 days, length of cambial necrosis is measured
- Mean rate in cm caused by different isolates is calculated

Inoculation on branches of 8-yrs old trees (N=120)



mycelial growth in freshly cut tissues

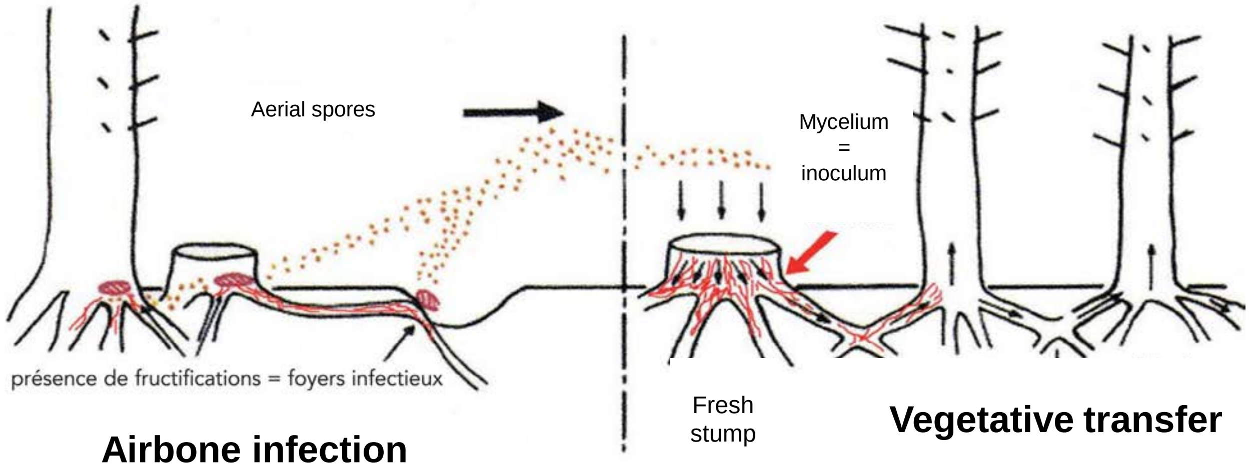
Rate of mycelial growth in freshly cut tissues

	Mean rate of mycelial growth (cm / year)	Max rate of mycelial growth (cm / year)
Mean of inoculated branches with 6 isolates (N=44)	**25.83**	87
Mean in stump roots (N = 49) into the wild	***26.25***	*60.62*
Mean in Finland (Pukkala 2005)	**50**	
Mean of inoculated branches with one isolate (N=59)	**52**	114

Rate of mycelial growth in living trees

	Rate of mycelial growth (cm / year**)**
Stems (cm/year) N=120	**6.64**
Mean in Finland (Pukkala 2005, Bendz – Hellgren et al. 1999)	**10**

Model description: root fungus dynamics



1.Prediction of a fresh stump becoming infected by spores after thinning: Pinf

- *Number of aerial spore per m² per season*
- *Percentage of infected stumps after a thinning according to edaphic factors*
- *Value of efficiency of stump treatment: for ex. use of biological control agent*

2. Prediction of a fresh stump becoming colonized: Pcol

- according to edaphic factors

3. Growth of H. annosum in stump/living trees: Gha

- growth rates according to edaphic factors and type of tissue
- modeling the radius of coarse root system
- modeling the number of year and the radius of infected zone

4. Vegetative transfer of H. annosum to healthy trees: PtransfertST

- according to edaphic factors

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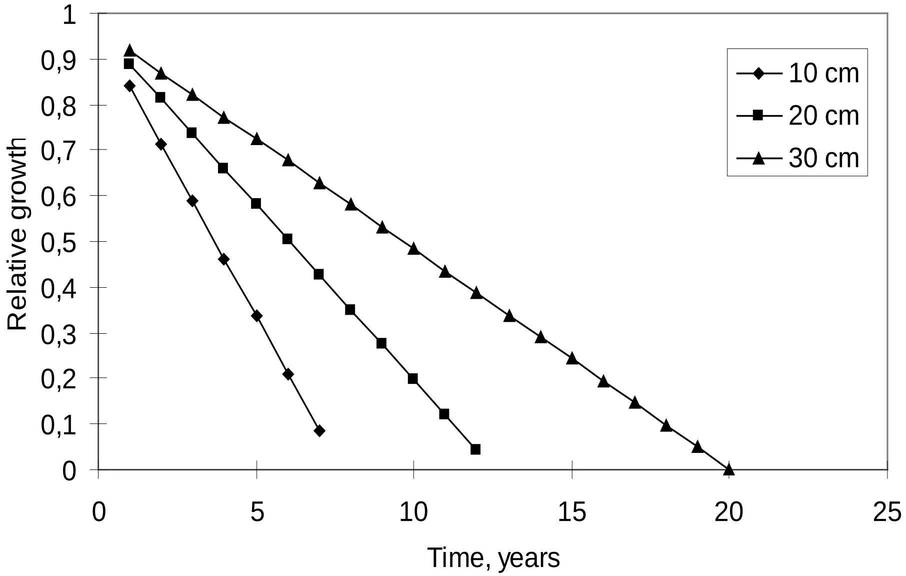
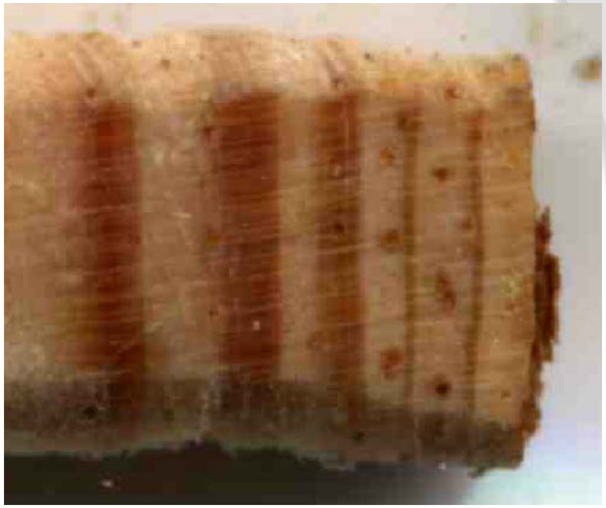
The effect of Heterobasidion ssp. on tree growth: overview





Scot pine in Finland (Pukkala 2005)

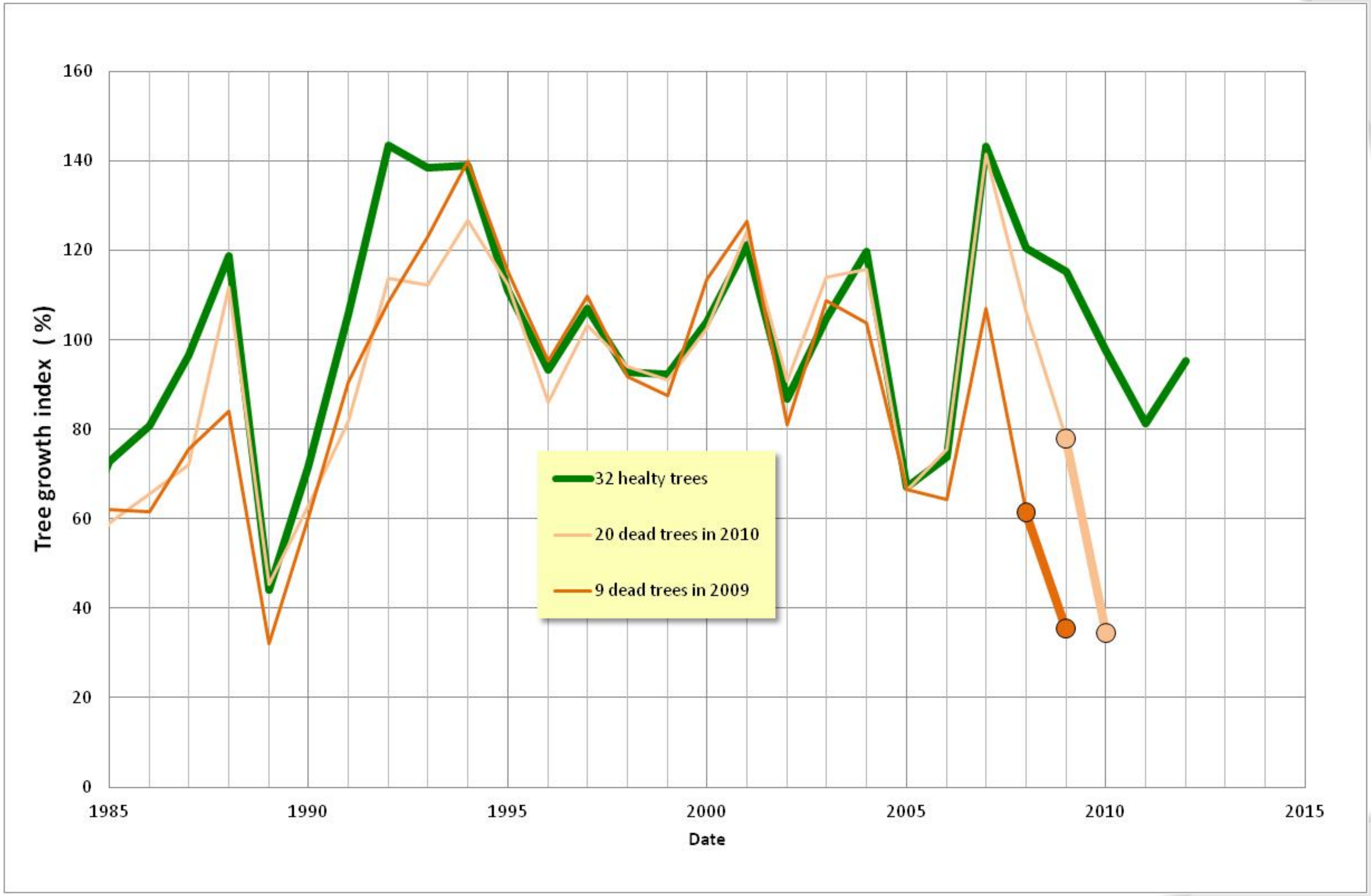
Maritime pine in South-West France

Relative diameter increment loss

from 7 to 20 years ……….

2 or 3 years…?

The effect of H. annosum on tree growth: Results



⇒A least two years of diameter increment loss before the death

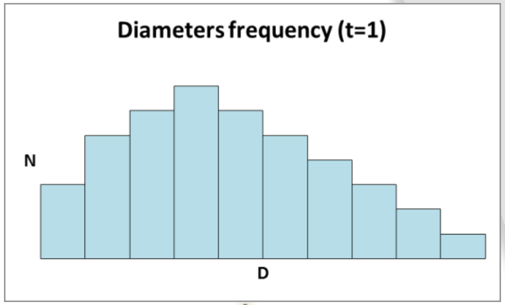
⇒No influence of initial diameter

Model implementation

t=1

Theoretical (or real) initial stand

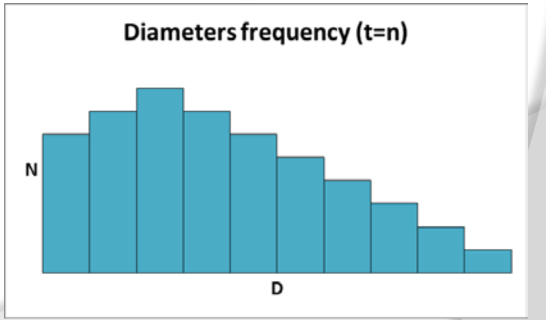
Initial stand:
Age≥7 years-old,
Density, G, Hdom



PP3→ Empirical tree growth model for Maritime pine calibrated on undammaged, healthy stand and trees

Dyear2=Dyear1+ΔDt

Sylvicultural practicies : thinnings



t=n

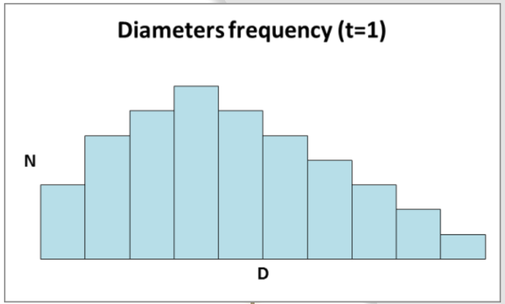
Final stand: Density, G, Hdom

Theoretical final stand

- Initial centers of Heterobasidion ssp. at the beginning of rotation : position of the colonized clear-cut stumps

Sylvicultural practicies : previous infected stand or not, with or without stump treatments (removal, etc..)

Initial stand: Age≥7 years-old, Density, G, Hdom

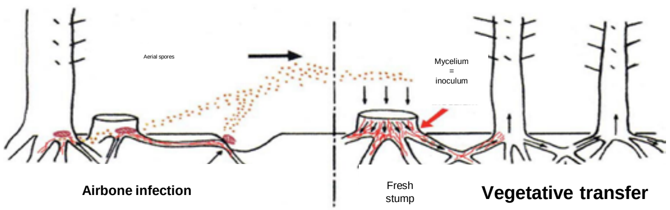


t=1

- Position of all the planted maritime pines at t=1

Effects on tree: growth and survival

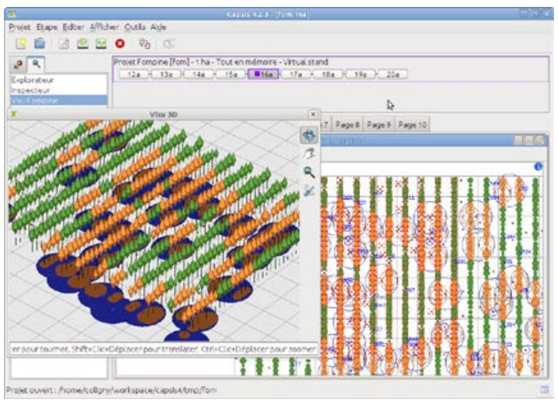
Root fungus dynamics



For one infected tree:
Dyear2=Dyear1+ΔDt – growthLoss

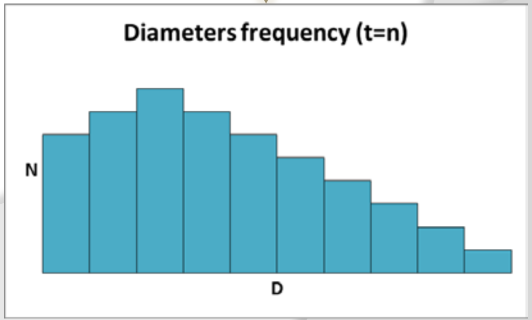
If a tree shows growth loss during two years then Pdie = 1

Sylvicultural practicies : thinnings with or without stump treatment



t=n

Final stand: Density, G, Hdom

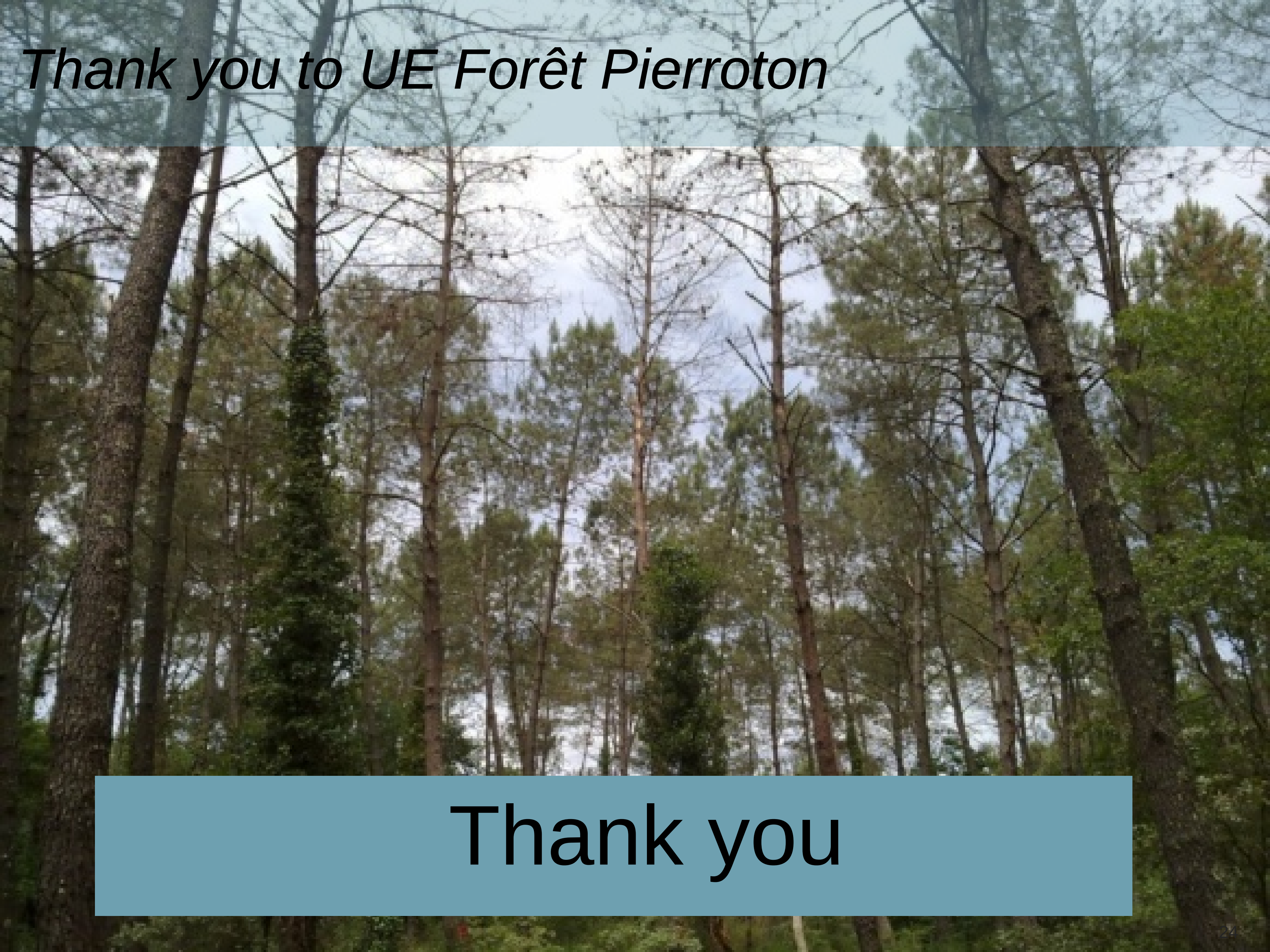


Theoretical final stand

WORK IN PROGRESS

- Improve or add new equations or parameters
  - Improve the dynamics of stump root colonization : variability of the rate of mycelium growth (isolates, edaphic conditions…)
  - Validate the aerial spore emission depending of climate to integrate climate change
- Implement FomPine-PP3 model into Capsis platform
- Made simulations and sensitivity analysis
  - Optimize the management of infected sites
  - Avoid stand infection
- Validate the FomPine-PP3 model with a network of experimental plots
  - Variability of sensitivity among the Maritime pine species
  - Stump removal/ no removal experiment
  - Thinning Stump treatment/no treatment experiment

Thank you to UE Forêt Pierroton



Thank you