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

Brigitte Lung Lung-Escarmant, Didier Bert, Xavier Capdevielle, Thierry Labbé, Jean-Baptiste Lasnier, Raphael Segura, Gilles Saint-Jean, Céline Meredieu

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Predicting the spread of *Heterobasidion annosum* in even-aged *Pinus pinaster* stands in South-West France

Brigitte Lung-Escarmant, Didier Bert,
Xavier Capdevielle, Thierry Labbé,
Jean-Baptiste Lasnier, Raphaël Ségura,
Gilles Saint-Jean, Céline Meredieu

INRA, UMR1202 BIOGECO,
F-33610 Cestas, France



Introduction: *Heterobasidion annosum*

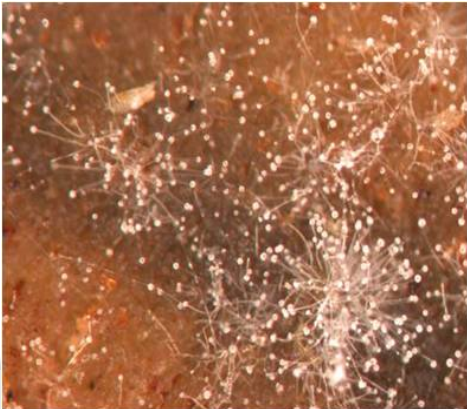
Pathogenic fungus



Root rot disease of
pine forests

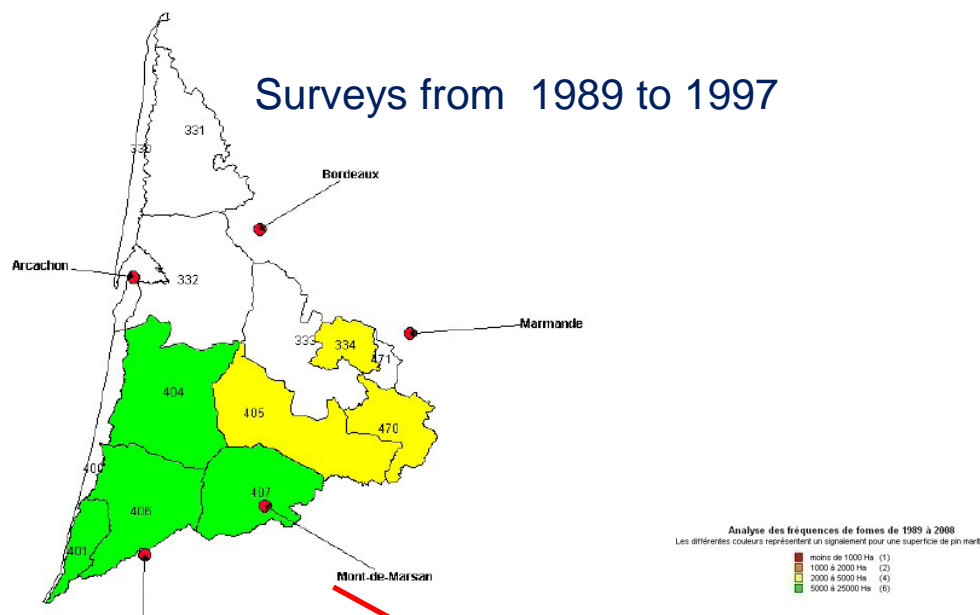


Diagnosis on the field or at laboratory



Introduction: More and more severe damages for Maritime pine

Surveys from 1989 to 1997

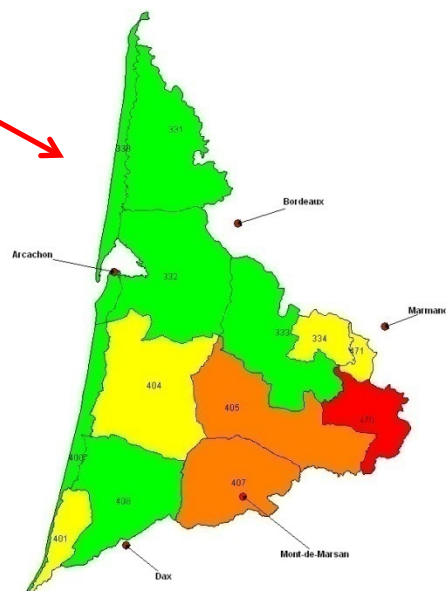


Campet forest (47)

Surveys from 1998 to 2008

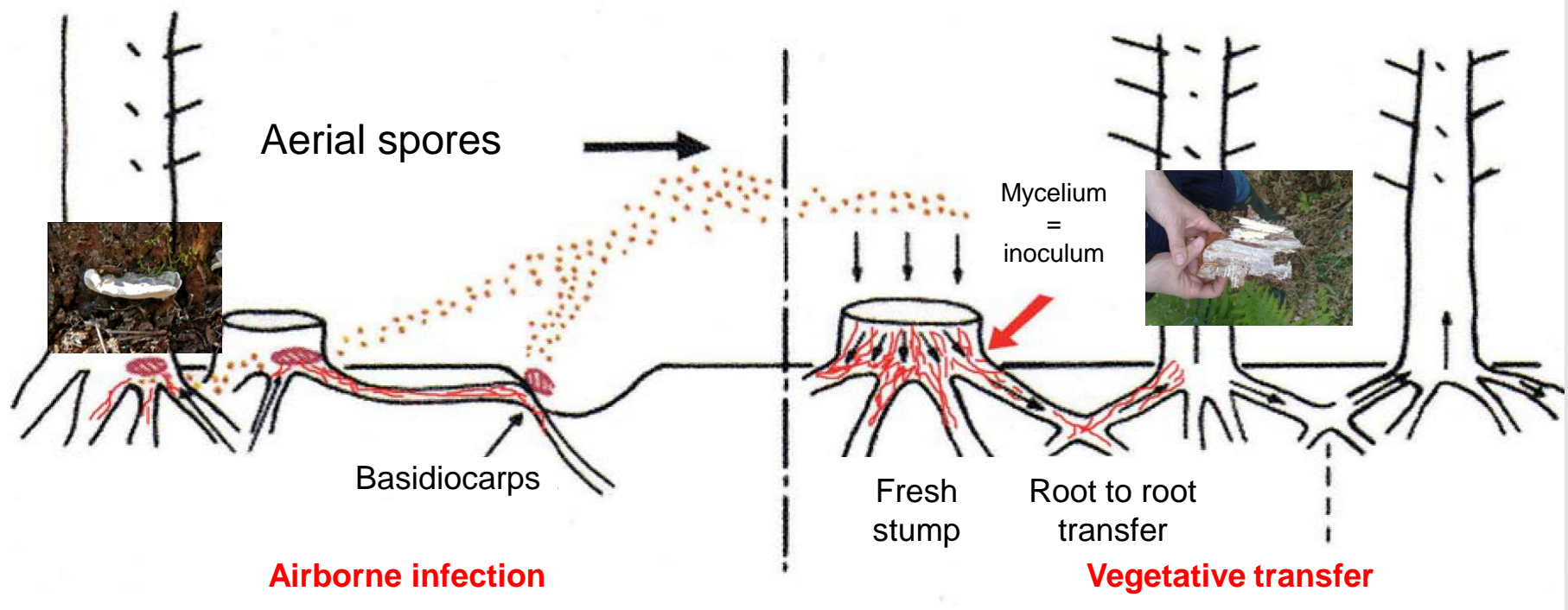
- Increase of forest damages in South-West Maritime pine forests between 1997 and 2008

(T. Aumonier – DSF 2008)



Lizay forest (Ile de Ré - 17) 3

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 ?

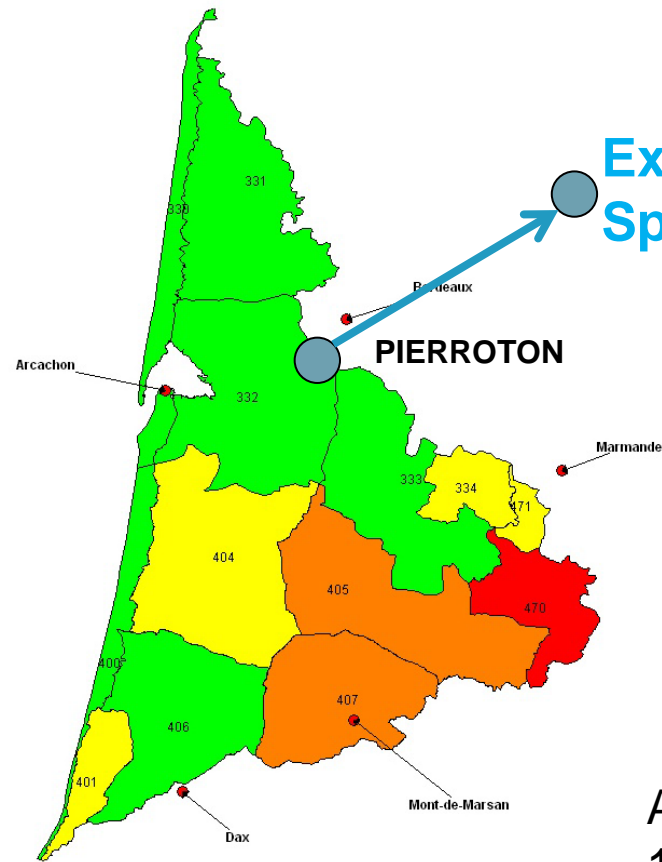
◎ The root fungus dynamics

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

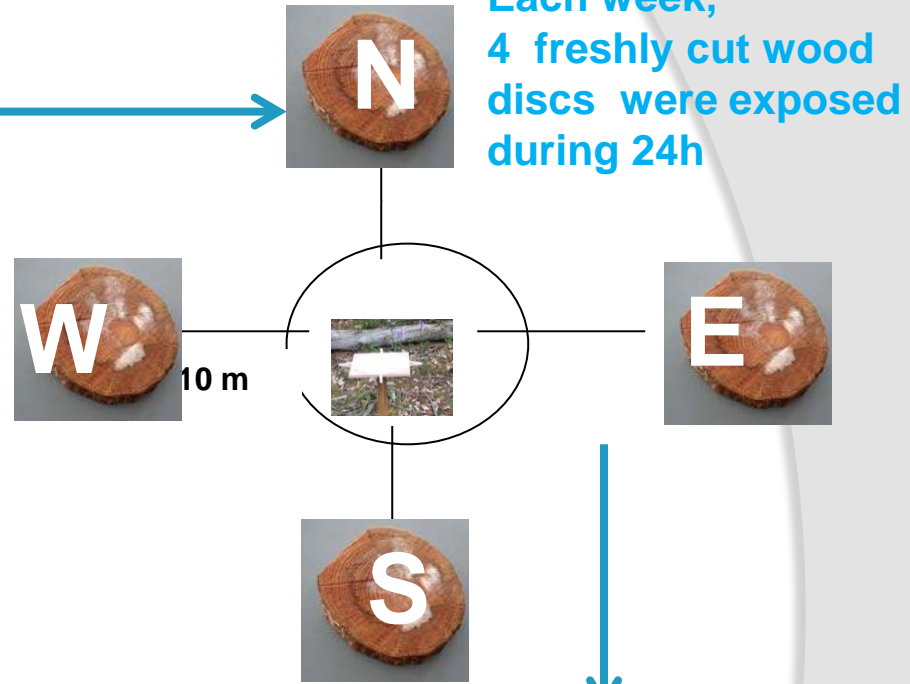
◎ Effect on trees

- Disease effect on tree growth and survival

Monitoring the aerial spore deposition: wood-disk method



Experiment 1: Spore traps



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*)

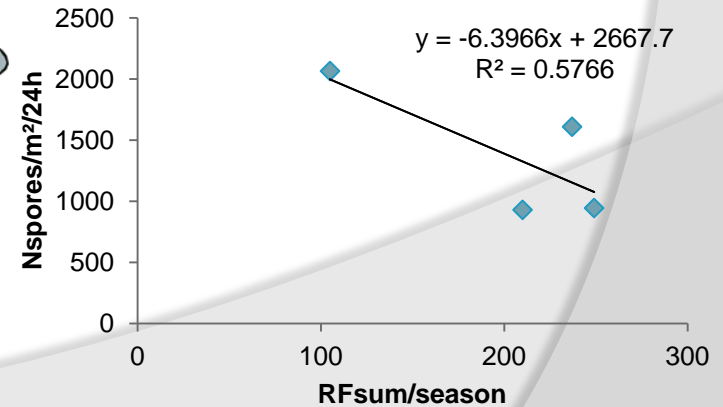
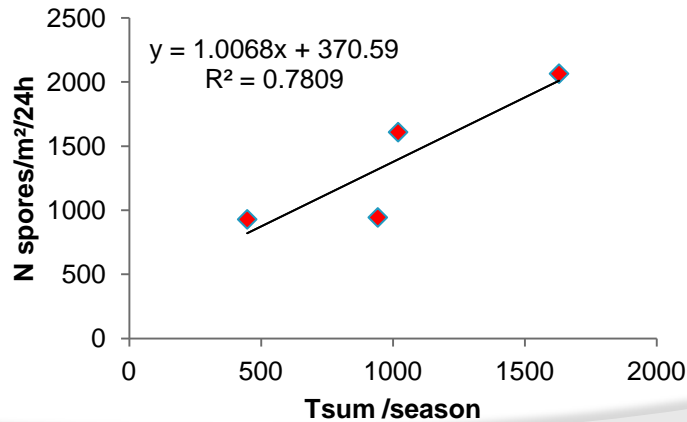
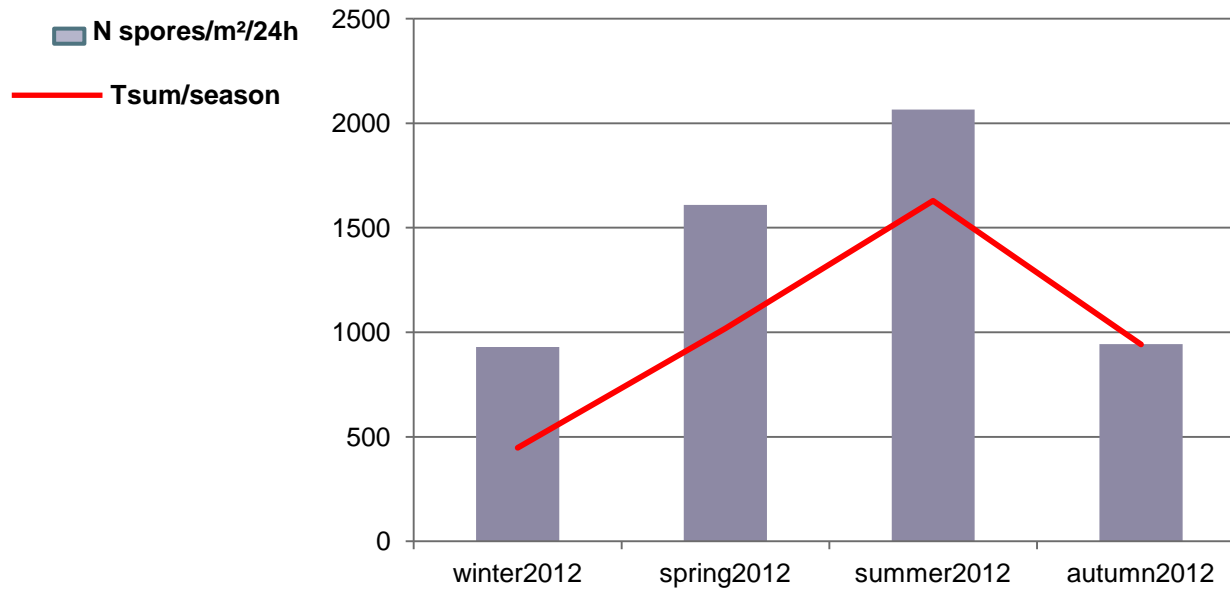
% of stumps
infected by
H. annosum



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

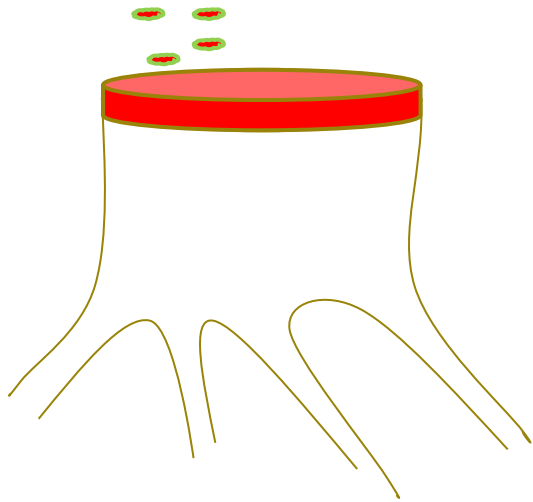
Experiment 1: Seasonal pattern of spore deposition - Results

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

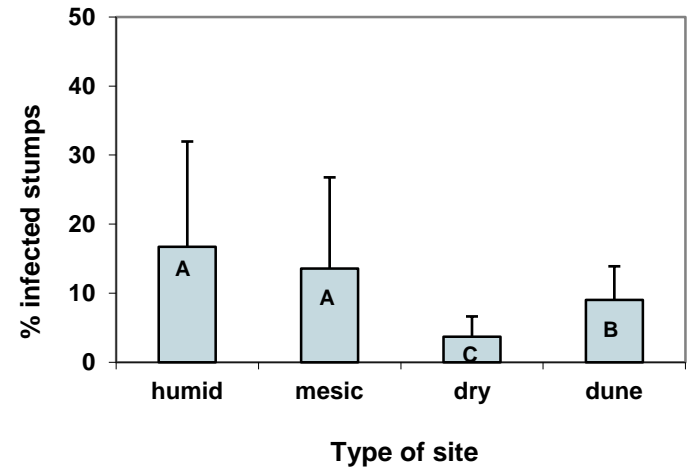
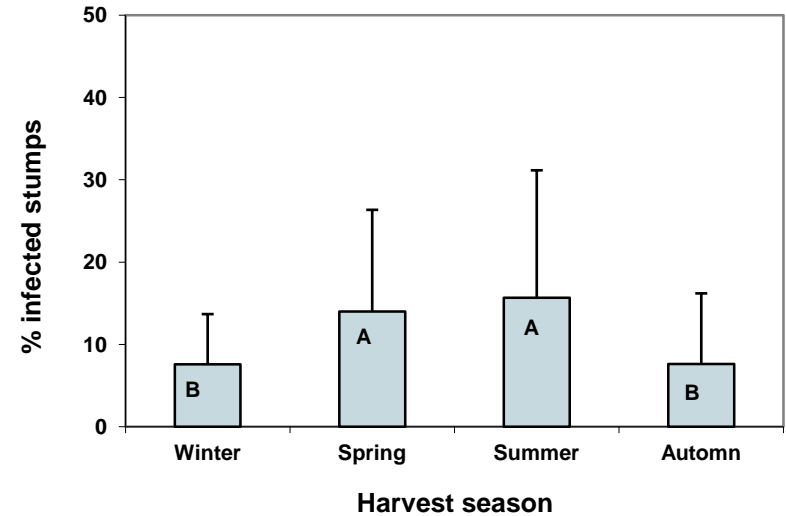


Experiment 2: Infection of thinning stumps - Results

Actual infection probability = $f(\text{Season})$

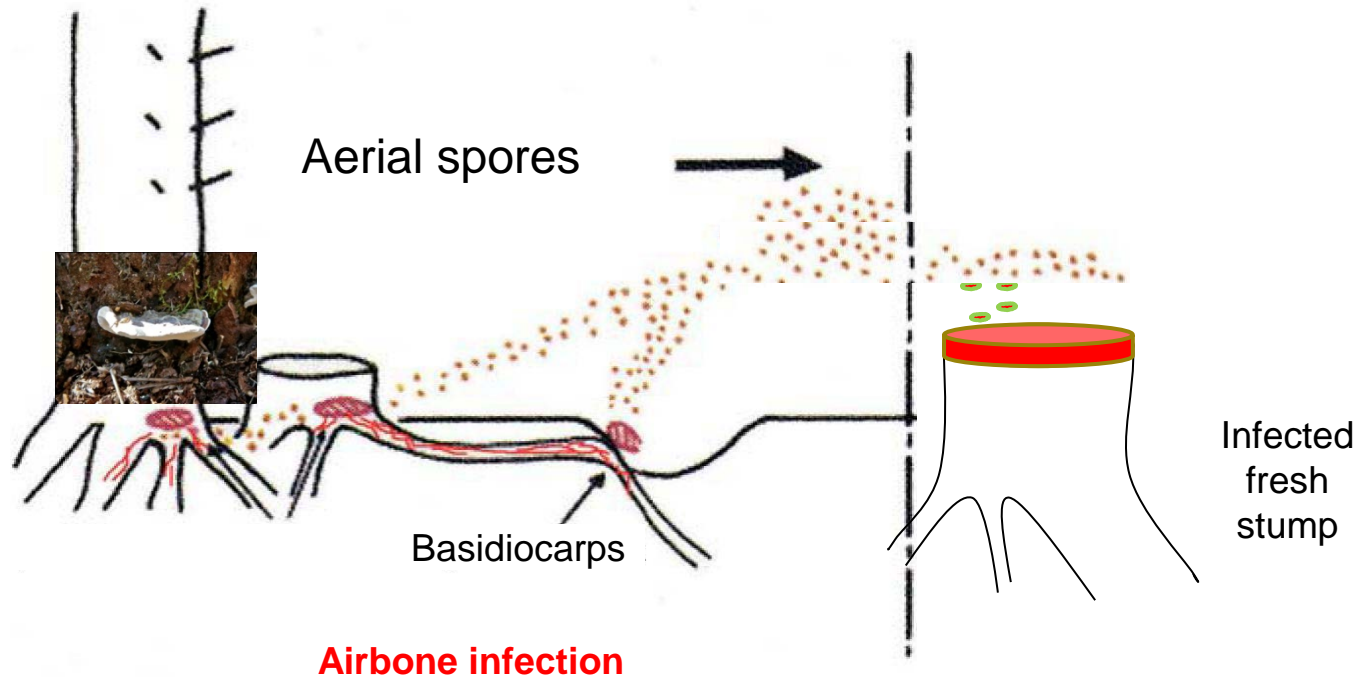


Actual infection probability = $f(\text{Type of site})$



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 m^2 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**

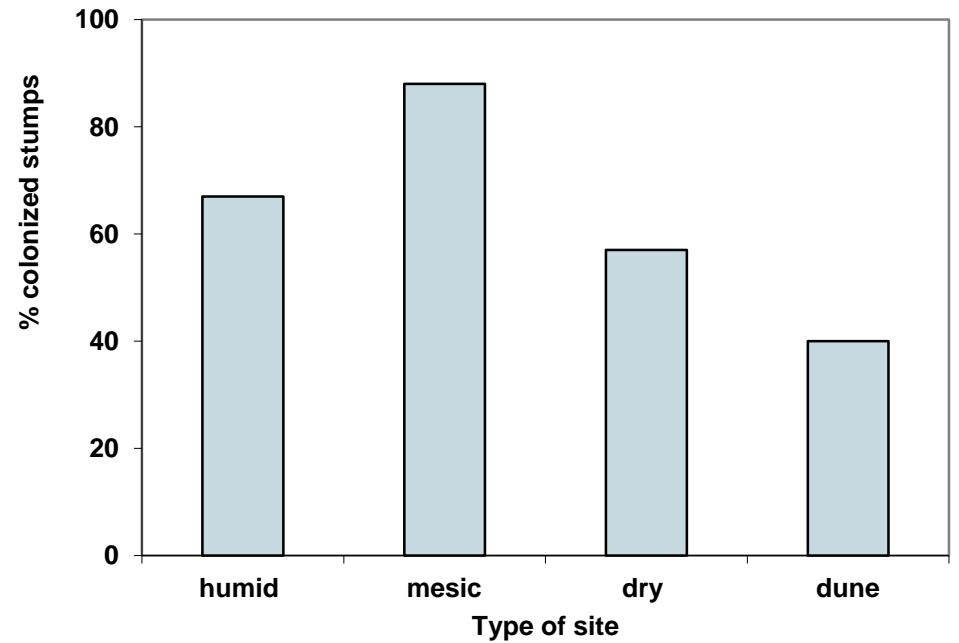
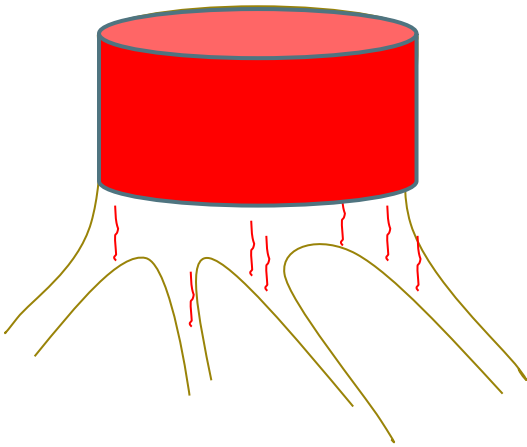


We measured:

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

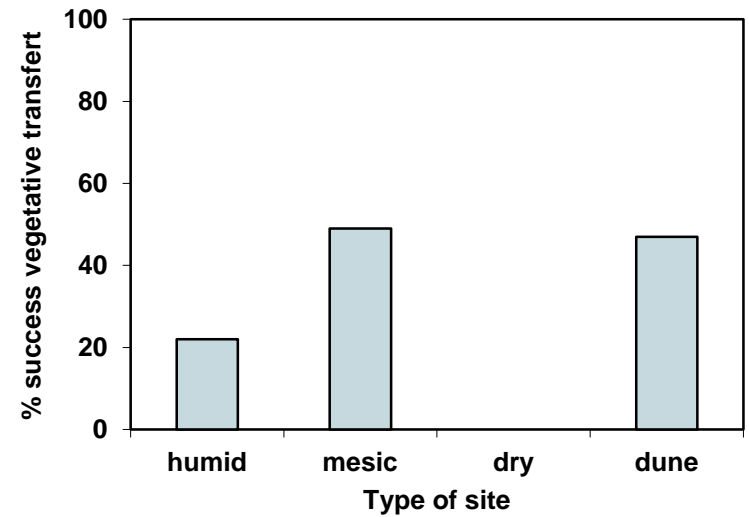
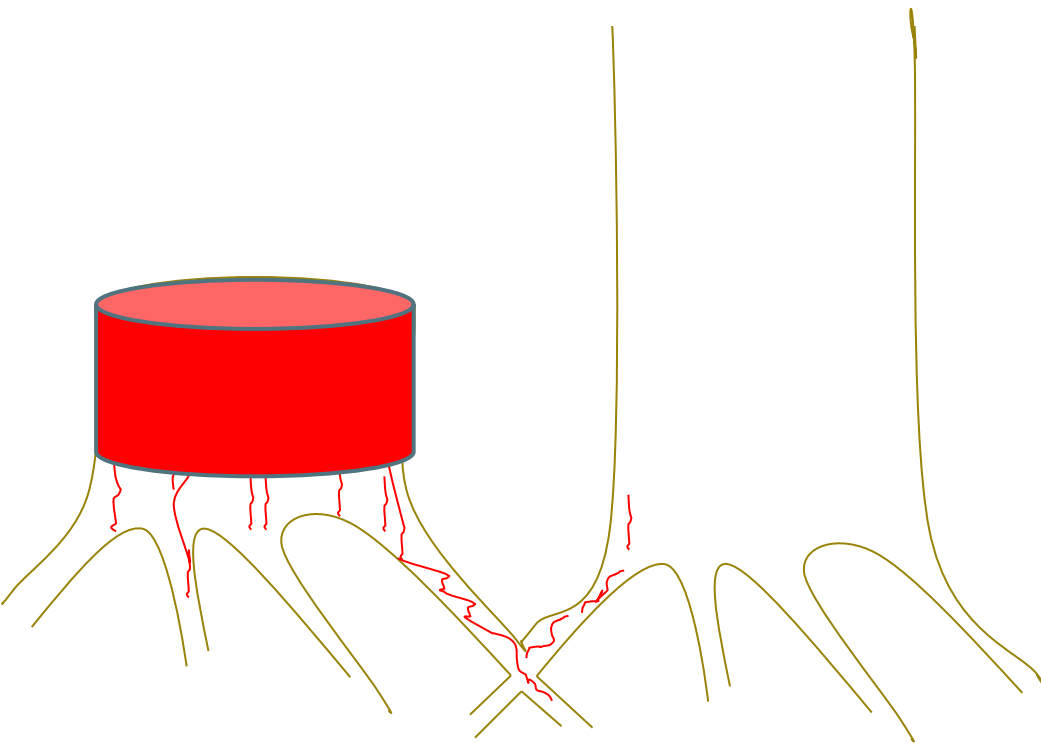
Stump and root colonization of thinning stumps: Results

Probability of infected stump to be colonized = $f(\text{Type of site})$



Stump and root colonization of thinning stumps: Results

Probability of transfer from stump to living tree = $f(\text{Type of site})$



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

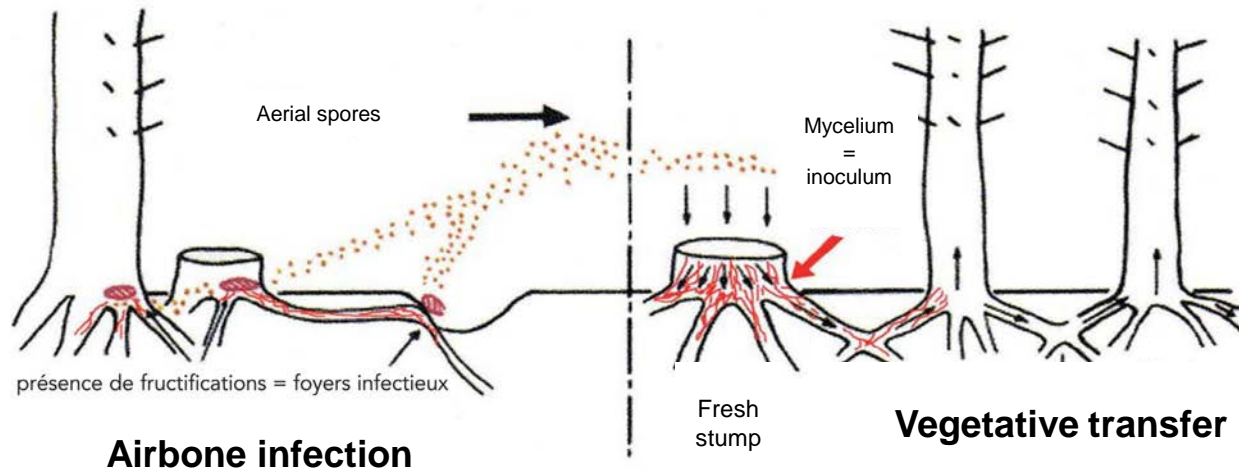
Rate of mycelial growth in freshly cut tissues

	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
<i>Mean in stump roots (N = 49) into the wild</i>	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: P_{inf}

- Number of aerial spore per m^2 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: P_{col}

- according to edaphic factors

3. Growth of *H. annosum* in stump/living trees: G_{ha}

- 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: $P_{transfertST}$

- according to edaphic factors

How to model the disease dynamics ?

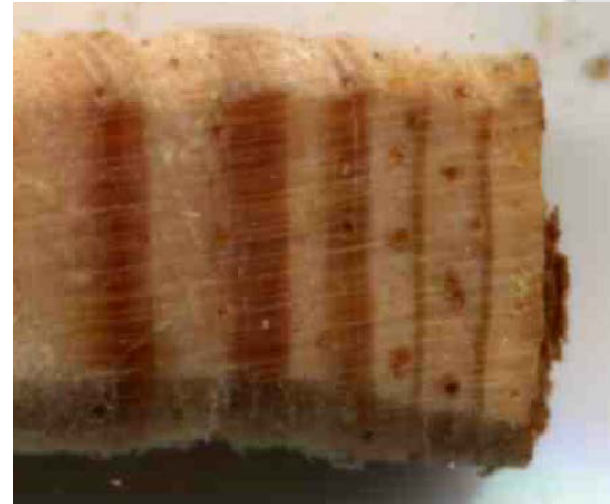
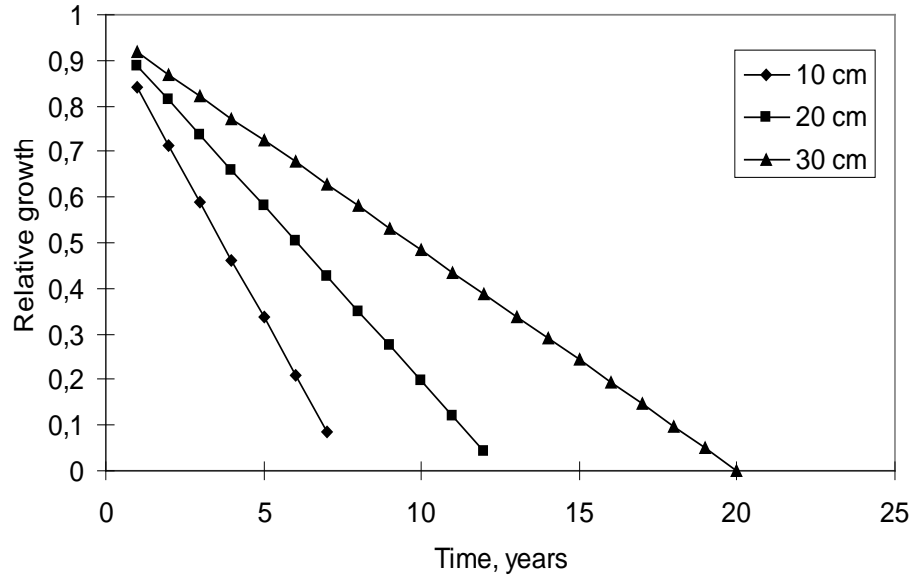
◎ The root fungus dynamics

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◎ Effect on trees

- Disease effect on tree growth and survival

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

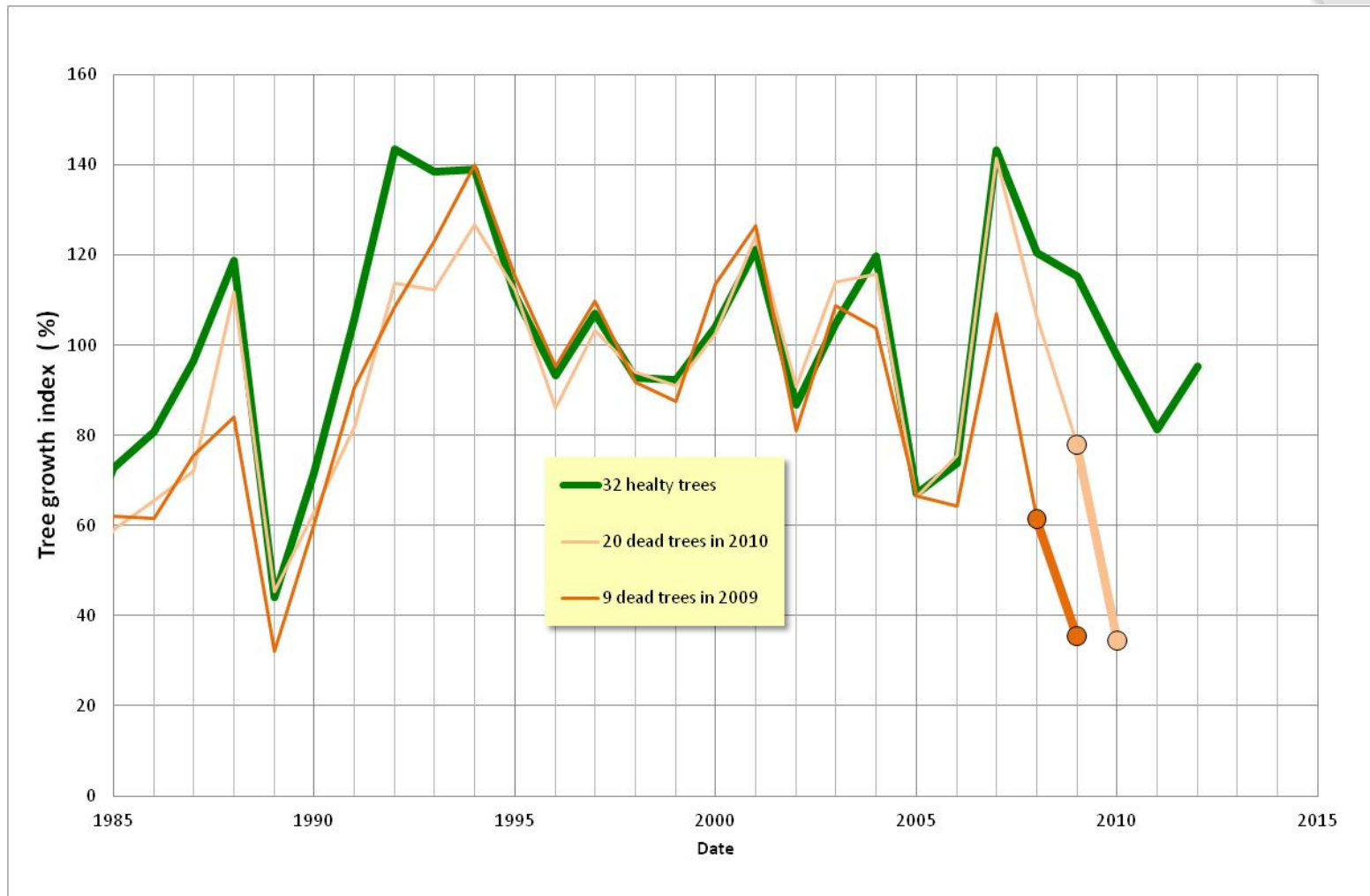


from 7 to 20 years



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

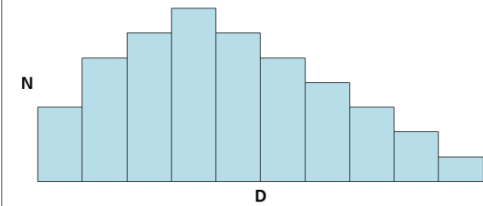
t=1

Theoretical (or real) initial stand

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

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

Diameters frequency (t=1)



Sylvicultural practices : thinnings

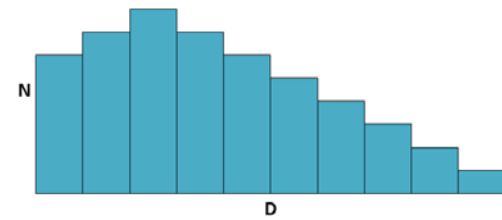
$$D_{\text{year}2} = D_{\text{year}1} + \Delta Dt$$

t=n

Final stand: Density,
G, Hdom

Theoretical final stand

Diameters frequency (t=n)

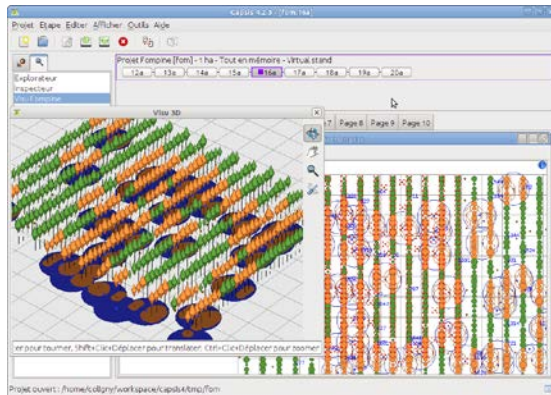
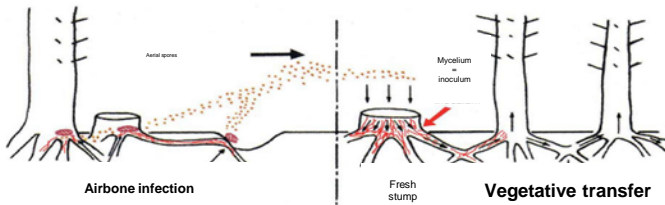


- Initial centers of *Heterobasidion* ssp. at the beginning of rotation : position of the colonized clear-cut stumps

t=1

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

Root fungus dynamics



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

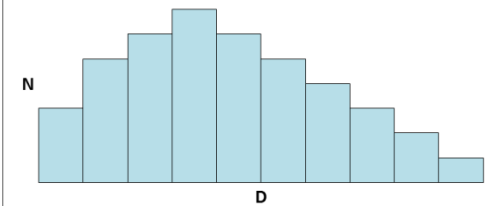
Initial stand: Age ≥ 7 years-old, Density, G, Hdom

Sylvicultural practices : thinnings with or without stump treatment

Final stand: Density, G, Hdom

Theoretical final stand

Diameters frequency (t=1)



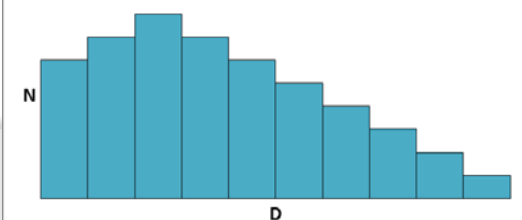
Effects on tree: growth and survival

For one infected tree:

$$D_{\text{year}2} = D_{\text{year}1} + \Delta D t - \text{growthLoss}$$

If a tree shows growth loss during two years then $P_{\text{die}} = 1$

Diameters frequency (t=n)



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