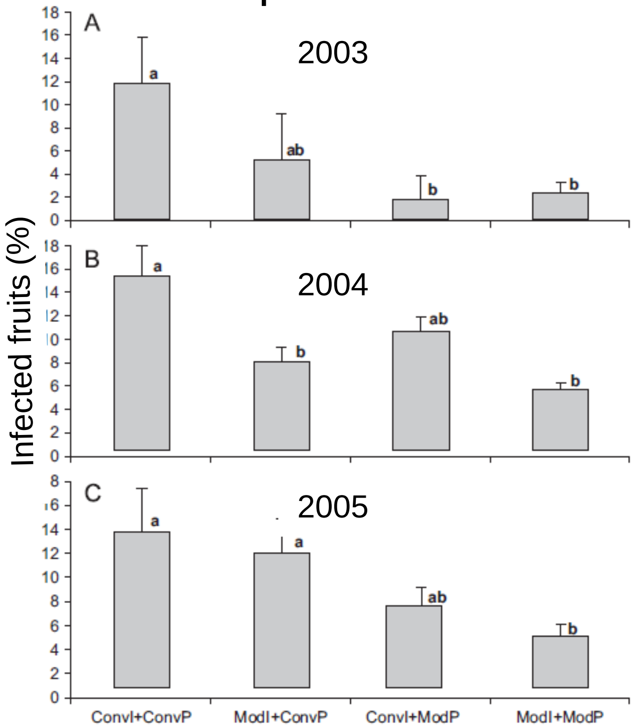
A compartmental epidemiological model for brown rot spreading in fruit orchards

ISHS HORTIMODEL2016
19-22 September 2016, Avignon

Introduction

Brown rot, caused by *monilinia* spp., is one of the main fruits disease (apple, peach, pear etc.)

Empirical observations



$I^{+}P^{+}$ $I^{-}P^{+}$ $I^{+}P^{-}$ $I^{-}P^{-}$

Irrigation (I) & Pruning (P) Treatments

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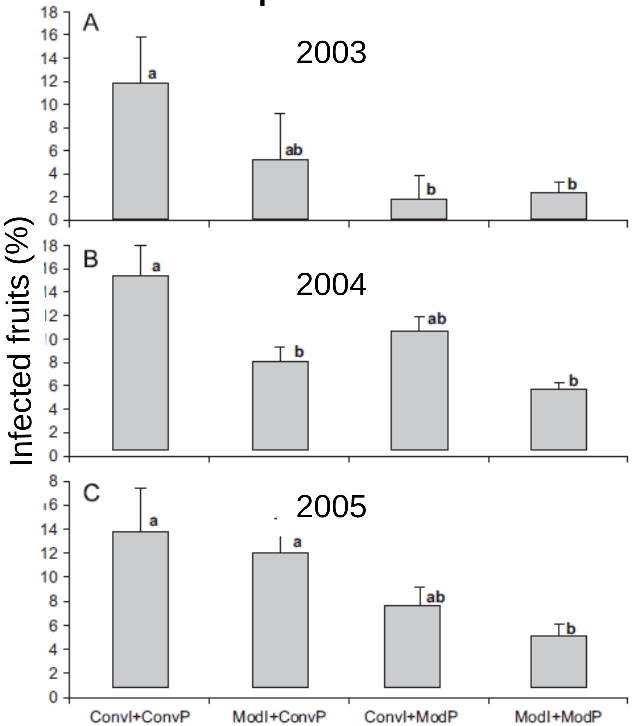

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Statistical models

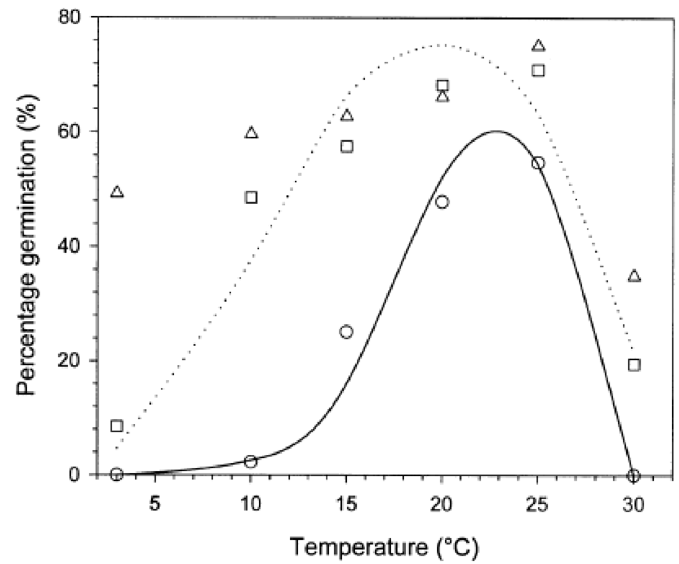

Figure 1 Relationship of average percentage germination of *Monilinia fructigena* conidia on PDA media to temperature. The symbols ○, □ and △ represent germination at assessment times of 2, 6 and 24 h, respectively; the solid and dotted lines are the fitted models for 2-h (equation 1 in text) and 6-h (equation 2 in text) data, respectively.

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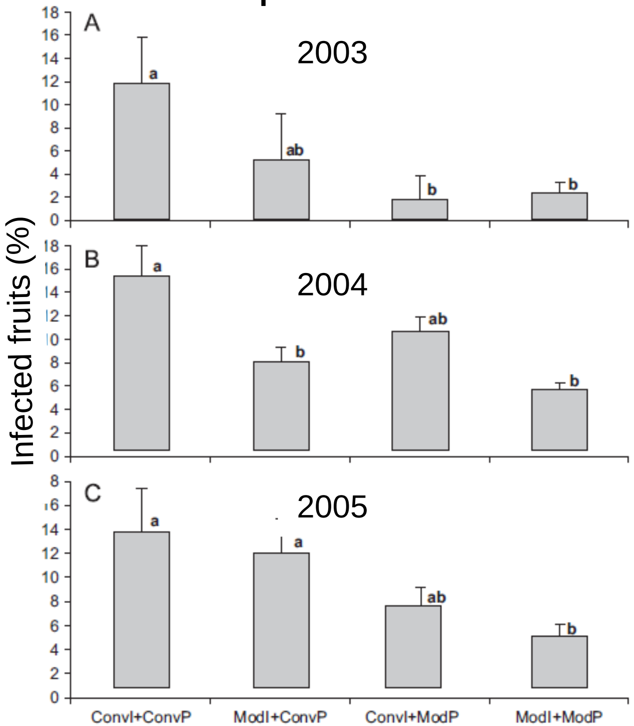

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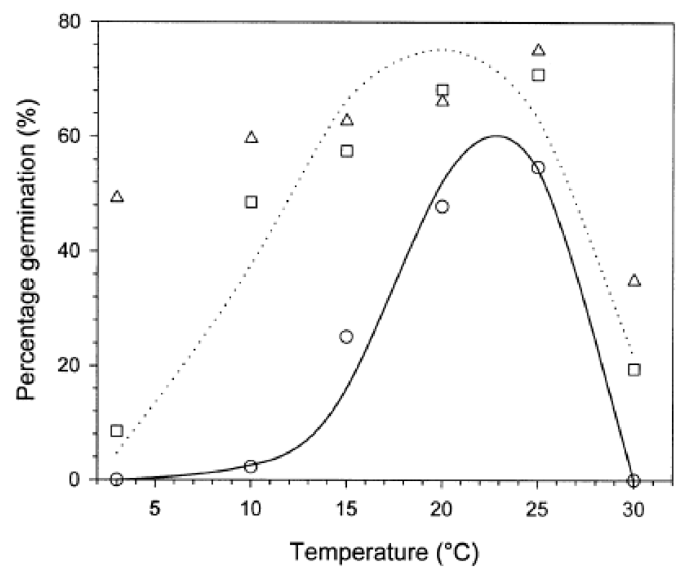

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Mechanistic models (only fruit sensibility)

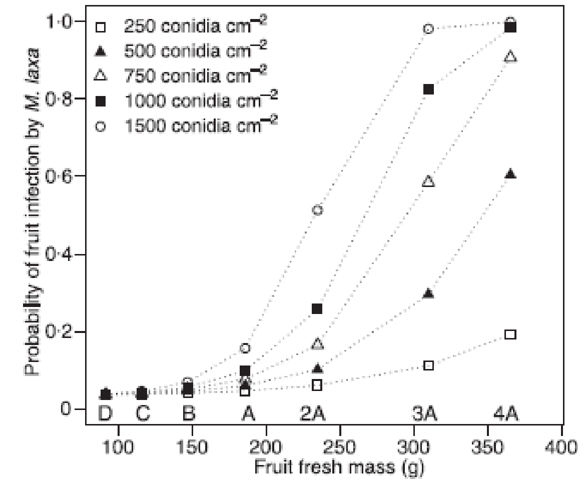

Figure 5 Sensitivity analysis of the model of necatrine fruit infection by *Monilinia laxa* to the input variables inoculum density and mean fruit fresh mass. The latter variable corresponds to mean commercial grades (indicated by letters D, C, B, A, 2A, 3A and 4A) inducing variable fruit and cuticular crack surface areas. The cuticular crack density is deduced from the fruit fresh mass by means of this equation: $Y = b^{\frac{1}{\lambda}} \times [(X^{\lambda} - a)]^{\frac{1}{\lambda}} if X \geq a^{\frac{1}{\lambda}}$ with $\lambda = 0.41$, a = 5.396 (± 0.086 [g$^{\lambda}$]) and b = 0.635 (± 0.024 [(%/g)$^{\lambda}$]).

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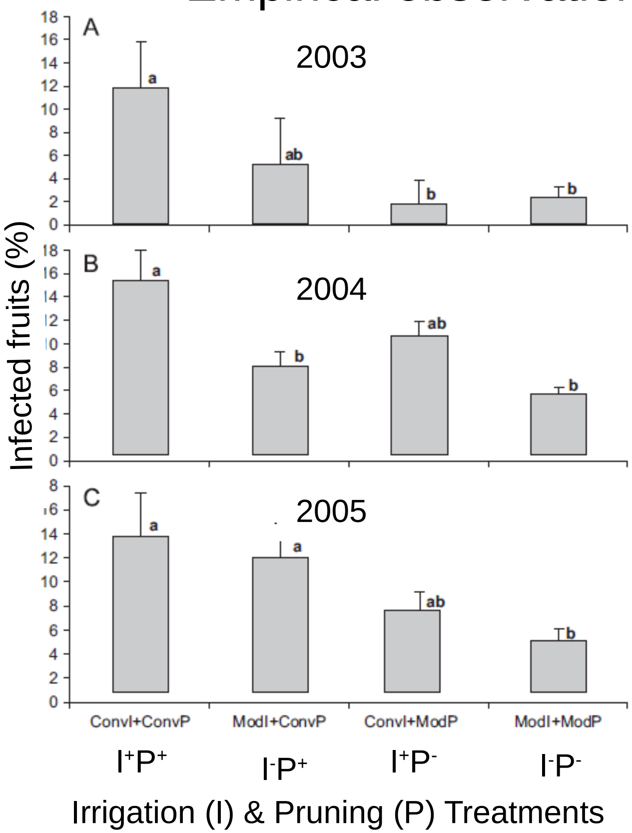

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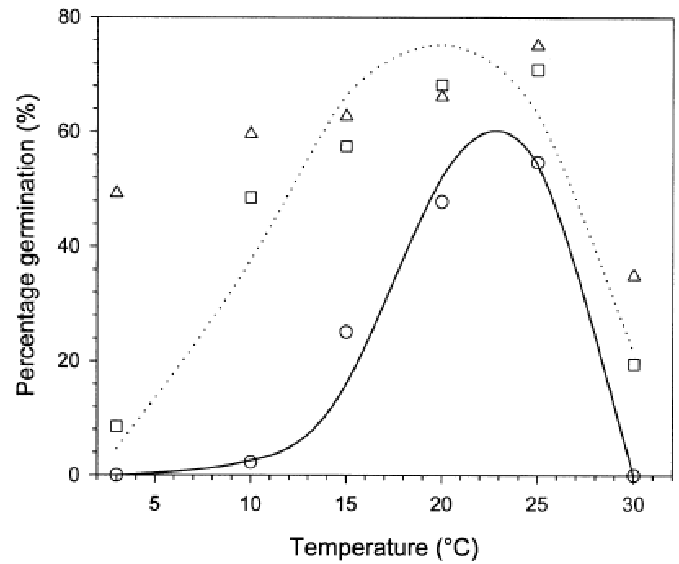

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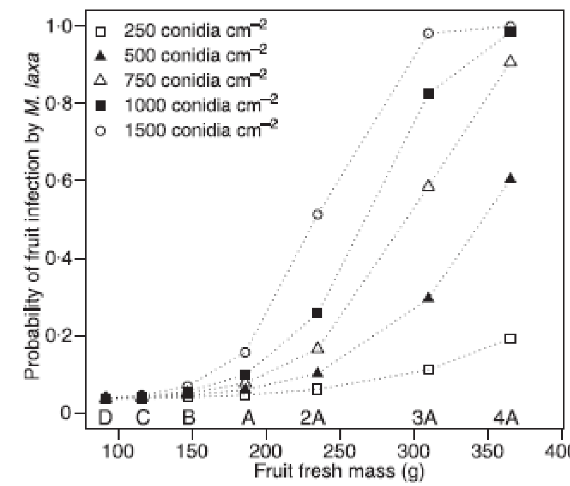

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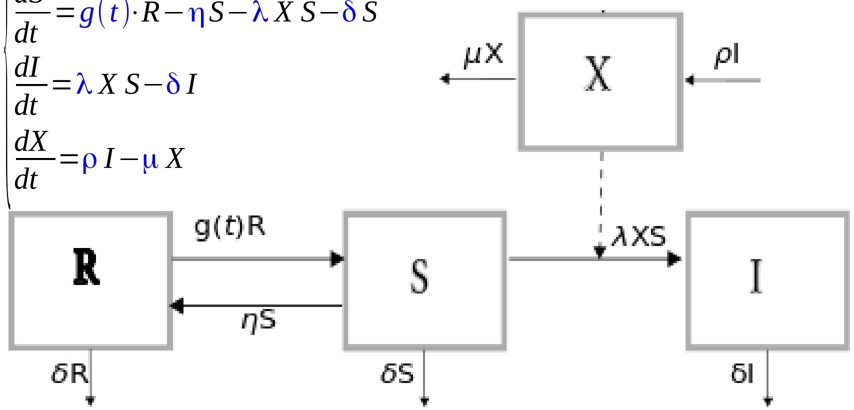
Aim of present work:

- Develop a general mechanistic modelling framework for brown rot spreading
- Apply the model to a real study case (*Prunus persica – monilinia* spp)
- Derive general guidelines for brown rot control in peach orchards

The model

$$\begin{cases} \dfrac{dR}{dt} = \eta S - g(t)\cdot R - \delta R \\ \dfrac{dS}{dt} = g(t)\cdot R - \eta S - \lambda X S - \delta S \\ \dfrac{dI}{dt} = \lambda X S - \delta I \\ \dfrac{dX}{dt} = \rho I - \mu X \end{cases}$$



Variable Param.	Definition
R	Resistant fruits
S	Susceptible fruits
I	Infected fruits
X	Pathogen
g(t)	Cracking rate
η	Crack healing rate
δ	Fruit dropping rate
λ	Infection rate
ρ	Path. Reproduction rate per infected host
μ	Path. Mortality rate

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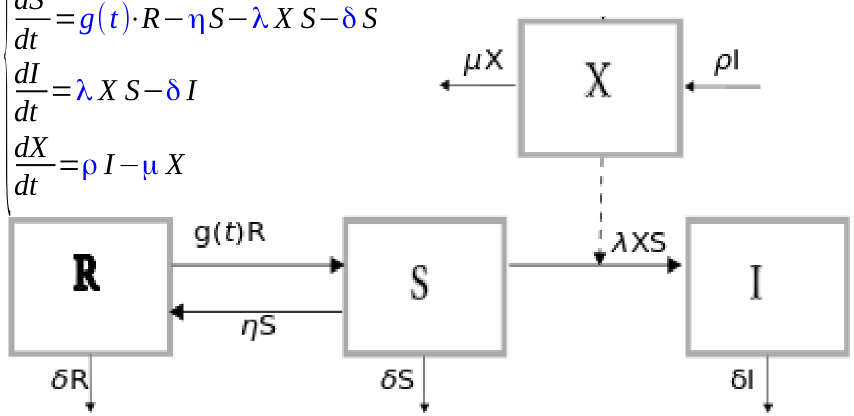

Cracking rate assumptions:

Null under a critical fruit mass (FM)

Proportional to fruit growth

$$g(t) = \begin{cases} 0 & for \quad FM < FM_{CR} \\ c\,\dfrac{d\,FM(t)}{dt} & for \quad FM \geq FM_{CR} \end{cases}$$

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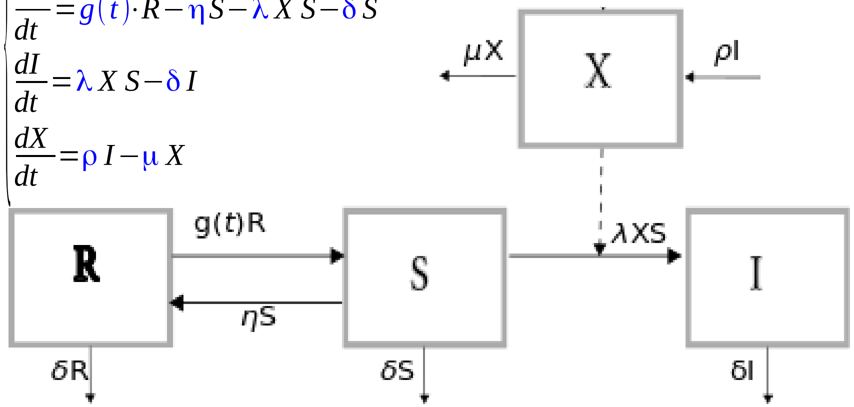

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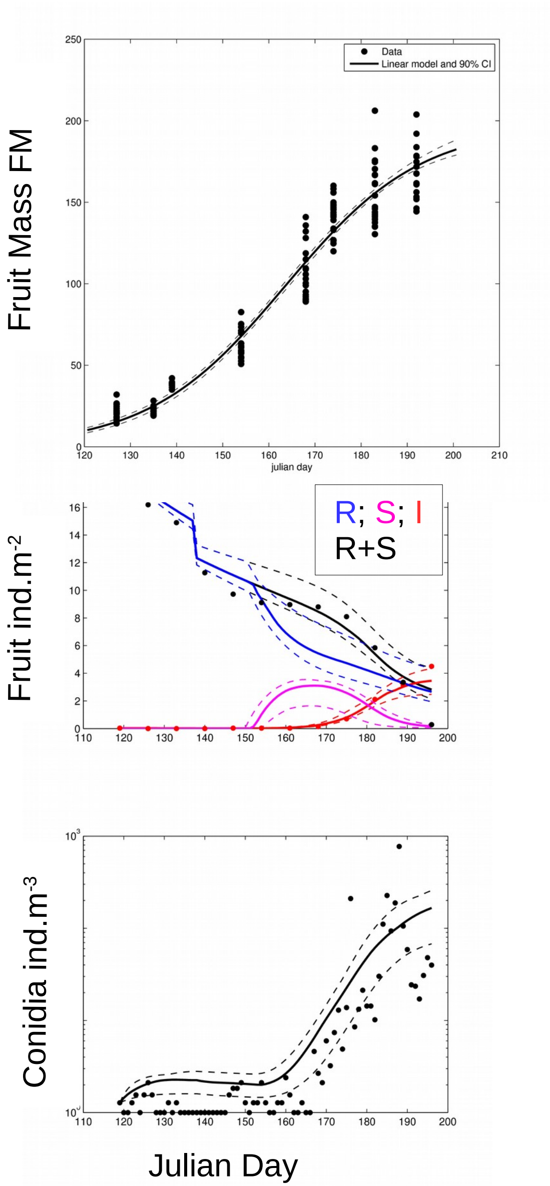
Available data

An experimental peach orchard of 43 trees not treated with fungicide. 18 trees monitored every other week from 5th May (after thinning) until 31th July (before harvest):

- Fruit size
- Fruit status, i.e. healthy (R+S) or infected (I)
- Airborne pathogen density

Calibration, analysis & simulations

Parameter estimate and uncertainty (MC methods)



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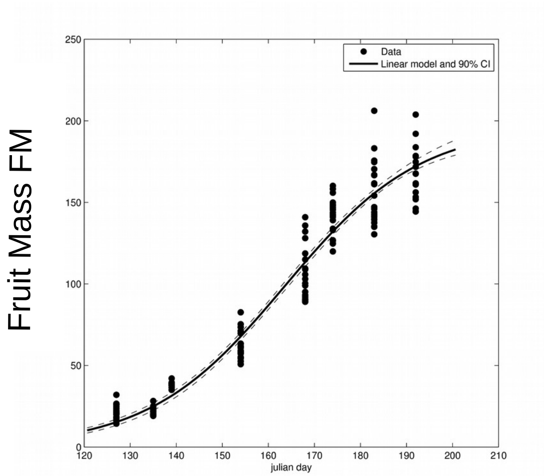
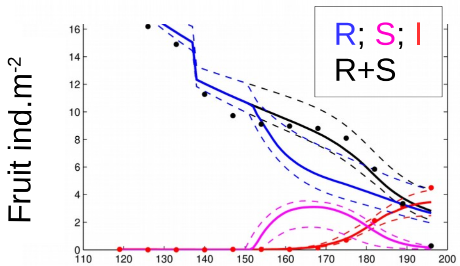
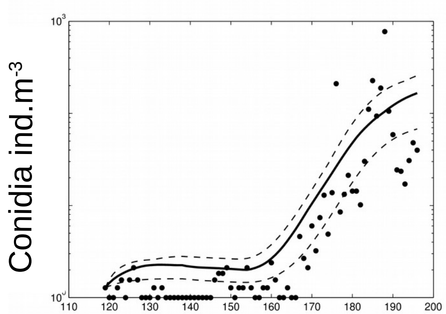
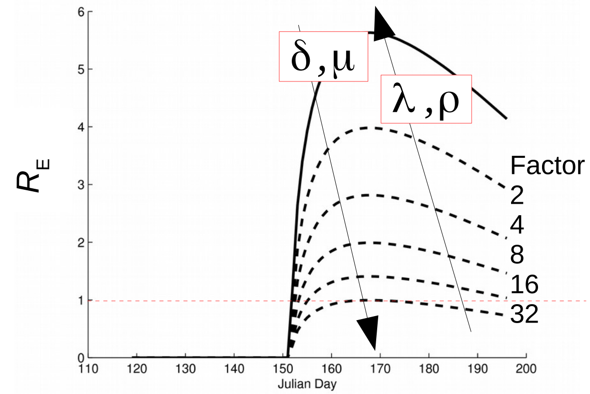


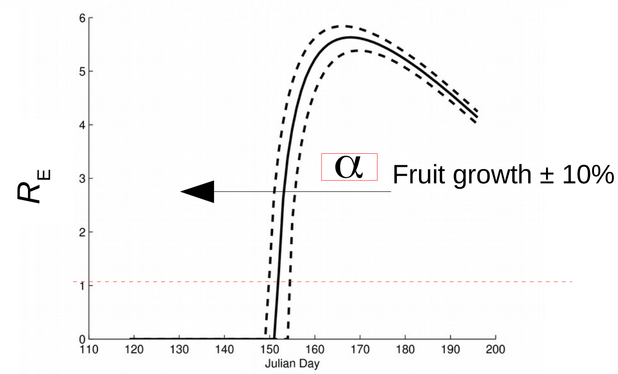


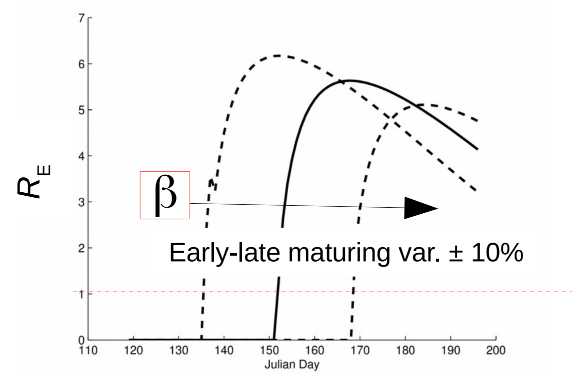


Reproductive number sensitivity

$$R_E = \sqrt{\frac{\lambda \rho S(t)}{\delta \mu}}$$







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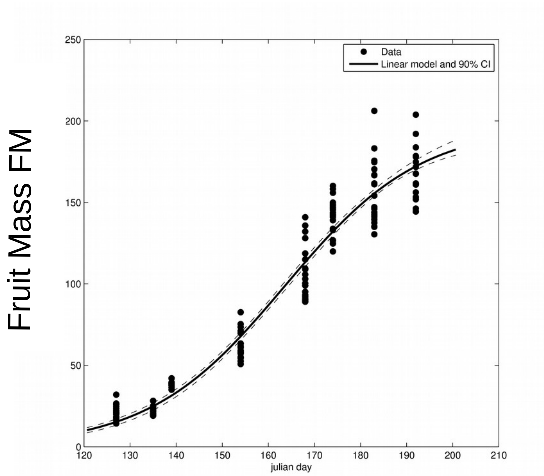
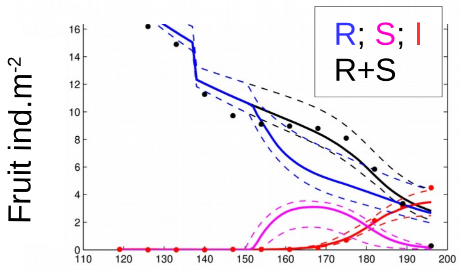
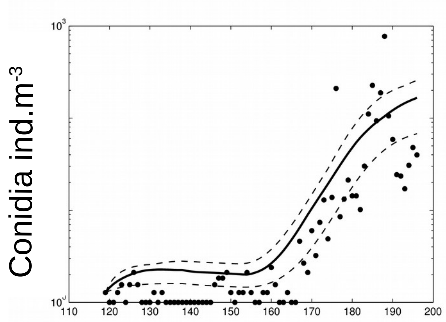
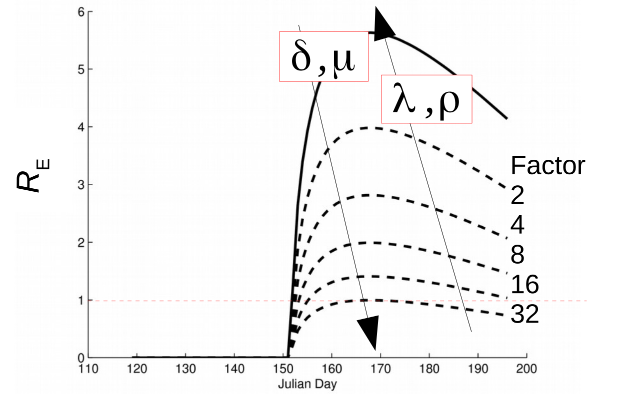
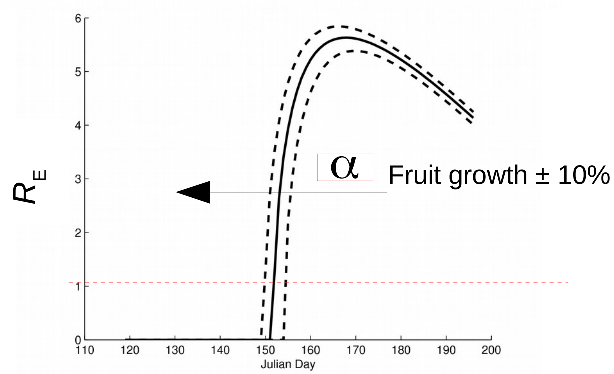
Yield sensitivity

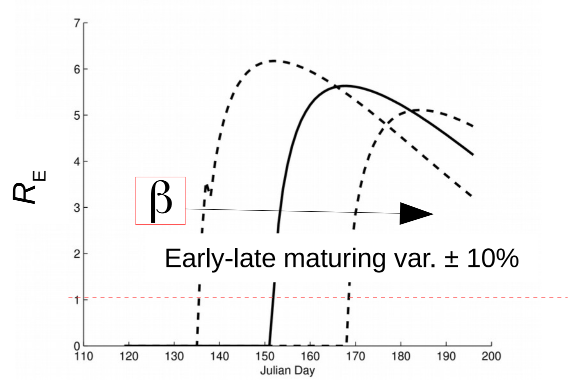


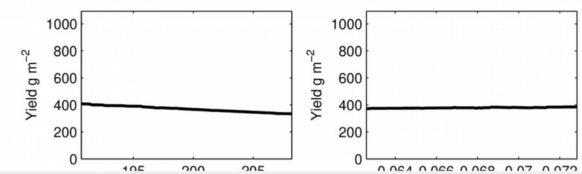












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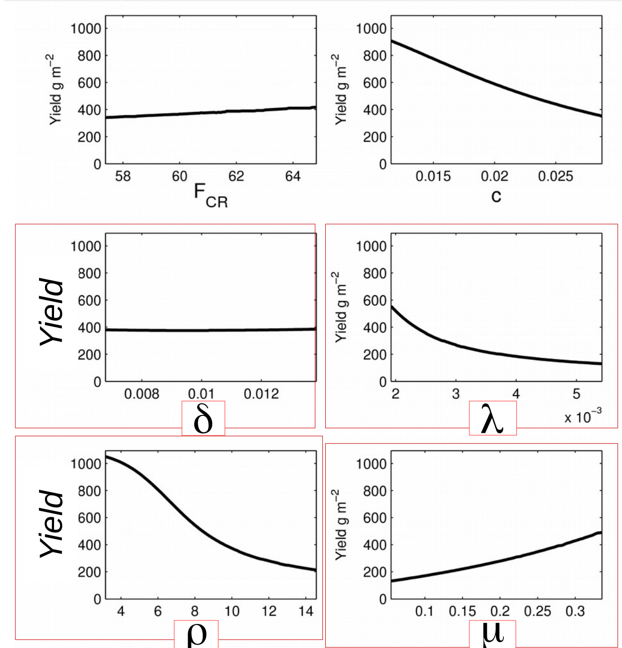

Main findings & further work

- The assumptions of the conceptual model are likely to hold in the real world
- In favorable environmental conditions it is very difficult to impair brown rot spreading
- Fungicide application can be minimized with applications in a given temporal framework
- In absence of fungicide treatments, yield can be enhanced by
  - Decreasing fruit growth
  - Decreasing fruit density

NEXT: Quantify relationships between environmental conditions, possibly controlled by management practices, and model parameter values

Acknowledgments:
This work has been partly carried out as part of the ECOVERGER project funded by ONEMA within the call APR "Résistance et pesticides" managed by the MEDDE French ministry.