# Adapting STICS-MILA crop model to Yellow Rust of Winter Wheat

## from calibration to simulation of climate change impacts

*Eugène Masson, Tiphaine Vidal, Marie-Odile Bancal, Doriane Hamernig, Patrice Lecharpentier, Dominique Ripoche, Laurent Huber, Marie Launay*

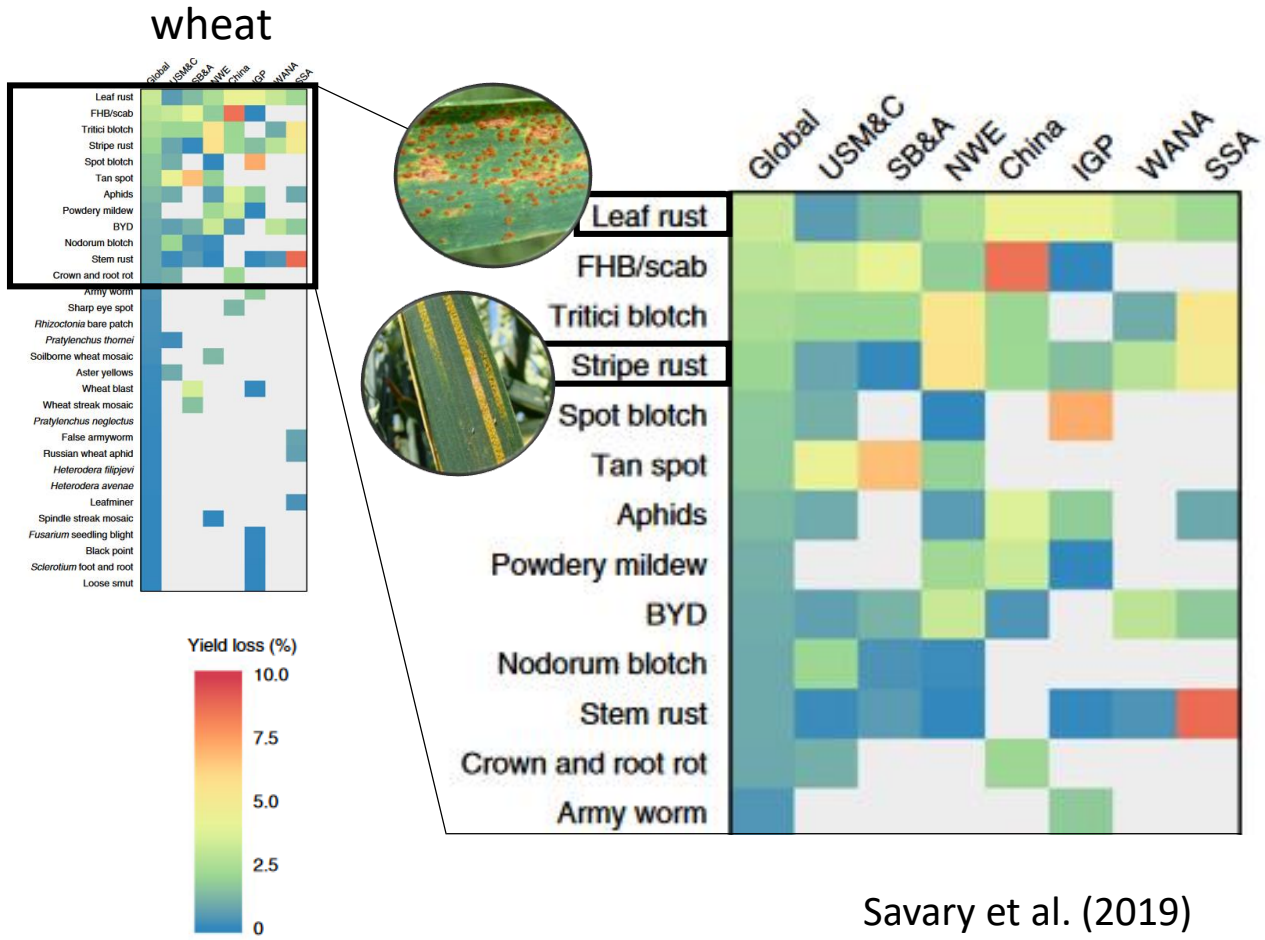
**XIII Séminaire STICS**
**13-16 Novembre 2023**
**Aérocampus Aquitaine Floirac**

Mercredi 15 novembre 2023
Session 4 – Systèmes de culture et changement climatique

Cland
INRAE la science pour la vie, l'humain, la terre
AgroParisTech Talents d'une planète soutenable
université PARIS-SACLAY
ARVALIS

# Plant diseases and climate change

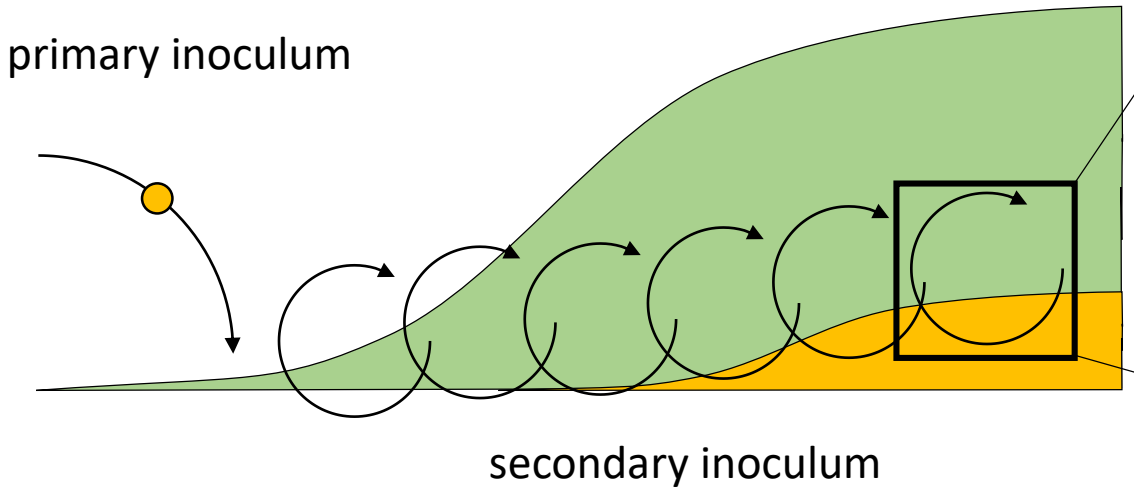
- Importance of plant diseases
  - Foliar diseases reduce green area, thus impacting yield in the absence of control
  - A limited number of diseases cause extensive yield losses

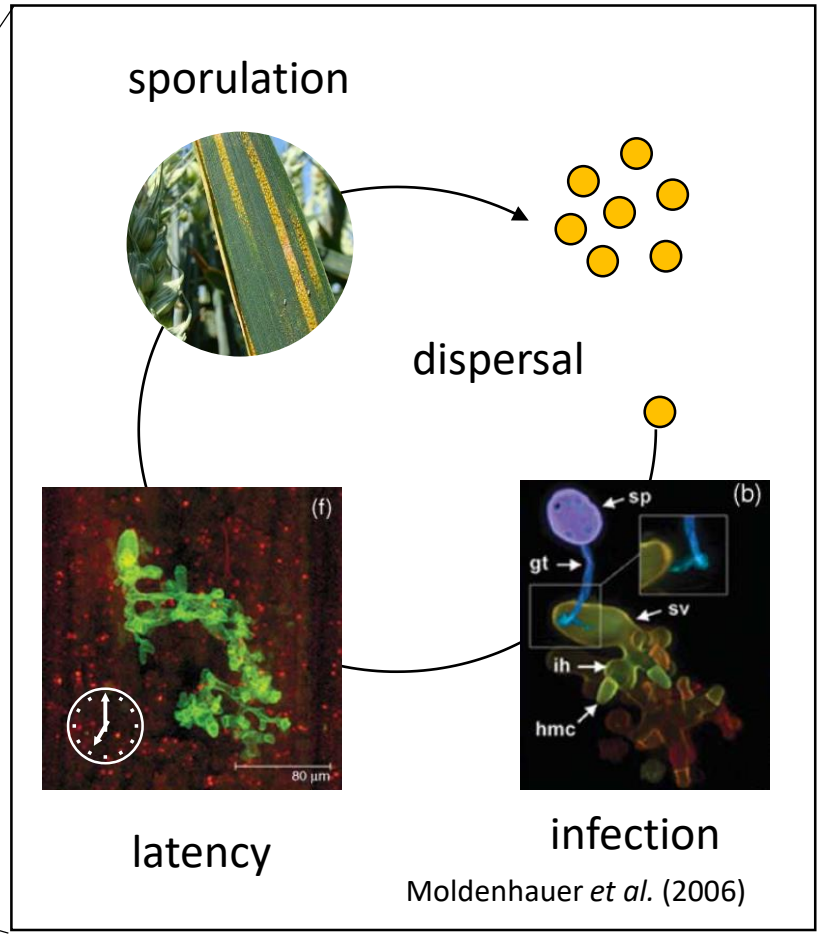



Savary et al. (2019)

# Plant diseases and climate change

- Importance of plant diseases
- Disease propagation

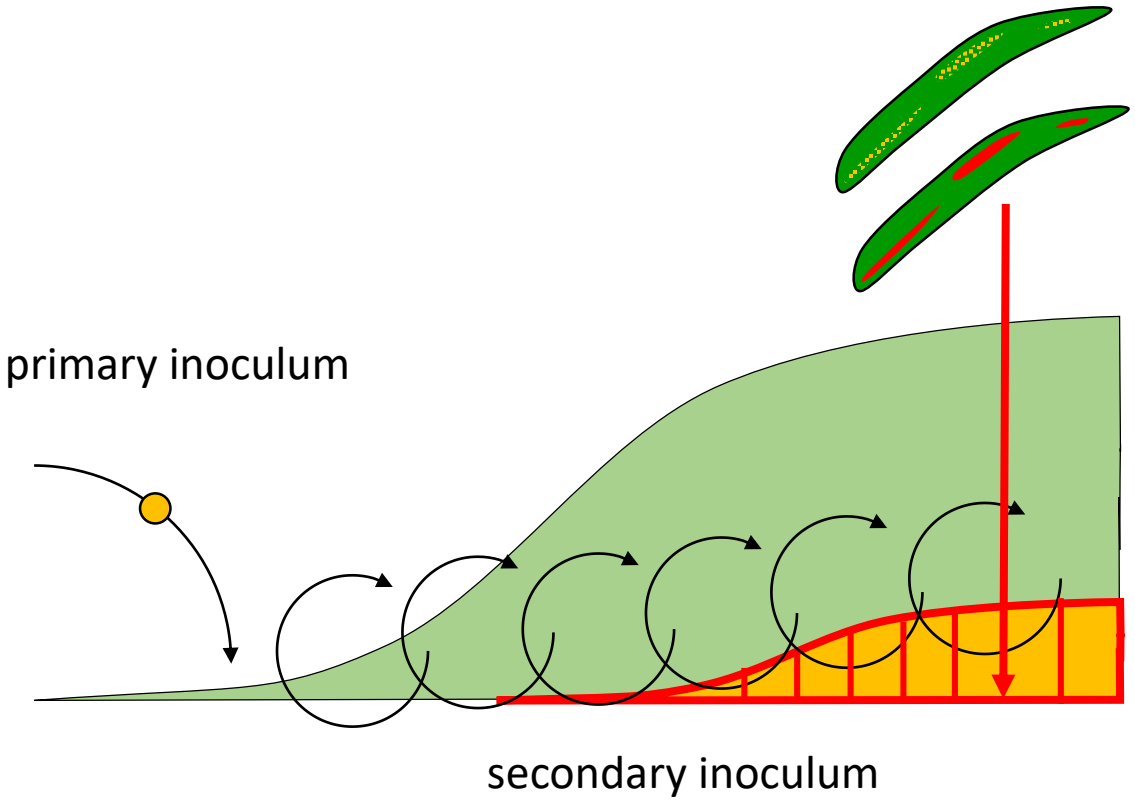



Moldenhauer *et al.* (2006)

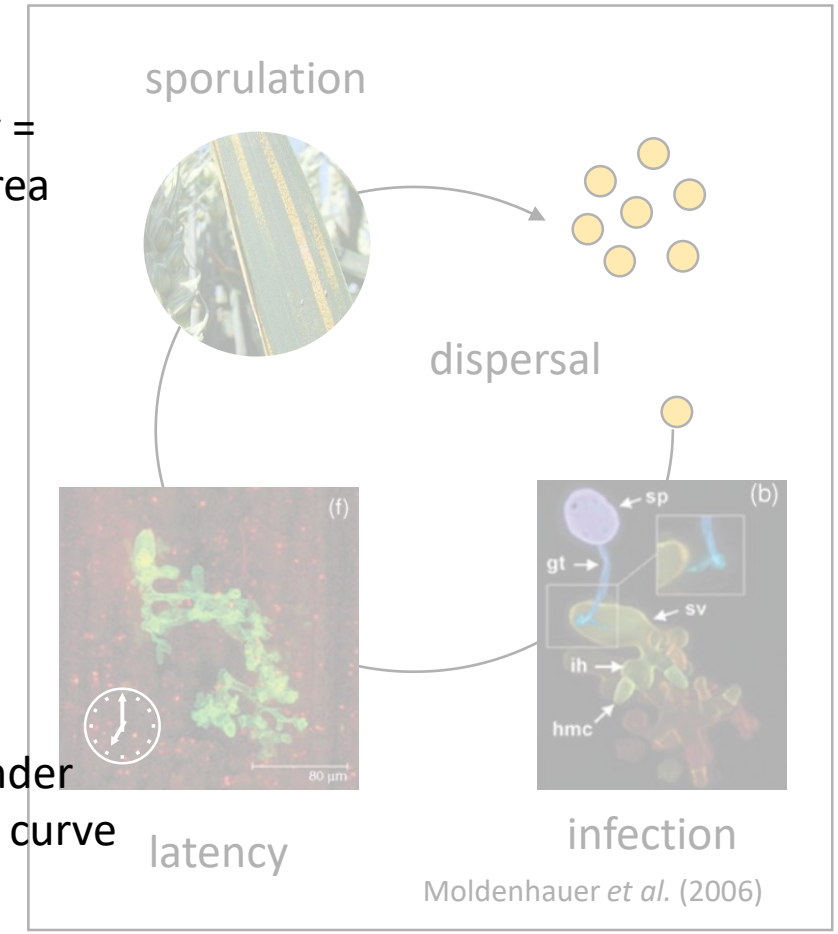
# Plant diseases and climate change

- Importance of plant diseases
- Disease propagation



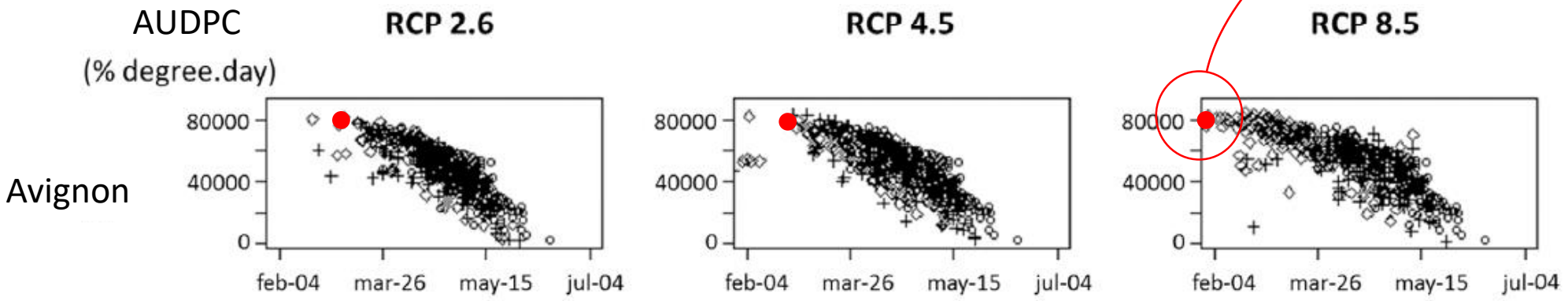

Disease severity =
% sporulating area

AUDPC = area under
disease progress curve



# Plant diseases and climate change

- Importance of plant diseases
- Disease propagation
- Impact of climate change on leaf rust




Date at which 5% of disease severity is reached

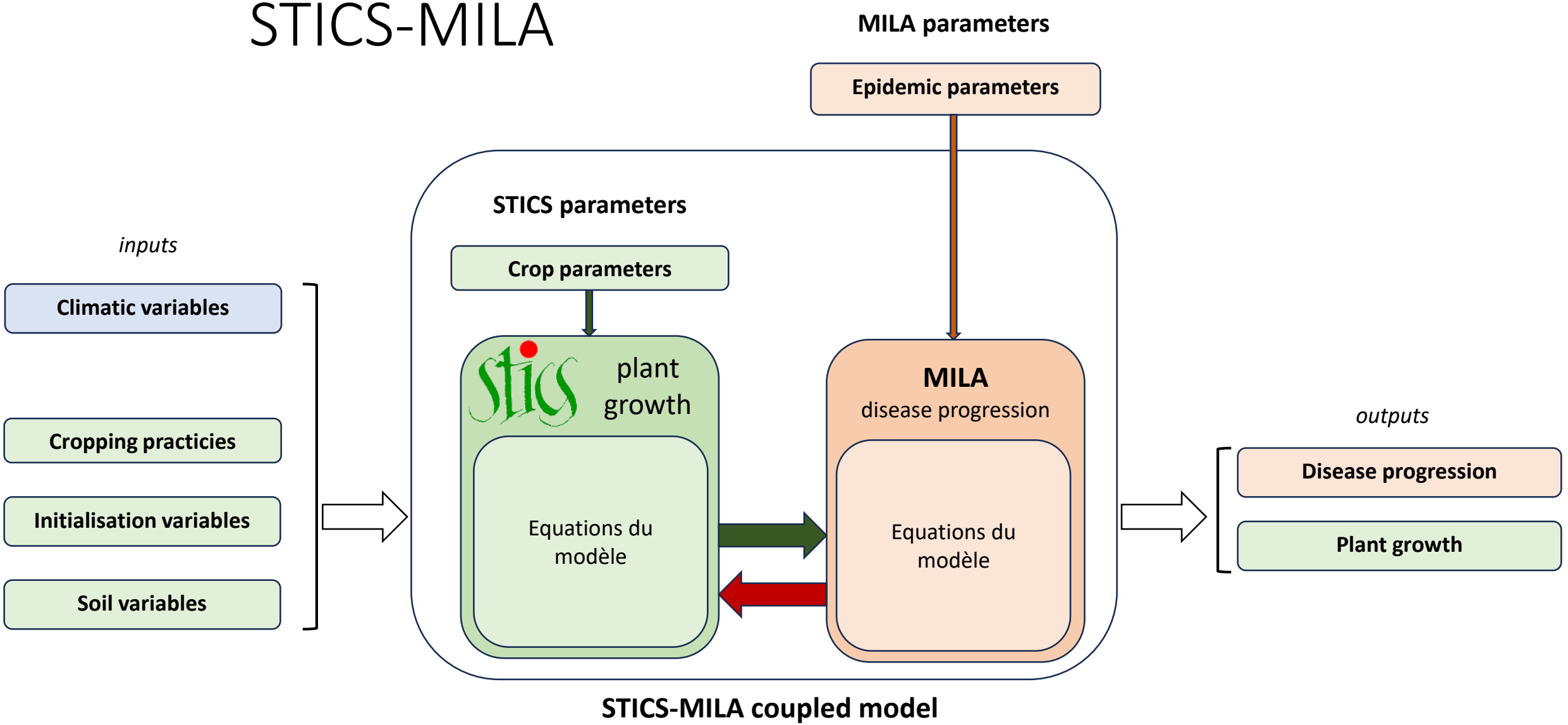
Caubel et al. (2017)

# Impact of climate change on yellow rust epidemics ?

- Case of yellow rust (YR), caused by *Puccinia striiformis* f.sp. *tritici* (*Pst*)

- Adaptation of leaf rust model based on data from litterature
- Comparison of model simulation with field data
- Numerical experiments: impact of climate change on epidemics

# STICS-MILA


MILA parameters
Epidemic parameters
STICS parameters
Crop parameters
inputs
Climatic variables
Cropping practicies
Initialisation variables
Soil variables
plant growth
Equations du modèle
MILA
disease progression
Equations du modèle
outputs
Disease progression
Plant growth
STICS-MILA coupled model

# Parameterizing STICS Mila for yellow rust

## Infection

- Eimax = 0,251

- Tmin= 0 °C
- Topt2 = 8,75 °C
- Topt1 = 7,74 °C
- Tmax = 21,5 °C

- Aweibull = 0,133
- Bweibull = 1,37

*Vidal et al. 2022*
*De Vallavieille-Pope et al. 1994*

## Latency

- Lat_min = 14,2 j

- Tmin= 4,67 °C
- Topt = 18,8 °C
- Tmax = 26,3 °C

*Vidal et al. 2022*

## Sporulation

- Surf_les = 0,00007 mm

- Tmin= 0 °C
- Topt2 = 6,6 °C
- Topt1 = 13,3 °C
- Tmax = 20,2 °C

- Kverhulst = 3300000
- Rverhulst = 2

*Mc Gregor and Manners (1985)*
*Sache et de Vallavieille-Pope 1993*

## Life duration of lesions

- DVmax = 14 j

- Tmin= -6,43 °C
- Topt = 8,64 °C
- Tmax = 41,3 °C

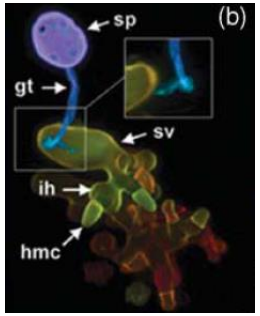
*Mc Gregor and Manners (1985)*

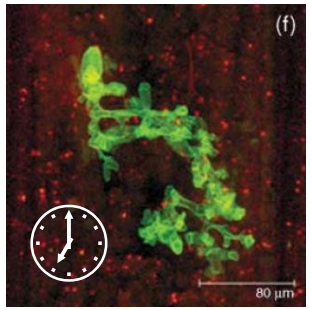
## Life duration of spores

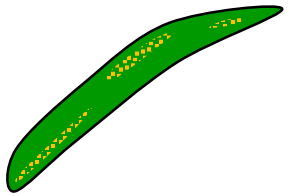
- DVmax = 8,9 j

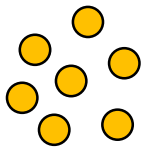
- Tmin= -16,94 °C
- Topt = 5 °C
- Tmax = 50,2 °C

*Dennis (1987)*



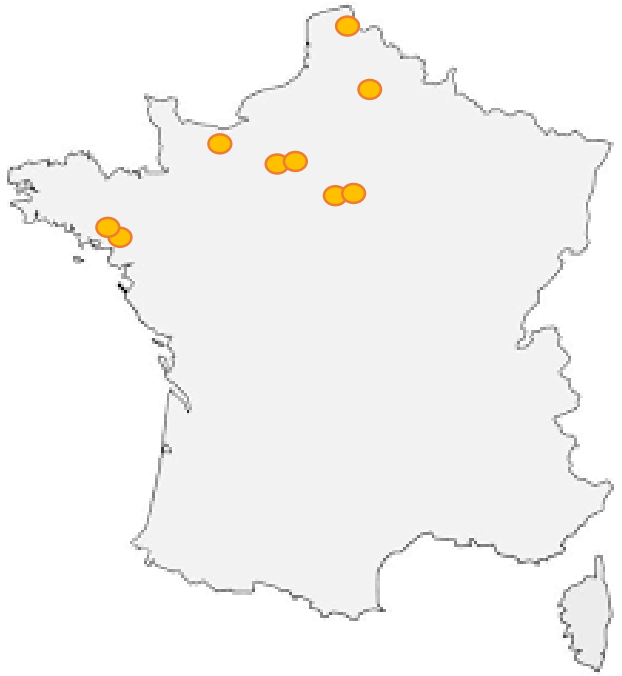



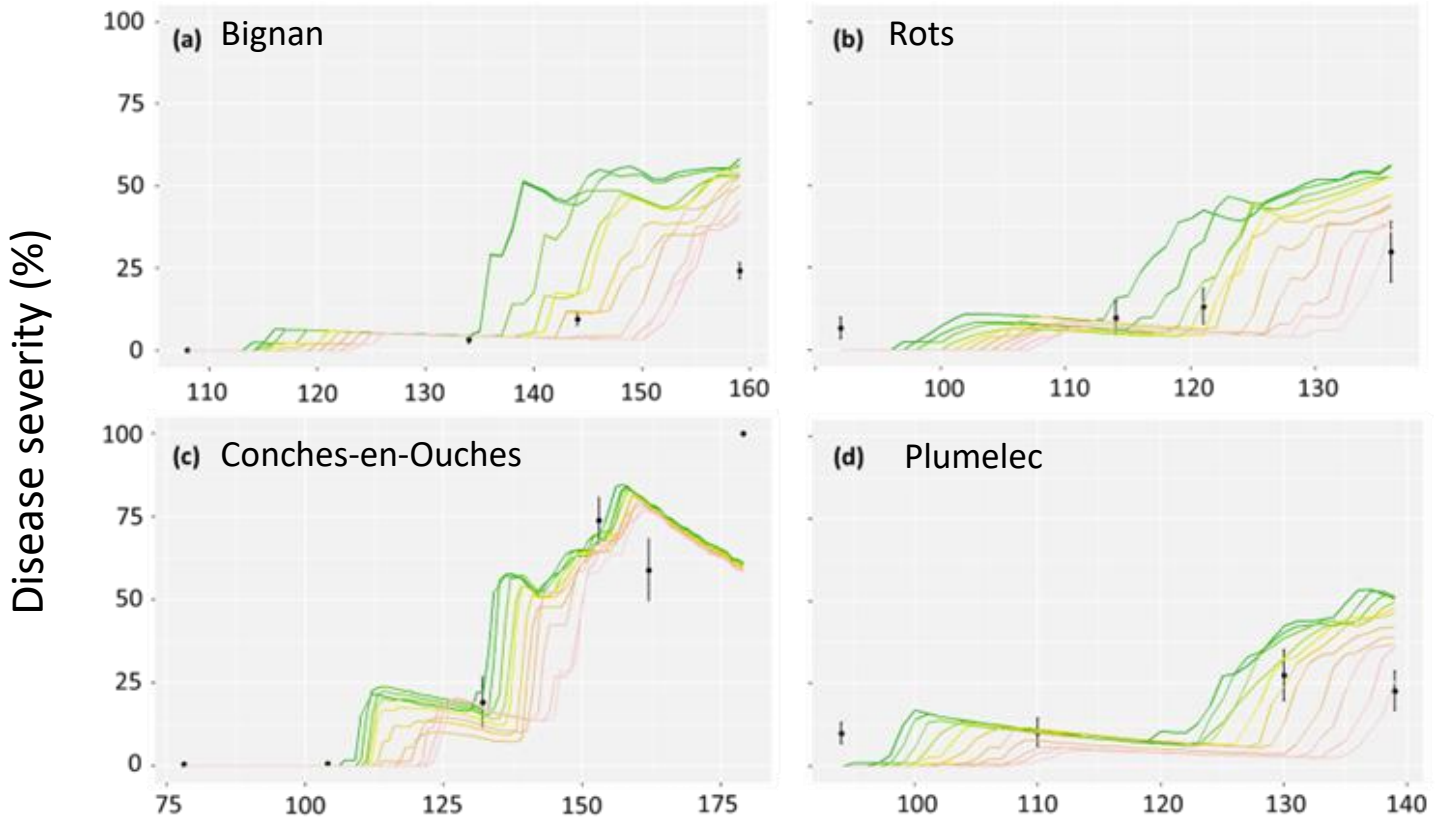


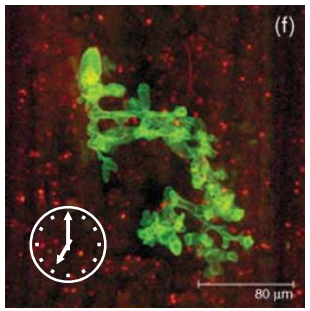
# Assessement of model behaviour

- Model assessment dataset (Arvalis)
- Non treated and inoculated field trials
- 10  trials in 7 different sites (favorable to YR)
- 7 cultivars (+/- resistant to YR)

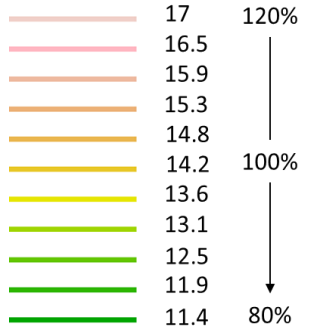


# Adjusting the model to experimental data




LATENCY PERIOD

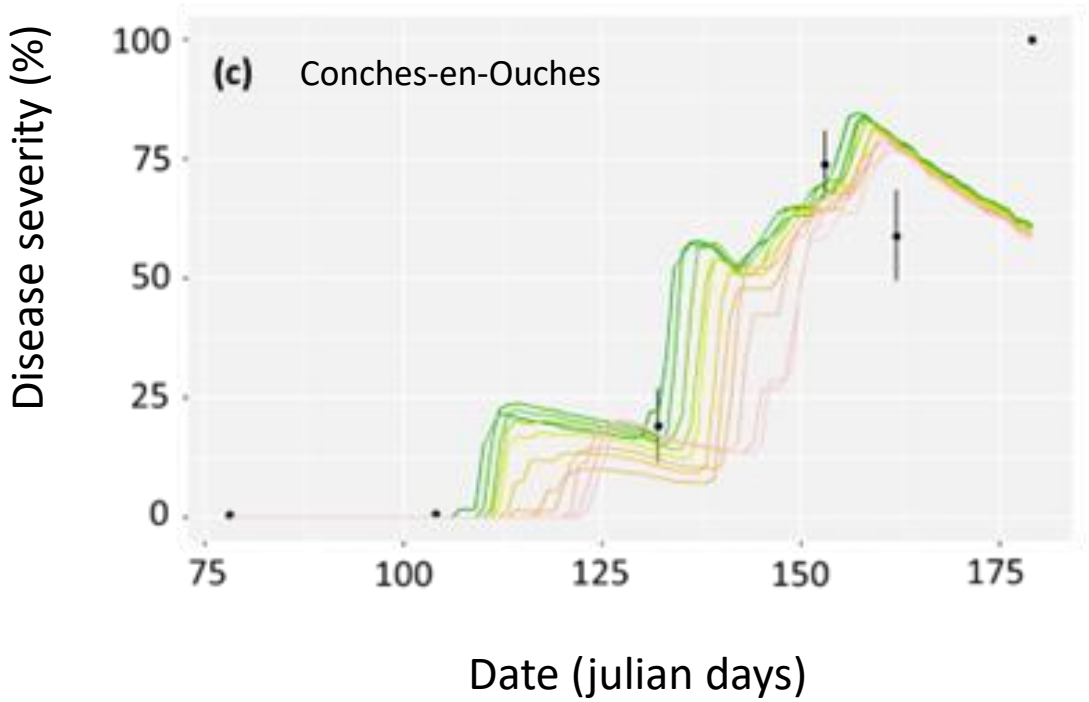


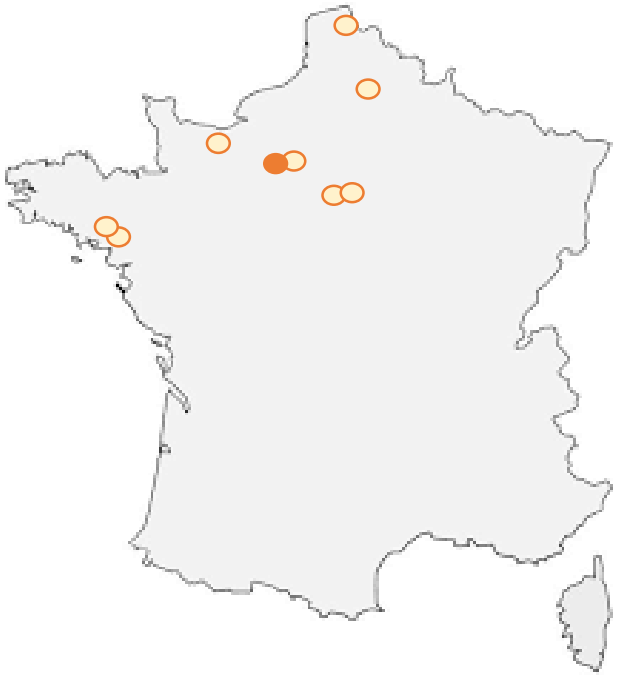

Reference parameter value

case of a susceptible cultivars

# Simulating the impact of CC on YR epidemics

- One site where simulation are well simulated
  - Conches-en-Ouches



# Simulating the impact of CC on YR epidemics

- One site where simulation are well simulated
  - Conches-en-Ouches

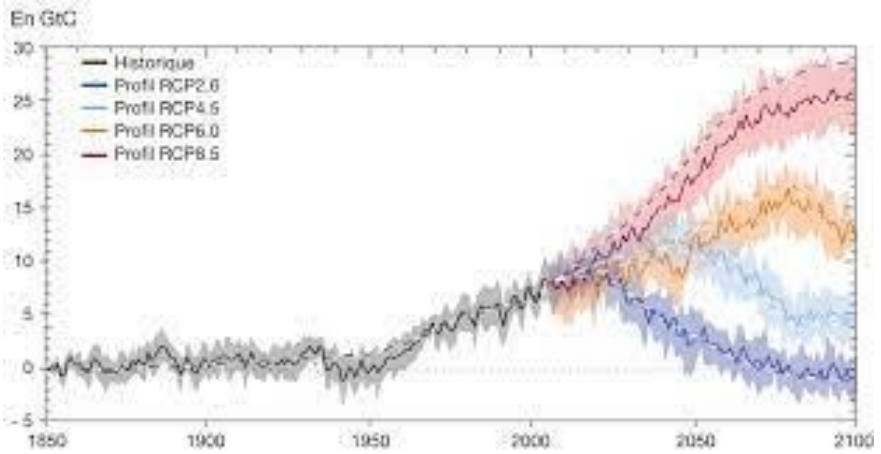
- Climatic data generated using 3 different models
  - CNRM.Aladin, CNRM.Racmo, EC.Eart.Racmo
  - Mean of 3 model outputs used to generate climatic data

# Simulating the impact of CC on YR epidemics

- One site where simulation are well simulated
  - Conches-en-Ouches

- Climatic data generated using 3 different models
  - CNRM.Aladin, CNRM.Racmo, EC.Eart.Racmo
  - Mean of 3 model outputs used to generate climatic data

- Two climatic scenarios were tested
  - RCP 4.5: limitation of green house gas emissions to a low level
  - RCP 8.5: climatic intaction and constant increase of GHG emissions



# Simulating the impact of CC on YR epidemics

- One site where simulation are well simulated
  - Conches-en-Ouches

- Climatic data generated using 3 different models
  - CNRM.Aladin, CNRM.Racmo, EC.Eart.Racmo
  - Mean of 3 model outputs used to generate climatic data

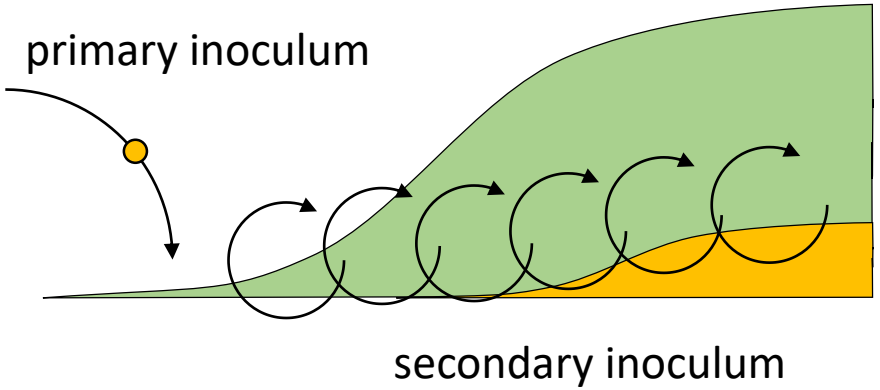
- Two climatic scenarios were tested
  - RCP 4.5: limitation of green house gas emissions to a low level
  - RCP 8.5: climatic intaction and constant increase of GHG emissions

- 3 study periods (Recent past : 1990-2020; Near future : 2030-2060; Far future : 2070-2100)

# Simulating the impact of CC on YR epidemics

- One site where simulation are well simulated
  - Conches-en-Ouches

- Climatic data generated using 3 different models
  - CNRM.Aladin, CNRM.Racmo, EC.Eart.Racmo
  - Mean of 3 model outputs used to generate climatic data



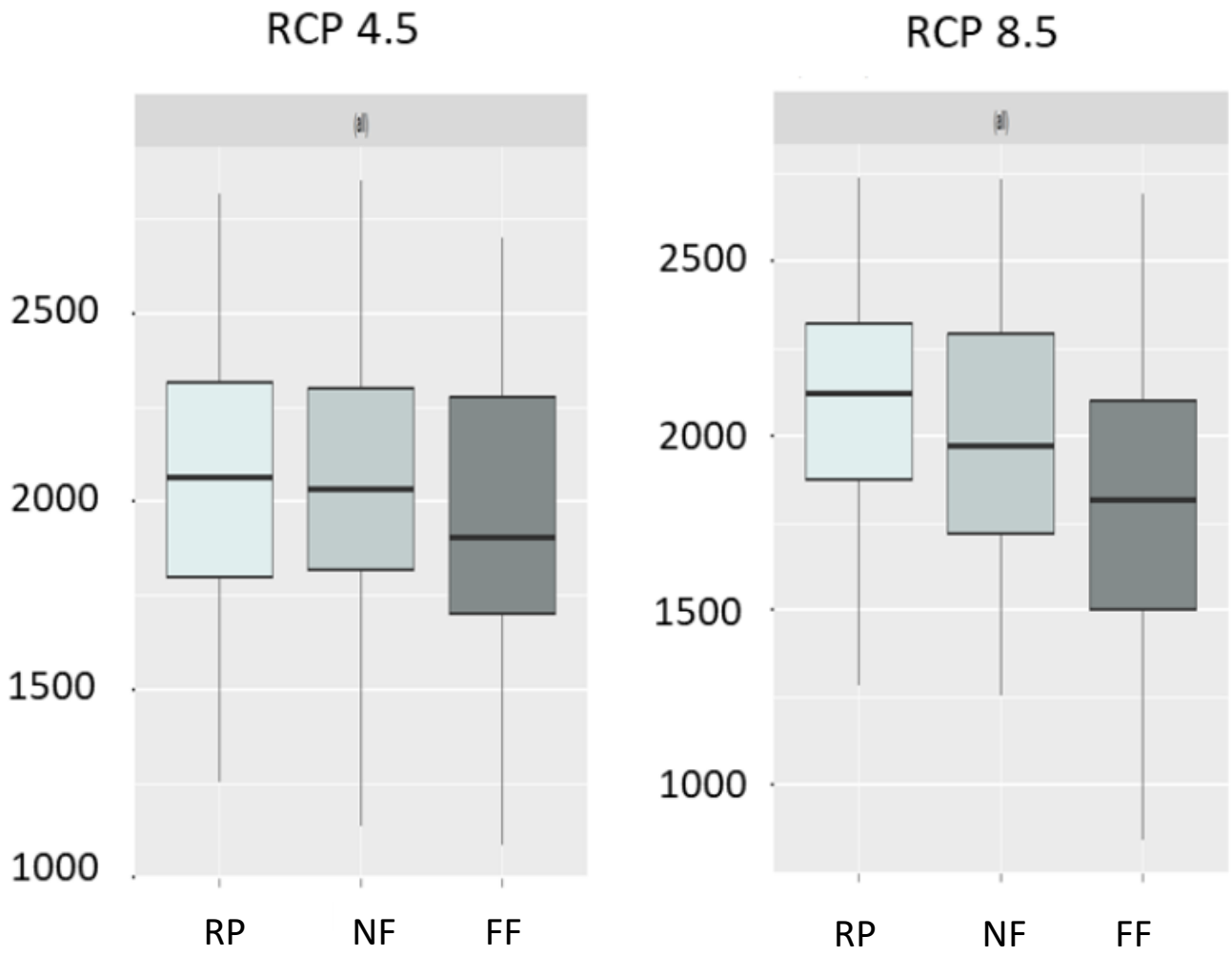

- Two climatic scenarios were tested
  - RCP 4.5: limitation of green house gas emissions to a low level
  - RCP 8.5: climatic intaction and constant increase of GHG emissions

- 3 study periods (Recent past : 1990-2020; Near future : 2030-2060; Far future : 2070-2100)

- 3 densities of primary inoculum (100; 1000; 10 000 spores/m2)

# A tendency for reduced YR epidemics

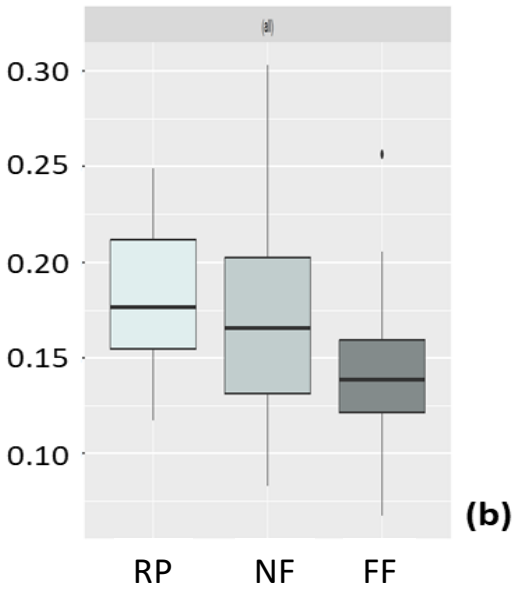
**Epidemic intensity**
(area under disease progress curve – assessed in % severity)



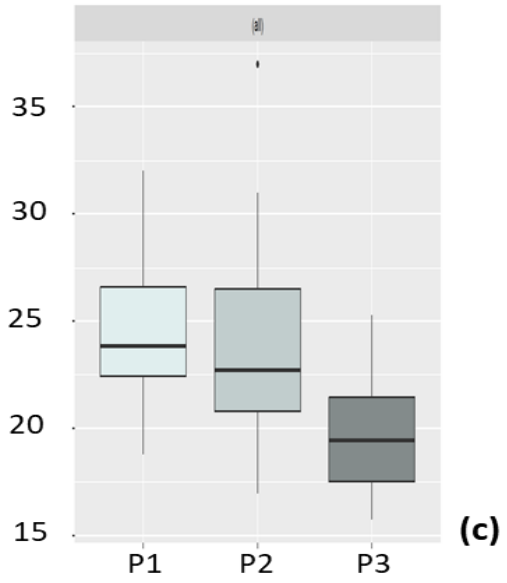
# Evolution of pathogen performance

Mean pathogen performance during stem elongation (BBCH 31-39, RCP8.5)

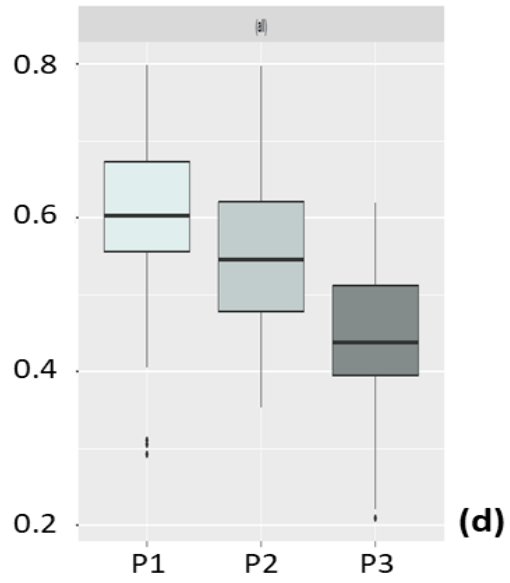
Infection efficiency




Latency period




Sporulation rate




Lower infection efficiency = less spores causing sporulation

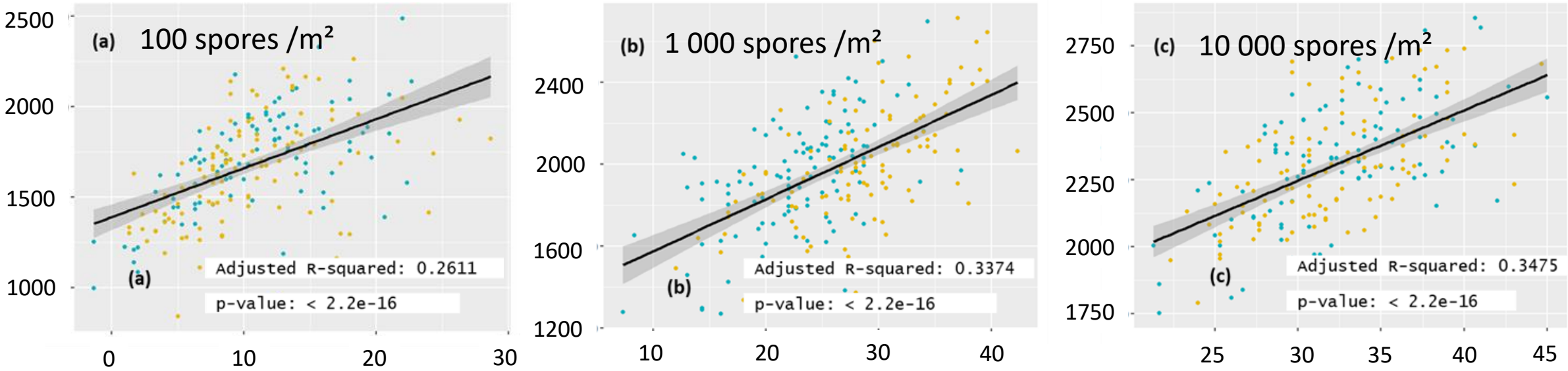
Shorter latency period = more cycles

Lower sporulation rate

# Impact of primary inoculum

**Epidemic intensity**
(area under disease progress curve)

Epidemics can start earlier (up to 45 days before flag leaf ligulation) and cause more intense epidemics with high primary inoculum




**Delay between start of the epidemy and crop growth**

Date of flag leaf ligulation – date of start of the epidemic (5% severity)

RCP 4.5 RCP 8.5

# Discussion

- Under-estimation of current performance under high temperatures ?
  - Thermal response curves were based on historical datasets
    - Adaptation to high temperature has been characterized for recent european isolates
  - YR causes high impacts in some warm regions of the world
    - High light intensity can compensate for high temperature
    - Low temperature can allow infection at night when it is impossible during the day
- Possible adaptation of fungi populations to future climatic conditions
- Primary inoculum has a large impact
  - Importance of oversummering and overwintering

# Next step

- A first assessment of model behaviour
  - Extend assessment dataset
    - More trials in contrasted pedoclimatic conditions
    - More information on trial conditions (soil, crop management, …)
    - More dates of observations of epidemics
- Numerical experiments on one site
  - Extend to larger scale
- Sensitivity analysis
  - Impact of pathogen parameters
    - Response to climatic conditions
- To go fowards: factors determining primary inoculum
  - From arbitrary parameter setting to mechanistic understanding ?

# Thank you for your attention

Questions ?

Contact: tiphaine.vidal@inrae.fr