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# Impact of climate change on fungal diseases of agroecosystems

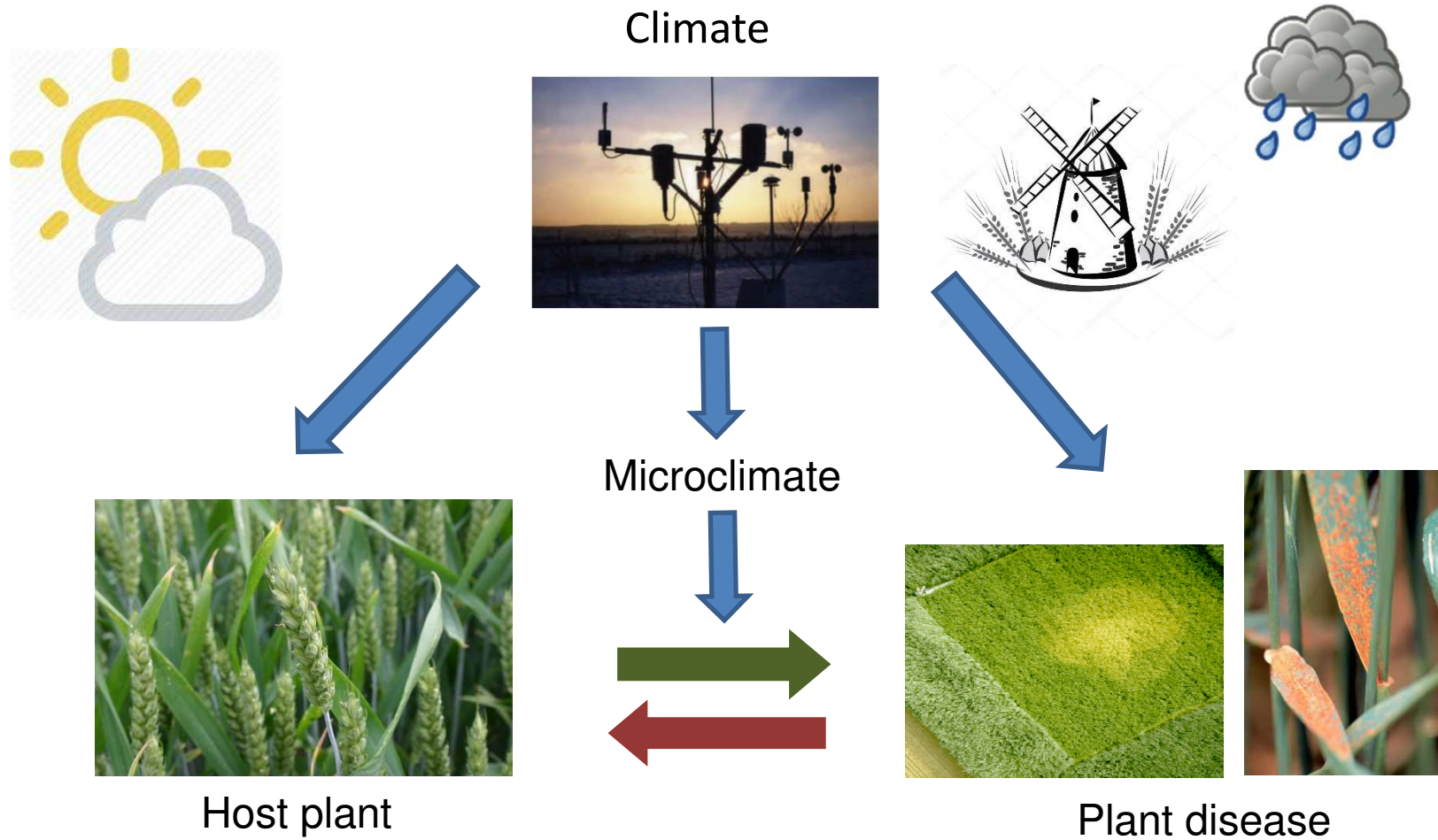
*L. Huber<sup>1</sup>, M.-O. Bancal<sup>2</sup> and M. Launay<sup>3</sup>*

*<sup>1</sup>INRA, Joint Research Unit EcoSys, Thiverval-Grignon, France*

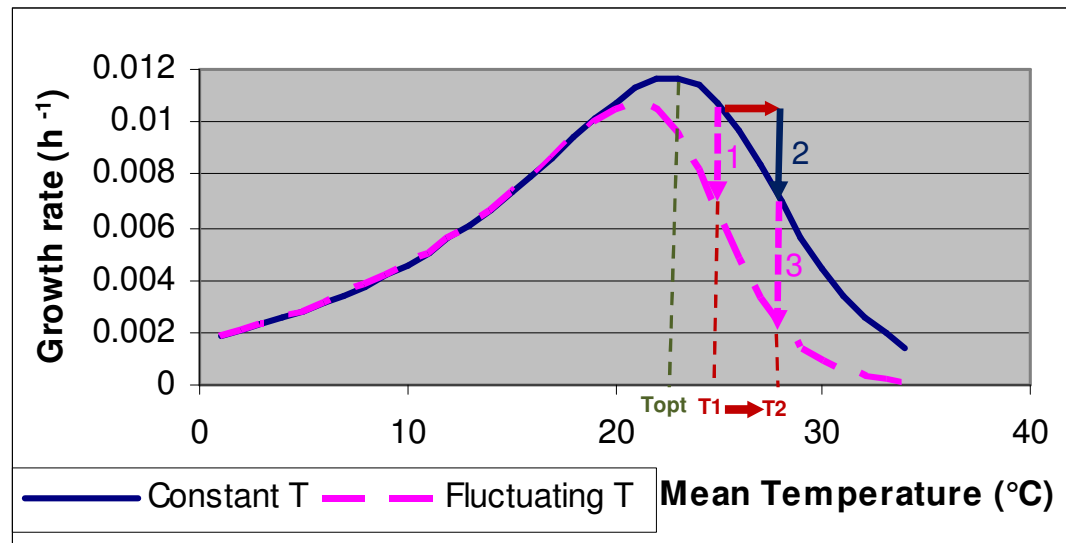
*<sup>2</sup>AgroParisTech, Joint Research Unit EcoSys, Thiverval-Grignon, France*

*<sup>3</sup>INRA, AgroClim Unit, Avignon, France*

# *Past and recent climate : temporal and spatial variability*



# Fungal growth response to temperature



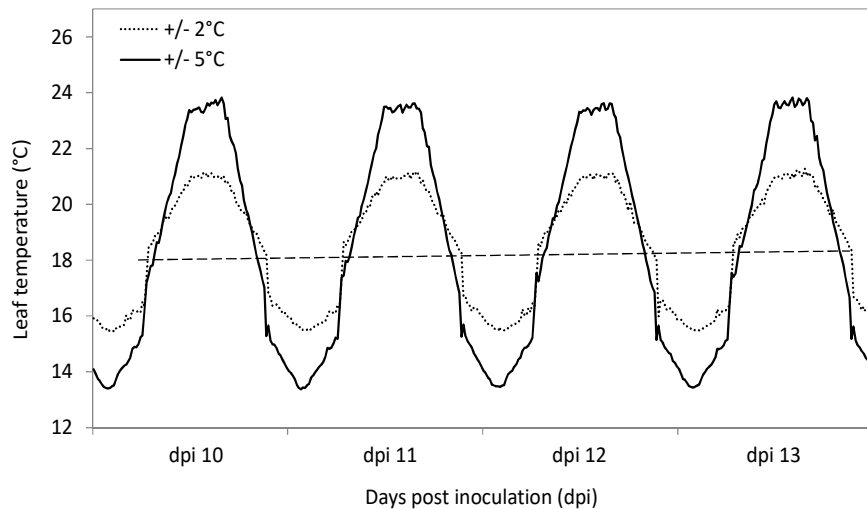
For  $T_{\text{mean}} > T_{\text{opt}}$  :

1. At  $T_1$  under fluctuating T  
⇒ Growth rate ↓
2. From  $T_1$  to  $T_2$  at Constant T  
⇒ Growth rate ↓
3. At  $T_2$  under fluctuating T  
⇒ Growth rate ↓ ↓

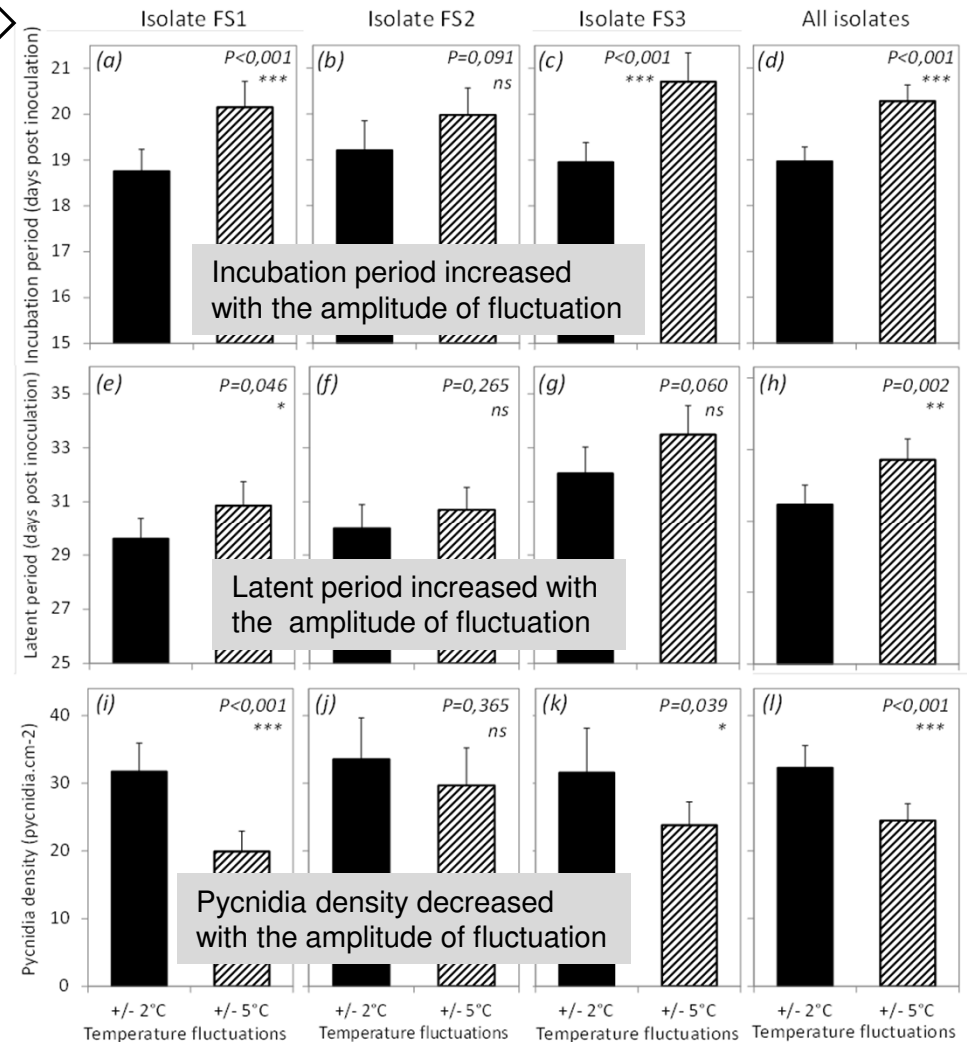
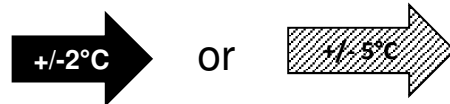
Experiments under controlled conditions of **constant** or **fluctuating** temperature and **global warming**  $T_2 - T_1$  (→)

# Fungal growth response to the leaf temperature fluctuating around optimal temperature

Fungal pathogen :  
*Zymoseptoria tritici* with 3 isolates



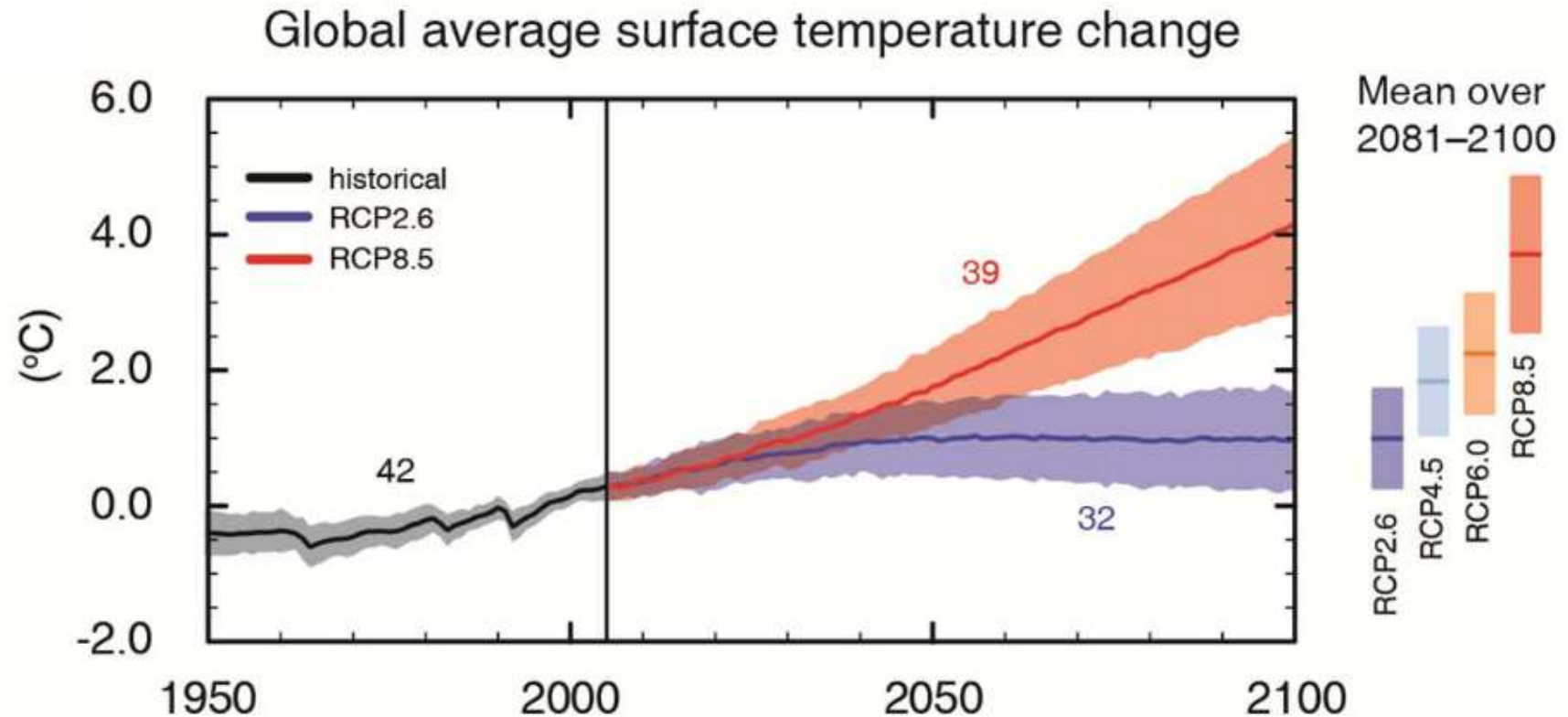
Experiments under controlled conditions on adult wheat plants  
 T<sub>optimal</sub> = T<sub>mean</sub> = 18 °C with fluctuations of temperature





# Climate change in the near and far future

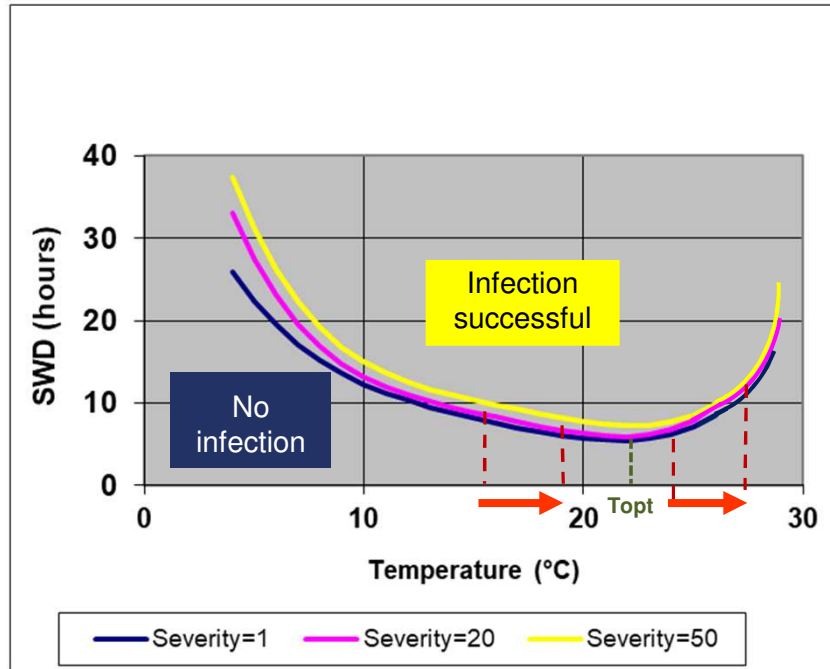
## 1. Solutions for continuous variables such as temperature



## 2. What about intermittent variables such as rainfall and leaf wetness duration ?

(IPCC, 2014)

# Temperature-dependent response of fungal infection to leaf wetness duration



For  $T < T_{optimal}$  :

$T \nearrow \Rightarrow SWD \searrow$

$\Rightarrow$  Potential opportunity for the pathogen

For  $T > T_{optimal}$  :

$T \nearrow \Rightarrow SWD \nearrow \nearrow$

$\Rightarrow$  Potential threat for the pathogen

Experiments on infection efficiency under controlled conditions of temperature and Surface Wetness Duration with **virtual global warming of + 3 °C ( $\rightarrow$ )**

Criteria for predicting apple scab infection periods  
Leca et al, Agricultural and Forest Meteorology, 2011  
McHardy and Gadoury, Phytopathology, 1989

Brown rust and yellow rust on wheat seedlings  
de Vallavieille-Pope et al, Phytopathology, 1995, 2002

# Effects of climate change on pathogens, host plants and aerial diseases

- ❖ Direct effects of climatic factors on epidemiological processes
  - effects of UV-B, CO<sub>2</sub>, O<sub>3</sub>, temperature, heat/water stress, rainfall, drought, ...
- ❖ Indirect effects of warming on pathosystems
  - shift in host phenology and spatial distribution
  - pathogen adaptation to host plant resistance
- ❖ Consequences for foliar plant diseases
  - allowing emergence of infectious diseases in new territories
  - varying incidence and severity of native diseases
  - filtering (or generating new) pathogens, pathotypes, races, ...
- ❖ Protection and prevention against diseases
  - no technological rupture in near-future tactical measures
  - manipulating biodiversity : possible long-term lever

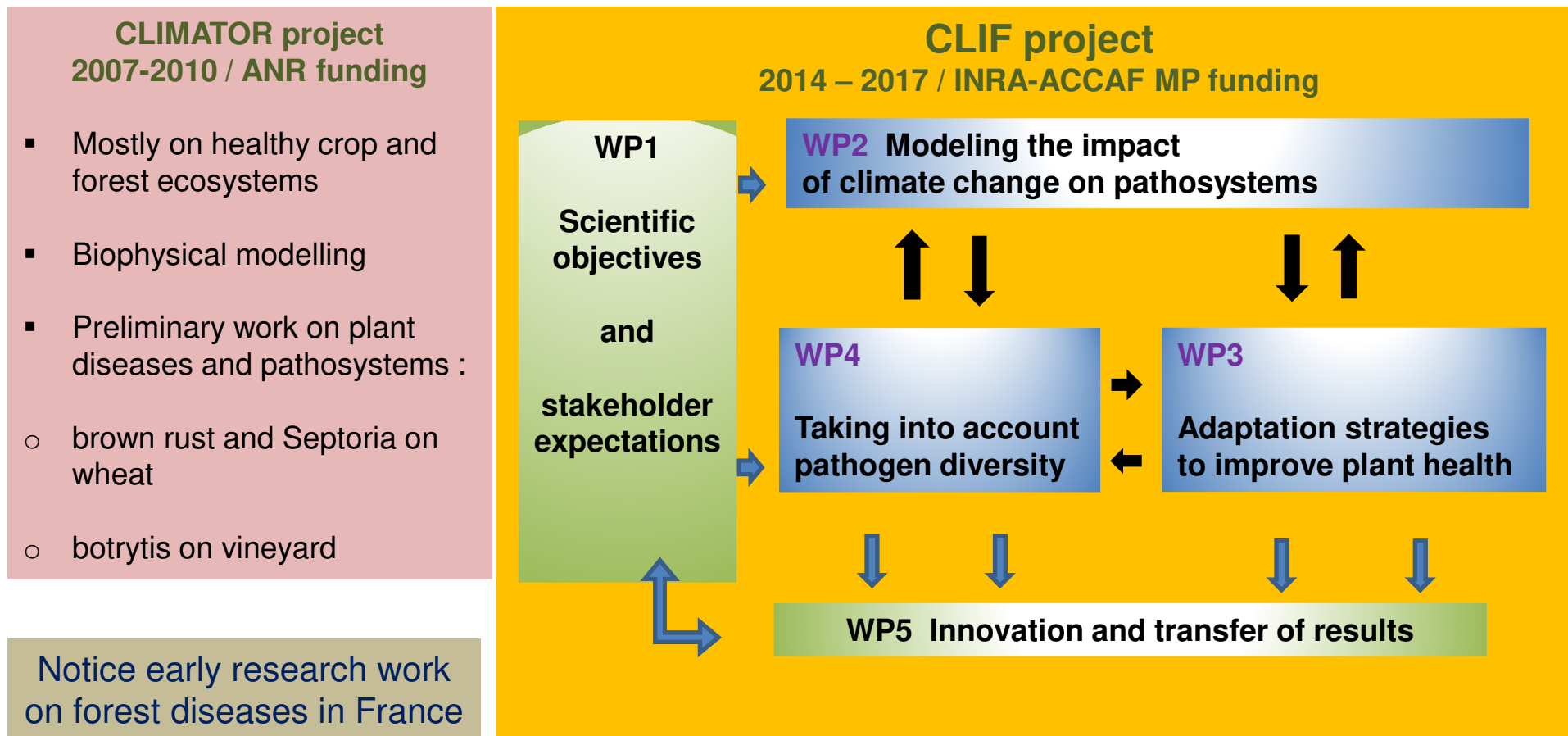


Future distribution of vineyards in Europe ?



# Effects of CC on crop diseases and pathosystems

Contribution of French research institutions and R&D organisations



Climate x Pathogen    Climate x Pathogen x Host    Climate x Pathosystem x Practices

## WP2

# Simulating Leaf Wetness Duration (LWD) to predict future fungal infection events

3 models to  
estimate LWD

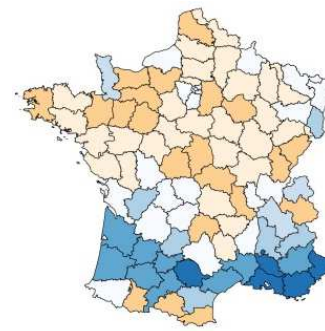
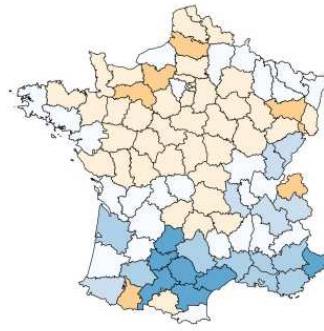
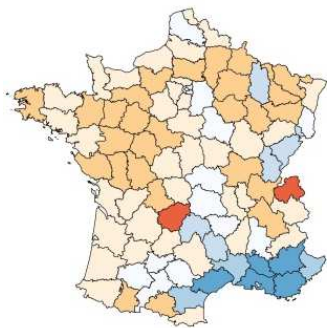
Huard F et al, AGU Fall Meeting, 2014

(Huber, Bancal, Launay, 2017. INRA-Accaf CLIF project, final report)

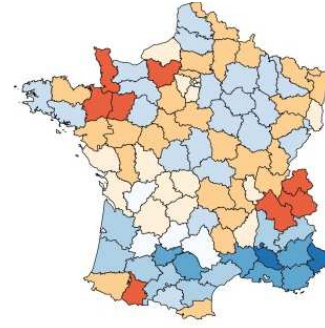
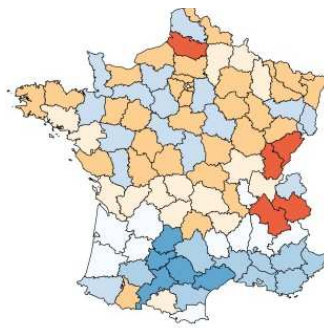
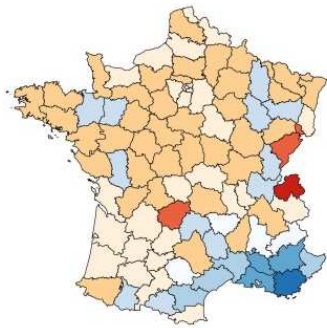
*LWD variation (%)  
relative to the period  
1976-2005*

*Future climate data obtained  
using Aladin model, RCP 8.5,  
and QQ method*

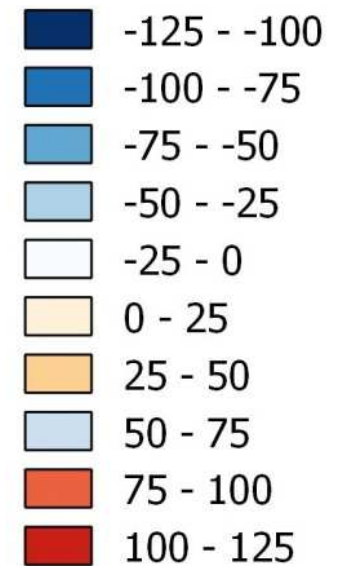
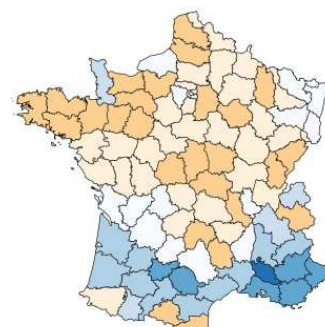
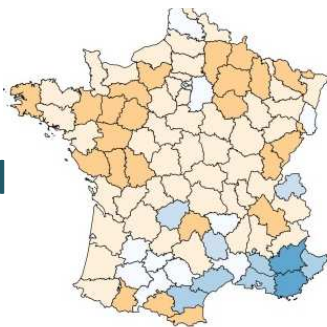
DPD  
Vapour  
pressure  
deficit



CART  
Decision  
Tree



MEDHI  
Statistical



**2021-2050**

**2051-2070**

**2071-2100**

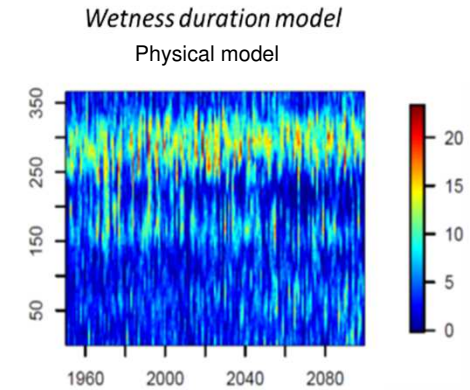
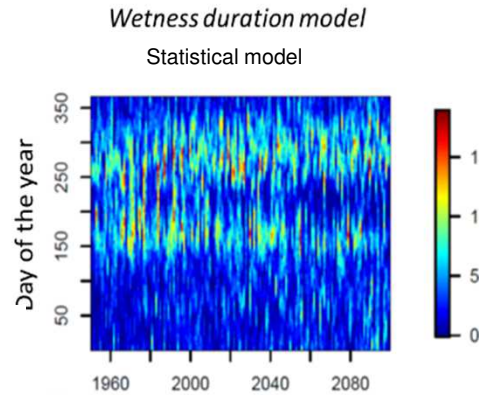
# Estimating disease trends and uncertainties in relation to modeling assumptions

## Case study : wheat infection by brown rust

Simulation of disease  
infection risks based on :

- 2 LWD models
- 2 infection models

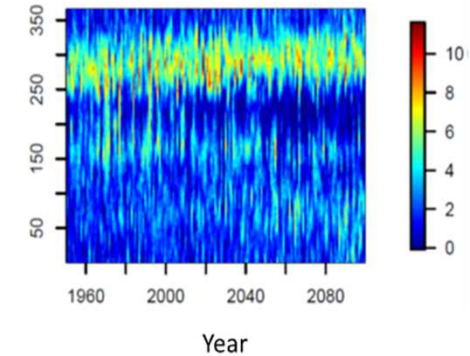
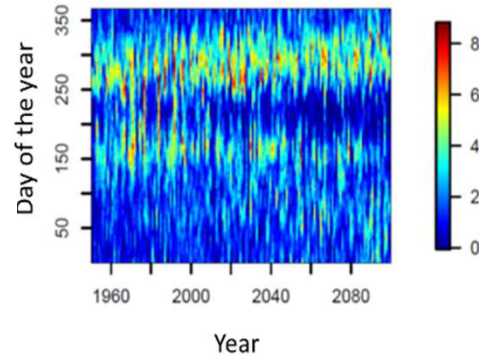
*Infection model  
de Vallavieille-Pope*



### Results

*Predicted infection values differ  
significantly depending on both  
LWD and infection models but  
temporal trends are similar*

*Infection model  
ClimInferR*



*Disease infection risks :*

- increasing in the fall and winter
- decreasing in summer

*Huber, Bancal, Launay. 2017*

*NRA-Accaf CLIF project, final report*

# WP2 *Understanding disease trends according to climate and microclimate evolution*

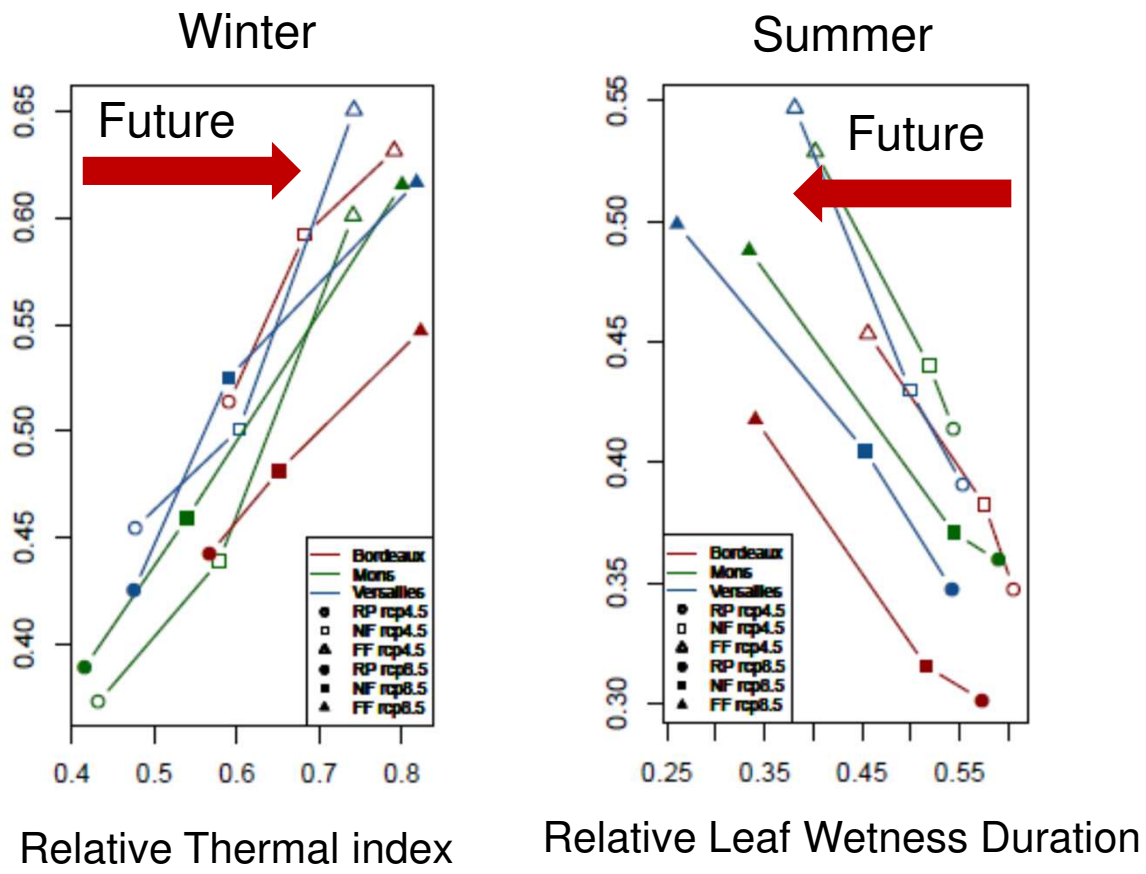
## Case study : wheat infection by brown rust

Simulation of the relative number of days with infection efficiency > 5%

### Results

Whatever the site (northern or southern France) and whatever the scenario (RCP 4.5 or 8.5):

- The number of infectious days is
- Significantly increased in winter by the expected warming
- Significantly reduced in summer by the predicted drought



Huber, Bancal, Launay 2017  
INRA-Accaf CLIF project, final report

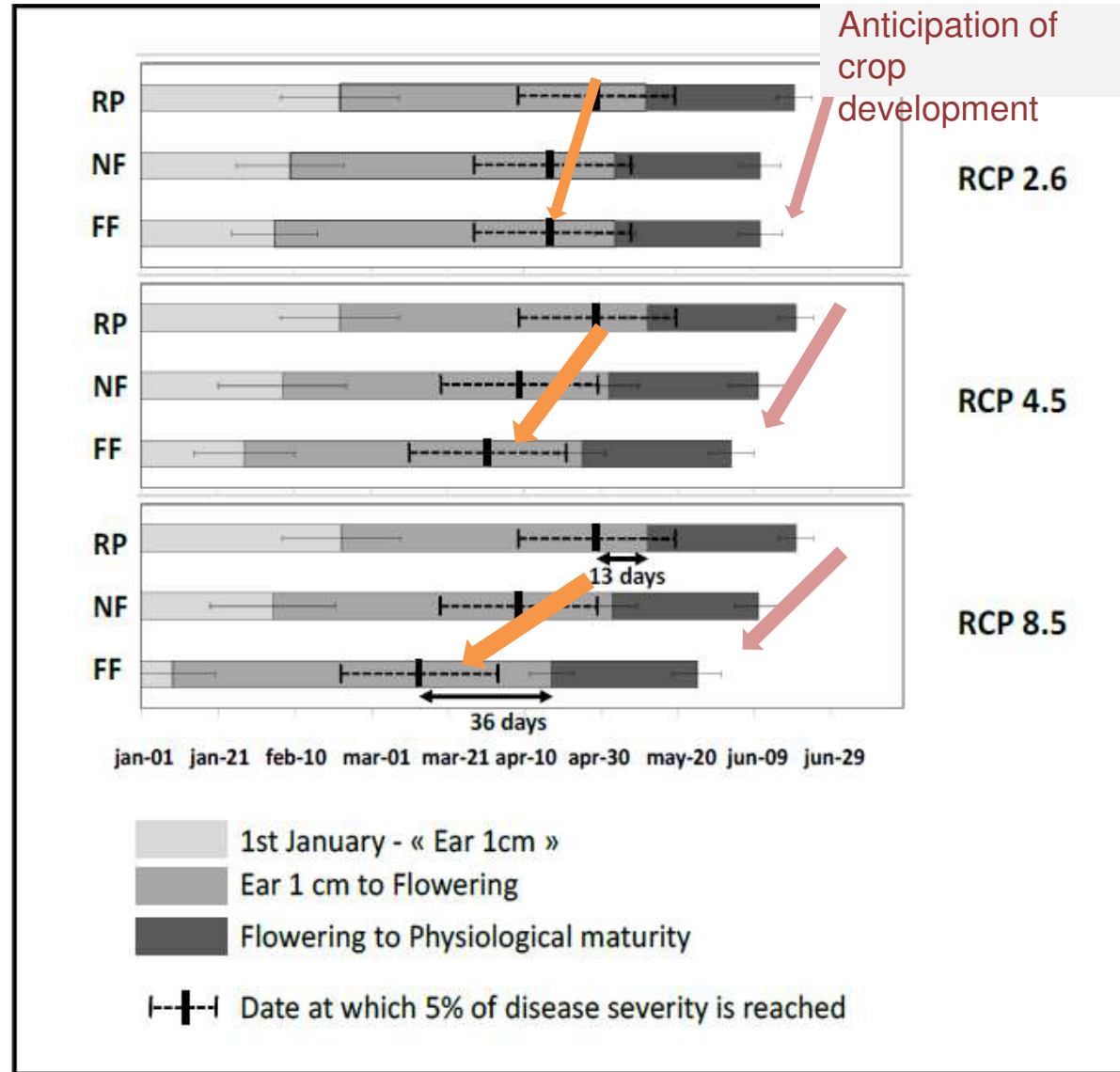
<span style="color: red;">—</span>	Bordeaux	○	●	Recent past (1976-2005), RCP 4.5 and 8.5
<span style="color: green;">—</span>	Mons	□	■	Near future (2021-2050), RCP 4.5 and 8.5
<span style="color: blue;">—</span>	Versailles	△	▲	Far future (2070-2099), RCP 4.5 and 8.5



# Impact of Climate Change scenario on wheat crop growth and *Puccinia tritici* development



5% of disease severity is reached sooner in wheat under future climate

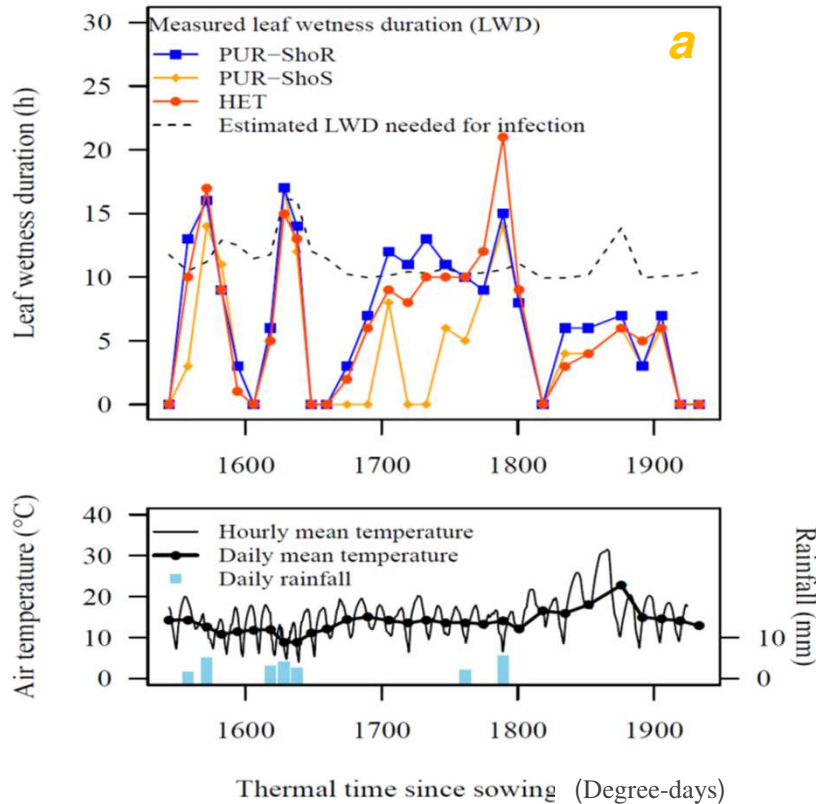


Caubel et al., 2017,  
European Journal of  
Agronomy

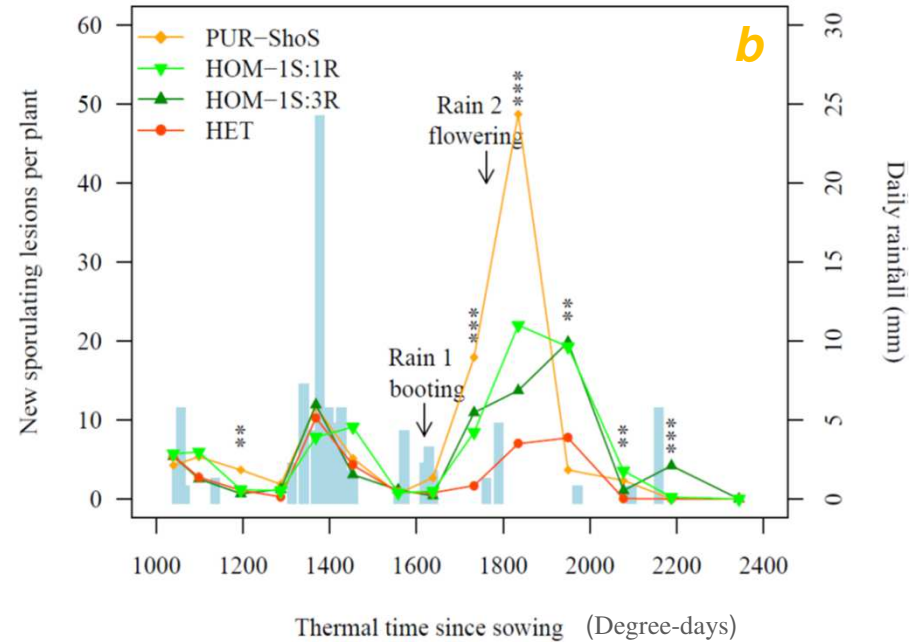
WP3

# Manipulating the microclimate using cultivar mixtures

Crop heterogeneity as a lever to lower infection (a) and limit splash-dispersal (b)



PUR-Sho : short pure stand  
Resistant (R) or Susceptible (S)



HOM : homogeneous mixture = Short S + Short R  
HET : heterogeneous mixture = Short S + Tall R

In the HET mixture, upper leaves of tall R cultivar protect bottom leaves of short S cultivar from :

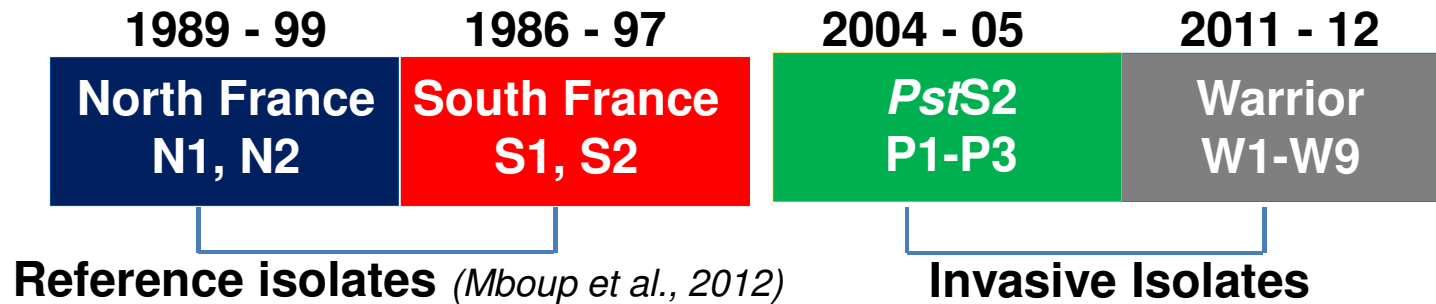
- radiative loss and dew deposits (a)
- incident rainfall drops and splash dispersal (b)



# Thermal impact on Infection Efficiency (IE) & Latent Period (LP)

(Vallavieille-Pope et al, Plant Pathology, 2018)

## Controlled-conditions experiments on 16 *Puccinia striiformis* isolates



2 susceptible wheat varieties: cv-Cartago, cv-Victo

### 2 thermal regimes for LP

**Cold**  
10/15°C

**Warm**  
16/25°C

### 5 temperatures for IE

5°C

10°C

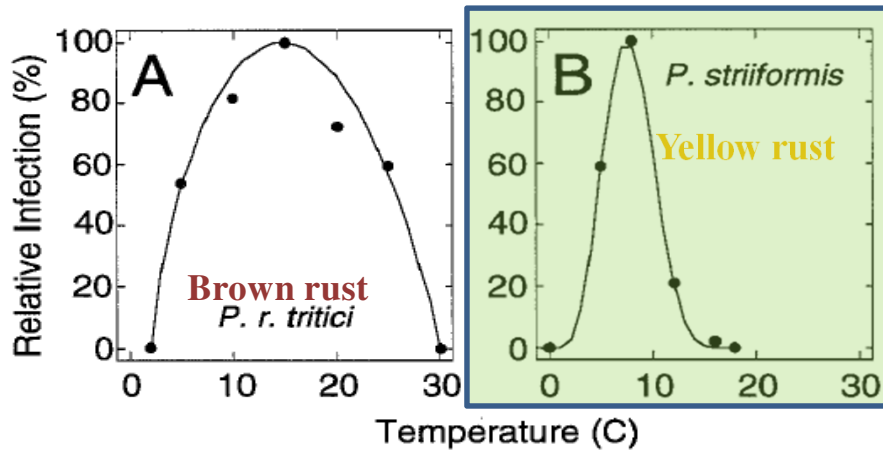
15°C

20°C

23°C

40 leaves per experiment, 2 biological replicates

# Combining isolate-response of infection efficiency and temperature scenario in the near and far future

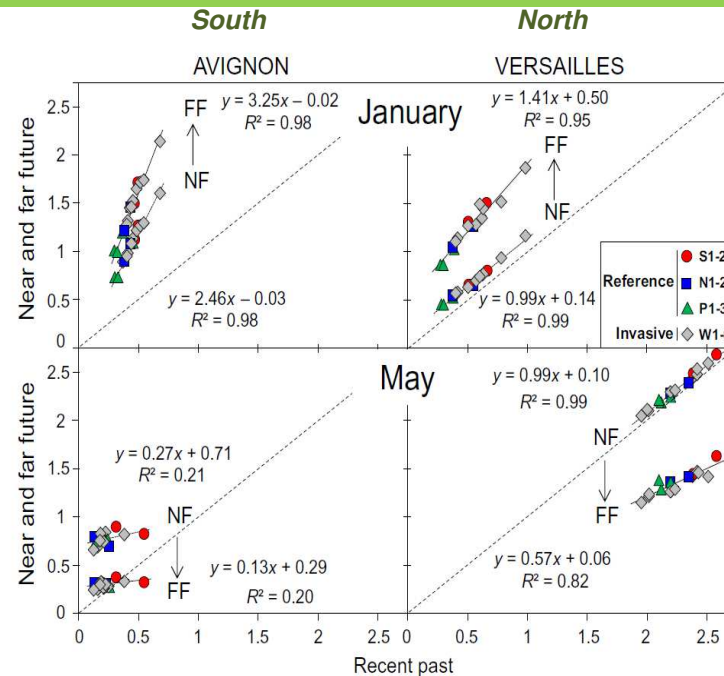
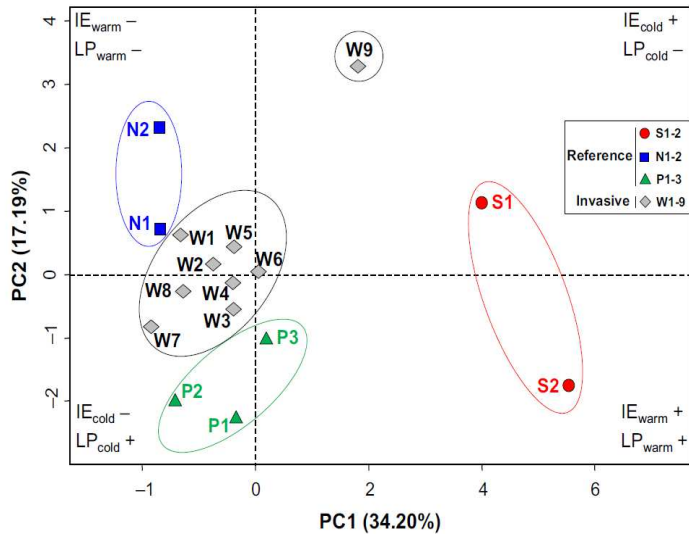


Comparing Northern (N) and Southern (S) reference isolates to invasive PstS and W in terms of response to temperature assessed using 2 major epidemiological processes : Infection Efficiency (IE) and Latent Period (LP)

**Does the response to temperature provide an advantage to S or W isolates ?**

Vallavieille-Pope et al, 2002, 2018

## Approach including both experiments and thermal response models



Mean monthly infection efficiencies in January and May for two French sites

January : IE(FF) > IE(NF)  
May : IE(FF) < IE(NF)

# *Conclusions and perspectives*

❖ Pathogens are sensitive to climate, likely more than their host plants, and particularly to persistence and motion of liquid water in the canopy

- modelling intermittent variables such as leaf Wetness duration
- simulating diseases in relation to climate scenarios and knowledge gaps
- controlled conditions experiments to anticipate climate-disease relationships
- field experiments to increase disease prevention and ecosystem resilience

⇒ methods to assess the CC effects on native diseases of existing crops

❖ What about disease emergence risks ? primarily linked to crop area expansion, pathogen introduction, technological tools, globalized trade, human migrations, ... rather than direct CC effects (von Tiedemann et al., 2017)

❖ What could be our contribution to the understanding of disease emergence ?

- incorporating the human behaviour : sensitivity analysis to modifications of agricultural practices, use of technological innovation
- assessing the impact of CC adaptation to abiotic stresses on plant disease risks
- applying system dynamics in a wider approach to emerging risks