INRA
SCIENCE & IMPACT

EpiArch

Improve knowledge in Agro-ecology and Exploit natural regulation mechanisms

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26 / 03 / 2014

CONTEXT

Which architecture modifications affect the risk and dynamics of pathogen and insect infestations?

Can plant architecture be used to control pests and reduce pesticide use?

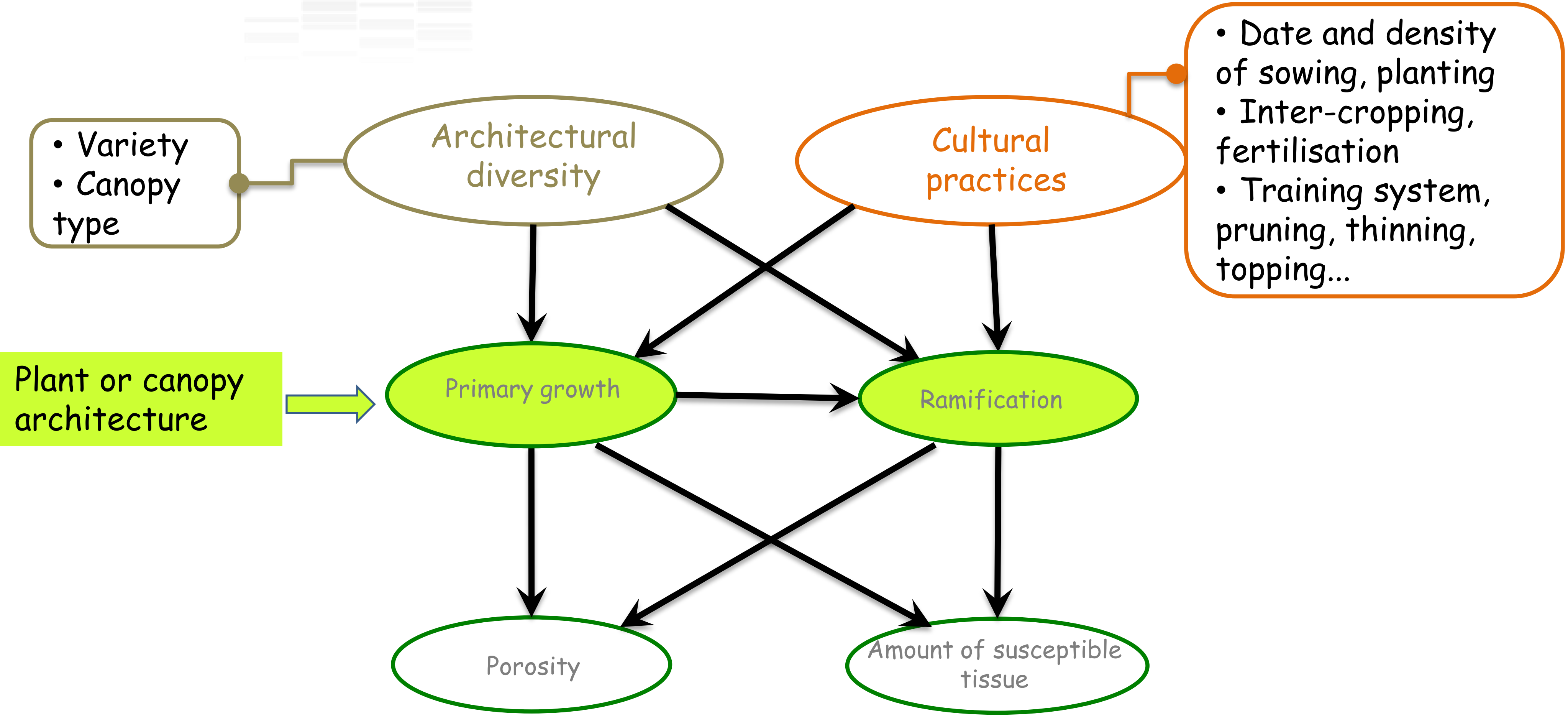
Which cultural practices can modify plant growth and architecture?

How to combine this driver with others?

SUMMARY

- Plant - Canopy Architecture and Epidemiology.
- Key results.
- EpiArch a Key action SMaCH and a scientific network.

Plant - Canopy Architecture and Epidemiology



- Variety
- Canopy type

Architectural diversity

Cultural practices

- Date and density of sowing, planting
- Inter-cropping, fertilisation
- Training system, pruning, thinning, topping...

Plant or canopy architecture

Primary growth

Ramification

Porosity

Amount of susceptible tissue

Cultural practices

Grapevine

Training system
Pruning type

Density of plantation
Date of pruning
Cover-cropping

Yam

Training system

Agro forestry system

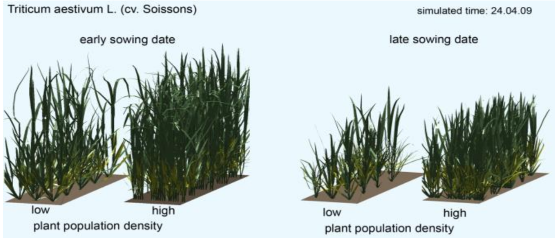
Mixed cropping

Apple tree

Training system
Pruning types

Wheat

Density of sowing
Date of sowing



Carrots

Trimming

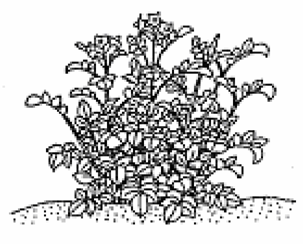
Architectural diversity

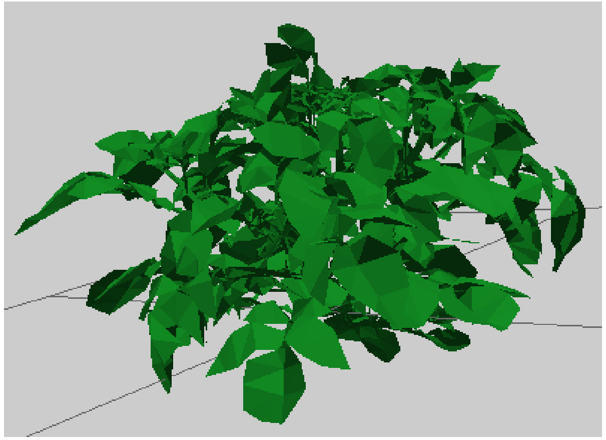
Different varieties with various canopy type:

effects on primary growth, ramification, porosity

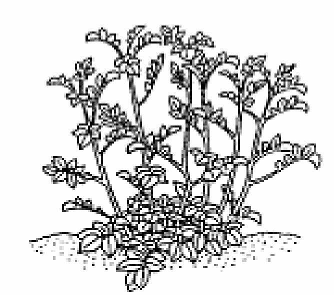
Potatoes

cv. Bindge

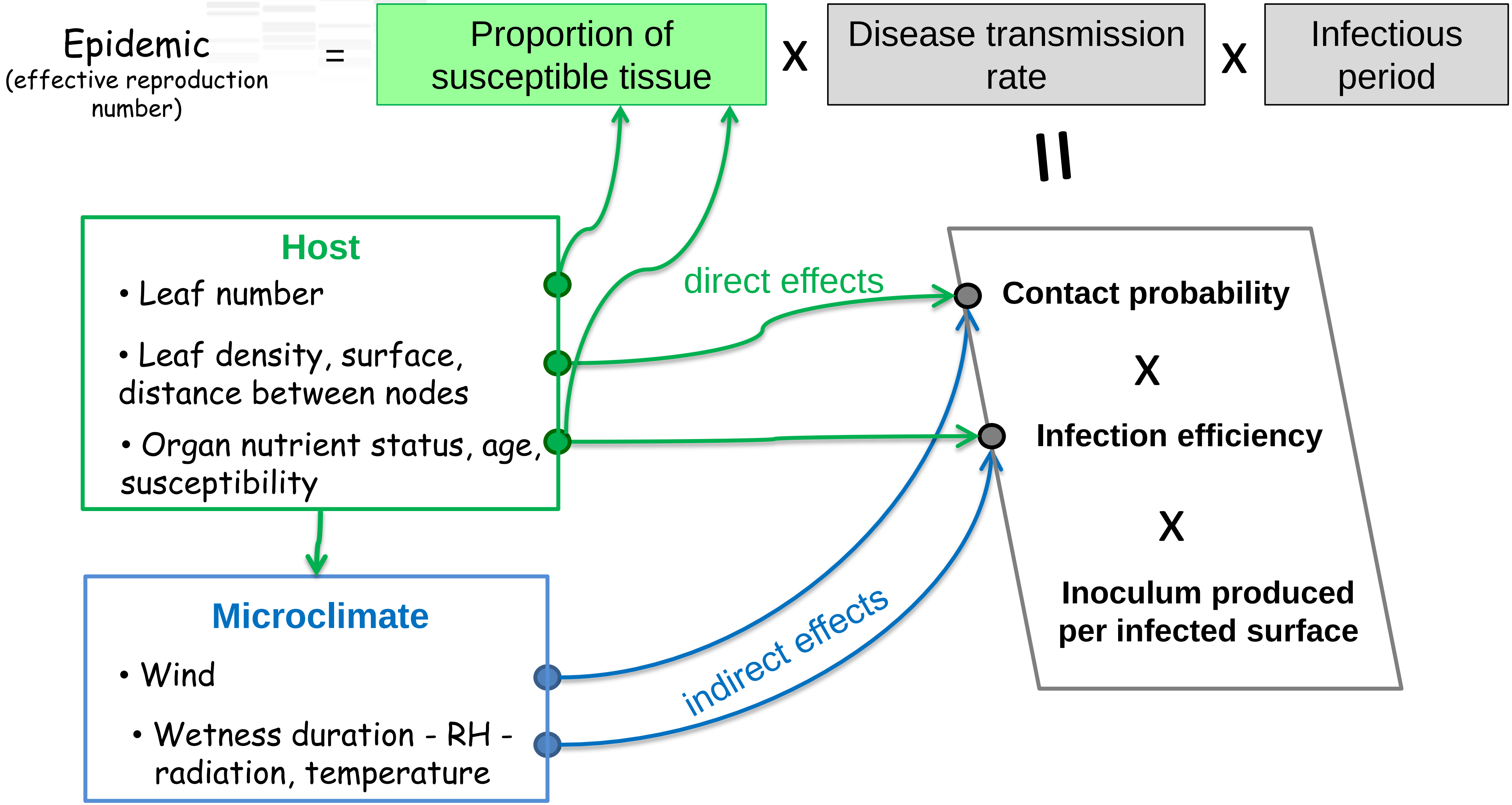




cv. Monalisa



What makes an epidemic?



Epidemic
(effective reproduction number)
=
Proportion of susceptible tissue
X
Disease transmission rate
X
Infectious period

=

Contact probability

X

Infection efficiency

X

Inoculum produced per infected surface

Host

- Leaf number
- Leaf density, surface, distance between nodes
- Organ nutrient status, age, susceptibility

direct effects

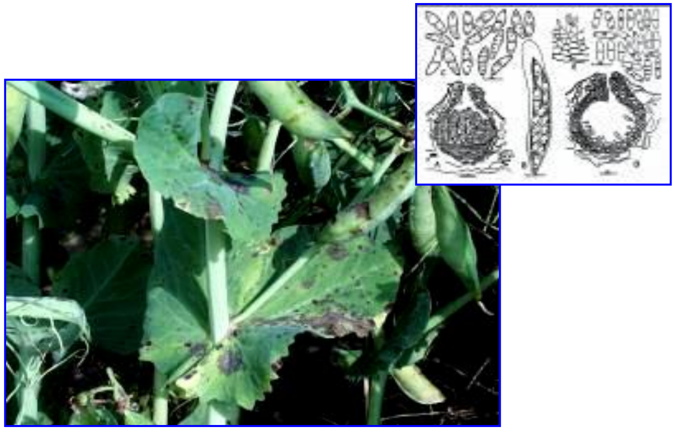
Microclimate

- Wind
- Wetness duration - RH - radiation, temperature

indirect effects

Traits like infection constraints, Spore type, dispersion processes depends on pathogen

Powdery mildews
Wind dispersed
Water reluctant
Resource dependant

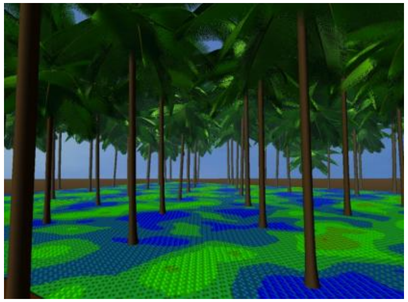


Ascochytose
Wind, splash dispersal
Infection wetness dependent

Anthracnose, mildews
Wind, splash, runoff dispersed
Infection wetness dependent

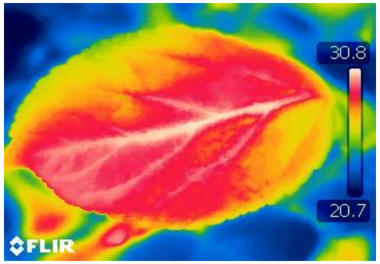
Architecture-Insects interactions can depend on the life-history traits: mobility, body size, feeding strategies

Mirids / Cocoa

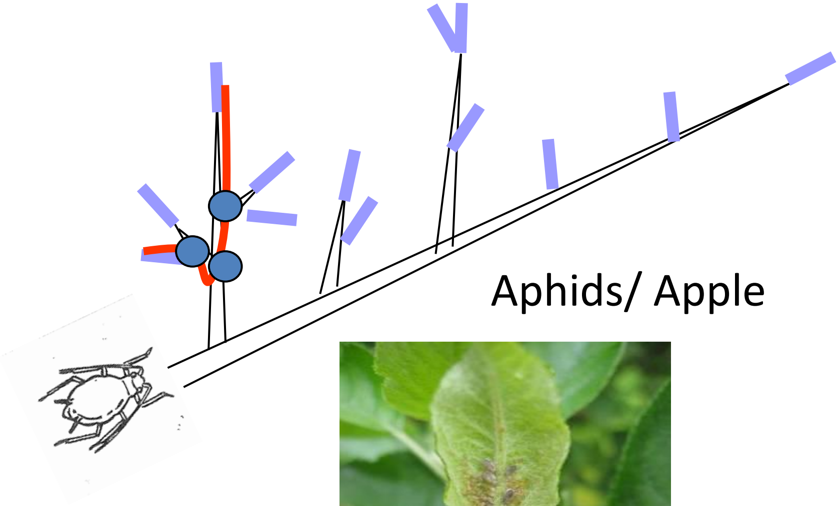


Shading can limit their infestations

Arthropods / Apple

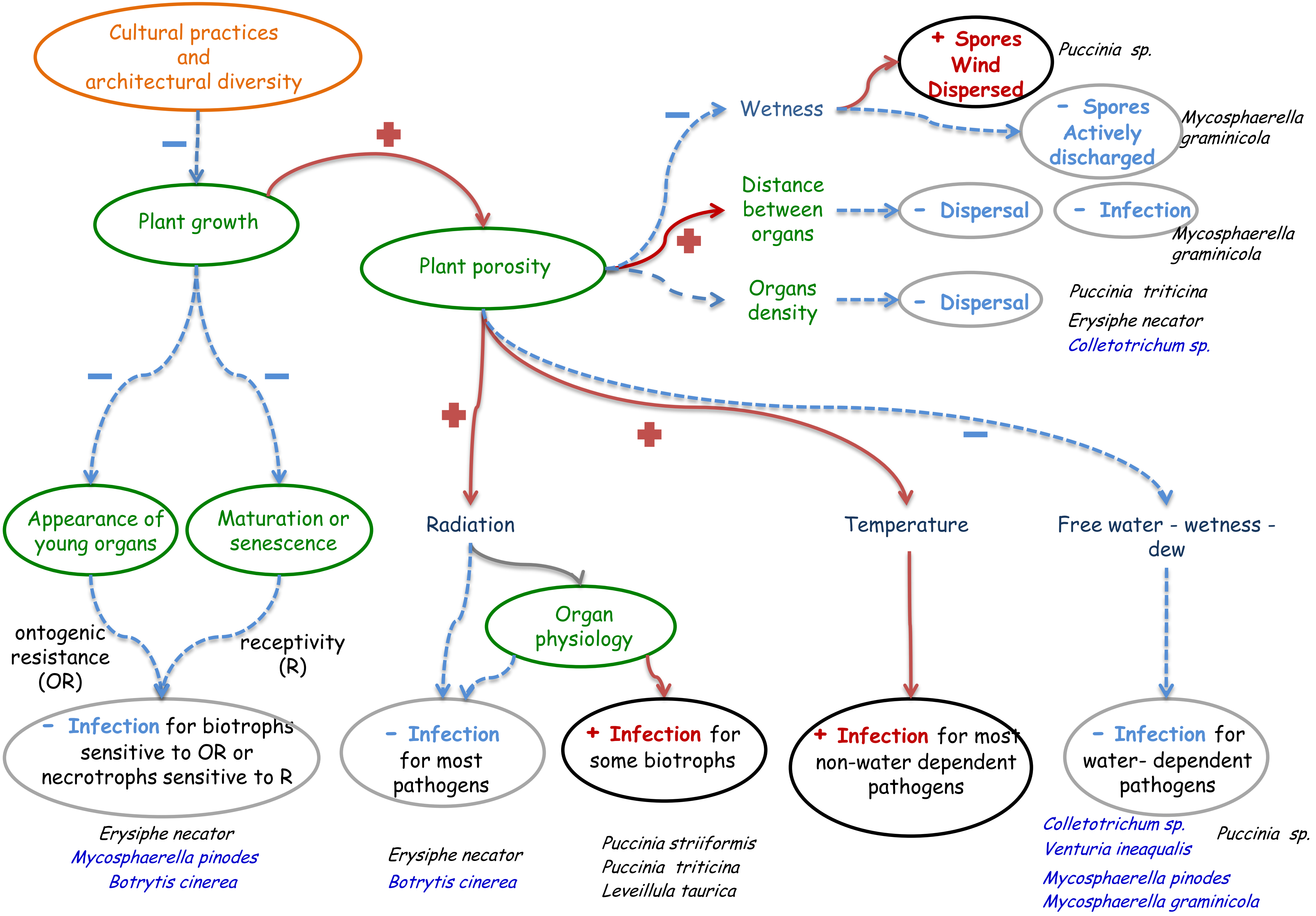


They are able to quickly escape high temperature



Aphids/ Apple

Branching can limit their ability to move and find ressourses

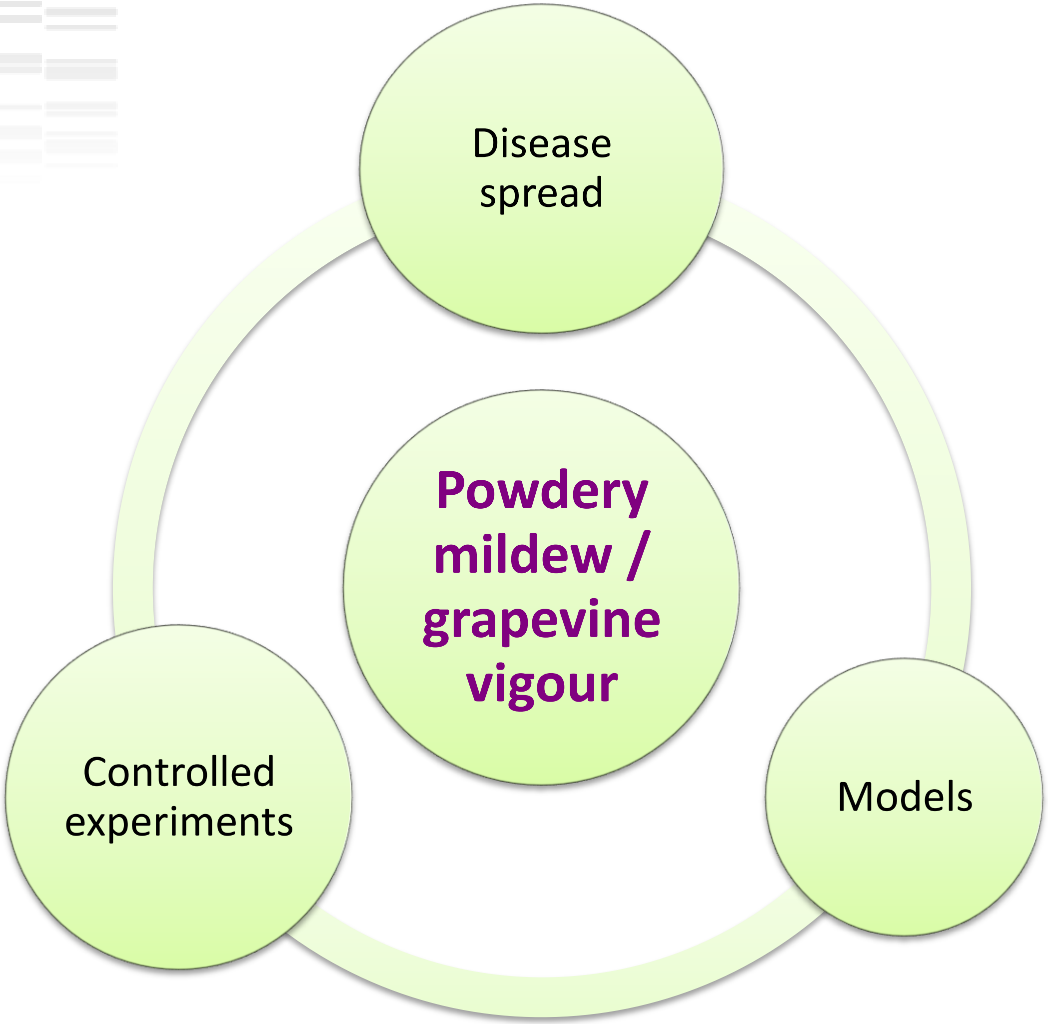

Cultural practices and architectural diversity
−
Plant growth
+
Plant porosity
−
Wetness
+ Spores Wind Dispersed
Puccinia sp.
− Spores Actively discharged
Mycosphaerella graminicola
Distance between organs
+
− Dispersal
− Infection
Mycosphaerella graminicola
Organs density
− Dispersal
Puccinia triticina
Erysiphe necator
Colletotrichum sp.
−
−
Appearance of young organs
Maturation or senescence
+
+
−
Radiation
Temperature
Free water - wetness - dew
Organ physiology
ontogenic resistance (OR)
receptivity (R)
− Infection for biotrophs sensitive to OR or necrotrophs sensitive to R
− Infection for most pathogens
+ Infection for some biotrophs
+ Infection for most non-water dependent pathogens
− Infection for water- dependent pathogens
Erysiphe necator
Mycosphaerella pinodes
Botrytis cinerea
Erysiphe necator
Botrytis cinerea
Puccinia striiformis
Puccinia triticina
Leveillula taurica
Colletotrichum sp.
Puccinia sp.
Venturia ineaqualis
Mycosphaerella pinodes
Mycosphaerella graminicola

Relationships between plant growth & architecture: complex and contradictory

Necessity to use control experiments to
assess and disentangle the factors

Necessity to develop and use models to
characterise and explore these relationships
test various cultural practices

Key results



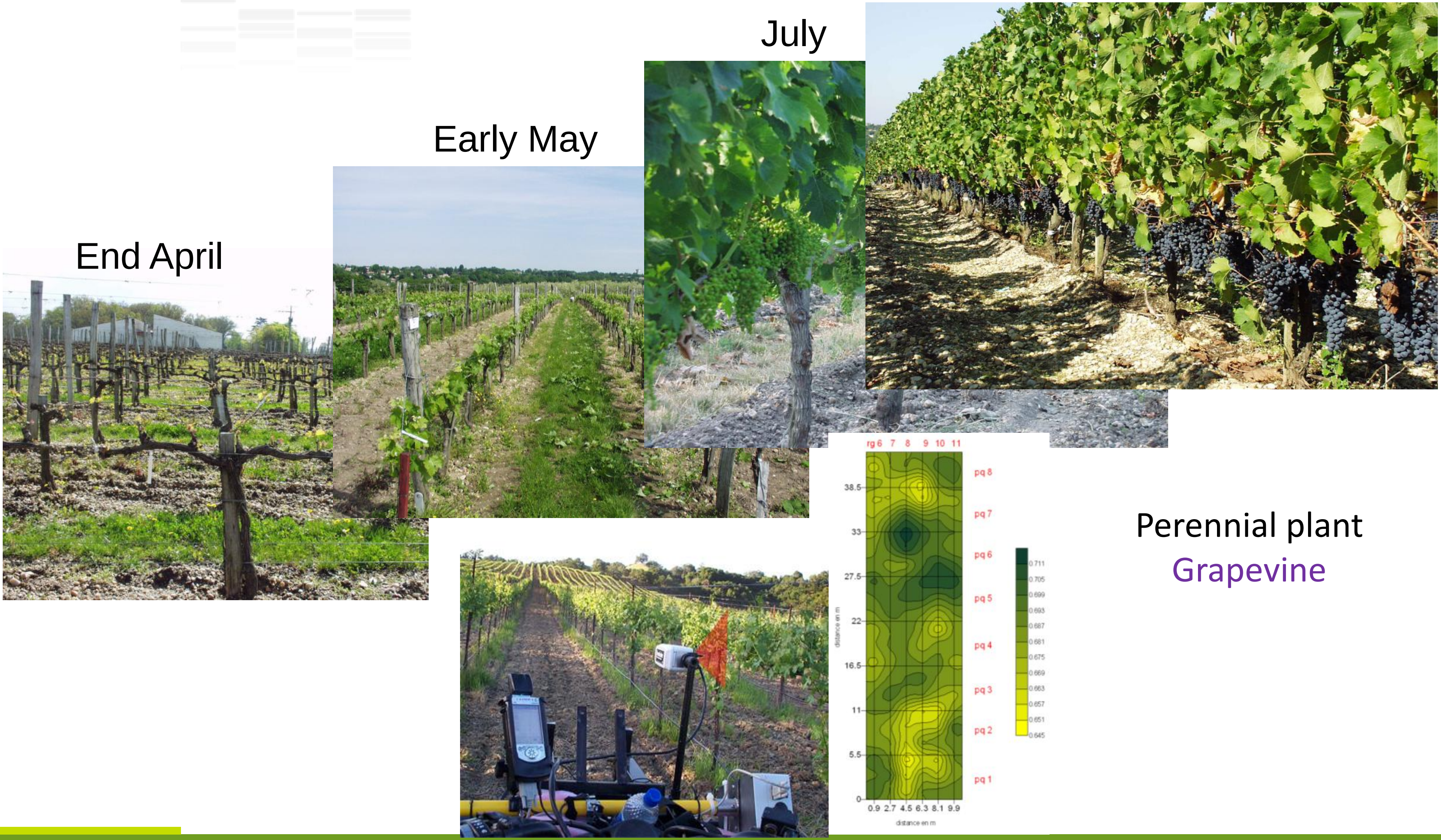
Disease spread

Powdery mildew / grapevine vigour

Controlled experiments

Models

Characterize the changes of development and structure over time



End April

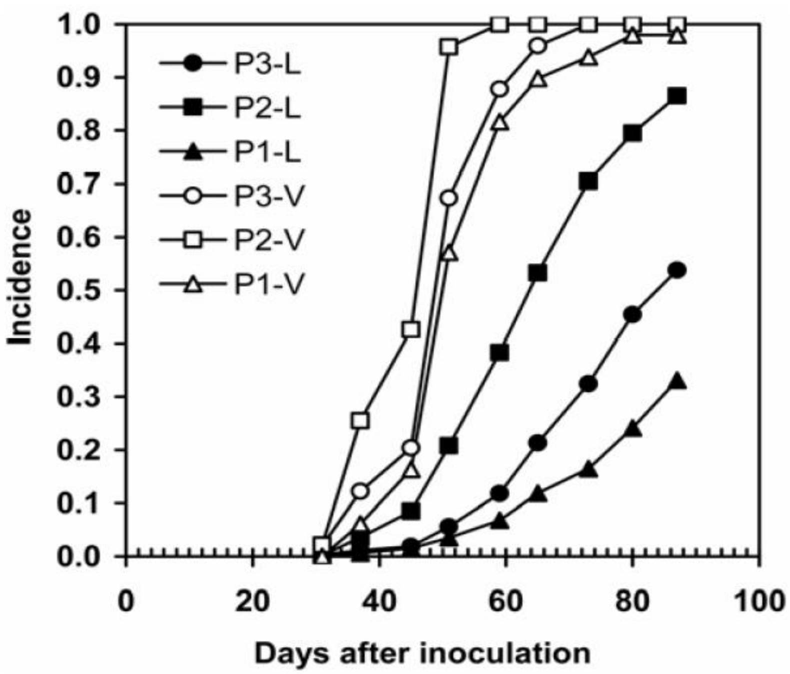
Early May

July

September

Perennial plant
Grapevine

Evolution of disease spread in plots with various levels of vigour

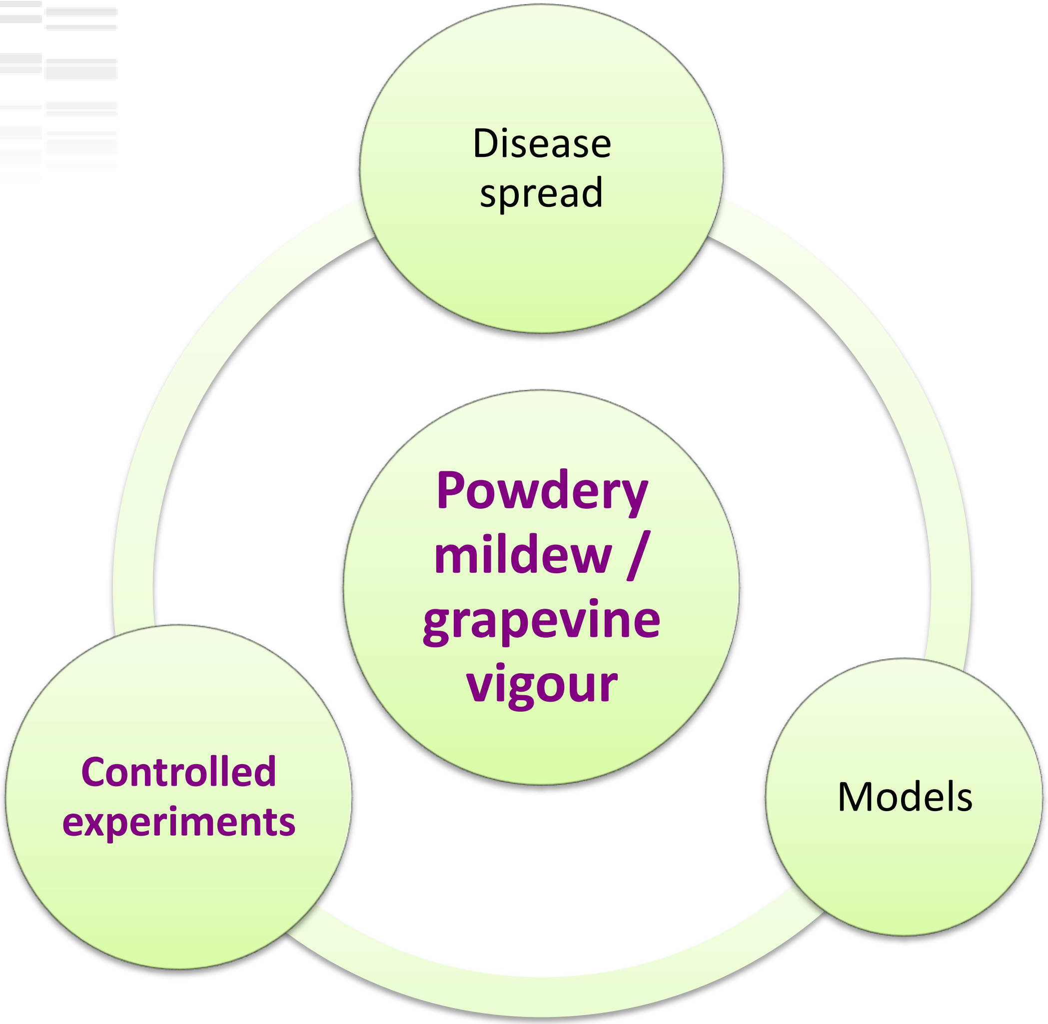


Velocity of disease spread up to 4 times lower on plots with low vigour

Calonnec et al., 2009, *Phytopathology* 99:411-422

This can be explained by the rate of leaf emergence Valdes et al., 2011, *Crop protection*, 30:1168-1177

Can it be explained by modification of leaf susceptibility in vigorous plots?



Disease spread

Powdery mildew / grapevine vigour

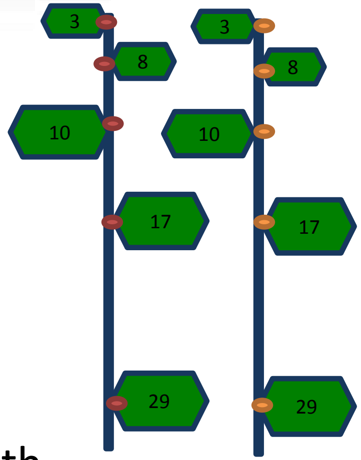
Controlled experiments

Models

Controlled experiments to disentangle the processes

in the field

Characterise plant growth (shoot length, rate of leaf emergence..)

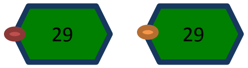


Sampled shoots from two training systems

Dualex

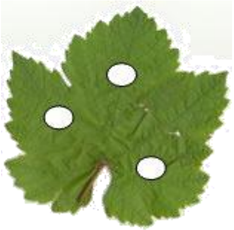
and physiology (chlorophyll, Nitrogen...)

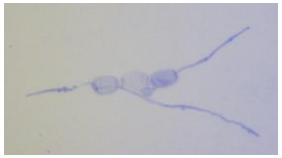
in the lab.



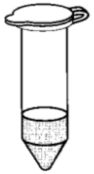
for each leaf (age, area, physiology)

Pathogenicity tests





% Infection

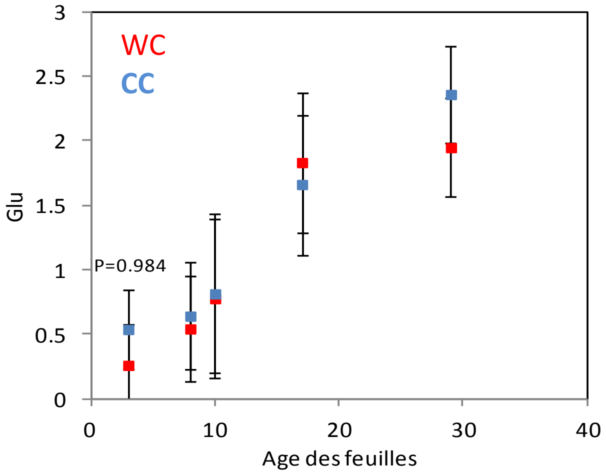


Sugar

Water content

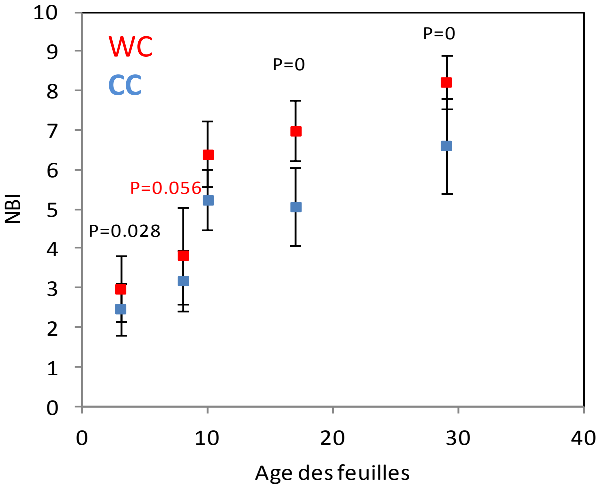
Sporulation...

Sugar indicator of sink to source transition



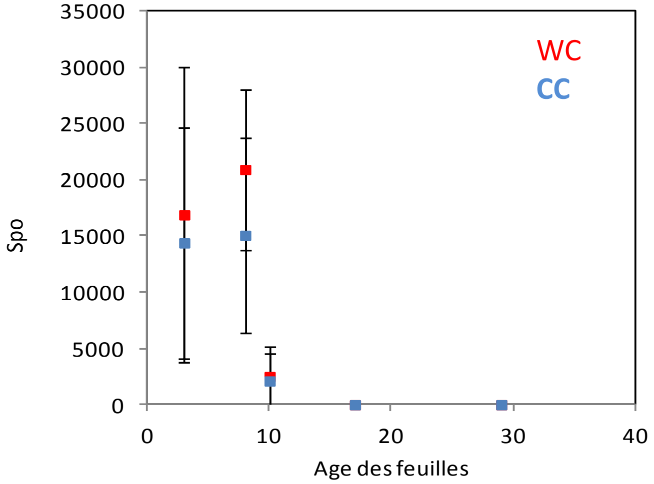
Indicator of ontogenic resistance

NBI index of vigour



Indicator of vigour for old leaves

Leaf age indicator of susceptibility

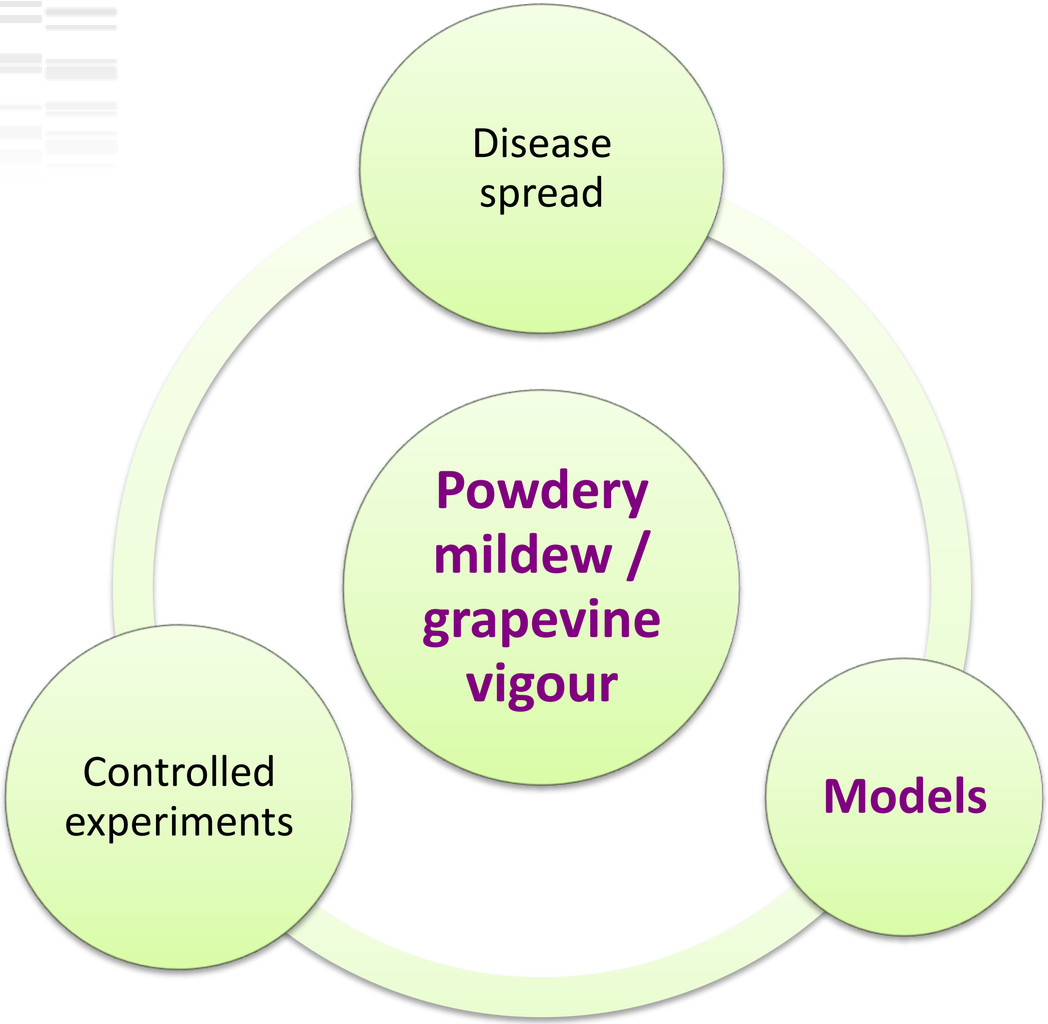


Leaves that differ for amount of NBI are no longer susceptible

Difference of physiology measured between plots cannot explain the variability of disease severity!

The cultural management tested did impact the leaf susceptibility

The effect of vigour on disease reduction is consecutive of the higher rate of leaves production
(resource effect)



Disease spread

Powdery mildew / grapevine vigour

Controlled experiments

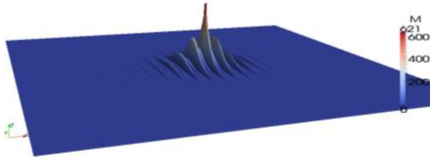
Models

Models

3D mechanistic process based model

calibration

PDE-ODE continuous model



- **Plant scale**
- **Model of vinestock development** (dynamics, organ susceptibility, vigour, shoot topping..)
- **Model of powdery mildew** (infection, growth, sporulation function of leaf age and temperature)
- **Dispersion process** inside the plant (wind)
- Rank the effects of host development on the disease

- **Plot scale**
- **Model of leaf area evolution** (Susceptible, Exposed, Infectious, Removed, onTogenic)
- **Model of spores dispersion in the plot** (advection diffusion)
- **Plot heterogeneities** (structure, susceptibility, vigour, phenology...)
- **Cultural management** (densities, rows, fungicide, topping)

Plant scale

Plot scale

Strong effect of the date of contamination = proportion of young susceptible leaves

Strong effect of the emergence rate of leaves = vigour effect

Effects vary depending on the climatic scenario = effect of temperature on the rate of plant growth

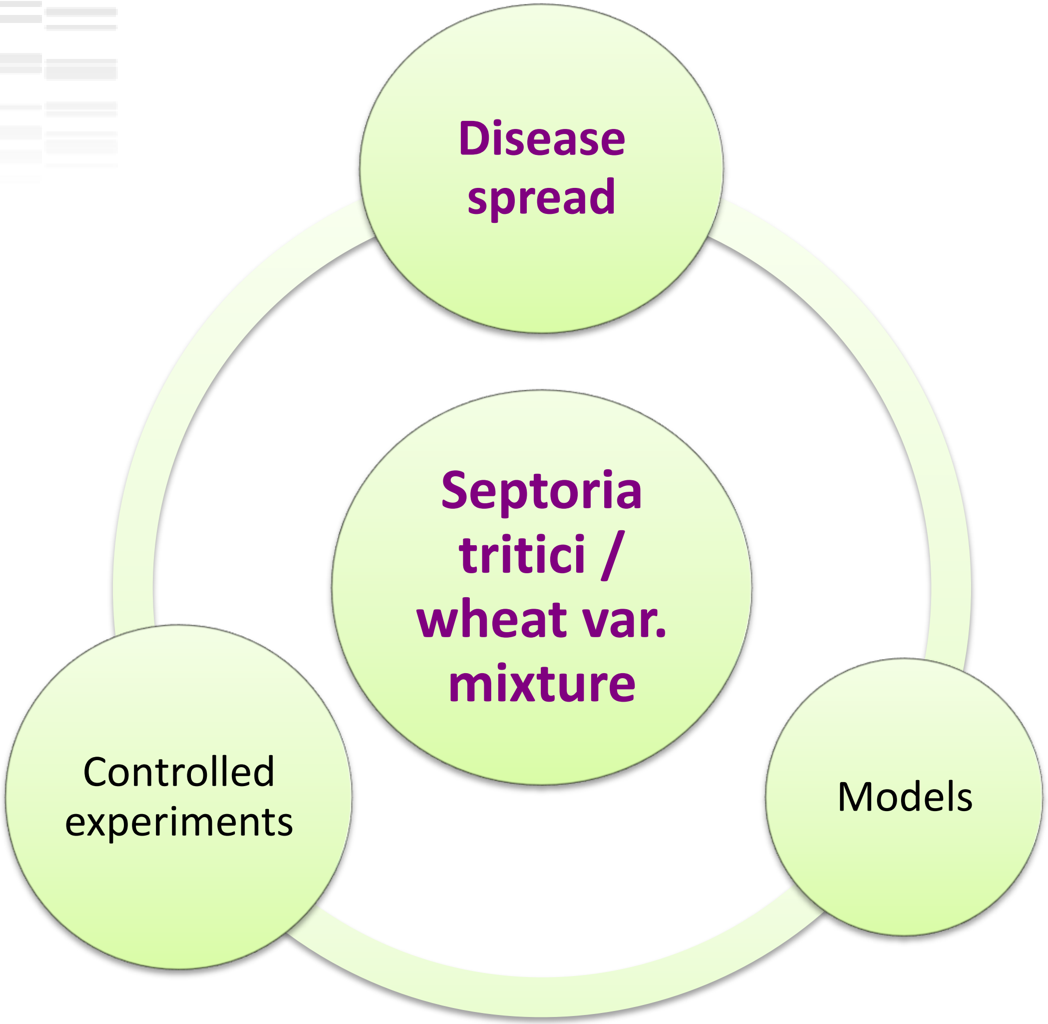
The ontogenic resistance parameter is sensitive to the date of contamination

Calonnec et al., 2008, *Plant Pathology*
Burie et al., 2011, *Annals of botany*

Stronger effect on disease reduction when Heterogeneities are combined in rows rather than in patches

Highest effect when combining fully resistant and susceptible varieties in rows

Mammeri et al., 2014, *Ecological Modelling*



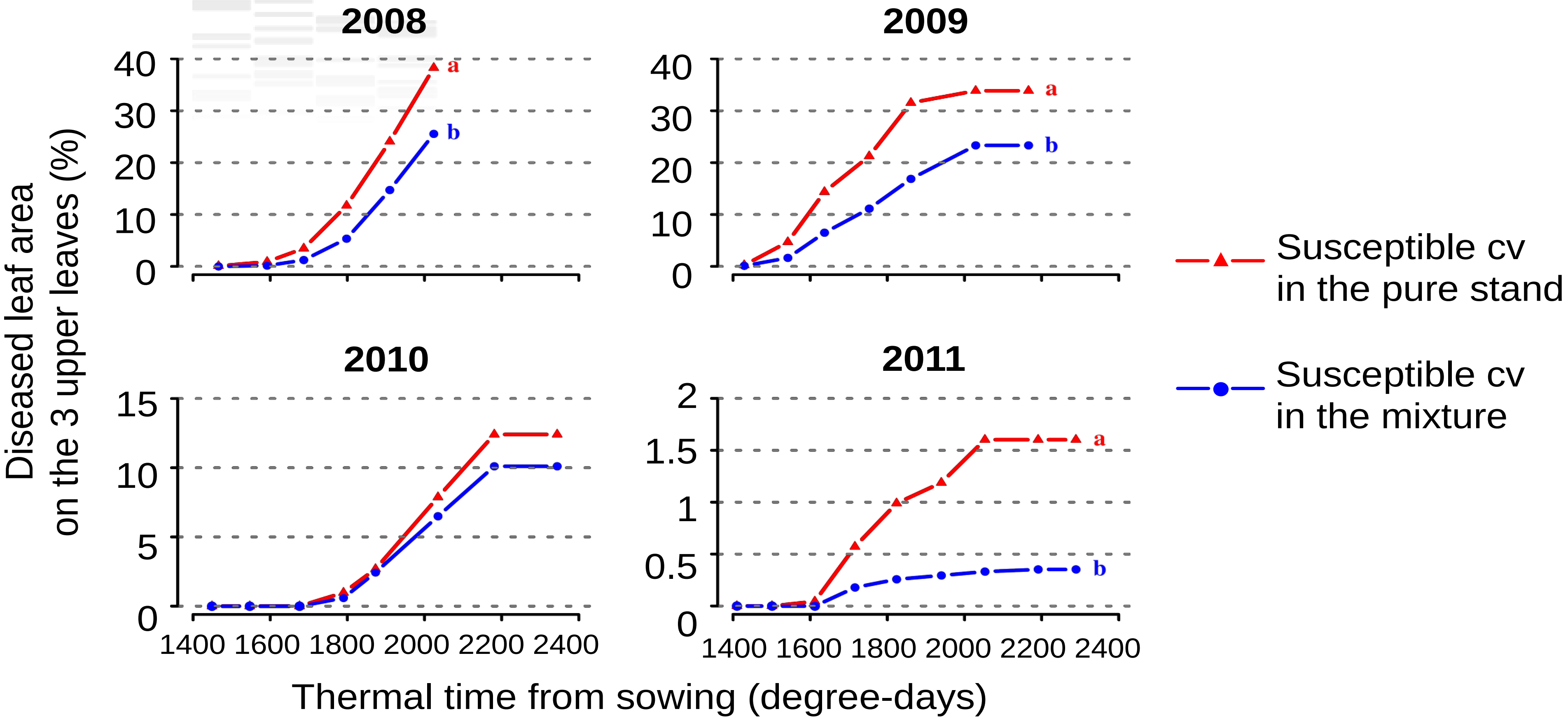
Septoria tritici / wheat var. mixture

Disease spread

Controlled experiments

Models

Evolution of disease spread on wheat cultivar mixture

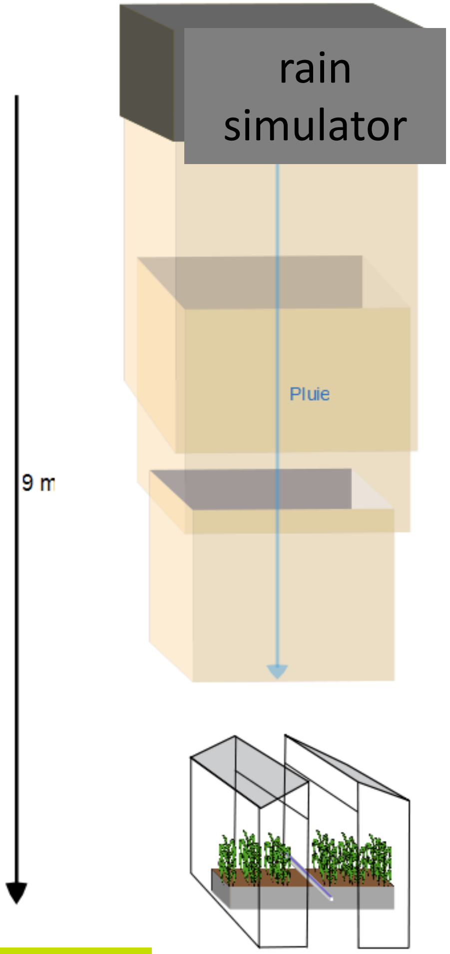


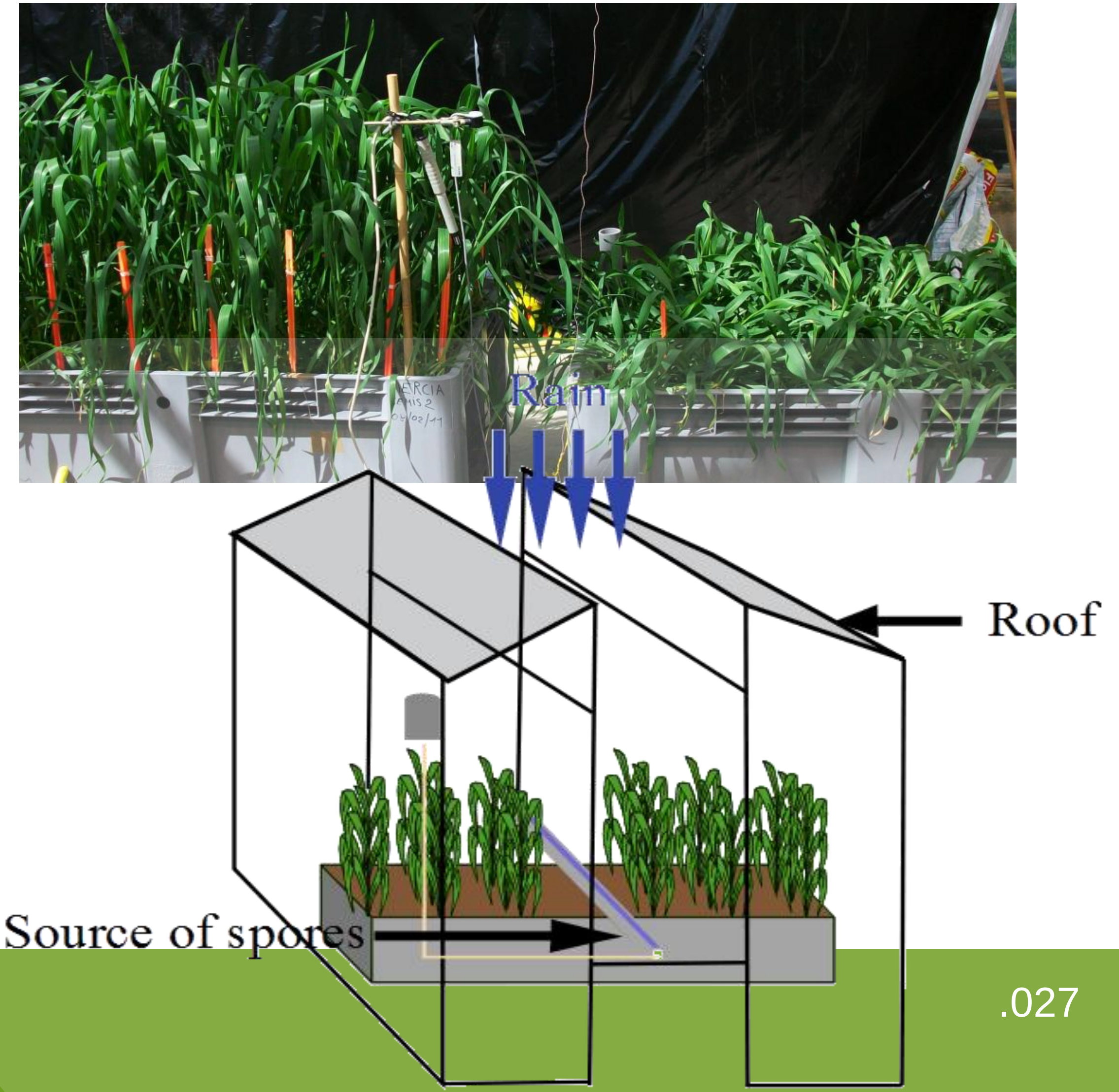
Up to 42% reduction of disease leaf area for the three upper leaves.
After major rainfall events, the number of sporulating lesions on the susceptible cultivar was reduced on average by 45% in the mixture compared to the pure stand.

Gigot et al., 2013, *Plant Pathology*

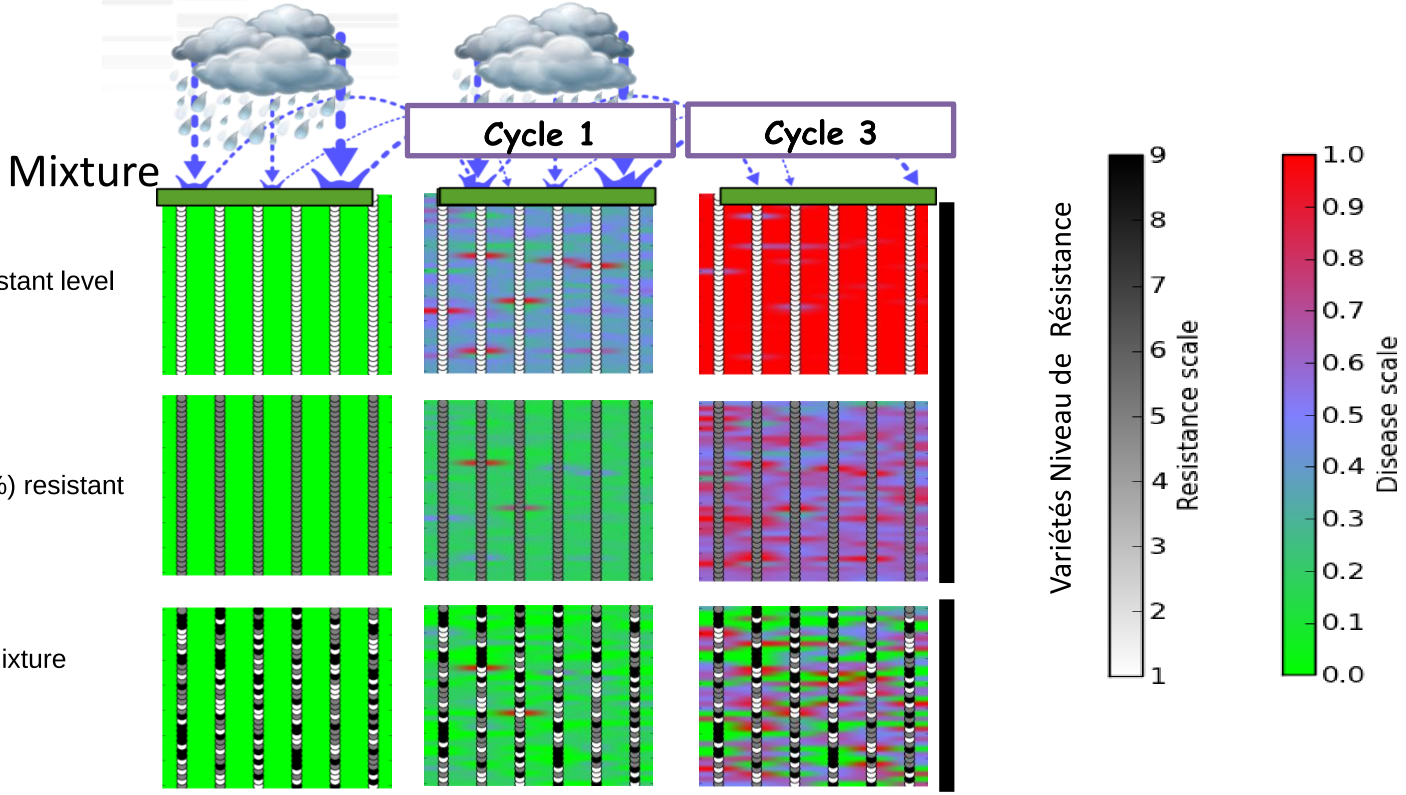
Controlled experiments to disentangle the processes

A rain simulator to quantify the effect of crop density or architecture on splash dispersal





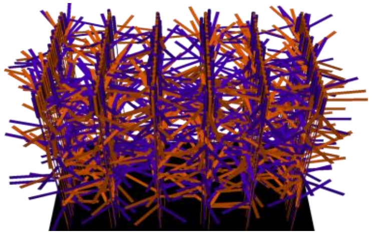
A model at the plot scale to simulate disease spread and rain in varietal mixture



Susceptible +
Low (5%) resistant level

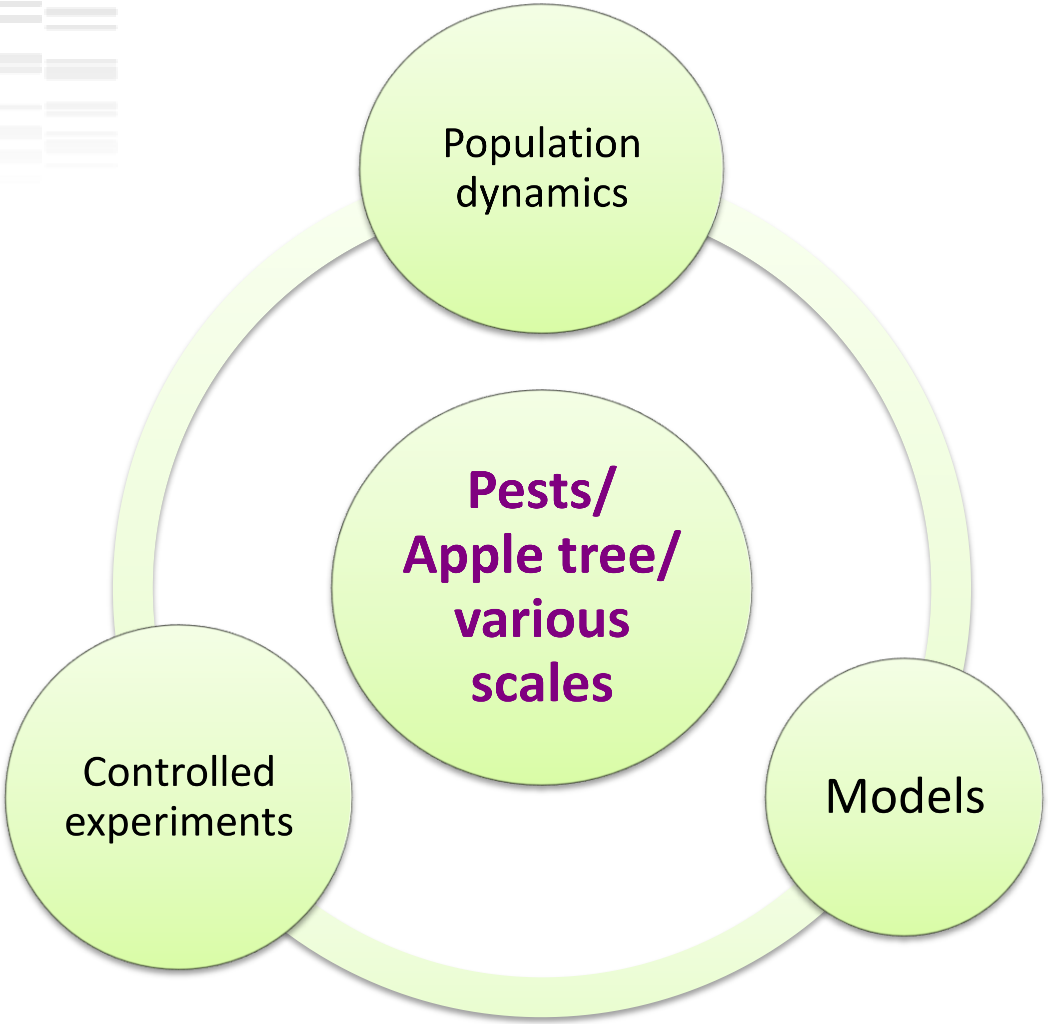
Susceptible +
moderate (50%) resistant level

Susceptible +
3 varieties in mixture



Disease was reduced by 45% at the end of the season due to cumulative effects of reduction of spore dispersion by splashing

Saint-Jean *et al.* 2008, Aspect of Applied Biology; Gigot *et al.* 2013



Population dynamics

Pests/ Apple tree/ various scales

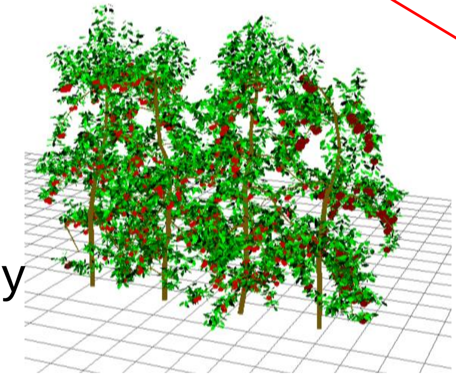
Controlled experiments

Models

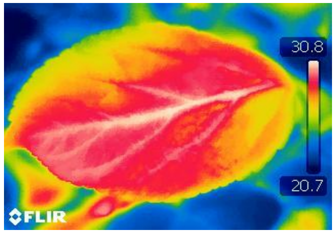
Integration of Climate, microclimate and plant models to predict the dynamics of insects

Regional climate model

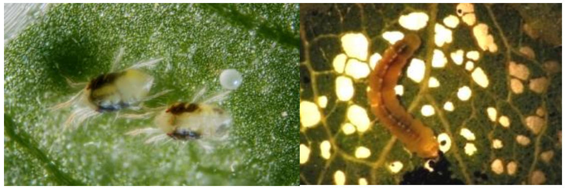
Cascading through spatial scales to predict the behaviour of insects (miners) or arthropods with climate change



Radiation interception model inside the canopy



Micro-climate model at the leaf scale



Pest heat budget = individual performance

Population dynamic models

These models are used as predictive models to forecast the impact of climate change on insects

When simulating climate change at the end of the century, spotted tentiform leaf miner mortality was 12% higher for pruned orchard than for unpruned ones.

Saudreau et al., 2013, *Trees*.

The variability in insect development time and mortality within a year change markedly with climatic variations = best to use non-linear rate curves and insect body temperatures instead of air temperature in forecasting models

Pincebourde et al., 2007, *Journal of Animal Ecology*

Pincebourde and Woods, 2012, *Functional Ecology*

EpiArch a network & SMaCH Key action

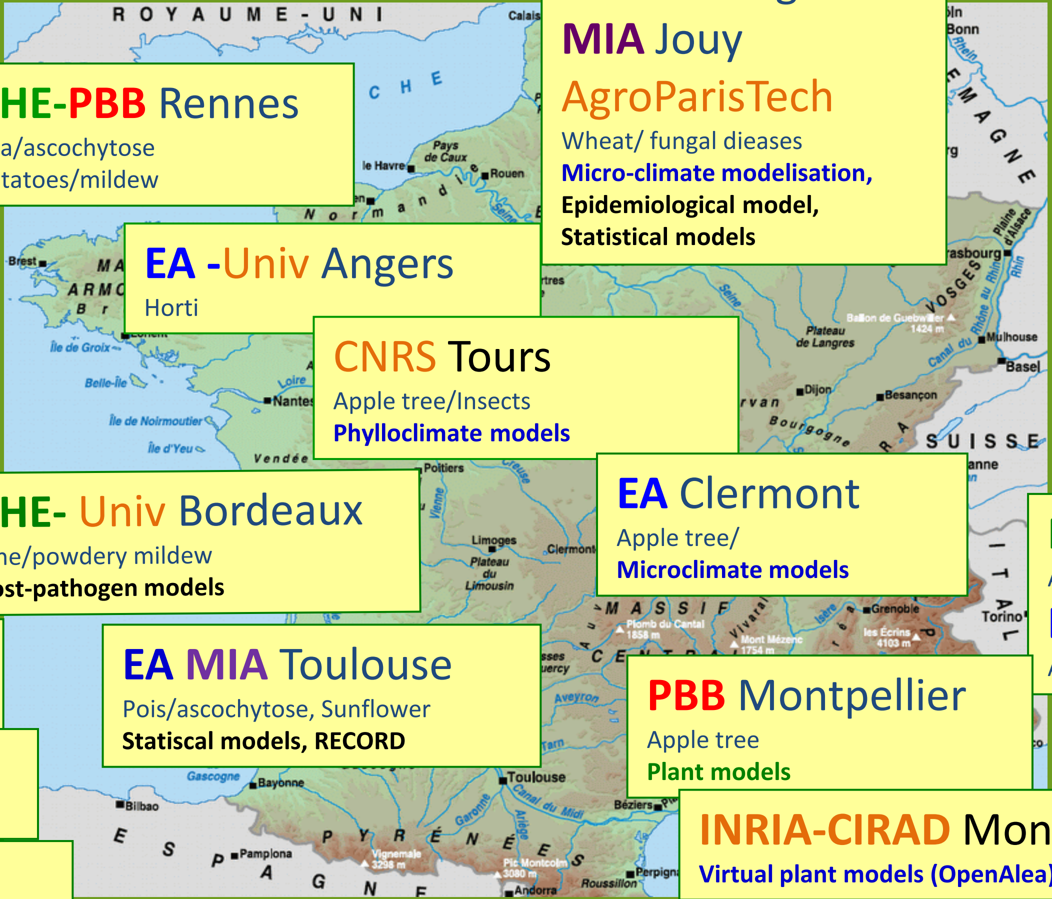
EpiArch

A SMaCH key action and a scientific network of about 40 scientists

4 INRA scientific divisions involved: Plant Health & Environment, Environment & Agronomy, Plant Biology and Breeding, Mathematical and Computer Science,

Universities, CIRAD, INRIA, CNRS, AgroParisTech,

More than 10 pathosystems are considered



PHE-PBB Rennes

Pea/ascochytose

Potatoes/mildew

EA-PHE Grignon

MIA Jouy

AgroParisTech

Wheat/ fungal dieases

Micro-climate modelisation,

Epidemiological model,

Statistical models

EA -Univ Angers

Horti

CNRS Tours

Apple tree/Insects

Phylloclimate models

PHE- Univ Bordeaux

Vine/powdery mildew

Host-pathogen models

EA Clermont

Apple tree/

Microclimate models

PHE Gotheron

Apple tree/Insects/ Apple scab

EA Avignon

Apple tree/carpocapse /Aphids

EA-PHE Guadeloupe

Yam/anthracnose

EA MIA Toulouse

Pois/ascochytose, Sunflower

Statiscal models, RECORD

PBB Montpellier

Apple tree

Plant models

CIRAD Guadeloupe

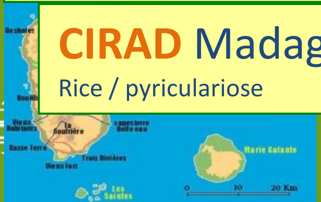
Banana/cercosporiose

INRIA-CIRAD Montpellier

Virtual plant models (OpenAlea), Models of pests dynamics

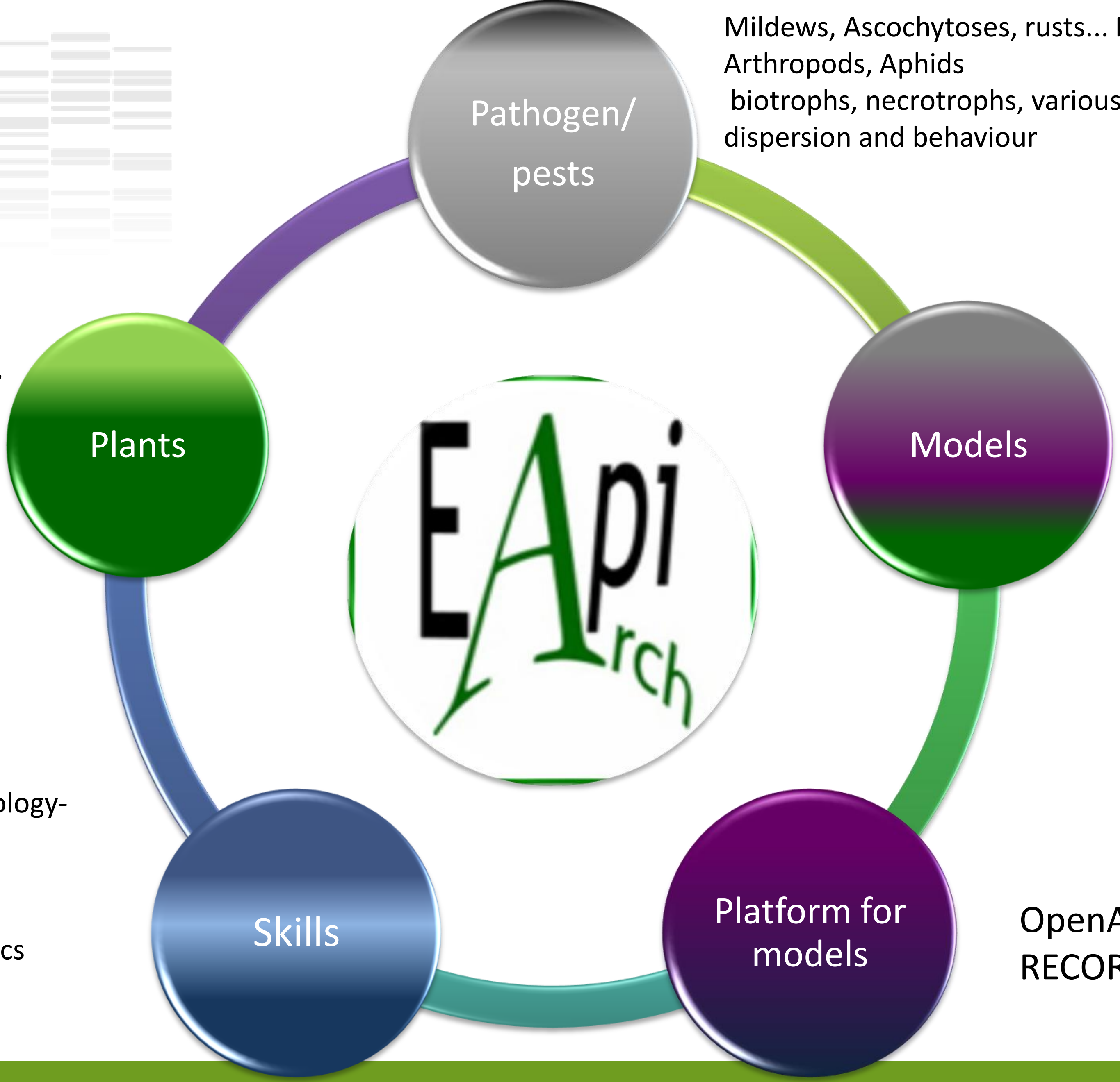
CIRAD Madagascar

Rice / pyriculariose



EA Sophia Antipolis

Rose



Pathogen/ pests

Mildews, Ascochytoses, rusts... Miners, Arthropods, Aphids
biotrophs, necrotrophs, various mode of dispersion and behaviour

Models

3D plant-pathogens, dynamical, micro-climate, generic

Platform for models

OpenAlea
RECORD

Skills

Pathology – Entomology-Epidemiology
Agronomy
Genetics
Micro-climate physics
Mathematics
Computer science

Plants

Wheat, Pea, Rice,
Sunflower, Potatoes, Yam,
Banana, Vine, Rose
Apple tree, Peach tree

A special issue of European Journal of Plant Pathology (2013) vol. 135(3)

European Journal of Plant Pathology

B.Tivoli et al., Current knowledge on plant/canopy architectural traits that reduce the expression and development of epidemics

E. Costes et al., Introduction to plant architecture, its diversity and manipulation in agronomic conditions

A. Calonnec et al - Effect of plant growth and canopy architecture on pathogen development processes and consequences for the epidemic and population dynamics.

B. Ney et al - Physiological modifications (vigour and senescence) induced by several traits of plant/canopy architecture and/or by disease severity: consequences on disease epidemiology

D. Andrivon et al – Designing and validating architectural ideotypes to reduce epidemic development

B. Richard et al., Effect of pea canopy architecture on microclimate and consequences on aschochyta blight infection under field conditions

- Review article in a popular science magazine: Biofutur

Façonner l'architecture végétale pour contrôler les maladies des plantes

Un changement brusque dans l'intensité de la maladie sur une population de plantes dans le temps et dans l'espace. Telle est la définition, largement acceptée, d'une épidémie sur un couvert végétal. Définition qui souligne que les épidémies sont des processus dynamiques avec des taux de maladie qui varient. Quelle est la responsabilité des modifications de la croissance de la plante dans ce processus pathogène ?

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La dynamique de croissance d'une population de plantes au cours de la saison est la conséquence de modifications de traits architecturaux ou de pratiques culturales. La production de nouveaux organes modifie, en trophique entre les organes…) et exogènes (répartition de la lumière, quantité d'eau dans le sol, éléments nutritifs, température, vent…). Pour les plantes pérennes, des changements importants dans la croissance et l'architecture peu- la lumière peuvent être modifiés. Pour les plantes annuelles, des pratiques agronomiques comme la densité et la date de semis, la fertilisation azotée ou l'utilisation de régulateurs de croissance jouent un rôle important dans

l'auteur

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et Réseau Inra EpiArch

- A project article in the INRA web magazine dedicated to the transfer of agriculture innovations