Design of spatiotemporal strategies to control black sigatoka of banana using the model landsepi

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Banana production

1. Continuous production
Monoculture
Massive use of fertilisers & fungicides
(applications every 5-7 days by plane)
TFI (fungicides) = 60

2. Harvest & local transport

3. Rinse (latex & pesticides)
Cardboard removal

4. Cut bananas and segregate by calibre
Wash in soap water & drying
Spray pesticides (post-harvest diseases)

5. Individual labelling
Packaging
Transport
Export to Europe and the US

Export of products with so many fungicide applications will be forbidden in Europe by 2024

Black Sigatoka

Disease

Causal agent: *Pseudocercospora fijiensis* (ascomycete)
Host: *Musa acuminata*
Symptoms: necroses on leaves

Impact

Main phytosanitary constraint on banana :

- reduced yield
- premature ripening
- reduced green duration

Management

- Visual inspections
- Manual leaf removal
- Fungicide applications (contact & systemic)
- Development of resistant cultivars:
  CIRAD925, CIRAD938, CIRAD3138

Life cycle

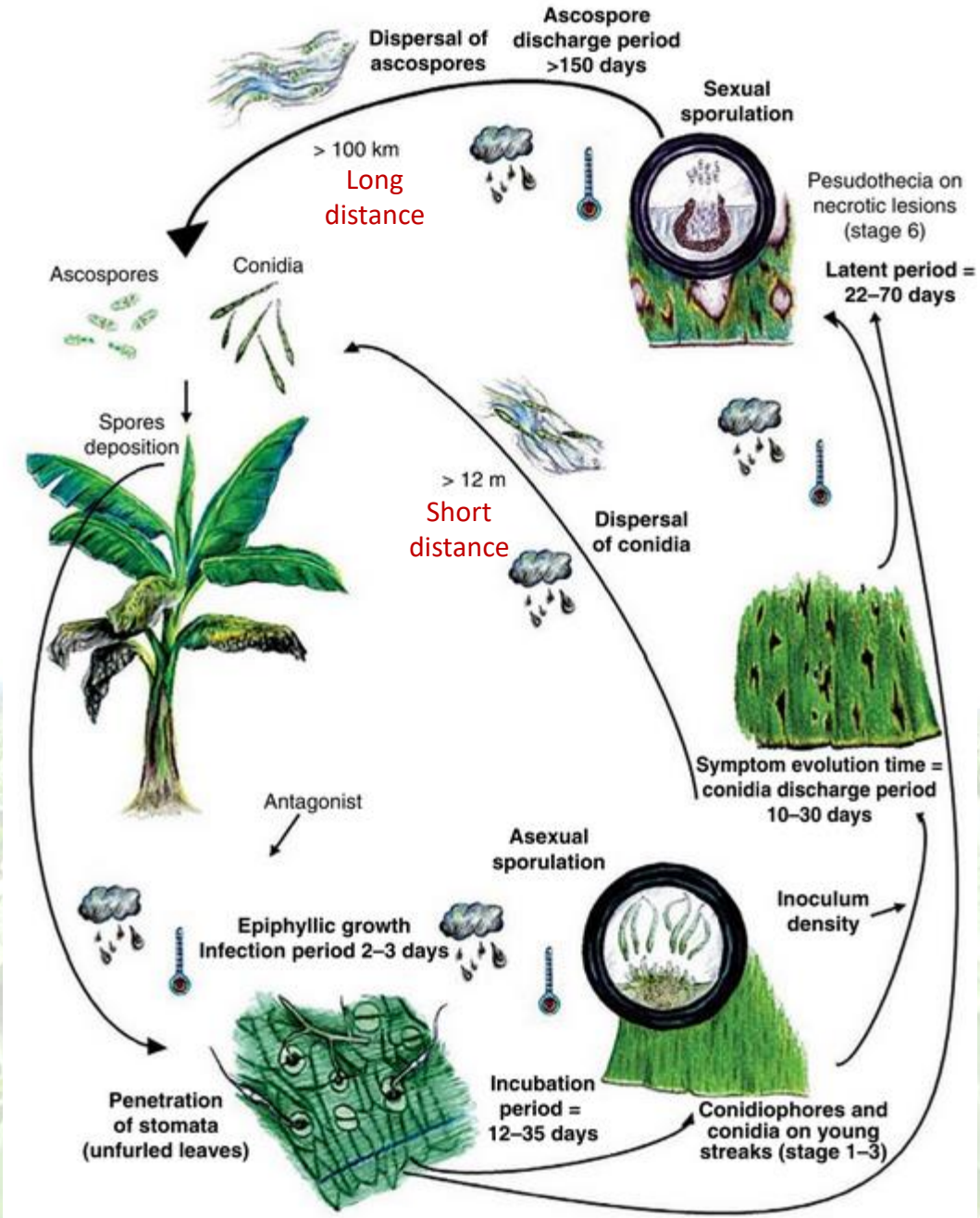
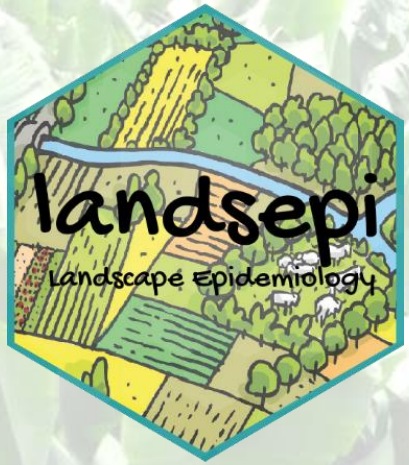


Fig. 2.3. Life cycle of *Pseudocercospora fijiensis* (syn. *Mycosphaerella fijiensis*) by L. de Lapeyre de Bellaire, L. Pérez-Vicente and M. Guzmán (drawing by A.M. Granados-Cáseres).

With the aim of reducing pesticide use,

is it possible to efficiently control black sigatoka using spatiotemporal strategies of pesticide applications or resistance deployment?

Explorations using the mathematical model landsepi



Black sigatoka
(*Pseudocercospora fijiensis*)
on banana

Finca San Pablo

Experimental farm managed by CORBANA

Length - Width: 3.1 km – 1.7 km
Area: 280 ha (300 independent subunits of 120x110 m)
Density: 18,000 plants/ha
Yield: 26 kg/plant
Production (export): 57.6 t/ha/an (total >16,000 t/an)
Continuous for more than 20 years

Reducing pesticide use in Costa Rica

Reducing pesticide use while maintaining sufficient disease control

- Direct reduction of TFI
  - Reduction of application frequency
  - Reduction of spatial coverage
  - Reduction of fungicide dose (hence efficiency)
- Replacement by resistance deployment
  - Increase in spatial coverage
  - Increase in resistance efficiency
  - Choice of target pathogenicity trait

Fungicides are costly for the environment but allow disease control:

What is the optimal strategy to minimize TFI while maximizing epidemiological control?

Resistant cultivars allow for disease control but have a smaller yield:

What is the optimal strategy to maximize yield?

Calibration to black sigatoka in Costa Rica

Parameter value
Effect of fungicide application
Effect of partial resistance (cultivar CIRAD 925)

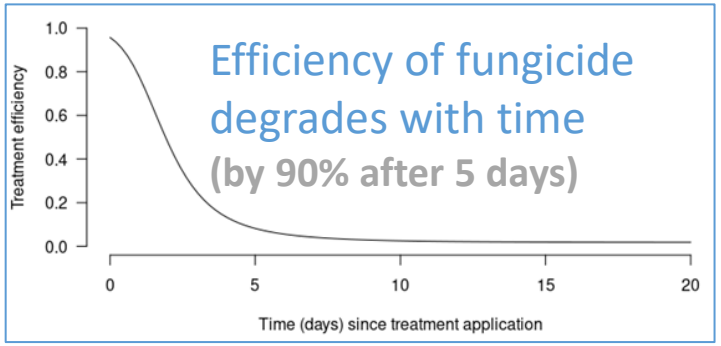
$$K(\rho) = \frac{2\pi b}{g_0^2 \Gamma\left(\frac{2}{b}\right)} e^{-\left(\frac{2\pi\rho}{g_0}\right)^b}$$

Only ascospores are modelled

Ascospores (sexual spores)

Dispersal
$g_0 = 9.32.10^{-20}$
b = 0.064

Sporulation rate
90.9 spores/lesion/day
-92%



Growth rate
0.02 day^{-1}

H

Infection rate
2%

L

+45%

Latent period
25.5 days

I

Infectious period
22 days

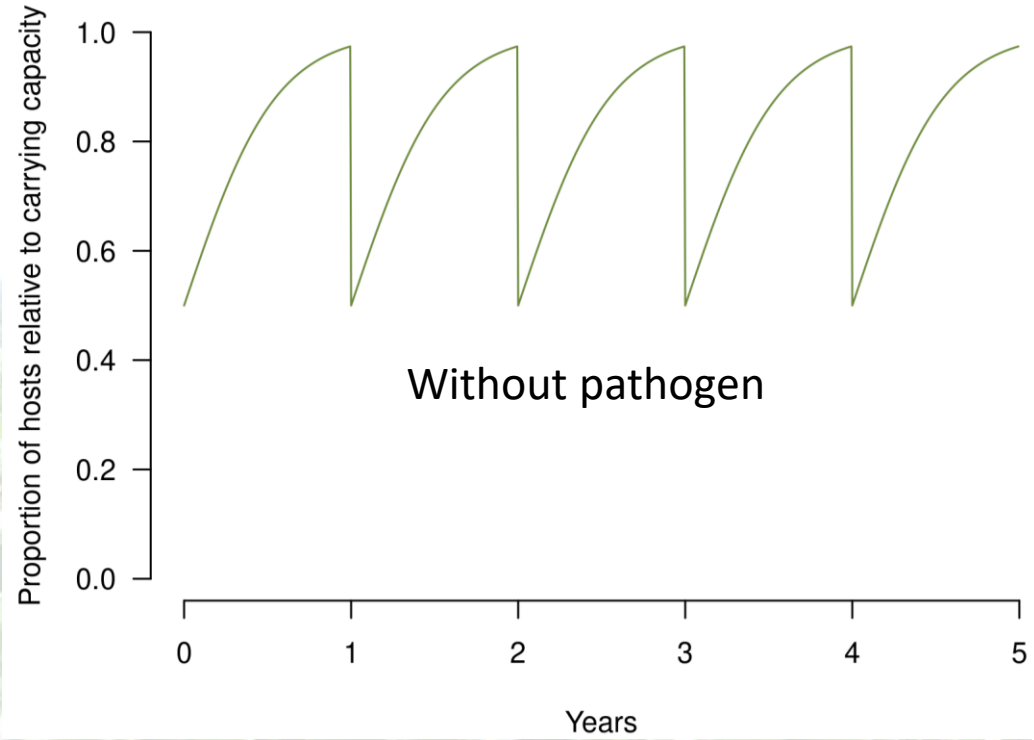
R

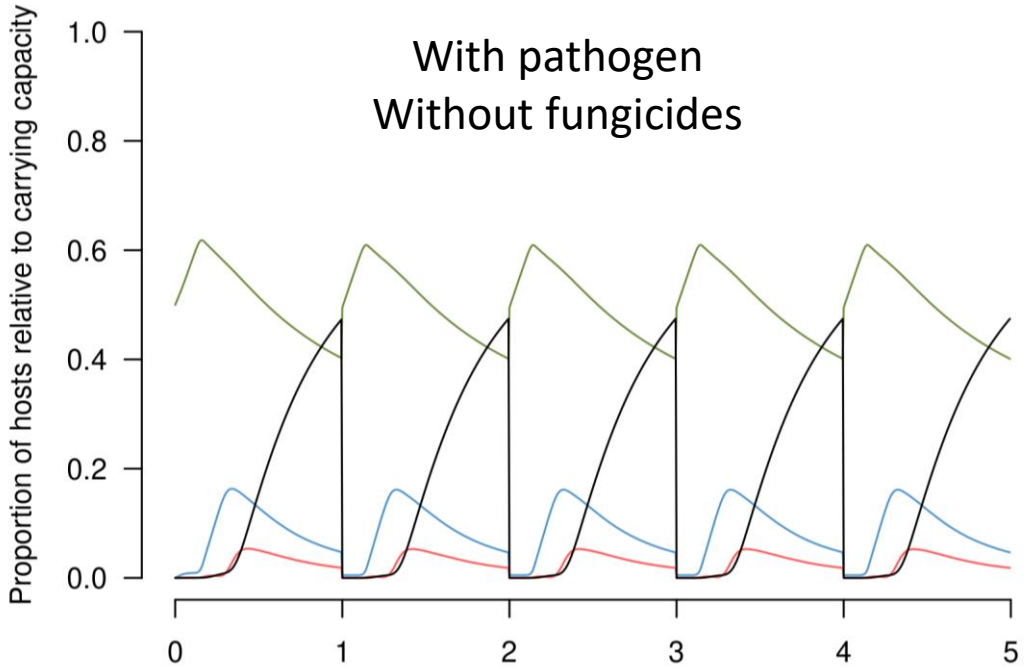
Yield: 28.8 t/ha/season
-15%

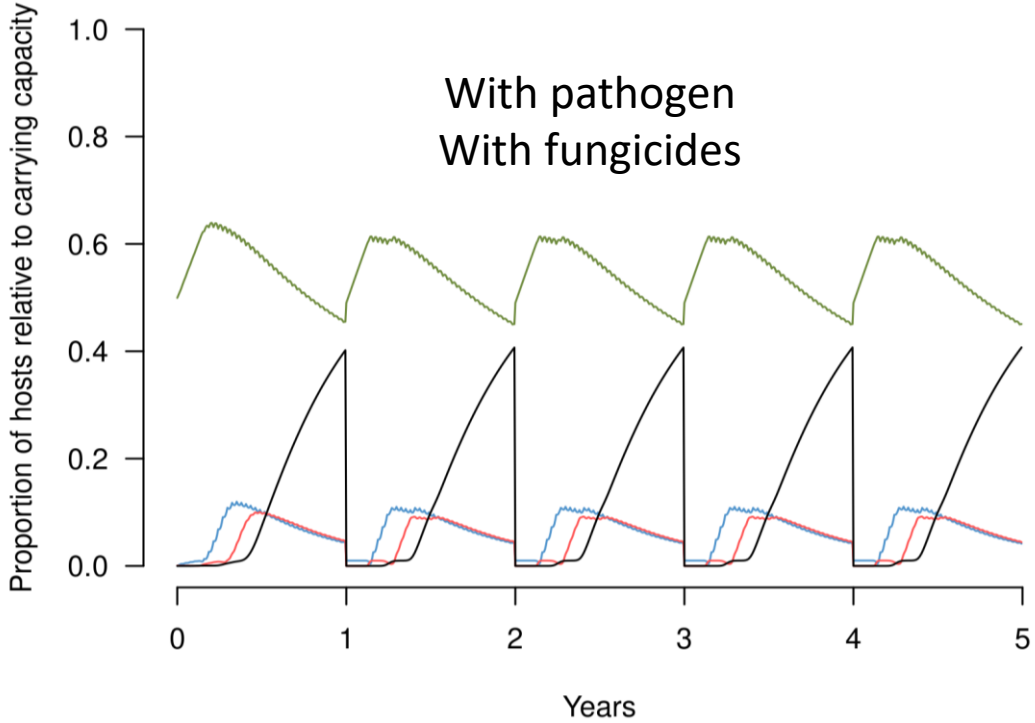
0 t/ha/season

landsepi 1.3.0

Epidemic dynamics in a 100% susceptible landscape







Status:
- H
- L
- I
- R

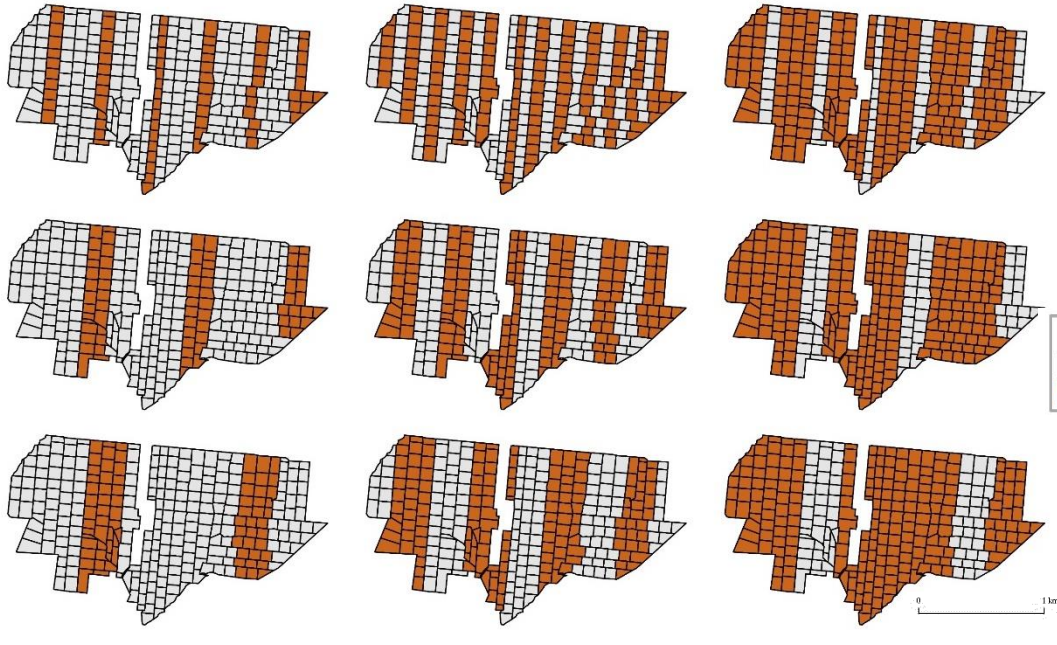
Fungicide applications

Spatial aggregation

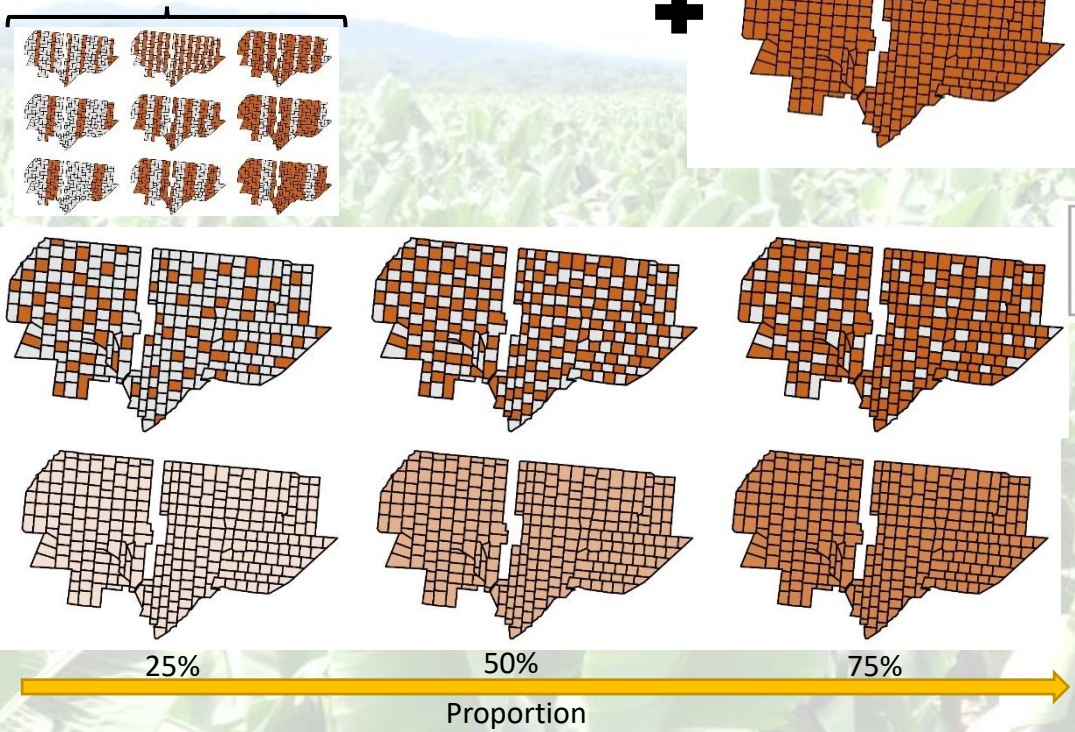
Low

Medium

High



Resistance deployment



3 **Temporal allocation**
every 5/10/15 days

10 **Spatial allocation**
aggregation/proportion

4 **Treatment efficiency**
25/50/75/100 %

120 combinations

272 combinations

16 **Spatial allocation**
aggregation/proportion

4 ✖ **Resistance gene**
IR/LAT/PR/IP

4 ✚ **Gene efficiency**
25/50/75/100 %

1 **Elite variety**
CIRAD 925 / 938

17

no pathogen adaptation

30 **Repetitions**

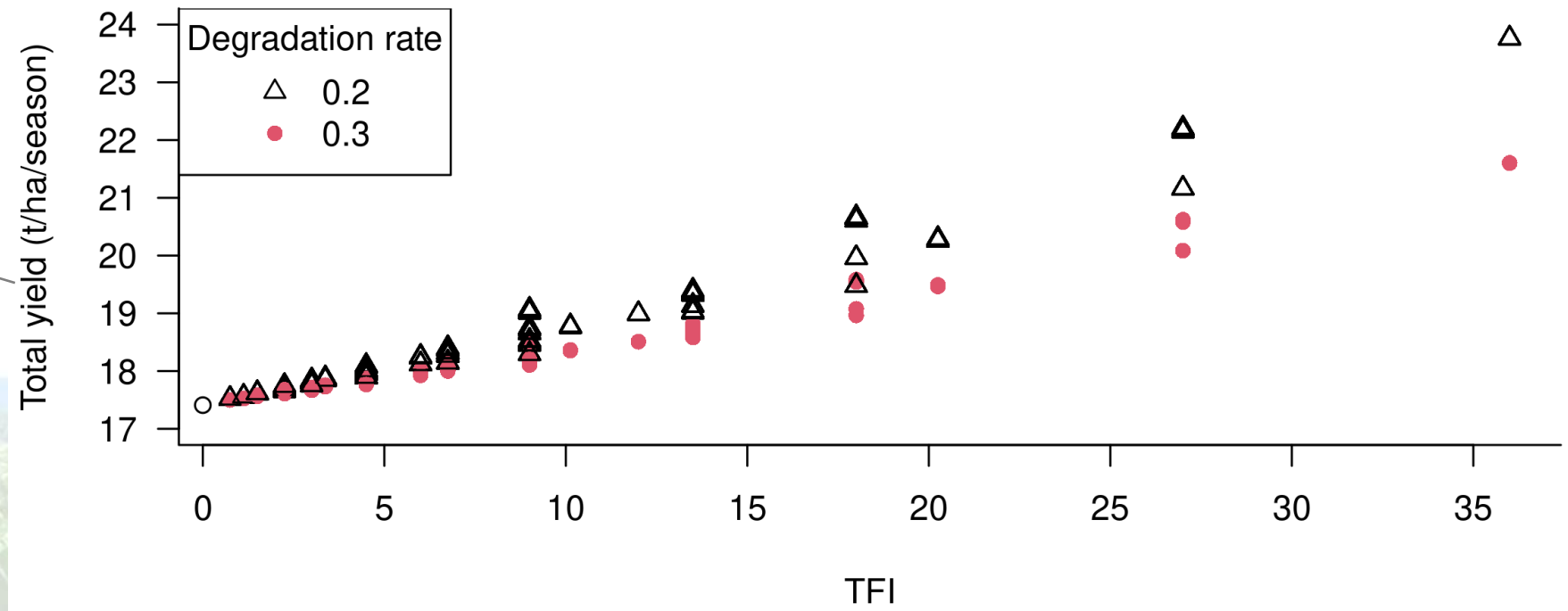
3600 simulations

8160 simulations

First results

What is the optimal strategy to minimize TFI while maximizing epidemiological control?

Correlated with sanitary status (epidemiological control)



Equivalent number of treatments at full dose per cropping season and per ha

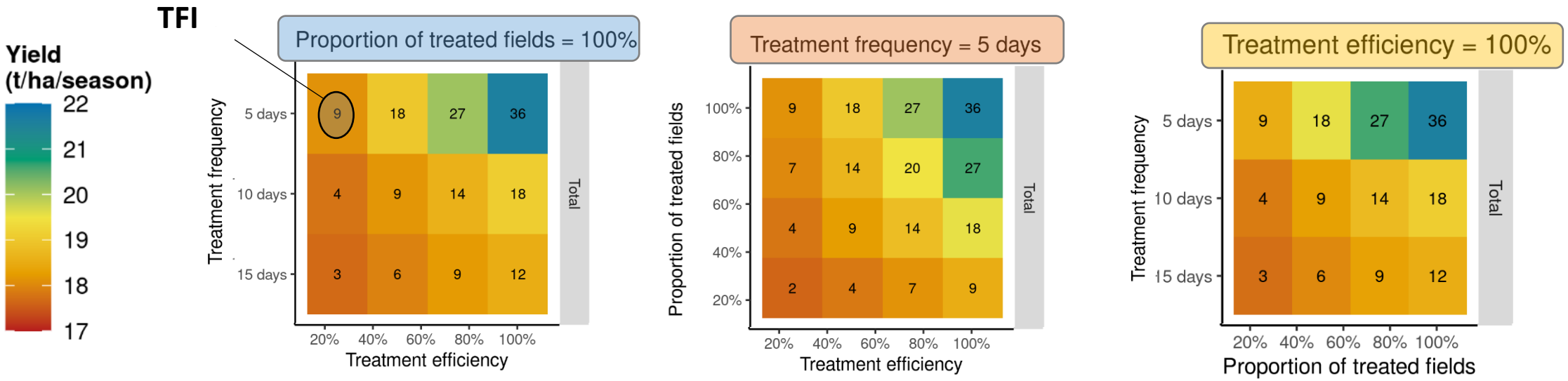
$$TFI = \frac{crop\ season\ duration}{Interval\ between\ 2\ treatments} \times Relative\ dose \times Relative\ surface$$

Frequency

Efficiency

Proportion of treated fields

First results: yield in the whole landscape



Is there an optimal trade-off between TFI and yield?

To be followed…

- Carry out a real sensitivity analysis to identify most influent parameters on yield?
- Compare local and global inoculum?

- Analyse resistance scenarios
- Combine resistance & fungicides

Special thanks to:

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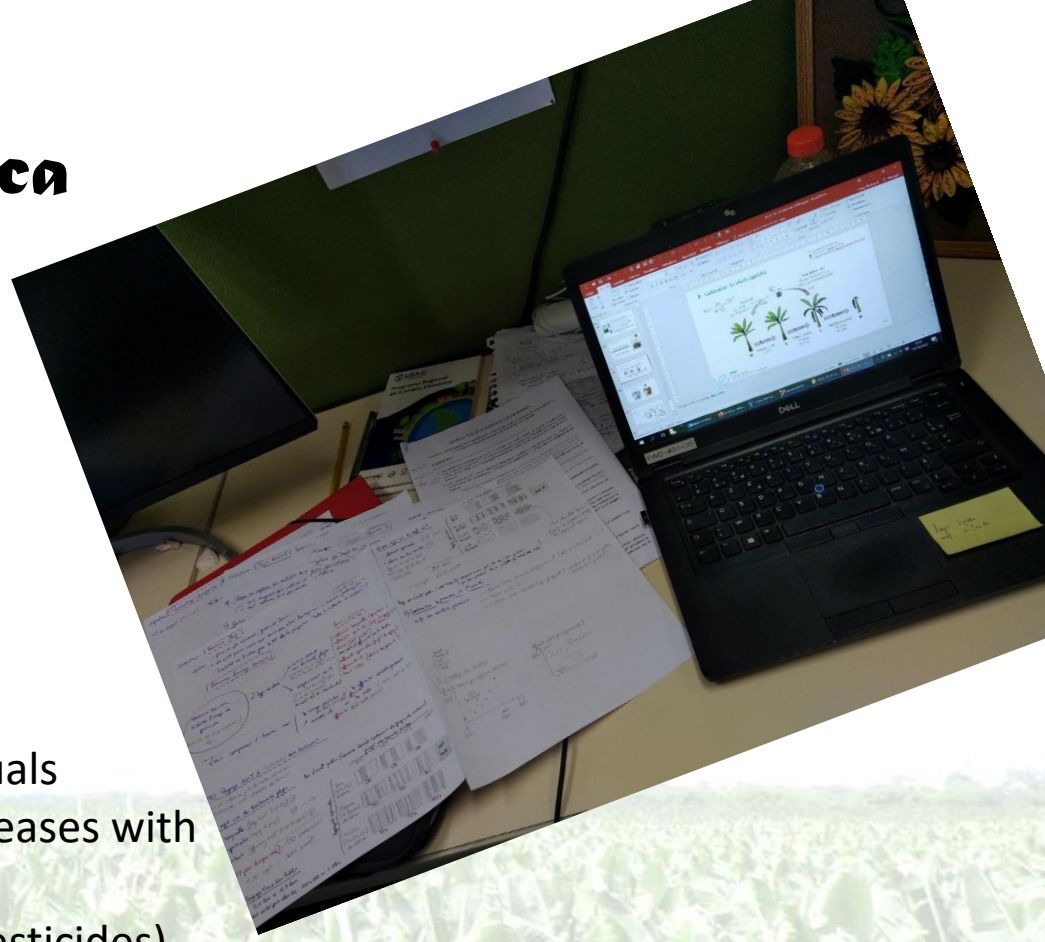
MaIAGE

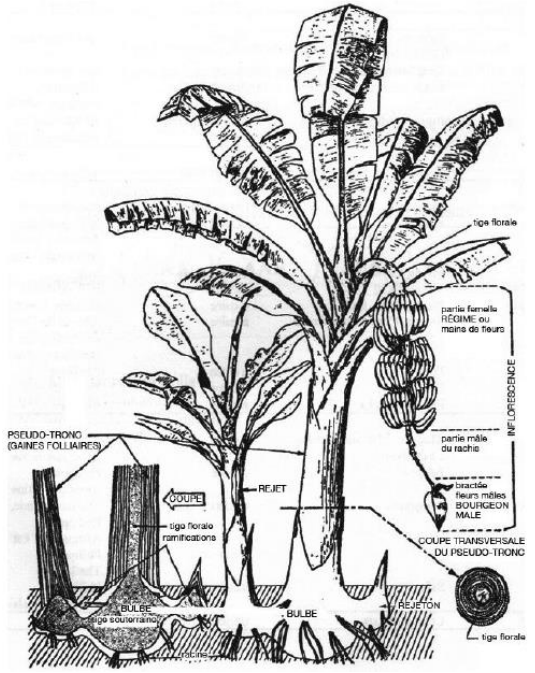
Modelling black sigatoka in Costa Rica

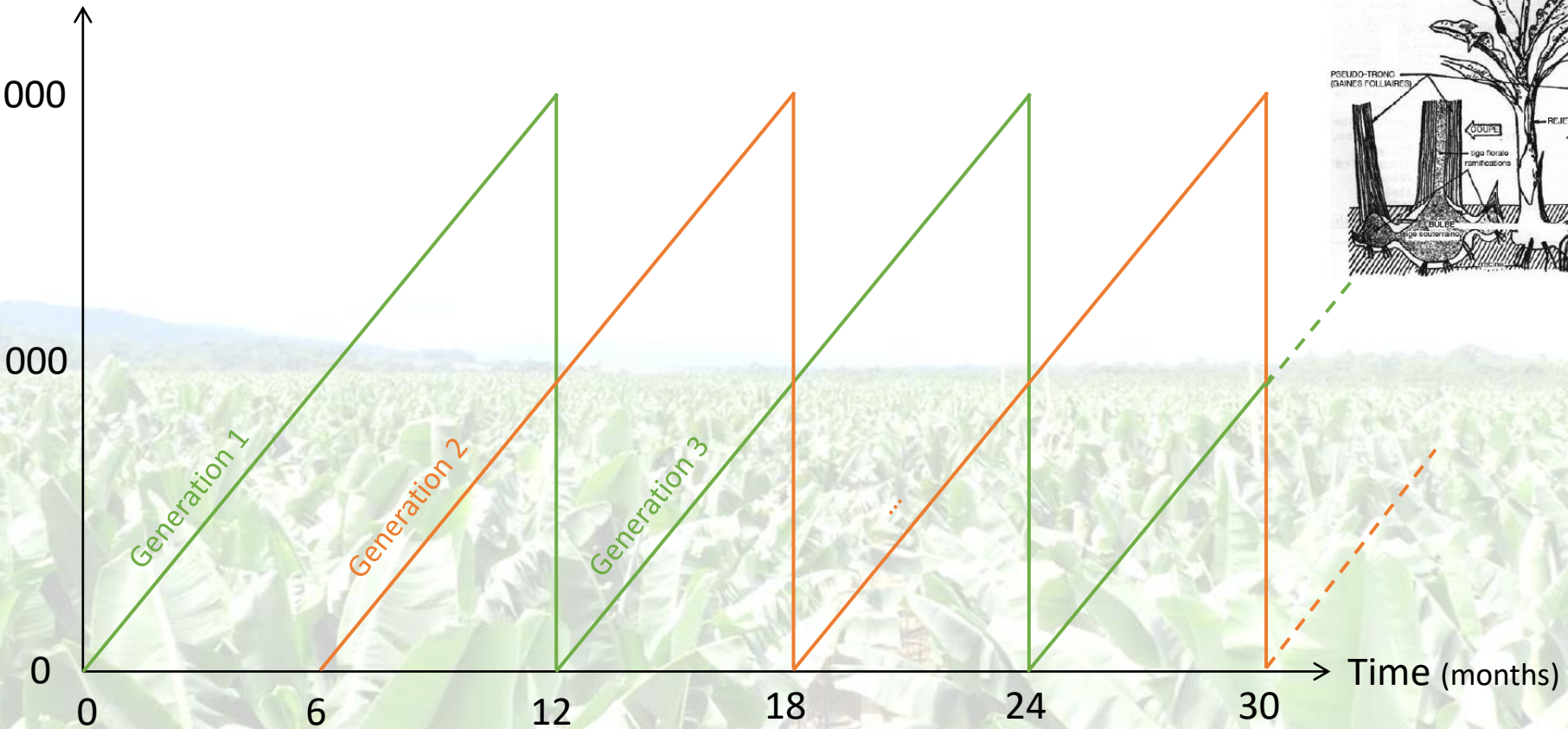


Assumptions

1. Spatial unit = « pinta » (1ha-subunit)
2. host individual = 1 banana leaf
3. Environment and climate are constant
4. Density-dependence of pathogen infection
5. Crop yield depends on the average amount of producing host individuals
6. The fungicide reduces the pathogen infection rate ; its efficiency decreases with host growth and time
7. Components of a mixture are independent each other (growth and pesticides)
8. There is no pathogen adaptation to cultivar resistance or to the fungicide
9. Ascospores are the major driver of epidemics and losses [Stover 1980; Gauhl 1993]

Host dynamics: host growth & harvest





Just before harvest,
3 generations overlap

Host dynamics: host growth & harvest

Host density
(nb of leaves/ha)

18 000

9 000

0

Model
(plant canopy)

Generation 1

Generation 2

Generation 3

...

Cropping season
T = 182 days
(i.e. 6 months)

C^{max} = 1.8 leaf/m²

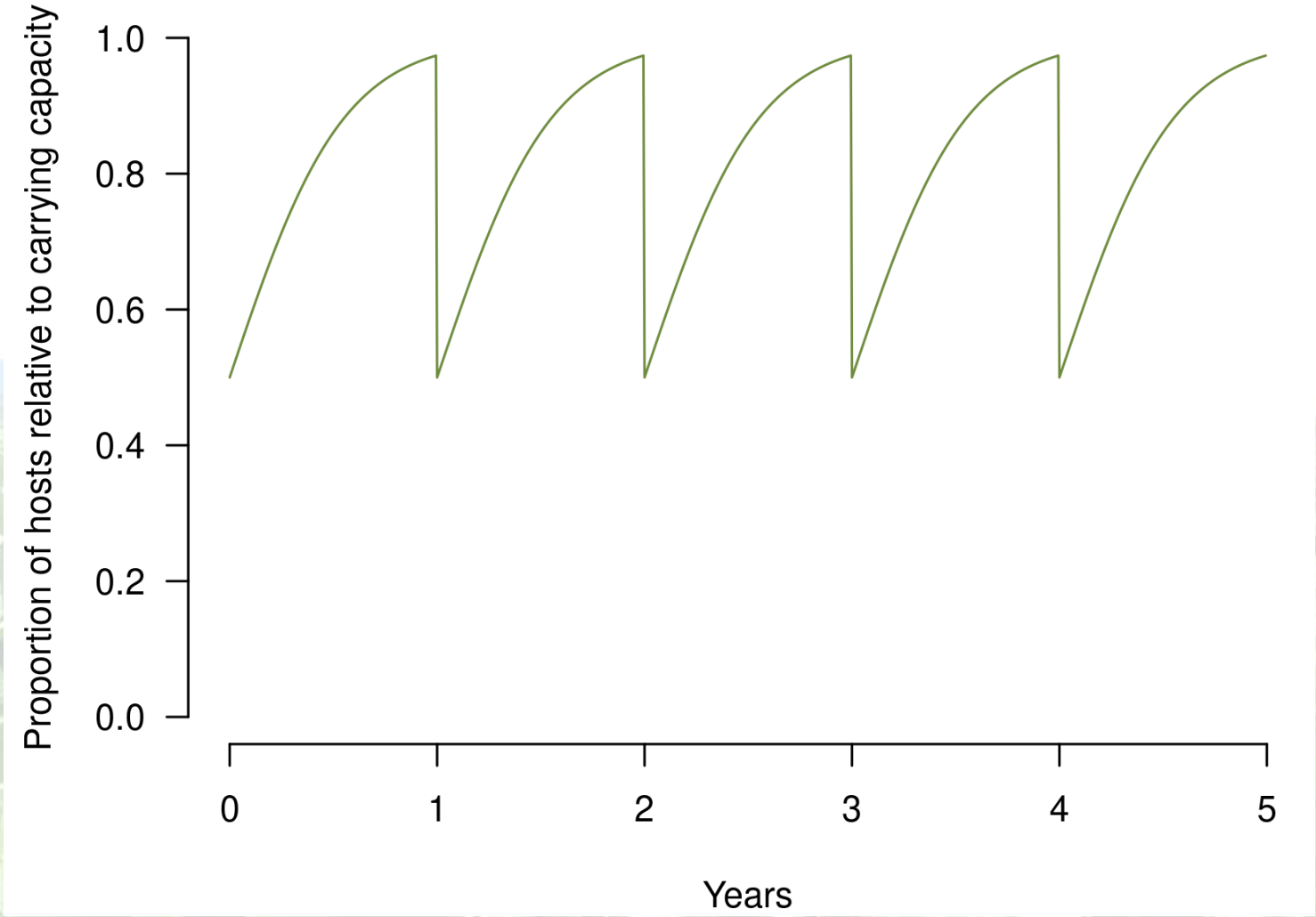
C^0 = 0.9 leaf/m²

0 6 12 18 24 30

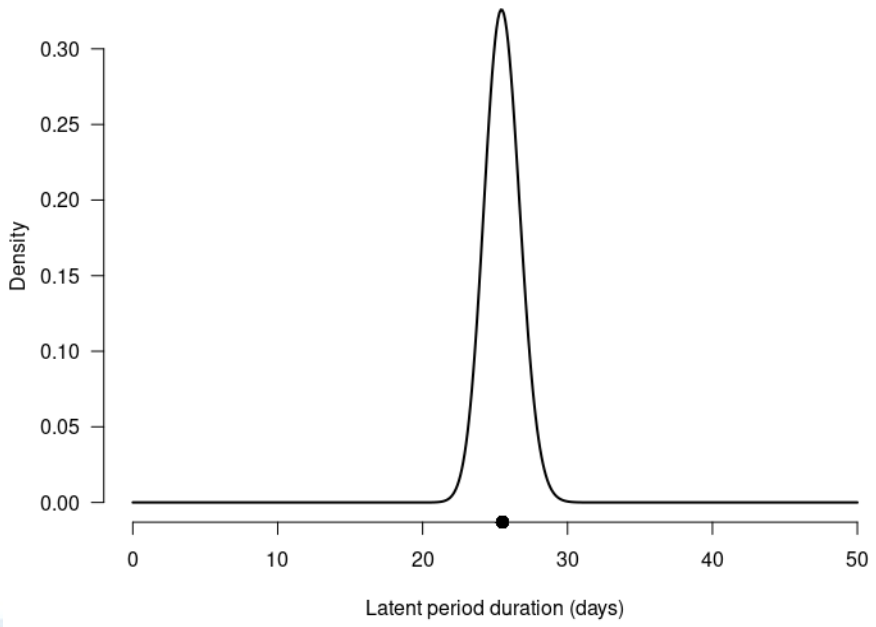
Time (months)

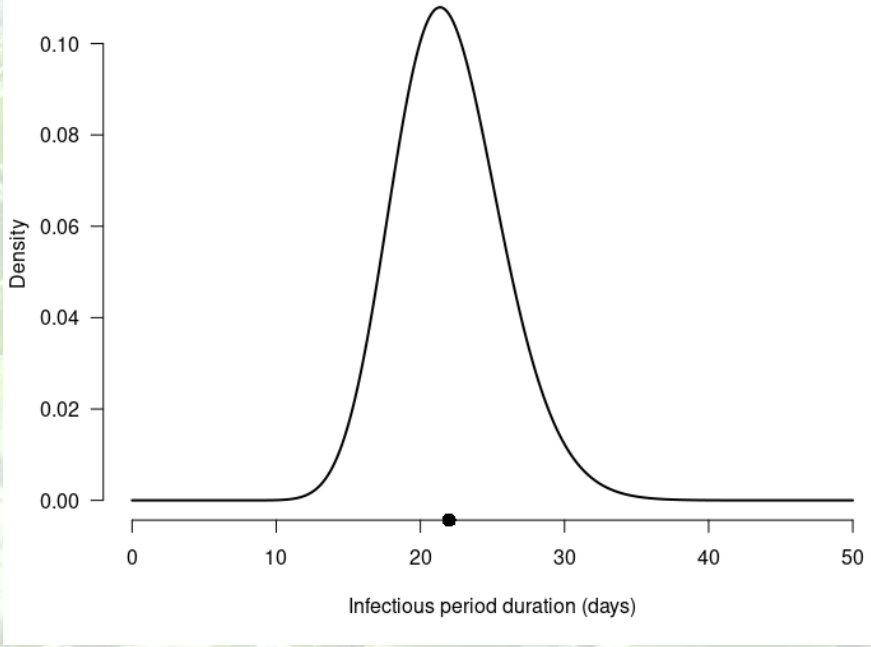
Just before harvest,
3 generations overlap

Epidemic dynamics in a 100% susceptible landscape

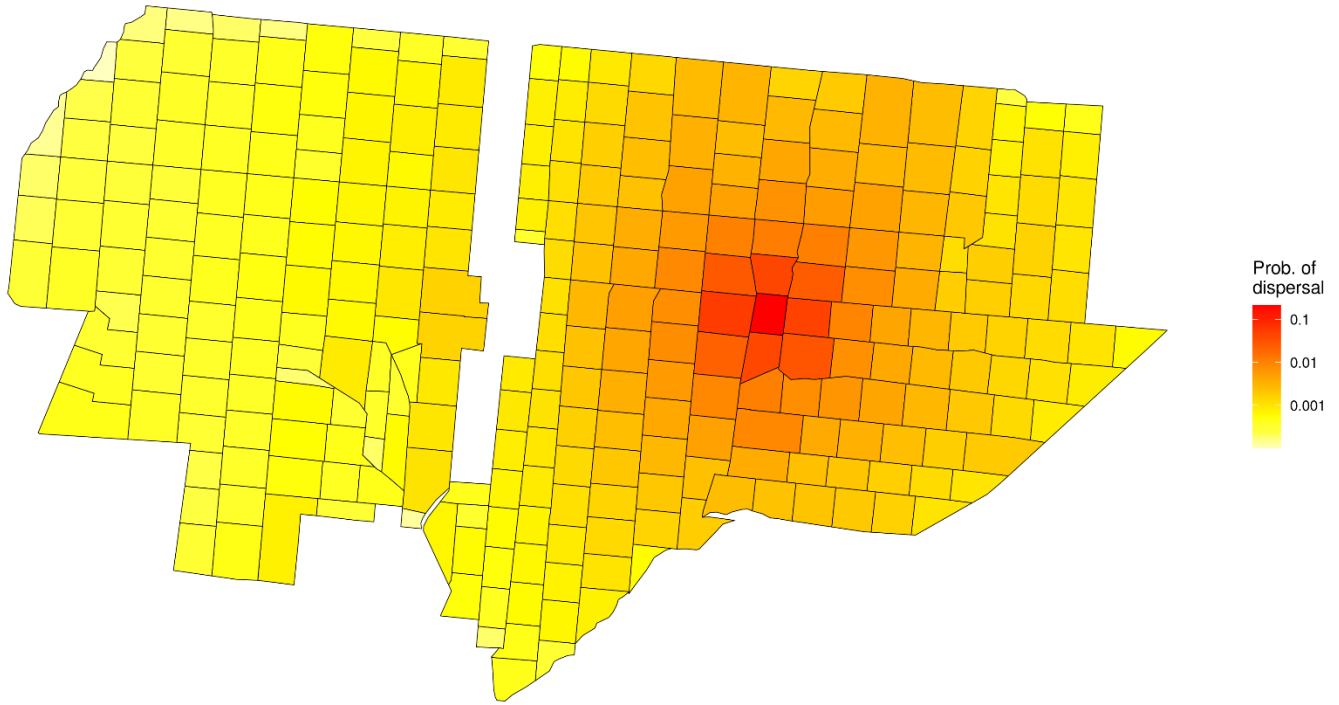


Model calibration



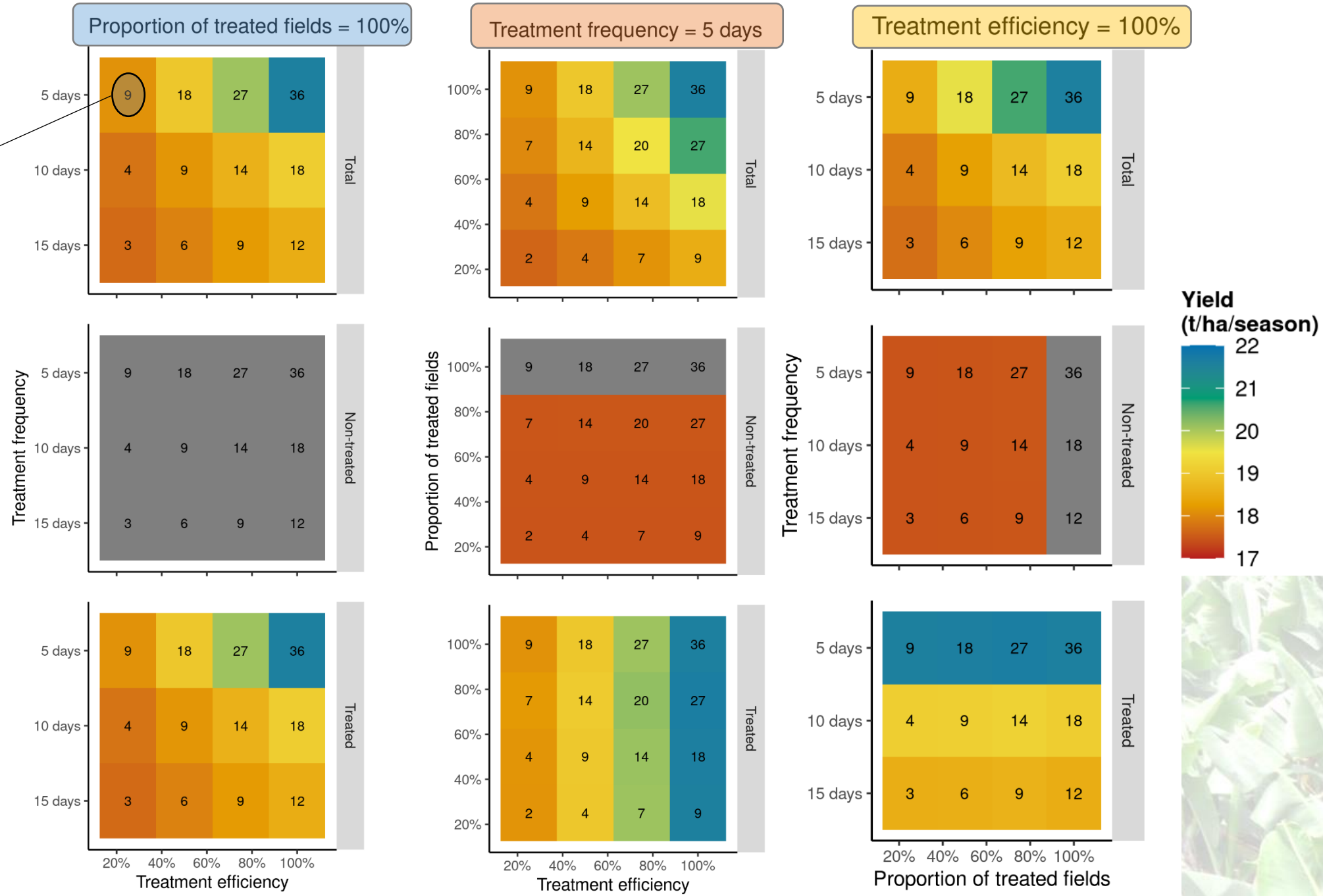


Ascospore dispersal



First results

TFI



→ Non-treated fields are always devastated

→ Yield in treated fields increases with efficiency and frequency