Overview of INRA researches on peach brown rot
First results, current works and prospects

Bénédicte Quilot-Turion
Outline of the presentation

- *Monilinia* species, cycle, attacks and control
- potential mechanisms of resistance: hypotheses from literature
- experimentations and first results from INRA Avignon
- prospects
Monilinia species

- **Monilinia fructicola**
  North and South America, New-Zealand, Australia and Europe

- **Monilinia laxa**
  Europe, Asia, America and Australia

- **Monilinia fructigena**
  Europe and Asia

- **Monilia polystroma**
  Asia and Eastern Europe

Byrde 1977, Fan et al. 2010, Hu et al. 2011
Monilinia spp. cycle

They multiply mainly by sexual forms

Adaskaveg 1993
Pacheco 2009
Attacks and symptoms

Twig blight

Blossom blight

Fruit brown rot
Brown rot in peach orchards

**Situation**
- can cause up to 30 - 40% of losses at harvest
- no resistant cultivar available
- current prophylactic measures are insufficient
- chemical control is generalized

**High environmental impact**

**Sanitary troubles**

**Apparition of resistance to pesticides**

**2 levers for action**
- genetic resistance
- cultural practices

**Limit brown rot in orchards and increase fruit quality by association of resistant cultivars and sustainable cultural practices**

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Bolinha: a high level of resistance

Bolinha, a cultivar from Brazil

- Small fruits
- Thick cuticle
- High level of phenolic content

Feliciano et al. 1987

Gradziel et al. 1998 & 2003
Lee & Bostock 2006
Lee & Bostock 2007

Which fruit tissue confer resistance?
Is it a chemical or physical resistance or both?
Resistance at the level of cuticule and epiderm?

A  APRICOT

PEACH

Number of infected fruits
A: without wounds
B: wounded

Pascal et al., 1994

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### Context

**The cuticle and epidermis: a physical barrier**

### Hypotheses

**Efficiency largely reduced by ‘open doors’**
- microcracks
- stomates
- lesions and wounds

-> in most studies, *Monilinia spp.* are considered to be opportunistic!

**Some cultural practices (low thinning, moderate irrigation) decrease apparition of microcracks**

### Results

<table>
<thead>
<tr>
<th>Fruit mass (g)</th>
<th>S&lt;sub&gt;cracking&lt;/sub&gt; (cm&lt;sup&gt;2&lt;/sup&gt;)</th>
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<tbody>
<tr>
<td><strong>Low load</strong></td>
<td><img src="image1.png" alt="Graph" /></td>
</tr>
<tr>
<td><strong>High load</strong></td>
<td><img src="image2.png" alt="Graph" /></td>
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**Trees in container**

*Gibert et al 2007*
**Monilinia species** are not only opportunistic!
They can produce enzymes such as cutinase to penetrate the fruit.

Surface and epiderm compounds may interfere with infection:
- caffeic acid
- chlorogenic and neochlorogenic acids
- catechin and epicatechin

*Gradziel et al. 1998 & 2003; Lee & Bostock 2006; Lee & Bostock 2007*
**Objectives and means**

- discover other sources of resistance
  -> develop reliable infection tests to evaluate Monilinia resistance on fruits to screen accessions

- identify fruit physical and biochemical characteristics that are related to levels of infection
  -> profiling of traits on contrasted cultivars along fruit growth

- obtain indications on the genetic basis of resistance and fruit characteristics linked to resistance
  -> create progenies segregating for resistance

- describe propagation of brown rot between fruit and trees
  -> survey of Monilinia airborne spores in orchards and fruit infection

- simulate scenario to optimize GxE interactions
  -> include interesting information in an existing fruit growth model and develop optimization methods
Set up of standardized protocols for infection tests

Infections with suspension of spores of *M. laxa*

**Drop test in laboratory:** no wounds _ evaluate ‘chemical barrier’

- Infection probability
- Evolution of the lesion diameter

**Spray test in orchard:** evaluate global fruit resistance in a high-throughput way

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Evolution of susceptibility along fruit growth

**Cultivars:** Summergrand and Zephyr
7 harvest dates

**Fruit growth**

**Infection probability**
Phase I: young fruits are susceptible

- high density of open stomates
- low thickness of epicuticular waxes

**Susceptibility evolution**

**Context**

**Hypotheses**

**Results**

**Prospects**

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Study of the link between number of stomates, cuticular conductance and infection probability?

Evaluation of the number of stomates per fruit for 10 genotypes

Significant differences between genotypes

Next step: adapt the protocol to phenotype a progeny

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Phase II: pit-hardening, fruits are resistant

Surface and epiderm compounds how high negative correlation with fruit sensitivity to *M. laxa*

Yang, Y. 2012
Phase III: fruit becomes susceptible before maturity

- apparition of microcracks
- dilution of chemical compounds

**Context**

**Hypotheses**

**Results**

**Prospects**

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Studies of genetic determinism of resistance to *M. laxa*

**Phenotyping progenies for resistance to brown rot and traits potentially linked to it**

**BC2** (150 individuals)

\[ Prunus davidiana \times Summergrand \]

\[ SD40 \times Summergrand \]

\[ BC1 \times Zéphyr \]

\[ BC2 \]

99 individuals phenotyped with ‘Spray test’ in orchard in 2013 and 2014
125 individuals phenotyped by test ‘Drop test’ in laboratory in 2013 and 2014

**Bolinha\(^2\)** (130 individuals)

Progeny stemmed from selfing of ‘Bolinha’ cultivar
95 individuals phenotyped by ‘Drop test’ in laboratory in 2014

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Studies of genetic determinism of resistance to *M. laxa*

**BC2 progeny 2013 results**

- Spray test
- Drop test

**Infection probability**

Many individuals looked resistant to *M. laxa*

High variations within the progeny: probability from 0 to 100%

→ resistant factors may segregate in the progeny

→ Towards QTL of resistance

Same tests used by UNIMI colleagues to screen other progenies
Studies of genetic determinism of cuticular conductance of fruit

3 characteristics of cuticular conductance profiles:
- Early max
- Minimum
- Late max

Proxy of stomate number or cuticule thickness?

Towards QTL of parameters linked to cuticular conductance
Cultural practices and climate influence:
- fruit features
- orchard inoculum

Mercier et al, 2005, Phytoma

Physical and chemical features of fruits are potential factors of resistance for brown rot.

The ‘Virtual Fruit’, a process-based model
Bertin et al, 2010

Peach-brown rot is a complex system under the influence of genotype, environment and cultural practices.

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‘Virtual fruit’ simulates fruit growth and quality and µcracks

Low load crop

High load crop
A modelling approach of ideotype conception

optimisation

exploration of parameter space

Virtual fruit

Genetic parameters

stockage of best solutions

Evaluation of phenotypic performances

Simulation of traits

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Context Hypotheses Results Prospects

Crop load 
Irrigation 
Simulations 
Virtual fruit 
Genetic parameters 
Simulations
One genotype is defined by a set of 6 genetic parameters of the Virtual Fruit
The aim is to find best combinations of the 6 parameters to fulfill the objectives

Objectives: traits of interest simulated by the model
Fruit mass (g) to be maximised
Sweetness (%) to be maximised
Microracks density to be minimised

Environment and cultural practices: input of the model
Site: Avignon, France
Irrigation: 2 contrasted levels
Fruit load: 2 thinning levels

Optimisation methods
Multi-objective genetic algorithm (NSGA-II)
Parameter space is continuous and constraint by limits defined from observations or litterature

Kadrani et al. IJ Swarm Intelligence Research, 2012

Context
Hypotheses
Results
Prospects

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Explore the space of possible phenotypes

400 virtual genotypes
- non optimized
- optimized

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Propose ideotypes for different targets

Types:
- commercial
- alternative
- niche market
An integrative approach to tackle the whole system

Impact of climate factors
target traits underlying processes

Epidemiology

Peach-brown-rot interactions
biochemical resistance microcracks

Integration of genetic control
Quantitative genetics model

Genetic diversity
Traits determinism

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Thank you for your attention!