IPM 2.0 approach
to Potato late blight Control

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Outline

- Background on IPM
- *Phytophthora infestans* (in the Netherlands)
- Breeding efforts in Wageningen
- A potato late blight control strategy based on host resistance and *P. infestans* population monitoring
IPM (EU directive 2009)

- **IPM components:**
  - **Prevention** (rotation, sanitation, host resistance, healthy seed, landscaping)
  - Monitoring pathogens
  - **Appropriate, science-based, measures**
  - Biological $\rightarrow$ Physical $\rightarrow$ non-chemical $\rightarrow$ chemical
  - No side-effects
  - Sustainable application
  - **limit chance resistance / virulence development**
  - Professional use
Disease development & Spray decisions

- Weekly spray schedules ("IPM")
  - Host is present
- IPM 1.0
  - Host is present
  - Weather suitable for infection
    1st generation DSS’s
- IPM 2.0
  - Host is present
    - Susceptible?
    - Resistant? Which R-genes?
  - Weather suitable for infection (DSS’s)
    - For how long?
    - Do spores survive atmospheric transport (DWIP)
  - Pathogen is present
    - How much? (disease pressure)
    - Specific genotypes?
      - Specific virulences?
      - Fungicide resistance?
Phytophthora infestans in the Netherlands

3 groups were distinguished based on “PCA” & STRUCTURE results

Dutch population (2000-2009)
311 genotypes 652 isolates

Blue = Group 1
Red = Group 2
Green = Group 3
Phytophthora infestans in the Netherlands

![Graph showing the number of Phytophthora infestans isolates from 2000 to 2009. The x-axis represents the years from 2000 to 2009, and the y-axis represents the number of isolates. The graph includes various colors and patterns for different isolates, with peak years of occurrence marked.](image-url)
Effectiveness of IPM components

<table>
<thead>
<tr>
<th>Sub-models description</th>
<th>Compare submodels</th>
<th>Best Practice</th>
<th>Weather data</th>
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<tbody>
<tr>
<td>Case - Denmark</td>
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<tr>
<td>In Denmark farmers have been using reduced dosages for years.</td>
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<tr>
<td>In Denmark, data from the national monitoring network, weather-based infection pressure, cultivar resistance and crop growth stage determine strategies with reduced dosages.</td>
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<td>Case A: In Denmark farmers have been using reduced dosages for years.</td>
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<td>Case - the Netherlands</td>
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<tr>
<td>Test of control strategies including use of a DSS to</td>
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<table>
<thead>
<tr>
<th></th>
<th>Documentation</th>
<th>Barriers</th>
<th>Contribution to input reduction</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Rotation</td>
<td>Only on best farms/in some regions/in some countries</td>
<td>Economic/costs AND limited influence on blight</td>
<td>Intermediate</td>
<td>Applicable in organic farming</td>
</tr>
<tr>
<td>Primary inoculum sources</td>
<td>Only on best farms/in some regions/in some countries</td>
<td>Economic/costs AND risk perception</td>
<td>Intermediate</td>
<td>Applicable in organic farming</td>
</tr>
<tr>
<td>Planting time and density</td>
<td>Only on best farms/in some regions/in some countries</td>
<td>Economic/costs AND limited influence on blight</td>
<td>Small</td>
<td>Applicable in organic farming</td>
</tr>
<tr>
<td>Fertilization</td>
<td>Only on best farms/in some regions/in some countries</td>
<td>Limited influence on blight</td>
<td>Small</td>
<td>Applicable in organic farming</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Widespread in practice</td>
<td>Limited influence on blight</td>
<td>Small</td>
<td>Applicable in organic farming</td>
</tr>
<tr>
<td>Cultivar resistance</td>
<td>Only on best farms/in some regions/in some countries</td>
<td>Economic/costs AND risk perception</td>
<td>Lower dependency on chemicals AND Large</td>
<td>Applicable in organic farming</td>
</tr>
<tr>
<td>Fungicides</td>
<td>Widespread in practice</td>
<td>Economic/costs AND risk perception</td>
<td>Intermediate</td>
<td>Not applicable in organic farming, except that some countries allow use of Copper</td>
</tr>
<tr>
<td>DSS</td>
<td>Only on best farms/in some regions/in some countries</td>
<td>Economic/costs AND risk perception</td>
<td>Intermediate</td>
<td>Applicable in organic farming, excluding fungicide modules etc.</td>
</tr>
<tr>
<td>Desiccation</td>
<td>Widespread in practice</td>
<td>Risk perception</td>
<td>Small</td>
<td>Applicable in organic farming, excluding desiccation by applying chemicals</td>
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<tr>
<td>Harvest</td>
<td>Widespread in practice</td>
<td>Economic/costs</td>
<td>English (United States)</td>
<td>Applicable in organic farming</td>
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</tbody>
</table>
New technologies

- **Host plant resistance:**
  - Identification/cloning of many R-genes
  - Marker assisted breeding
  - GM breeding ([www.DuRPh.nl](http://www.DuRPh.nl))

- **Environment:**
  - Improved weather forecasts
  - DSS systems
  - Precision agriculture

- **Pathogen:**
  - Identification of Avr genes incl. variation
  - Effectoromics
  - Direct PCR assays for virulence in pathogen

<table>
<thead>
<tr>
<th>Avr</th>
<th>Ref</th>
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<tbody>
<tr>
<td>Avr1</td>
<td>Govers (pers comm)</td>
</tr>
<tr>
<td>Avr2</td>
<td>(Gilroy et al., 2011)</td>
</tr>
<tr>
<td>Avr3a</td>
<td>(Armstrong et al., 2005)</td>
</tr>
<tr>
<td>Avr3b</td>
<td>(Li et al., 2011)</td>
</tr>
<tr>
<td>Avr4</td>
<td>(van Poppel et al., 2008)</td>
</tr>
<tr>
<td>AvrBlb1</td>
<td>(Vleeshouwers et al., 2008)</td>
</tr>
<tr>
<td>AvrBlb2</td>
<td>(Oh et al., 2009)</td>
</tr>
<tr>
<td>AvrVnt1</td>
<td>(Vleeshouwers et al., 2011)</td>
</tr>
<tr>
<td>AvrSmira1</td>
<td>(Rietman et al., 2012)</td>
</tr>
<tr>
<td>AvrSmira2</td>
<td>(Rietman et al., 2012)</td>
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Monitoring for virulence with *Avr-blb1*

- **Rpi-blb1**
  - Class I Avr-blb1 absent: Virulent
  - Real time monitoring
  - Q-PCR for Blb1 virulence on *P. infestans*

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**Theo van de Lee**
Champouret et al, 2009 MPMI
An IPM 2.0 control strategy for PLB

- Proof of concept
- IPM 2.0 control strategy for Potato Late Blight (PLB):
  - **Host:**
    - presence / absence & growth stage
    - residual fungicide protection
    - Resistance → reduced dose rates of protectants
  - **Pathogen:**
    - DWIP → go / no go on resistant cultivars (Skelsey et al 2009)
    - Virulence for R gene(s) used
  - **Environment:**
    - Significant infection event predicted (DSS)
    - Length of infection event: → reduced dose rates

**We DO NOT spray unless ... ALL** criteria for disease development are full filled

**Goal:**
- More durable and efficient use of resistance and fungicides
- Durable cultivation of potato
Field Trials

- Two years (2010 & 2011)
- Two locations (Lelystad & Valthermond)
- **Default Strategy:**
  - Range of host resistance: S - MR - HR
    - Bintje/Starga
    - Escort (R1R3R10) or Santé (R1R10) MR
    - Bionica (Blb2)
    - Chc1
    - Blb1
    - Vnt1 (2010)
  - Custom experimental IPM 2.0 DSS → Spray timing
- **WITH or WITHOUT** Continuous monitoring for virulence:
  - Weekly lesion counts in monitoring plots
  - Weekly lesion samples → PCR analysis Blb1 virulence
Field trial set up in Lelystad & Valthermond
Avr-Blb1 virulence assay within 5 hrs

96 well format
Lelystad 2010
Valthermond 2010
Monitoring plots Lelystad & Valthermond
Lesion counts monitoring plots

2010

Lelystad

Valthermond

2011

# Lesions in Monitoring Plots

Week 29 Week 30 Week 31 Week 32 Week 33 Week 34 Week 35 Week 36

Week 26 Week 27 Week 28 Week 29 Week 30 Week 31 Week 32 Week 33
Avr-Blb1 effector Screening

- **2010**
  - NO infections on Blb1 plant material
  - PCR: 633 samples, **1 virulent isolate** in Lelystad
  - Confirmed in Bio Assay!

- **2011**
  - First infections on Blb1 plant material:
    - Lelystad: 8 August 2011
    - Valthermond: 15 August
  - First PCR positive Blb1 virulent isolates:
    - Lelystad: 25 July 2011 (Bintje & Bionica)
    - Valthermond: 15 August 2011 (Blb1 plant)
Results

- Valthermond 2011

![Bar chart showing results for Valthermond 2011. The chart compares different practices and their outcomes with and without certain brands such as Starga, Santé, Bionica, Chc1, and Blb1.](chart.png)
Results

Valthermond

2010

Full dose rate equivalents / Severity (%)

End of Season Severity (%)

Valthermond 2010

2011

Full dose rate equivalents / Severity (%)

End of Season Severity (%)

Valthermond 2011

Lelystad

2010

Full dose rate equivalents / Severity (%)

Lelystad 2010

2011

Full dose rate equivalents / Severity (%)

Lelystad 2011
Conclusions

- The full potential of IPM in PLB control is not yet realized, ... not even close!
- Ample room for improvement **IF** host resistance is introduced
- *P. infestans* highly adaptive → Resistance should be designed / introduced in the most durable way (stacking of R-genes, multilines, landscaping etc.)
- Resistance should be managed after introduction. It’s NOT a silver bullet
- Fungicides remain an integral part of the control strategy but input is lower
- Spin off of IPM 2.0 control strategy for PLB to other “aerial” pathosystem e.g. rusts & mildews in cereals, downy mildew in grapes, apple and pear scab ...