Strategies for integrated deployment of host resistance and fungicides to sustain effective blight control

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HAPI - HORTICULTURE AND POTATO INITIATIVE

Supporting high-quality industrially relevant research projects on potato and edible horticulture crops
Aim: To maximise durability of effective control by integrated deployment of host resistance and fungicides

Two dynamic interactions

Fungicides
- Introduction of new MOA
- Evolution of insensitivity

Host resistance genes
- Introduction of a new gene
- Evolution of virulence
Integration is believed to increase sustainability

High efficacy  
High risk  

Partial efficacy  
Low risk  

Qualitative host resistance  
Quantitative host resistance  

Single-site MOA  
Multi-site MOA
Virulent/resistant strains gain a competitive advantage over existing 'wild-type' strains because they are able to grow more rapidly in the presence of the control measure that they are able to overcome.

However:
A new virulent strain will still be slowed by fungicides, reducing its competitive advantage – hence fungicides may slow down selection for virulence

Similarly, cultivar resistance may slow down selection for fungicide insensitivity
Generic principles

\[ sT = (r_R - r_S)T \]

- Rate of evolution of resistance
- Exposure time
- Rate of increase of resistant strain
- Rate of increase of sensitive strain

Strategy 1: Reduce both \( r_R \) and \( r_S \)
Strategy 2: Reduce \( r_R \) relative to \( r_S \)
Strategy 3: Reduce exposure time

84% of published cases agree with prediction
5% disagree
Hypotheses and objectives

- H1: Deployment of crop resistance reduces selection for fungicide insensitivity.
- H2: Deployment of fungicides reduces selection for virulence.
- H3: How crop resistance genes and fungicides are integrated is a key determinant of the durability of control.
4 inter-linked objectives

Test the effect of

1) Host resistance on selection for fungicide insensitivity
2) Fungicide treatments on the selection for virulence
3) Develop a basis for integrated control to constrain pathogen evolutions towards fungicide insensitivity and virulence
4) Develop strategies for durable control using fungicides and cultivar resistance
What did we need? 2013

H1: Deployment of crop resistance reduces selection for fungicide insensitivity.

- Pairs of isolates with similar aggressiveness that have different fungicide sensitivity (metalaxyl)
- Pairs of cultivars with different levels of host resistance (King Edward, Cara)

H2: Deployment of fungicides reduces selection for virulence.

- Pairs of isolates with similar aggressiveness that have different virulences (+/-avr2)
- Pairs of cultivars with different R genes - King Edward (-R2), Pentland Dell (+R2)
<table>
<thead>
<tr>
<th>Isolate</th>
<th>Genotype (unique fingerprint)</th>
<th>Met</th>
<th>Race</th>
<th>Infects P. Dell (R2)?</th>
<th>Infects KE (no R2)?</th>
<th>Aggressiveness (Relative Growth Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>13_A2</td>
<td>R</td>
<td>1,2,3,4,5,6,7,10,11</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>1.25</td>
</tr>
<tr>
<td>H2</td>
<td>13_A2</td>
<td>R</td>
<td>1,2,3,4,5,6,7,10,11</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>*</td>
</tr>
<tr>
<td>H3</td>
<td>13_A2</td>
<td>R</td>
<td>1,2,3,4,5,6,7,10,11</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>1.05</td>
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<tr>
<td>H4</td>
<td>13_A2</td>
<td>R</td>
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<td>✓ ✓</td>
<td>1.24</td>
</tr>
<tr>
<td>H5</td>
<td>6_A1</td>
<td>S</td>
<td>1,3,4,7,8,10,11</td>
<td>xx</td>
<td>✓ ✓</td>
<td>1.11</td>
</tr>
<tr>
<td>H6</td>
<td>6_A1</td>
<td>S</td>
<td>1,3,4,7,10,11</td>
<td>xx</td>
<td>✓ ✓</td>
<td>0.49</td>
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<tr>
<td>H7</td>
<td>6_A1</td>
<td>S</td>
<td>1,3,4,7,10,11</td>
<td>xx</td>
<td>✓ ✓</td>
<td>1.25</td>
</tr>
<tr>
<td>H8</td>
<td>6_A1</td>
<td>S</td>
<td>1,3,4,7</td>
<td>xx</td>
<td>✓ ✓</td>
<td>0.75</td>
</tr>
<tr>
<td>H9</td>
<td>8_2_A1</td>
<td>S/l</td>
<td>1,3,4,7,10,11</td>
<td></td>
<td>✓ ✓</td>
<td>0.88</td>
</tr>
<tr>
<td>H10</td>
<td>8_2_A1</td>
<td>(S)</td>
<td>1,3,4,7,11</td>
<td></td>
<td>✓ ✓</td>
<td>1.04</td>
</tr>
<tr>
<td>H11</td>
<td>8_2_A1</td>
<td>R</td>
<td>1,3,4,7,10,11</td>
<td></td>
<td>✓ ✓</td>
<td>0.86</td>
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<tr>
<td>H12</td>
<td>8_2_A1</td>
<td>S</td>
<td>1,3,4,7,10,11</td>
<td></td>
<td>✓ ✓</td>
<td>1.24</td>
</tr>
</tbody>
</table>
Experimental set-up 2014

- Experiments 1 and 2
- H1: Deployment of partial cultivar resistance to late blight reduces selection for fungicide insensitivity (x 2 exp x 2 sites – Wales (ADAS) and Scotland (SRUC))

<table>
<thead>
<tr>
<th>Variety</th>
<th>KE and Cara</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicates</td>
<td>6</td>
</tr>
<tr>
<td>Treatments</td>
<td>6 = 3 fungicide doses: Ridomil Gold 480SL 0, 0.25, 0.5 (relative to g/ha in full dose of Fubol) x 2 varieties: King Edward (3), Cara (5)</td>
</tr>
<tr>
<td>Design</td>
<td>Split plot (variety as sub-plot, fungicide as main plot)</td>
</tr>
<tr>
<td>Inoculation</td>
<td>8 plants inoculated/plot 5 x10^4 sporangia/ml (95:5 met sens: res)</td>
</tr>
<tr>
<td>Sampling</td>
<td>8 Aug, 18 Aug</td>
</tr>
</tbody>
</table>
Foliar blight progress inside (I) and outside (O) inoculated plot area – Exp 1, ADAS

Fungicide applied and first sample taken (8 Aug)

Second sample taken (18 Aug)

Inoculated 18 July 2014

Assessment date


Foliar blight (%) plot area affected

- Cara Untreated (I)
- Cara 0.25 (I)
- Cara 0.5 (I)
- King Edward Untreated (I)
- King Edward 0.25 (I)
- King Edward 0.5 (I)
- Cara Untreated (O)
- Cara 0.25 (O)
- Cara 0.5 (O)
- King Edward Untreated (O)
- King Edward 0.25 (O)
- King Edward 0.5 (O)

Mancozeb over-sprays x 4
Sampling and genotyping

- Experiment 1 (ADAS site)
- Inoculated 18 July
- Sample 1, 8 Aug = At fungicide application
- Sample 2, 18 Aug = 10 days after fungicide application
- 16 sporulating lesions/plot (not from inoculated plants) – FTA cards using Euroblight protocol
- 16 lesions/plot x 6 reps x 6 treatments x 2 dates = 1152 samples/expt
- Genotyped to assess frequency of metalaxyl resistant v sensitive isolates recovered v 95 S : 5 R ratio applied – is there an effect of cultivar resistance?
- Maximum of 96 samples/trt, 774 samples genotyped.
- Fewer samples on date 1 - less disease established on Cara
- 8_A1 established on KE pre-inoculation
- 8_A1 out-competed on Cara
8_A1 ingress

2014 FAB Blight reception early and severe

Moray Taylor - Fera
Testing the hypothesis – preliminary analysis (H1, Exp 1 only)

H1: Deployment of crop resistance reduces selection for fungicide insensitivity.

Growth (units of LAI per 7 days) is calculated from \( \frac{\log \left( \frac{D_2}{D_1} \right)}{t} \),

\( t=7, \ D_2 \) population size at date2, \( D_1 \) population size at date1.

<table>
<thead>
<tr>
<th>Cara (Resistant)</th>
<th>13_A2 growth rate</th>
<th>6_A1 growth rate</th>
<th>13_A2 – 6_A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>No fungicide</td>
<td>0.187</td>
<td>0.073</td>
<td>0.113</td>
</tr>
<tr>
<td>fungicide</td>
<td>0.175</td>
<td>0.071</td>
<td>0.104</td>
</tr>
<tr>
<td>King Edward (susceptible)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No fungicide</td>
<td>0.214</td>
<td>0.008</td>
<td>0.206</td>
</tr>
<tr>
<td>fungicide</td>
<td>0.197</td>
<td>0.064</td>
<td>0.134</td>
</tr>
</tbody>
</table>

- Initial results (1 exp only) confirm the hypothesis, selection for the resistant strain is lower on Cara than King Edward
- Work in progress – 4 expts/hypothesis x 2 hypotheses
- More later...
Acknowledgements

Field and technical staff at ADAS, SRUC, JHI