Crop Resistance to Insect Pests

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What is crop resistance?

• The use of heritable plant traits to reduce plant damage resulting from insect herbivory

• Crop resistance is a relative phenomenon, eg. a plant genotype is more less resistant to insect herbivory than another plant genotype
Types of resistance

• **Antibiosis**: growth and development of the pest are affected

• **Non-preference (antixenosis)**: density of the pest infesting the plant is reduced

• **Tolerance**: plant supports the pest without loss of vigor or yield
Lecture plan

• Domestication of crops, effects on resistance to herbivory

• Developing resistant crops: 2 examples
Do crops become more susceptible to insect pests as they evolve as a result of selection by humans?
Evolutionary relationships among wheats
Larvae feed on a developing seed within the floret. The floret consists of 4 glumes that completely enclose and protect the seed.
Structure of a modern wheat spike
Lineages of species in the genus *Triticum* - level indicates major evolutionary step

<table>
<thead>
<tr>
<th>Level</th>
<th>Species</th>
<th>Lineage 1</th>
<th>Lineage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Index of infestation</td>
<td>Index of glume tightness</td>
</tr>
<tr>
<td>1</td>
<td><em>speltoides</em></td>
<td>0.11</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td><em>monococcum</em></td>
<td>0.40</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td><em>timopheevii</em></td>
<td>0.34</td>
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</tr>
<tr>
<td>3</td>
<td><em>zhukovskyi</em></td>
<td>1.32</td>
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</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<td>5</td>
<td></td>
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</tbody>
</table>

Note: Index of infestation (proportion of infested seeds) indicates the proportion of *T. aestivum* ‘Roblin’. Glume tightness:

1. free threshing; 2. not free threshing; 3. glumes affixed to seed.
Lineages of species in the genus *Triticum* - Level indicates major evolutionary step

<table>
<thead>
<tr>
<th>Level</th>
<th>Lineage 3</th>
<th>Lineage 4</th>
<th>Lineage 5</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Species</td>
<td>Index of infestation</td>
<td>Index of glume tightness</td>
</tr>
<tr>
<td>1</td>
<td><em>tauschii</em></td>
<td>0.07</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td><em>dicoccum</em></td>
<td>0.88</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td><em>spelta</em></td>
<td>0.29</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td><em>macha</em></td>
<td>0.58</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
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</tr>
</tbody>
</table>

1, free threshing; 2, not free threshing and glumes not affixed to seed; 3, glumes tightly affixed to seed.
Conclusion for wheat midge and wheat

- Humans selected free threshing wheat
- Free threshing wheat is more suitable for wheat midge
- Domestication has increased susceptibility of the crop
Crop resistance to insect pests –
Hessian fly and wheat
wheat midge and wheat
Hessian fly, *Mayetiola destructor* (Say)

Wheat leaf removed to expose puparium
Wheat stem infested and broken by Hessian fly
Wheat infested by Hessian fly
Hessian fly infestation of row plots, 2000

Infested stems, %

<table>
<thead>
<tr>
<th></th>
<th>Superb</th>
<th>AC Barrie</th>
</tr>
</thead>
<tbody>
<tr>
<td>±5.0</td>
<td>±3.9</td>
<td></td>
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</table>

Broken stems, %

<table>
<thead>
<tr>
<th></th>
<th>Superb</th>
<th>AC Barrie</th>
</tr>
</thead>
<tbody>
<tr>
<td>±0.9</td>
<td>±3.9</td>
<td></td>
</tr>
</tbody>
</table>
Hessian fly on seedlings in laboratory

**Eggs per plant**

- Guard: 7
- Superb: 9
- Barrie: 9

**Larval survival, %**

- Guard: 0%
- Superb: 10%
- Barrie: 60%
Resistance in seedlings in laboratory

- No deterrence of oviposition
- Antibiosis, expressed as reduced survival from egg to puparia
- Superb is antibiotic, but not as antibiotic as resistant standard Guard
Stems infested (%) by Hessian fly - field

- 2000
- 2002
- 2003
- 2002-multi

Superb
Barrie
Hessian fly infested stems that break, %
Seed production on unbroken, infested stems

1000 seed wt, g

Seeds per spike
Resistance of Superb in the field

- Antibiosis that reduces infestation
- Tolerance that reduces the proportion of infested stems that break
- Tolerance that maintains the number of seeds on standing, infested stems
Conclusions:

- Superb shows substantial resistance to Hessian fly
- Resistance results from antibiosis and tolerance
- The resistance would be adequate to protect Canadian spring wheat under most circumstances
Wheat midge

Bread wheat

Durum wheat
Oviposition deterrence in durum wheat

Eggs / spike

Choice

No choice

'Kahla 47'

'AC Avonlea'
Oviposition on resistant and susceptible wheat

![Bar chart showing the number of eggs per spike with error bars for different treatment percentages of susceptible wheat. The chart indicates a decrease in the number of eggs as the percentage of susceptible wheat increases.]
Antibiosis in wheat with the Sm1 gene

- Inducible hypersensitivity
- Increased levels of ferulic and $p$-coumaric acids
- Levels drop to normal at seed maturity
Inheritance and expression of resistance
Antibiosis

- Controlled by a single gene - \textit{Sm1}
- Resistance is partly dominant
- Same gene in all known resistance sources
Antibiosis in spring wheat

The fact that antibiosis is due to a single gene means that:

- It is readily incorporated into breeding programs.
- It is likely that virulent midge will evolve to overcome the resistance.
Terms

Wheat plant
resistant – antibiotic to midge
susceptible – not antibiotic to midge

Wheat midge
virulent – adapted to resistant wheat
avirulent – not adapted to resistant wheat
Could wheat midge develop virulence?

• Evolution of virulence occurs in other pest-crop systems

• On resistant wheat, 1 mature wheat midge larva per 175 spikes

• The occasional larva is within the size range of larvae from susceptible wheat
Hessian fly resistance gene, *H3*
*(from Foster et al. 1991)*

<table>
<thead>
<tr>
<th>Year</th>
<th>% Acreage</th>
<th>% Infestation <em>(H3)</em></th>
<th>% Infestation <em>(susceptible)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>29</td>
</tr>
<tr>
<td>1960</td>
<td>35</td>
<td>&lt;1</td>
<td>15</td>
</tr>
<tr>
<td>1964</td>
<td>74</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>1965</td>
<td>80</td>
<td>9</td>
<td>10</td>
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Managing crop resistance

- Sequential release of resistance genes
- Pyramiding resistance genes
- Provide a refuge for avirulent insects
Using refuges to delay virulence evolution

Deploying refuges:

- Plant in separate, adjacent blocks.
- Mix with resistant plants so susceptible plants are interspersed.
Using refuges to delay virulence evolution

Separate blocks or interspersed mixtures?

• Ensure that mating is random among genotypes.

• Larvae on resistant plants must not be able to move to susceptible plants.
Deploy crop resistance with a susceptible refuge

- minimize damage
- eliminate insecticides
- preserve resistance
- preserve parasitism
With and without interspersed refuges in large field plots

![Graph showing the percentage of midge-damaged seed against the percentage of susceptible wheat.](image)
Conclusions:

Resistance against wheat midge possible

An interspersed refuge can protect the resistance gene