Similar to farmers in the UK, Irish farmers will have to cope without neonics this year. This is creating understandable worry amongst them and their advisers about BYDV. Ireland also has pyrethroid resistance issues in the grain aphid which is adding to control concerns.
- Give bees a chance -
No GMOs, no pesticides
On 27\textsuperscript{th} April 2018, the EU agreed to extending the ban on 3 neonicotinoids from the end 2018 to ALL outdoors crops, making pest control more difficult.
The effects of losing Neonicotinoid seed treatments

- More water will be used
- Increased use of Slug Pellets
- Increased Diesel use and increased work load
- More foliar insecticide sprays will be applied
- Potential yield loss primarily from viruses
Grain Aphid: *Sitobion avenae*

Pyrethroid Resistance

Bird-Cherry Oat Aphid: *Rhopalosiphum padi*

Main Vector?

Rose-Grain Aphid: *Metopolophium dirhodum*

All three Cereal aphid species are potentially vectors of BYDV.
**Sitobion avenae**

- Important pest on wheat, barley (oats)
- Reduces grain yield
- Transmits BYDV
- Previous good control with pyrethroids
Courtesy of Alan Dewar (Dewar Crop Protection)
Lambda-cyhalothrin spray failures reported against grain aphids, *Sitobion avenae*, in England in June 2011
Sodium channel mutations implicated in pyrethroid resistance

Anopheles gambiae
Aphis gossypii
Bemisia tabaci
Blattella germanica
Boophilus microplus
Ctenocephalides felis
Culex pipiens
Drosophila melanogaster

Helicoverpa armigera
Heliothis virescens
Hematobia irritans
Leptinotarsa decemlineata
Musca domestica
Myzus persicae
Pediculus capitis
Plutella xylostella

1° resistance mutation
2° resistance mutation
effects not characterised
2011 *Sitobion avenae* sample contained kdr mutation, L1014F
<table>
<thead>
<tr>
<th>Species</th>
<th>Iw</th>
<th>D</th>
<th>G</th>
<th>Ay</th>
<th>N</th>
<th>Y</th>
<th>P</th>
<th>K</th>
<th>BB</th>
<th>We</th>
<th>H</th>
<th>RT</th>
<th>Wr</th>
<th>SP</th>
<th>EM*</th>
<th>SX</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tribolium confusum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribolium castaneum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Testing for presence of target site kdr mutation
Mechanism-specific diagnostics
TaqMan PCR

Fluorescence assay - high throughput - no post PCR steps

*No data for 2009 and 2010 at Rothamsted
kdr-SR Grain aphids have also been found in:

Ireland and Germany

Samples tested from Denmark, France and the USA (Kentucky) contained only kdr-SS aphids
What about natural populations of cereal aphids on crops in the field?
Bioassay approach

Application

Coating

Incubation

5h and 24h Scoring
Response to lambda-cyhalothrin vs kdr-SS and -SR *Sitobion avenae* clones

- **Log concentration (ng/cm²)**
- **Affected + dead (probits)**
- **Affected + dead (percentage)**

- **Sa kdr-SS**
- **Sa kdr-SR**
- **Sa1-2018**

Field rate
Response to lambda-cyhalothrin vs kdr-SS and -SR *Sitobion avenae* clones

![Graph showing the response to lambda-cyhalothrin vs kdr-SS and -SR *Sitobion avenae* clones. The x-axis represents the log concentration (ng/cm²), and the y-axis represents the affected + dead (probits). Different clones are indicated by different colors and symbols: Sa kdr-SS (white circles), Sa kdr-SR (purple circles), and Sa2-2018 (red circles). The graph shows a clear trend of increased resistance in the Sa kdr-SR and Sa2-2018 clones compared to Sa kdr-SS.](image_url)
Response to lambda-cyhalothrin vs kdr-SS and -SR *Sitobion avenae* clones

- **Log concentration (ng/cm$^2$)**
- **Affected + dead (probits)**
- **Affected + dead (percentage)**

- **Sa kdr-SS**
- **Sa kdr-SR**
- **Sa3-2018**

Field rate
Response to lambda-cyhalothrin vs kdr-SS and -SR *Sitobion avenae* clones

Log concentration (ng/cm²) vs Affected + dead (probits) for different clones:
- **Sa kdr-SS**
- **Sa kdr-SR**
- **Sa1-2019 (pink)**

Field rate indicated by an arrow.
Response to lambda-cyhalothrin vs kdr-SS and -SR *Sitobion avenae* clones

![Graph showing the response to lambda-cyhalothrin vs kdr-SS and -SR *Sitobion avenae* clones.](image-url)

- **Log concentration (ng/cm²)**
- **Affected + dead (probits)**
- **Affected + dead (percentage)**

- **Sa kdr-SS**
- **Sa kdr-SR**
- **Sa2-2019 (pink)**

Field rate
Response to lambda-cyhalothrin vs kdr-SS and -SR *Sitobion avenae* clones

Log concentration (ng/cm$^2$)

Affected + dead (probits)

Affected + dead (percentage)

Sa kdr-SS

Sa kdr-SR

Sa3-2019

Field rate
Table 1. LC$_{50}$ responses to lambda-cyhalothrin (ng/cm$^2$ after 5h) of *Sitobion avenae*, *Metopolophium dirhodum* and *Rhopalosiphum padi* standard clones and field samples in coated glass vial bioassays.

<table>
<thead>
<tr>
<th>Clone</th>
<th>N</th>
<th>LC$_{50}$</th>
<th>95% CL</th>
<th>Slope</th>
<th>Resistance ratio$^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sa-SS</td>
<td>230</td>
<td>1.137</td>
<td>0.660-1.869a</td>
<td>1.6</td>
<td>1</td>
</tr>
<tr>
<td>Sa-SR</td>
<td>201</td>
<td>40.1</td>
<td>31.80-50.12c</td>
<td>2.6</td>
<td>35</td>
</tr>
<tr>
<td>Sa1 (2016)</td>
<td>345</td>
<td>38.30</td>
<td>18.78-73.74bc</td>
<td>1.5</td>
<td>33</td>
</tr>
<tr>
<td>Sa4 (2016)</td>
<td>194</td>
<td>19.65</td>
<td>11.91-29.50b</td>
<td>2.0</td>
<td>17</td>
</tr>
<tr>
<td>Sa1 (2017)</td>
<td>151</td>
<td>34.49</td>
<td>14.30-67.13bc</td>
<td>1.7</td>
<td>30</td>
</tr>
<tr>
<td>Sa3 (2017)</td>
<td>145</td>
<td>43.25</td>
<td>21.92-80.04bc</td>
<td>1.9</td>
<td>38</td>
</tr>
<tr>
<td>Sa1 (2018)</td>
<td>61</td>
<td>64.74</td>
<td>32.84-104.1c</td>
<td>2.0</td>
<td>57</td>
</tr>
<tr>
<td>Sa2 (2018)</td>
<td>161</td>
<td>57.77</td>
<td>40.34-94.97c</td>
<td>1.6</td>
<td>51</td>
</tr>
<tr>
<td>Sa3 (2018)</td>
<td>177</td>
<td>48.76</td>
<td>23.81-120.9bc</td>
<td>1.5</td>
<td>43</td>
</tr>
<tr>
<td>Sa1 (2019)</td>
<td>216</td>
<td>1.318</td>
<td>0.936-1.838a</td>
<td>1.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Sa2 (2019)</td>
<td>212</td>
<td>0.959</td>
<td>0.662-1.351a</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Sa3 (2019)</td>
<td>166</td>
<td>13.02</td>
<td>8.11-21.73b</td>
<td>1.4</td>
<td>12</td>
</tr>
<tr>
<td>Md (S)</td>
<td>156</td>
<td>10.69</td>
<td>5.33-18.96ab</td>
<td>2.3</td>
<td>1</td>
</tr>
<tr>
<td>Md1 (2016)</td>
<td>432</td>
<td>11.83</td>
<td>7.29-17.85b</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Md1 (2019)</td>
<td>165</td>
<td>4.665</td>
<td>3.166-7.188a</td>
<td>1.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Rp (S)</td>
<td>281</td>
<td>6.346</td>
<td>3.276-12.61a</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Rp1 (2017)</td>
<td>126</td>
<td>31.8</td>
<td>16.46-72.98b</td>
<td>1.3</td>
<td>5.0</td>
</tr>
</tbody>
</table>

$^a$Total number of aphids tested (including controls).

$^b$Concentration resulting in 50% dead or irreversibly poisoned (in ng/cm$^2$).

$^c$Confidence limits at 95%; values followed by the same letter do not differ significantly (i.e. they overlap).

$^d$Ratio of clone LC$_{50}$/LC$_{50}$ for Baseline S clone.
Grain aphid pyrethroid repellency assays

Winged aphid release point

Lambda

Untreated

Lambda

Lambda

Untreated

Lambda
% of winged kdr-SS and -SR *Sitobion avenae* settling on untreated barley in field simulators

Clone effects: P < 0.001
**Sitobion avenae** Super Clone (kdr-SR) Sav3

Sav3 (kdr-SR) sexual males and females?

Possibility of kdr-RRs?

A real-time PCR assay for detecting BYDV in cereal aphids

Suction trap aphids (R. padi) controls

Aphids infected with MAV virus

Uninfected

Aphids infected with PAV virus
BYDV testing of *R. padi* from UK suction traps (Autumn 2018)

<table>
<thead>
<tr>
<th>Trap</th>
<th><em>R. padi</em></th>
<th>% BYDV</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>625</td>
<td>18</td>
</tr>
<tr>
<td>Y</td>
<td>15808</td>
<td>12</td>
</tr>
<tr>
<td>P</td>
<td>15995</td>
<td>15</td>
</tr>
<tr>
<td>K</td>
<td>11887</td>
<td>3</td>
</tr>
<tr>
<td>BB</td>
<td>8696</td>
<td>13</td>
</tr>
<tr>
<td>We</td>
<td>6929</td>
<td>6</td>
</tr>
<tr>
<td>H</td>
<td>6445</td>
<td>3</td>
</tr>
<tr>
<td>RT</td>
<td>3734</td>
<td>0</td>
</tr>
<tr>
<td>Wr</td>
<td>10471</td>
<td>21</td>
</tr>
<tr>
<td>SP</td>
<td>2752</td>
<td>4</td>
</tr>
<tr>
<td>W</td>
<td>6406</td>
<td>8</td>
</tr>
<tr>
<td>SX</td>
<td>3971</td>
<td>8</td>
</tr>
</tbody>
</table>

- Initial results show considerable geographic variation in the frequency of *R. padi* infected with BYDV.
- Further monitoring is planned for the spring and autumn of 2019, funded by AHDB.
Diversity/clonal nature of UK *Sitobion avenae* population?

Search for kdr-RR homozygotes continues!
Where do we go from here?
Revision to *IRAG-UK Guidelines*: insecticide resistance status in UK cereal crops (2019)

“When grain aphids are clearly the main aphid pest present then growers need to be aware that pyrethroid sprays may not be effective. If they spray and suspect that control has been poor they should not spray again with a pyrethroid-based product but switch to another insecticide with an alternative MOA”.
Aphicides

**Pirimicarb** – carbamate very specific for aphids – available for use on wheat in the UK

Pymetrozine – being phased out

Sulfoxaflor – not approved in the UK

Spirotetramat - marketed in UK but not for cereals

Cyantraniliprole - marketed in UK but not for cereals

**Flonicamid** – approved for use on wheat in the UK
Alternative methods

Biological control to attack using other organisms (natural enemies)

- Predation
- Parasitism
- Pathogens
What are the natural enemies of cereals pests?

Remember, there is a Lag Period: natural enemies take time to build up their numbers.
Conservation via agronomy: Insecticides (OSR crop)

Temporal succession of parasitoid emergence

Spray ONLY when necessary!
Increased pyrethroid spraying will have a negative effect on Beneficials
Conservation via habitat management: field margins

Commercial mixtures for birds, bees and butterflies ... ... but none for biocontrol!

- Most work has focused on aphid control in wheat:

- Grassy margins support cereal aphids and their natural enemies
  e.g. Holland et al., 2012 Ag. Ecosyt. Env. 155:147-152

- Nectar-rich mixtures can attract generalist predators
Resistant plant varieties: ‘Wolverine’
BYDV-resistant Wheat
Summary

• The knockdown resistance (kdr) mutation L1014F has been identified in field populations of *Sitobion avenae*.

• The mutation confers ~35-fold resistance to lambda-cyhalothrin and is found in areas with control failures.

• Analysis of suction trap samples shows that the kdr mutation is present at high frequency (>50%) in some areas BUT ONLY as heterozygotes (SRs).

• The mutation was first seen at low levels in 2009 but took hold in 2011 when control failures were first reported.

• Measures need to be taken to mitigate further spread of the mutation, see Guidelines and advice published by IRAG-UK and HGCA.

• There is recent evidence of pyrethroid tolerance in *Rhopalosiphum padi* in Ireland (Lael Walsh/Michael Gaffney)
The ‘Good Old Days’…

DIVERSITY of insecticides is essential for Resistance Management
The ‘Bad New Days’?
The Future?
Courtesy of Alan Dewar (Dewar Crop Protection)
“You did order the chemical-free insecticide.”