NOVEL STRATEGIES FOR THE CONTROL OF WIREWORM IN POTATOES

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Outline of Presentation

• Background to Wireworms
  ➢ Biology
  ➢ Life cycle
  ➢ Significance as crop pests
  ➢ Current control

• Summary of research to date
  ➢ BANP group
  ➢ Other groups

• Overview of current project
  ➢ Progress to date
  ➢ Future plans
Background
Wireworm: Biology

• Subterranean larval form of the click beetle (Coleoptera: Elateridae).
• Species of agricultural importance: *Agriotes sputator, A. lineatus, A. obscurus*.
• Adults primarily lay eggs in pasture: 170 -200 eggs / female.
• Larvae long-lived - ~ 3-5 years.
• Polyphagous: feeds on wide range of plants.

http://soilcropandmore.info/crops/Wheat/Insects/Wireworm06.jpg
Life Cycle

Syngenta, 2010
Wireworm: Crop Pests

• Pests of many crops e.g. cereals, root crops, potatoes
• Damage varies from cosmetic to complete destruction.
• Feeding damage can leave plant open to bacterial / fungal infection.
• Withdrawal and restrictions of chemical insecticides a global challenge to control
Wireworm: Pests of Potatoes

- Stunted plant growth, cosmetic damage, secondary infections - reducing yield and marketability
- Occurrence dependent on environmental factors; soil moisture, temperature, food availability.
- Severity of damage depends on instar, density and species.
- Europe – ca.630,000 ha potatoes at risk
- Current losses up to 0.6 tonne / ha
Current monitoring and control

Monitoring
• Adults monitored using pheromone +/- light plus traps (e.g. Funnel trap, Vernon trap)
• Larvae monitored using bait traps (e.g. stocking trap) or examination of soil core

Control
• Chemical: Mocap® - Control for wireworm, PCN.
• Cultural: Crop rotation (not always feasible if dedicated to specific crop)
Current “biological pesticides”

- **ATTRACAP®**
  - Consists of attractant and biological control agent (BCA)
  - Attractant: CO₂ generated by encapsulated yeast
  - BCA: *Metarhizium brunneum*, entomopathogenic fungi (EPF) – slow acting

http://biocare.de/attracap-e/
Current “biological pesticides”

• Pheromones
  – Monitoring
  – Mass trapping of Adult males
  – Potential for mating disruption (neglected area of research)
  – Lure & Kill

• Garlic
  – Repellent / antifeedant for wireworm (still in development)
Summary of Research of BANP & other groups
Biocontrol & Natural Products (BANP) Group

- Overall goal: Develop sustainable, environmentally friendly products and strategies for the control of arthropod pests of global socio-economic importance

- [http://www.swansea.ac.uk/biosci/researchgroups/biocontrolandnaturalproductsgroup/banp/](http://www.swansea.ac.uk/biosci/researchgroups/biocontrolandnaturalproductsgroup/banp/)

- EPF strains identified that are highly pathogenic to wireworm

- Developing strategies which reduce or eliminate use of conventional chemical pesticides e.g. “lure & kill” and “stress & kill” control strategies.
Entomopathogenic Fungi (EPF)

- EPF: Best strain gives same control as Mocap 3 weeks post–treatment [1].

- EPF: Swiss strains evaluated against ethoprophos (active in Mocap). Best gave 80% control after 8 weeks [2].

Entomopathogenic nematodes (EPN)

• EPN: Only *H. bacteriophora* strain HbUWS1 gave control >60%

![Nematode infected wireworm](https://www.gardensalive.com/product/grub-away-nematodes-1)

Summary of BANP wireworm work to date

- Strains of *M. anisopliae* (ART2825 & V1002) identified as highly pathogenic to all three main wireworm species
- Lure & kill strategy shows promise
- Wireworm attracted to CO\(_2\) and plant kairomones – these can be used to lure pest to control agent. Helps reduce inputs of insecticides or EPF.
Research of groups around the world

• Canada (Todd Kabaluk)
  – Identified virulent strains of *Metarhizium* research.
  – Demonstrated synergy between insecticide and *Metarhizium* (“Stress & Kill”) [1]

• Germany (Stefan Vidal, Anant Patel)
  – Developed Attracap (CO₂ + EPF) – part of “lure & kill” strategy [2]

• Belgium (Fanny Barsics):
  – Identified kairomones that could enhance CO₂ attraction – improve “lure & kill” [3]

Overview of current project
Project Aims

- **Lure & kill** – building on existing research to increase efficacy of biocontrol solutions

  - Augmentation of CO$_2$ with short range chemical cue

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Erb et al., 2013. Advances in Insect Physiology 45: 53–95
Project Aims

• Repellents – identification of compounds suitable as repellent or fumigant
  - Potato: Needs protection throughout growing season
  - Complimentary with PhD in France (maize) to test garlic products with potato.

• Stress & kill – use of reduced rate insecticide with a biological control. Stressed animals more susceptible to fungal infection [1,2].

Progress to date

• Wireworm crop preferences
  – Screen VOCs for further study
  – Develop a capture assay for lab & glasshouse

• Terrarium experiments
  – Behavioural observations; quantified movement and choice assays

• Screening of natural fumigants & plant oils as potential biopesticides
  – Entomopathogenic nematode (EPN)
  – Plant parasitic nematode (PPN) e.g. Meloidogyne sp.
  – Wireworm
Progress to date: Trap Crop results

- Potential trap crops identified literature review
- Early results indicate maize as a favoured species in dual choice studies.
- Movement of larvae between arenas – favouring maize
Wireworm capture assay

View Above

Capture Tube

Cross Section

Seedling

Wireworm

2 Litres Soil
Progress to date: Trap Crop Results

Wireworm capture rate for various crops

Number of Wireworm

<table>
<thead>
<tr>
<th>Crop Species</th>
<th>Present</th>
<th>Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td></td>
<td></td>
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<tr>
<td>Control (Empty)</td>
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<td></td>
</tr>
</tbody>
</table>

Present: Blue bars, Absent: Green bars
Progress to date: Fumigants, plant oils

- **Work with Natural Fumigants**
  - Fumigants: natural volatile organic compounds (VOCs)
  - VOCs show activity against a range of invertebrate pests (insects, nematodes) and plant pathogens (*e.g.* *Fusarium*).

- **Essential Plant Oils.**
  - Actives in oils have insecticidal, nematicidal and antifungal properties [1-3]
  - Actives may inhibit/kill
  - Need to identify/quantify actives using GC/MS
Progress to date: Plant oils

• Essential oils screened
  – Lemon [1]
  – Citronella [2]
  – Rosemary [3]
  – Tea Tree [4]
  – Cedarwood [5]

• Assayed using terraria

Deconstructed terrarium with clear wireworm trail

Terrarium assay

Control

Treatment

295mm

395mm
## Plant Oil: Repellency Results.

| Rosemary | Control | Treatment | | Control | Treatment |
|----------|---------|-----------| |          |           |
|          | A       | B         | C | D    | E  | F  | G  | H   | | A  | B  | C  | D  | E  | F  | G  | H  |
| 1        | 0       | 0         | 0 | 1    | 0  | 0  | 0  | 0   | | 1  | 2  | 1  | 1  | 0  | 0  | 0  | 0  |
| 2        | 0       | 2         | 5 | 10   | 1  | 0  | 0  | 0   | | 2  | 3  | 7  | 4  | 4  | 2  | 0  | 0  |
| 3        | 0       | 6         | 4 | 4    | 1  | 0  | 0  | 0   | | 3  | 3  | 6  | 8  | 6  | 2  | 0  | 0  |
| 4        | 0       | 4         | 3 | 16   | 4  | 1  | 2  | 2   | | 4  | 0  | 2  | 7  | 4  | 5  | 0  | 1  |
| 5        | 3       | 2         | 0 | 4    | 3  | 4  | 2  | 5   | | 5  | 2  | 4  | 5  | 4  | 4  | 0  | 0  |
| 6        | 6       | 4         | 1 | 4    | 2  | 2  | 0  | 0   | | 6  | 0  | 2  | 3  | 5  | 0  | 2  | 1  |

| Lemon    | Control | Treatment | | Control | Treatment |
|----------|---------|-----------| |          |           |
|          | A       | B         | C | D    | E  | F  | G  | H   | | A  | B  | C  | D  | E  | F  | G  | H  |
| 1        | 2       | 1         | 1 | 0    | 0  | 0  | 0  | 0   | | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  |
| 2        | 3       | 7         | 4 | 4    | 5  | 6  | 0  | 0   | | 2  | 3  | 6  | 8  | 6  | 2  | 0  | 0  |
| 3        | 3       | 6         | 8 | 6    | 2  | 0  | 0  | 0   | | 3  | 6  | 8  | 6  | 2  | 0  | 0  | 0  |
| 4        | 0       | 2         | 7 | 4    | 5  | 0  | 1  | 0   | | 4  | 0  | 2  | 7  | 4  | 5  | 0  | 1  |
| 5        | 2       | 4         | 5 | 4    | 4  | 1  | 0  | 0   | | 5  | 2  | 4  | 5  | 4  | 4  | 1  | 0  |
| 6        | 0       | 2         | 3 | 5    | 0  | 2  | 1  | 0   | | 6  | 0  | 2  | 3  | 5  | 0  | 2  | 1  |

| Citronella | Control | Treatment | | Control | Treatment |
|------------|---------|-----------| |          |           |
|            | A       | B         | C | D    | E  | F  | G  | H   | | A  | B  | C  | D  | E  | F  | G  | H  |
| 1          | 2       | 2         | 0 | 1    | 1  | 0  | 0  | 0   | | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  |
| 2          | 1       | 4         | 2 | 3    | 2  | 2  | 0  | 0   | | 2  | 1  | 6  | 0  | 6  | 4  | 5  | 2  |
| 3          | 8       | 6         | 6 | 3    | 1  | 1  | 2  | 0   | | 3  | 0  | 4  | 3  | 0  | 3  | 9  | 1  |
| 4          | 3       | 1         | 5 | 6    | 0  | 1  | 2  | 0   | | 4  | 1  | 1  | 0  | 5  | 8  | 2  | 2  |
| 5          | 8       | 5         | 4 | 8    | 1  | 1  | 0  | 0   | | 5  | 0  | 0  | 0  | 0  | 8  | 9  | 1  |
| 6          | 6       | 3         | 6 | 3    | 0  | 5  | 1  | 2   | | 6  | 0  | 0  | 0  | 0  | 1  | 2  | 2  |

| Cedarwood | Control | Treatment | | Control | Treatment |
|-----------|---------|-----------| |          |           |
|           | A       | B         | C | D    | E  | F  | G  | H   | | A  | B  | C  | D  | E  | F  | G  | H  |
| 1         | 0       | 0         | 0 | 0    | 1  | 2  | 1  | 0   | | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 0  |
| 2         | 1       | 6         | 0 | 6    | 7  | 10 | 4  | 2   | | 2  | 1  | 6  | 0  | 6  | 7  | 10 | 4  |
| 3         | 3       | 1         | 5 | 6    | 0  | 1  | 2  | 0   | | 3  | 1  | 5  | 6  | 0  | 1  | 2  | 0  |
| 4         | 1       | 1         | 0 | 5    | 8  | 2  | 2  | 0   | | 4  | 1  | 1  | 0  | 5  | 8  | 2  | 2  |
| 5         | 0       | 0         | 0 | 0    | 8  | 9  | 3  | 1   | | 5  | 0  | 0  | 0  | 0  | 8  | 9  | 3  |
| 6         | 0       | 0         | 0 | 0    | 1  | 2  | 2  | 2   | | 6  | 0  | 0  | 0  | 0  | 1  | 2  | 2  |

| Tea Tree  | Control | Treatment | | Control | Treatment |
|-----------|---------|-----------| |          |           |
|           | A       | B         | C | D    | E  | F  | G  | H   | | A  | B  | C  | D  | E  | F  | G  | H  |
| 1         | 0       | 1         | 0 | 0    | 1  | 2  | 1  | 0   | | 1  | 1  | 0  | 1  | 0  | 1  | 2  | 1  |
| 2         | 0       | 6         | 3 | 6    | 2  | 0  | 3  | 1   | | 2  | 3  | 3  | 0  | 5  | 15 | 10 | 4  |
| 3         | 0       | 4         | 1 | 4    | 4  | 2  | 0  | 0   | | 3  | 3  | 4  | 1  | 2  | 2  | 11 | 4  |
| 4         | 1       | 3         | 4 | 5    | 3  | 0  | 1  | 0   | | 4  | 0  | 1  | 3  | 4  | 4  | 1  | 1  |
| 5         | 2       | 2         | 2 | 5    | 5  | 3  | 0  | 2   | | 5  | 0  | 3  | 0  | 2  | 2  | 1  | 2  |
| 6         | 3       | 0         | 6 | 1    | 2  | 1  | 3  | 1   | | 6  | 0  | 0  | 0  | 2  | 5  | 0  | 0  |

<table>
<thead>
<tr>
<th>Wireworm Presence</th>
</tr>
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<tbody>
<tr>
<td>Strong</td>
</tr>
<tr>
<td>Weak</td>
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</table>
Stress and Kill

• Plant Oils: fumigatory effects to induce stress or mortality
  – Possible synergy with EPF
  – Augmentation of current control strategies. Eg. ATTRACAP.

• Low dose insecticide: Semi-field trial aims to assess mortality for:
  – Reduced rate Mocap®
  – Additive application for continued protection of crop using garlic
  – Synergistic control; EPF applied with reduced rate Mocap
**Adults: Mass Trapping**
- Physical & light traps
- Capture 1K females, prevent up to 200K larvae

**Adults: Mating Disruption**
- Sex pheromones
- Prevent mating
- Reduce egg numbers
- Inoculate males with biocontrol, use as vectors

**Early control**
- Target pest in pasture to control at source

**Larval Control**
- Lure & Kill
- Stress & Kill

**Integrate Approach to Control**
- Adults: Mating Disruption
- Adults: Mass Trapping
- Larval Control
  - Lure & Kill
  - Stress & Kill
  - Adults overwinter in soil cavity
  - Adult click beetles emerge April to August with peak in May
  - Ley eggs just below soil surface in grassy or weedy ground
  - Pale coloured larva hatch
  - Larvae feed on live vegetable matter in soil
  - Larvae moults up to three times each year
  - Larval colour deepens as they grow
Knowledge Economy Skills Scholarships (KESS) is a pan-Wales higher level skills initiative led by Bangor University on behalf of the HE sector in Wales. It is part funded by the Welsh Government’s European Social Fund (ESF) convergence programme for West Wales and the Valleys.