Combating insecticide resistance in major UK pests: modelling section

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Project aim

• Key questions:
  ➢ Are mixtures beneficial?
  ➢ First need to understand what is the effect of dose on resistance?

1. Build a model of insecticide resistance
2. Explore various measures relating to both:
  ➢ Providing effective control of populations
  ➢ Delaying build up of resistance
Insects in the UK

• Peach-potato aphid
• Potato aphid

• Grain aphid
• Pea aphid
• Rose-grain aphid
• Currant-lettuce aphid
• Glasshouse whitefly
• Two-spotted spider mite
• Western flower thrips

• Diamondback moth
• Leaf miner

• Pollen beetle
• Cabbage stem flea beetle
• Wheat bulb fly
• Orange wheat blossom midge
• Pea moth
• Codling moth
• Pea and bean weevil

Generations per year

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<th>Multiple</th>
<th>Single</th>
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<tbody>
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<td>Asexual</td>
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<td>Asexual / Sexual</td>
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Multiple

Asexual

Asexual / Sexual

Sexual

Single
Model introduction

Overwintering insects

Maturation

Larvae
SS SR RR

Adults
SS SR RR

Birth

Crop

Insecticide

Immigration (Susceptible adults)

Damage:
• Feeding
• Virus transmission
• Contamination
Model introduction

![Graph showing Logit mortality against Dose (log10)].

- Logit mortality
- Dose (log10)

- Insecticide
- Maturation
- Birth
- Crop

- Larvae
- Adults

- SS
- SR
- RR

- 0.01
- 0.1
- 0.9
- 0.99

- Absolute mortality
Simulations

Grain aphid

Data from Skirvin, D.J., Perry, J.N. & Harrington, R.
Ecological Modelling, 96, 29-39

Pollen beetle

Data from Sam Cook, Rothamsted
Model introduction

![Graph showing insect density over time](image)

- Total
- Larvae
- Adults

Time (days)

Insect density
Model introduction
High dose hypothesis

- Does a high dose lead to reduced or increased selection for resistance?
High dose hypothesis

- Applying a very high dose can lead to slower resistance frequency build up

**Scenario 1**

- Graph showing the relationship between multiple of single dose (log scale) and resistance frequency.

**Scenario 2**

- Graph showing the relationship between multiple of single dose (log scale) and R allele frequency.
High dose hypothesis

Scenario 1

Scenario 2

Insecticide Efficacy (Mortality)

Scenario 1

Scenario 2

Multiple of single dose

Res. freq on log scale

Dominance

0.0 0.2 0.4 0.6 0.8 1.0

0.80 0.85 0.90 0.95
High dose summary

- One important mechanism allows high dose to reduce selection
  - Immigration from external source

- Under most parameter combinations tested, lowering the dose will lower the selection for resistance
Resistance management & yield

• Coupling control of the pest with resistance management

• Effective life
  - Number of years that the insecticide effectively controls the insect pest
  - Following results:
    - Number of years until yield loss (reduction in HAD) exceeds 20% (an arbitrary value)

- Still to consider:
  - Contamination
  - Virus infection
Exploring effective life

- Graphs show effective life
- Graphs show difference in effective life between applying a full dose and a half dose.
Conclusions about half dose

• Preliminary conclusion:
  ➢ When the insecticide dose can be reduced without incurring unacceptable yield losses, it will lead to reduced selection for resistance

• Is there data available?
• Possible to test in cage / field experiments?
Two insecticides

- Two insecticides

- What is the consequence of mixing the two insecticides when:
  - Resistance is developing to only one of the insecticides
  - Resistance is developing to both insecticides
Evolution against one insecticide in the mixture

- Three key determinants:
  - Emergence from an overwintering population
  - Immigration from an untreated population
  - If an insect stage (larvae / adults) is present but not affected by the insecticide

- No emergence
- No immigration
- All stages susceptible

- With emergence
- No immigration
- All stages susceptible

- No emergence
- With immigration
- All stages susceptible

R allele frequency after 5 years
Future work

• High-risk mixtures

• Exploration of the effective life of mixtures

• Testing different strategies for two insecticides:
  - Mixtures
  - Alternation (within year)
  - Rotation (between year)
  - Sequential use

• Validation
Conclusions

• We have developed a tool to test management strategies

• With a single insecticide spray:
  ➢ Reduce dose as much as possible without compromising control

• We are currently exploring additional management strategies

• Determine critical characteristics of insects
• Group insects by the optimal management strategy