# Integrated Pest Management of Tree Fruit

BAPL

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# British Apples and Pears Ltd

- Opportunities for Integrated **P**est and Disease Management in **A**pples and **P**ears: Tackling British Apple and **P**ears **L**td. Prioriti**e**s: PAPPLe
- Develop, evaluate and deliver new strategies for P&D control to UK apple and pear growers
- Complementary to current practices
- Include new biological and technological developments alongside advancing and improving existing developments for integrated pest and disease control
- Strategies might initially appear labour intensive, but the aim would be to automate
- Address current priority pests and diseases, as well as prepare for effective management of emerging threats in the future

# Need for project

- Growing pest/disease challenges, especially:
  - Hard bodied pests
  - Invasive/new pests
  - Codling moth
  - Canker
  - Scab
- Withdrawal or restriction of key products, leaving…
- FLiPPER, a contact acting bio-insecticide
- Few new chemical control products entering the UK market
- Alternative plant protection products such as biopesticides, plant extracts and defence elicitors

# Loss of products

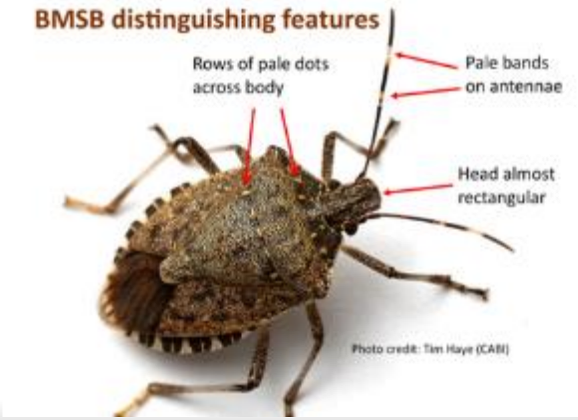
| Product | Use | Change/issue |
|---|---|---|
| Thiacloprid | Weevils, caterpillars, sawfly | Withdrawn |
| Chlorantraniliprole | Codling moth | Reduced number/dose of applications |
| Spirotetramat (Batavia/Movento) | Aphids, polyphagous mites | Timing of applications |
| Copper-based products (copper oxychloride) | Canker | Withdrawn |
| Captan | Scab | Withdrawn |
| Tebuconazole | Fungal diseases | Single application/year |

# Five Work Packages

- **WP 1.** Identifying new and emerging P&D to UK apple and pear production
- **WP 2.** Understanding role of soil properties in apple canker (*Neonectria ditissima*) management
- **WP 4.** Control of WAA, *Eriosoma lanigerum,* using non-chemical approaches
- **WP 5.** Optimising control of hard-bodied insect pests through precision monitoring, semiochemical and biological manipulation
- **WP 6.** Evaluate CM (*Cydia pomonella*) control strategies for future IPM

# **WP 1.** Identifying new and emerging pests and diseases that may pose a threat to UK apple and pear production.

- AHDB TF 223
- *Halyomorpha halys* (BMSB), *Anthonomus spilotus,* Pear shoot sawfly, Apple maggot fly, Black and white citrus longhorn beetle, False codling moth, Ambrosia beetle on nursery stock, Gypsy moth, Magdalis beetle on pear, *Rhagoletis cingulata*, Green Citrus Aphid, American plum borer, European grapevine moth, Peach fruit moth, Oriental fruit fly, *Diaporthe* spp. causing shoot dieback and leaf spot of apple, *Xanthomonas arboricolae, pv. pruni*, and *Xylella fastidiosa*.
- Task 1.1. Update future risk register for apples and pears
- Task 1.2. Review of the tested strategies for monitoring and control of BMSB *(Halyomorpha halys)*




# Task 1.2: New, emerging and re-emerging pests and diseases that may pose a threat to UK apple and pear

**Objective**

- Updated future risk register for apples and pears

**Methods**

- Internet searches for potential new and invasive pests and diseases were reviewed and summarized; symptoms, distribution, impact, monitoring and control
- Pests from earlier (AHDB-funded) work are included

**Outcomes**

- Register of pests and pathogens emerging in apple and pear growing regions around the world and recommended monitoring/control strategies
- Inform industry ahead of potential pest and disease outbreaks allowing better monitoring, preparation, prevention and control options

# Bacterial Threats

- **Two Bacterial Species:**
- 1. *Xylella fastidiosa*: Causative agent for Bacterial Leaf Scorch and
- 2. *Erwinia pyrifoliae*: Causative agent for Asian Pear Blight

# Bacterial Threats

***Xylella fastidiosa***

- **Origin and Presence:** Native to the Americas, present in Europe 2013
- **Host Range**: Over 300 plant species, including apples and pears
- **Symptoms:** Leaf scorch, wilt, dieback, and eventual plant death
- **Spread Mechanism:** Primarily insect vectors feeding on plant xylem
- **Control and Monitoring Measures:**

  - Eliminating affected plants

  - Controlling insect vectors

  - Annual surveillance programs, including PCR monitoring

  - National monitoring in the UK conducted via BRIGIT

- **Status:** Classified as quarantine pathogen, high risk to top fruit, not yet detected in the UK


Grape leaf showing signs of *X. fastidiola* infection
Credit: University of California:
https://edis.ifas.ufl.edu/publication/IN174

# Virus and Viroid Threats

- **Overview:** Identified nine (9) virus and viroid species as potential threats

- *Apple Stem Grooving Virus*
- *Apple Chlorotic Leaf Spot Virus*
- *Apple Stem Pitting Virus*
- *Pear Chlorotic Leaf Spot-Associated Virus*
- *Apple Necrosis Mosaic Virus*
- *Apple Scar Skin Viroid*
- *Apple Dimple Fruit Viroid*
- *Apple Luteovirus 1*
- *Apple Rubbery Wood Virus 1 and 2*

*Pear Chlorotic Leaf Spot-Associated Virus*
Image courtesy: https://apsjournals.apsnet.org/doi/10.1094/PDIS-01-20-0040-RE

# Five Fungal Threats were identified

***Diplodia bulgarica*** (Black Canker of Apple and Pear)

**Distribution & Hosts:** First detected in Bulgaria in 2012. Present in Germany, Turkey, Iran, and India

**Host plants:** Apple and Pear

**Symptoms:** Deepened brown elliptic lesions with a series of concentric circles symptoms of canker, gummosis (abnormal resinosis), dying-off and twig-decay symptoms. Often together with bark injuries like cracks, pruning wounds or damage by the sun

**Control:** Not from literature

**Monitoring Measures:** EU: recommend destroying infected (plant) material, where application of fungicides not possible or allowed. Culture of the pathogen and PCR

Image courtesy: J. Hinrichs-Berger, K. & Zegermacher, G. Zgraja. First report of **Diplodia bulgarica** causing black canker on apple (Malus domestica) and pear (Pyrus communis) in Germany. New Disease Reports, Volume: 43, Issue: 1, First published: 15 March 2021, DOI: (10.1002/ndr2.12004)

**Other Fungal Threats:** ***Venturia asperata*, *Diplocarpon coronariae*** (Apple Blotch), ***Stemphylium vesicarium*** **(**Pear Brown Spot**)** and ***Diaporthe eres***

# Pest Threats

- 15 pest threats identified with varying levels of threat to apple and pear
- **Notable Threat: Brown Marmorated Stink Bug** (separate detailed report submitted, covered on subsequent slides)

**Key Pest Species by Order**

- **Hemiptera:** Comstock Mealybug (*Pseudococcus comstocki*), Yellow-Spotted Stink Bug (*Erthesina fullo*), Spotted Lanternfly (*Lycorma delicatula*), Pear Shoot Sawfly (*Janus compressus*), Apple Maggot Fly (*Rhagoletis pomonella*), Oriental Fruitfly (*Bactrocera dorsalis*) and Mottled Shieldbug (*Rhaphigaster nebulosa*)
- **Lepidoptera:** Decolorella (*Blastobasis lacticolella*), Yellow-headed Fireworm (*Acleris minuta*), Snowy-shouldered Acleris Moth (*Acleris nivisellana*), American Plum Borer (*Euzophera semifuneralis*), Peach Fruit Moth (*Carposina sasakii*) and Manchurian Fruit Moth (*Grapholita inopinata*)

**Popillia japonica Japanese beetle**
Image credit: Koppert

- **Coleoptera:** Japanese Beetle (*Popillia japonica*) and Magdalis Beetle (*Magdalis armigera*)

# Recommendations for Growers

Popillia japonica Japanese beetle
Image credit: Koppert

- Growers and agronomists should be vigilant to new diseases and pests in the UK
- All imported plant material should be isolated and rigorously checked before planting especially to mitigate against viruses
- All control options should be checked with a BASIS-qualified adviser

# Task 1.2: A Review of Brown Marmorated Stink Bug (*Halyomorpha halys*) Control Strategies

**Objective:** Summarise global strategies for monitoring and controlling the BMSB tailored for UK apple and pear growers.

**Research Methodology**

- Comprehensive review of studies post-2013 using Google Scholar

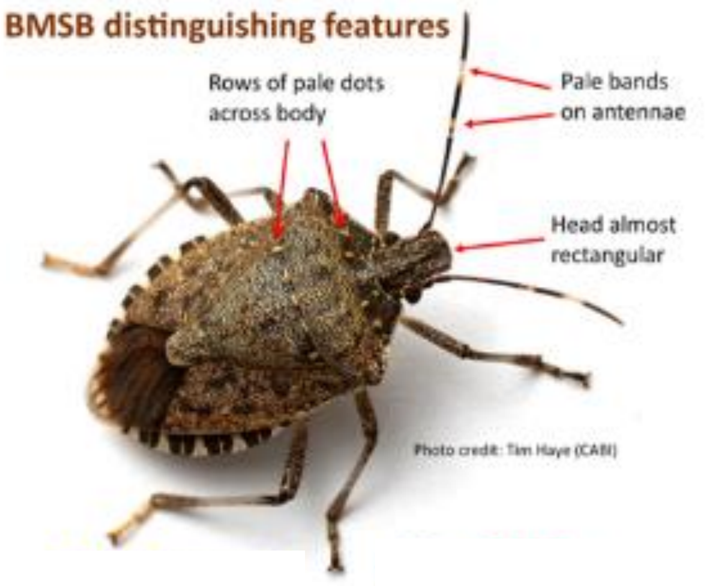
- Search terms included 'BMSB parasitoids,' 'BMSB sterile insect technique,' 'BMSB insecticide,' etc.

- Analysis of data from AHDB project SF 174, focusing specifically on BMSB monitoring and control

**Structure of Review:** 5 main sections, **Introduction, Control measures, Monitoring, Conclusions** and **Recommendations**

- Each section concludes with key findings

- Final recommendations provided for BMSB monitoring, control, and future research specific to UK pears and apple growers



# Background: Spread and Establishment of BMSB in Europe

- **Origin and Expansion:** Native to Asia, BMSB has significantly expanded globally over the last three decades
- **First European Presence:** 2004 in Liechtenstein and Switzerland
- **UK Situation:**

- BMSB interceptions at UK ports since 2010

- NIAB tracks adult BMSB sightings (from 2018)

- 2021: male and female BMSB in UK

- Significant increase in sightings reported in 2023 NIAB surveillance report

- 2023: Large number of BMSB reported by campervan owner returning from France

| Location | Year | Sex |
|---|---|---|
| Otley, North Yorkshire, England | 2021 | - |
| Crediton EX17 | 2021 | - |
| Hyde Road, South Essex | 2021 | ♀ |
| Hyde Road, South Essex | 2021 | - |
| North Wales | 2021 | 1 x ♀, 1 x ♂ |
| Five Mile Drive, Oxford | 2021 | - |
| Bristol, West Gloucestershire | 2021 | - |
| Little Mead, Leicestershire | 2021 | - |
| RHS Wisley, Surrey | 2021 | ♂ |
| London, Belgravia | 2021 | - |
| Clapham, South London | 2022 | - |
| Parliament square, London | 2022 | - |
| WC1, London | 2022 | - |
| RHS Wisley, Surrey | 2022 | 1 x ♀, 1 x ♂ |
| Natural History Museum, London | 2022 | 1 x ♀, 1 x ♂ |
| London | 2023 | Unknown |
| Yorkshire | 2023 | Unknown |
| London, Westminster | 2023 | 1 x ♀ |
| London, Kenninghall Road | 2023 | Unknown |
| West Yorkshire | 2023 | >200 x ♀,♂ |
| Porton, Witshire | 2023 | |
| Fife, Scotland | 2023 | Unknown |

# Control strategies: Advances in BMSB Trapping Techniques

- **Enhancing Trap Attraction:** Utilising a combination of visual cues (like LED lights) and olfactory stimuli (pheromones) to significantly increase BMSB capture
- **New Trap Designs:** Exploring new designs like wind vane-based traps and Nazgûl traps for higher efficiency
- **Strategic Trapping:** Importance of aligning trap deployment with BMSB's life cycle and local agricultural phenology to maximise effectiveness

**Nazgul Trap.** Image Courtesy Suckling, DM, et al (2019). https://doi.org/10.3390/insects10120433

☺ A ~~cheeky~~ picture of the Nazgul trapper at work

# Control strategies: Biological Control Strategies for BMSB

- **Exploiting Natural Predators:** Identification of native predators in various regions and their impact on controlling BMSB egg populations
- **Role of Parasitoids:** Investigating the success rate of both Asian and European parasitoids in different environmental conditions
- **Strategic Parasitoid Use:**

- Assessing climate compatibility and potential non-target impacts before releasing parasitoids

- Understanding the dynamics between different parasitoid species to optimize biological control

- **Future Outlook:** Steps towards integrating parasitoid use into larger, more comprehensive biological control frameworks

The samurai wasp (*Trissolcus japonicus*), a highly effective parasitoid against BMSB.

Image Courtesy: https://extension.usu.edu/pests/

# Monitoring Strategies: Pheromone-Based Methods for BMSB Monitoring

**Aggregation Pheromones:** BMSB's reliance on specific chemical signals for attraction and behaviour

**Pheromone trap deployed and with BMSB trapped**
Image Courtesy: NIAB

# Monitoring Strategies: Remote Sensing, Drone and Molecular Technology

- **Innovative Use of Drones:** Employing drones with UV light and video cameras for identifying BMSB
- **Terrain and Canopy Analysis:** Correlation between BMSB populations and environmental factors in orchards

**Molecular Tools in BMSB Detection**

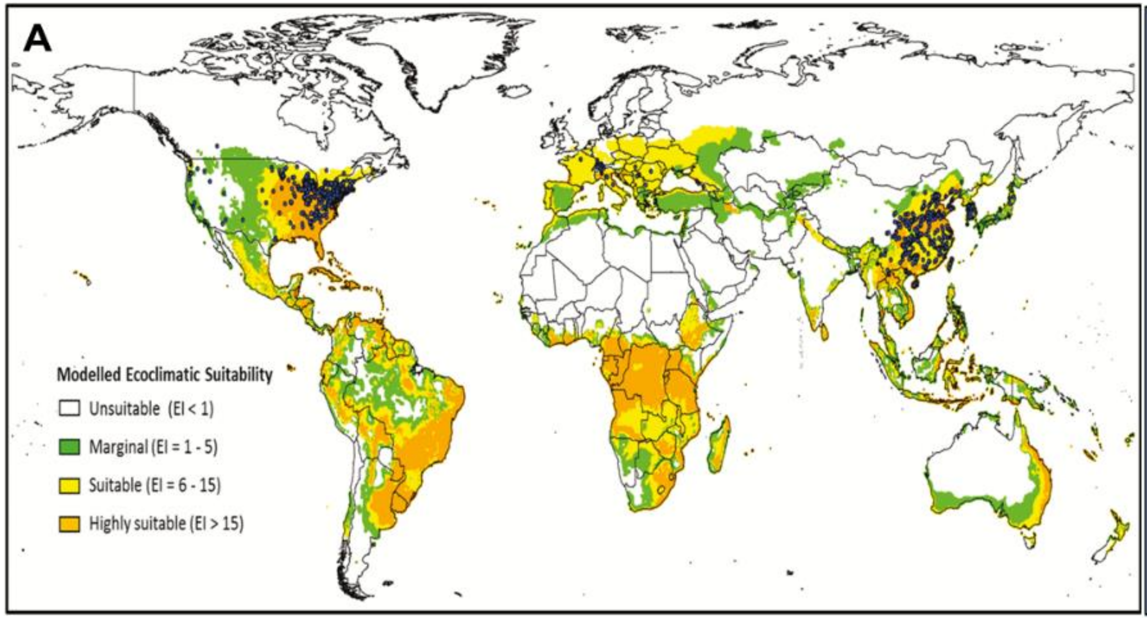
- **eDNA Surveying:** Revolutionary approach for detecting BMSB presence in agricultural fields
- **Genetic Sequencing and Diversity Analysis:** Uncovering hidden genetic diversity and tracing BMSB invasion sources
- **Forensic Identification:** Rapid DNA-based methods for BMSB identification, even with trace material

# Predictive Modelling of BMSB Spread and Climate Change Impact

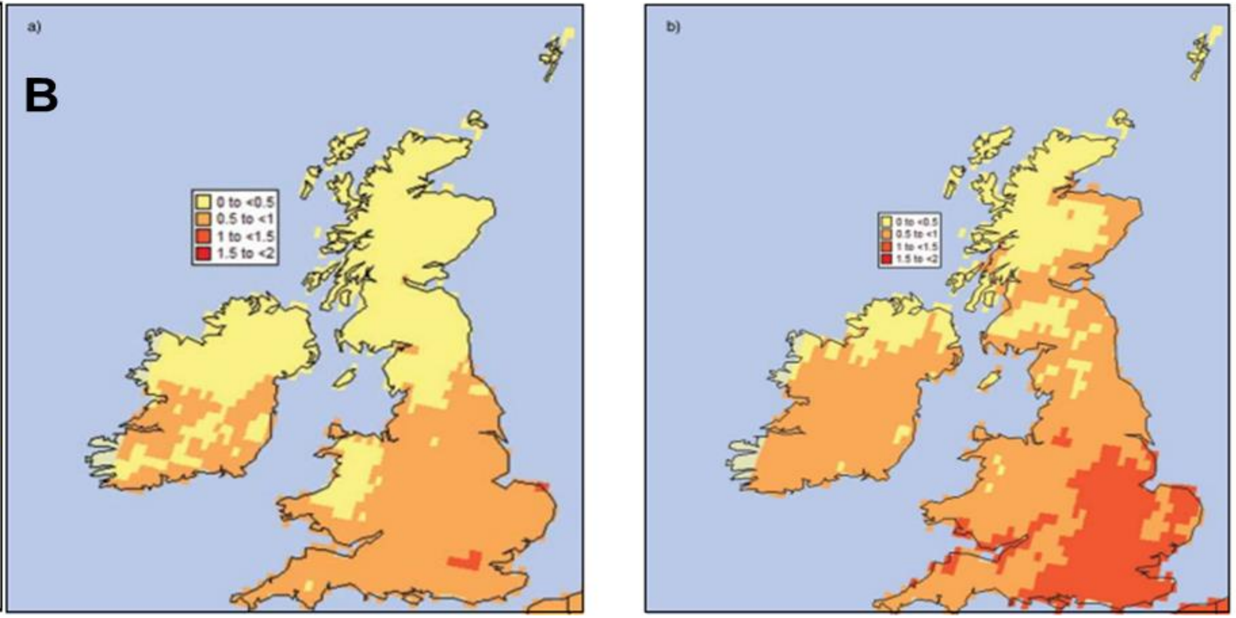
- **CLIMEX Modelling:** Projecting shifts in BMSB distribution under current and future climate scenarios
- **Implications for Agriculture:**

  - Anticipated expansion of suitable habitats for BMSB

  - Predictions of increased BMSB generations due to climate change




The potential global distribution of the BMSB (Kistner, 2017)




Potential number of BMSB generations per year under (a) historical 30-year (1961-1990) average climate and (b) projected climate for 2050 in the British Isles (Powell et al., 2021).

# Recommendations for Growers

- Deploy pheromone-baited traps to monitor BMSB populations
- Conserve native generalist egg predators like shield bugs, assassin bugs, and ants that can contribute to mortality
- Lobby for approval of commercially available Asian egg parasitoids
- Cover susceptible tree fruit crops with row covers or fine exclusion netting to prevent initial infestation
- Scout for BMSB activity and apply selective insecticides
- Diversify orchard diversity to boost beneficial arthropod populations that can aid pest control
- Remove alternate host plants such as the tree-of-heaven, *Ailanthus altissima*, around orchard borders to reduce pest reservoirs

# **WP 2.** Understanding **the role of soil properties in apple canker** (*Neonectria ditissima*) management.

- Past 15-20 years, *Neonectria* (European) canker most important diseases of apple and pear
- High susceptibility of modern commercial varieties
- AHDB TF223 focused on rootstocks and soil amendments (Arbuscular mycorrhizae, *Trichoderma*)
- New biocontrol agents (*Trichoderma* spp., *Bacillus* spp., *Clonostachys spp*, *Aureobasidium spp.),* elicitors, biostimulants, plant extracts and sustainable plant protection compounds
- <u>Task 2.2: Assess the contribution of soil properties to canker expression/severity in newly established orchards</u>

# **WP 2.** Understanding **role of soil properties in apple canker** (*Neonectria ditissima*) management

**Our previous data indicated that:**

- **Canker symptom expression differ significantly between sites and sometimes between blocks within site**
  - 3 commercial farms, Same tree source, Same inoculum levels, management practice
- What drives site differences is not known.
- Soil properties may be one of the factors.
  - Management, inoculum pressure, climate, age, scion, rootstock….

# **WP 2.** Understanding role of soil properties in apple canker (*Neonectria ditissima*) management

Methods:

1. **Collect** existing data from commercial apple orchards across UK:

   **Soil analysis** data AND **Canker severity** data

2. **Determine** which soil parameter(s) correlate (+/-) with canker severity

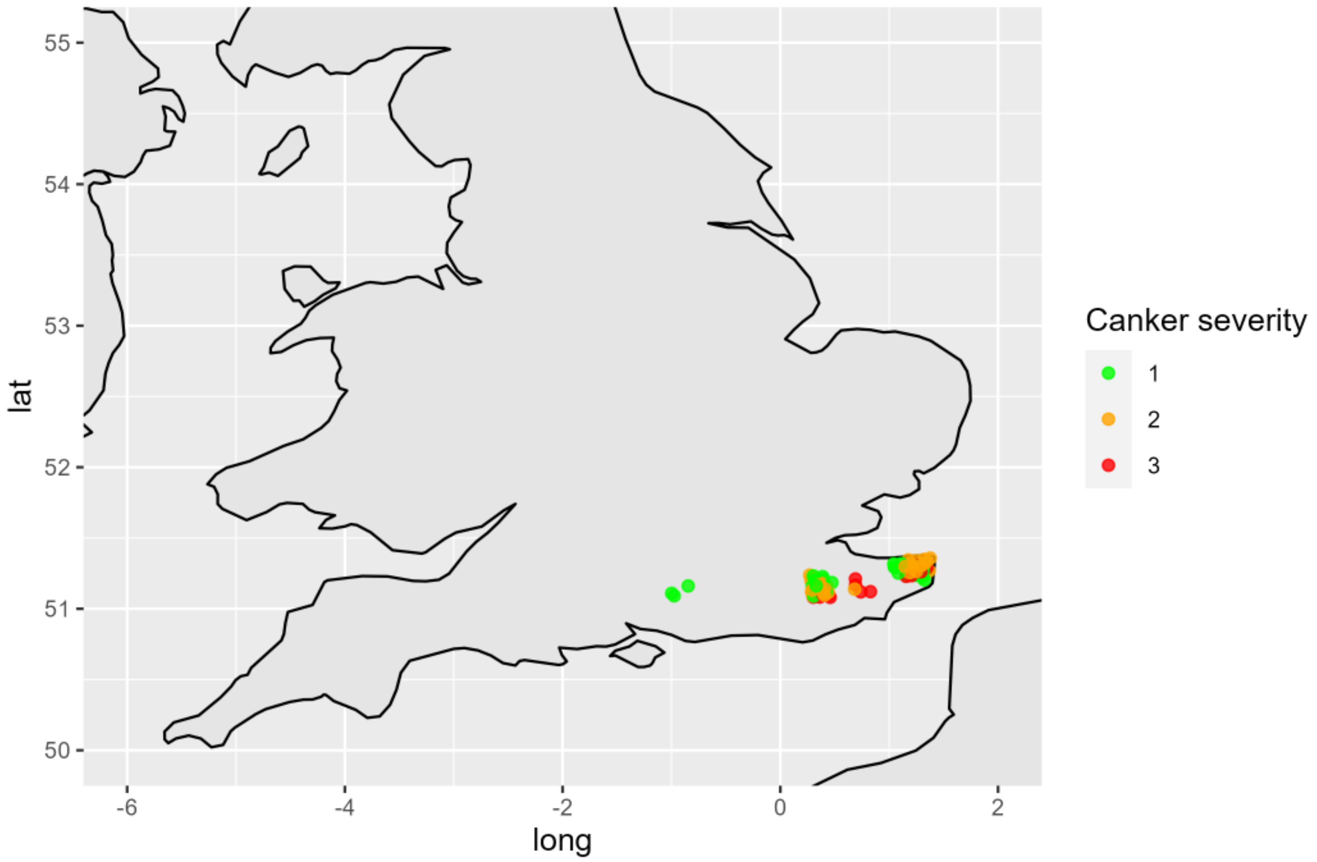
3. **Validate** by detailed observations of:
   - Soil properties – detailed analysis between and within orchards
   - Assess canker severity in contrasting orchards

4. Share outcomes with apple industry worldwide.
5. Discuss/Design possible site-specific soil improvements.

# WP 2: Soil / Canker – Summary of results

CHALLENGE 1: Collecting the **soil and canker** data

- To date, 7 individual growers contributed the dataset
    - **140 individual orchards** or orchard blocks
    - Across **17** separate **farms**

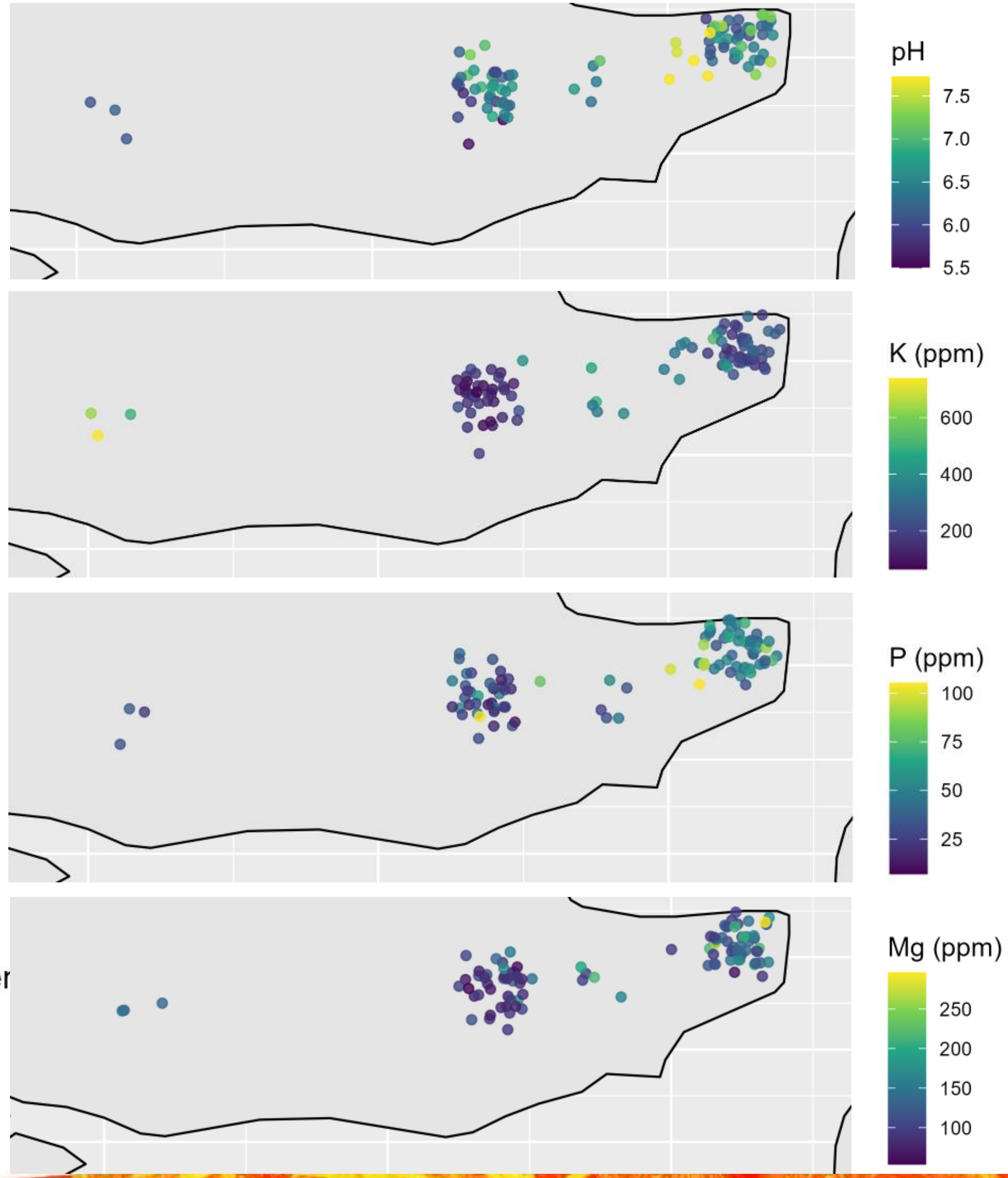



Missing data from:

- E / W Midlands
- East Anglia
- Many large growers in S / SE UK

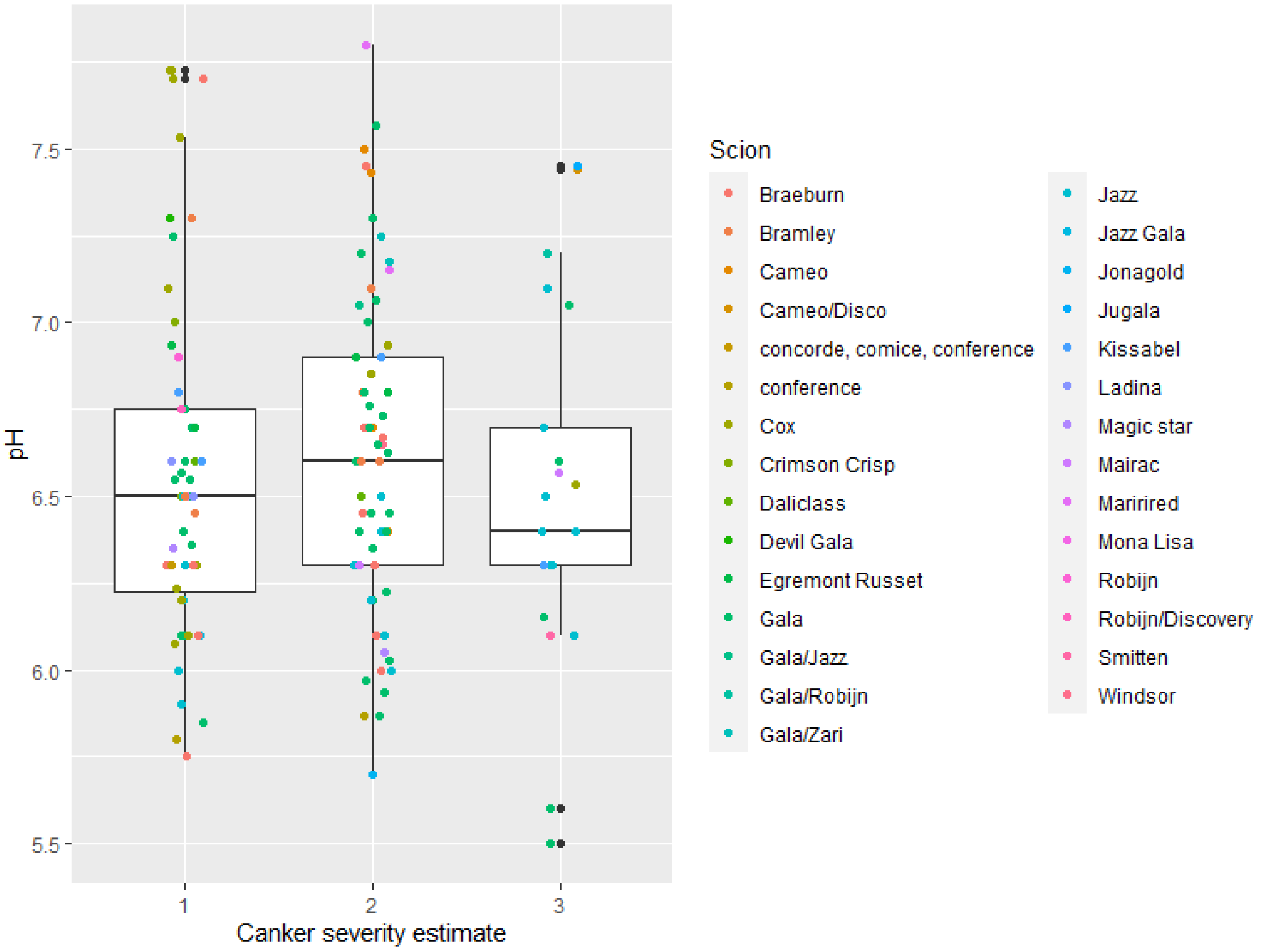
# WP 2: Soil / Canker – Summary of results

- Challenge 2: Limitations in available data – quality
  - Broad canker severity score (1 – 3)
    - more quantitative measure would be ideal
  - Few soil properties measures on all sites: pH, K, P, Mg
  - Some regional differences but **not enough sites** to yield robust conclusions

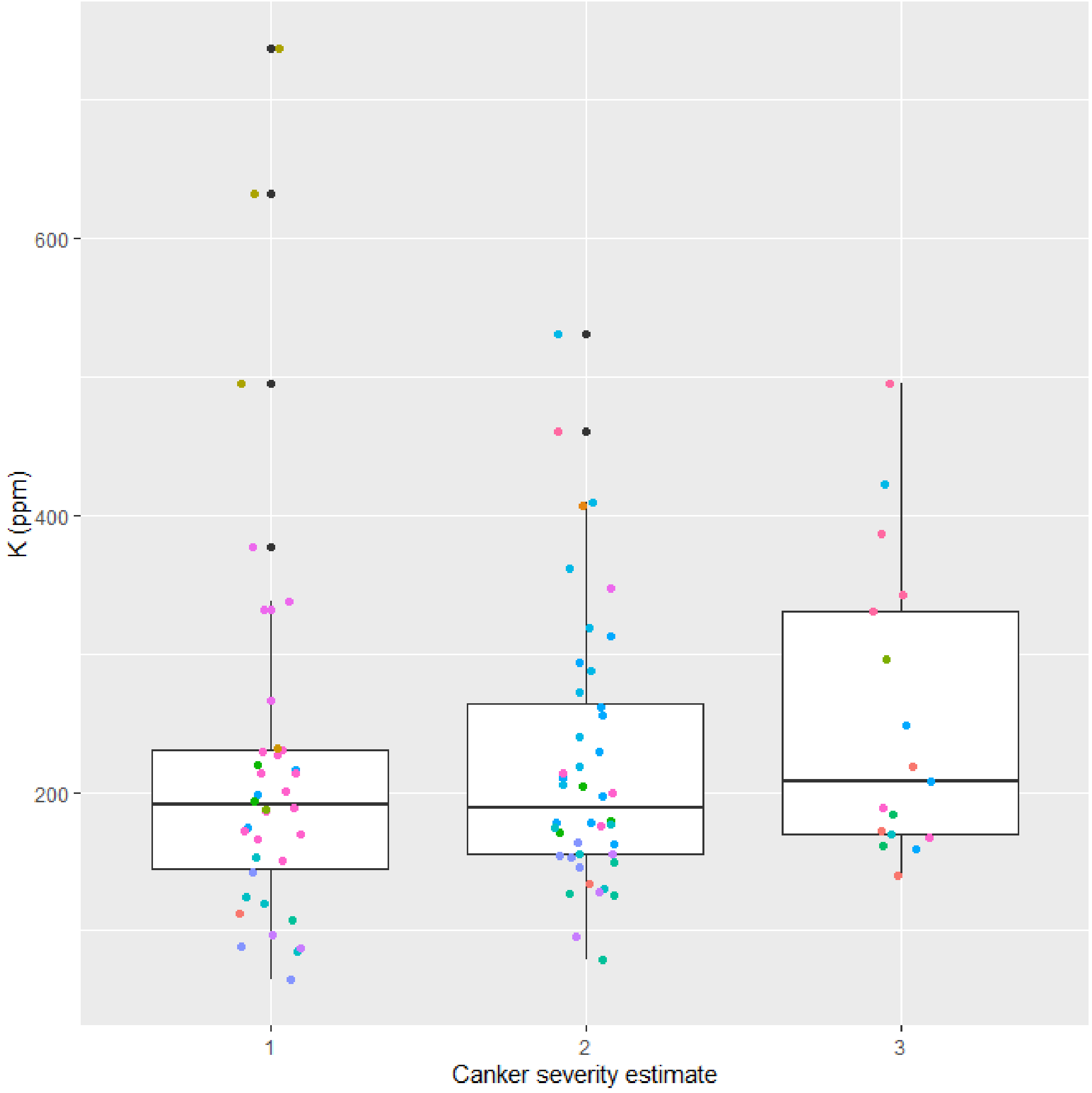
# WP 2: Soil / Canker – Summary of results

- Challenge 2: Limitations in available data – confounding factors
  - Many orchard ages: 1990-2022
  - Many scion cultivars (combinations)
    - Various susceptibility



# WP 2: Soil / Canker – Summary of results

- Soil K content may be related to canker severity
  - Slight trend, **more data needed**

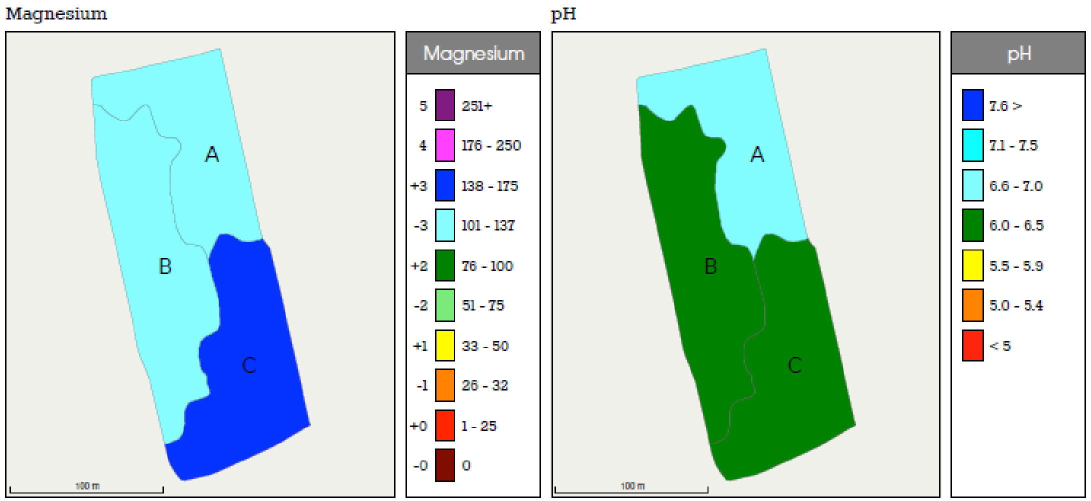


# **WP 2.** Understanding role of soil properties in apple canker (*Neonectria ditissima*) management

## NEXT STEPS:

1) Get more **soil and canker data** from across UK orchards.

- **WE NEED YOUR HELP:**
  - **Ca. 10 years old orchards**
  - **Gala, Braeburn, Cox, Jazz and other common commercial varieties are priority**
  - **Detailed soil data**
  - **Orchard location**
  - **Canker severity estimate**
    - **Grower assessments? % Trees with canker?**



# **WP 2.** Understanding role of **soil properties in apple canker** (*Neonectria ditissima*) management

Plan for 2024:

2) Detailed canker and soil assessment in selected orchards.

- Validation and Data expansion to other variables (nutrients)

3) More **data analysis** → conclusions → future research.

4) Disseminate results before 2024/25 planting season.

# **WP 4.** Control of woolly apple aphid (WAA, *Eriosoma lanigerum*) using non-chemical approaches.

- Woolly apple aphid, *Eriosoma lanigerum*
- Earwigs, *Forficula auricularia*, are an important generalist predator
- ‘Wignest’, developed in an IUK project, Russell IPM

- Task 4.1. Mass relocation of earwigs to orchards with WAA

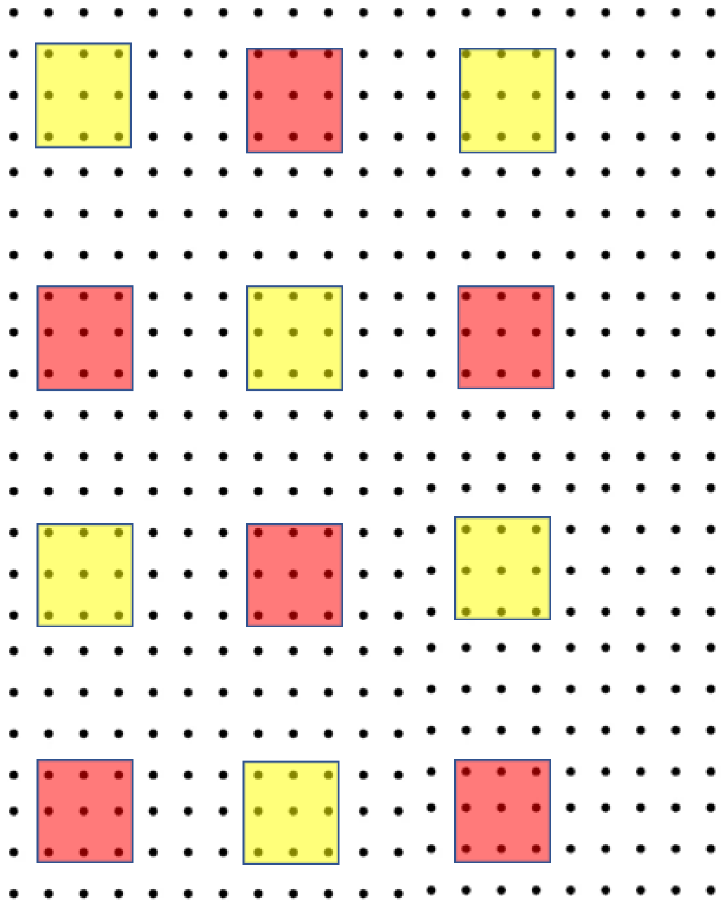
# Background and Methods

Wignest

- Developed by NIAB/Russell IPM/NRI
- Available from Agrovista

- Shelter for earwigs
- Contains food
- Hang in orchard
- Encourage earwigs to where needed

- 3 orchards
- 2 treatments – with and without earwigs
- 6 reps / orchard
- 9 trees per rep



Wignests were deployed on 27/06/2023 (Site 1), 28/06/2023 (Site 2) and 30/06/2023 (Site 3)

# Methods

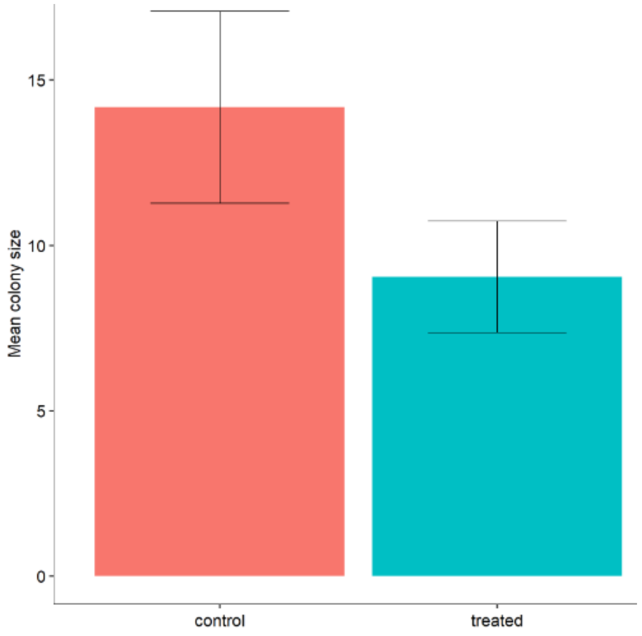
1. Collection of earwigs
2. Housing in Wignests (x5/nest)
3. Deploy onto trees

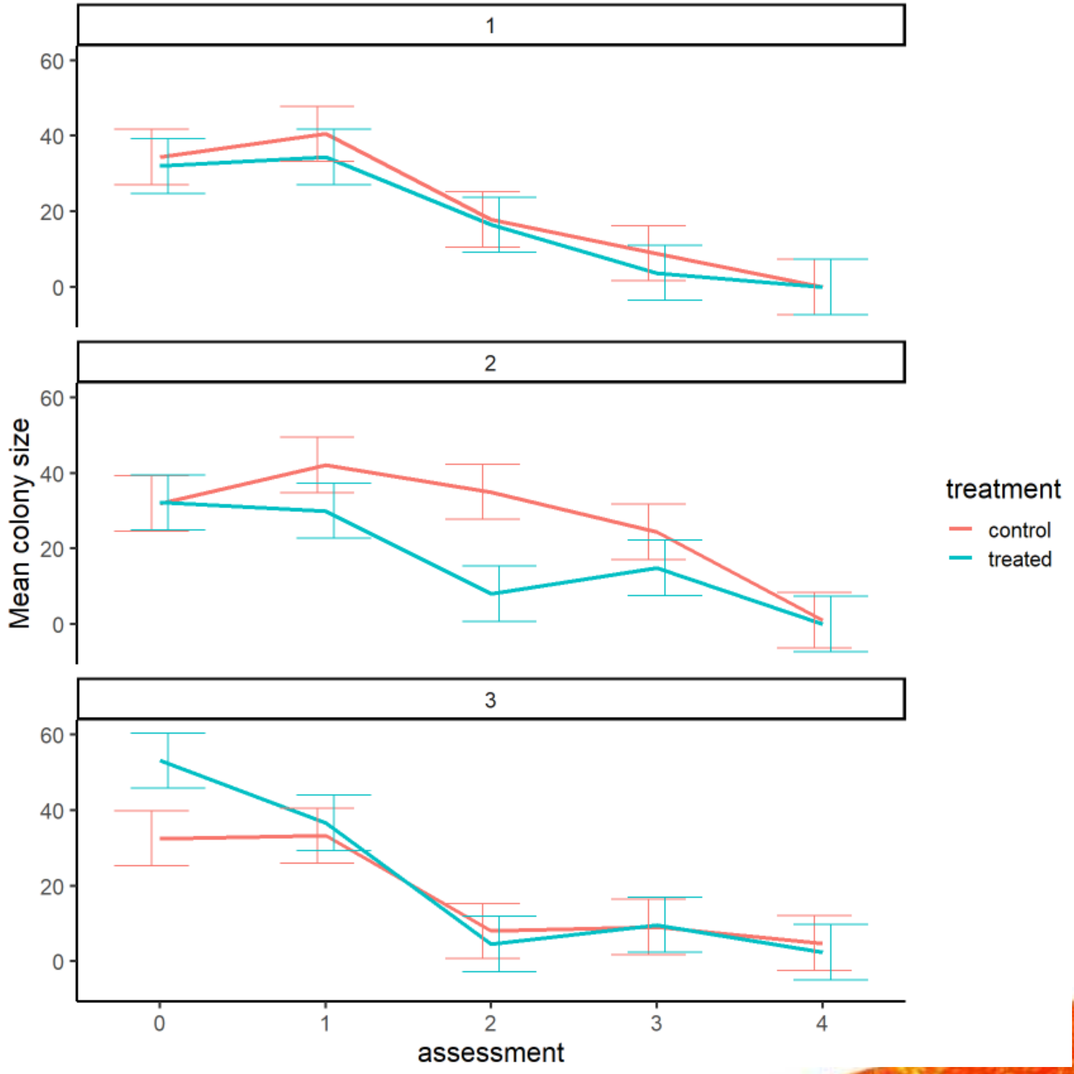
# Assessments

1. Number of WAA per colony on bark
2. Number WAA colonies on young shoots (leaf nodes)
3. Number earwigs in wignests

WAA assessments, preassessment (27 to 30/06/2023), then 13/07/2023, 28/07/2023, 03/08/2023 and 23/08/2023

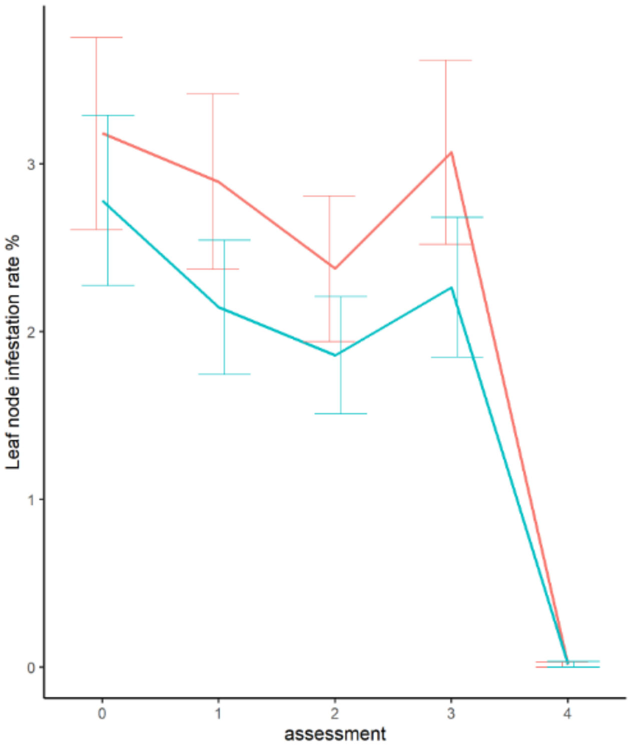
# 1. Number of WAA per colony on bark

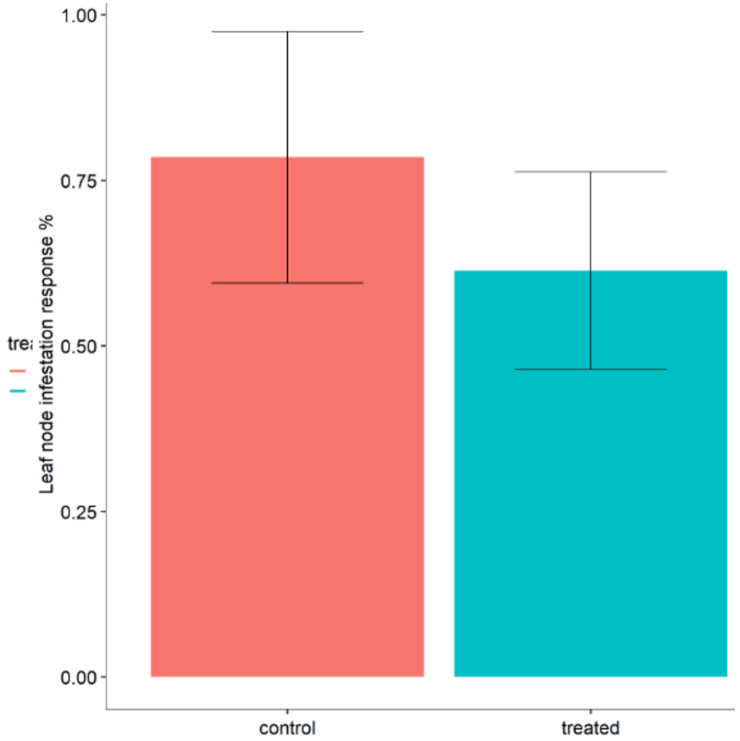



| Numbers of WAA per colony on each plot of the older bark of apple trees in 3 orchards | | | |
|---|---|---|---|
| | Chisq | Df | Pr(>Chisq) |
| **Site** | 3.201 | 2 | 0.218 |
| **Assessment** | 103.844 | 3 | <0.001 |
| **Treatment** | 2.755 | 1 | 0.097 |

# 2. Number of WAA colonies on young shoots



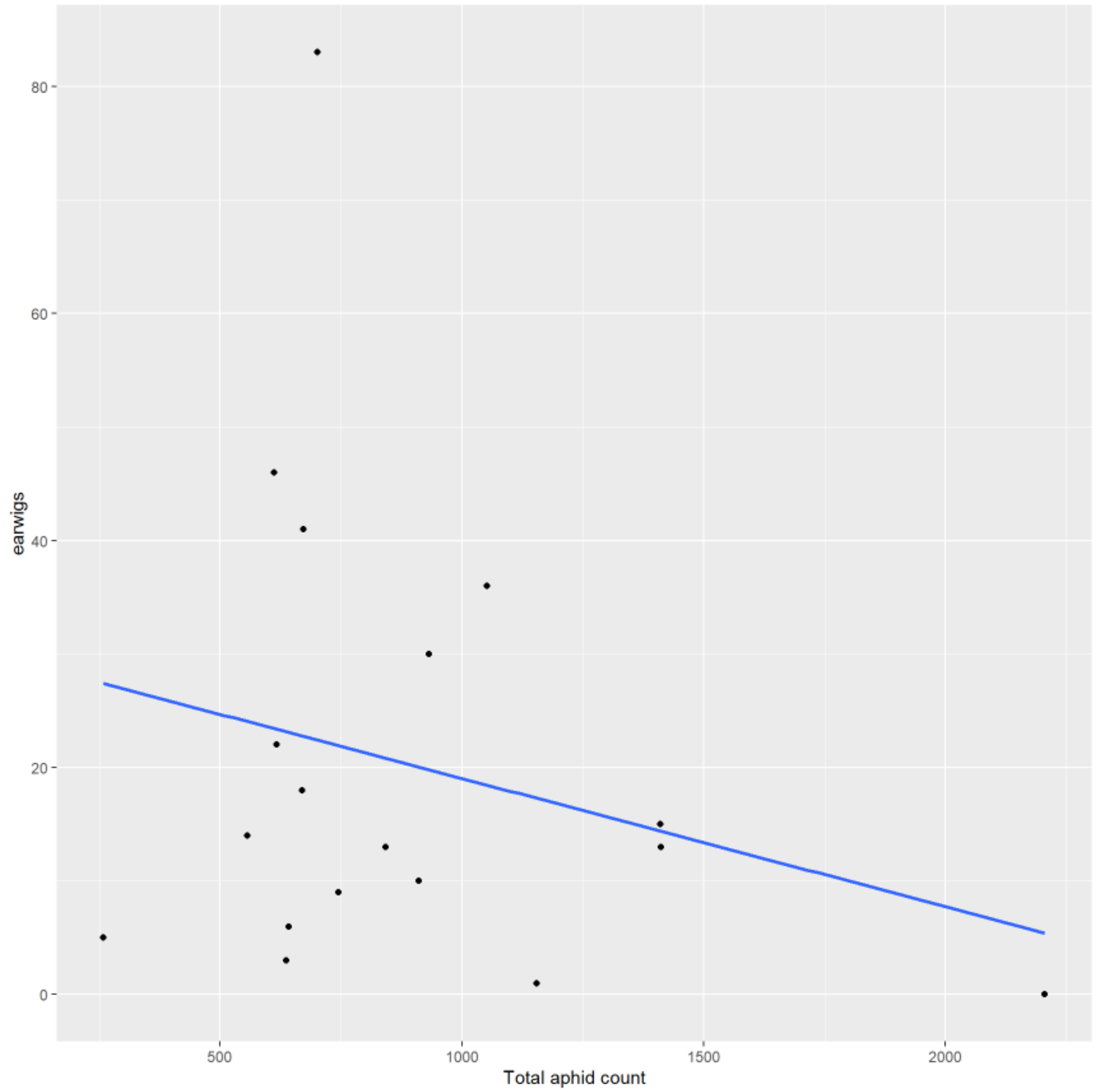



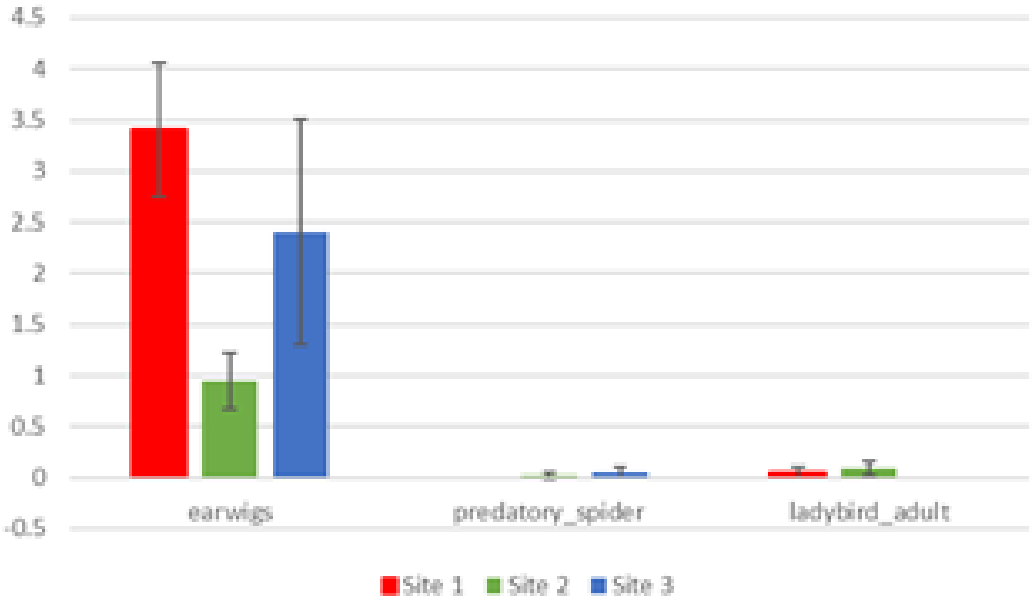

25 randomly selected young shoots with WAA per plot

**Numbers of WAA infested leaf nodes on each shoot (means expressed as rates and including an offset (number of leaf nodes) in the model), of apple trees in 3 orchards.**

| | Chisq | Df | Pr(>Chisq) |
|---|---|---|---|
| **Site (orchard)** | 1.228 | 2 | 0.541 |
| **Assessment** | 51.492 | 3 | <0.001 |
| **Treatment** | 1.076 | 1 | 0.300 |

# 3. Earwigs in Wignests




# Recent publications

- Review article (Adhikari 2022): 73 species of predatory insects worldwide belonging to Coleoptera, Diptera, Neuroptera, Dermaptera, and Hemiptera
- Alins et al. (2023) tested releases in Catalonia. Releases reduced colony size from the second year onwards, and were compatible with *A. mali*
- Hanel et al. (2023) removed earwigs from Oregon and Washington State stone fruit orchards using rolled cardboard traps relocated in apple and pear orchards. Plots with mass releases had slight trend in lower pest density
- Bischoff et al. (pre-proof, 2023) introduced earwigs in gauze-bagged branches with WAA. Spatial complexity and earwig density. Long, complex branches less control; reduce tree complexity

# Conclusions

1. Earwig refuges (Wignests) in apple tree canopies did not significantly reduce WAA in one season
2. Trends were in right direction
3. Greatest impact on shoot leaf nodes in mid season (13/07 - 03/08)
4. Long-term impacts in UK orchards?
5. Reinoculations?
6. Orchard complexity?

# **WP 5.** Optimising control of hard-bodied insect pests through precision monitoring, semiochemical & biological manipulation.

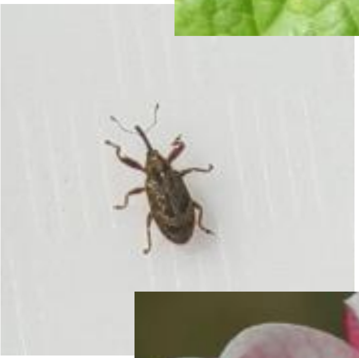
- Task 5.1 Deploy and test a large-scale integrated management system for hard-bodied pests and resulting impact of fruit damage
- 1. Lybolty capsid repellent - 5 m spacing
- 2. ABW shelter traps on every fourth tree - frozen - numbers of weevils counted
- 3. ABW trial repellent of walnut leaf extract in sachets
- 4. Magipal™ 100/ha attract hoverflies and lacewings, may also be repellent to ABW
- 5. ASF sticky traps at 100/ha, blue or white




# Aims/focus of activities

- 1. Field trials of non-spray interventions to control key hard-bodied pests
  - Apple sawfly (ASF)
  - Capsids
  - Apple blossom weevil (ABW)
  - (Rhynchites)

- 2. Lab pilot trial of nematodes to control apple sawfly

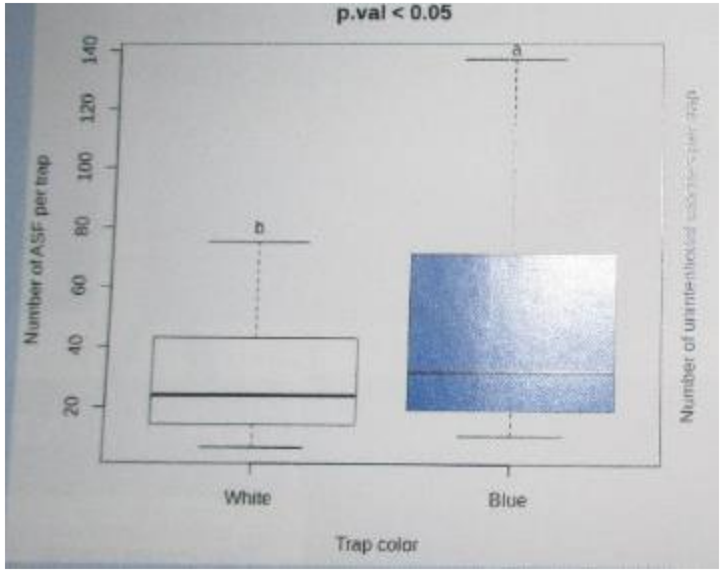



# ASF – mass trapping

- Sticky traps
- Deploy early spring before emergence
- Collect by mid/late spring
- Attracts ASF adults, reduce oviposition
- Currently being used by some organic growers

# ASF – blue or white traps?

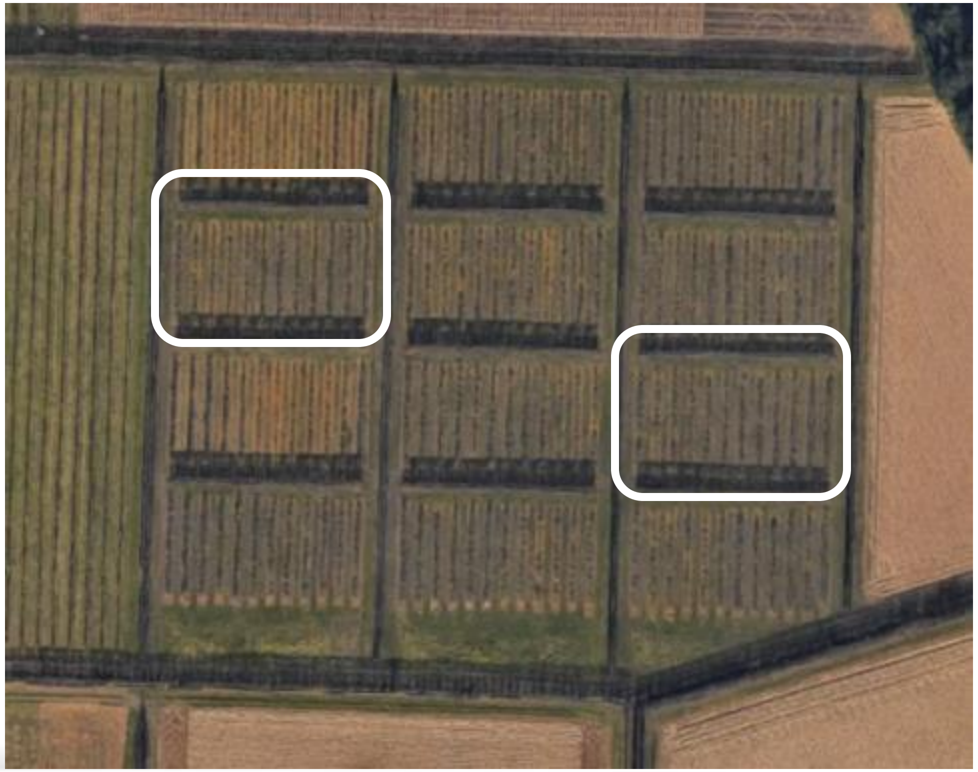
- French team reported better results from blue
- Test in UK




Jacquot, M. (2021) Effect of the colour of sticky traps to catch apple sawfly. API-Tree No. 7.

# ASF sub-trial

- Participating commercial orchards had few ASF overall
- Part of NIAB site has high numbers of ASF
- Blue and white traps tested (10/subplot on 2 x subplots)



# ABW – shelter traps

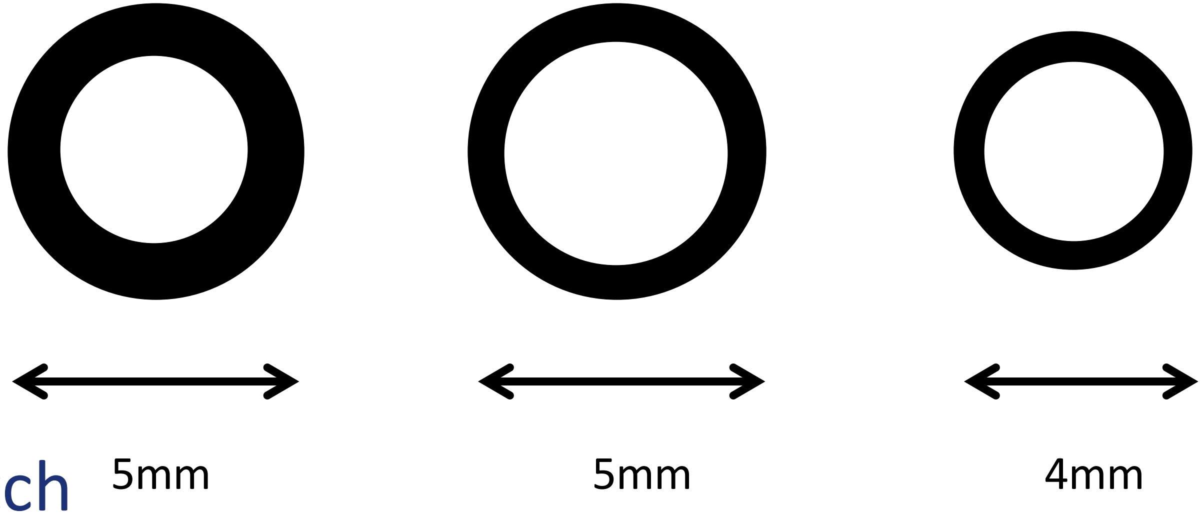
- Dutch and Belgian teams previously tested shelter traps
- Black tree-bind/tying tube
- Put out in May
- Collect in November/December
- Cold-store in sealed bags
- Can reuse if cleaned out

| Location | Variety | Plantyear | Bundles per tree | Replicates | Reduction compared to reference (%) |
|---|---|---|---|---|---|
| 1 | Natyra | 2015 | 1 | 3 | 65 |
| 2 | Natyra | 2015 | 1 | 4 | 90 |
| 2 | Elstar | 2016 | 1 | 4 | 87 |
| 2 | Natyra | 2017 | 1 | 6 | 70 |
| 3 | Pinova | 2007 | 1 | 4 | 54 |
| *mean* | | | *1* | | *74* |
| 3 | Pinova | 2007 | 2 | 4 | 73 |

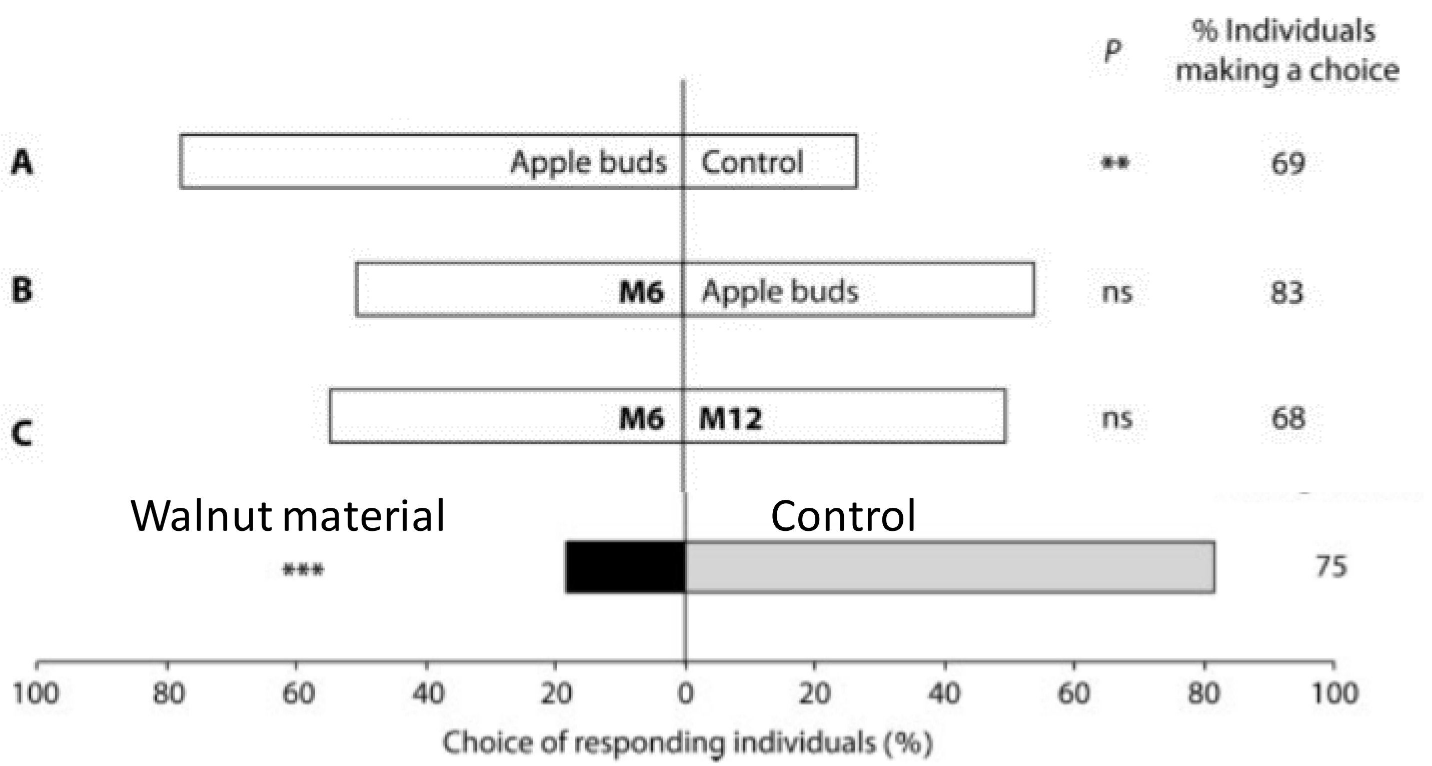
Brouwer et al. Delphy

# ABW shelter traps, sub-trial

- Commercial orchards have low ABW
- We also deployed shelter traps on Wiseman organic orchard at East Malling – known ABW populations
- Trialled 3 thicknesses of tube
- Also gave spatial information about organisms in orchard
- Deployed in May
- Retrieved in December, stored at 4°C until processed.
- Checked for ABW, Rhynchites, by-catch



# ABW – walnut odour

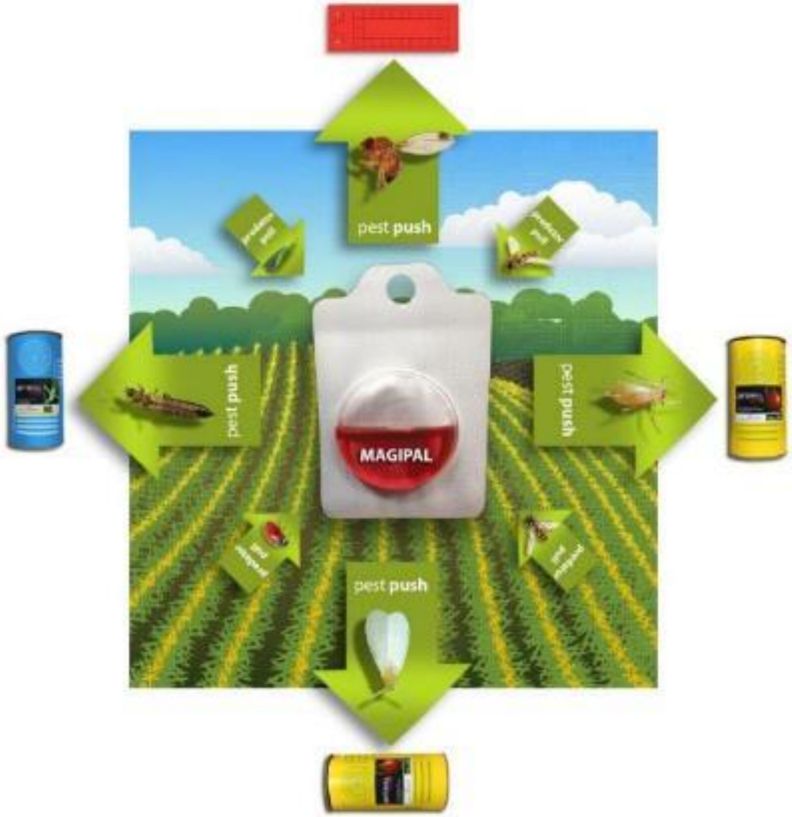



- 2013 paper indicates that walnut buds/leaves may be repellent to ABW
- May be due to presence of methyl salicylate
- Walnut leaves have a strong, spicy odour
- Early pilot test to explore
- Bags of dried walnut leaf every 5th tree

Collatz, J., & Dorn, S. (2013). A host-plant-derived volatile blend to attract the apple blossom weevil *Anthonomus pomorum*–the essential volatiles include a repellent constituent. *Pest Management Science*, *69*(9), 1092-1098.

# ABW/general pests - Magipal

- Fairly new product from Russell IPM
  - Codeveloped with NIAB, NRI
- Tested mostly in soft-fruit/protected cropping
- Generic attractant (beneficials)/repellent (pests) - synomone



# Capsids - Lybolty

- New product from Russell IPM
  - Codeveloped with NIAB, NRI
- Wax hemisphere with odour
- Repels capsids in covered soft-fruit
- Untested in top-fruit

**Lybolty**

What is it?

Lybolty is part of a push-pull system that deters capsids from entering and feeding on the crop, while pushing the pests toward traps. Lygus Push-Pull was developed in collaboration with NIAB East Malling, the Natural Resources Institute and AHDB.

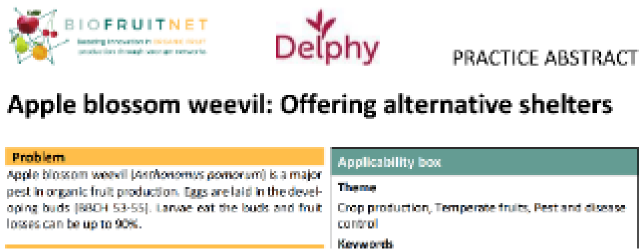
Target pests

European tarnished plant bug and common green capsid.

Key advantages

- Pesticide-free and effective method of managing capsid pests in strawberry and cane fruit as part of an integrated programme

# Field trials – general procedure


BIOFRUITNET

Delphy

PRACTICE ABSTRACT

**Apple blossom weevil: Offering alternative shelters**

**Problem**

Apple blossom weevil (*Anthonomus pomorum*) is a major pest in organic fruit production. Eggs are laid in the developing buds (BBCH 53-55). Larvae eat the buds and fruit losses can be up to 90%.

**Applicability box**

**Theme**

Crop production, Temperate fruits, Pest and disease control

**Keywords**

- 5 orchards (commercial)
  - 1 x organic, Discovery
  - 4 x conventional: Gala, Cox, Crimson Crisp (x 2)
  - 3 sites had known pest issues (mainly ASF, Rhynchites)
- Subplots
  - 25 x 25m – Magipal (100/ha), Lybolty (every 5th tree), ABW shelter traps (~every 5th tree)
  - 25 x 50m – ASF sticky traps (100/ha)
  - 10 x 25m – perforated bag with 50g dried walnut leaves (every 5th tree)
- Subtrials at NIAB – white versus blue sticky traps for ASF, ABW shelter traps

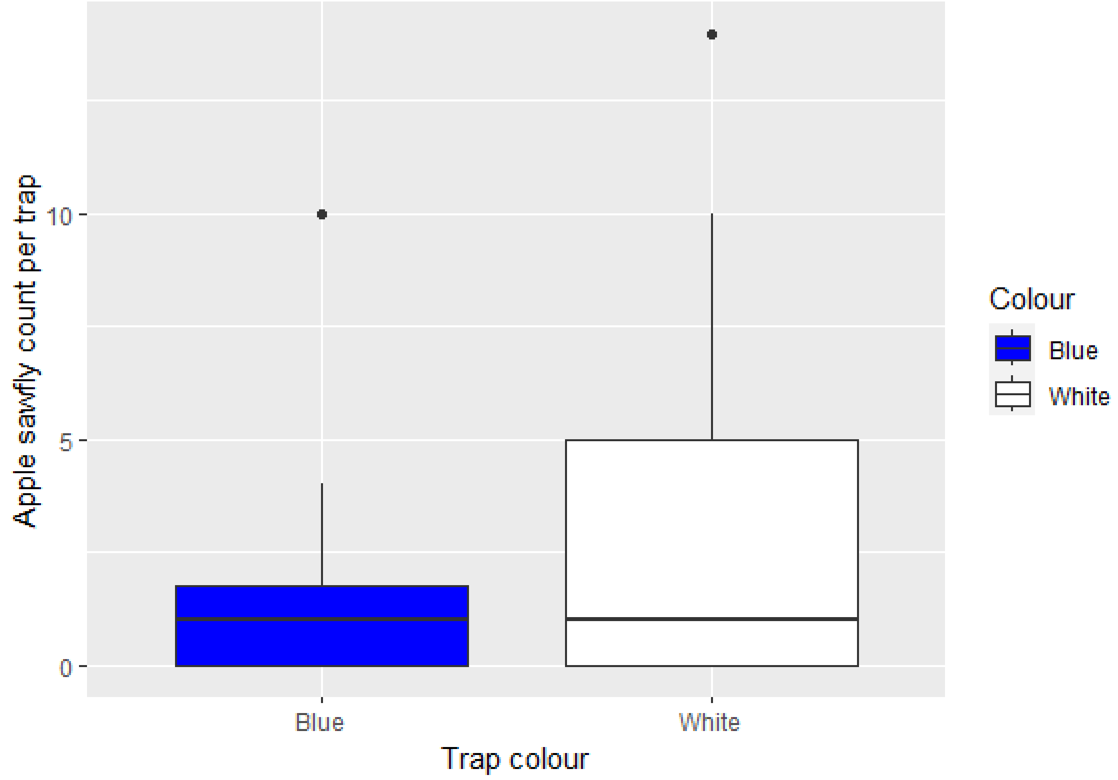

control

# Measurements

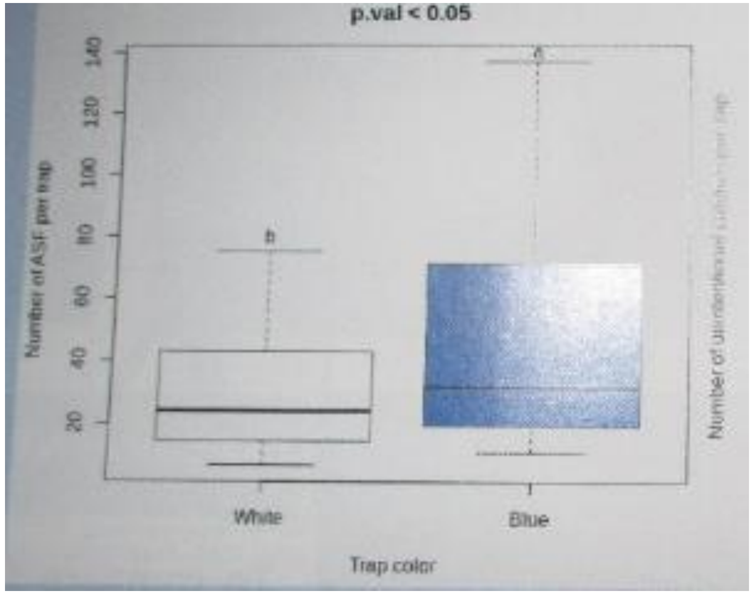
- June: tap-sampling and damage assessment (30 trees per subplot)
- July: tap-sampling (30 trees per subplot)
- August-September (harvest time): pick 1000 apples per subplot and score damage
- November: collect ABW shelter traps

- NB ABW shelter traps will not have firm results till 2024 but preliminary results presented

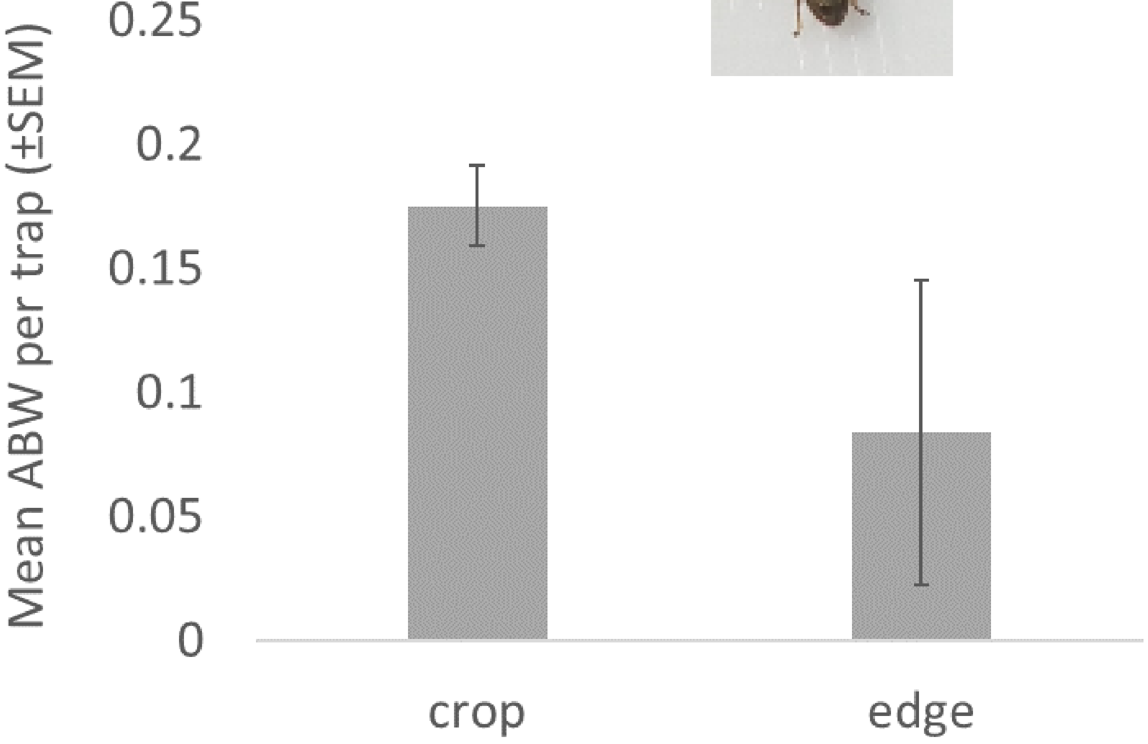
# White traps catch more ASF in UK




- Recommendation: continue to use white in UK, no evidence supporting blue being better



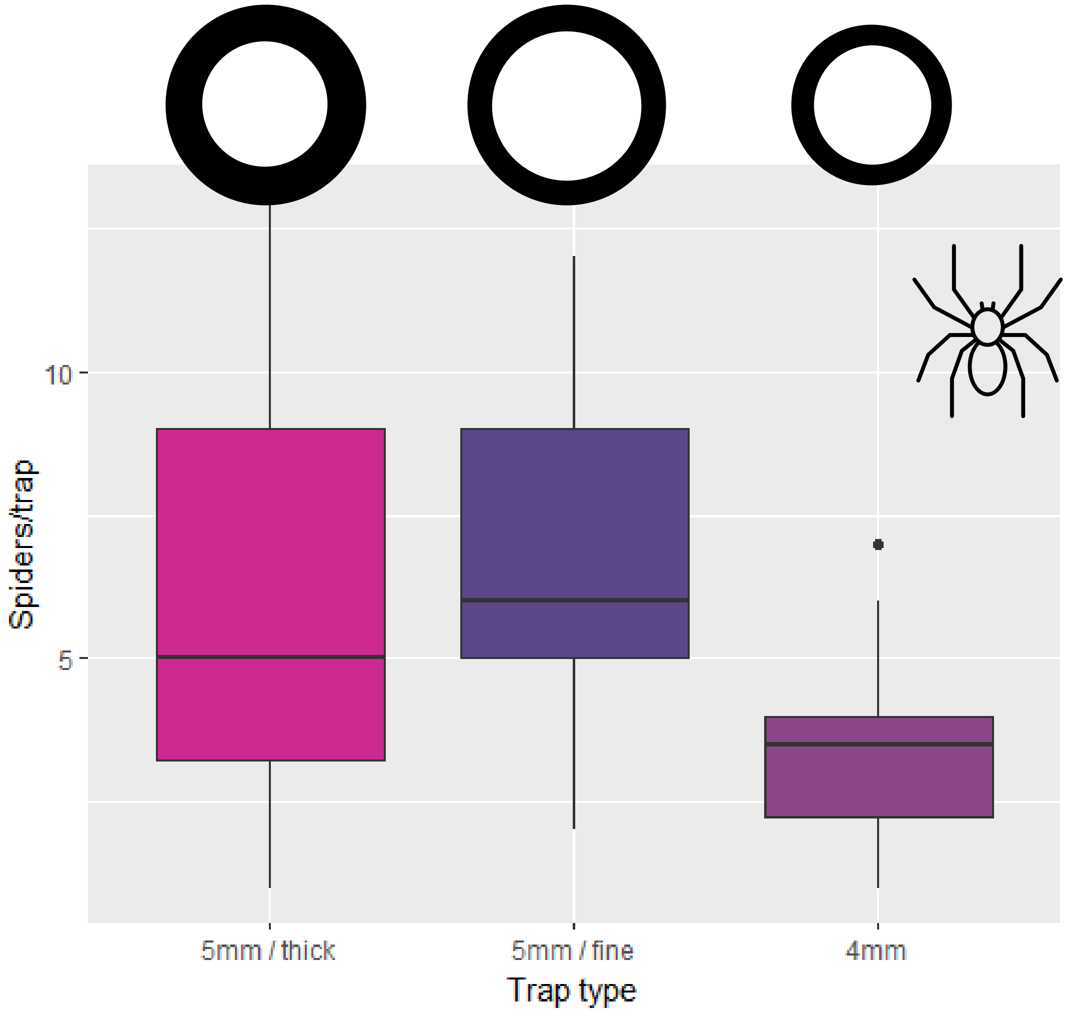
# ABW shelter-trap overview

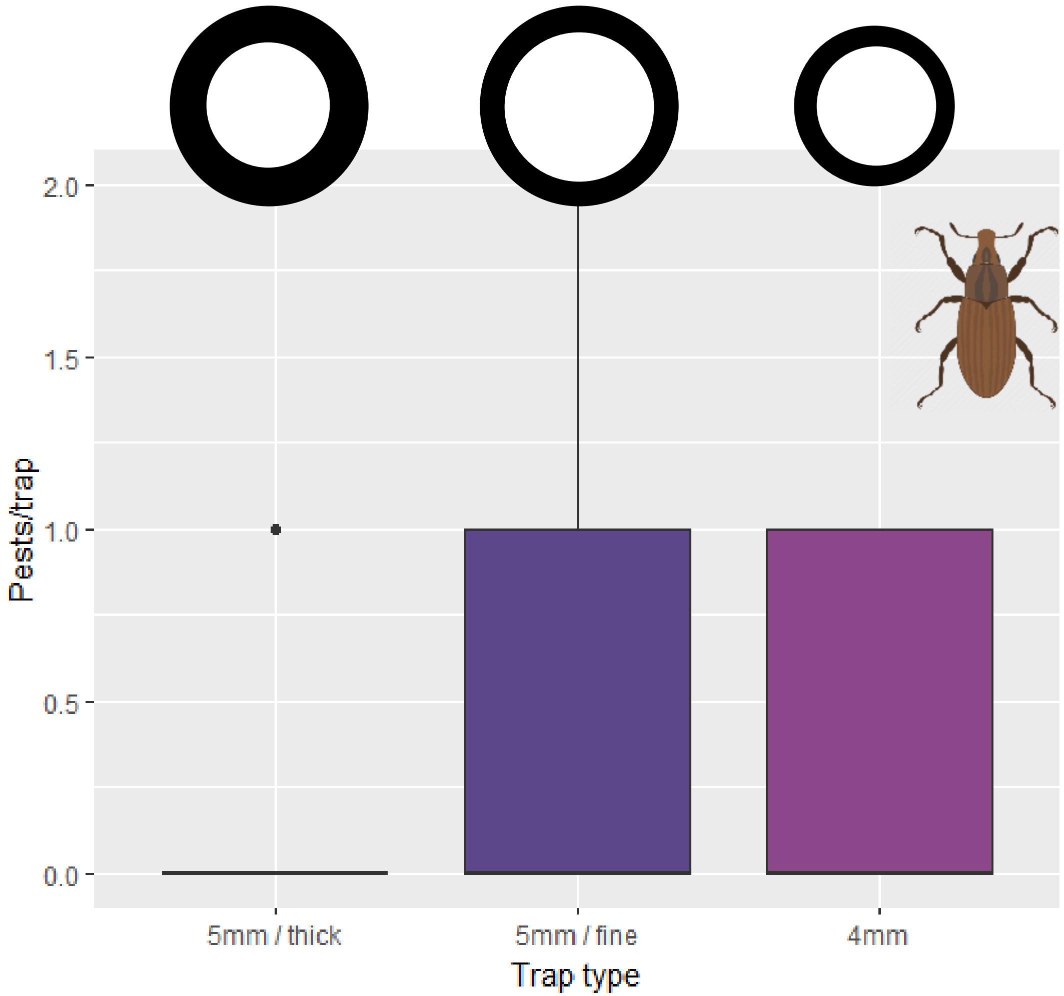



- Small number of ABW retrieved from traps in commercial orchards (2 sites, both conventional)
    - One of these had detected ABW by tap-sampling earlier in year
    - But little actual damage detected
    - ABW mostly in crop rather than edge of crop – edges not especially ABW-vulnerable
- One only ABW in traps in Wiseman (NIAB organic)
- Range of other invertebrates, mostly spiders
- No Rhynchites

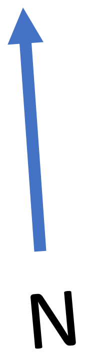
# ABW subtrial: type of shelter trap

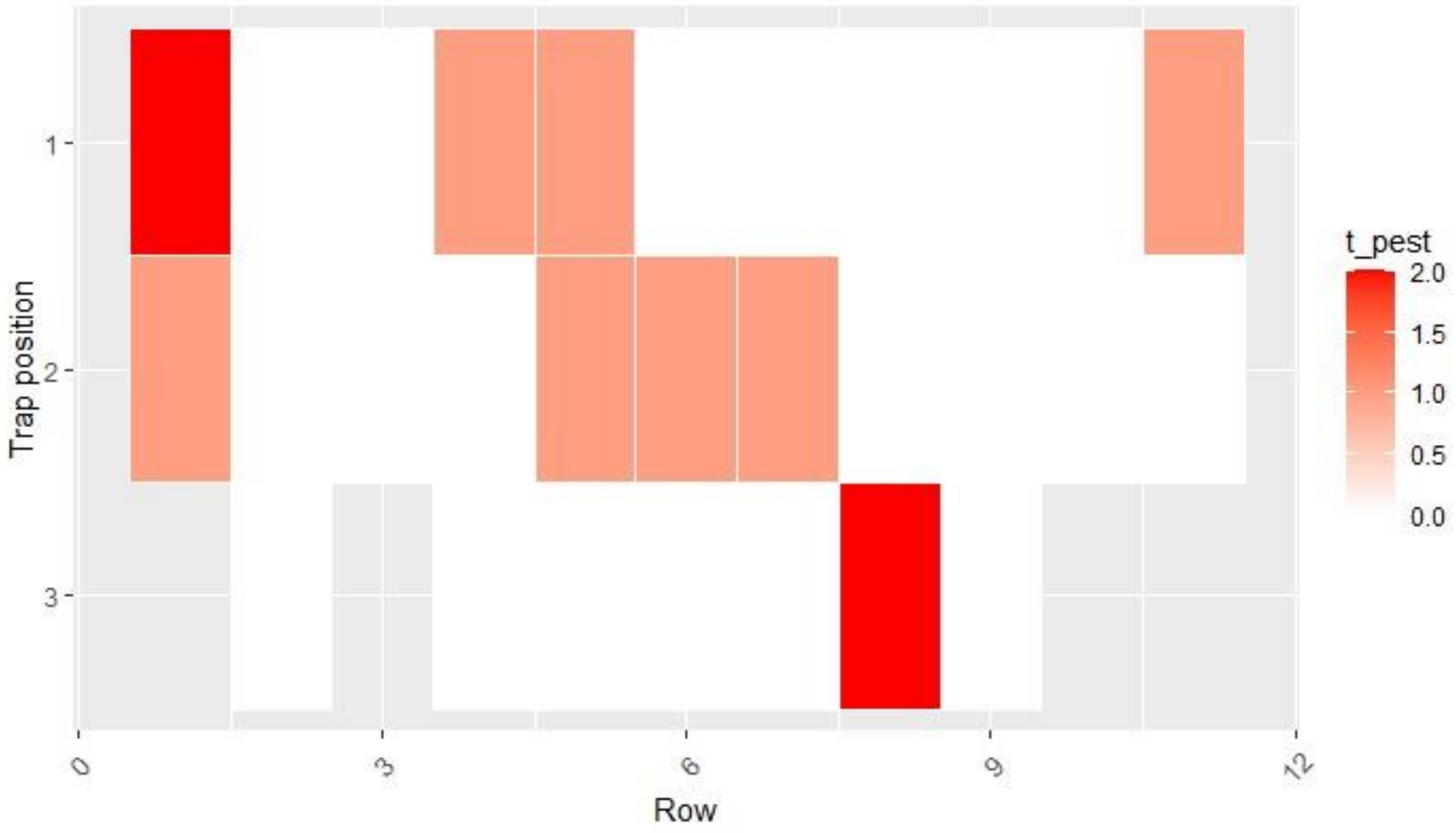
## 5mm with thin walls tends to get most pests but also most beneficials.

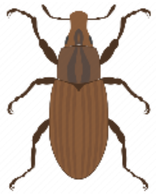


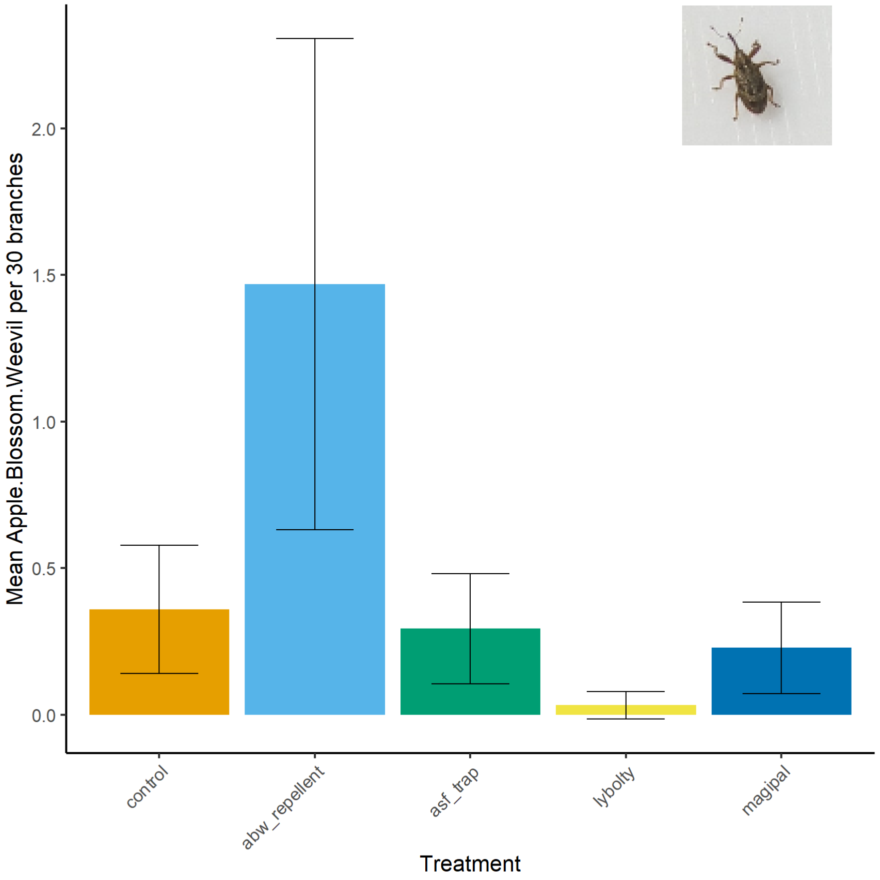
# Some spatial patterns of pests within the test orchard

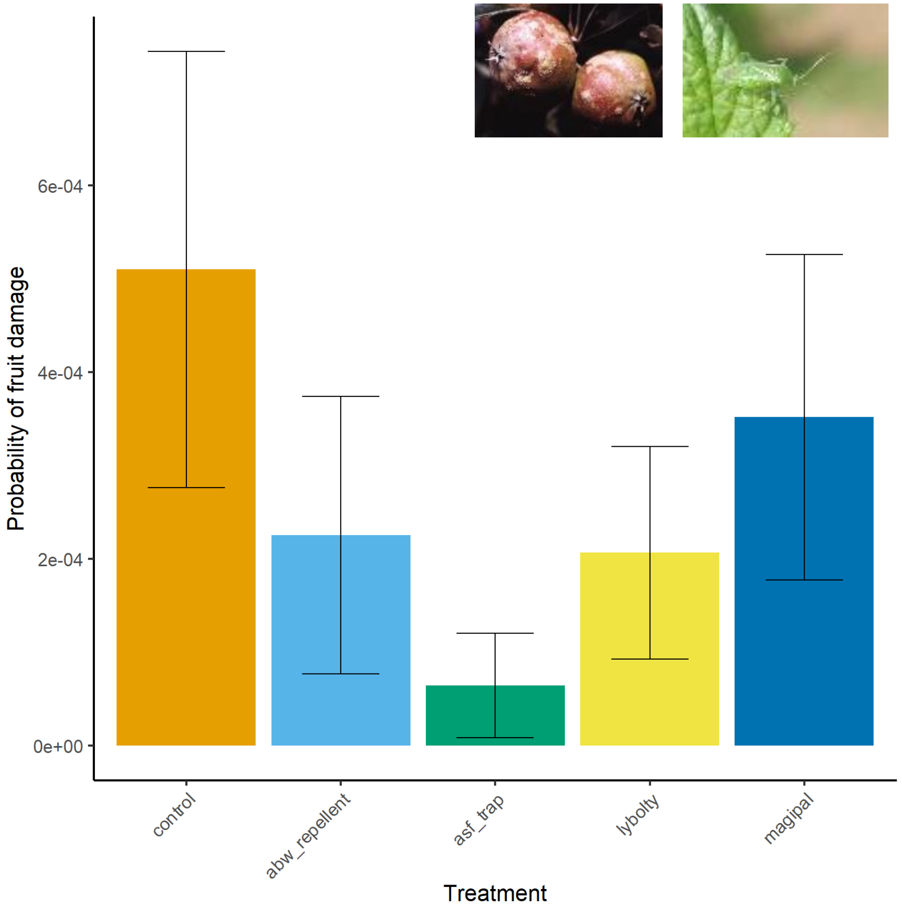


# Mid-summer: Subtle effects of treatments on pests/beneficials




ABW walnut-leaf repellent does not repel **ABW** mid-summer.

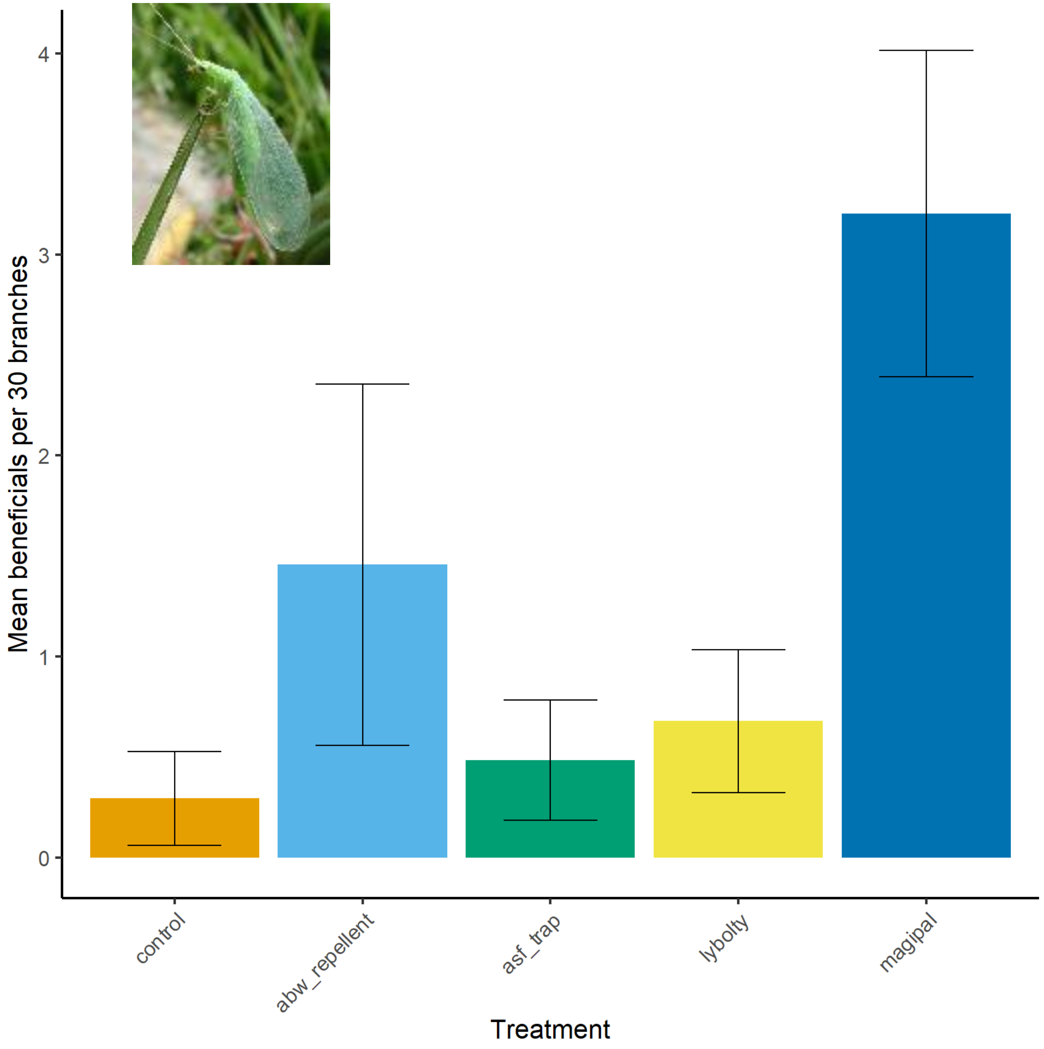
Some effect of treatment overall on **capsid** damage ($p$ = 0.00016) but no individual treatment significant (**weak possibility of Lybolty effect**, $p$ = 0.06).

Treatments overall did not significantly affect pest and natural enemy numbers in June

# Mid-summer: Magipal increases beneficial insect activity overall

Lacewings, ladybirds, earwigs and *Orius* combined

$p = 0.014$

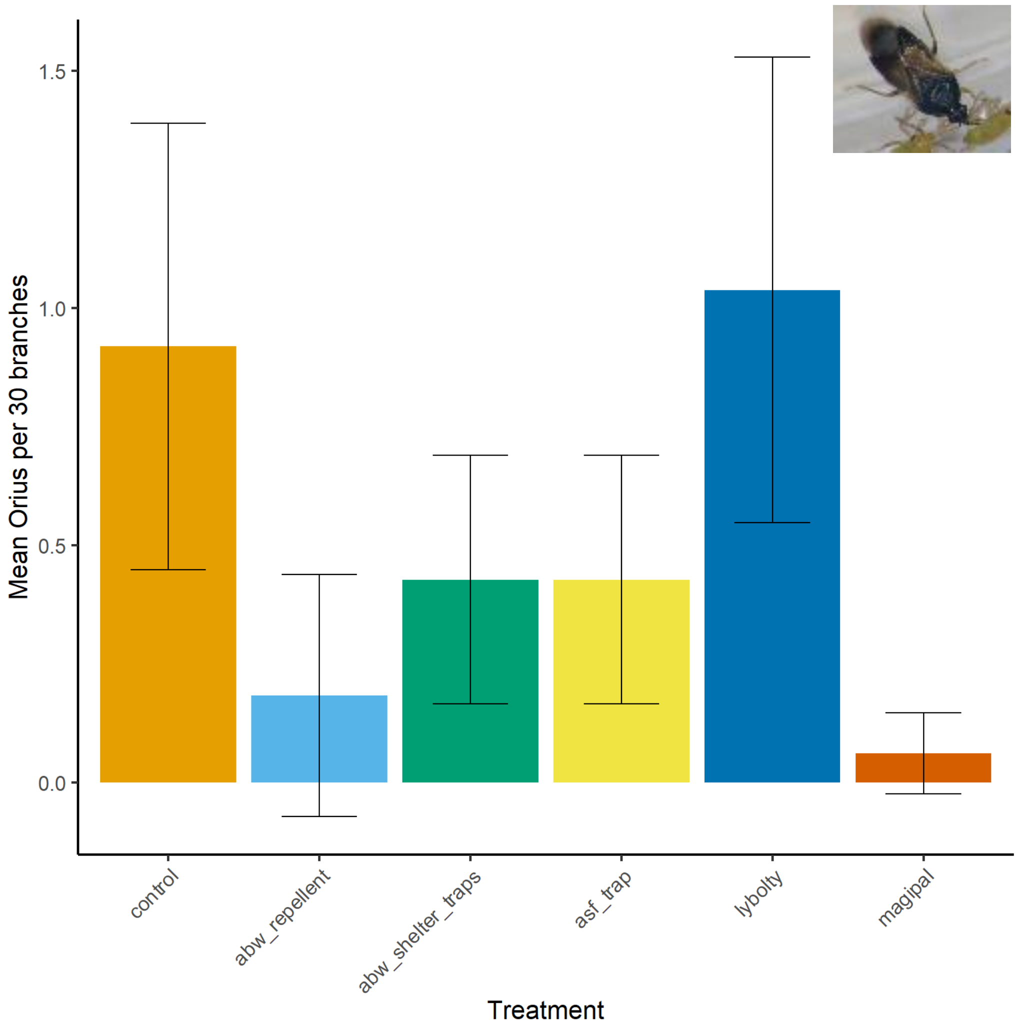


# Summary – Mid-summer assessment

| Treatment | ABW numbers | ABW damage | Capsid numbers | Capsid damage | Spider numbers | Beneficial insects |
|---|---|---|---|---|---|---|
| ASF mass-trapping | N | N | N | **[D]** | N | N |
| ABW walnut repellent | **Y - increased** | N | N | **[D]** | N | N |
| Lybolty | N | N | N | **[D – possible decrease]** | N | N |
| Magipal | N | N | N | **[D]** | N | **Y – increased** |

Y = yes (effect)
N = no (no effect)
D = depends (evidence base weak/ inconsistent)

# Harvest time: Pest and natural enemy activity



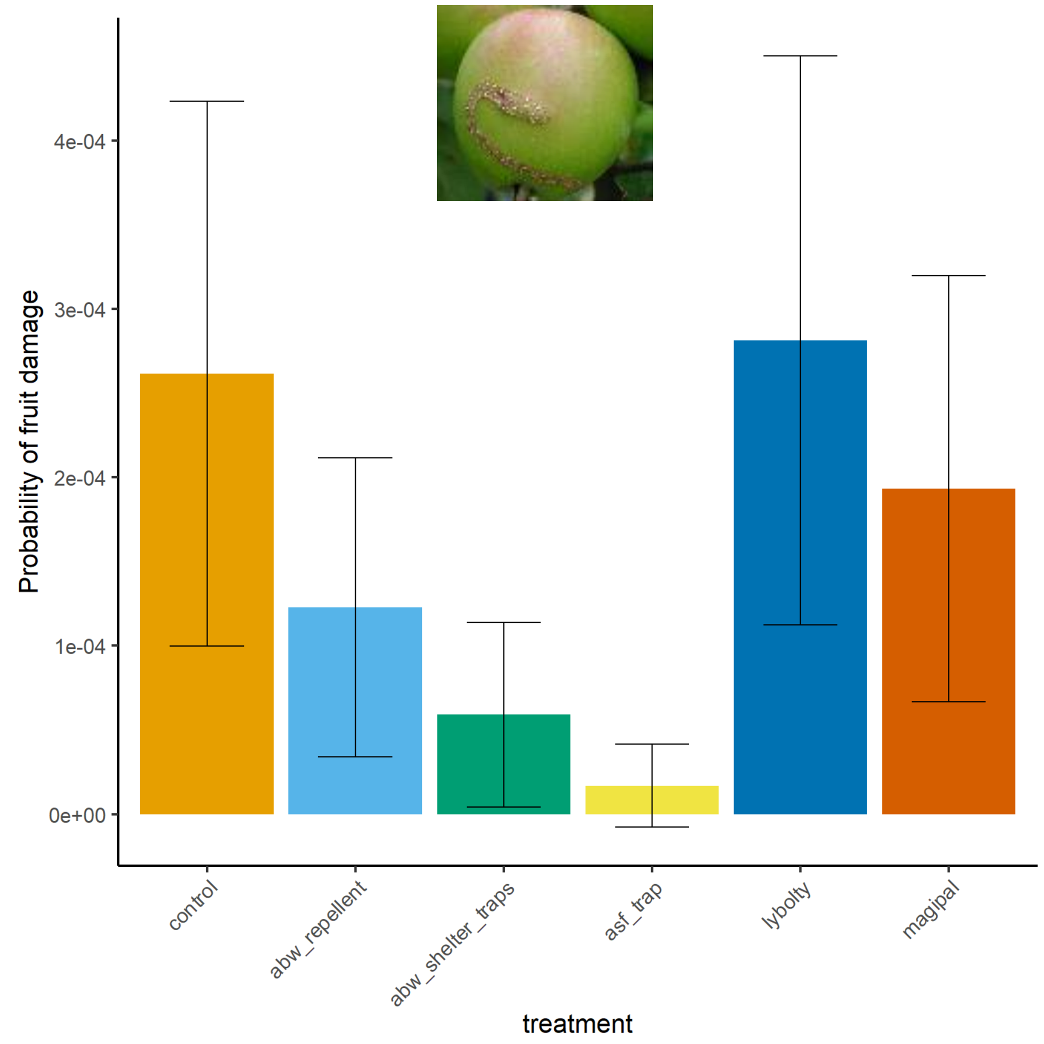

- Low pest numbers overall
- Some variability in *Orius* (predatory bug) activity between treatments.
- Fewer spiders in Lybolty treatment compared to ASF traps.
    - Should not be over-interpreted.
- Other pests/natural enemies not significant.

# Summary – pest/beneficial activity around harvest

| **Treatment** | **Capsids** | **Spiders** | **Parasitoid wasps** | **Harvestman** | **Woodlouse** | **Beneficial insects** |
|---|---|---|---|---|---|---|
| ASF mass-trapping | N | **[D – slight chance of decrease]** | N | N | N | N |
| ABW walnut repellent | N | N | N | N | N | N |
| ABW shelter traps | N | N | N | N | **[D – slight chance of increase]** | N |
| Lybolty | N | N | N | N | N | N |
| Magipal | N | N | N | N | **[D – slight chance of decrease]** | N |

Y = yes (effect)
N = no (no effect)
D = depends (evidence base weak/ inconsistent)

# Harvest time: ASF traps may reduce sawfly damage slightly

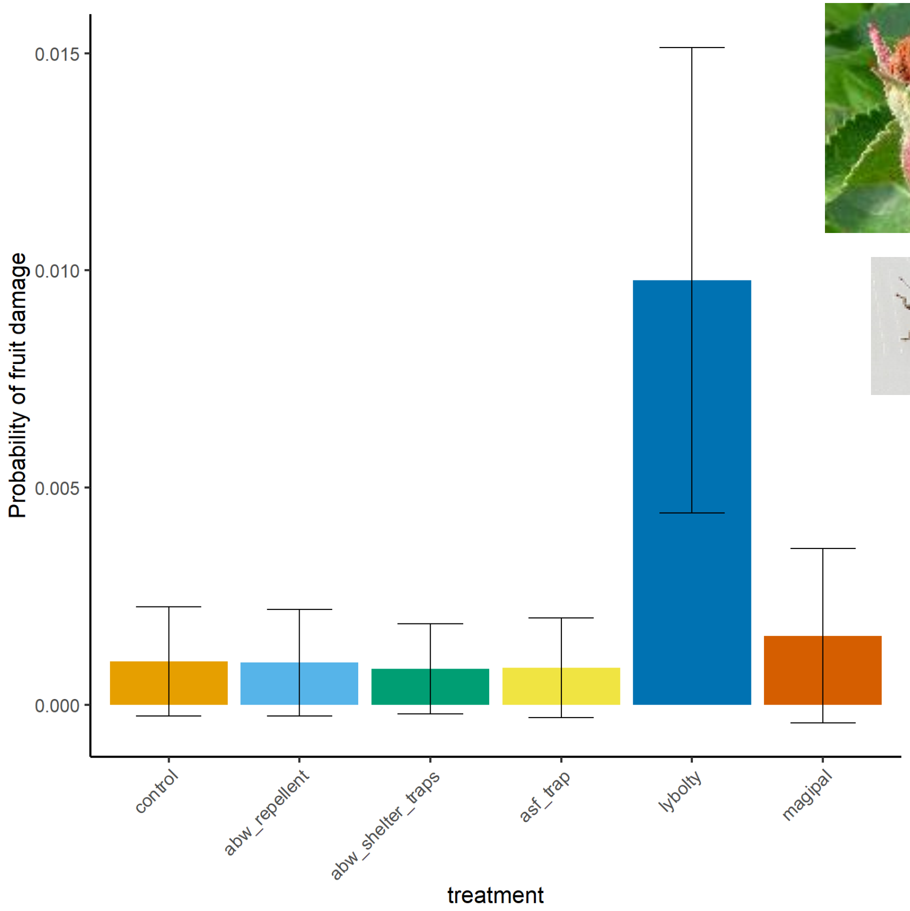



ASF damage to fruit on tree lower - $p = 0.06$

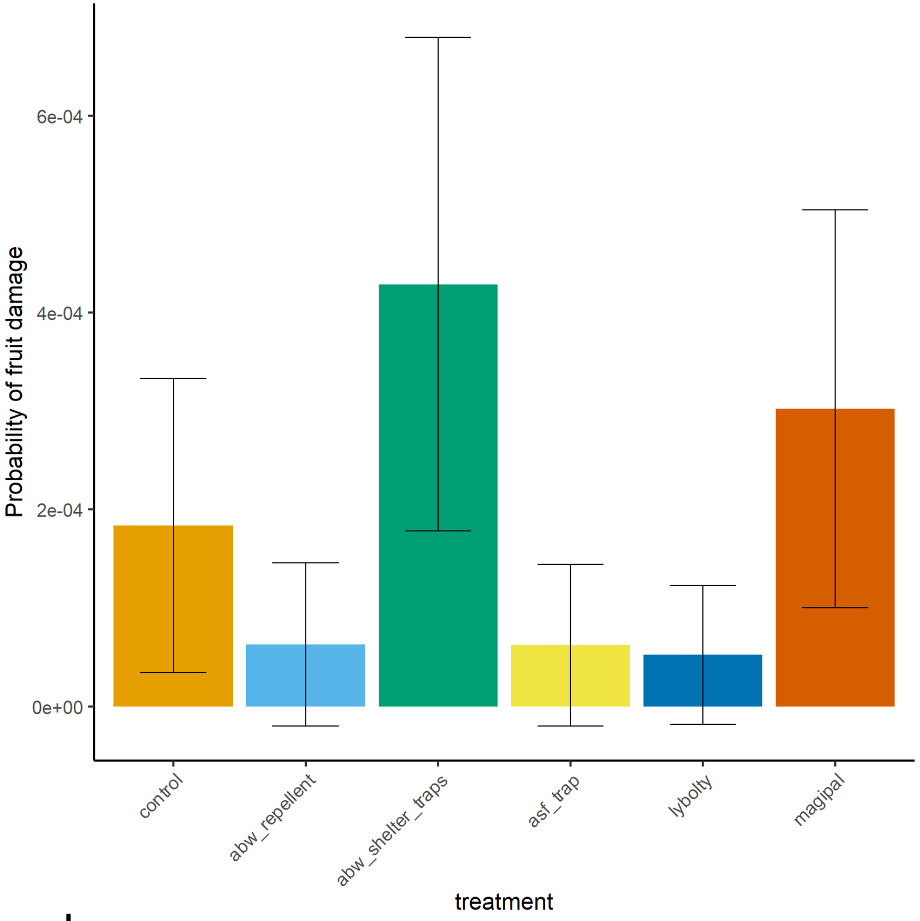
Same pattern in dropped fruit but not significant

# Harvest: Lybolty – possible increase in ABW damage (on VERY low numbers) on dropped fruit only

## Dropped fruit (on ground)

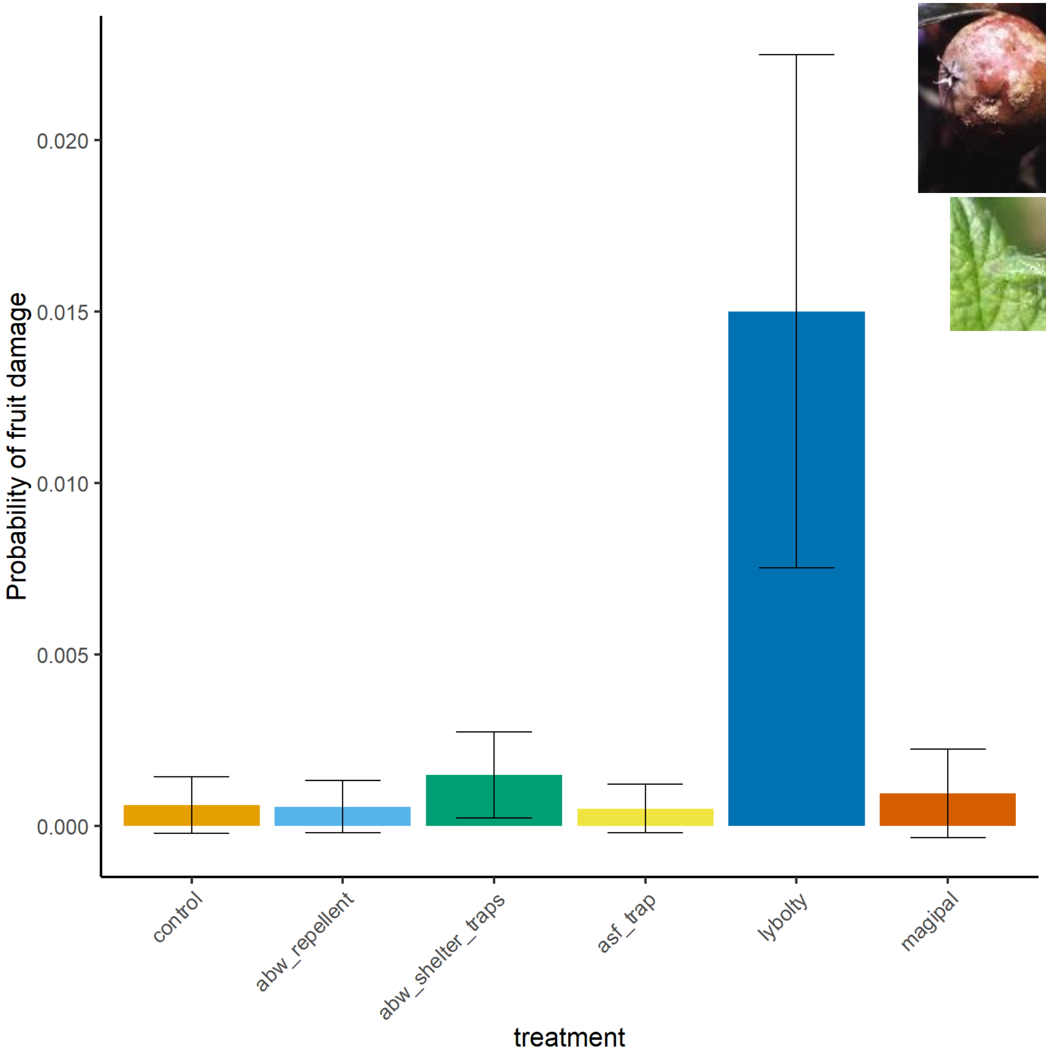


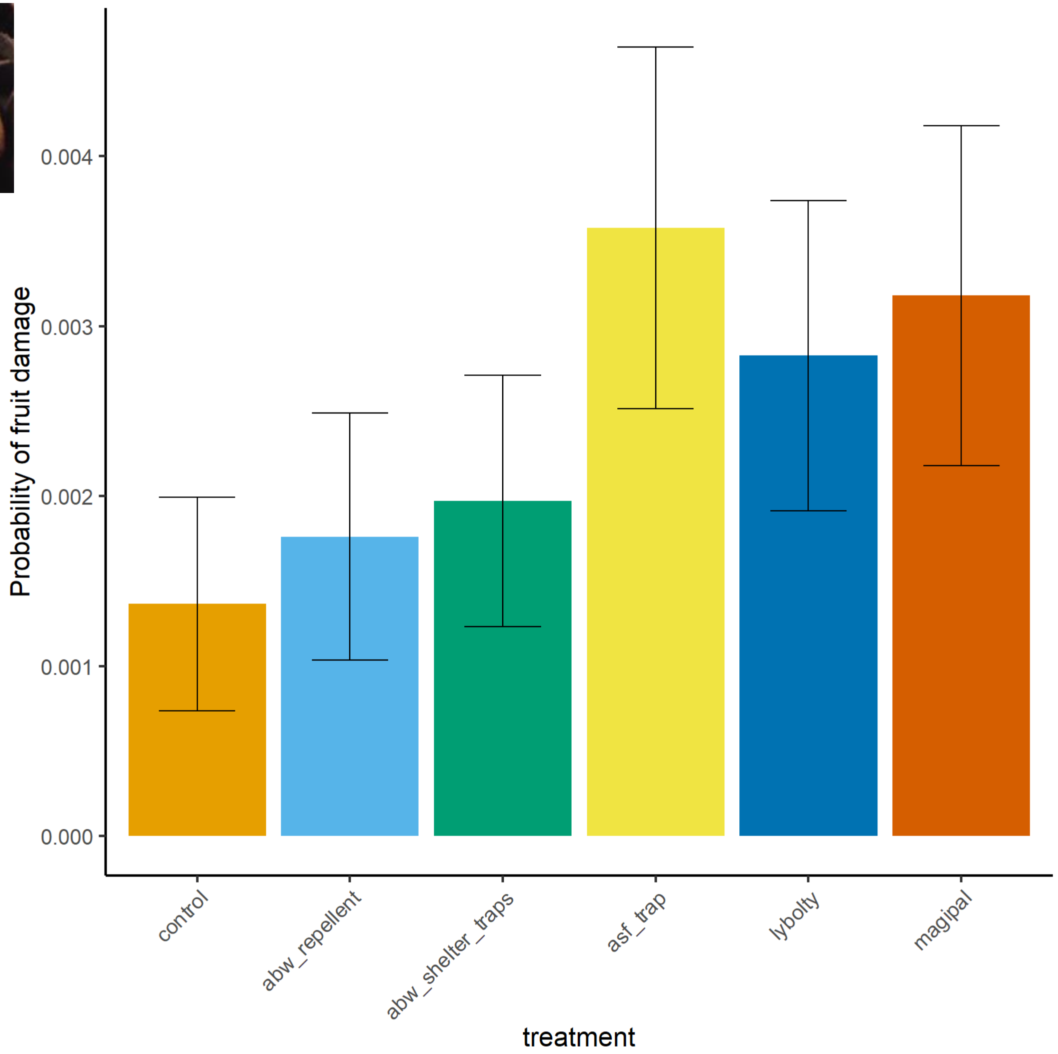

## Fruit on tree




Mechanism unclear

# Harvest: Lybolty increases capsid damage, but only on fallen apples (minority) not on tree



# Summary – fruit damage at harvest

| **Treatment** | **Capsid damage** | **ABW damage** | **Sawfly damage** | **Codling damage** | **All damage** |
|---|---|---|---|---|---|
| ASF mass-trapping | N | N | **[D - possible decrease]** | N | N |
| ABW walnut repellent | N | N | N | N | N |
| ABW shelter traps | N | N | N | N | N |
| Lybolty | **[D – possible increase]** | **[D – possible increase]** | N | N | N |
| Magipal | N | N | N | N | N |

Y = yes (effect)
N = no (no effect)
D = depends (evidence base weak/ inconsistent)

# Conclusions/recommendations – WP5 fieldwork

- Magipal: may attract beneficials but effect is weak
- Lybolty: some potential for capsid control but more trials needed
  - Examine non-target impacts
- ASF mass-trapping: worth further trials, focus on white traps
- ABW walnut repellent: more ABW – but not more damage
- ABW shelter traps: ABW use, on sites where they are present, worth further trials
  - 5mm thick tube with thin walls seems best
  - Recommend not to deploy on sites with low ABW pressure as they will catch more beneficials (spiders) than pests
  - Recommend further trials on sites with known ABW issues, with monitoring in the year following deployment

# **WP 5.** Optimising control of hard-bodied insect pests through precision monitoring, semiochemical & biological manipulation.

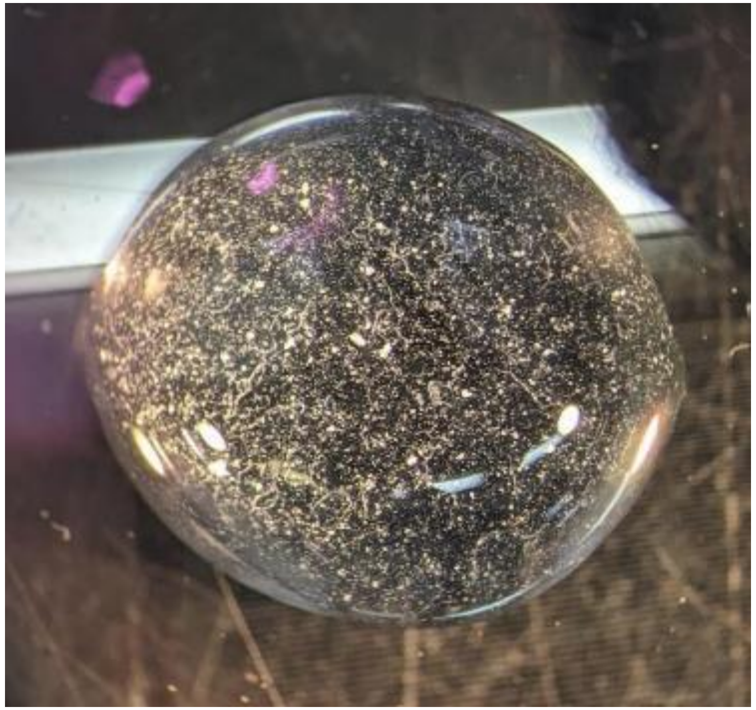
- Task 5.2 Nematode control for ASF and (in future years) codling moth

# Apple sawfly nematode trial

- Apple sawfly complete their lifecycle in soil
- Nematode treatments have been very successful on other soil invertebrates (e.g. vine weevil)
- Targeted nematode treatments on orchards based on e.g. trap data or future digital predictions?

# Apple sawfly nematode trial

- Set up 40 tall, mesh-lined pots of moist compost
- Emerged ASF larvae from ~1000 apple fruitlets
- Treated with either *Steinerema feltiae* (Exhibitline sf), *Heterorhabditis bacteriophora* (Exhibitline hb) or *Steinerma kraussi* (Nemasys L)
  - QA check that nematodes were viable and at suitable concentration
- Manual sift to retrieve larvae after 14 days
- Dissection of individuals to check for nematodes



# Nematode results

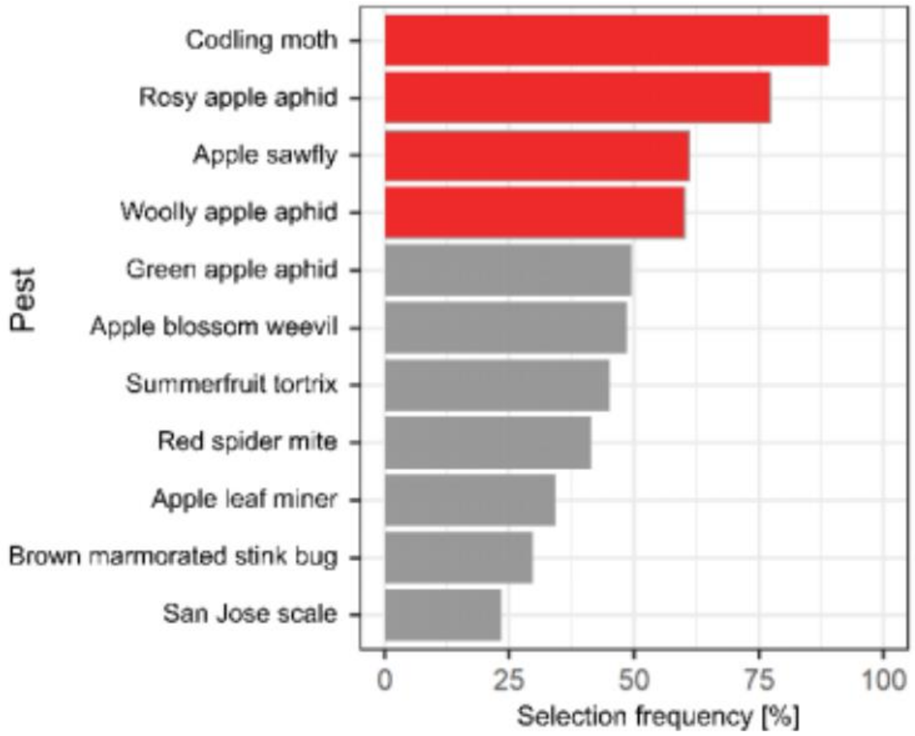
- Very high mortality in all treatments (including control)
  - Very low larval retrieval rates
  - Reason = compost unsuitable?
- Of larvae retrieved, 100% were dead
- *S. feltiae* and *S. kraussei* had both infected several larvae and emerged in large numbers

*S. kraussi*

*S. feltiae*

# **WP 6.** Evaluate future codling moth (*Cydia pomonella*) control strategies for future integrated pest management testing.

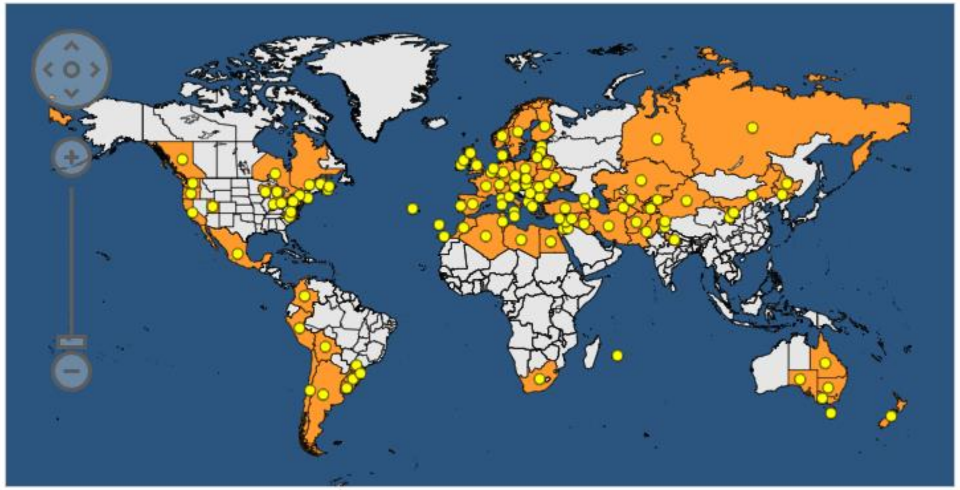
- Task 6.1. Review of the latest (10 years) findings on CM control globally. Report to the CM interest group and BAPL
- **Industry meeting:** March 2023, key UK industry players including growers, agronomists, agri-chem, producers of novel products, and equipment/technology suppliers
- phenology, IPM, pesticides, remote monitoring and smart traps, female attractants, flight (distance), climate change, pupal survival and overwintering, population modelling (e.g. RIMpro-Cydia), landscape influences and habitat manipulation, pheromone control, nematode control, granulosis virus, drone dispersal of parasitoids, SIT, and predation including birds and bats
- Follow-up meeting in March 2024



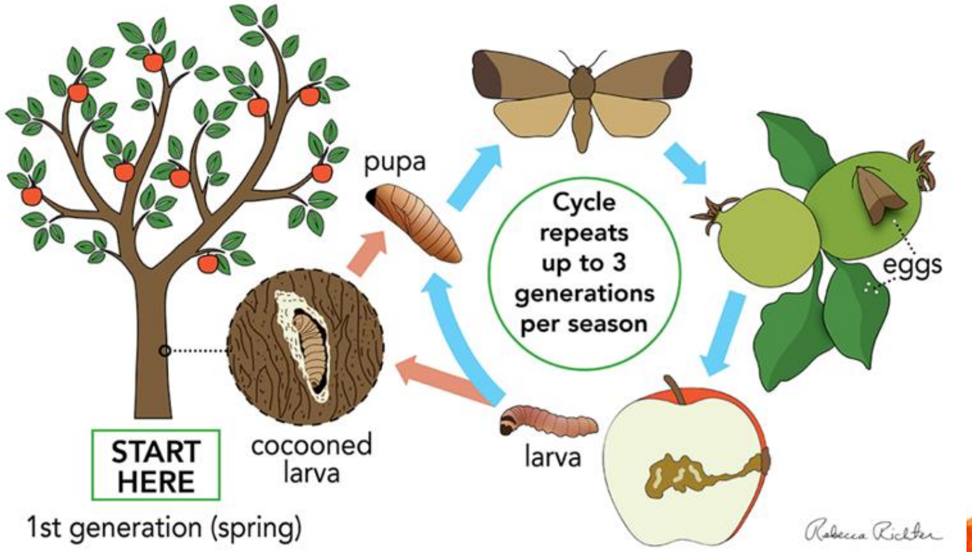

Ranking of pests occurring in organic apple orchards, seventeen European countries, EU-funded project BIOFRUITNET. Most relevant pests and diseases mentioned by more than half of the respondents in red (from Furmanczyk et al. 2022)

# Review

- Aim: Identify direction of UK CM research and control strategies that target all life stages
- Gathered and summarised published and peer-reviewed global studies on CM **~350 papers**
- Incorporates relevant papers since 2003 through a Google Scholar search
- Main conclusion of studies and a list of recommendations for CM control and future research directions for UK



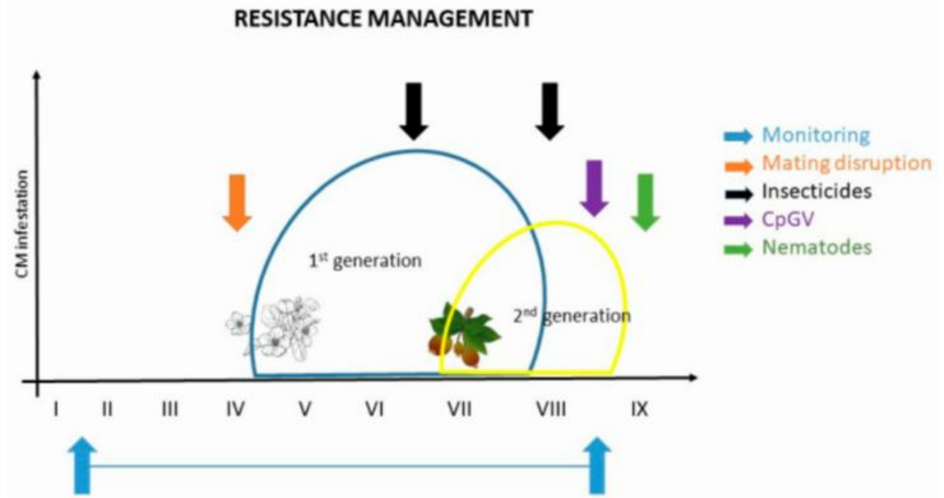
Global distribution of CM (from EPPO accessed 20 09 2023)



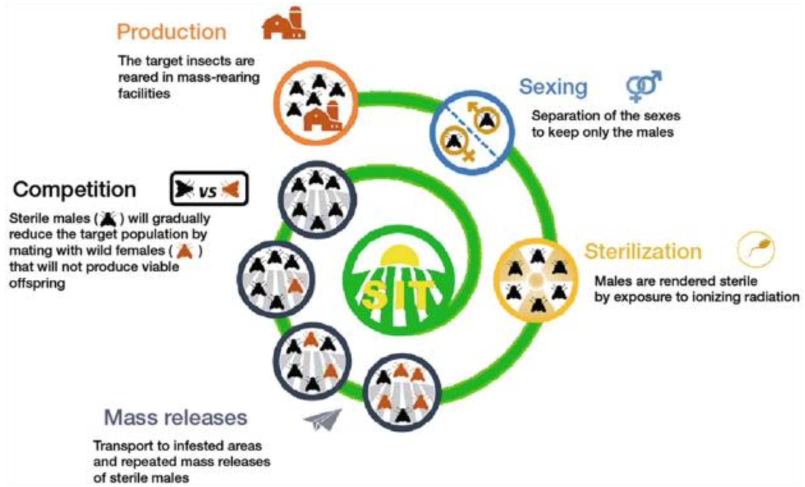

Codling moth lifecycle (from agresearch.montana.edu)

# Topics

- 2. Recent reviews – 8, from 2011 – 2023
- 3. Integrated Pest Management (IPM)
- 4. Area-wide management
  - CAMP: 5-year (Codling Moth Areawide Management Program) in the USA
  - OKSIR: Okanagan-Kootenay Sterile Insect Release programme, southern British Columbia, Canada, over 20 years
  - Uruguay: increased from 300 ha to over 3563 ha, over 85% of production and 360 growers, and 70 scouts
- 4.1. Sterile Insect Technique (SIT)




Example of CM resistance management - combination of different measures (from Balaško et al. 2020; modified by Martina Kadoic´ Balaško)




SIT from production to release for insect pest control (from Oliva et al. 2022)

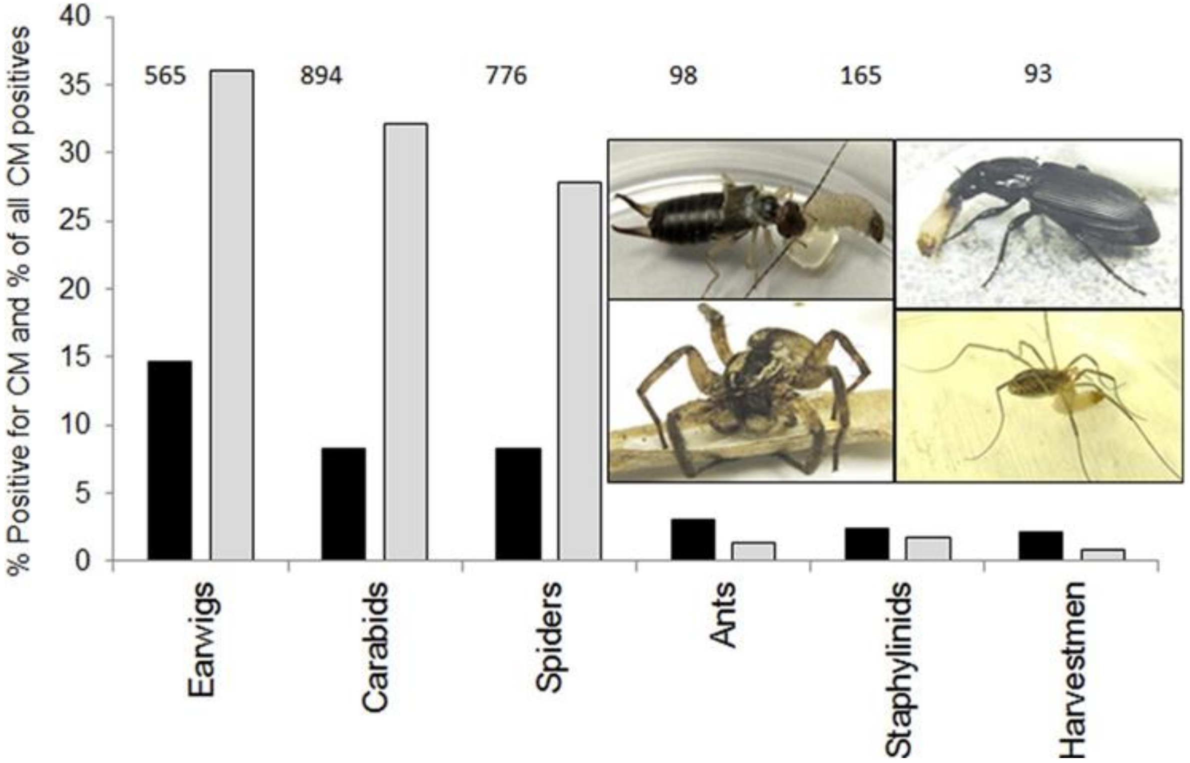
# Topics

- 5. Semiochemicals
    - 5.1. Mating disruption (MD)
    - 5.2. Female attractants
        - 5.2.1. Identifying and testing VOCs for female CM attraction
        - 5.2.2. Combining attractants with other IPM control strategies
        - 5.2.3. Improving population monitoring lures
        - 5.2.4. Repellents
    - 5.3. Trapping
- 5.4. Thresholds and Models
- 5.6. Larvae and Pupae
- 5.7. Climate change
- 11. Insecticides
    - 11.1. Treatment with drones

# Topics

- 6. Biological control
  - 6.1. Generalist Predators
  - 6.2. Parasitoids
  - 6.3. Entomopathogenic nematodes
  - 6.4. Vertebrate predators
  - 6.5. Virus

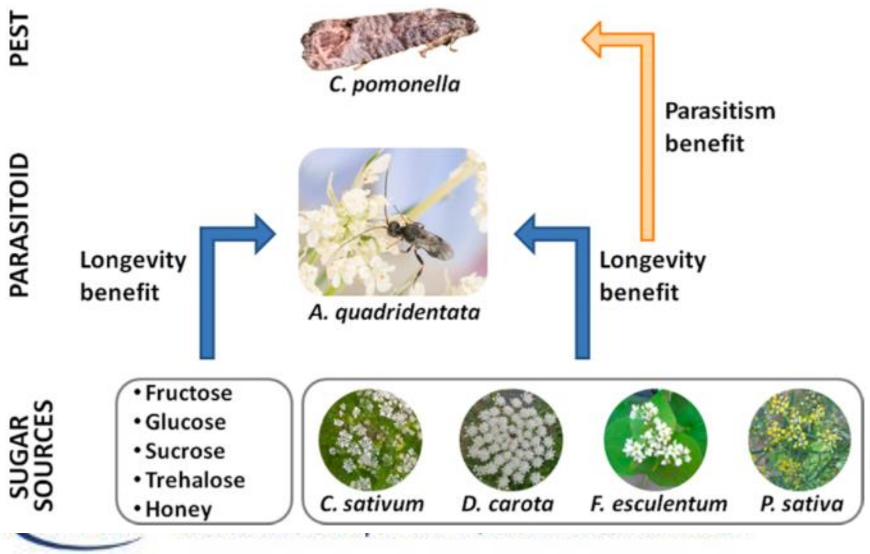
Applying nematodes to the base of a tree (from Adolphi and Oeser 2023)




Percentage of predators testing positive for feeding on CM (from Unruh et al. 2016)

# Topics

- 7. Habitat management
- 8. Exclusion netting
- 9. Cultivars
- 10. Post harvest
    - Clean orchards
    - Detection




Relationship between floral resources, parasitism and CM (from Mátray and Herz 2022)


Exclusion systems: (A) Alt'Carpo incomplete exclusion system (Sévérac and Romet, 2008); (B) incomplete exclusion dual system (adapted from Charlot et al., 2014); (C) and (D) complete exclusion system (photos: G. Chouinard) (From Chouinard et al. 2016 and 2017)

# Conclusions

- CM increasingly difficult to control in the UK
  - withdrawal of many insecticides
  - and changes in climate
- Control works best on an area-wide basis
- Range of measures that target each life stage
- UK tree fruit industry needs a more long-term, strategic and coordinated approach
- CM populations are reduced over many years and maintained at very low levels
- Current UK control strategies rely primarily on targeting egg hatch

# Conclusions - Area-wide management

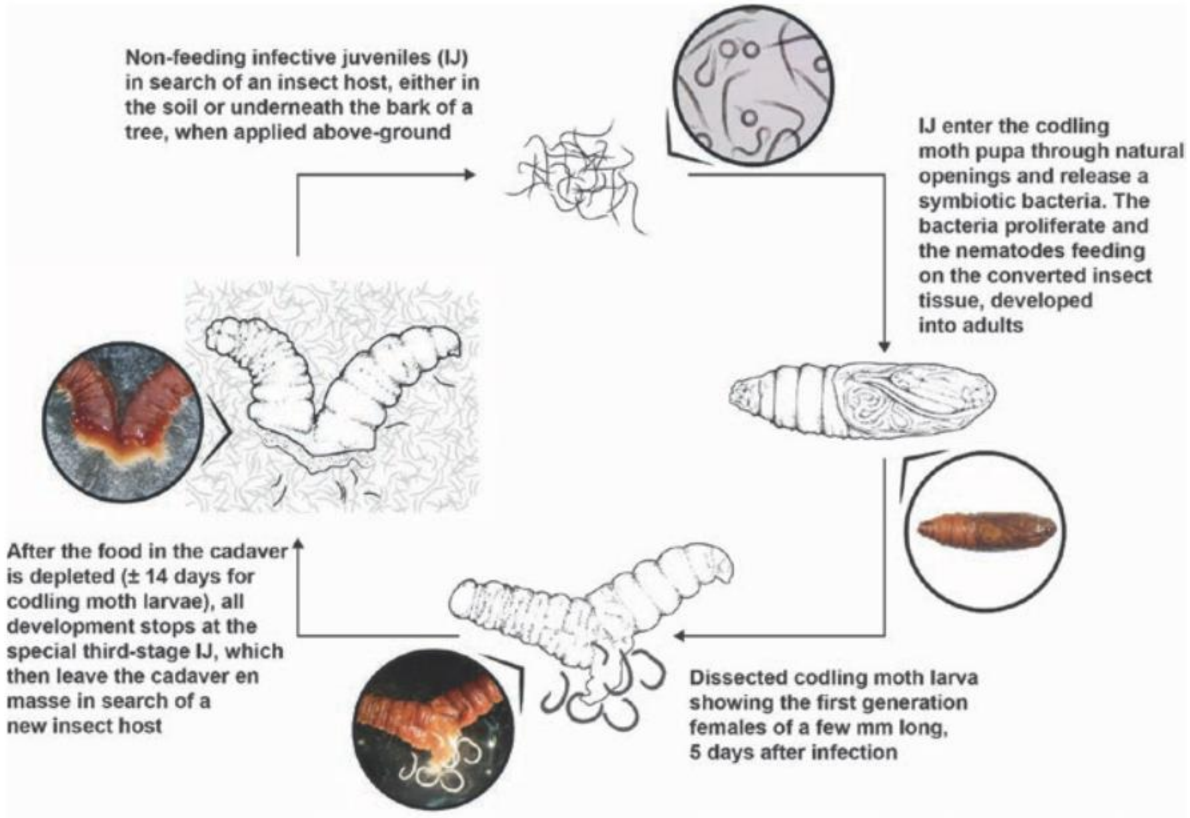
- Minimum of 16 ha with 200 m buffer zones
- MD and SIT
- Preventative rather than reactive
- New approvals for MD should include other leaf rolling tortricids
- Local SIT CM would be advantageous
- Remote CM monitoring to identify ‘hot-spots’
- Suggested monitoring trap densities are 2.5 traps per ha
- Monitor female CM flight
- CM DA-Combo or 4-K lure
- Trap-out female CM in the future?

# Conclusions - Area-wide management

- Action thresholds change in MD strategies; should be investigated in UK orchards
- Continuous flight through the season = Granulovirus
- Destroy larvae hatching between main mating peaks
- Tree management to enable spray penetration
- Non-insecticidal control approaches - boost natural enemies
- Incorporation of tailored wildflower mixes into the alleyway
- Bring predators and parasitoids closer to CM eggs, larvae and pupae
- Control other pests e.g. leaf-rollers spider mites and aphids
- Hedgerows for nesting birds which predate larvae; also spiders, ground beetles and parasitoids

# Conclusions

- Nematode sprays in late summer/autumn
- Target the bark and litter dwelling cocoon stage - further reducing next years population
- Wider landscape?
  - Are there orchards adjacent?
  - How are these treated?
  - Working with neighbours?
  - Rogue or garden trees within 200 m?
  - Treated or grubbed?



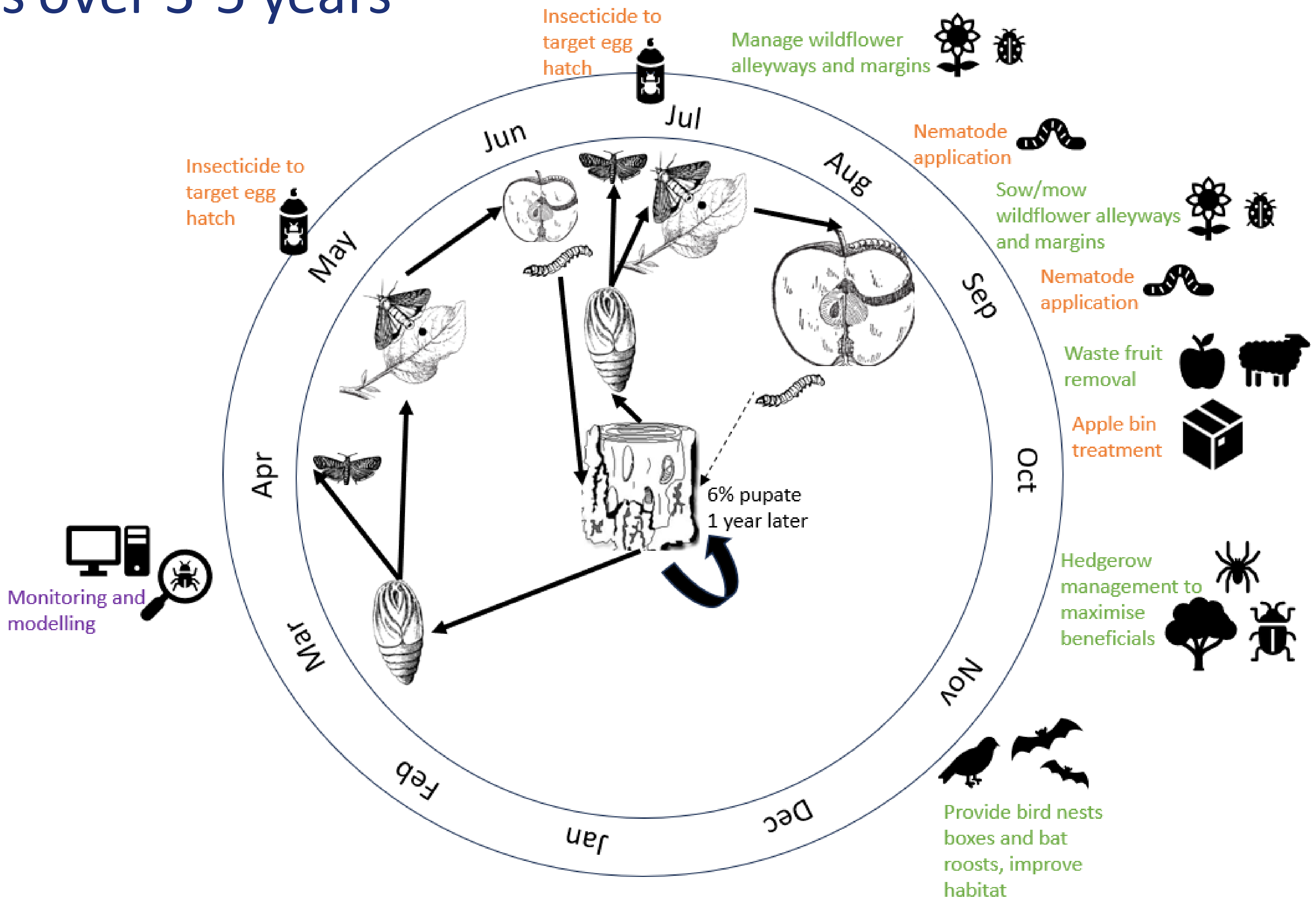

Simplified illustration of the life cycle of entomopathogenic nematodes (Photos: Antoinette Malan, University of Stellenbosch, Stellenbosch, South Africa; Illustration: Hannes Visagie, North-West University, South Africa) (from Malan and Ferreira 2017)

# Conclusions

- Lack of CM control post-harvest
- Wooden bins source of CM cocoons; nematode treated
- Waste fruit removed and destroyed

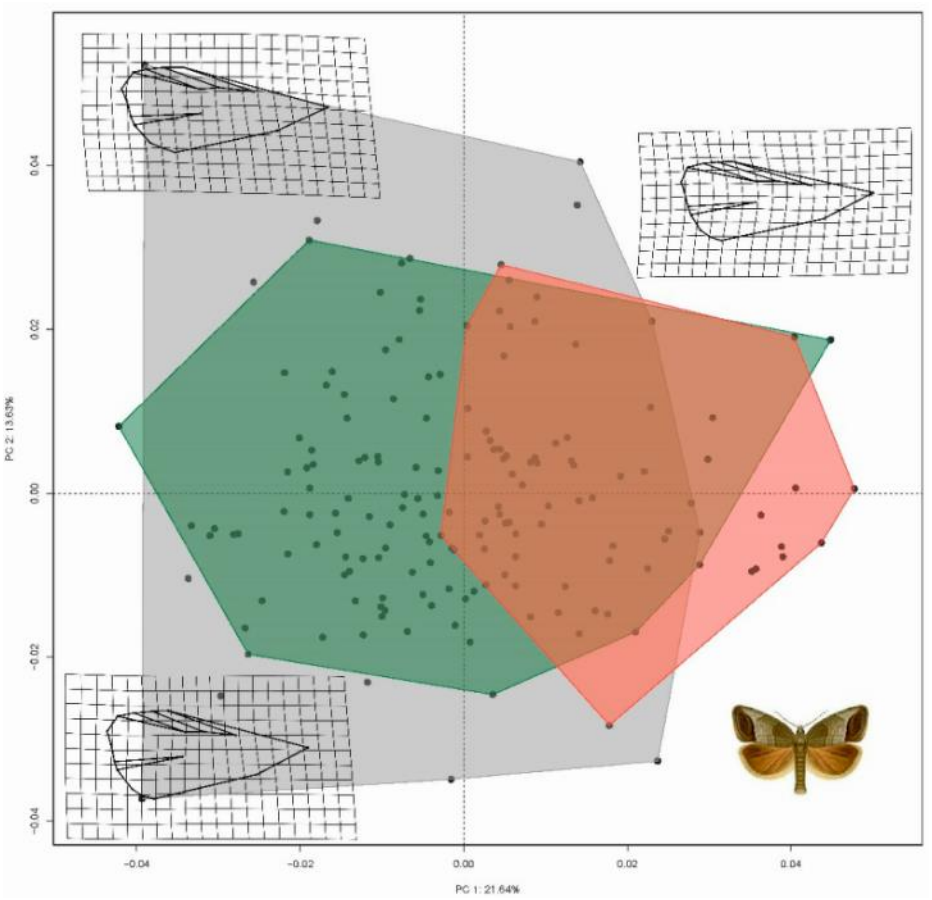
- Nesting, roosting and habitat for CM vertebrate predators
- Passerines (blue tits and great tits)
- Encouraging bats for evening predation of CM adults
- Interaction with MD
- Recommended density for bat boxes and/or bird nests is ~10/ha for each type

# Combined strategies over multiple seasons to bring down CM numbers over 3-5 years



# Future recommendations

- Test standard practice CM management over a fully integrated IPM strategy using all available tools
- Full economic costing with CM population and fruit damage monitored for at least 4 years
- Targeted research areas;
  - 1 full and 1 partial generation or 2 full generations
  - Does second generation contributes to the following year's first generation
  - Genetic structure of CM populations in different regions; flight capacity



Principal component analysis of average forewing shape among different populations from integrated orchard, organic orchard, and laboratory populations of CM: red, integrated orchard; green, organic orchard; grey, laboratory population (from Balaško et al. 2022)

# Future recommendations

- Biological Control
  - Better understanding of CM predator food web - molecular technique
  - Identification of key CM egg, larval and pupal parasitoids and parasitism rate

  - Improving habitat for bird and bat species
  - Explore if the interaction between MD and bat predation
  - Economic impact of wildflower alleyways on CM control

  - Granulovirus applied more frequently between main peaks of CM treated with Coragen

  - Releases of parasitoids *Mastrus ridens* pupal stage, and *Trichogramma* egg stage

  - Efficacy of autumn applications of *Steinernema feltiae* with and without wetters

# Future recommendations

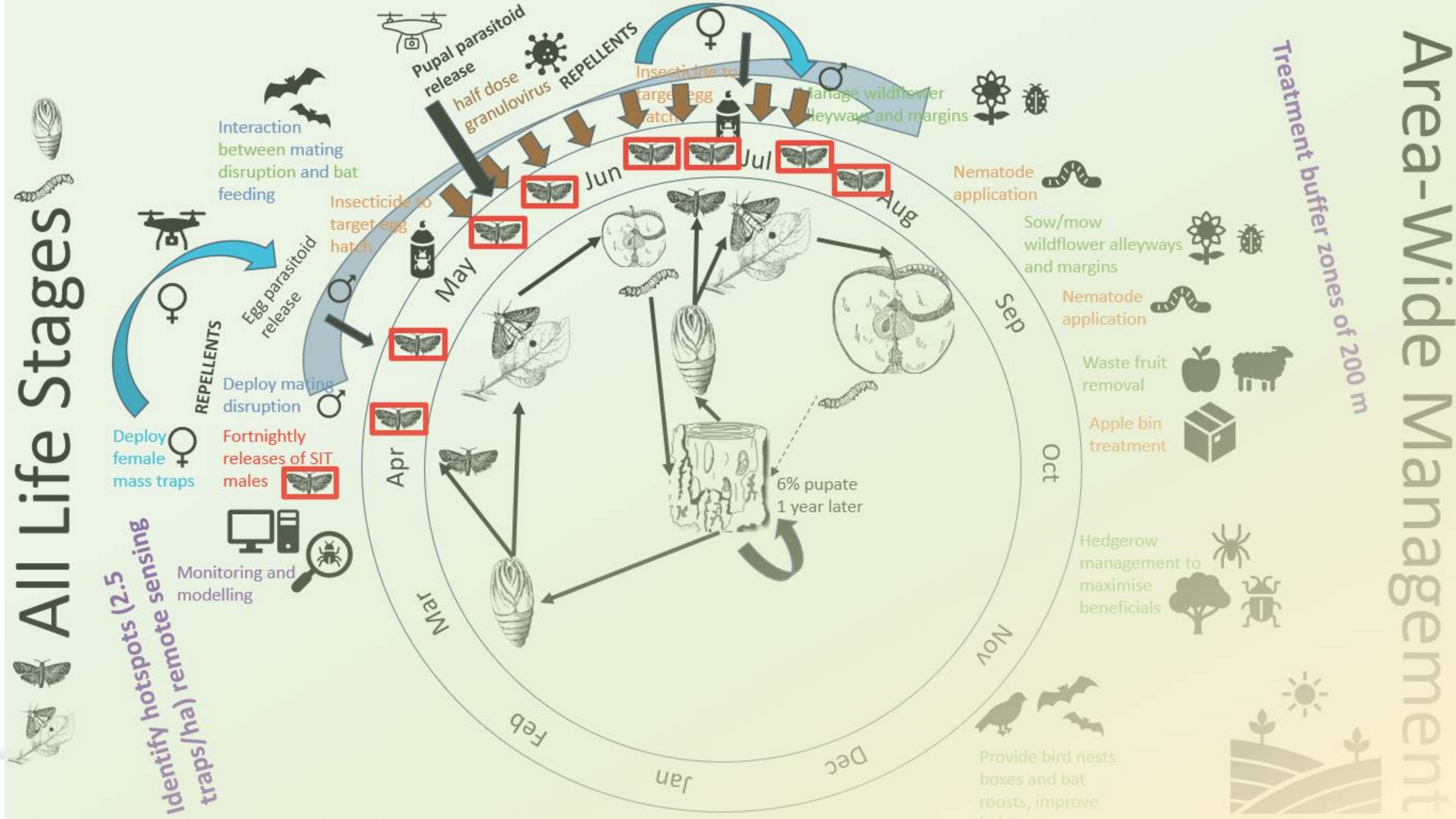
- Physical controls
  - Compare nets and side effects
  - Economic impact including hail events could be included
- Monitoring
  - Demonstration of integrated monitoring system to identify hot-spots
  - Assess reliability of latest female or dual sex attractants for capturing females
  - Compare and assess automated traps against manual counts in UK orchards, including software services, population models, and reliability of smart traps
  - Investigate potential for developing a system to distinguish male and female CM

# Future recommendations

- Semiochemical control
  - Exploit existing female attractants to mass trap female CM
  - Incorporating other VOCs
    - including (E)-β-ocimene, DMNT, (Z)-3-hexenyl acetate, nonanal, β-caryophyllene, germacrene D, (E,E)-α-farnesene, and methyl salicylate
  - Determine UK action thresholds for CM insecticide sprays under MD
  - Investigate repellent spray formulations at peak egg laying
    - benzaldehyde and butyl acetate
  - Develop microencapsulated repellent
    - 1,8-cineole (eucalyptol) and α-terpinyl acetate
  - Combine pear ester as feeding attractant with granulovirus
  - Combine female attractants and repellents in a ‘push-pull’ approach
  - Addition of UV-A lights as mass-trapping

# Future recommendations

- SIT
  - Can the UK produce its own SIT manufacturing and deployment programme?
  - What are the consequences for F1 generation?
  - Compare sterile male vs sterile male+female vs standard control for CM in a 4-year treatment programme (~6% of cocoons may diapause for 2 years)
- Models
  - Identify which predictive models are most accurate for the UK climate
- Thresholds
  - Identify Action Thresholds for female monitoring traps; first and second generations
- Others to follow;
  - Larvae and pupae, Climate change, Drone release of SIT and Natural Enemies
  - Insecticides, Cultivars, Post-harvest


All Life Stages
Area-Wide Management
Treatment buffer zones of 200 m
Identify hotspots (2.5 traps/ha) remote sensing
Interaction between mating disruption and bat feeding
Pupal parasitoid release
half dose granulovirus
REPELLENTS
Insecticide to target egg hatch
Manage wildflower alleyways and margins
Egg parasitoid release
REPELLENTS
Deploy mating disruption
Deploy female mass traps
Fortnightly releases of SIT males
Monitoring and modelling
Nematode application
Sow/mow wildflower alleyways and margins
Nematode application
Waste fruit removal
Apple bin treatment
Hedgerow management to maximise beneficials
Provide bird nests boxes and bat roosts, improve
6% pupate 1 year later
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec