BBSRC-FAPESP JOINT PUMP–PRIMING AWARDS for AMR and INSECT PEST RESISTANCE IN AGRICULTURE: *Understanding and managing resistance, including novel methods, for pathogen and pest control.*

PARTNERSHIP BUILDING WORKSHOP

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SMART CROP PROTECTION

Challenge 3: Monitor and forecast the spread of pests, weeds and diseases in real time.

Challenge 4: Combine genetic, chemical, ecological & agronomic strategies for smart crop protection.

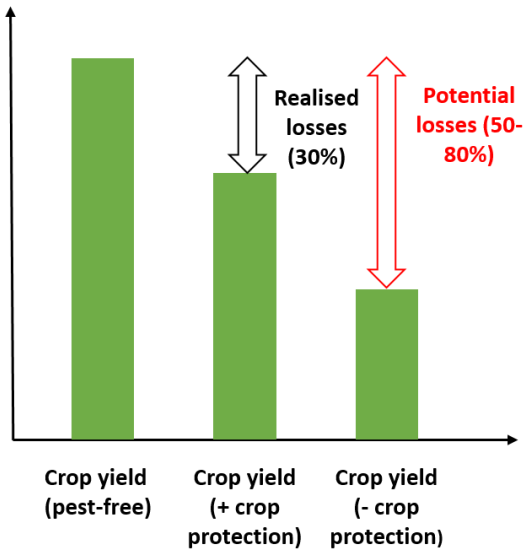
A gene to landscape approach to deliver more targeted and sustainable control of insect pests, weeds and diseases in agroecosystems.

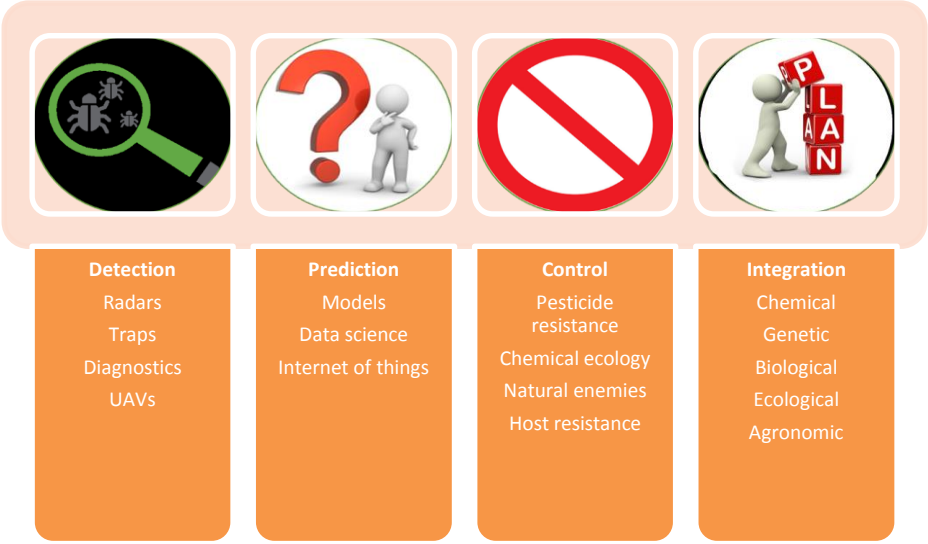
BBSRC bioscience for the future | Newton Fund | FAPESP | AMR Tackling Antimicrobial Resistance

Seven principles of Smart Crop Protection:

1. **Pesticide-dominated** crop protection strategies are **not sustainable**
2. Next-generation crop protection needs **novel targets** and **new interventions**
3. Pests, weeds and pathogens will adapt to all interventions. Crop protection needs to be **'evolution-smart'**
4. A **systems-approach** integrating genetic, chemical, biological, ecological and agronomic interventions is required
5. More **targeted delivery** of crop protection using new technologies to provide a step-change in monitoring and surveillance
6. Improved monitoring and surveillance will deliver **evidence-based crop protection**
7. Crop protection needs to **minimise trade-offs** between production, sustainability and environmental objectives

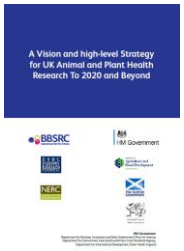
ROTHAMSTED RESEARCH





The Challenge: pesticide resistance, regulation, lack of innovation, new threats, environmental costs.

***The Vision*:** more targeted crop protection, less pesticide use and less resistance, novel control options, integrated strategies, reduced environmental trade-offs.



"The UK needs to develop a more integrated, whole-system approach to animal and plant health science"

SMART CROP PROTECTION Institute Strategic Programme (ISP):

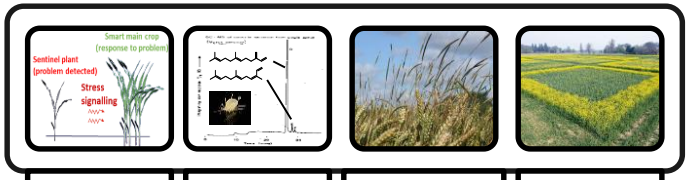
A gene-to-landscape approach to deliver more targeted and sustainable control of insect pests, weeds and diseases in agroecosystems

WP1: Smart surveillance of insects, pathogens & weeds

Genomic surveillance for in-field pest detection and status	Studies of pest dispersal, migration, population genetics and population dynamics	Next-generation technology for pest monitoring – radar entomology, spore traps, UAVs.	Predictive models of pest invasion and dispersal. Design and implementation of monitoring networks

GENE TO LANDSCAPE

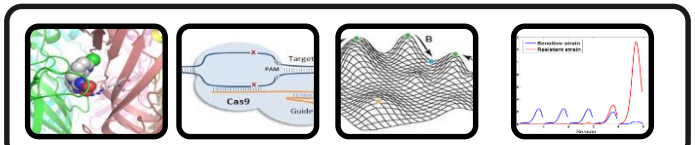
WP3: Next-generation crop protection



Underpinning chemical ecology for testing sentinel and smart plant concepts	Explore new strategies for overcoming resistance to chemical signals	Characterise new rhizosphere signalling for weed control	Field testing of chemical ecology-based interventions

GENE TO LANDSCAPE

WP2: Pesticide resistance evolution & management



Resistance mechanisms, pesticide mode of action and diagnostics	CRISPR/Cas9 gene editing for genotype / phenotype studies	Understanding evolution of pesticide resistance	Integrative models for resistance management

GENOTYPE PHENOTYPE SELECTION MANAGEMENT

SCP addresses priority areas of Newton Fund call:

- host/pest/pathogen interactions
- underpinning mechanisms
- epidemiology
- disease management and control

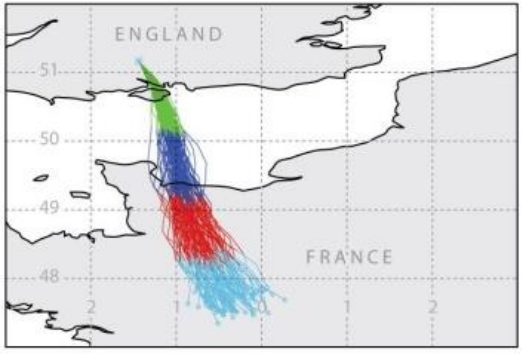
Next-generation Vertical Looking Radar

CHALLENGE

Detect small insect pests (aphids, beetles, midges) using radar technology. Derive parameters including wing beat frequency, cross-sectional area, body mass and flight speed for species discrimination.

APPROACH

A new vertical looking radar prototype based on millimetre wave band (mVLR) that would continuously sample insects up to a height of 200m. Supplement mVLR with ground-based insect sensors and NC suction trap data to validate observed migrations at altitude.



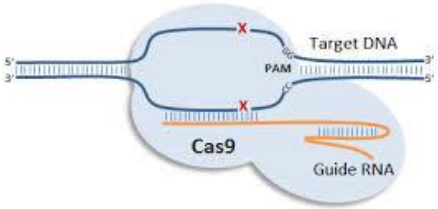
OUTCOME

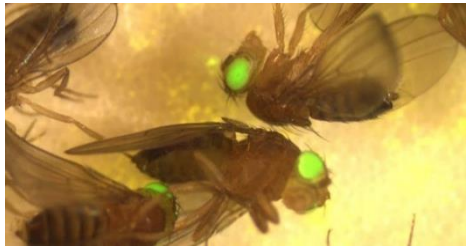
Early warning of pest invasion (i.e. diamondback moth). New insight on migrations of beetle pests. A new generation of models for forecasting

Gene editing for genotype/phenotype studies in pesticide resistance

CHALLENGE

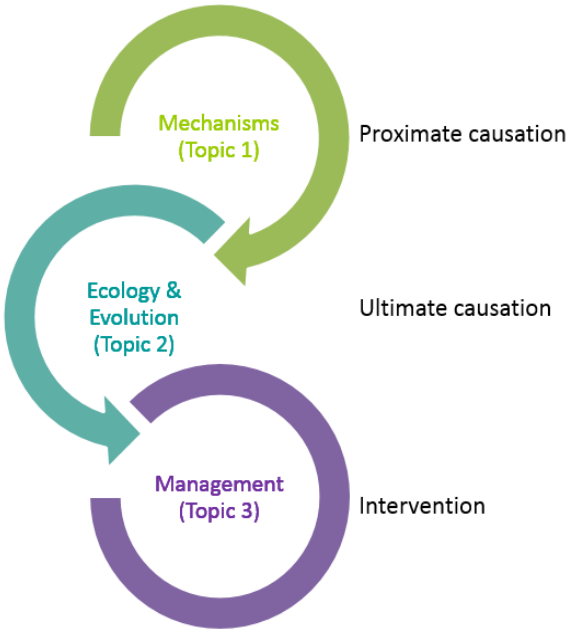
To use CRISPR/Cas9 gene editing to integrate putative and confirmed resistance mutations into pest insects (Plutella xylostella and white flies).





APPROACH

Directly link genotype to phenotype for functional validation of resistance mutations in edited insects. Assess the contribution of resistance genotype to phenotype and quantify interactions between resistance mechanisms and mutations.



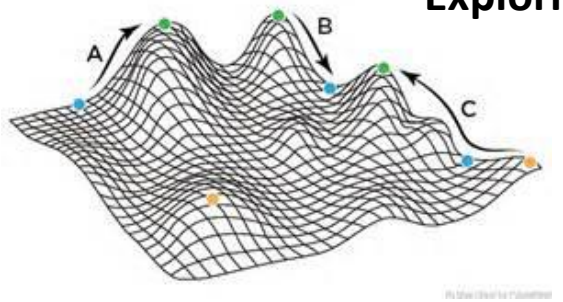
OUTCOME

Field simulator and modelling-based studies to determine how combinations of resistance mechanisms are impacted by contrasting selection regimes.

Exploring the fitness landscape for pesticide resistance

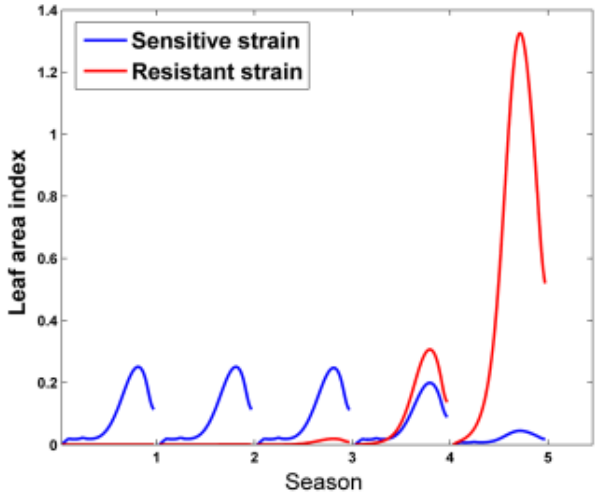
CHALLENGE

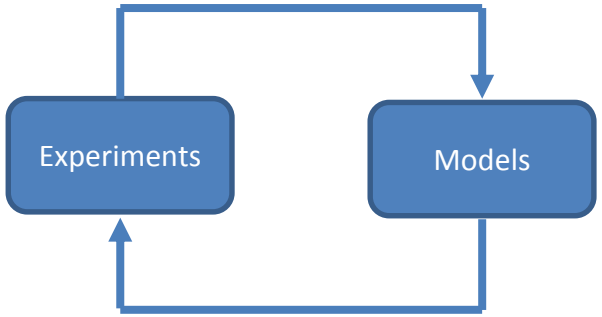
The repeatability of evolutionary outcomes is a fundamental question in evolutionary biology. Does a given selection history (pesticide regime) always result in predictable outcomes? To answer this question we must investigate the fitness landscape for evolution of resistance.



APPROACH

Integration of empirical and theoretical approaches, and access to management histories for characterised resistance lines, enables us to conduct a series of 'replay the tape' experiments to unravel the predictability of pesticide resistance evolution.





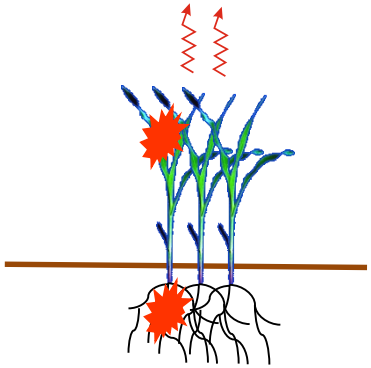
OUTCOME

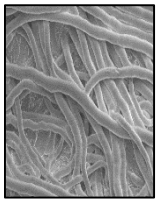
More informed resistance management strategies with predictable outcomes. Potential to design novel strategies to disrupt resistance evolution.

Exploiting plant-pest signalling for novel crop protection

CHALLENGE

To deliver small lipophilic molecule (SLM) semiochemical-based crop protection by exploiting plant genetic diversity and using genetic-engineering of crop and companion plants.



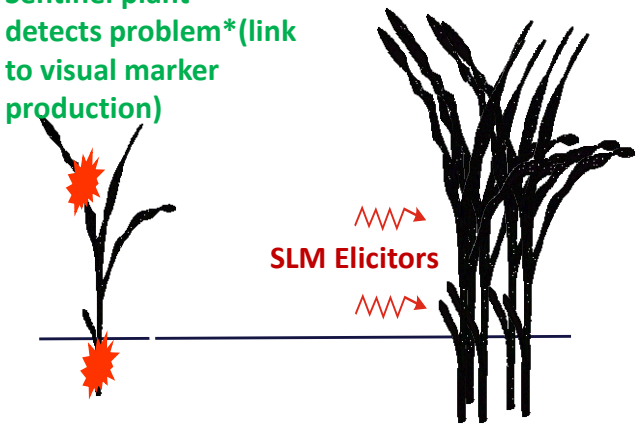


APPROACH

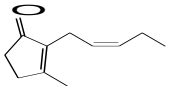
Building on our track record on elucidating induction of plant defence signalling in crops plants upon biotic stress, we aim to develop **sentinel and smart plants** that detect and respond rapidly to pests. When the (cryptic) pest is detected, sentinel plants will signal to sensors (physical or biosensors). Smart plants will either be selected or engineered to deliver induced secondary metabolite-based resistance traits (direct or indirect defence)

Smart main crop**
- responds to problem

Sentinel plant – detects problem*(link to visual marker production)

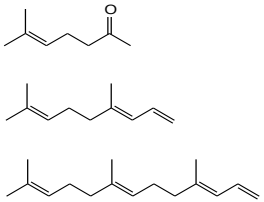


Lipid-derived elicitors



- Newly-identified egg mass compounds

SLM signals

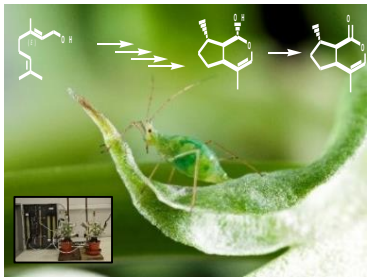


OUTCOME

The delivery of novel crop protection via seed and the enhancement of conservation biocontrol.

CHALLENGE

To explore the evolutionary processes by which pest resistance to pheromones and other semiochemicals develops



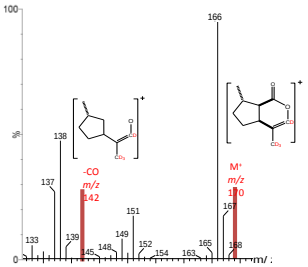
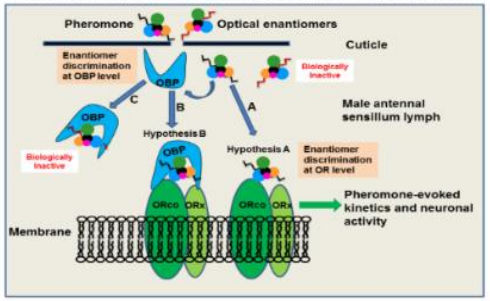
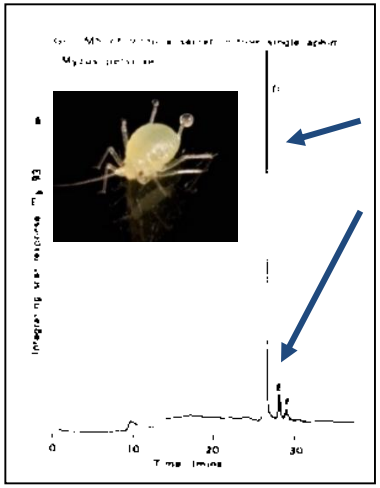
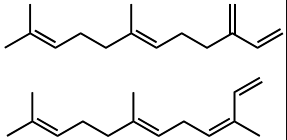


Figure 3. Experimental Model to Elucidate Molecular Mechanisms of Olfaction







APPROACH

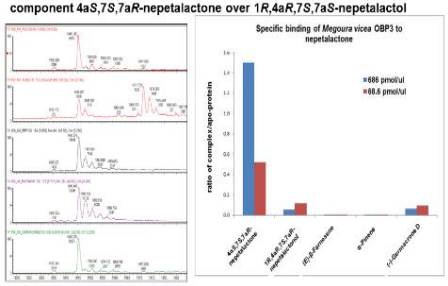
*Elucidate the process by which pheromone **biosynthesis** in pests can change by selection….*

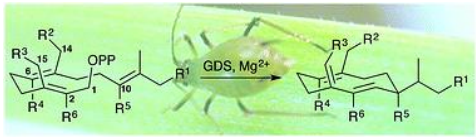
*Elucidate the process of **molecular recognition** in insect olfaction*

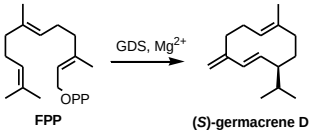
*Explore the chemical space of semiochemical biosynthesis enzymes using **synthetic biology** for acceptance of 'unnatural' substrates….*

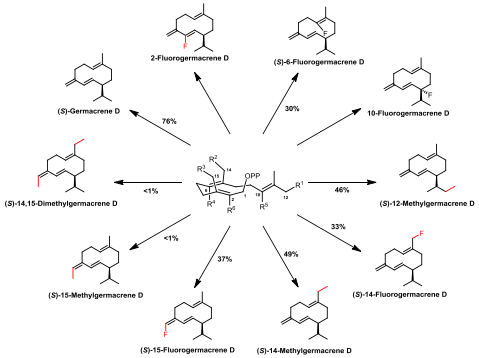
High throughput ESI-MS

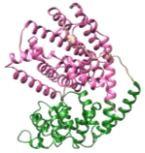
Figure 5. Use of high through put ESI-MS to measure OBP/ligand specific binding demonstrating aphid OBP3 differentially bind to sex pheromone component 4a*S*,7*S*,7a*R*-nepetalactone over 1*R*,4a*R*,7*S*,7a*S*-nepetalactol

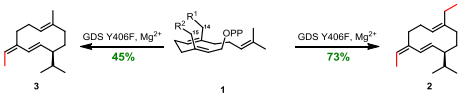












OUTCOME

Elucidation of the evolutionary processes by which insects switch to new chemical signals, and development of rational approaches to the identification of newly evolved signals.

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Issues/needs/challenges in relation to this call:

1. **Pesticide-dominated** crop protection strategies are **not sustainable**
2. Next-generation crop protection needs **novel targets** and **new interventions**
3. Pests, weeds and pathogens will adapt to all interventions. Crop protection needs to be **'evolution-smart'**
4. A **systems-approach** integrating genetic, chemical, biological, ecological and agronomic interventions is required
5. More **targeted delivery** of crop protection using new technologies to provide a step-change in monitoring and surveillance
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ROTHAMSTED RESEARCH