Agroecology and IPM:

How applied research addresses pesticide reduction policies, food security and biodiversity

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A LEAF Linking Environment And Farming INNOVATION CENTRE

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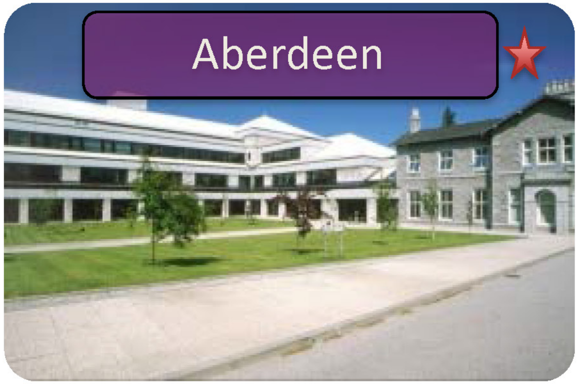
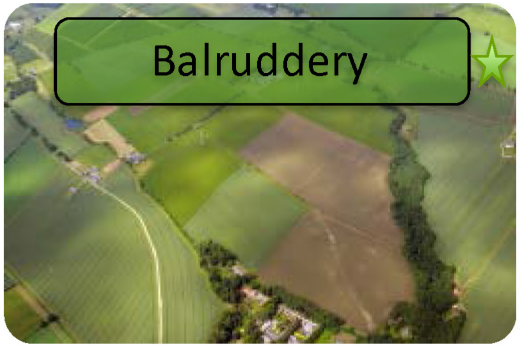
James Hutton Institute, Scotland



Laboratories and growth rooms

Laboratories, glasshouses and 97ha arable land



170ha arable farm - site of Centre for Sustainable Cropping

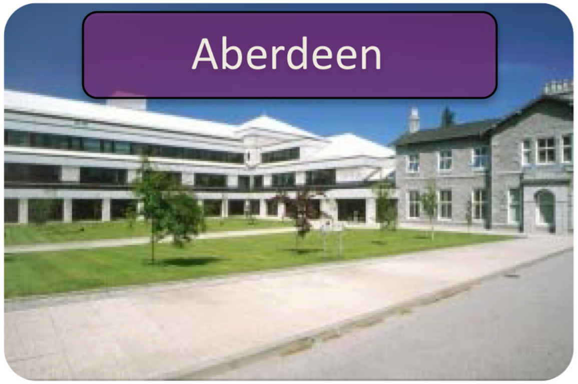
Linking Environment And Farming

350ha rotational and permanent grassland, moor and woodland

865ha rotational grassland, permanent pasture, heather moor and peat

James Hutton Institute, Scotland

Aberdeen



Laboratories and growth rooms

Dundee

Laboratories, glasshouses and 97ha arable land

Balruddery

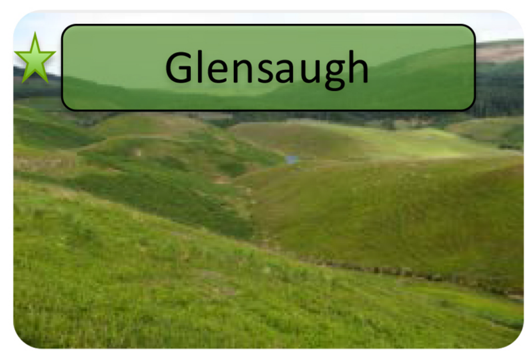
170ha arable farm - site of Centre for Sustainable Cropping

LEAF Linking Environment And Farming

Hartwood

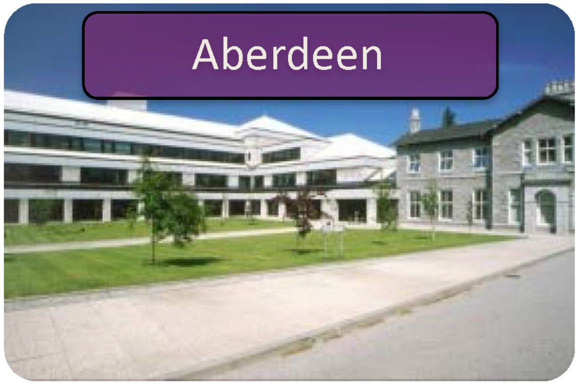
350ha rotational and permanent grassland, moor and woodland

Glensaugh



865ha rotational grassland, permanent pasture, heather moor and peat

James Hutton Institute, Scotland



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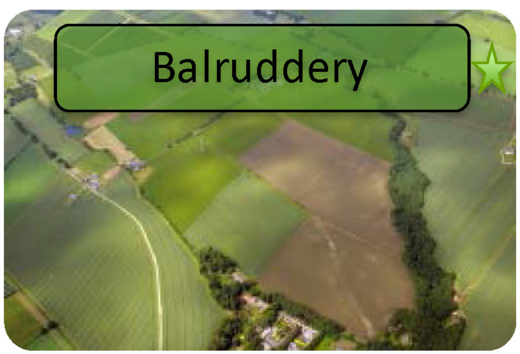

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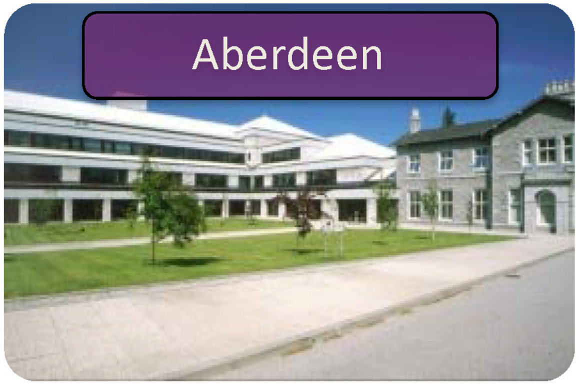

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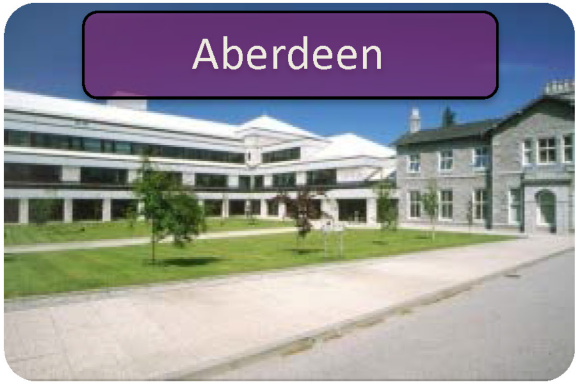

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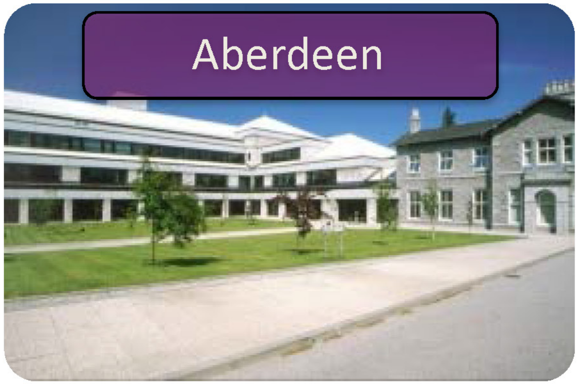

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Basic and applied research:

IPM, sustainable farming, crop breeding+ genetics, food, drink + health, modelling+ statistics, policy

≈ 600 staff (450 scientists) + >130 PhDs

Main crops: potato, cereals, soft fruit

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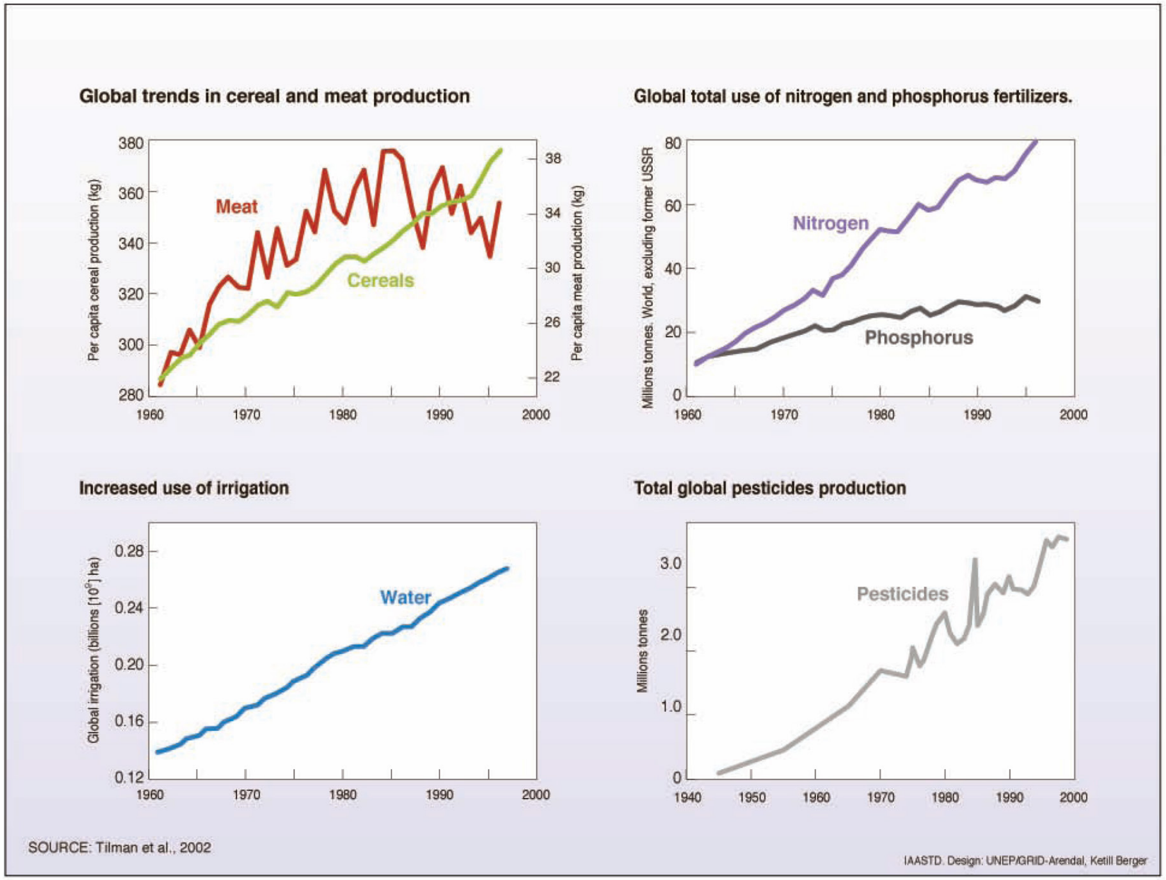
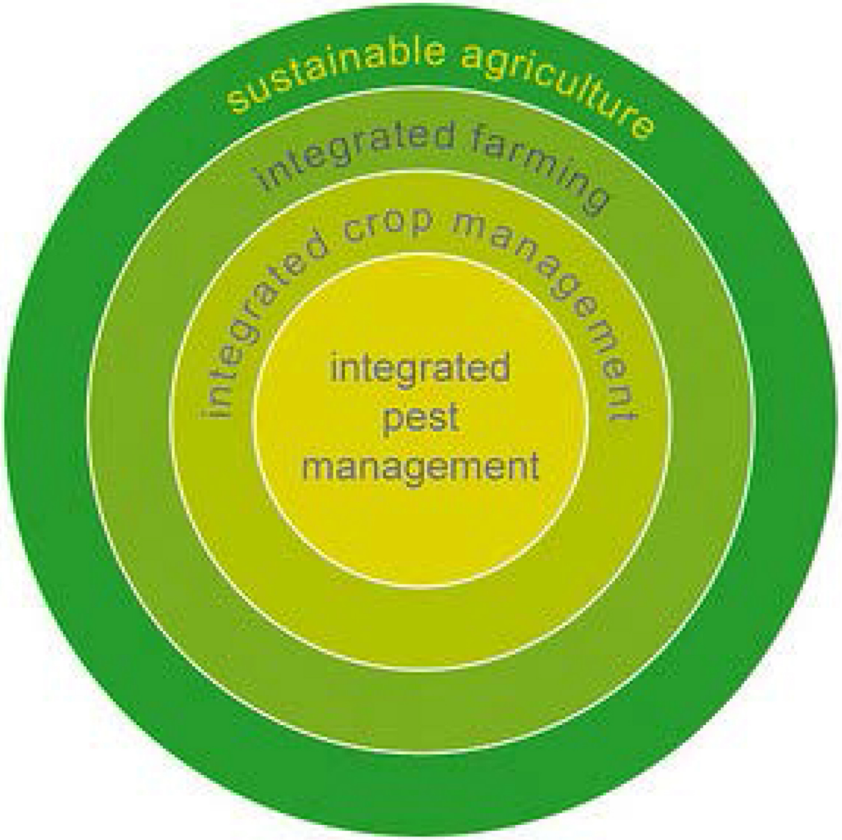
Rapidly increasing inputs: Global pesticides



IPM is central to sustainable farming and pesticide reductions (EU)



Pesticide use in the EU

- EU is the **world's largest producer, user and exporter** of pesticides. **$10.42 billion = a third of the global market (Eurostat 2007).**
- **Crop losses due to pests and diseases: 25 – 40+%, the same over last 40 yrs (globally).**
- **60+% of active insecticidal chemicals lost**, leading to fewer (c40 ai’s) allowed pesticide products in the EU and
- **More resistant pests** (>500 insect pest spp + 30+ weed spp; many with multiple resistance).
- **Risk of reducing farm profits by c 35%** if EU continues to remove available products (AIC, 2014).
- **Further limits on the use of remaining pesticides** due to additional legislation (91/414/EEC, Maximum Residue Limits legislation, Sustainable Use and Water Framework Directives).

Key ecosystem services (ES) for IPM

- **Biocontrol** (balanced food webs to suppress pests)
- **Genetic resources** (crop + companion plants, R genes, biopesticides)
- **Refugia** (weeds, crops, margins: Habitats to sustain ES providers)
- **Pollination** (ensure fertility of plant populations)
- **Soil nutrient cycling** (soil formation and health)
- **Water supply + regulation** (irrigation to reduce abiotic stress)
- **Climate regulation** (global and local)
- **Disturbance regulation** (landscape engineering/management)

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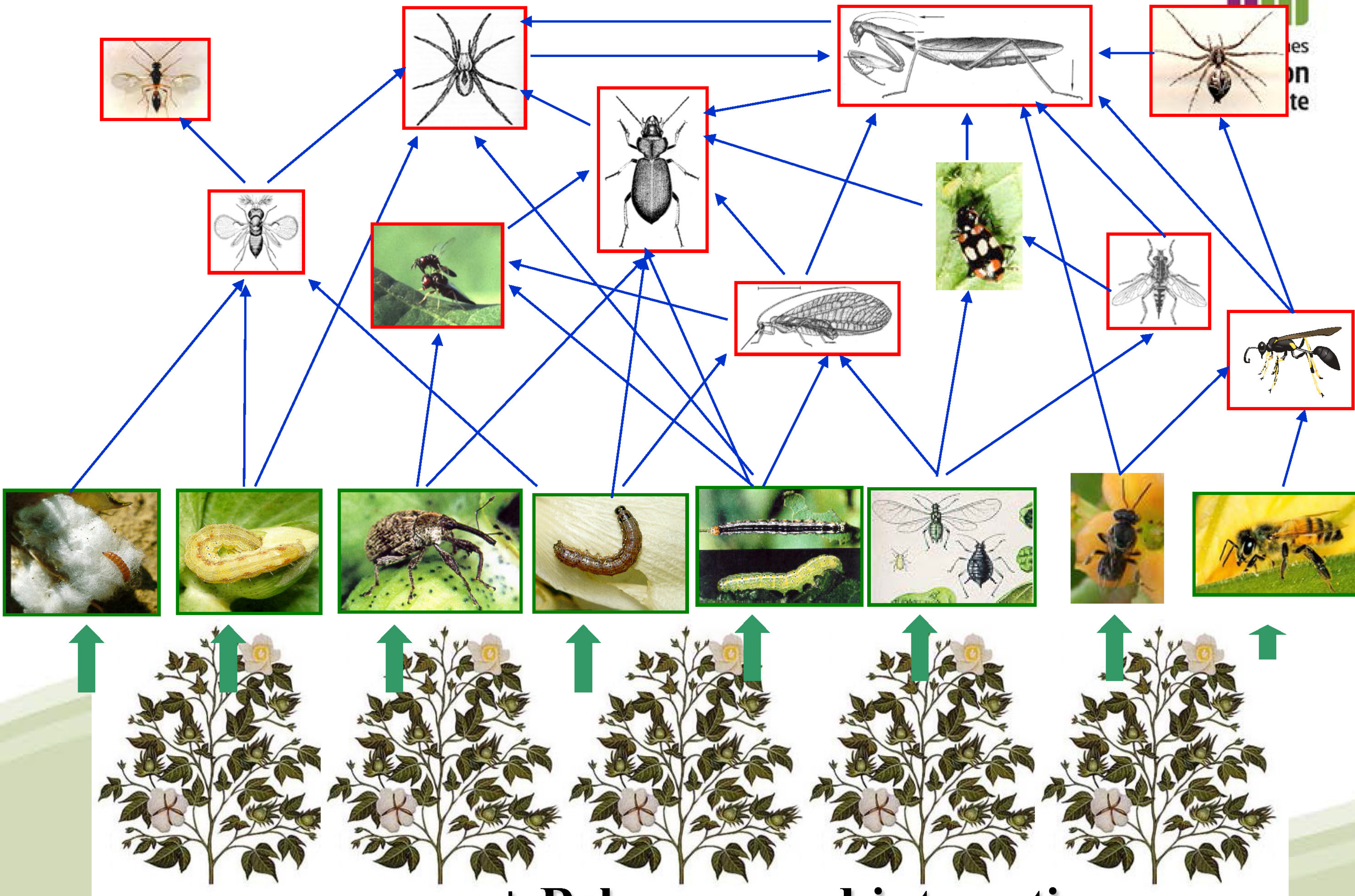
Food webs in IPM – complex ecology



+ Below ground interactions

Choosing IPM tools for the toolbox:

Crop and region specific options

IPM tools: Pros and Cons

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Technology	Example –ve impacts	Example + ve impacts
Synthetic pesticides (soft/non-persistent)	Non target impacts, resistance, 2ndary pests, food residues 1:200,000 success	Fast and effective, narrow-broad spectrum
Biopesticides + plant bio-actives	Non target impacts Some are slow acting	Repellents/deterrents prevent pest feeding.
Pheromones	Blend and release rates need to be precise	Species-specific monitoring and control
Biocontrol agents	Too late/slow, unless managed well	Complements R cvs, if developed in parallel 1:10 success
Resistant cvs (conventional + GM)	Virulent pest biotypes selected. Long term strategy (10 + yrs)	Can complement biocontrol, reduce pesticide use, if developed in parallel
'Ecological engineering' of fields/landscapes Adapted from RS 'Reaping The Benefits' Report 2009	Loss of productive land. Spatio-temporal complexity, scaling effects, regional differences.	Can complement R cvs biocontrol + pollination

Birch, Begg, Squire, (2011). J Expt Bot 62(10): 3251-3261

How collaboration helps (my IPM 'cookbook')

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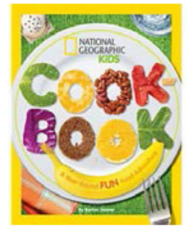


- Start with a **simple recipe**: target **single key pest** in crop system.
- **Understand pest's biology, ecology, behaviour** (basic research = IPM's foundation) .
- **Multi-disciplinary research** e.g. entomology, plant breeding, chemical ecology
- **Team up with industry** for practical IPM tools .

....**scientists *love* complexity and 'further research'...*but* farmers don't!**

- **Team up with regional IPM experts** - variability in cropping systems, climate, pest adaptations, social + economic factors.
- **Add more 'flavours': multiple IPM tools** give durability + robustness (**aphids)**.
- **Success builds success** – later on **target the regional pest complex (EU PURE).**
- **Dynamic IPM problems;** new pest threats, climate change, pesticide withdrawals,

  bees/pesticides, consumers/residues, cost:benefit v current practice, **(core research**).

EU funded IPM projects + networks involving JHI

Overview of the PURE project

Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management

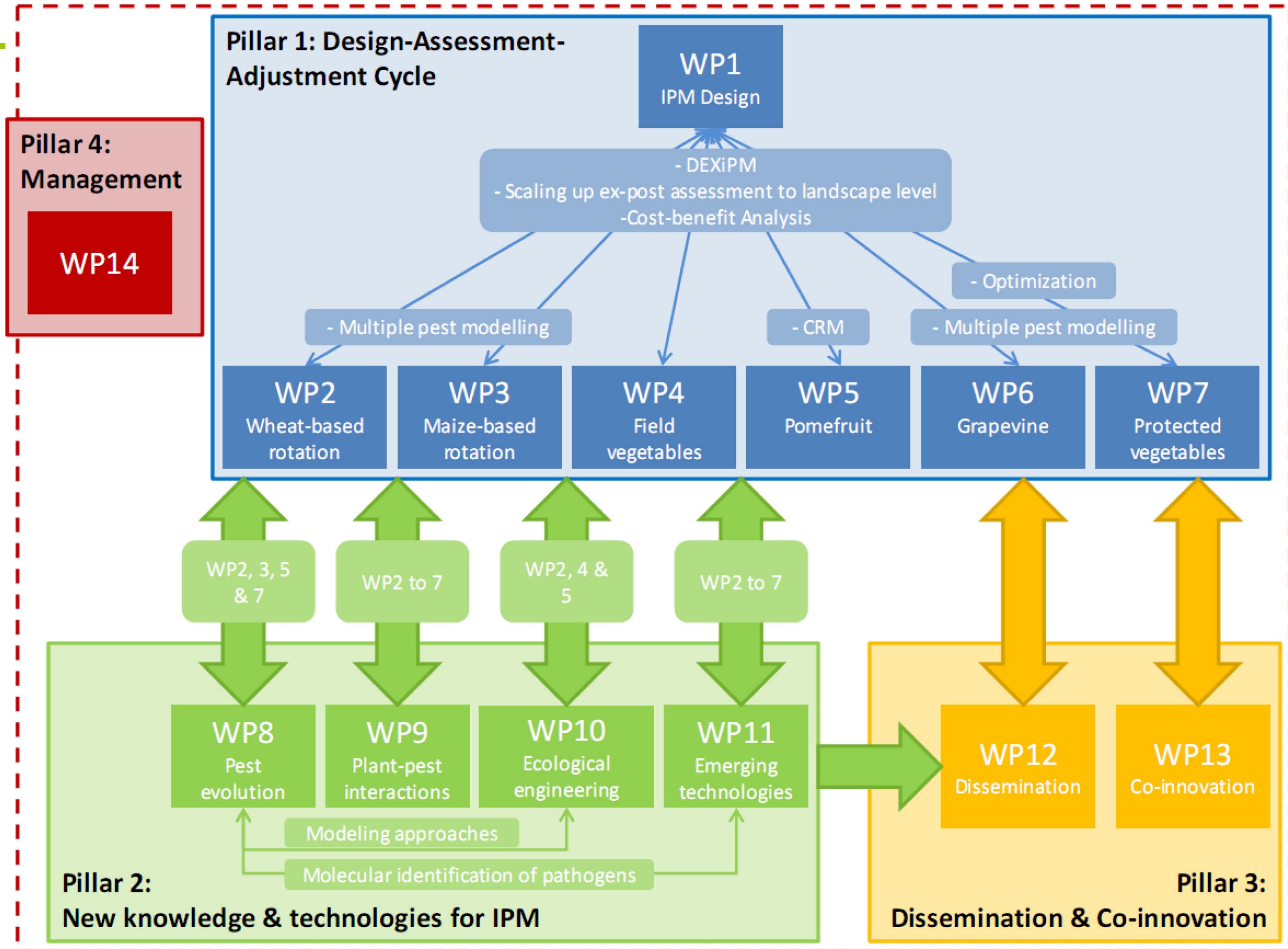
(FP7, 2011-2014)

Coordinator:
Françoise Lescourret, INRA

FOOD QUALITY AND SAFETY

SIXTH FRAMEWORK PROGRAMME

endure diversifying crop protection



FOOD QUALITY AND SAFETY

endure
diversifying crop protection

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IPM is a sustainable approach to managing pests by combining biological, cultural and chemical tools in a way that minimises economic, environmental and health risks.

FOOD QUALITY AND SAFETY

2007 — 4 years of EC financial Support

2010 — ENDURE ERG: self funded Network (14 founding members)

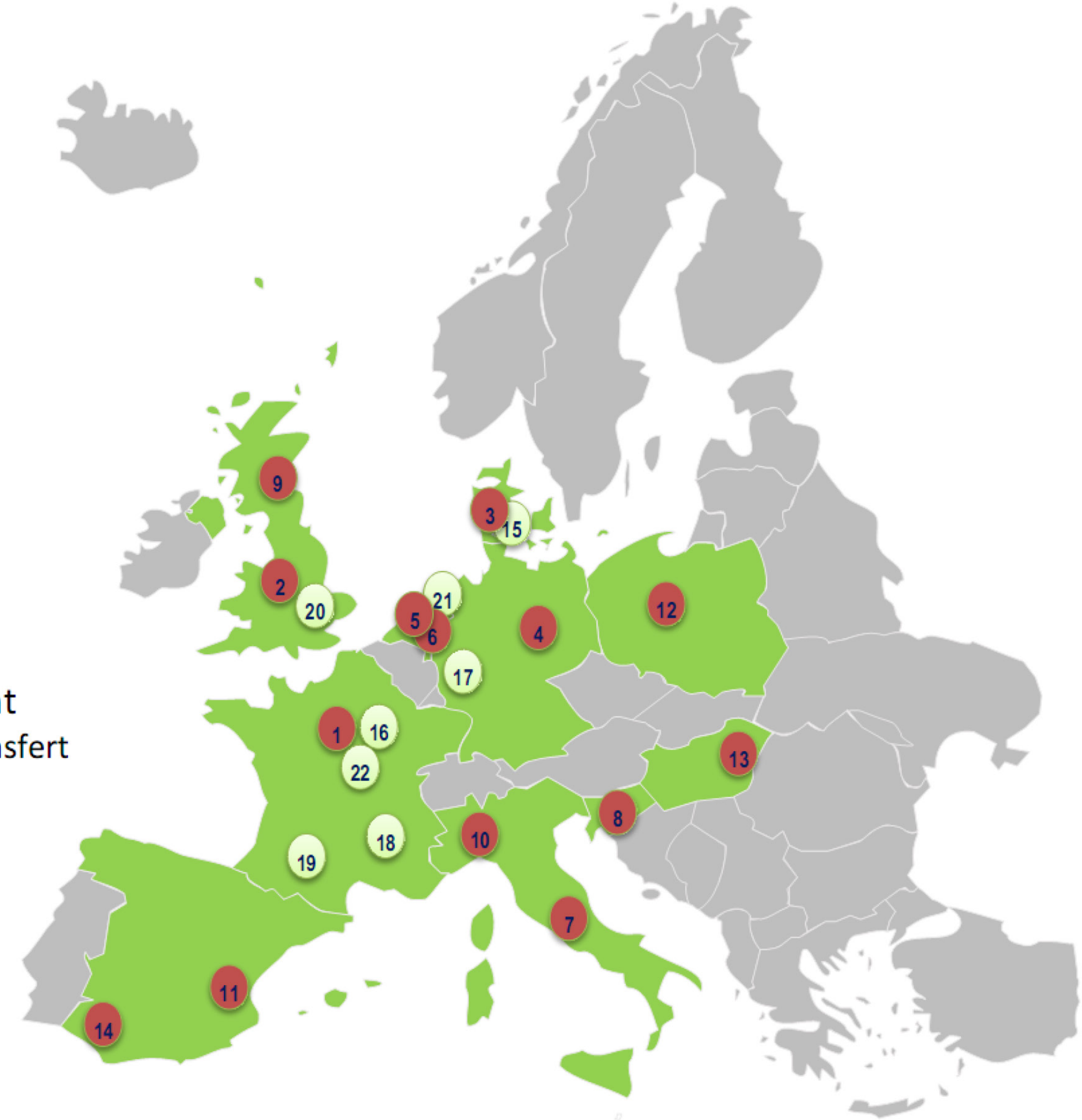
PURE partnership

Research
1 - INRA
2 - RRES
3 - AU
4 - JKI
5 - Stichting DLO
6 - WUR
7 - CNR
8 - KIS
9 - SCRI
10 - FEM
11 - IVIA
12 - IOR
13 - UDCAS
14 - JRC-IPTS

Extension
15 - DAAS
16 - ACTA

Industry
17 - BCS
18 - Biotop
19 - NPP
20 - Burkard
21 - Blgg

Management
22 - INRA Transfert



→ **trans-nationality**
→ **trans-disciplinarity**

3 main target audiences
- **scientists**
- **advisers**
- **Policy makers**

amiga

Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

Using pest-resistant crops in IPM

Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

European Commission

SEVENTH FRAMEWORK PROGRAMME

www.amigaproject.eu

European Commission

SEVENTH FRAMEWORK PROGRAMME

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EU AMIGA: Designing IPM for GM crops

The James Hutton Institute

THE AMIGA PROJECT

AMIGA «Assessing and Monitoring the Impacts of Genetically modified plants (GMPs) on Agro-ecosystems» is a new EU project, funded by the FP7, aiming to produce scientific data on the possible environmental and economic impacts of cultivation of Genetically Modified Plants (GMPs) in European environments.

Launched on the 1st of December 2011, AMIGA project will run for 4 years, until the end of 2015.

amiga

Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

www.amigaproject.eu

OBJECTIVES

The project aims to:

- **establish** baseline data on biodiversity in European agro-ecosystems in which GM crops may be grown
- **translate** regional protection goals into measurable assessment endpoints
- **define** lists of suitable bio-indicators for various European regions
- **improve** knowledge on potential long term environmental effects of GMPs
- **test** the efficacy of the EFSA Guidance Document (GD) for the Environmental Risk Assessment (ERA) of GMPs
- **explore** new strategies for post market monitoring
- **assess** the compatibility of GMPs with the Integrated Pest Management (IPM) principles implemented in the EU
- **provide** a systematic analysis of economic implications of GMPs cultivation in the EU
- **establish** a training and communication plan addressing public concerns about GMPs.

THE CONSORTIUM

The AMIGA consortium is composed by 22 partners, including Research Centres, Universities, State Agencies and SMEs, which together provide unrivalled expertise in the research and analysis of different aspects of GM plants and their cultivation. The partners are located in 15 EU countries, and also Argentina, which will provide experience from areas where GM crops are cultivated on large scales. The coordinator of the project is the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), which is the second largest research organisation in Italy.

ENEA
umweltbundesamt
WAGENINGEN UR
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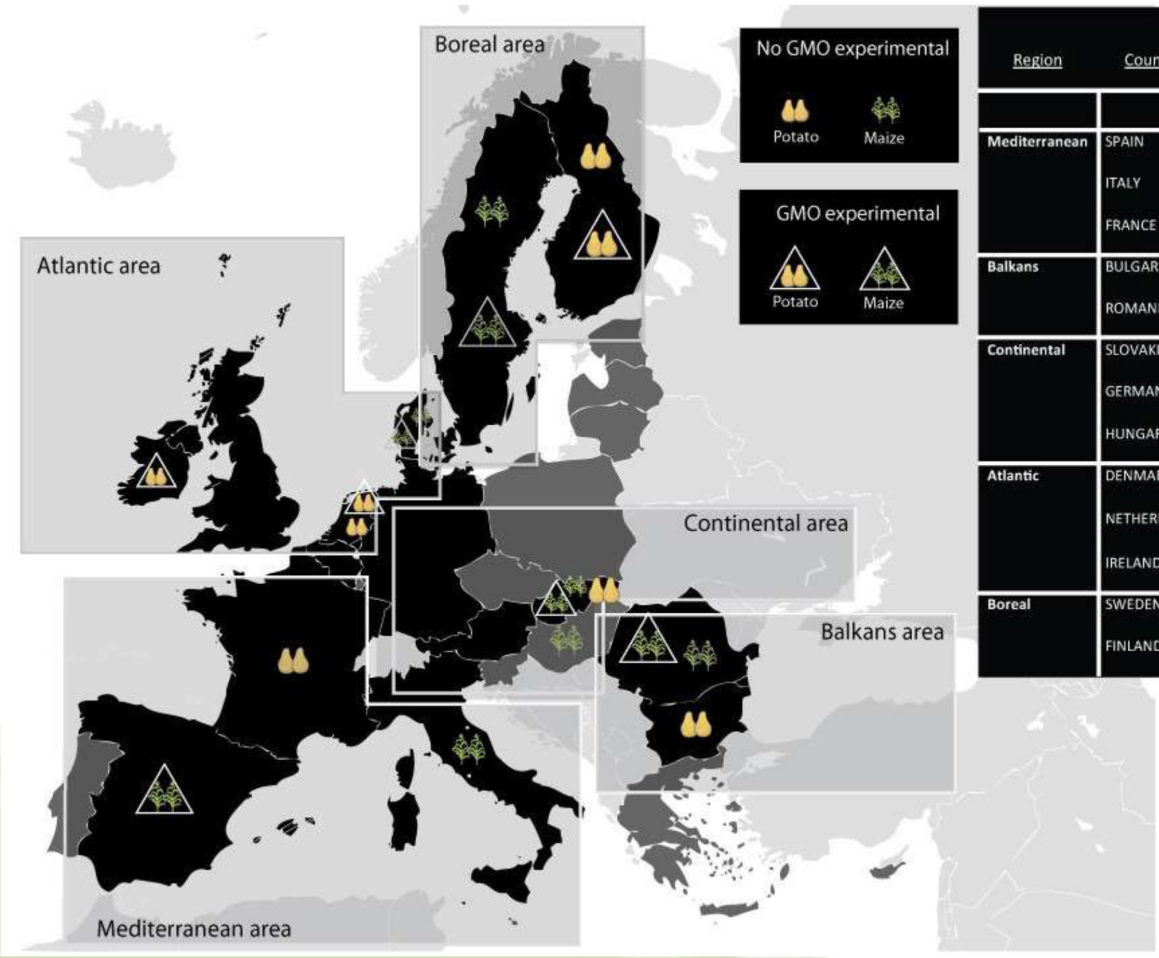
GEOSYS
INTA
ABI
THÜNEN
LUND UNIVERSITY
INRA
University of Reading
Büro Lang
Minerva

AMIGA field studies



Region	Country	GMO (Potato)	GMO (Maize)	Non-GMO (Potato)	Non-GMO (Maize)
Mediterranean	SPAIN		x		
	ITALY				x
	FRANCE			x	
Balkans	BULGARIA			x	
	ROMANIA		x		x
Continental	SLOVAKIA		x	x	x
	GERMANY				
	HUNGARY				x
Atlantic	DENMARK		x		x
	NETHERLANDS	x		x	
	IRELAND	x			
Boreal	SWEDEN		x		x
	FINLAND	x		x	

www.amigaproject.eu

AMIGA field studies maize + potato

- **NTO-oriented field trials**
  - Assess in practice the feasibility of the EFSA guidance document on NTOs (selection of species, representativeness, power, etc) → WP4/WP5/WP6
- **IPM-oriented field trials**
  - Assess the potential of GMOs to support the implementation of IPM (Cf 2009/128) → WP8

- **Survey on non-GM agro-ecosystems**
  - Establish/consolidate a baseline on NTO in biogeographical regions → WP2

Examples from berry fruit IPM:

IPM toobox: combining R cvs, biopesticides, biocontrol and semiochemicals

The James Hutton Institute

Recipe 1 (simple): 1 key pest (raspberry aphid)

Start with pest resistant varieties for IPM

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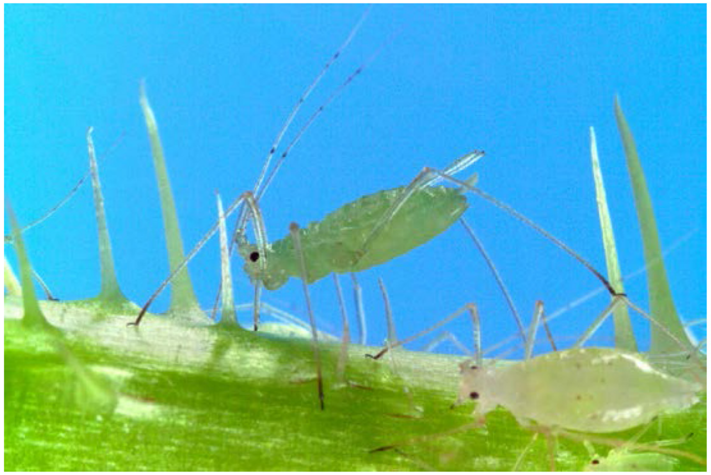
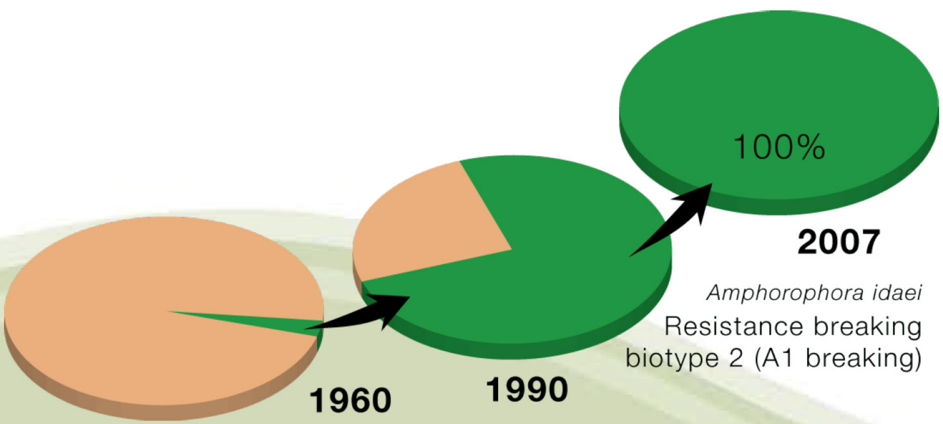


Large raspberry aphid; key virus vector



Breed resistant cvs for 30 years:

Entomology + plant breeding:

10+ years effort/ R cv.

BUT ...selected virulent aphid biotypes (single IPM tools not robust)

Combining constitutive and inducible pest resistance
(EU PURE)

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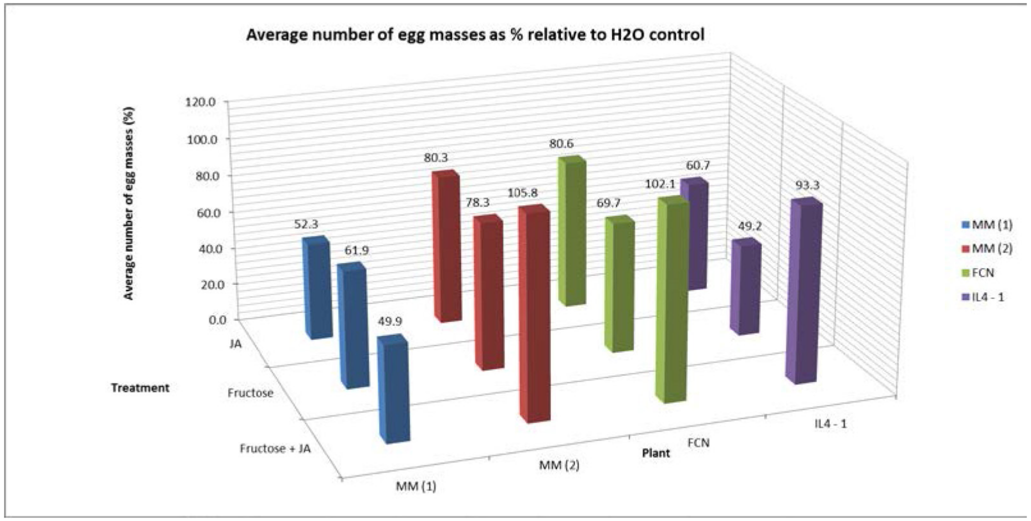


Suppression of root knot nematodes by combining partial resistance with inducible plant defences (primers / elicitors)

IPM case studies: *Rubus* food webs

Major cv and climatic effects on aphid pests and NEs

The James Hutton Institute

2007 +-2008 DATA: EXTRACTED

Tunnel (~ +3C)	Ample S	Rosa R
Orb spiders (NE)	1.7Y	5X
Hoverfly larvae (NE)	6Y	2X
Aphis idaei (pest)	0	2X
Amphorophora idaei (pest)	2.2Y	0
Macrosiphum euphorbiae (pest)	25Y	2

Field (ambient)	Ample S	Rosa R
Orb spiders	Y	X
Hoverfly larvae	Y	X
Aphis idaei	0	X
Amphorophora idaei	Y	0
Macrosiphum euphorbiae	Y	0

S = A_1 gene; now overcome by *Amph. idaei*   R = A_{10}, still effective v *Amph. Ideai in Scotland but not England (time bomb for breeders).*

G x E interactions <u>complex</u> but <u>vital</u> for durable IPM!

An introduction to SCEPTRE

Sustainable Crop and Environment Protection
- Targeted Research for Edibles (SCEPTRE)

SCEPTRE

Sustainable Crop & Environment Protection
- Targeted Research for Edibles

SCEPTRE Gap Analysis:

Impact of pesticide withdrawals by sector

	Reason	Bra	Car	Lee	Oni	Let	App	Ras	Str	Tom	HNS
Weeds	RFI	£1m – 5m/y	Over £10m/yr	£1m – 5m/y	£1m – 5m/y	Over £10m/yr	<£1m/yr	Over £10m/yr	Over £10m/yr	<£1m/yr	£1m – 5m/y
	Approvals	£1m – 5m/y	Over £10m/yr	Over £10m/yr	Over £10m/yr	Over £10m/yr	<£1m/yr	Over £10m/yr	Over £10m/yr	<£1m/yr	Over £10m/yr
	Water quality	£1m – 5m/y	Over £10m/yr	<£1m/yr	<£1m/yr	Over £10m/yr	Over £10m/yr	Over £10m/yr	Over £10m/yr	<£1m/yr	<£1m/yr
Pests	RFI	Over £10m/yr	Over £10m/yr	<£1m/yr	<£1m/yr	Over £10m/yr	<£1m/yr	£1m – 5m/y	Over £10m/yr	£1m – 5m/y	Over £10m/yr
	Approvals	<£1m/yr	<£1m/yr	<£1m/yr	<£1m/yr	Over £10m/yr	<£1m/yr	Over £10m/yr	Over £10m/yr	<£1m/yr	£1m – 5m/y
	Water quality	£1m – 5m/y	<£1m/yr	<£1m/yr	<£1m/yr	Over £10m/yr	<£1m/yr	£1m – 5m/y	Over £10m/yr	<£1m/yr	£1m – 5m/y
Diseases	RFI	Over £10m/yr	Over £10m/yr	£1m – 5m/y	£5m-10m/yr	Over £10m/yr	<£1m/yr	Over £10m/yr	Over £10m/yr	£5m-10m/yr	Over £10m/yr
	Approvals	<£1m/yr	£5m-10m/yr	<£1m/yr	Over £10m/yr	Over £10m/yr	<£1m/yr	Over £10m/yr	<£1m/yr	<£1m/yr	£1m – 5m/y
	Water quality	<£1m/yr	<£1m/yr	<£1m/yr	£1m – 5m/y	<£1m/yr	<£1m/yr	<£1m/yr	<£1m/yr	<£1m/yr	<£1m/yr

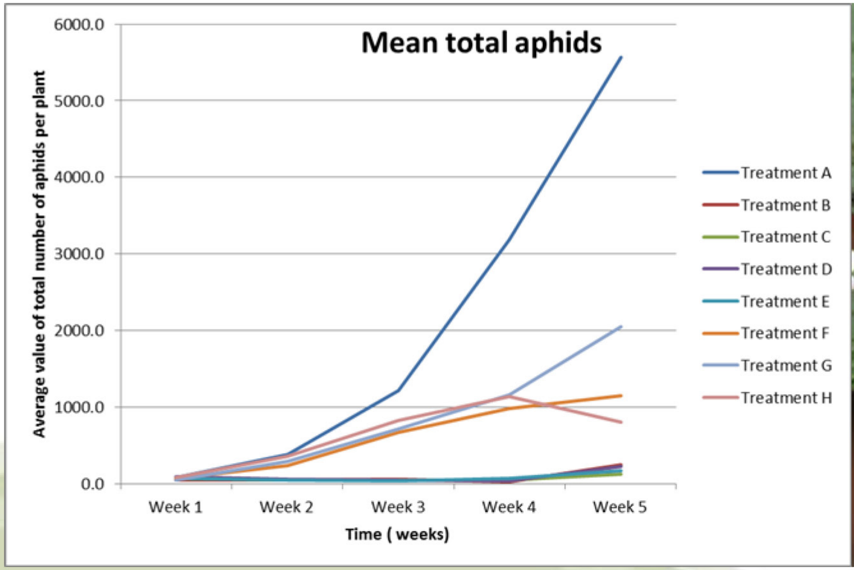
<£1m/yr | £1m – 5m/y | £5m-10m/yr | Over £10m/yr

RFI - room for improvement

Raspberry aphid IPM (II):

Adding biopesticides and biocontrol to the recipe

- **How to make genetic resistance more durable in the system?**
- *Add* biopesticides compatible with biocontrol (parasitoid wasp releases). In combination as effective as current insecticide.



New biopesticides suppress aphids. Hortlink SCEPTRE, glasshouse trials

Parasitoids released weekly can achieve 40% (F)-90% (GH) control of raspberry aphids (with Koppert Ltd and Viridaxis Ltd)

Adapting IPM recipes from vineyards

Biocontrol enhancement: 'Ecological engineering'

The James Hutton Institute

Buckwheat flowers attracts and retains hoverflies in raspberry providing natural aphid predation

Collaboration with Koppert Ltd and BioProtection Centre Lincoln University, N.Z

Teaming up with industry: traps and lures

Semiochemicals: GC-EAG identified key host plant attractants (bio-mimicry)

Raspberry beetle trap + lure design with optimised spatial deployment.

Collaborate with commercial partners, growers, supermarkets in several countries.

On-farm trials: UK, Norway, Switzerland, France, USA over 5 years: Regional variation= regional IPM

~ Raspberry IPM → 30% reduction in pesticides (Hortlink, Scottish and English on-farm, 4 years).

Fresh Produce Journal Sept 2008


feature

Pesticide-free – the new organics?

The list of pesticides available to conventional growers has been getting shorter every year. New proposals for EU regulations were being reviewed as FPJ went to press and, in response to the possible outcome, growing methods less reliant on pesticides are being increasingly explored. Damaris Freeman looks into pesticide-free and residue-free production

Pesticide-free and residue-free production are farming methods that aim to give growers an alternative to conventional farming. These systems offer a move away from pesticides and appeal to a consumer base that is becoming more aware of health and environmental issues. Both researchers and growers are looking to see how plants fare against pests and diseases without the pesticides they have relied on for their entire careers. It could be the first step into a brave new world, but growers first need to know if crop yield and quality can be sustained without the use of pesticides.

Andreas Moll, who heads up South Africa-based grower Bio-Select, came into the industry when he started to grow what he calls residue-free blueberries and blackberries. It took five seasons for the firm to develop its production methods. Moll is passionate about reducing pesticide use, and he is keen to stress the difference between pesticide-free and residue-free production and organic methods. "With organic farming, you are still allowed to use organic-registered chemicals," he explains. "If a grower uses organic-registered chemicals, residues can still be picked up with spectrometry.

"Organic fertiliser on the market is also sold and marketed in terms of nitrogen, phosphate and potassium. This is the basis of chemical farming and the number-one reason for our deteriorating soil life and plants with zero disease resistance."

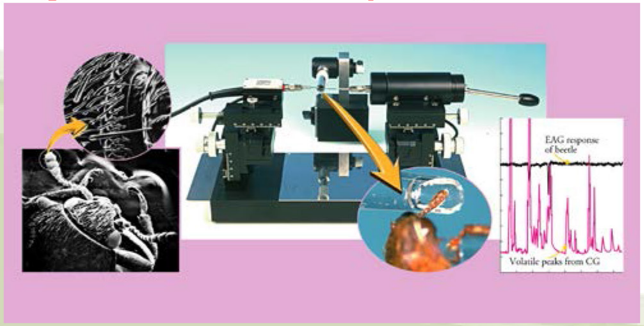
He claims there are significant environmental advantages to using fewer or even no pesticides. "It is sustainable in terms of soil health and input costs," he says. "With residue-free production, the input cost is under the control of the grower and not the chemical company."

Dr Nick Birch, a senior entomologist at the Scottish Crop Research Institute (SCRI) in Dundee, has 25 years' experience in raspberry crop production and protection. He says that he is struggling to keep up with new interest in pesticide-free methods, largely due to increasing consumer demand and recently proposed changes to EU legislation.

The institute works on ways to help growers find ecologically based alternatives for the use of pesticides, "especially those on the EU hit list", says Birch. "Growers are just beginning to realise that the pesticides they have relied on for 10 or 20 years are going to be taken away," he explains.

However, the timing of the EU proposals may prove problematic. "It can take at least 10 years to develop techniques for pest- and disease-resistant plant varieties and EU restrictions on pesticides are coming in ▸

5 SEPTEMBER 2008 FPJ 17



Collaborators: EMR, NRI, ADAS, Agrisense, Suterra, Agroscope (CH), Ctifl (Fr), M+S, Waitrose, Co-op, LEAF, Growers consortia

IPM examples from field vegetable research:

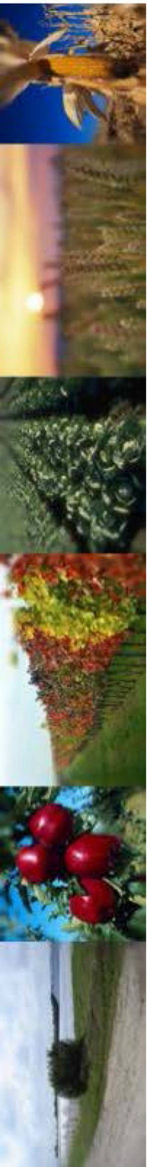
Chemical ecology of cabbage root fly

PhD studies; William Deasy (HDC+EU PURE)

Brassica IPM: Towards 'push-pull strategies'

EU PURE: French-Scottish collaboration

(entomology, chemistry, agronomy, plant breeding)

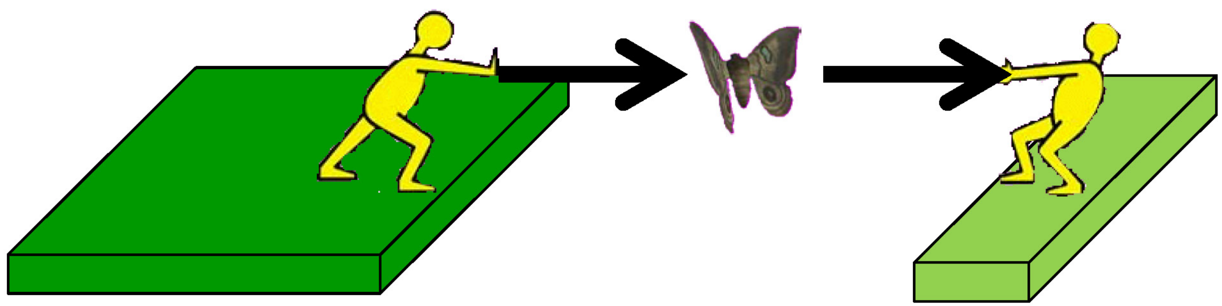


PUSH

from target crop

PULL

in trap crop
& control



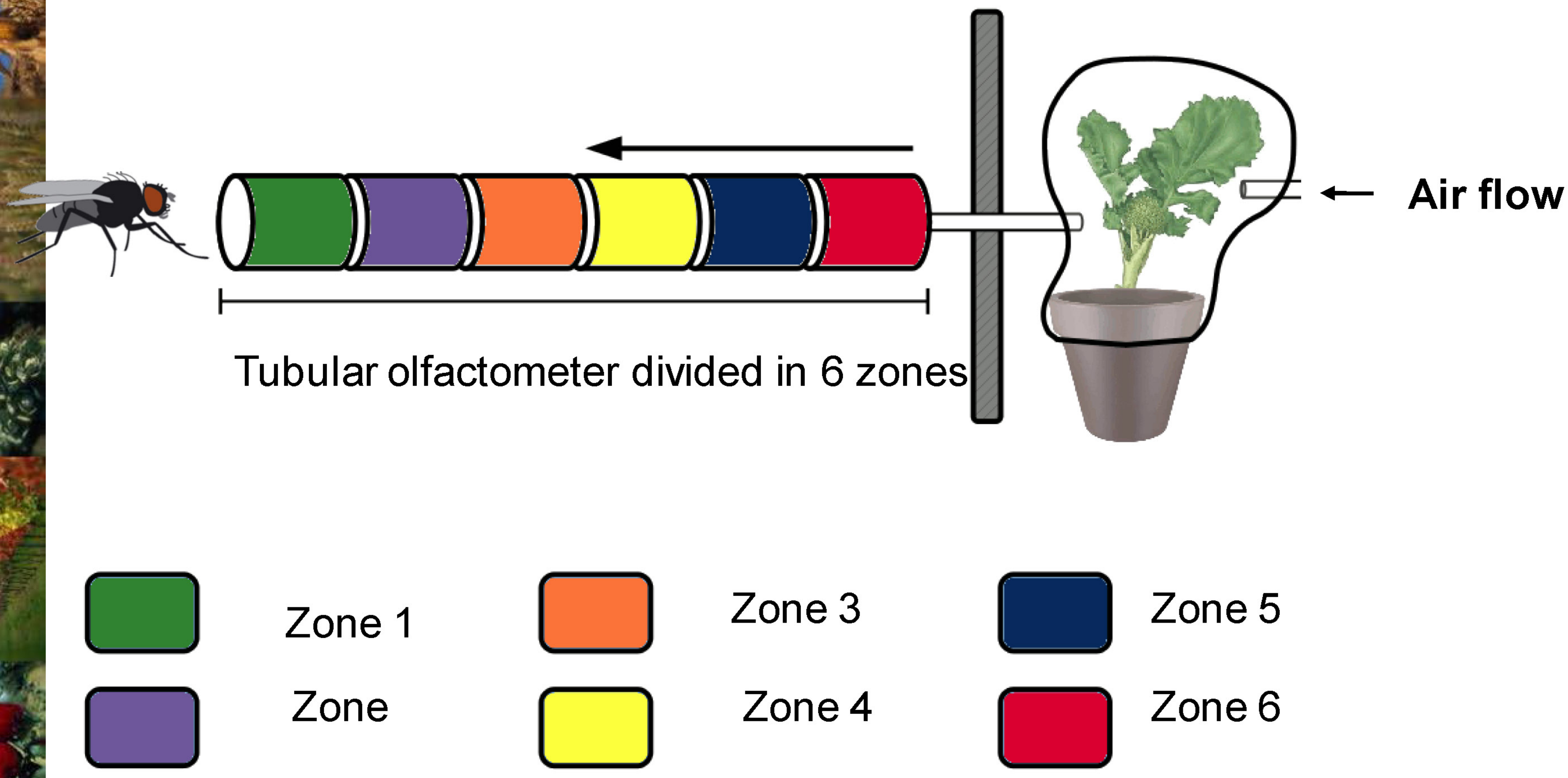
Need : Identify attractive and repellent plants/signals
Challenge: Keep trap crops as small an area as possible

- Identify <u>volatile plant signals</u> modifying pest behaviour = adult oviposition (AG) and larval feeding(BG)

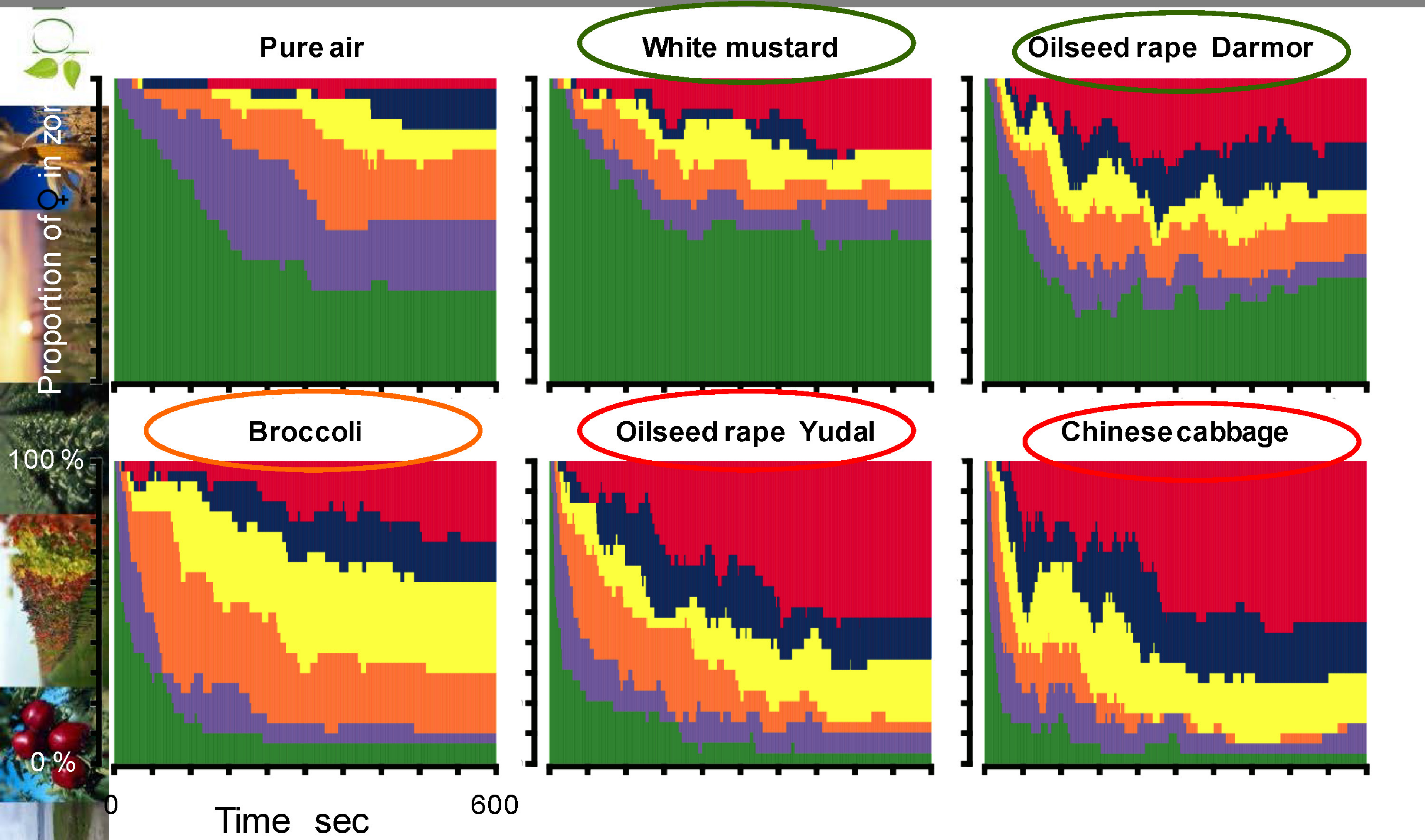
Above ground signals

Cortesero research group (FR)

Attractivity of Brassica plant volatiles to CRF: lab



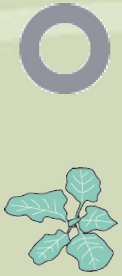
Attractivity of Brassica plant volatiles: lab



✓ **2 plants not very attractive (White mustard, OSR Darmor)**

✓ **2 plants very attractive: OSR Yudal & Chinese cabbage (*broccoli in between*)**

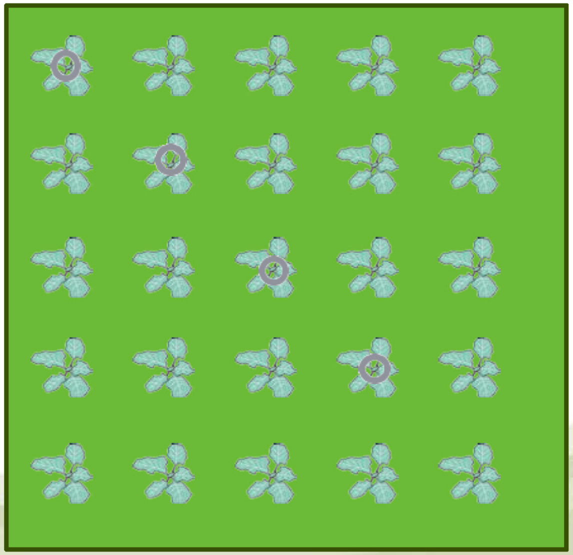
Attractivity of brassica plants: field



Felt trap

Plant

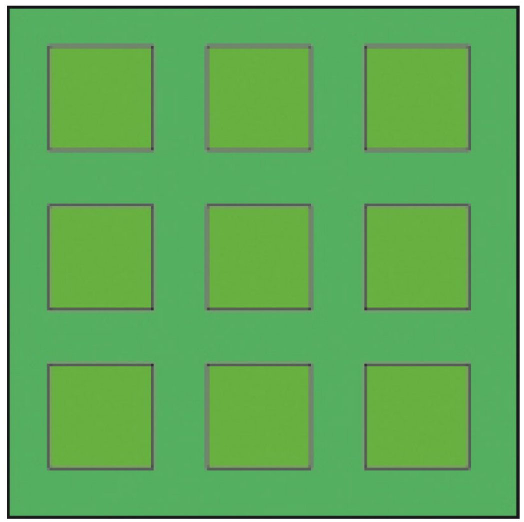
Detail of elementary plot



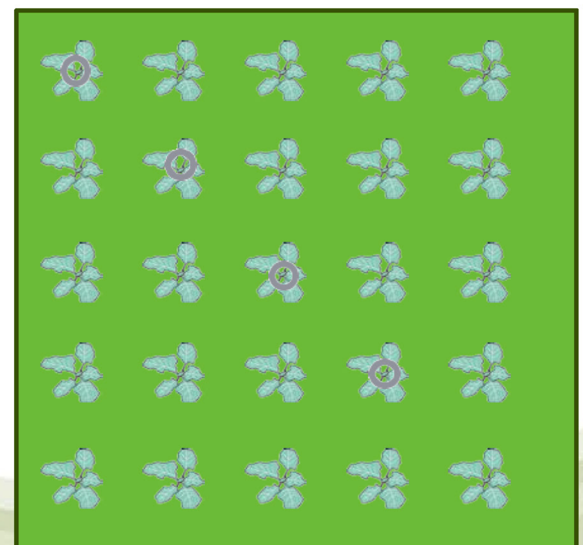
Attractivity of brassica plants: field

The James Hutton Institute

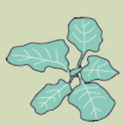
9 plots
= different plants



Detail of elementary plot



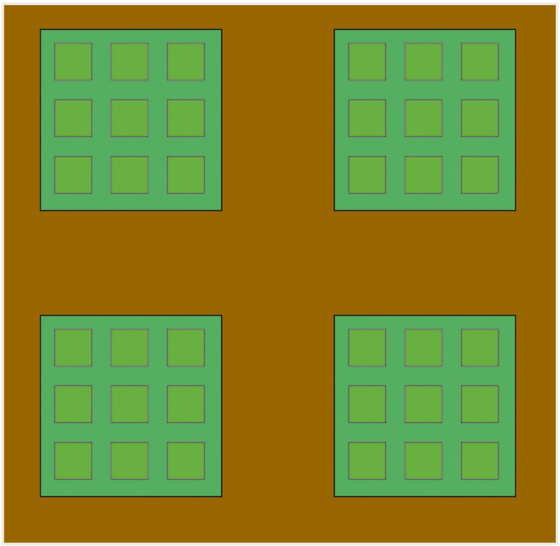
Felt trap



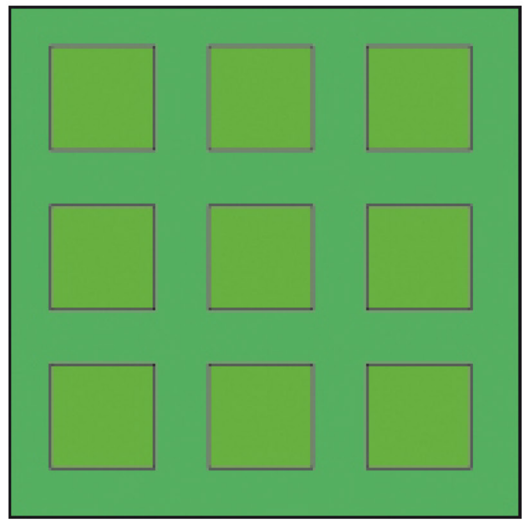
Plant

Attractivity of brassica plants: field

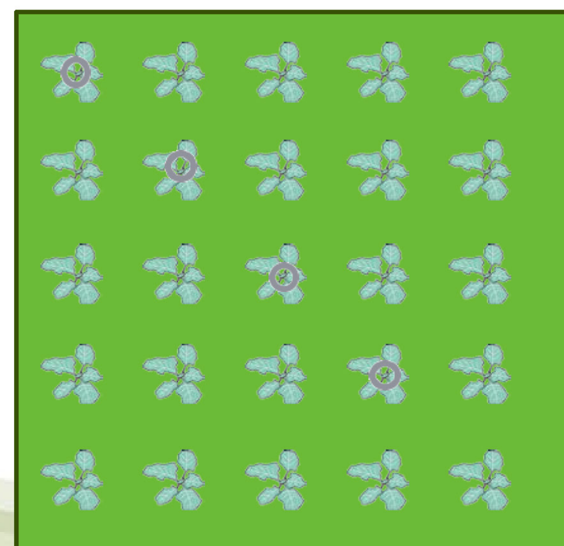
4 blocks
= replicates



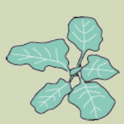
9 plots
= different plants



Detail of elementary plot

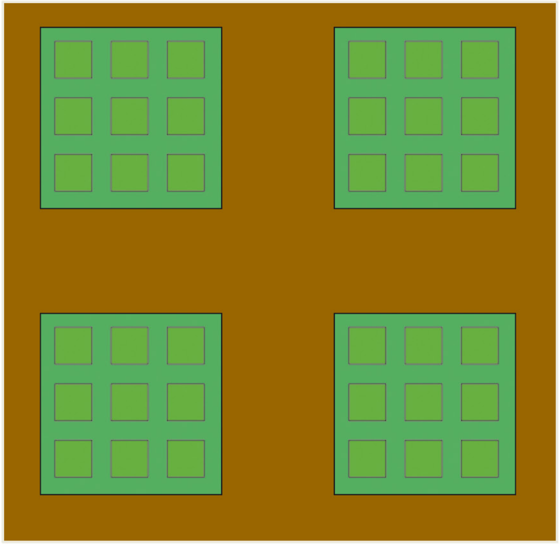


 Felt trap

 Plant

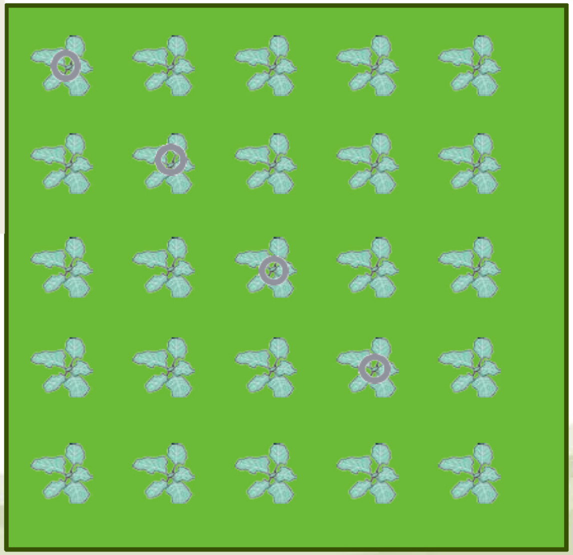
Attractivity of brassica plants: field

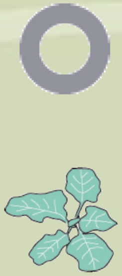
4 blocks
= replicates



Number of *Delia* eggs laid

Detail of elementary plot

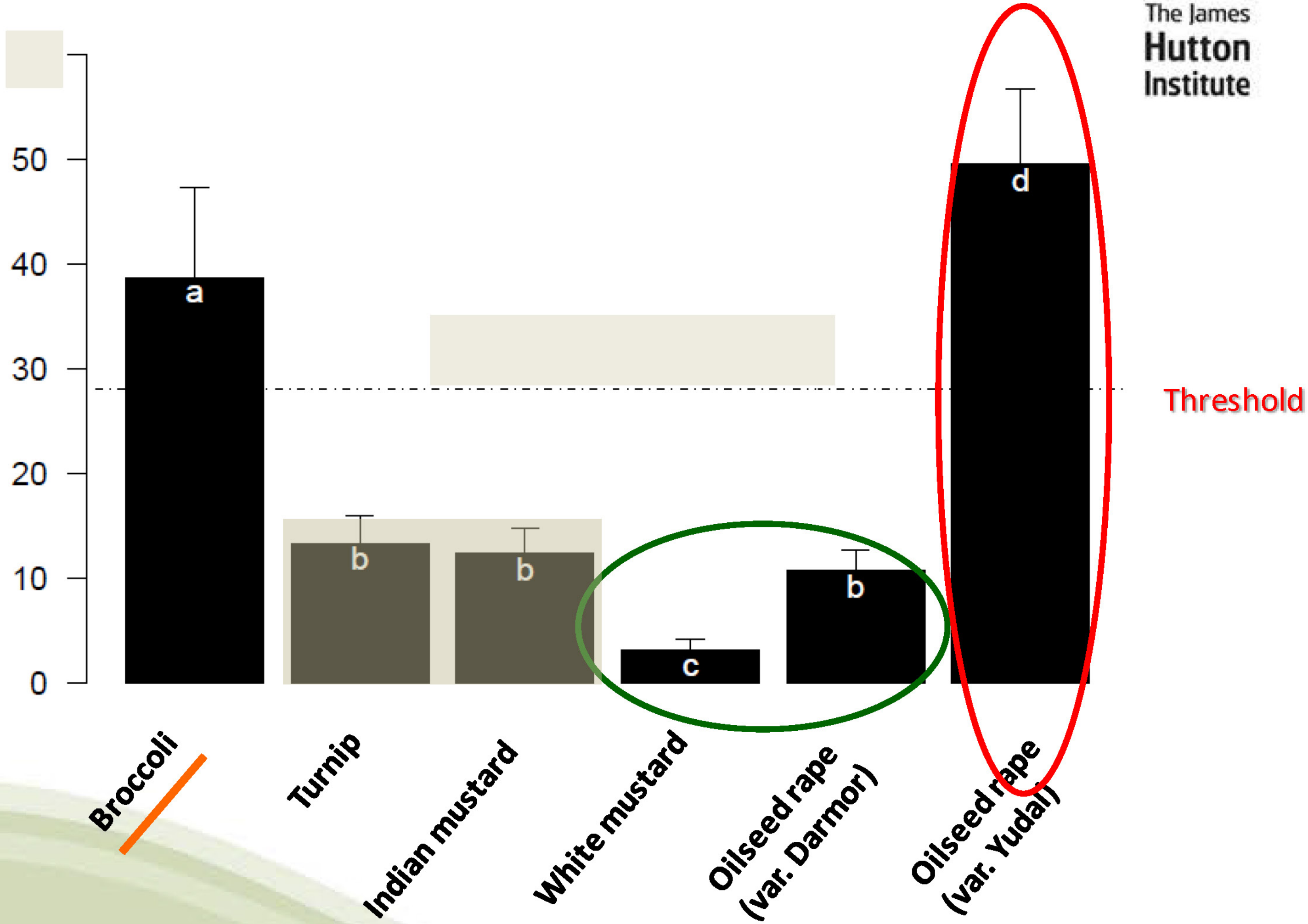




Felt trap

Plant

Number of Delia eggs laid: field



✓ The more attractive plants receive more eggs

✓ The less attractive plants receive less eggs

(Kergunteuil et al 2014, JAE)

Below ground signals from healthy and damaged roots

Root feeding on swede

CRF larvae

Birch group (UK) + William Deasy PhD studies

Laboratory root volatiles collection

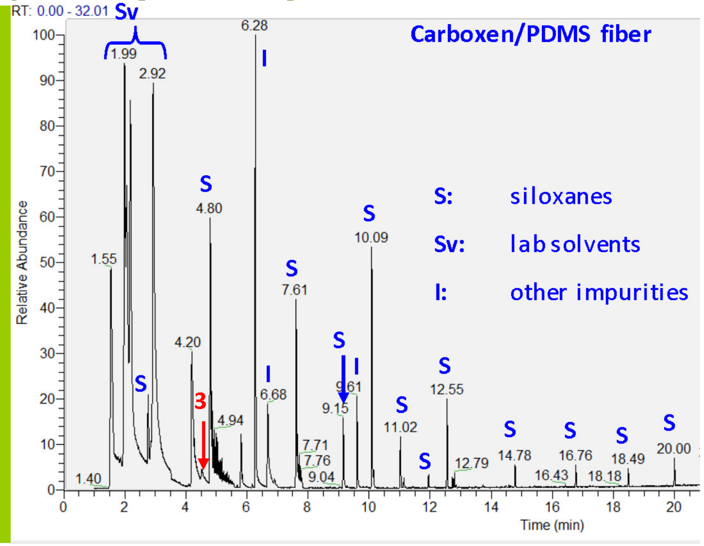
Root zone
SPME-GC-MS

Headspace
ATD-GC-MS

Plant signals in IPM:

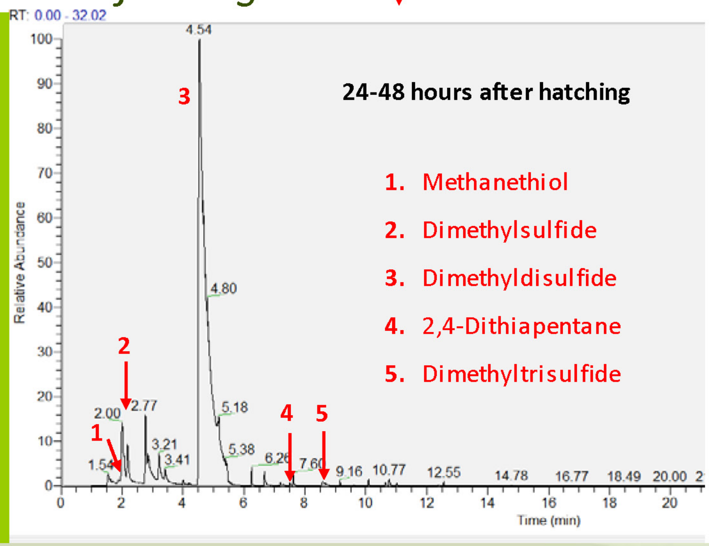
Root damage volatiles and Cabbage Root Fly behaviour

Pre-cabbage root fly larval feeding damage

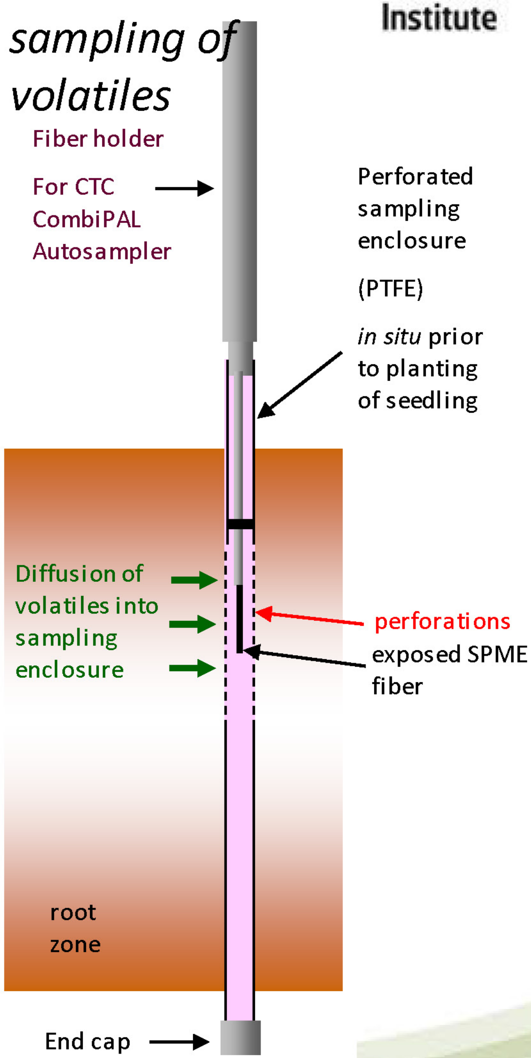


1 week post innoculation

Post-cabbage root fly larval feeding damage



in situ sampling of volatiles



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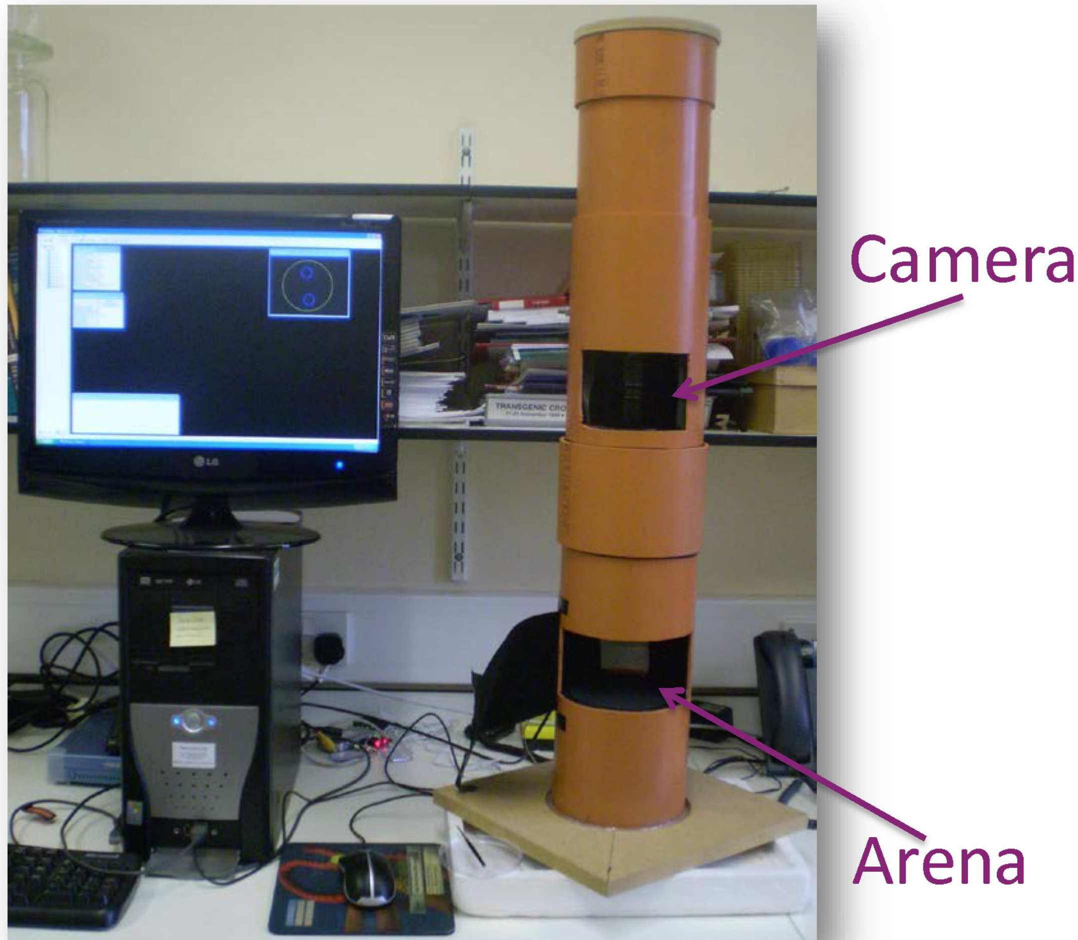
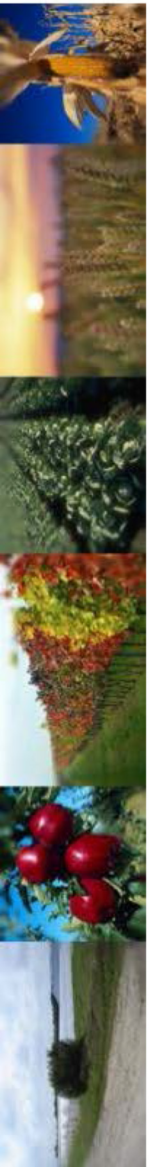
Larval behaviour tracking: lab

- Record larval responses in choice- test bioassays

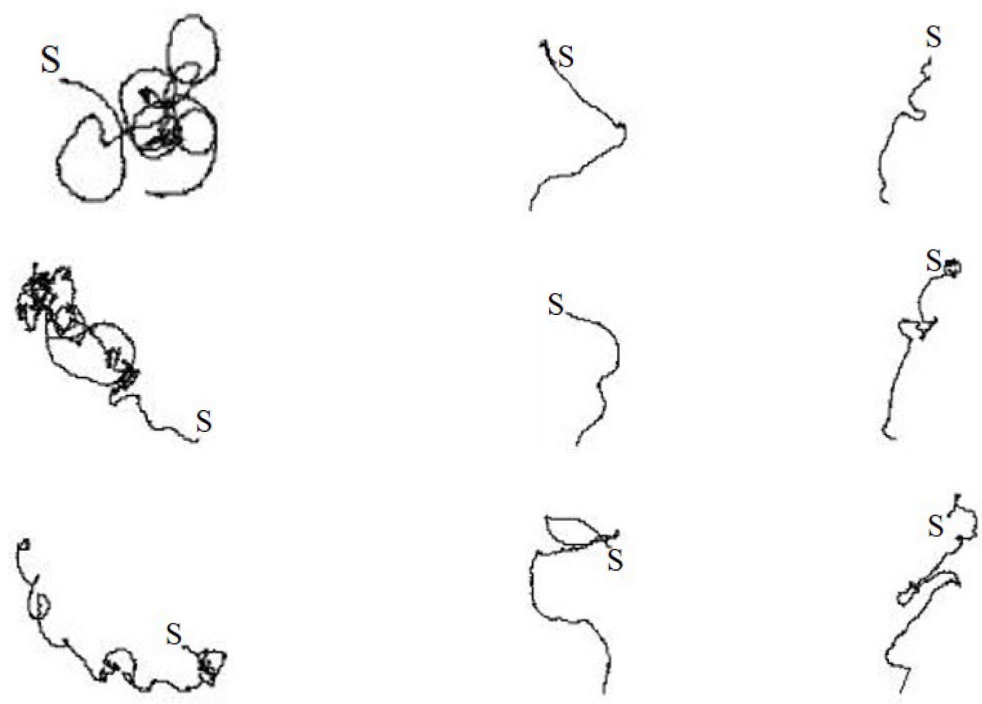
EthoVision® tracking software
IR camera

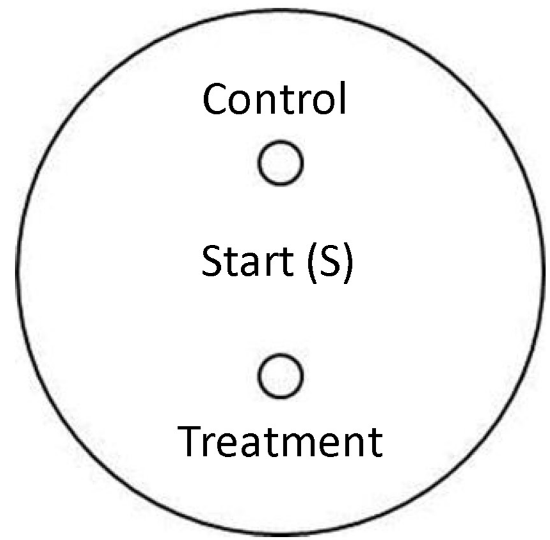




Larval responses to host & non-host plant root VOCs using EthoVision® on CRF larval tracks

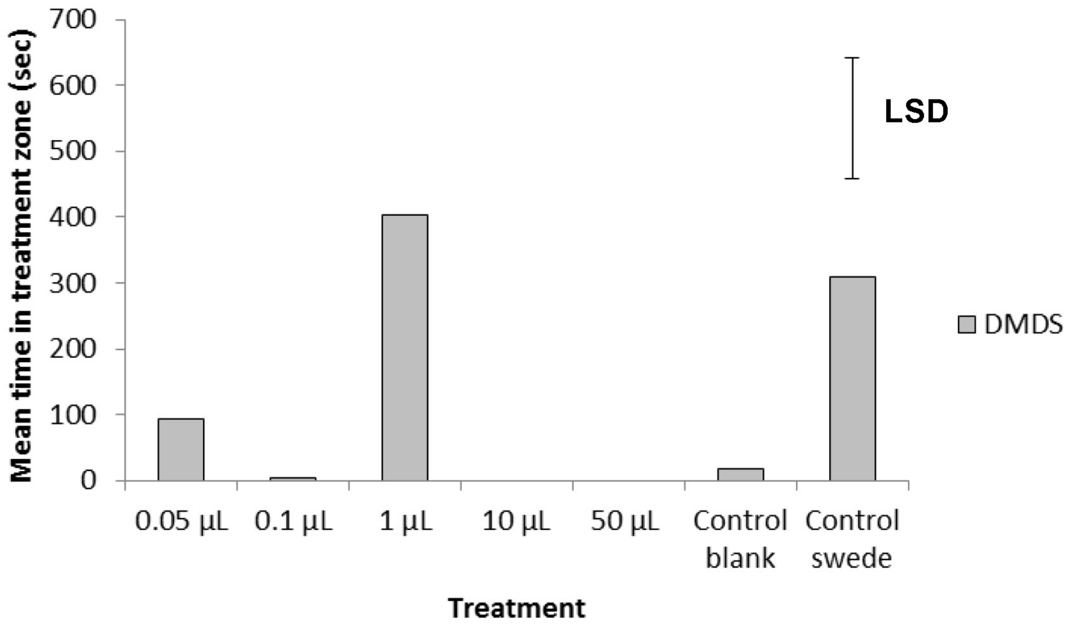
Control (water) | **Broccoli** | **Onion**





Larval movement relative to arena schematic

Dose-dependent effects of DMDS on CRF larvae
(DMDS related to root damage level)



- **Highly attractive at 1µl point source DMDS**
- **Toxic at highest concentration of 50µl point source DMDS**

Scaling up IPM: Landscapes

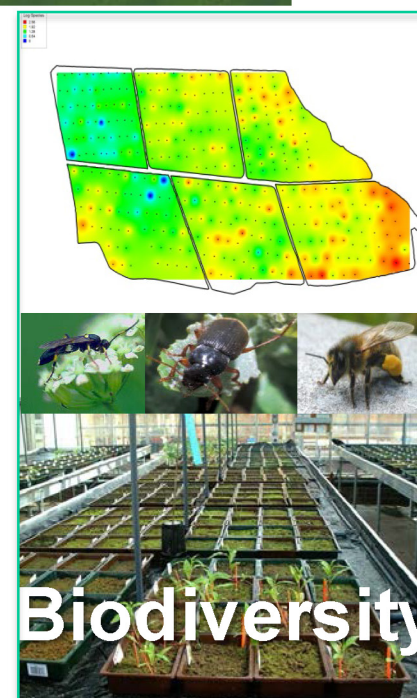
Spatio-temporal models + long term research platforms to optimise 'area-wide' IPM strategies

Centre for Sustainable Cropping, JHI Dundee

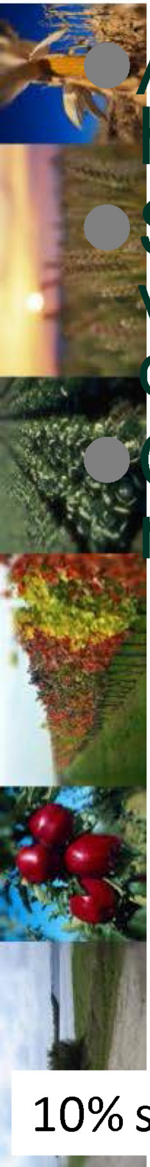
The Centre for Sustainable Cropping

www.hutton.ac.uk/csc

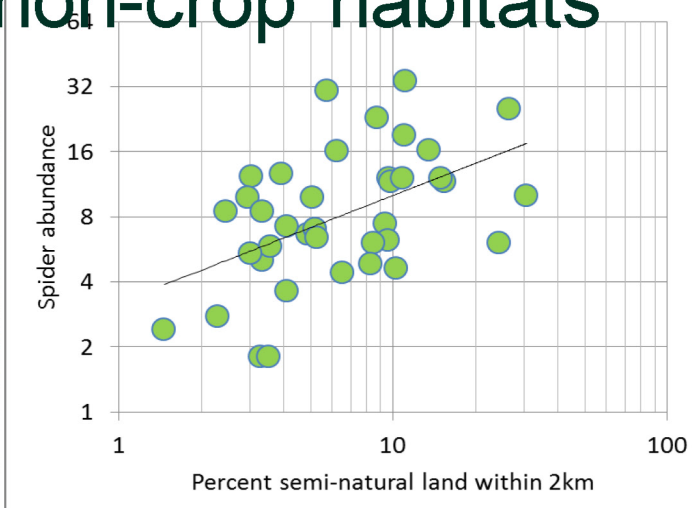
A whole-systems approach for optimising crop production, biodiversity and system health for long term food security.

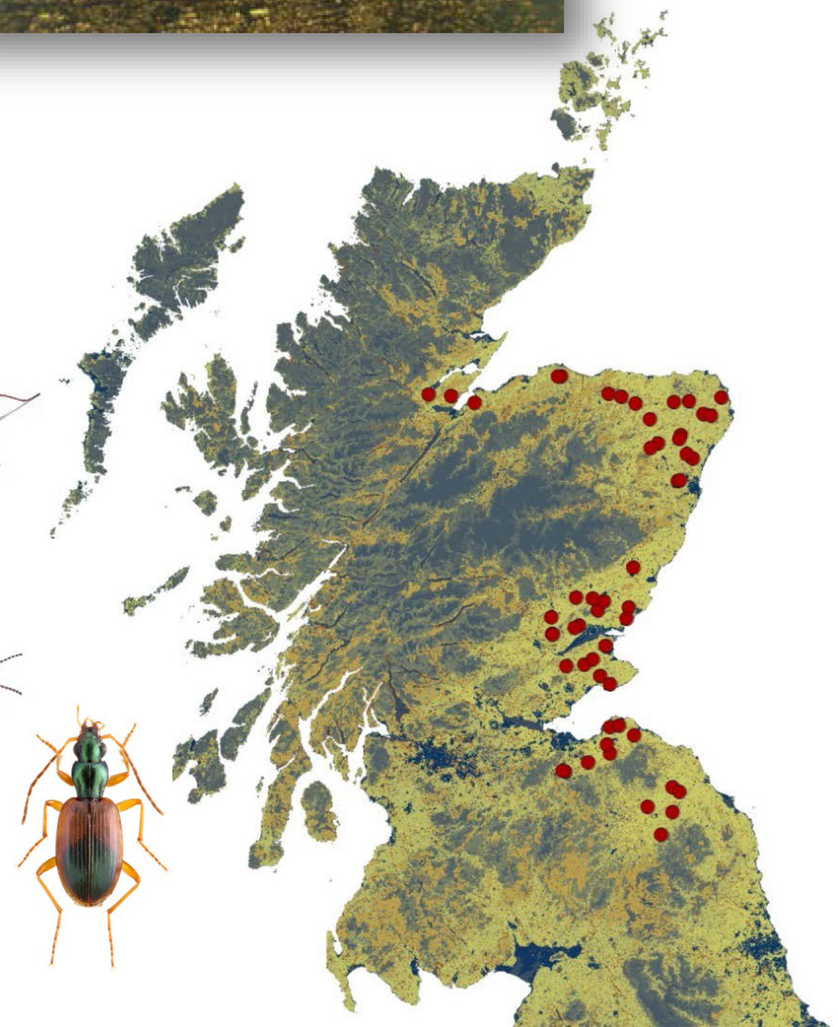


Mapping landscapes



- Arable landscapes are heterogeneous
- Spatial and temporal variation in habitat quality
- Cropping patterns and non-crop habitats

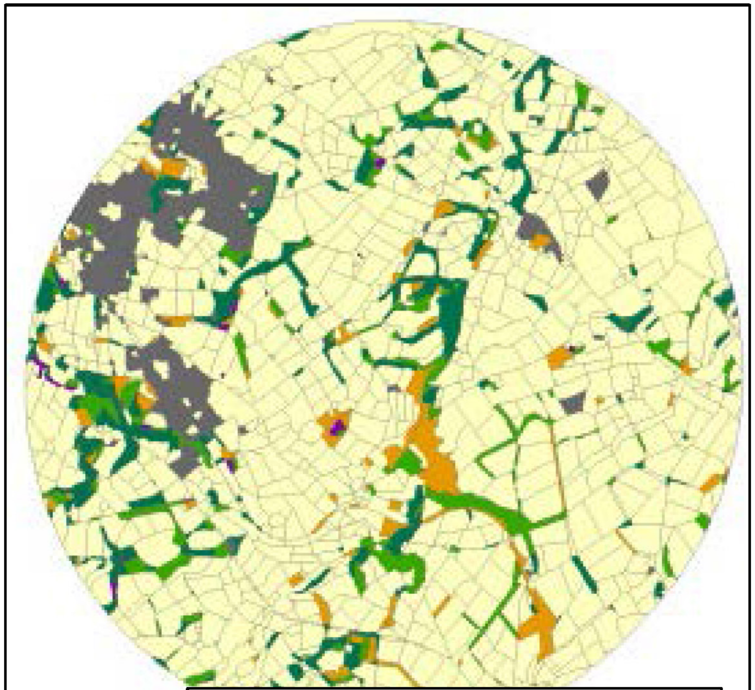




10% semi-natural => 4 fold increase in spiders

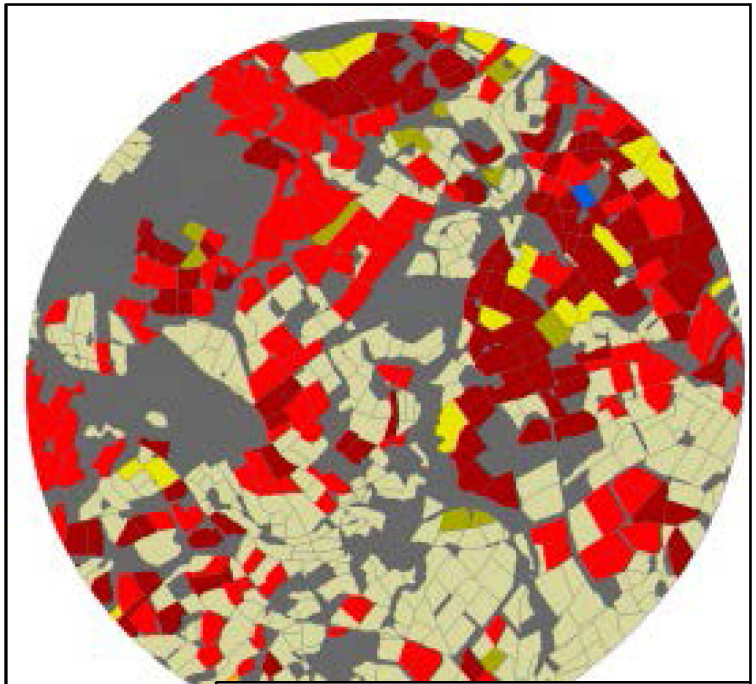
Land use and cropping patterns

Habitats



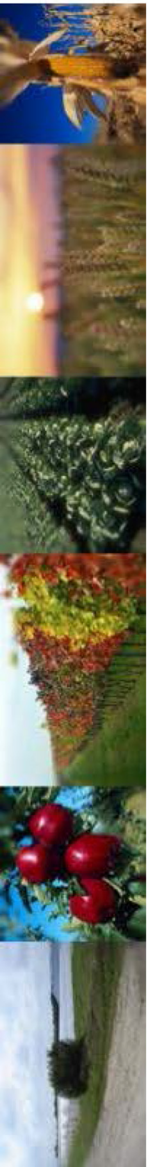
- Intensity
- Complexity
- Fragmentation
- Beneficial habitats

Crop



- Crop type
- Pesticide
- Resistance

Graham.Begg@hutton.ac.uk



Scottish collaborations: global research partners

How collaboration helps (my IPM 'cookbook')

- Start with a **simple recipe**: target **single key pest** in crop system. √
- **Understand pest's biology, ecology, behaviour** (basic research = IPM foundation) . need **multi-disciplinary research** √
- **Team up with industry** for practical IPM tools for farmers. √
- **Team up with regional IPM experts** (UK + EU) - variability in cropping systems, climate, pest adaptations √
- **Add more 'flavours':** multiple IPM tools give durability + robustness (**aphids**). √
- **Success builds success** – later on **target the regional pest complex (ongoing EU projects).**
- **Dynamic IPM problems;** new threats, climate change, pesticide withdrawals…

Biopesticides Consortium (SCEPTRE)

Thank you for your attention

- **IPM Funding sources include:**
- Scottish Government, RESAS
- EU PURE, EU ENDURE, EU AMIGA
- Hortlink SCEPTRE, AHDC, TSB
- Bioforsk, Koppert Ltd, Agrisense Ltd, Suterra Ltd, biopesticide companies.
- IPM (entomology) research valued at **>£ 1.8 million** to JHI , since 2009.

A LEAF
Linking Environment And Farming
INNOVATION CENTRE