

Leibniz Universität Hannover

Exploring the Interactions between the agricultural landscape and insect diversity

Dr Daniel Leybourne

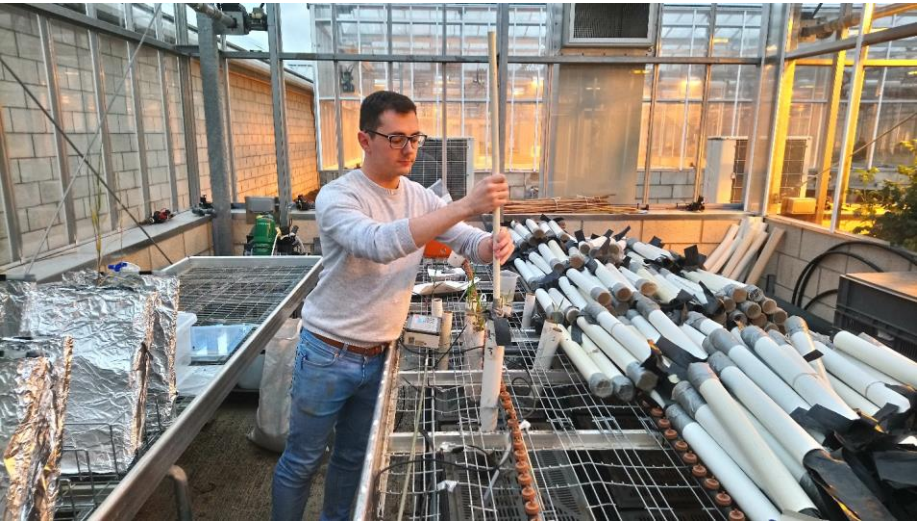
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BRITISH ECOLOGICAL SOCIETY

Introduction

PhD on insect-plant interactions under drought stress (2015-2019. Dundee, UK)





Research position in ADAS, a commercial agricultural research company, working on monitoring and management of herbivorous insects (2019+. York, UK)

Research Fellowship working on herbivorous insect interactions across different landscapes (2021-2023. Hannover, Germany)



Arable pests and crop protection

- Herbivorous insects are a significant contributor to yield reduction in arable food production systems
- Management options rely on pesticide applications
- Growing environmental, ecological, and public concerns over pesticide use
- Other management options required
- Recent estimations: for every 1°C rise in temperature yield loss will increase 10%



How can the landscape promote pest suppression and enhance pest management?

- More complex landscapes (generally) benefit from enhanced biodiversity
- More complex agricultural landscapes can boost the biodiversity of beneficial arthropods
- More biodiverse agricultural ecosystems are better able to provide natural pest management services
- Boosting natural arthropod populations could contribute to more sustainable pest management



Hannover research: Two herbivorous insect systems, two connected projects

1. Cereal aphids - The Agricultural Landscape and Arthropod biodiversity Nexus (ALAN)

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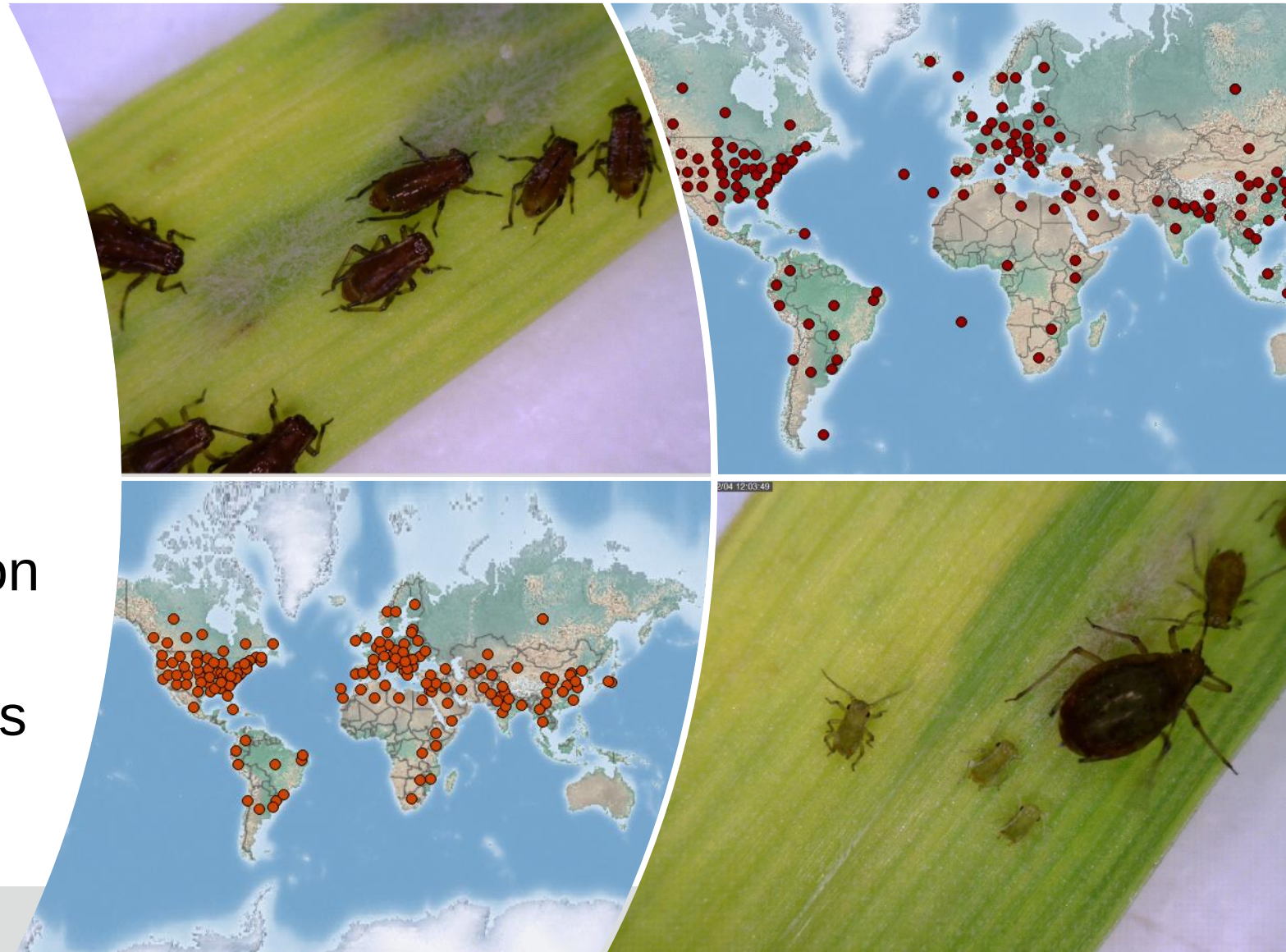
2. Cabbage stem flea beetle - Landscape effects on endosymbionts of the Cabbage stem flea beetle *Psylliodes chrysocephala*



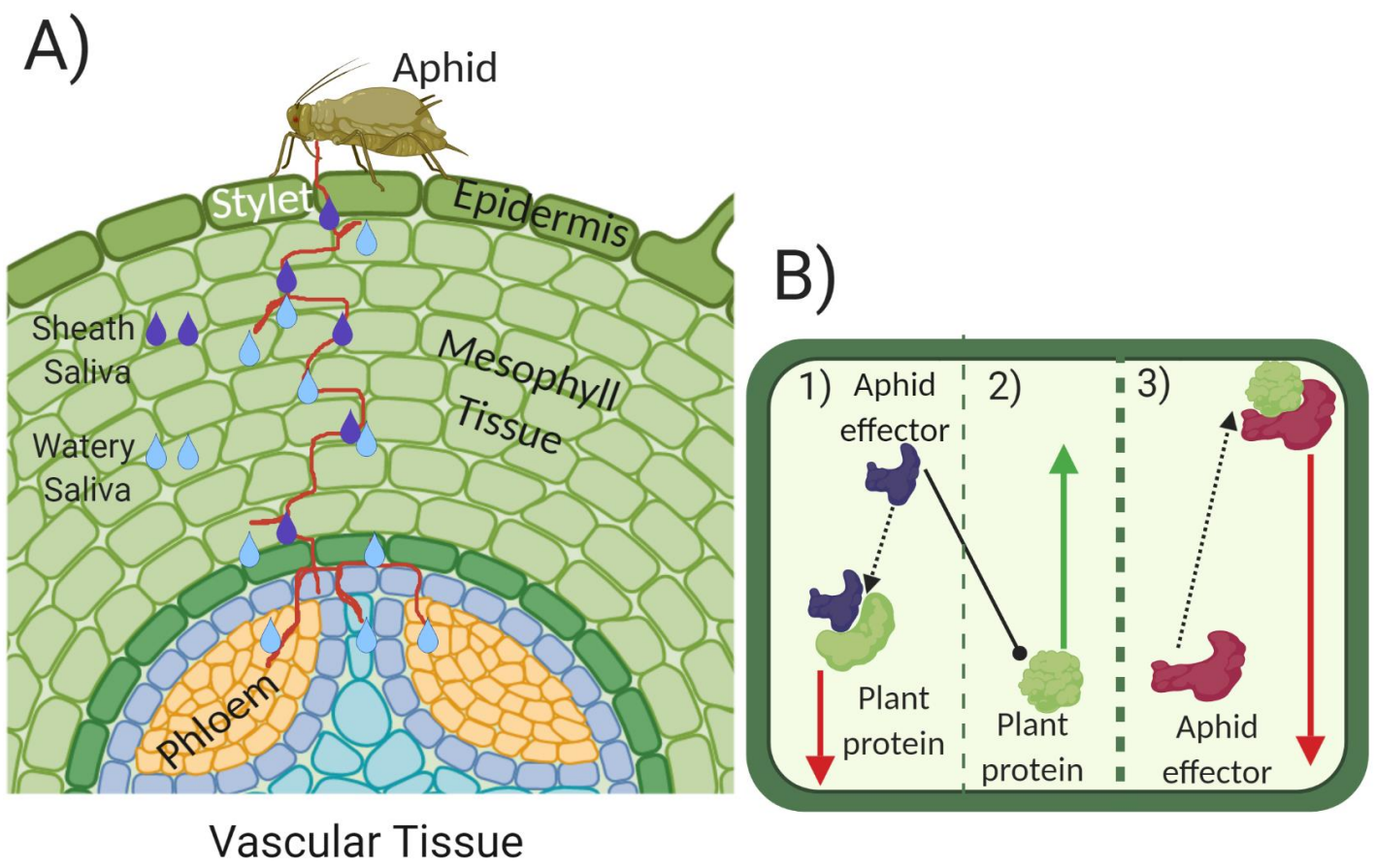
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Cereal aphids: Important sap-feeding herbivorous insects

- Cereal aphids are globally significant
- Three main species (two of significant importance)
- Can cause significant yield losses in wheat, barley, oats
- Management options reliant on pesticide application
- Pesticide resistant populations becoming more abundant



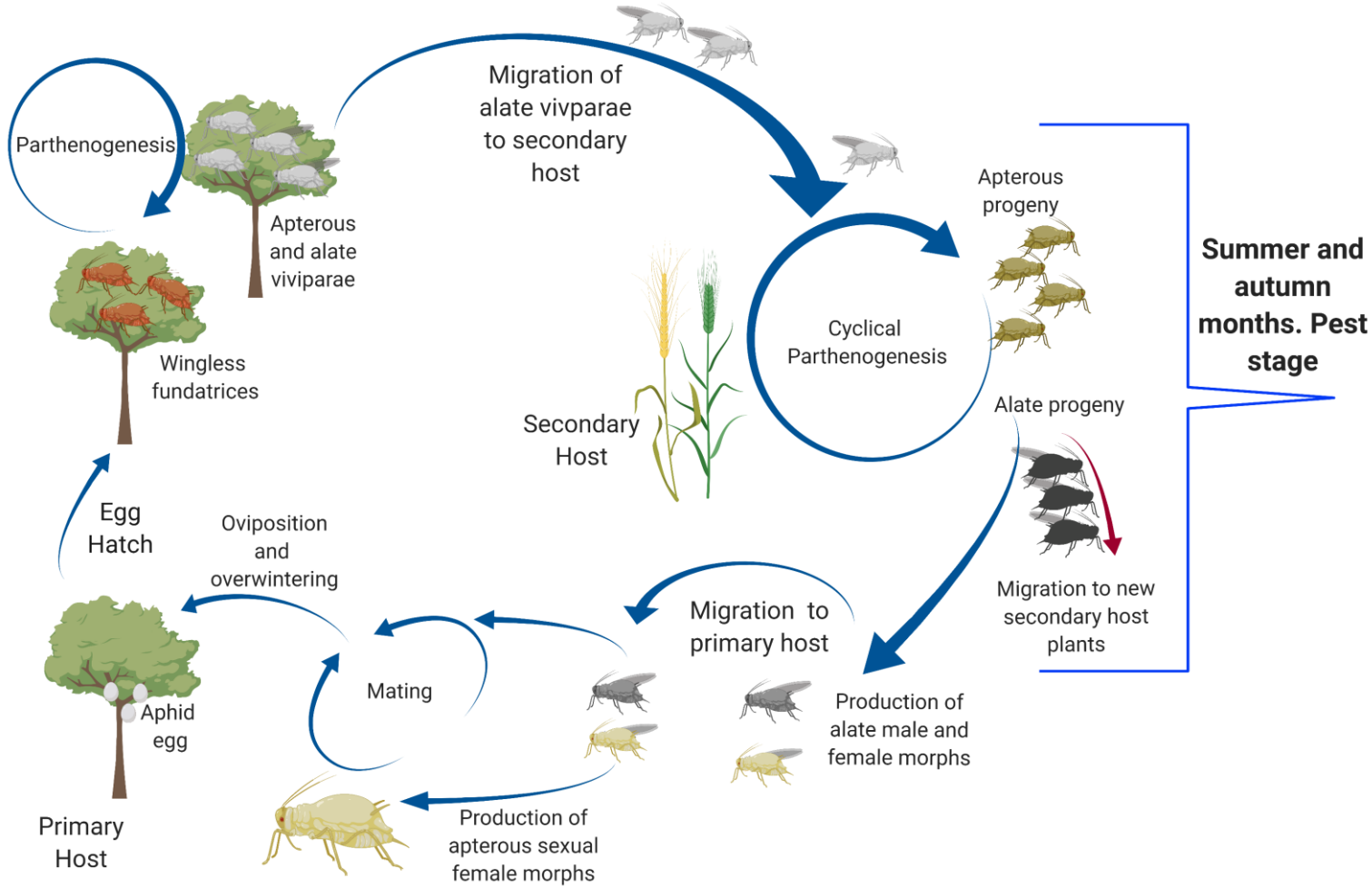
Cereal aphids: Important sap-feeding herbivorous insects





Graphic created with BioRender.com

Cereal aphids: Important sap-feeding herbivorous insects



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Cabbage stem flea beetle: Important chewing herbivorous insect

- Major pest of oilseed rape and other field Brassicas
- Significant adult infestation after crop planting can devastate yields through defoliation
- Insecticide resistant populations are widespread across Europe
- Pest biology significantly understudied





Cabbage stem flea beetle: Important chewing herbivorous insect

Aug-Oct
Adults move to new crop, mate and feed on leaves causing 'shot holing'



Sep-Nov
Eggs laid at base of plants

Oct-Feb
Eggs hatch when mild and larvae feed in leaf petioles



Mar-Apr
Larvae feed on main stem behind growing point

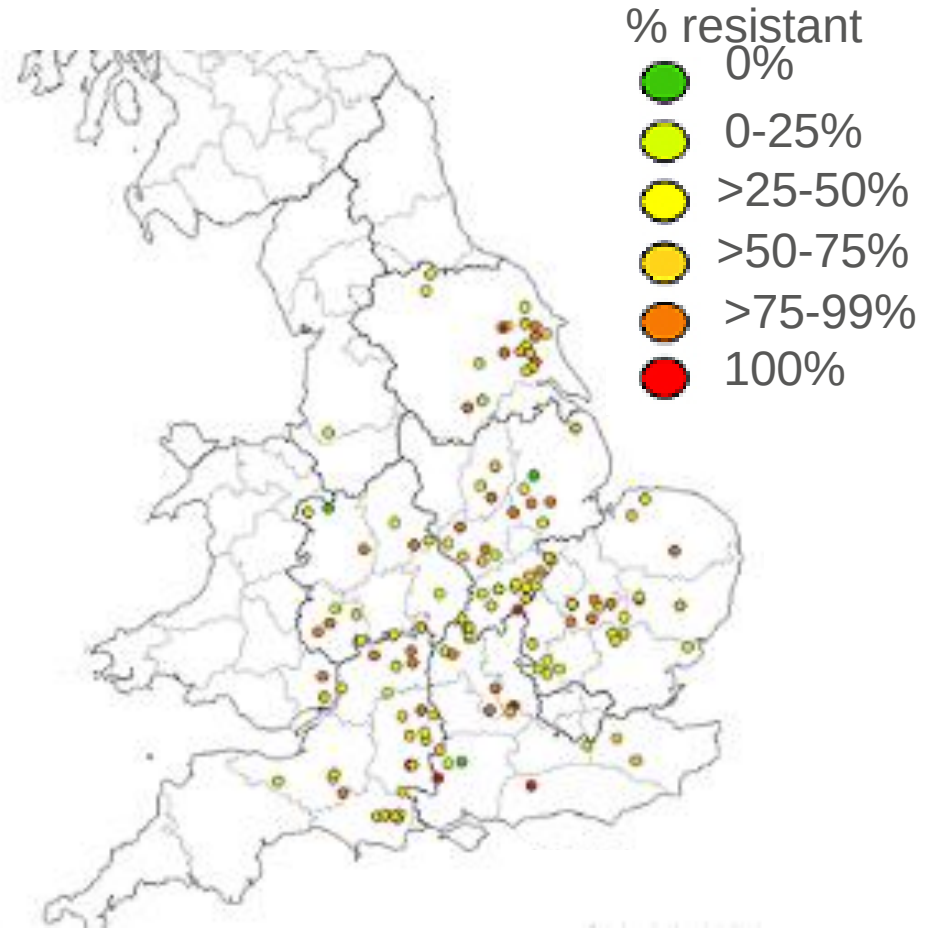
May
Larvae pupate in soil

Jun-Jul
Adults emerge and feed on foliage

Life cycle

Cabbage stem flea beetle: Important chewing herbivorous insect

- Insecticide resistance is widespread in EU populations
- A shift in public opinion away from pesticide use



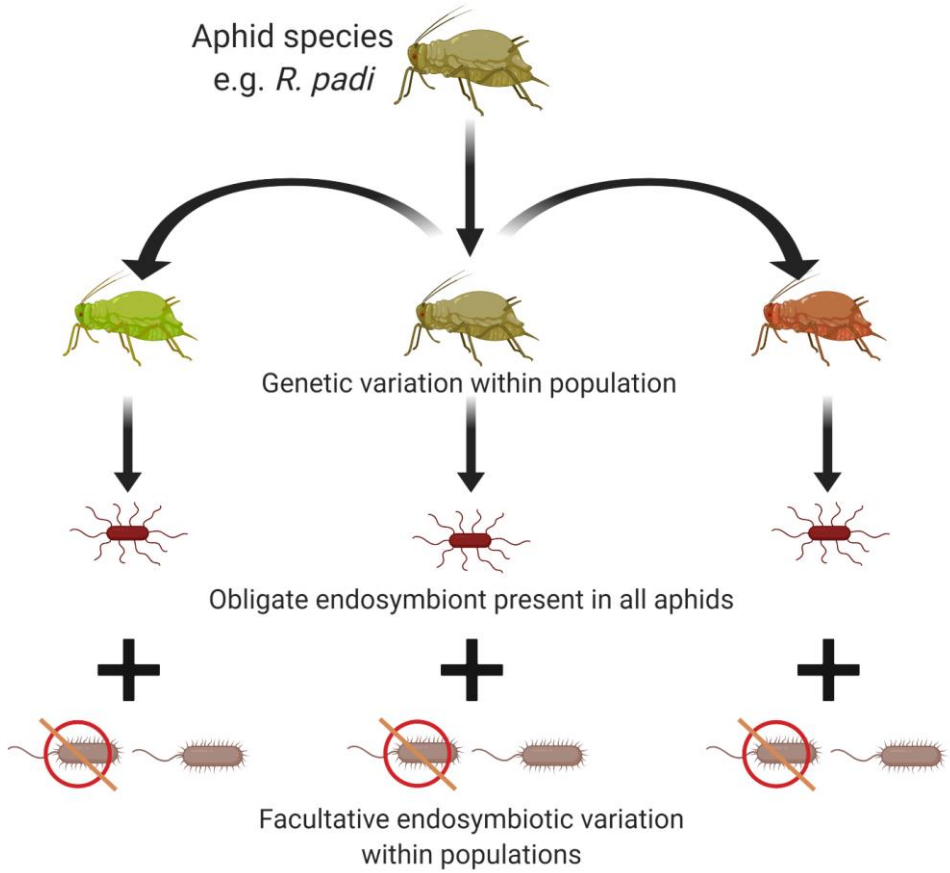
	Region	Populations	N[a]	*kdr* status			
				SS	SR	RR	%RR
Germany	LS	1	12	9	0	3	25
	SAC	12	85	85	0	0	0
	SAH	3	35	14	12	9	26
	BRB	25	237	131	25	81	34
	Total	41	369	239(64.8%)	37(10.0%)	93(25.2%)	

Højland et al., 2015

© Caitlin Willis/Rothamsted Research

Why is insect diversity is important?

- Herbivorous insects are naturally diverse
- Diversity can occur at several levels
  - Genetic diversity (genotypes)
  - Biological diversity (biotypes)
  - Other diversity (presence of non-essential symbionts)
- This diversity can have important consequences on the insect management plans

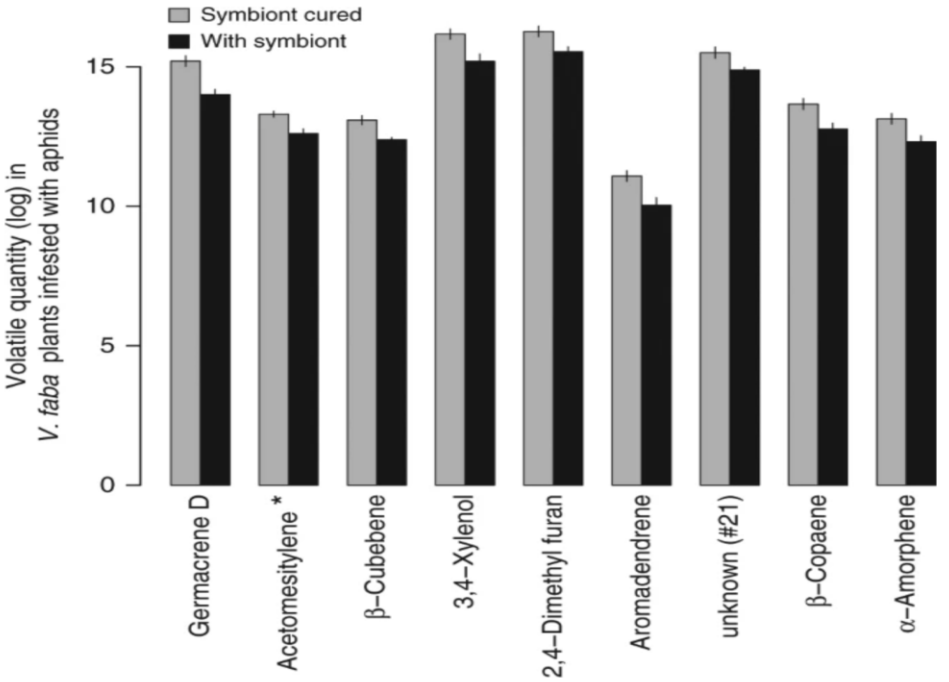


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Intra-species diversity in aphids: Endosymbiont-mediated effects

- Aphid endosymbiont *Hamiltonella defensa* provides protection against parasitoids in *R. padi*
- BUT pea aphids with *H. defensa* are predated on by ladybirds more readily
- Presence of *H. defensa* in aphids also alters the probing and feeding behaviour of aphids
- Plants infested with aphids containing *H. defensa* have a different volatile organic compound fingerprint than plants infested with aphids without *H. defensa*

- These are examples from ONE endosymbiont with > ten endosymbionts reported.
- These can also co-occur in aphids with additional consequences



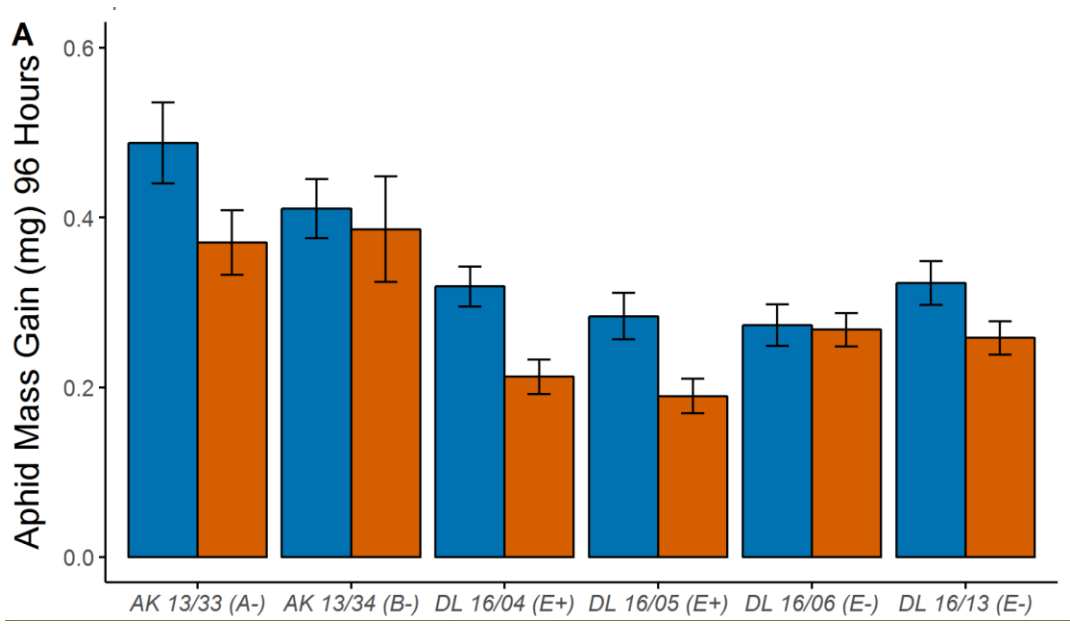


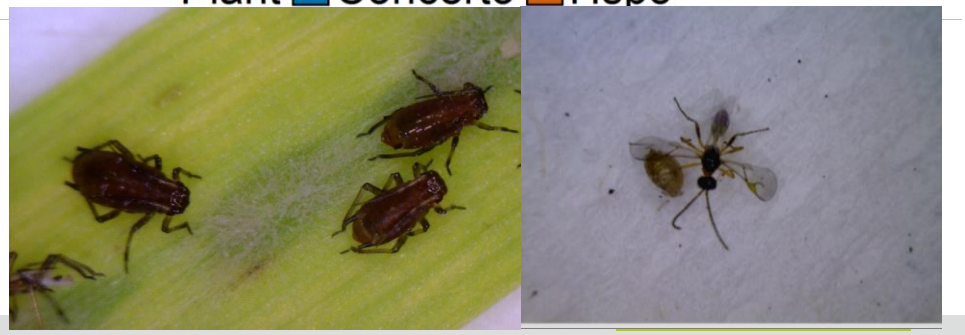


Polin et al., 2014; Frago et al., 2017; Leybourne et al., 2020; 2021

Intra-species diversity in aphids: Genotypic-mediated effects

- Specific genotypes in *S. avenae* are associated with pesticide resistance
  - Resistant genotypes are attacked more by parasitoid wasps than pesticide susceptible genotypes
  - Pesticide resistant genotypes produce fewer offspring than resistant genotypes
- Genotype in *R. padi* affects aphid reproductive rate and development





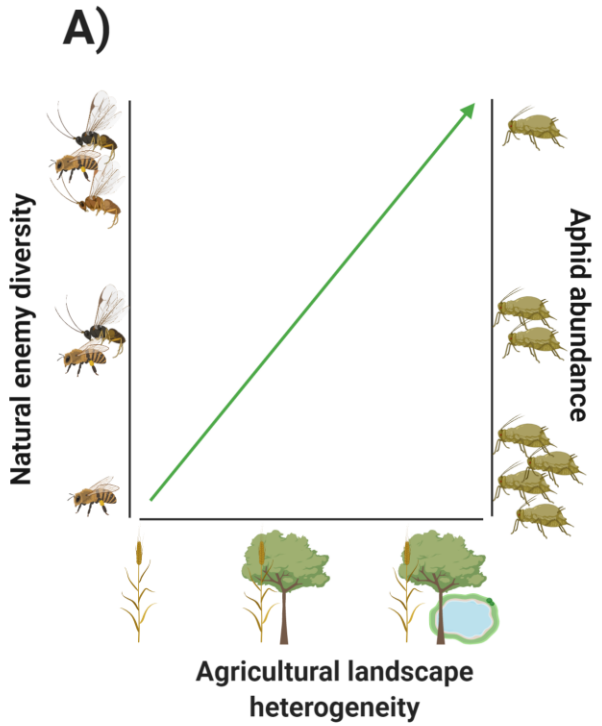
Jackson et al., 2020; Leybourne et al., 2020

Conclusion? Intra-species diversity in cereal aphids is complicated

- Most of these interactions characterised under lab conditions
- In field conditions *H. defensa* is only present in 16% of populations.
- Is there a trade-off under field conditions, what could this be?
- Studies have looked for bio-geographic drivers of intra-species diversity but found none, could the landscape be having an effect?



How might intra-species diversity and landscape complexity be linked?



A) Increased aphid suppression in more complex landscapes

B) Increased aphid suppression in more complex landscapes where aphid diversity is the strongest phenotypic selection

C) Observed aphid suppression in more complex landscapes where aphid phenotypic traits of agricultural importance are selected

D) Increased intra-specific diversity in more complex landscapes where aphid phenotypic traits of agricultural importance are selected

Graphic created with BioRender.com

Intra-species diversity in cabbage stem flea beetle is not well characterised

- Pesticide resistance widespread
- One study has looked at cabbage stem flea beetle endosymbiont diversity
  - Microbiome thought to help beetles detoxify secondary metabolites in their host plant
- No studies have explored genetic diversity

- Aim of cabbage stem flea beetle research:
  - 1) Determine how genetically diverse populations are
  - 2) Better characterise the beetle microbiome
  - 3) Examine whether any landscape-scale factors influence genetic and microbial diversity of beetle populations



Experimental overview

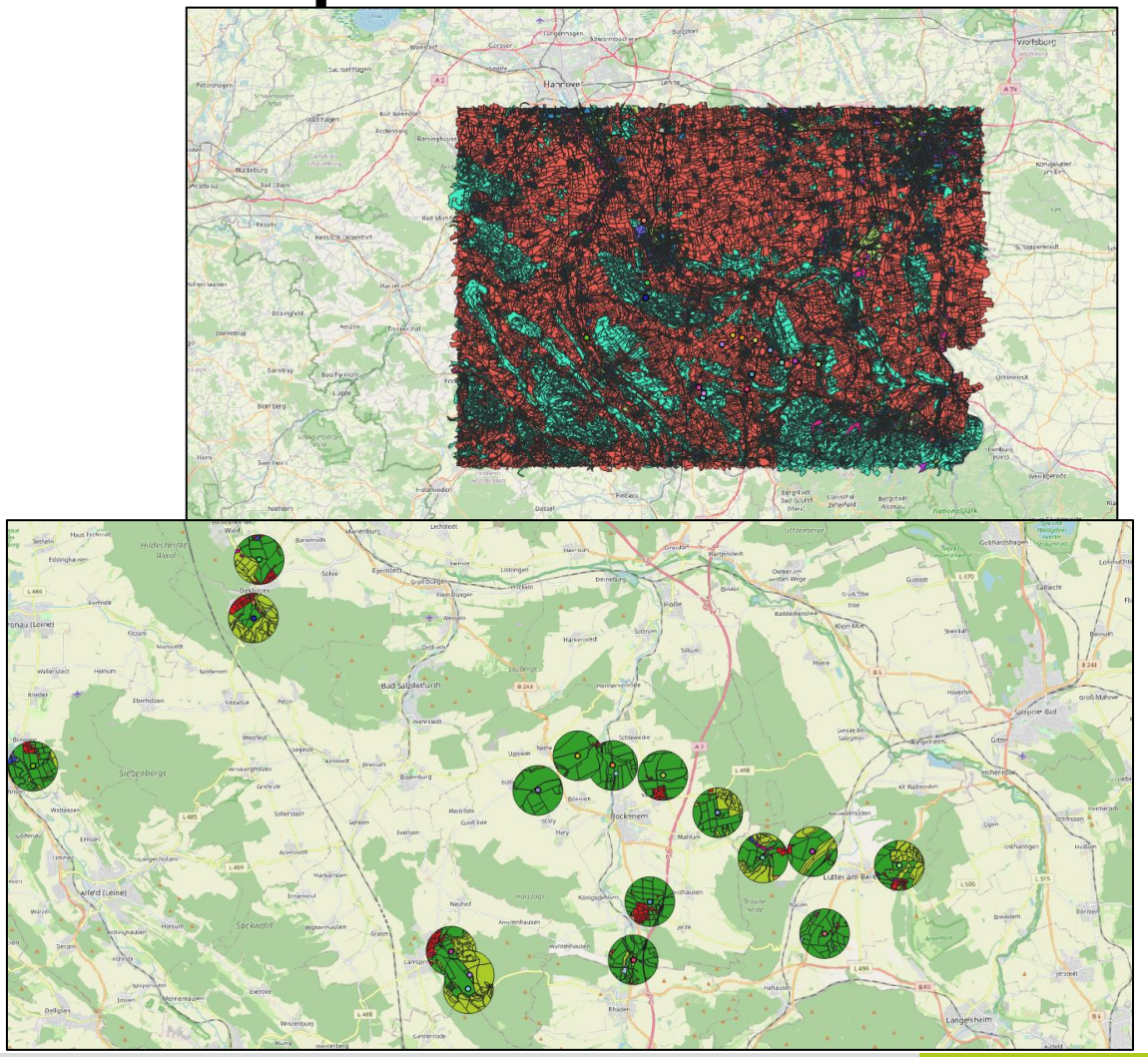
- Cereal sites:
  - One region (south of Hannover)
  - Two annual winter wheat crops (2021, repeat in 2022)
  - Field visits in summer
  - Aphid and natural enemy counts across transects, natural enemy monitoring (traps), aphid sampling (intra-species characterisation)
- Rapeseed sites:
  - Two regions (south and north west of Hannover)
  - Two annual winter rapeseed crops (2021, 2022).
  - Field visits summer (2021) and winter + summer (2022)
  - Natural enemy monitoring (traps) and beetle sampling (genotyping and microbiome)
  - Complementary MSc student project linking landscape with beetle populations, crop damage, and natural enemy diversity



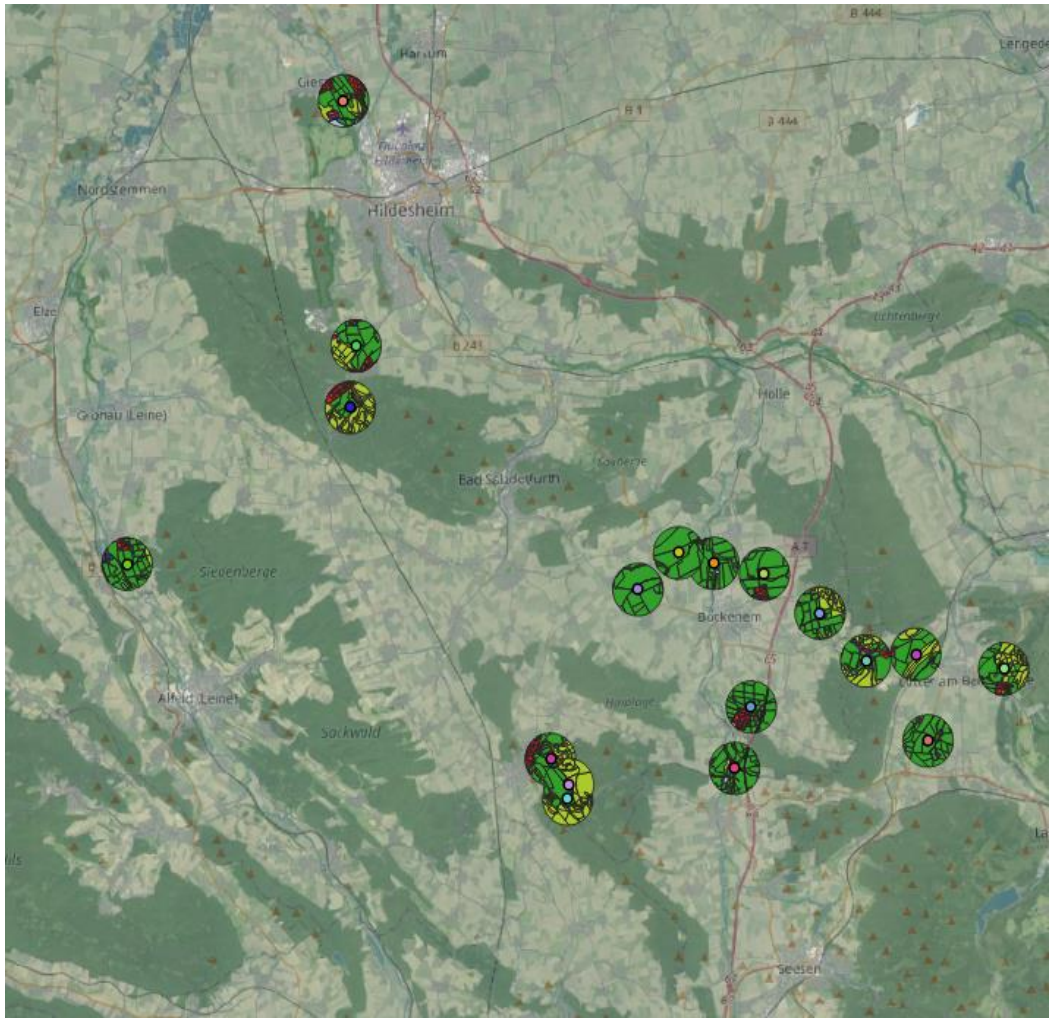


Landscape characterisation process

- Land-use data was obtained from Federal State
- Data describes
  - Agricultural land
  - Uncultivated land
  - Residential area
  - Industrial area
  - Waterbodies
  - Forest and woodland
  - Heathland and moorland
- Landscape composition was determined around each site



Experiment design: Cereal sites

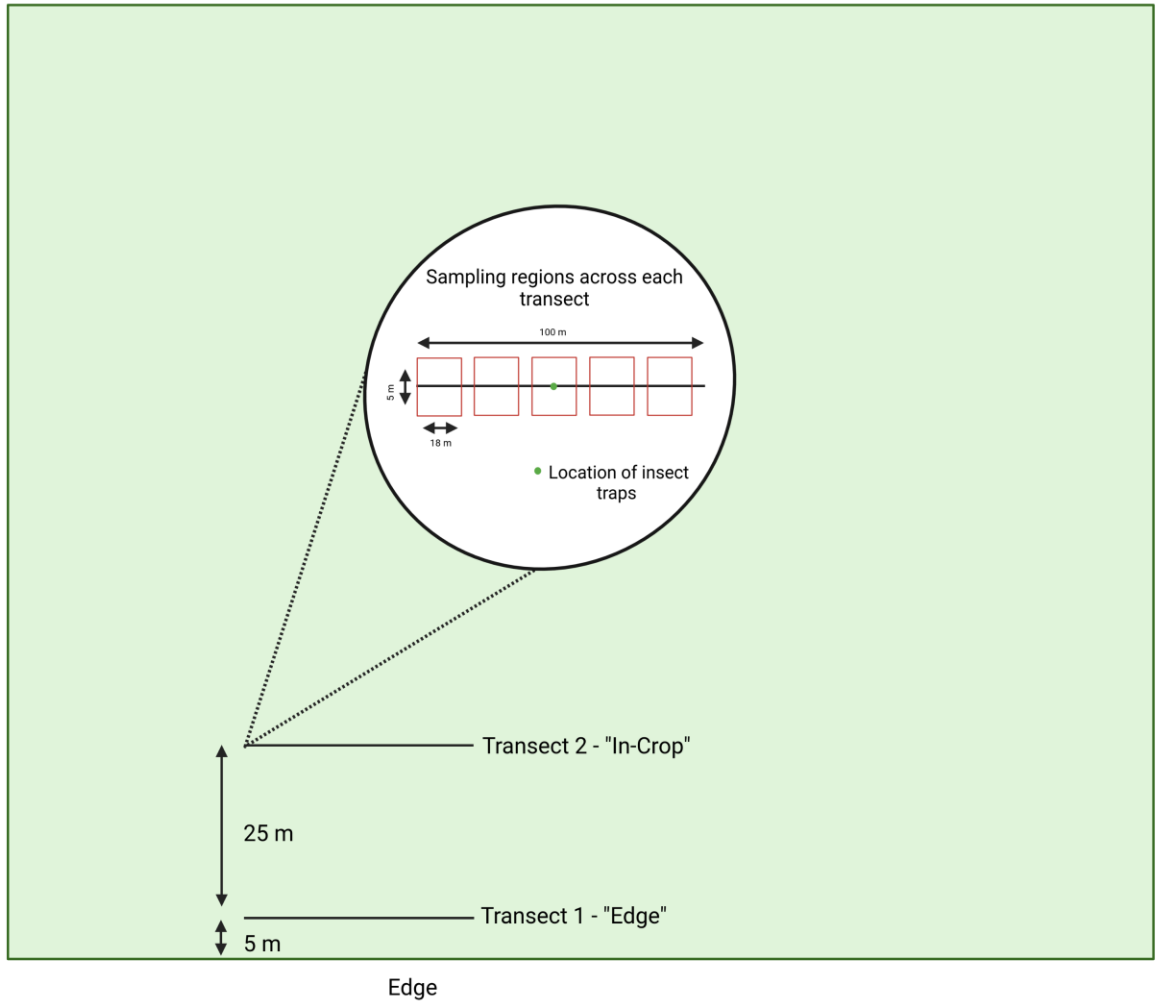


- Thank-you to BSc student (M Meyer) for finding farmers willing to provide field sites!





Experiment design: Cereal sites



18 sites visited on three occasions

- Insect diversity monitored (pan and pitfall traps)
- Aphid, mummies, parasitoids counted at five locations per transect
- Aphids, mummies, parasitoids sampled for molecular diagnosis of intra-species diversity
- Cereal beetle larva monitored







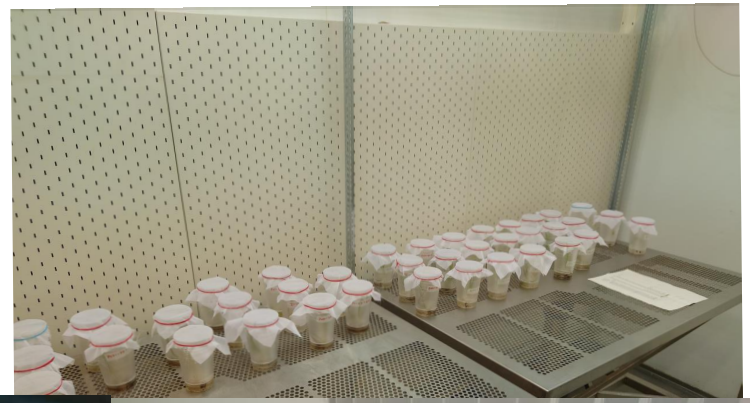
Experimental design: Rapeseed sites

- Design loosely followed cereal site approach
- Six sites (summer)
  - Insect diversity monitored (pan traps installed at four locations)
  - Live cabbage stem flea beetle collected from four locations per field
  - Beetles taken from traps if insufficient live samples
- 14 sites (autumn)
  - Insect diversity monitored (pan and pitfall traps)
  - Live cabbage stem flea beetle collected across each field
  - Beetles taken from traps if insufficient live samples
  - MSc student (A Pahl) is examining whether landscape complexity affects damage caused by adult beetles and larval numbers, will link this with natural enemy diversity

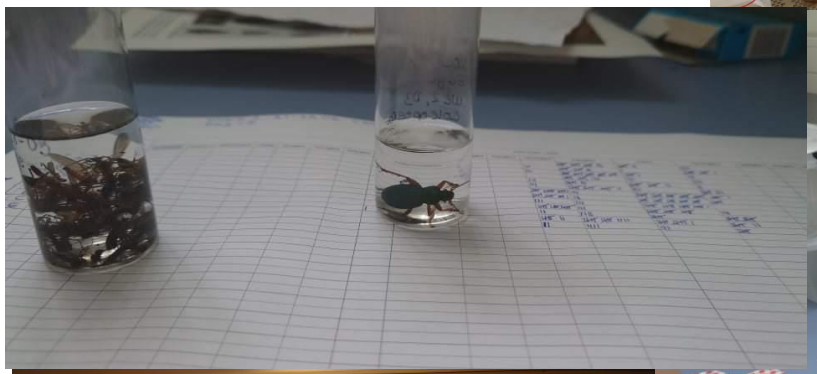


Fieldwork success: Cereal sites

- Multiple live cereal aphid cultures: 25 *S. avenae*, 7 *R. padi, 2 M. dihordum*



- 108 trap samples: processed and identified to insect Order





- 1 freezer full of samples stored awaiting intra-species diversity assessment



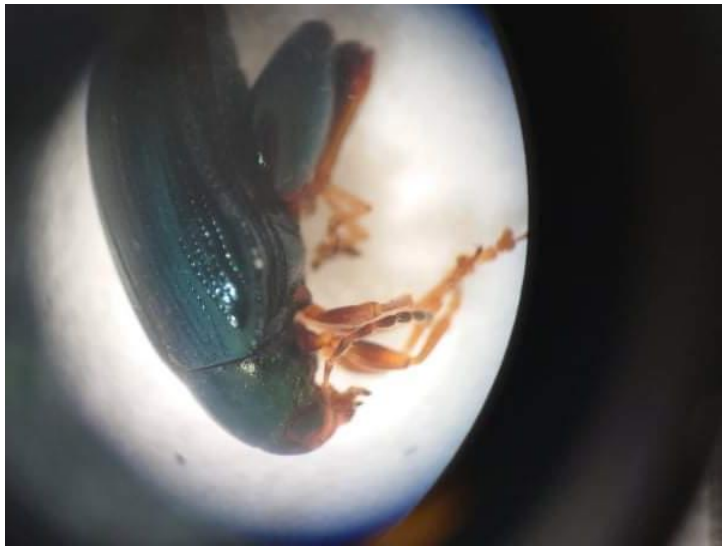


Fieldwork success: Rapeseed sites

- Summer samples – live beetles only present in 4/6 fields surveyed
- Autumn samples – live beetles only collected from 3/14 fields
- Good news – beetles present in most traps

- Summer: 48 pan trap samples processed and identified to insect Order
- Autumn 84 pan + pitfall traps to identify (A Pahl)

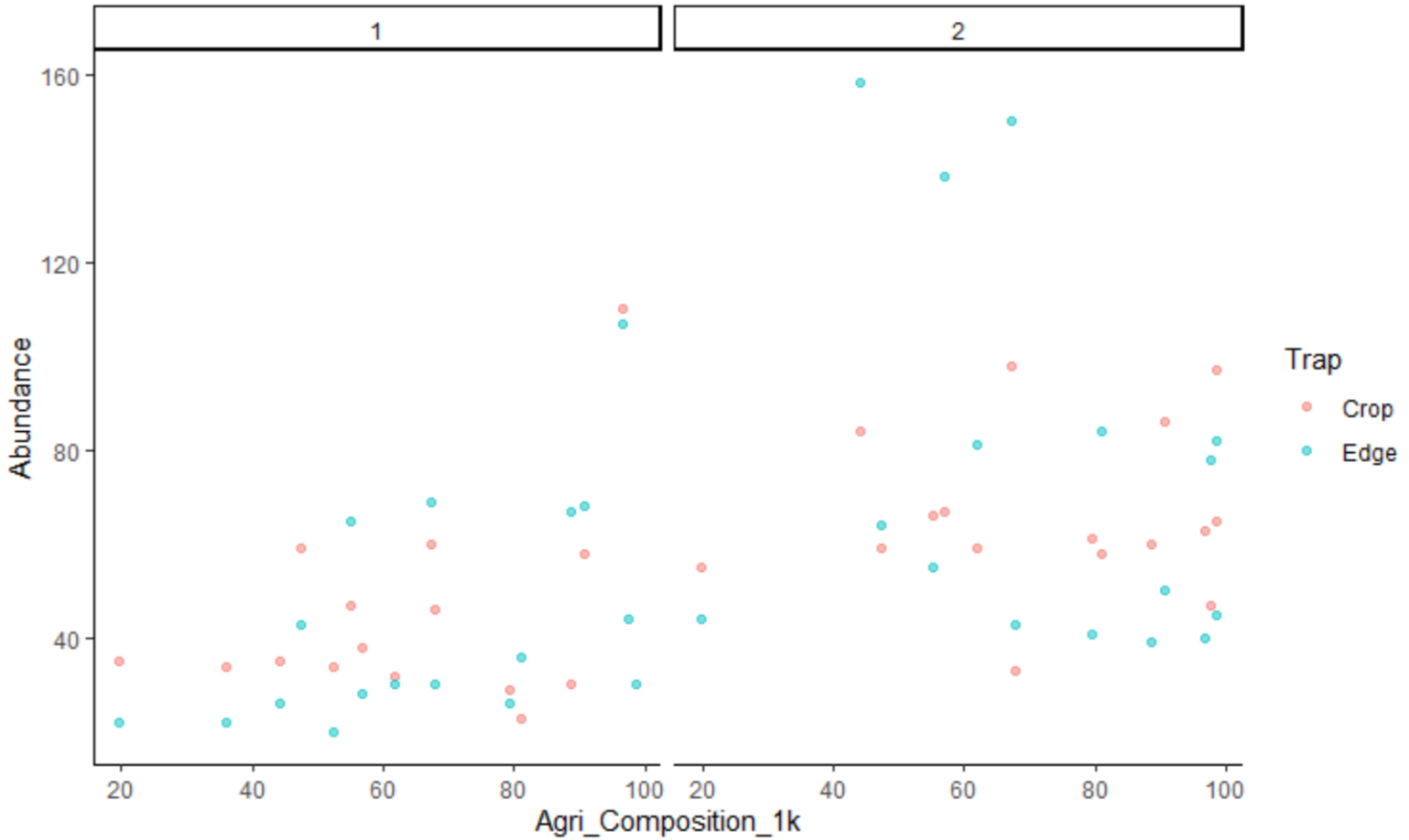
- Beetle samples stored ready for processing: dissection and sequencing of microbiome and beetle genotype





Preliminary fieldwork results: Cereal site traps

- Insect traps categorised to Order
- No trend with landscape detected BUT this data includes all insects
- Once insects identified to family can look more closely at functional groups



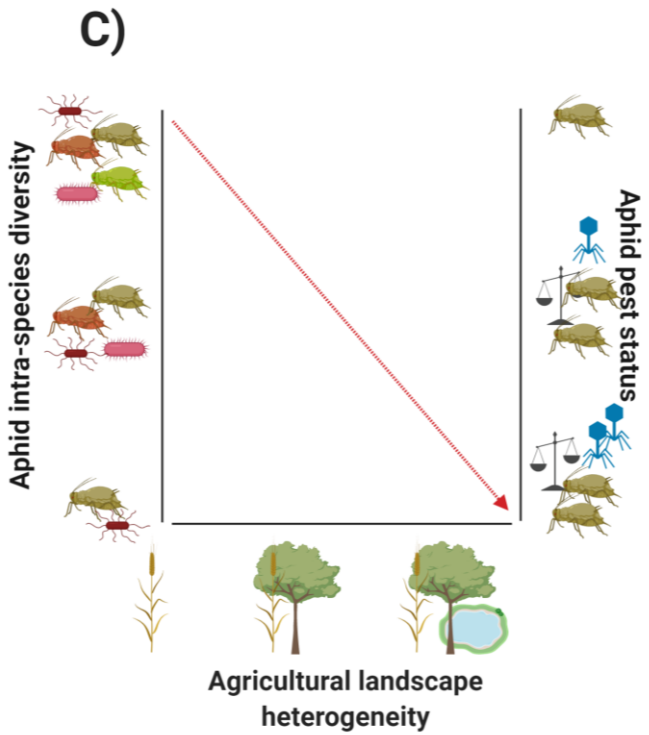
Fieldwork results

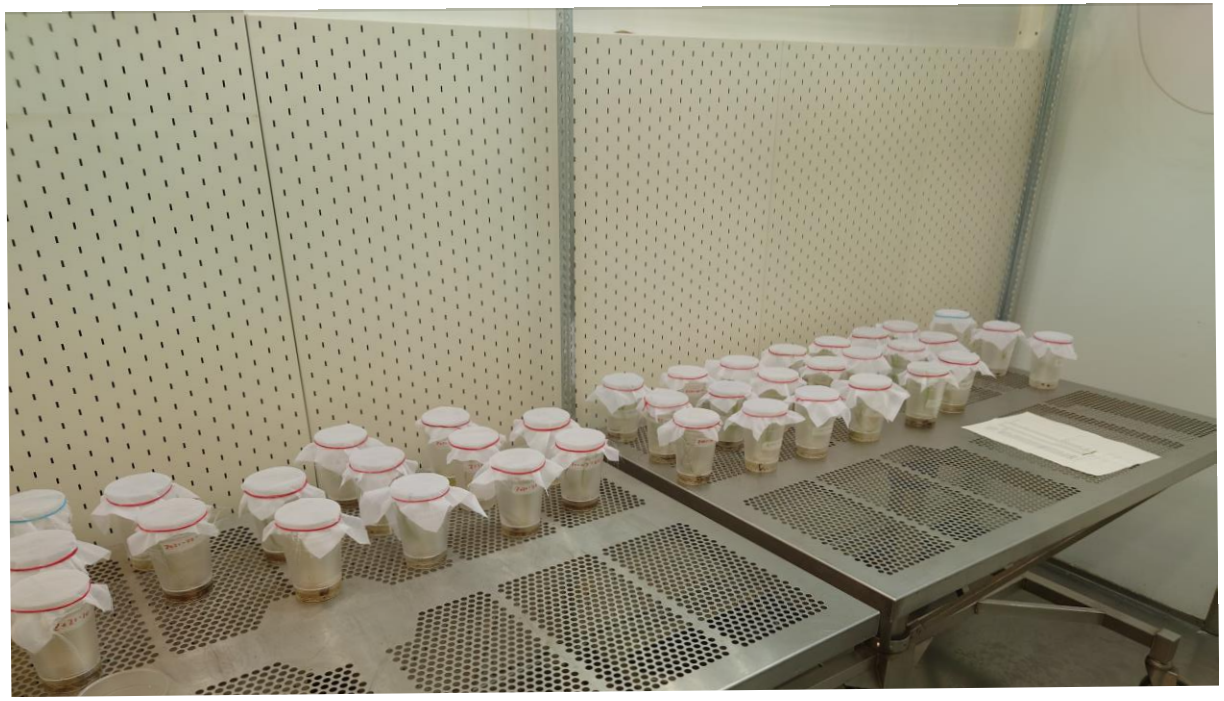
- Aphid samples collected from each field, intra-species characterisation (endosymbiont and genotype) ongoing
- Insect traps categorised to Order, further characterisation ongoing
- Field observations (aphid abundance in transects) will be assessed in relation to landscape complexity and natural enemy presence
- Beetle samples collected from each field, genotyping and microbiome characterisation ongoing





Preliminary phenotype results

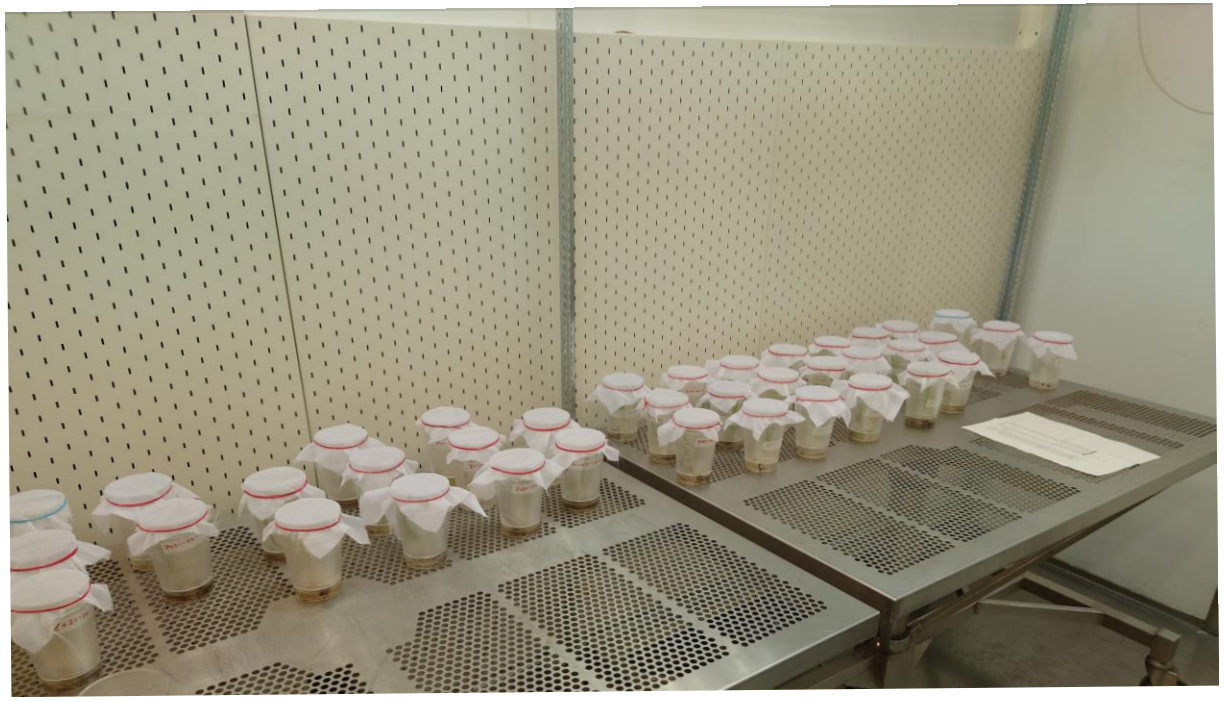




C) Observed changes in intra-species diversity correlate with a proliferation of phenotypic traits of agricultural importance

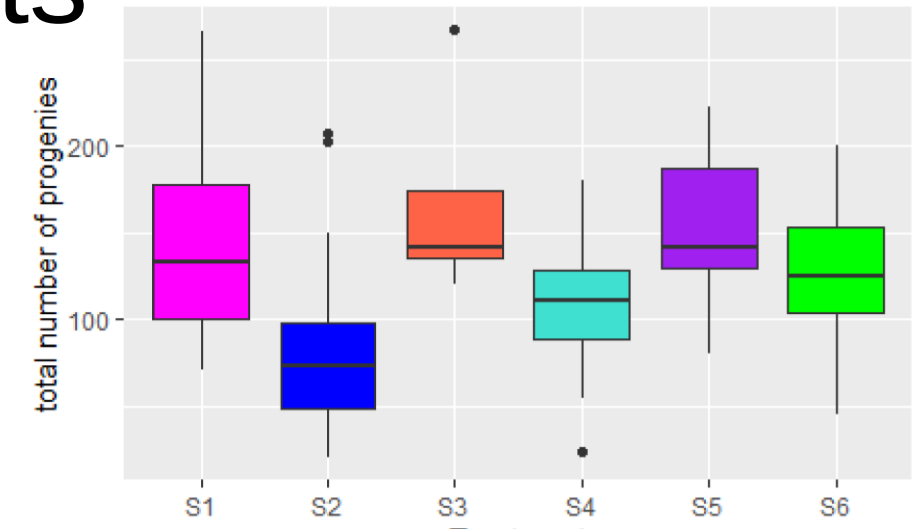
Preliminary phenotype results

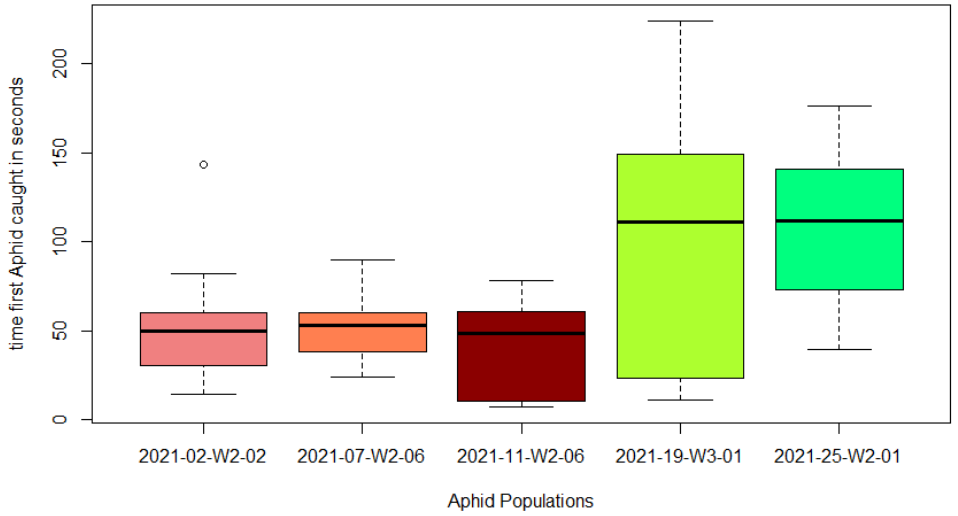
- Aphid lab cultures established
  - 25 *S. avenae*
  - 7 *R. padi*
  - *2 M. dihordum*
- Ongoing work to investigate phenotypic differences between the different populations
- Characterisation of intra-species diversity (Jan 2022) will link these phenotypes with intra-species traits



Preliminary phenotype results

- Preliminary student-led experiments
- Aphid fitness
  - Six aphid populations selected based on natural habitat (% landscape complexity) of the collection location
  - Range of insect life-history traits measured
  - Differences detected between populations
- Aphid-ladybird interactions
  - Six aphid populations selected
  - Populations selected based on colour (red or green) and natural habitat
  - Predator metrics assessed

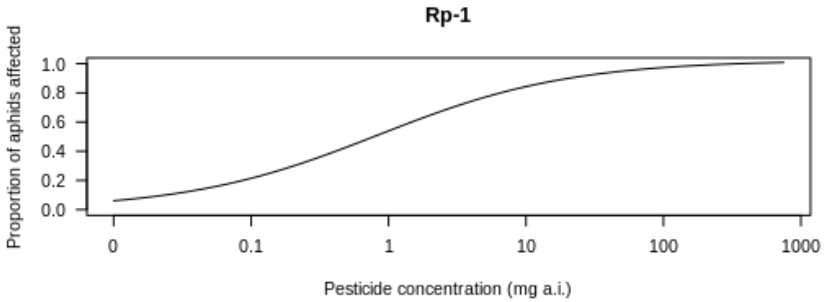


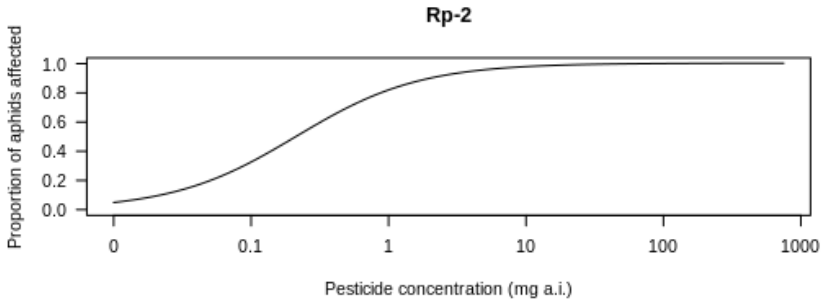


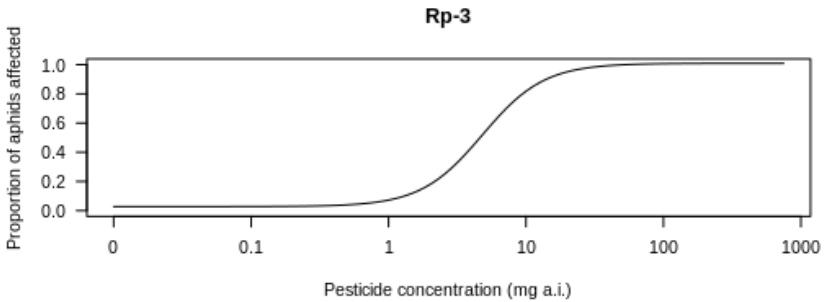
A Heitkamp, 2021; H Otto, 2021

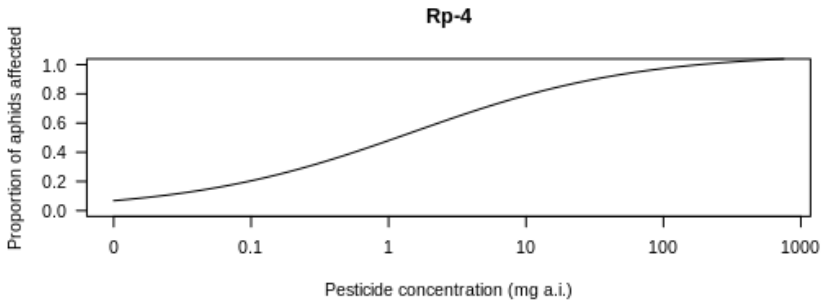
Preliminary phenotype results

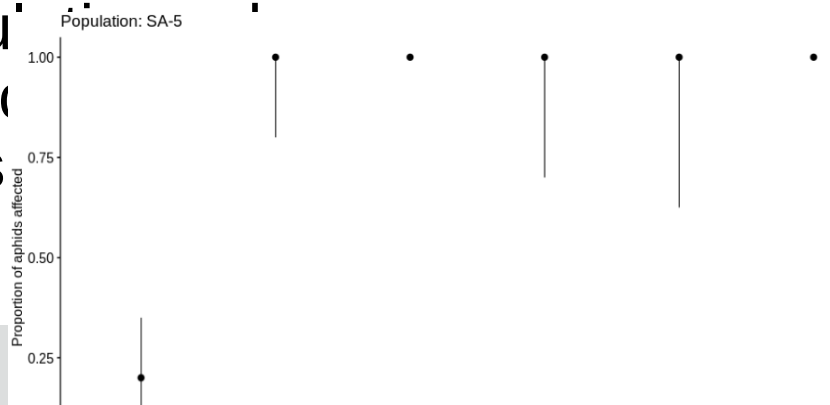
- Insecticide testing of collected populations
- *R. padi*: most populations controlled at field concentration
- BUT some decreased sensitivity?
- Grain aphid: most popu
  redu
  sens



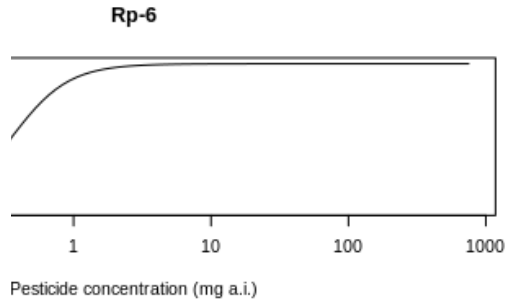












Ongoing and planned work

- Developing methodology for intra-species assessment (aphid)
- Processing summer samples to determine intra-species diversity (aphid)
- Phenotypic experiments: life-history, response to predators and parasitoids, insecticide sensitivity (aphid)
- Characterisation of aphid lab cultures: presence of endosymbionts, genotyping by sequencing
- Trap identification to family level for Coleoptera, Diptera, Hymentoptera, and Spiders (aphid + beetle)
- Repeating fieldwork in 2022 (aphid)
- Preparing beetle samples for sequencing: gut dissection, DNA extraction (flea beetle)
- Revisiting autumn sites in summer 2022 – does the beetle microbiome change across generations?
- Statistics, statistics, statistics

Acknowledgements

Agro-entomology projects:

Dr Emily Martin (Leibniz University Hannover, Germany)

Dr Sharon Zytynska (Liverpool University, UK)

Dr Antonino Malacrinò (University of Münster, Germany)

Dr Pilar Morera-Margarait (The James Hutton Institute, UK)

Petra Melloh (Leibniz University Hannover, Germany)

Antonia Pahl (MSc student; Leibniz University Hannover, Germany)

Meike Meyer (BSc student; Leibniz University Hannover, Germany)

Alexander Manentzos (BSc student; Leibniz University Hannover, Germany)

Anna-Lena Heitkamp (BSc student; Leibniz University Hannover, Germany)

Hannah Otto (BSc student; Leibniz University Hannover, Germany)

Christoph Harms (Student intern, Leibniz University Hannover, Germany)

Eric Muehlnikel (Student intern, Leibniz University Hannover, Germany)

Kristina Dauven (Student intern, Leibniz University Hannover, Germany)

