Barley yellow dwarf virus (BYDV)

Challenges & Opportunities for Effective Management

Lawrence Bramham
13/01/2025

ROTHAMSTED RESEARCH

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Overview

- Context
  - Collaborations are key
  - Barley yellow dwarf virus
- Challenges
  - Traditional control
  - Genetic resistance/tolerance?
  - Climate change (vectors? new strains?)
  - Rothamsted Insect Survey
  - What's out there?
- Opportunities
  - Diagnostics and high-throughput testing
  - Sampling

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Genetic Improvement Networks

Department for Environment Food & Rural Affairs

Defra supports the five GINs to improve major UK crop varieties:

VeGIN – The Vegetable Genetic Improvement Network

OREGIN – Defra Oilseed Rape Genetic Improvement Network

Wheat Genetic Improvement Network 5

PCGIN – Pulse Crop Genetic Improvement Network

&

Soft Fruit Genetic Improvement Network

Wheat Genetic Improvement Network (WGIN):

- **BYDV** = previous UK viral target, now diversifying
- Diverse management team and stakeholders

NIAB · John Innes Centre – Unlocking Nature's Diversity · ADAS · DSV · KWS · RAGT SEEDS · SAATEN UNION · Met Office · AHDB · Elsoms The Seed Specialists · Limagrain from earth to life · syngenta

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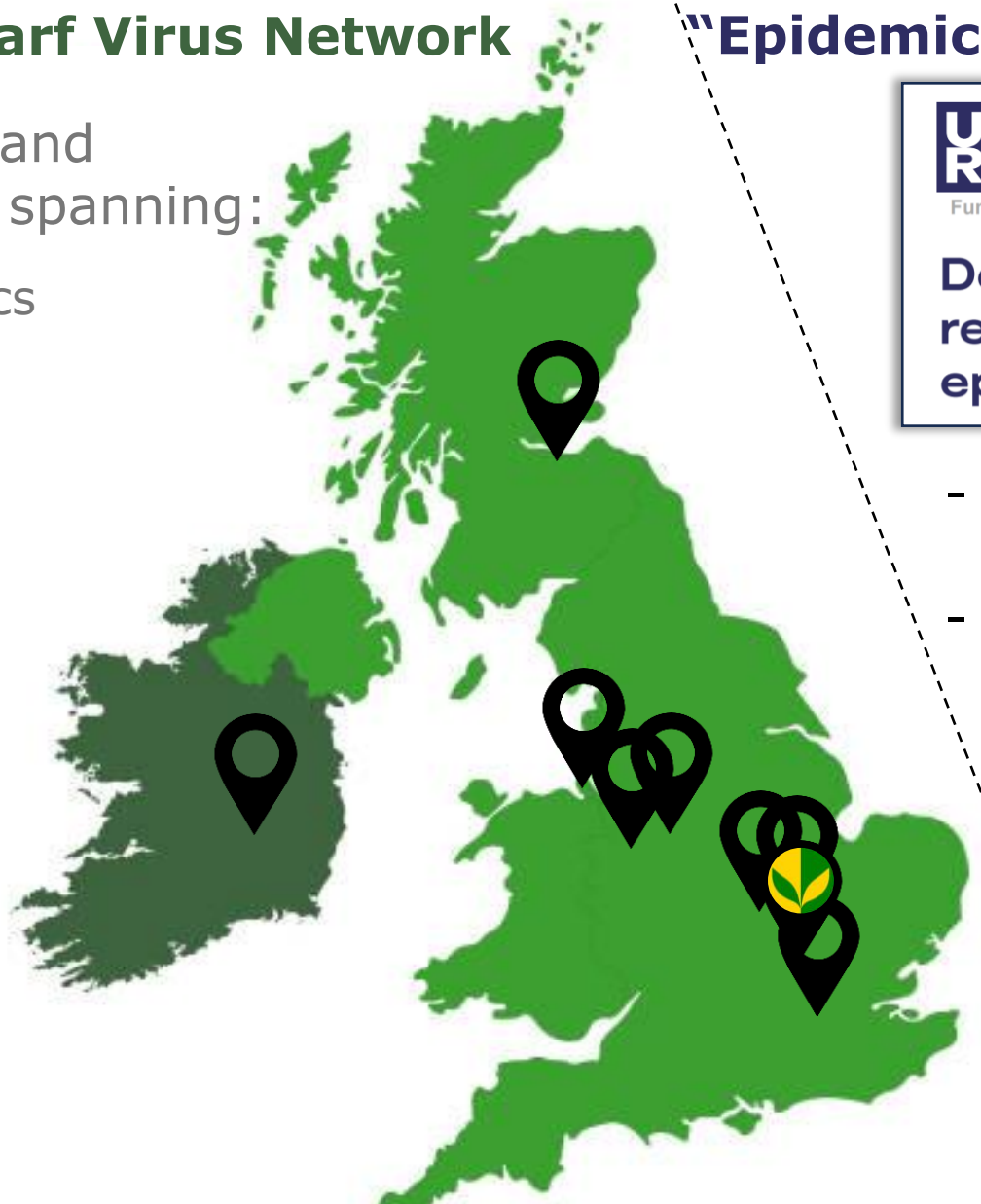
Collaborations are key

UK & Ireland Yellow Dwarf Virus Network

Virologists, entomologists and modellers at key locations spanning:

- Biomathematics & Statistics Scotland
- University of Liverpool
- Keele University
- Harper Adams University
- Teagasc
- University of Cambridge
- AHDB
- ADAS
- Rothamsted Research
- University of Greenwich
- **More and growing…**



"Epidemic Preparedness" Team

UK Research and Innovation

Funding opportunity

Develop interdisciplinary research proposals to tackle epidemic threats

- Workshop last Thu/Fri
- >20 experts tasked with evaluating the:

"***tools, technologies and policy devices required to tackle vector-borne viral and bacterial epidemics in agriculture***"

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Wheat-Insect-Virus Interactions

Subgroup within Wheat Pathogenomics Team
(RRes, PI: Prof. Kim Hammond-Kosack)

- Izayana Sandoval-Carvajal
SWBio DTP PhD student (RAGT, Uni of Bristol)

- Postdoc / subgroup lead

BYDV work =

Wheat Genetic Improvement Network

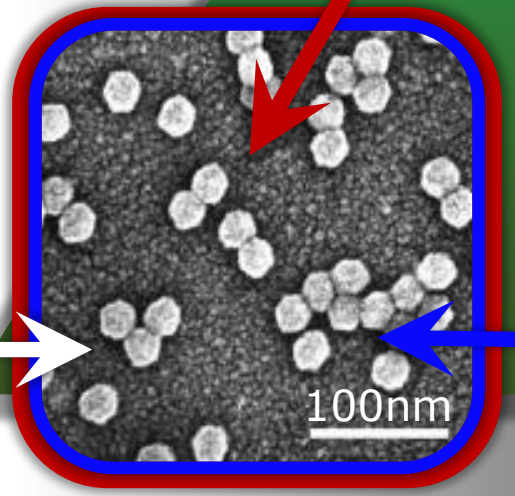
& SWBio DTP

Aphid resistance work =

DSW DELIVERING SUSTAINABLE WHEAT

Wheat

Diagnostics



Viruses
(BYDV)

Aphids

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Barley yellow dwarf virus (BYDV)

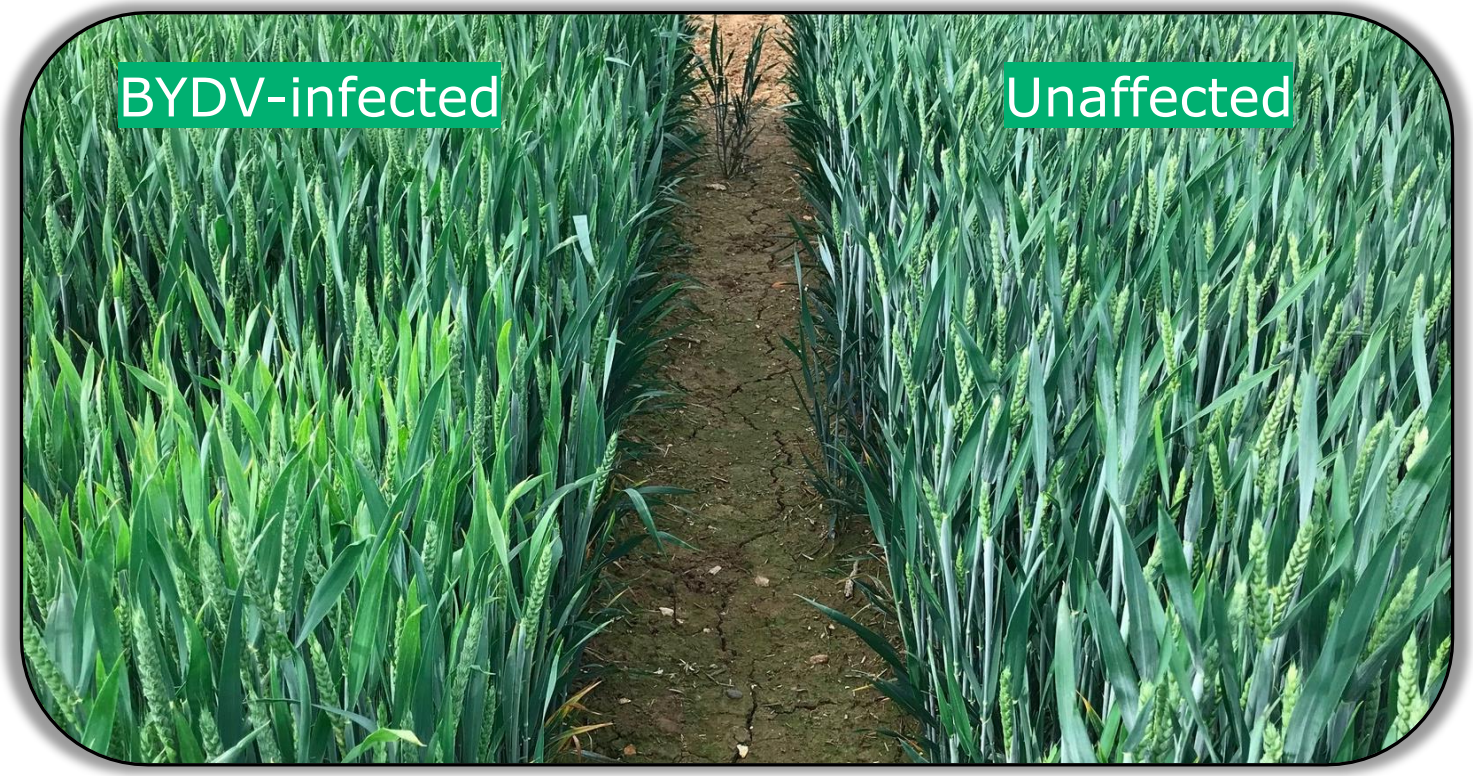
- Harvest yield loss in wheat due to natural BYDV infection = **5 - 80%**, average of **30%***

- Indistinct disease phenotype limits rapid diagnosis

- No practical virus-focussed chemical control

- Aphid vectors targeted, and ”resistant” cultivars developed

- Interactions between aphid vector species and BYDV strains = complex



*Aradottir & Crespo-Herrera (2021). *Current Opinion in Insect Science.*, *45*, 59-68

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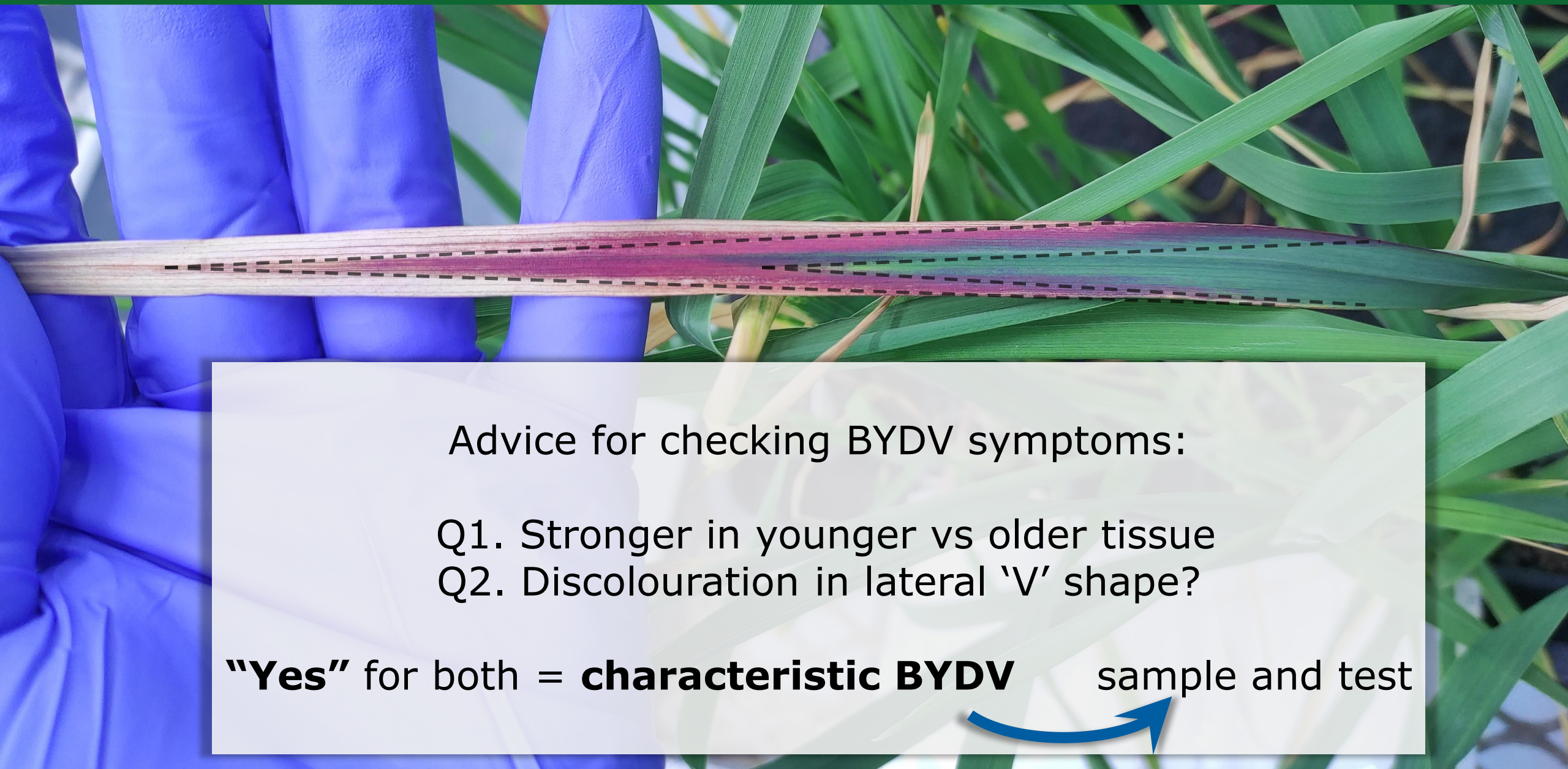
Barley yellow dwarf virus (BYDV)



Advice for checking BYDV symptoms:

Q1. Stronger in younger vs older tissue
Q2. Discolouration in lateral ‘V’ shape?

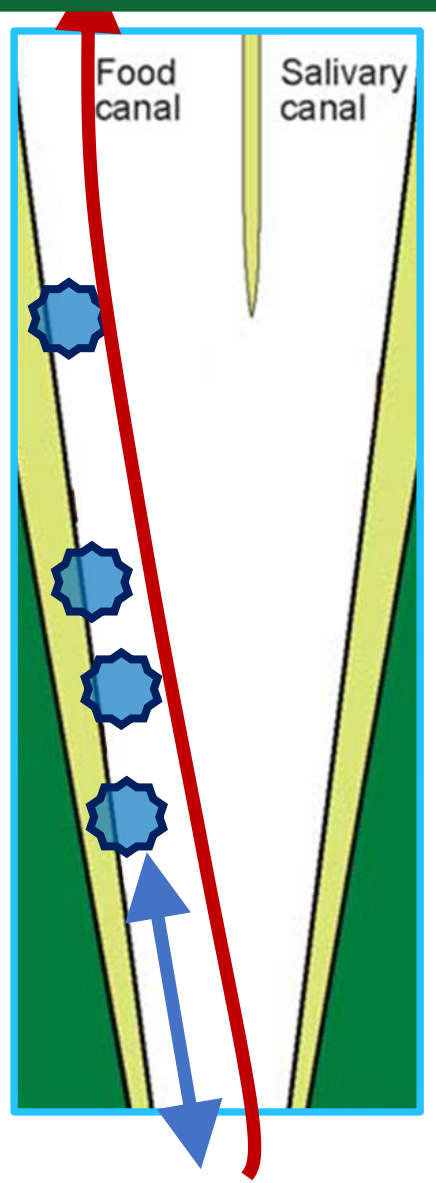
“Yes” for both = **characteristic BYDV** sample and test

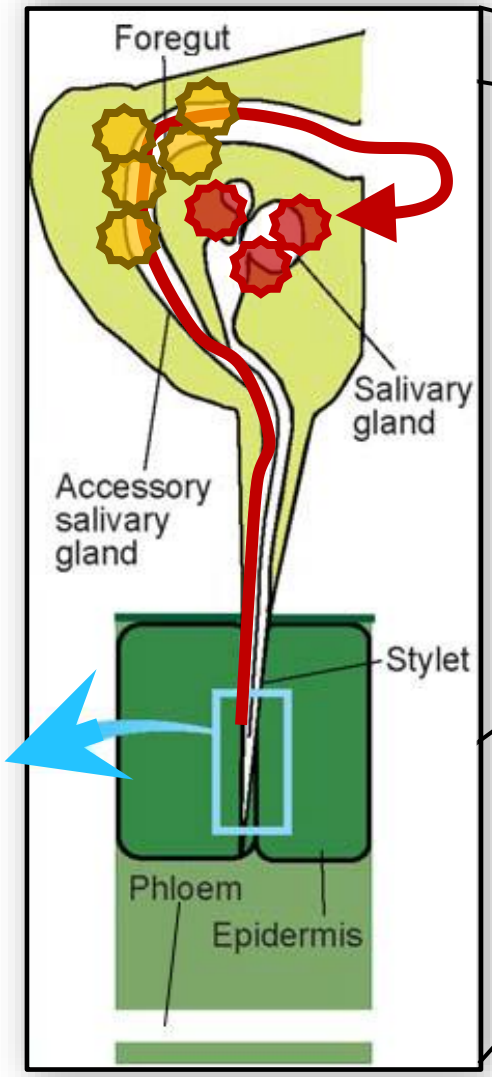
Aphid viral transmission

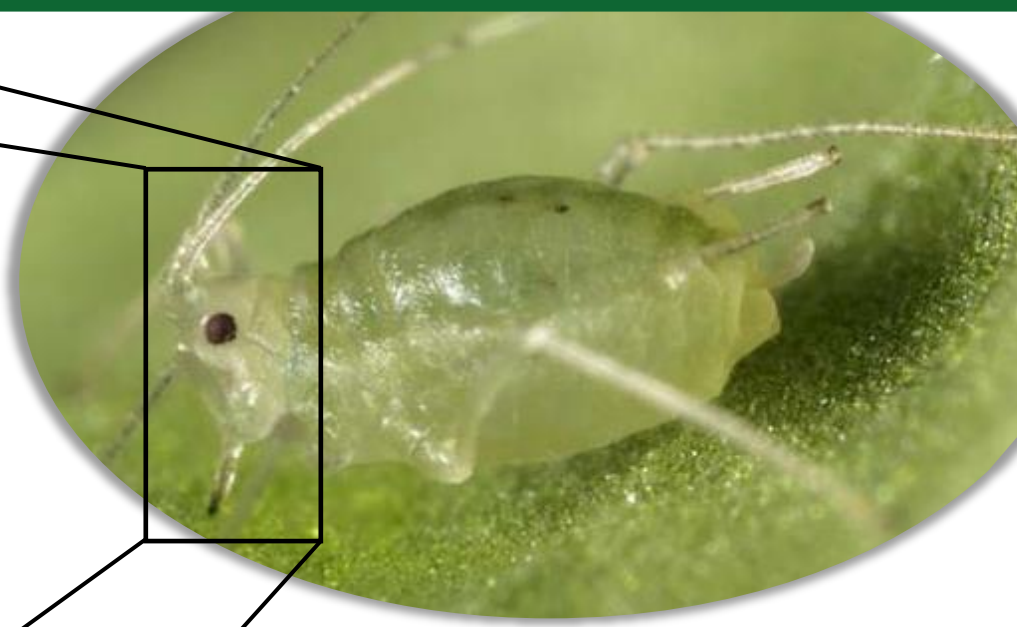
= Non-persistent

= Persistent "circulative"

= Semi-persistent





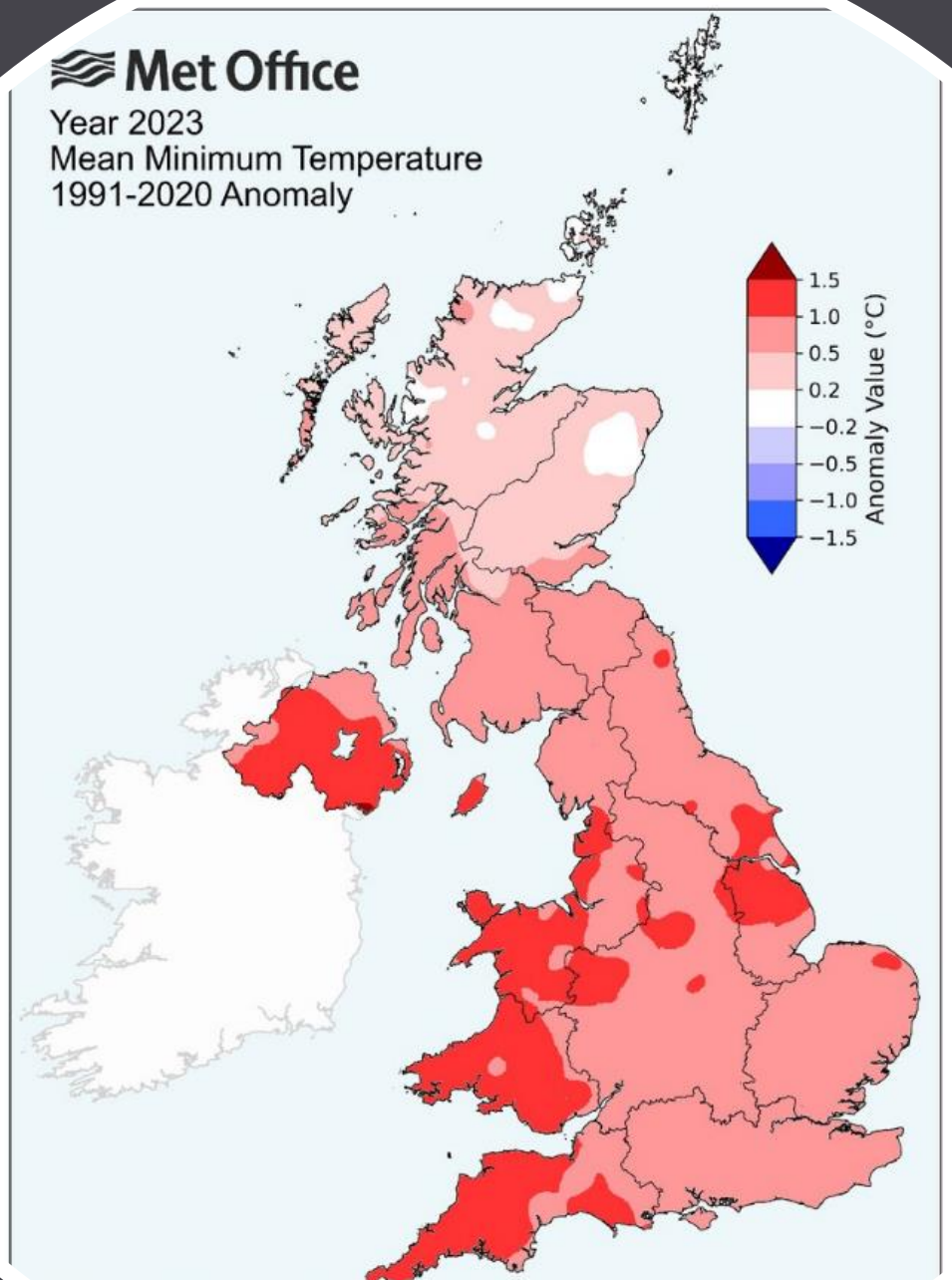


BYDV = persistent

- The ability and efficiency to vector BYDV strains varies between aphid species…and populations

Adapted from: Ng and Perry (2004) *Molecular Plant Pathology*, **5(5),** 505-511.

Challenges



Adapted from: State of the UK Climate 2023;
Kendon et al., (2024) *International Journal of Climatology,* **43,** 1-83

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Yellow dwarf virus strains

Genus	Species	Strain	Known aphid vectors*
Luteovirus	BYDV	**PAV**	*R. padi, S. avenae, Metapolophium dirhodum, Schizaphis graminum, Sitobion fragariae*
		MAV	*S. avenae, M. dirhodum, R. padi, S. fragariae*
		PAS	*Rhopalosiphum maidis*
		GAV	*Scizaphis graminum, S. avenae*
Polerovirus	CYDV	**RPV**	*R. padi, S. graminum*

Rhopalosiphum padi
bird cherry-oat aphid

Sitobion avenae
English grain aphid

*Aradottir & Crespo-Herrera (2021). *Current Opinion in Insect Science.*, *45*, 59-68

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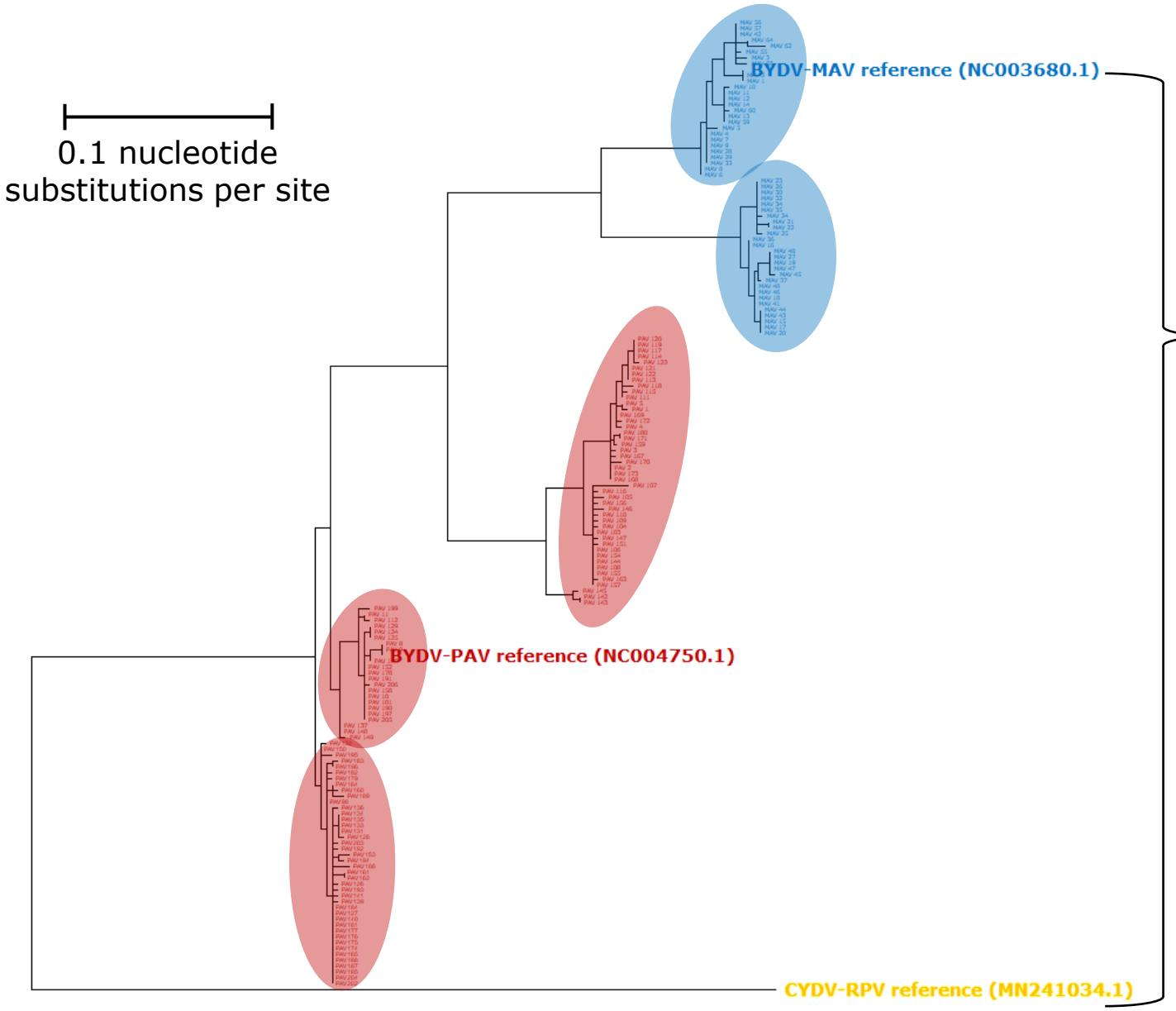
BYDV strain variation



- Strains **BYDV-MAV** and **BYDV-PAV** considered most impactful for UK
- Global **MAV** and **PAV** diversity, based on subset of NCBI data
- Substrain variation suggested on global scale
- **Molecular BYDV diagnostics often based on limited data**

BYDV-MAV sequences from NCBI, n = 53
BYDV-PAV sequences from NCBI, n = 110
NCBI, National Centre for Biotechnology Information

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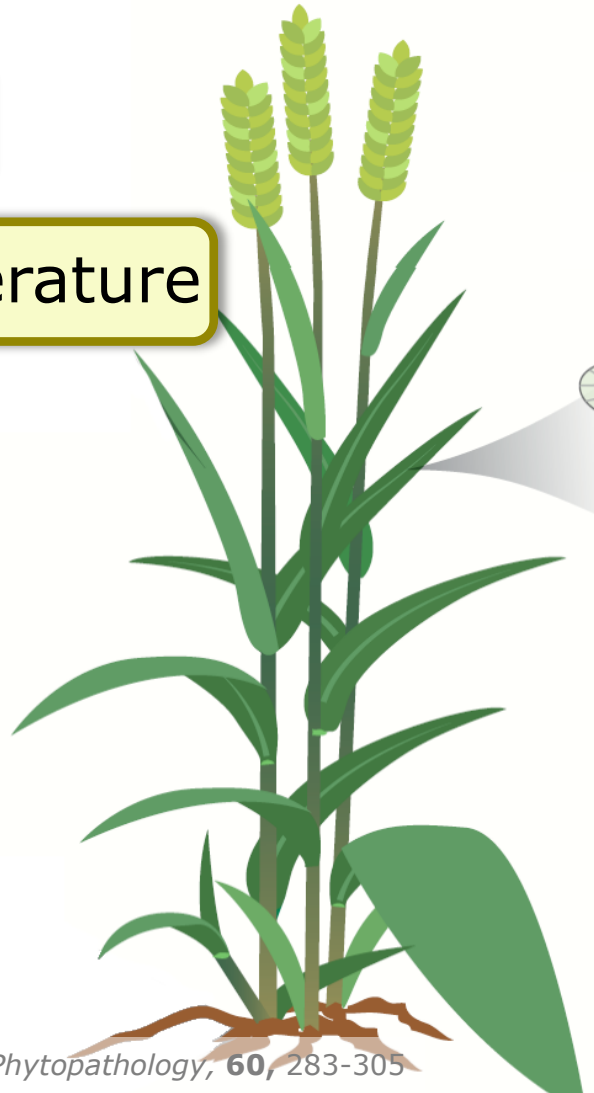
Climate change impacts

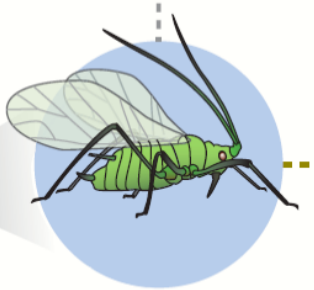
Future impacts upon aphid-wheat-virus pathosystems from:

- Elevated CO_2
- Elevated temperature
- Drought

Climate change to exacerbate need for BYDV management



Aphids



↓ (or no) Δ to population size
(yellow dwarf viruses)
eCO_2 × eTemperature × YDV
show no change to aphid fitness

↑ Food consumption
↑ Metabolic rate
↑ Abundance
↑ Alates
↑ Flight activity/movement
↑ Interplant movement by apterous aphids
↑ Dropping rate from plants
↓ Generation time

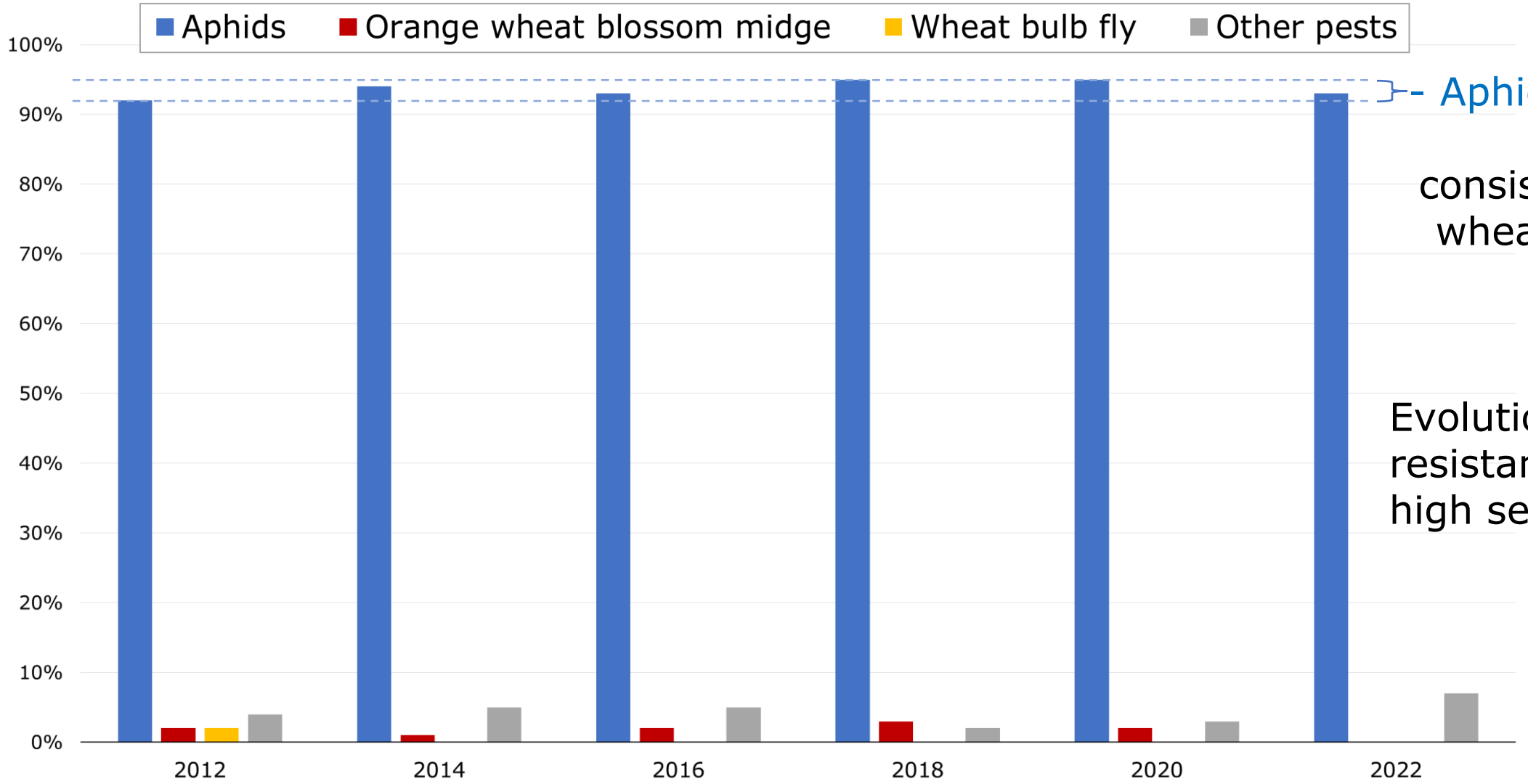
↑ Movement
↑ YDV transmission
↑ Alates
Drought × eTemperature
show increased aphid landing on plants

Adapted from: Peters et al., (2022) *Annual Review of Phytopathology*, **60**, 283-305

ROTHAMSTED RESEARCH

Aphids = key insecticide target

Insect targets, where stated, for foliar insecticide application to wheat in the UK*:



Aphids (**92 - 95%**)
=
consistent target for wheat applications

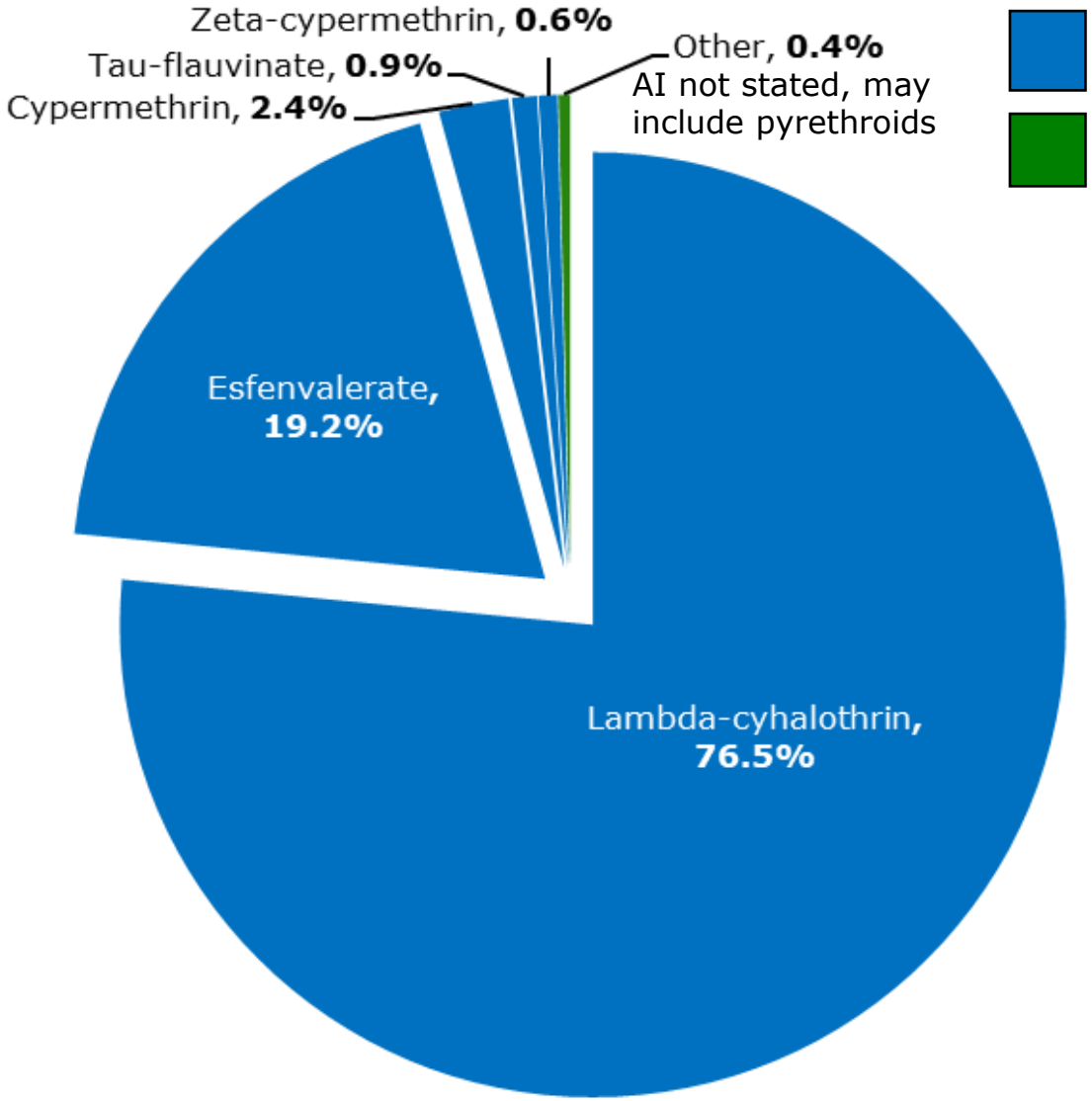
Evolution of insecticide resistance(s) due to high selection pressure

*UK Pesticide Usage Survey Reports: 250, 263, 271, 284, 295 & 309

ROTHAMSTED RESEARCH

Aphids = key insecticide target

Main foliar insecticide AI formulations (most recent data available, 2022 survey[1]):



- Pyrethroid-based active ingredient (AI)
- Other

&

Rhopalosiphum padi (bird cherry-oat aphid) = ***Sitobion avenae*** (English grain aphid)

impactful UK cereal aphids/BYDV vectors

- Moderate pyrethroid resistance widespread across UK *S.avenae*
- Evidence of pyrethroid tolerance in *R.padi* in Ireland[2]

[1]Ridley et al., (2023) UK Pesticide Usage Survey Report 309
[2]Walsh et al., (2020). *Outlooks on Pest Management,* 31, 5-9

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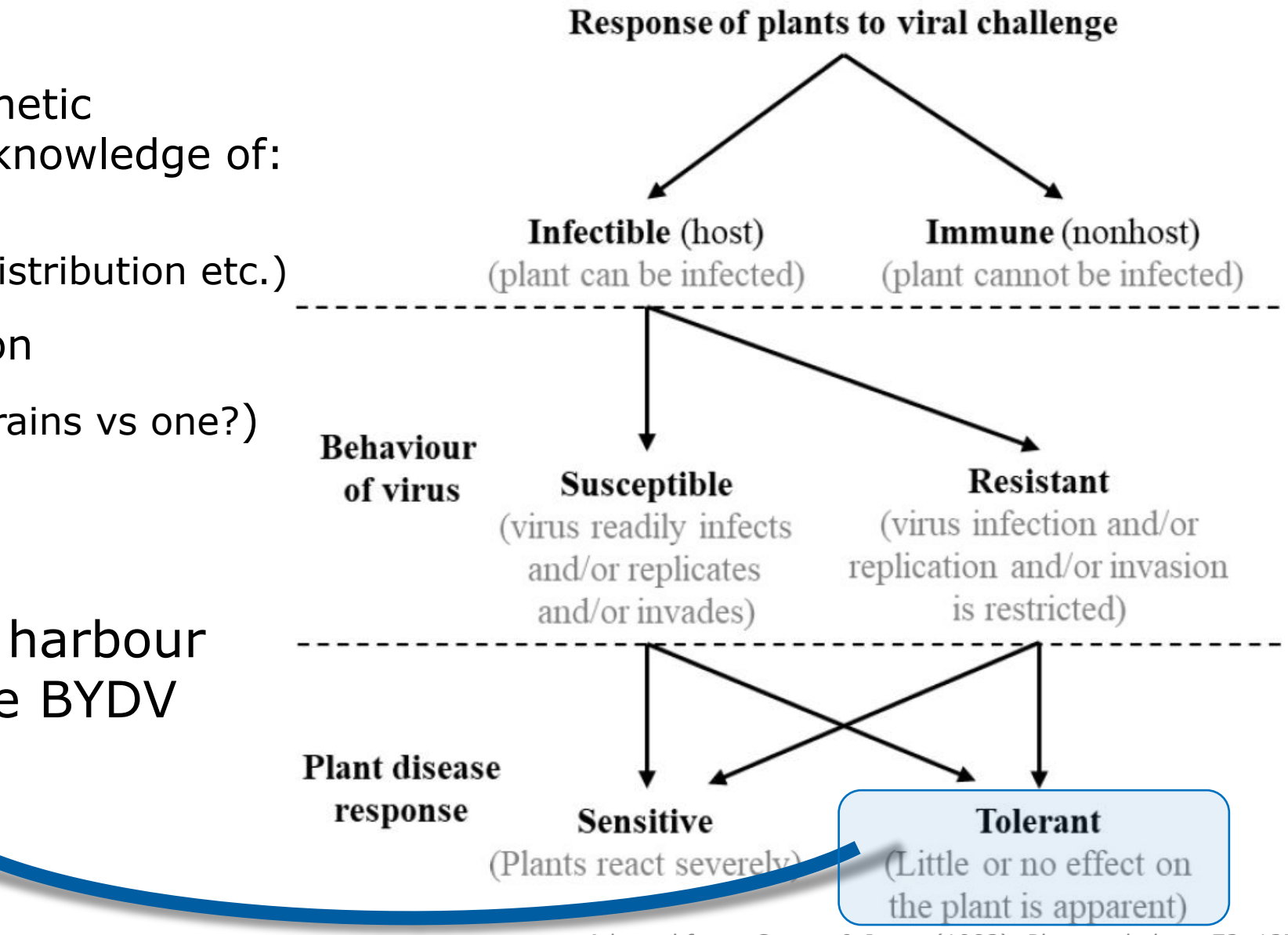
BYDV resistance?

Effective deployment of genetic resistances depends upon knowledge of:

- Inoculum (BYDV strains, distribution etc.)
- Resistance mode-of-action
- Resistance spectra (all strains vs one?)
- Resistance or tolerance…

"Can tolerant varieties harbour BYDV and/or influence BYDV prevalence?"



Adapted from: Cooper & Jones (1983). *Phytopathology*, 73, 127-128

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BYDV resistance?

Genetic sources of resistance are relatively scarce…

Barley:

- Four genes linked to tolerance/resistance ("*Ryd1* - *Ryd4Hb*", & 3 QTLs)
- *Ryd2* = most heavily deployed[1]
- Reduces viral titre in young plants, some doubt for older plants
- Virus can still spread systemically

Wheat:

- Similarly, four BYDV-resistance linked genes ("*Bdv1* – *Bdv4*")[2]
- *Bdv2* originated from *Thinopyrum intermedium*
- Winter wheat developed by:

R·A·G·T SEEDS

Genserus

[1]Jarošová, et al., (2016). *Field Crops Research*, *198*, 200-214.
[2]Aradottir & Crespo-Herrera (2016). *Current Opinion in Insect Science*, *45*, 59-68.

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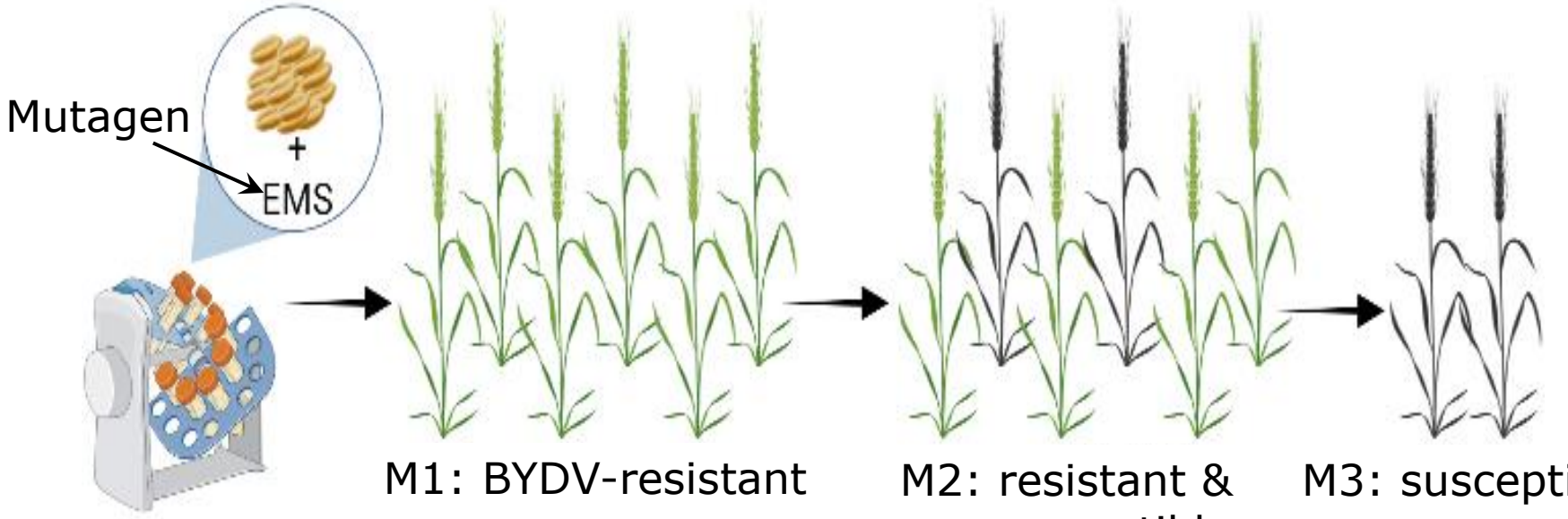
BYDV resistance?

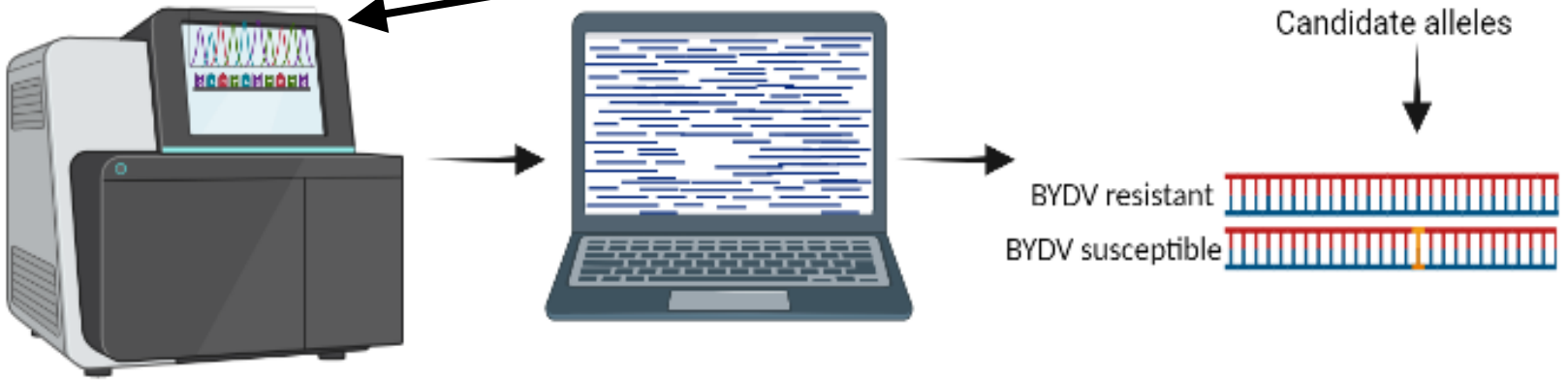
Exploring RGT cv. Wolverine BYDV resistance/tolerance

SWBio DTP

RAGT SEEDS

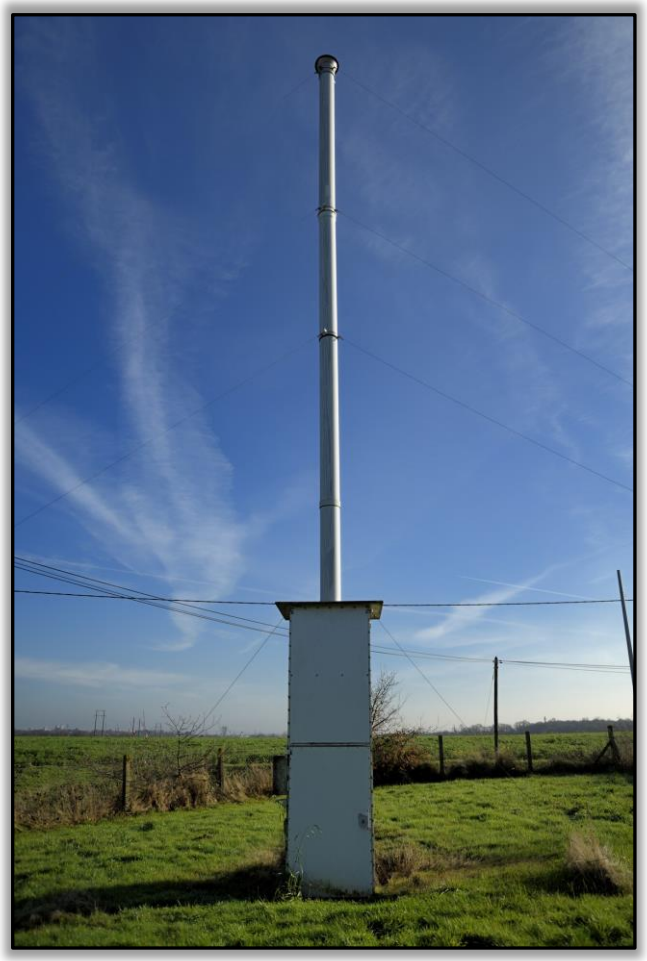
Genserus



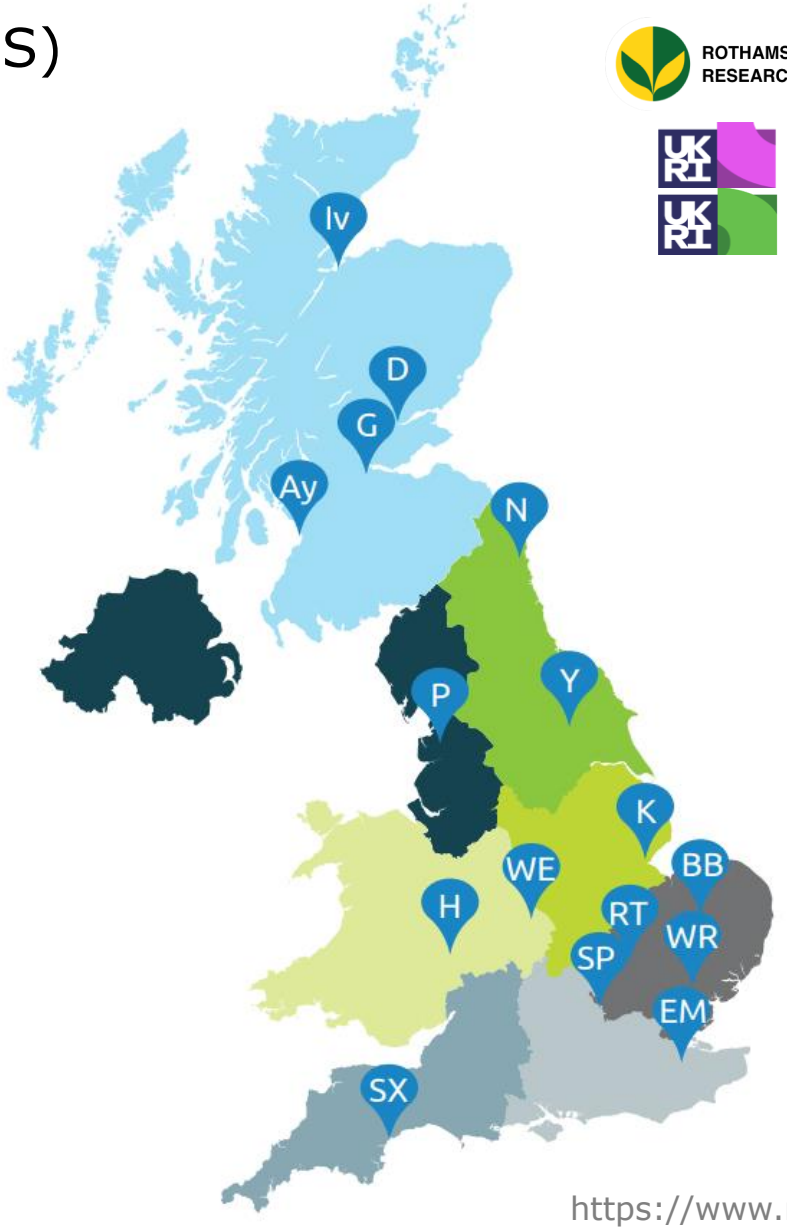


What's out there?

- Nationwide Rothamsted insect survey (RIS)
- Started in 1964



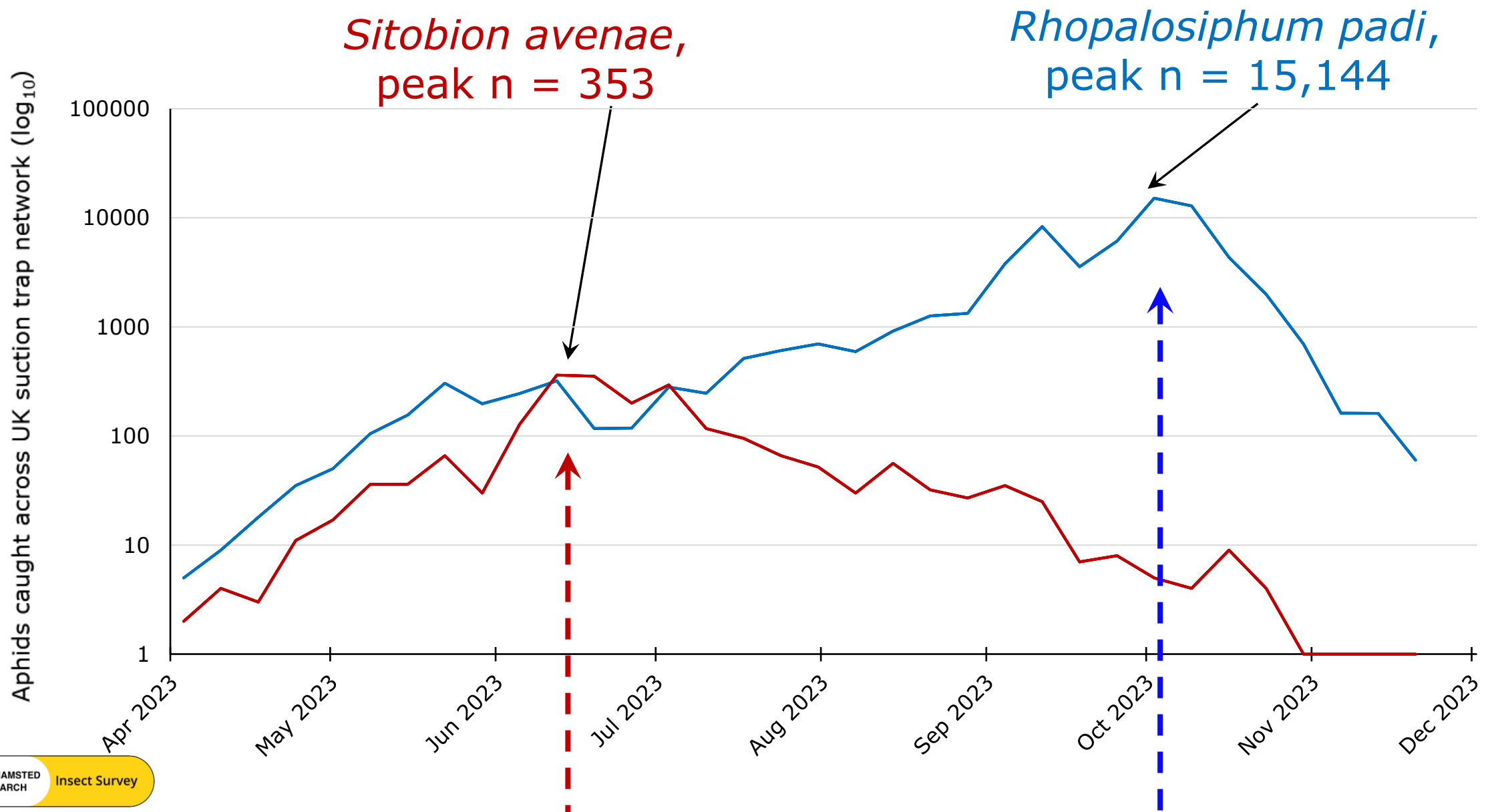
Suction traps (12.2m)



https://www.rothamsted.ac.uk/insect-survey

ROTHAMSTED RESEARCH

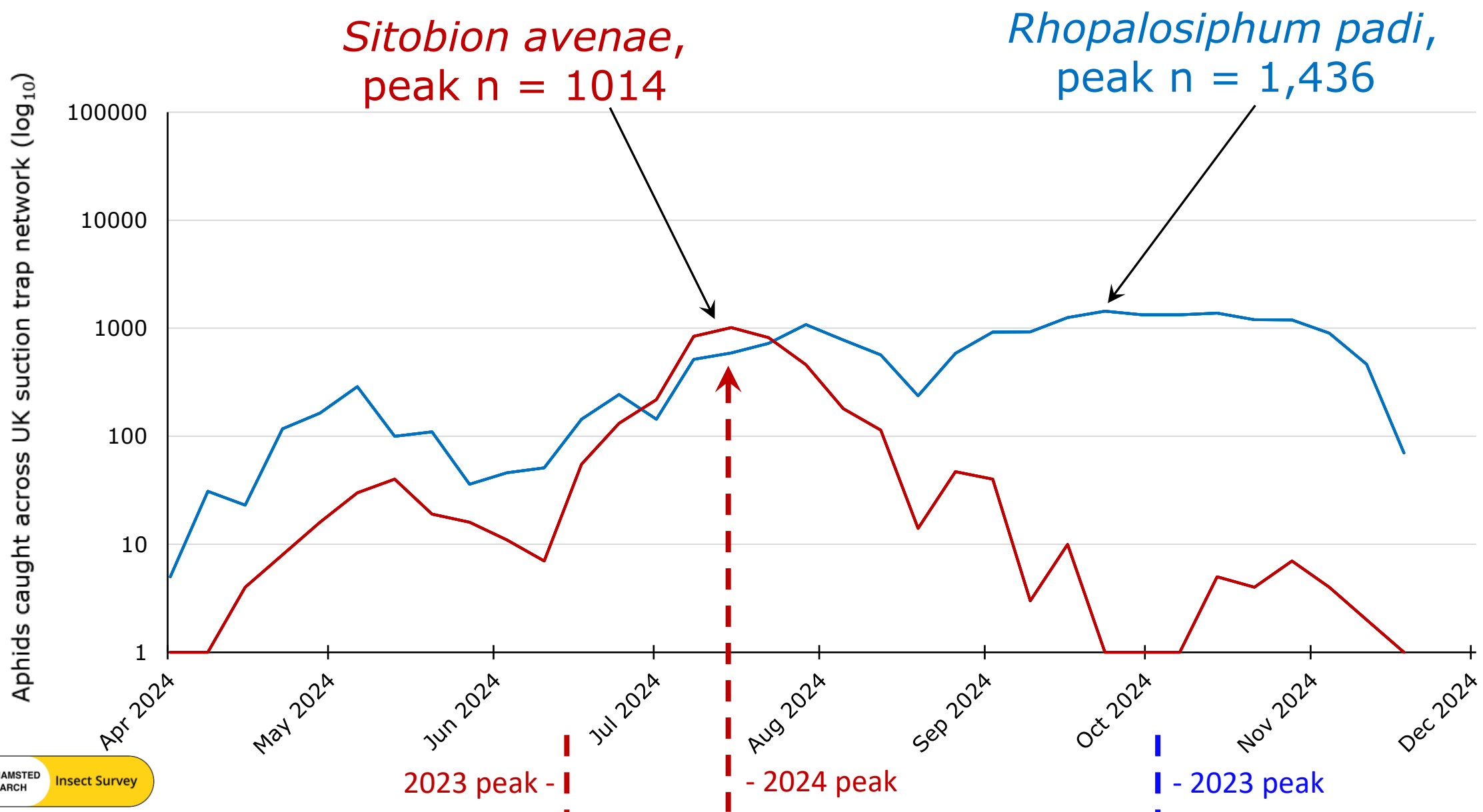
UK aphid pressure (2023)



ROTHAMSTED RESEARCH Insect Survey

ROTHAMSTED RESEARCH

UK aphid pressure (2024)



ROTHAMSTED RESEARCH Insect Survey

Routine BYDV detection

Year	*R. padi* carrying BYDV/total tested (**%**)	*S.avenae* carrying BYDV/total tested (**%**)
2020	329/1509 (**22%**)	77/252 (**31%**)
2021	231/1342 (**17%**)	34/224 (**15%**)
2022	128/980 (**13%**)	20/108 (**19%**)
2023	147/920 (**16%**)	29/88 (**33%**)
2024	153/990 (**15%**)	23/88 (**26%**)

*

- BYDV consistently detected UK-wide
- Highest incidence = 46% *S. avenae*, late July 2020
- lowest incidence = 5% *S. avenae*, early Aug 2021

Subset of aphids taken forward for informative CP sequencing

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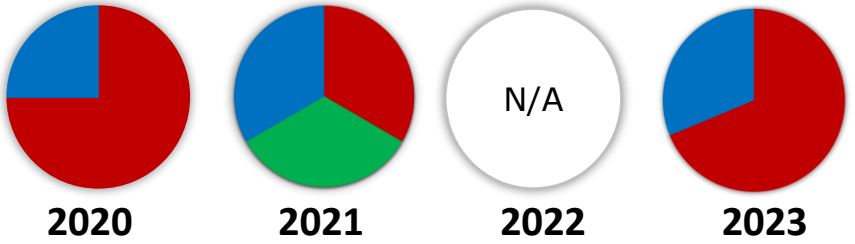
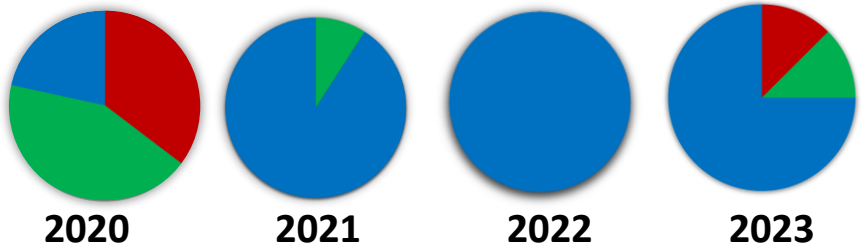
Strain variation across the UK

BYDV-MAV
BYDV-PAS
BYDV-PAV
GAV/unconfirmed

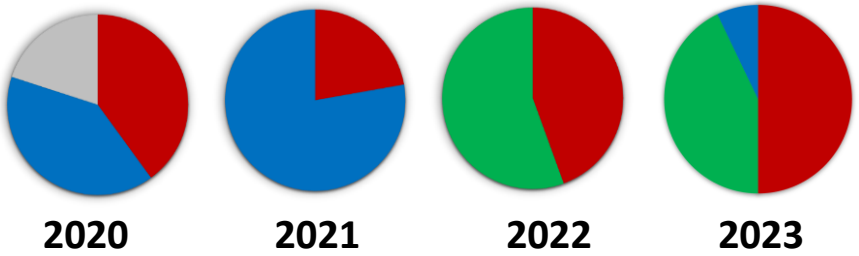
Edinburgh
n = 4, 3, 0, 16



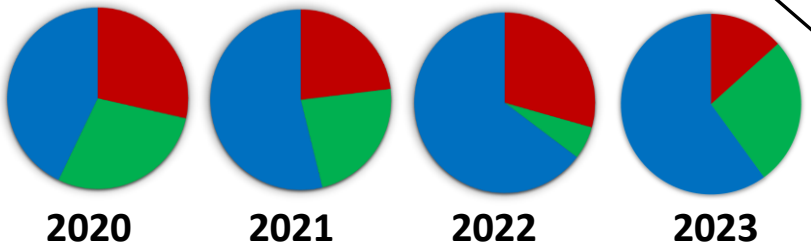
York
n = 14, 11, 12, 16



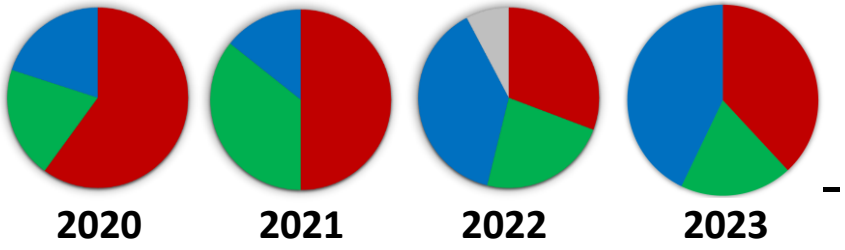
Brooms Barn
n = 5, 9, 9, 16



Hereford
n = 7, 13, 21, 15



Starcross
n = 5, 14, 13, 16



- BYDV strains not strictly conserved geographically
- Implications for resistance screening/germplasm deployment

ROTHAMSTED RESEARCH

Yellow dwarf virus strains

Genus	Species	Strain	Known aphid vectors*
Luteovirus	BYDV	**PAV**	*R. padi, S. avenae, Metapolophium dirhodum, Schizaphis graminum, Sitobion fragariae*
		MAV	*S. avenae, M. dirhodum, R. padi, S. fragariae*
		PAS	*Rhopalosiphum maidis,* ***R. padi, S. avenae***
		GAV	*Scizaphis graminum, S. avenae*
Polerovirus	CYDV	**RPV**	*R. padi, S. graminum*

Rhopalosiphum padi
bird cherry-oat aphid

Sitobion avenae
English grain aphid

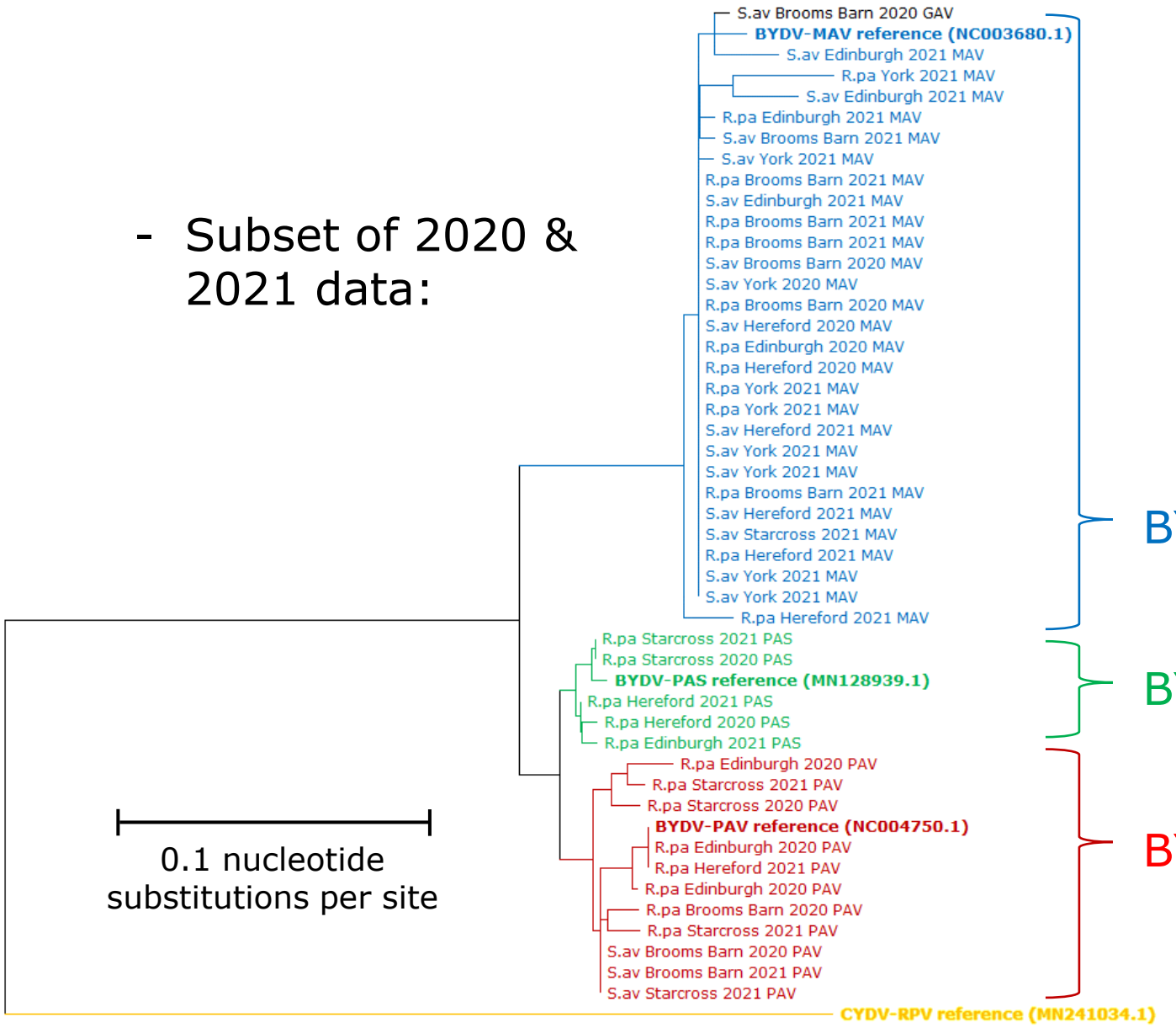
Previously unreported and confirmed via RIS sampling/testing

*Aradottir & Crespo-Herrera (2021). *Current Opinion in Insect Science.*, *45*, 59-68

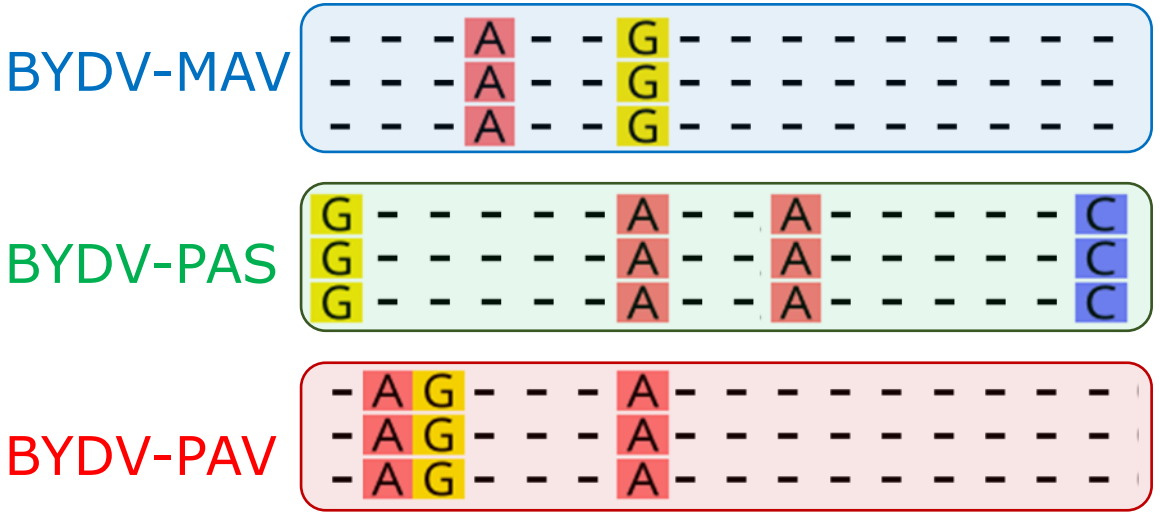
ROTHAMSTED RESEARCH

Better diagnostics

- Subset of 2020 & 2021 data:



- Sequencing information used to identify conserved, UK strain-associated polymorphisms



Sequencing data anonymised but representative

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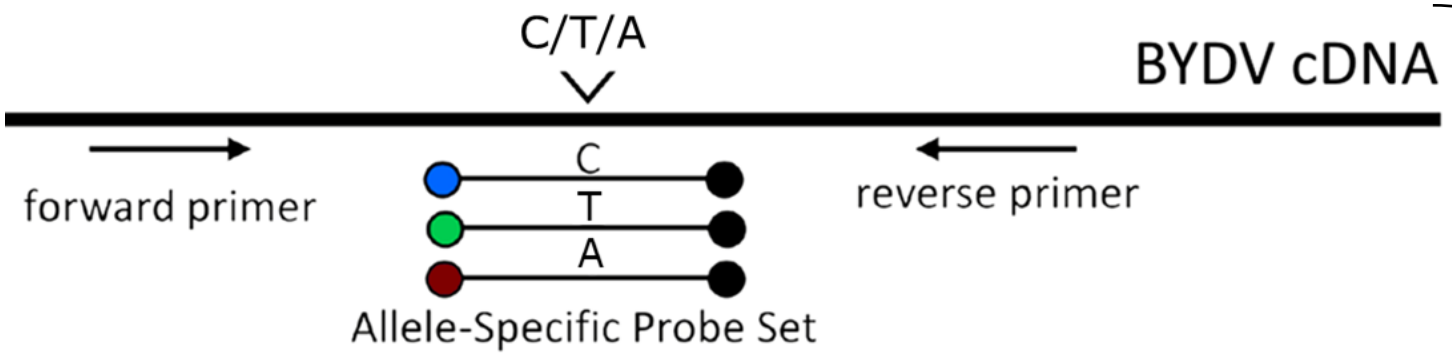
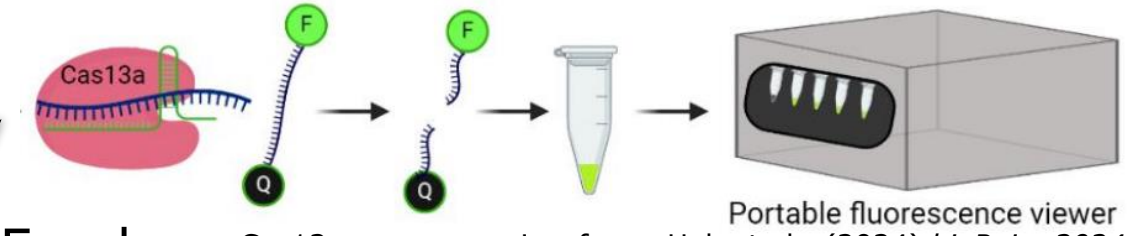
Better diagnostics



- **Taqman chemistry**
  robust diagnostic &
  valuable research tool

- Strain-specific Taqman, KASP, PCR & qPCR assays = **established**
- RT-LAMP & CRISPR-Cas13a assay
  = in progress, for **"*in-field*" testing**



Cas13a assay overview from: Hak et al., (2024) *bioRxiv, 2024-02.*

BSPP Small Project Fund

- Can now process up to 24 discrete molecular assays vs 192 samples
- **4,608** qPCRs in ~2h
- **Massive potential for higher-throughput exploration**

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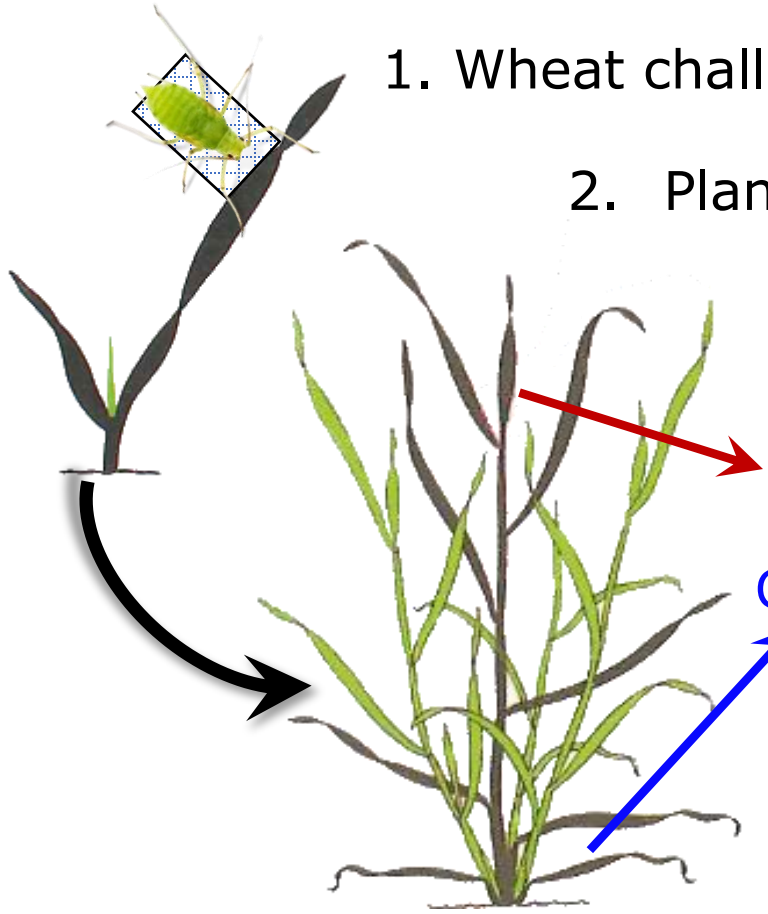
Sampling for BYDV

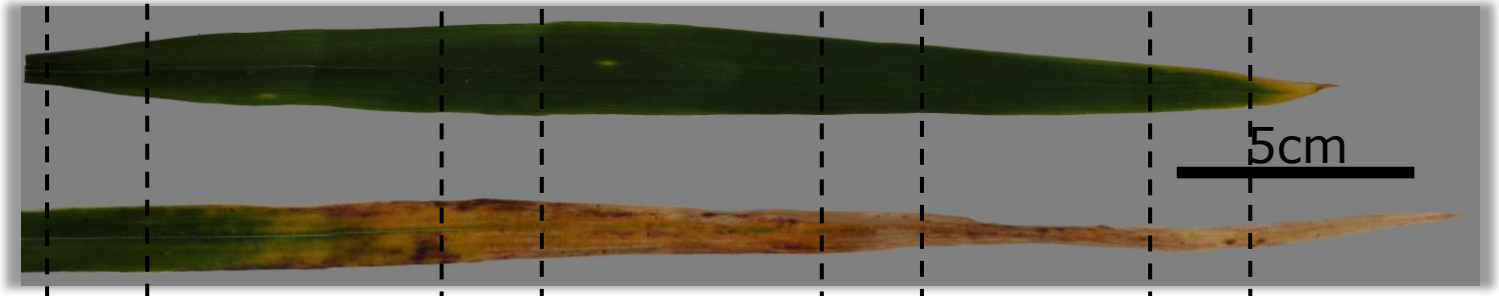
Does sampling location impact BYDV detection?

1. Wheat challenged with BYDV

2. Plant maintained until flag leaf developed

3. Flag leaf and BYDV-challenged leaf sampled





BYDV qPCR Ct values

Column-based RNA extraction	20.8	n/a	21.0	22.5
	20.7	22.4	21.8	22.7
Crude RNA extraction	33.6	33.3	31.4	37.3
	36.4	35.2	36.7	30.9

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Conclusion

- Challenges do exist
  - Shifting BYDV strains, aphid populations, climate…
  - Robust resistance deployment and ensuring current resistances last requires ongoing characterisation
- Opportunities
  - The resources exist for modelling changes to this important pathosystems
  - New tools (e.g. infectious clones, higher throughout multiplexed assays) are on the horizon

Aphid vectors are one element, any and all potential wheat samples with BYDV symptoms would be gratefully received

Many thanks...

- For your attention and the UKCPVS Stakeholders event organisers

- Rothamsted Wheat Pathogenomics Team (PI, Kim Hammond-Kosack)
  - Wheat-Insect-Virus Interactions Subgroup (PhD student, Izayana Sandoval-Carvajal)

- Continued assistance from the wider wheat and cereals community
  - DSW & WGIN and associated funding (UKRI & Defra, respectively)

- lawrence.bramham@rothamsted.ac.uk

BSPP Small Project Fund
– new 'in-field' assay development