Aphids: the secrets of their success

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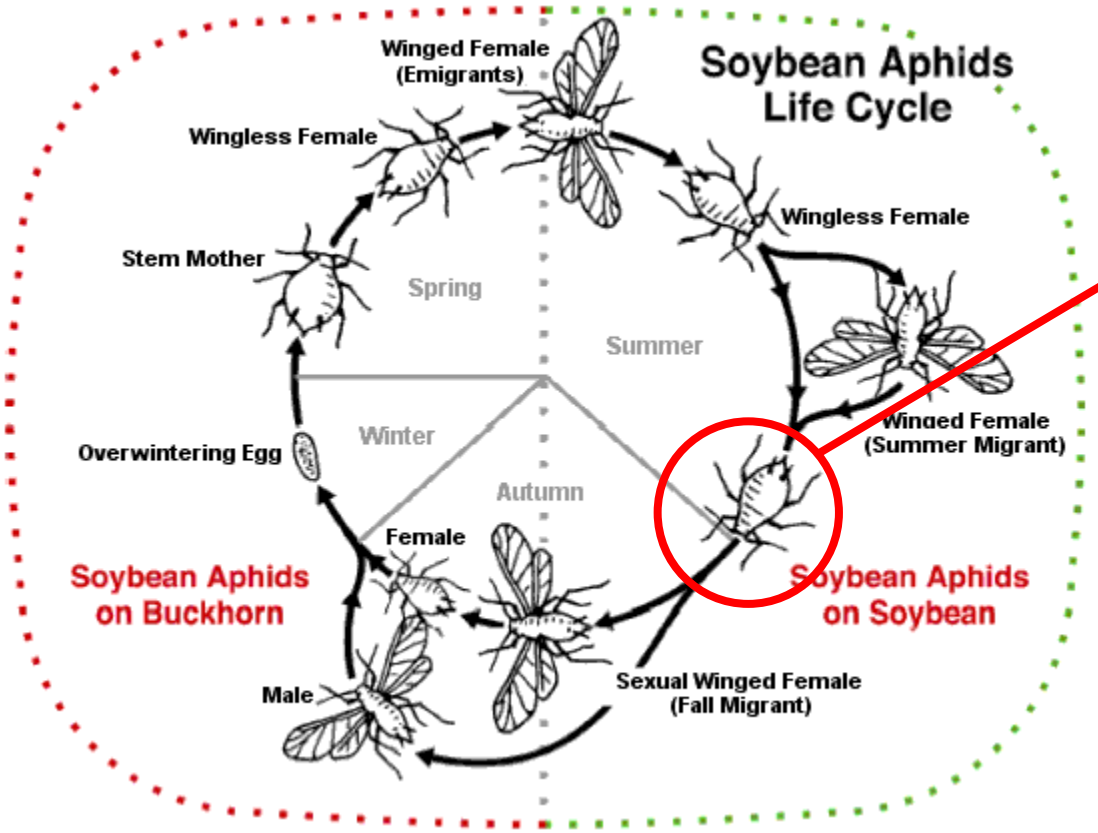
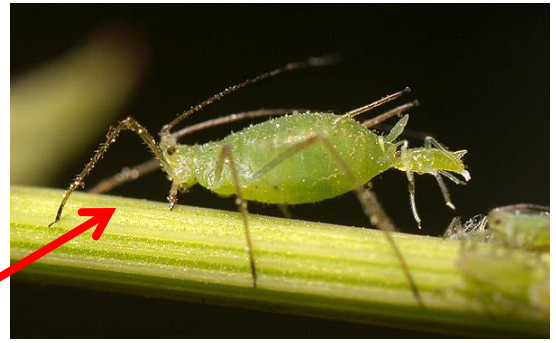
Aphid life cycle

Successful herbivores and pests due to their life cycle and ‘telescoping’ of generations



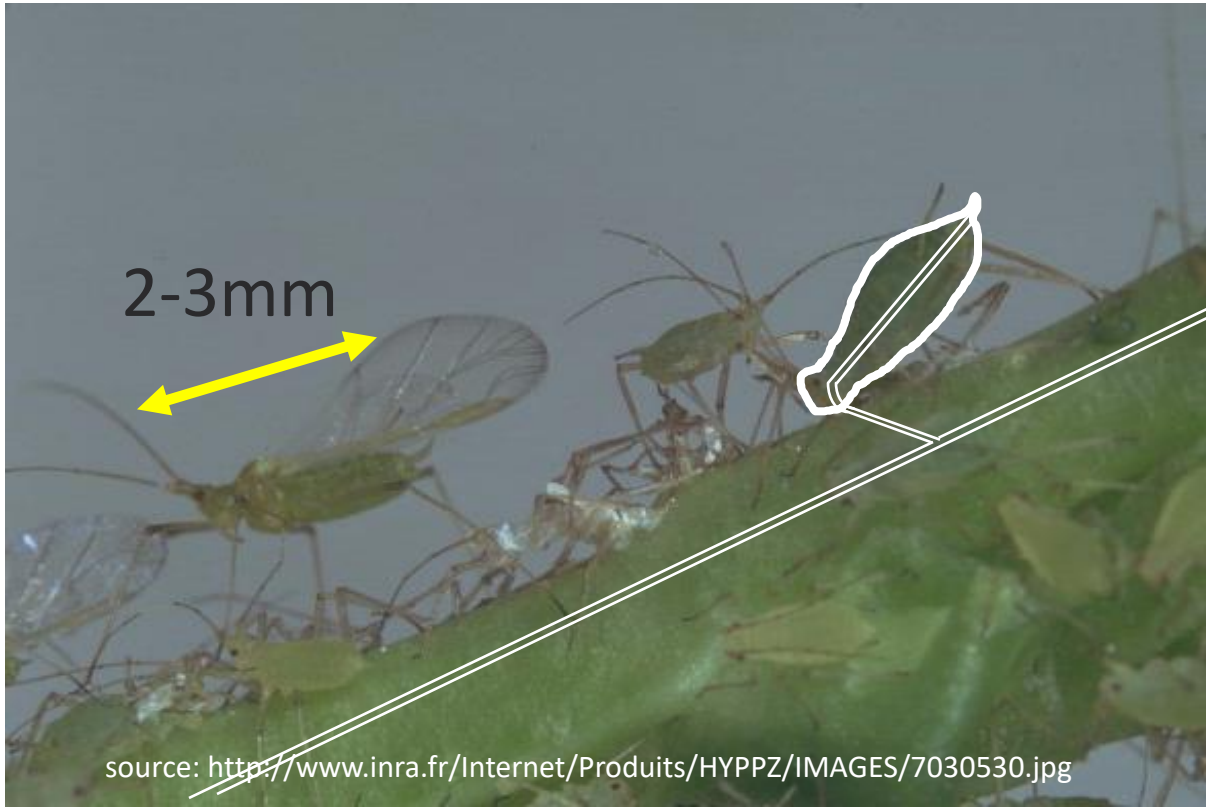


1 mg aphid gives rise to 1 kg in 46 days
(10 d development, 100 offspring per aphid over 4-5 week period)

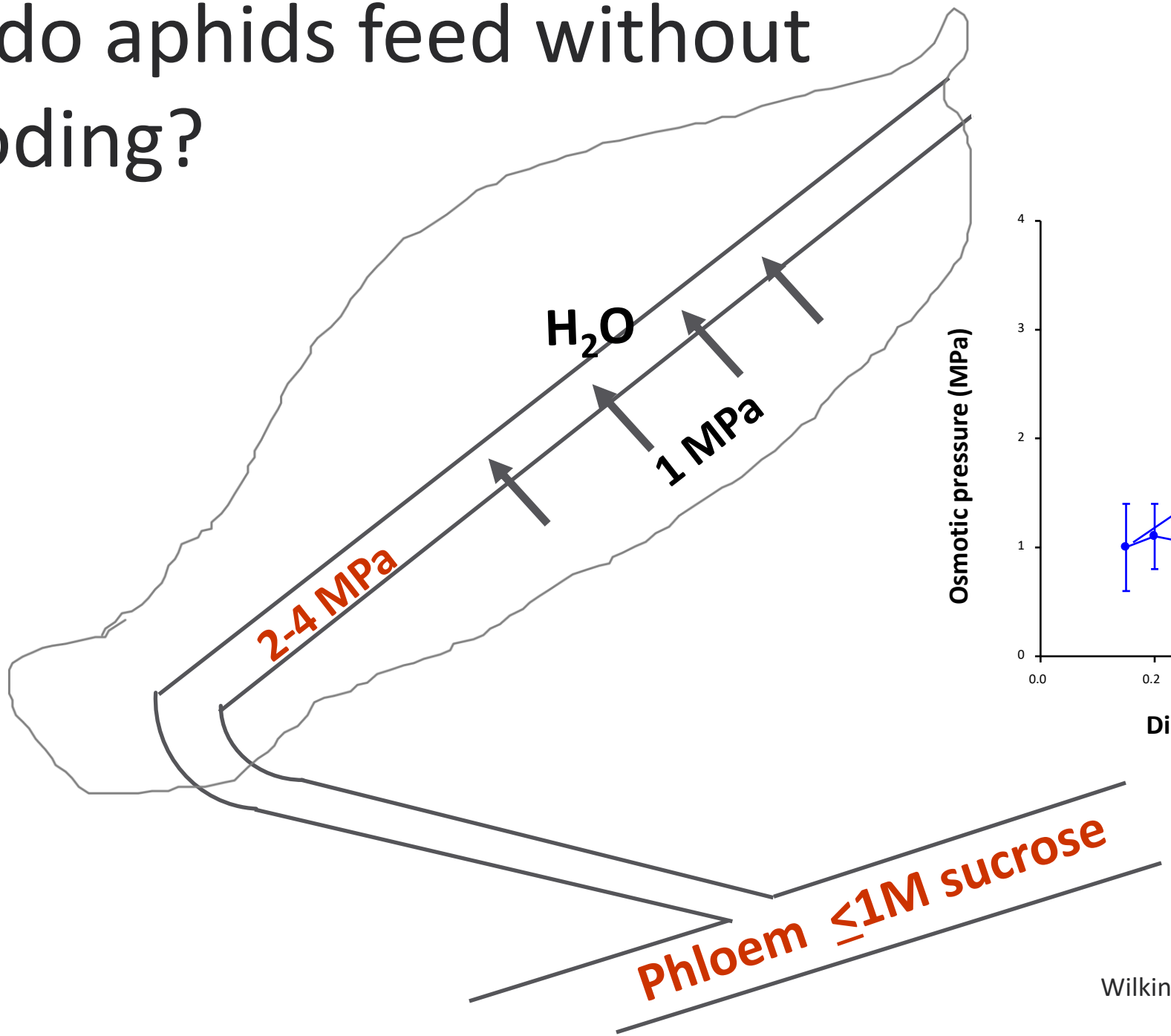
Rapid response to selective forces (e.g. insecticides)

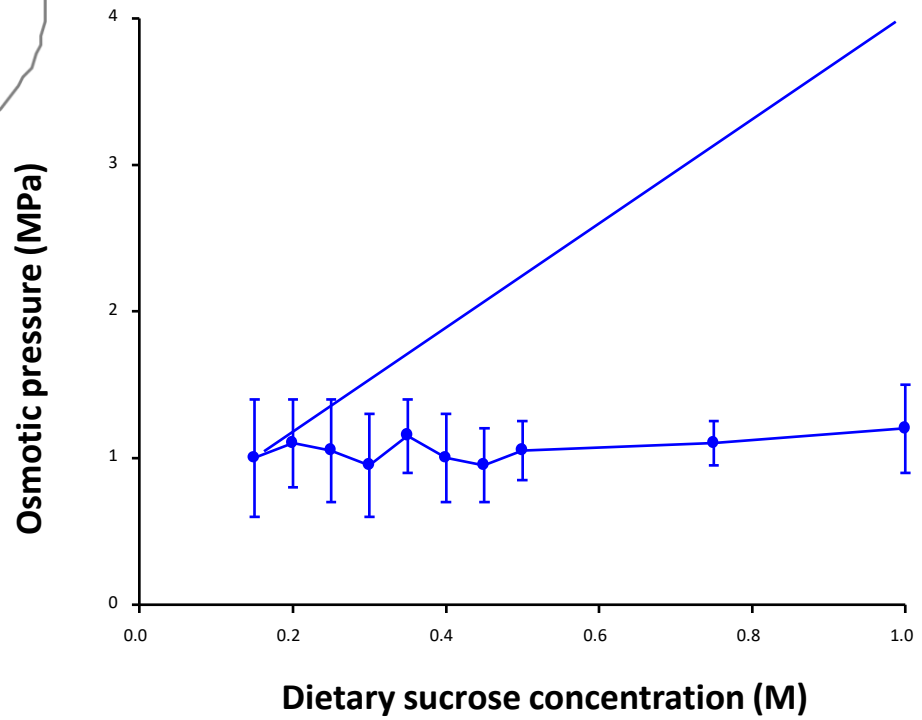
Phloem-feeding and osmotic stress

Phloem: long distance pressure-driven transport of organic compounds (sugars, amino acids) at high concentration (≤1 M)



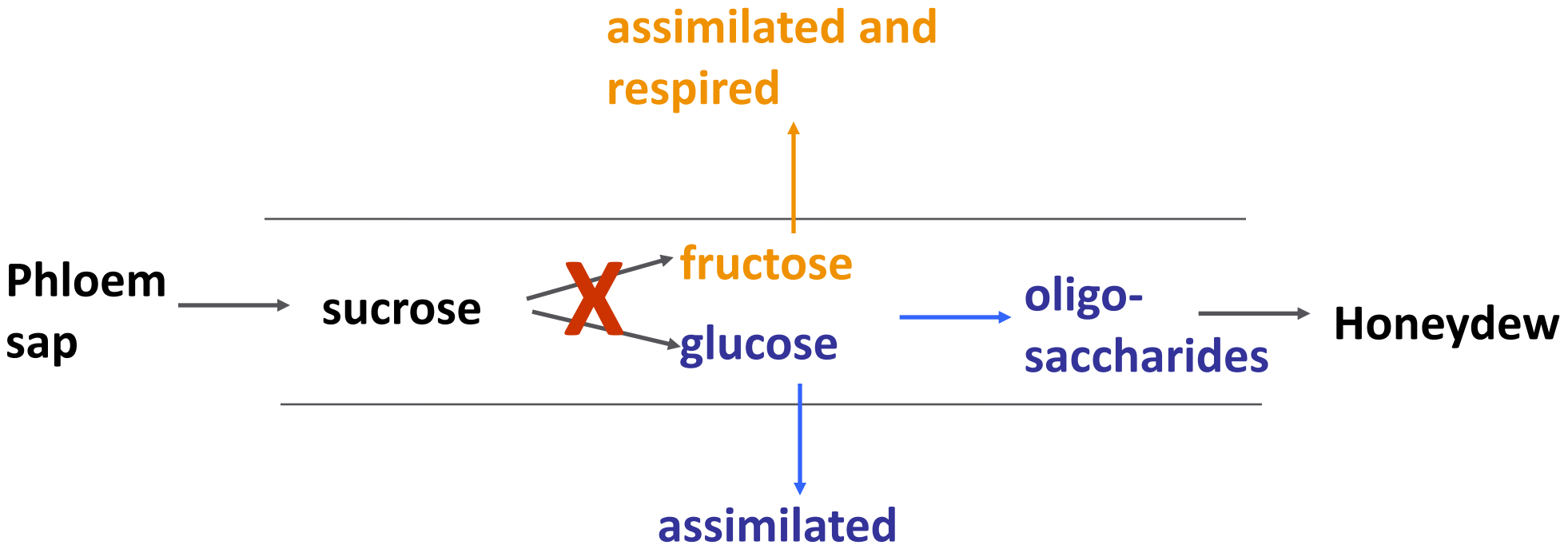
How do aphids feed without imploding?





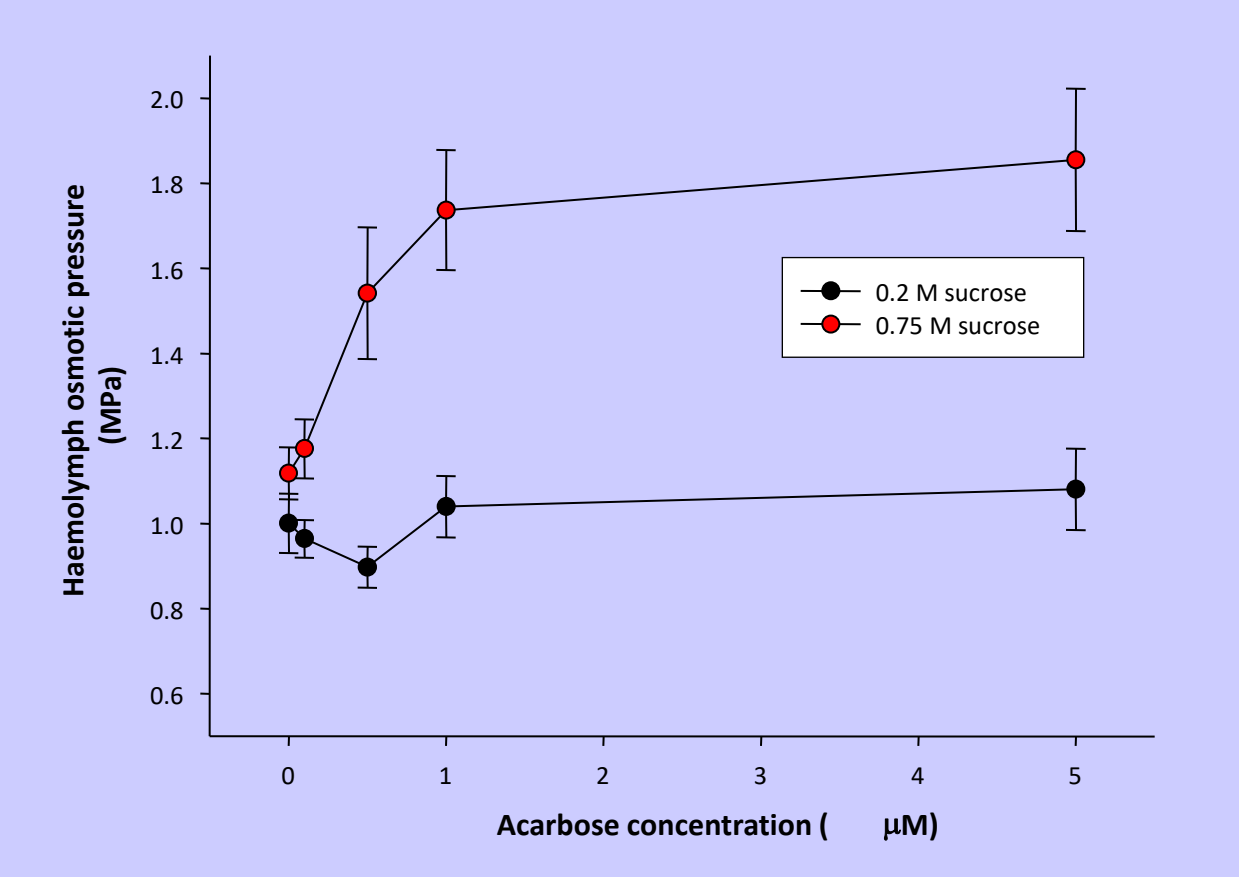
Wilkinson et al 1997 . Exp. Biol. 200, 2137-2143

Phloem sugars are polymerised to reduce osmotic stress



Phloem-feeding and osmotic stress

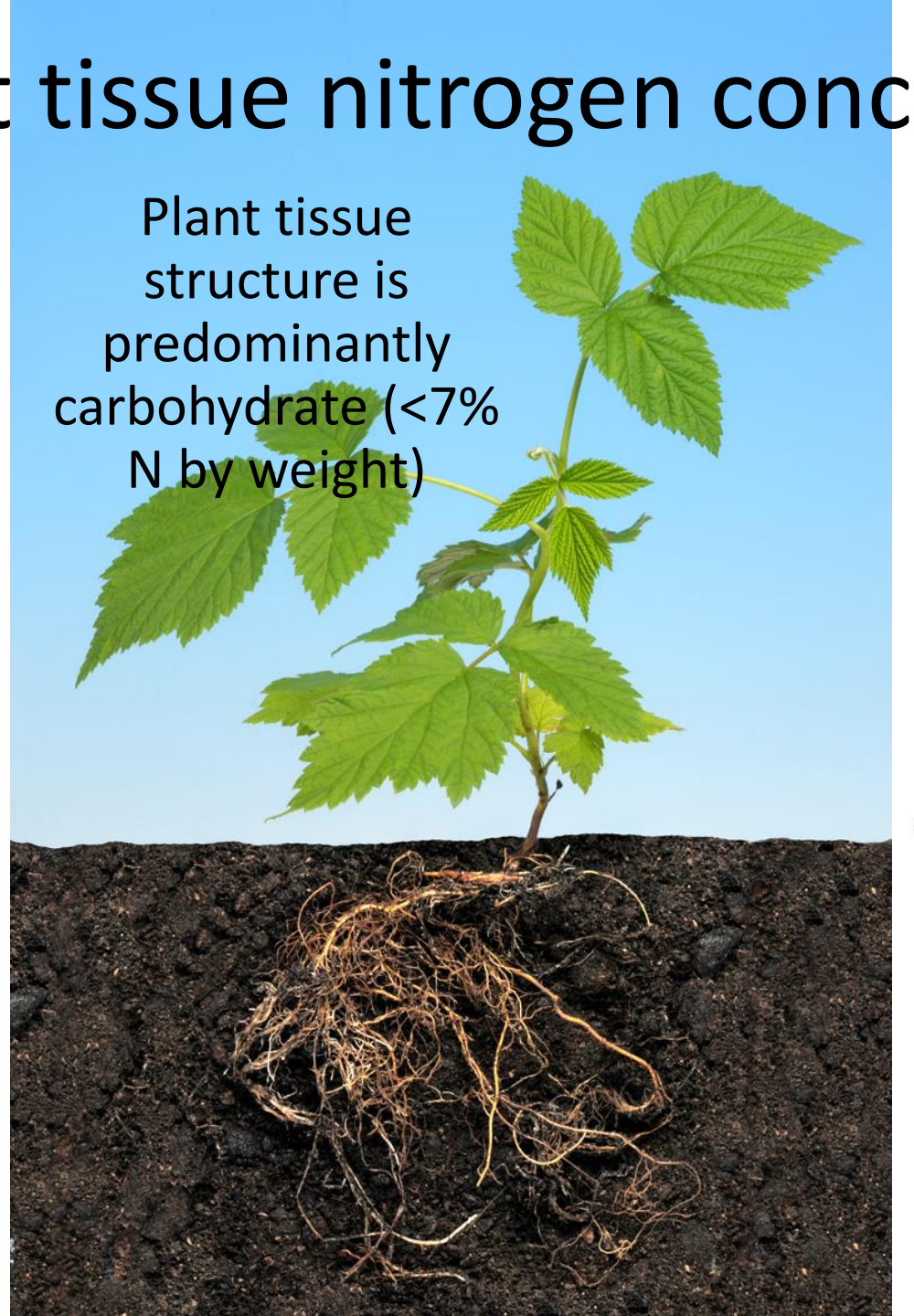
- Inhibiting the sucrase at high dietary sucrose results in aphid death
- Linked to increased haemolymph osmotic pressure

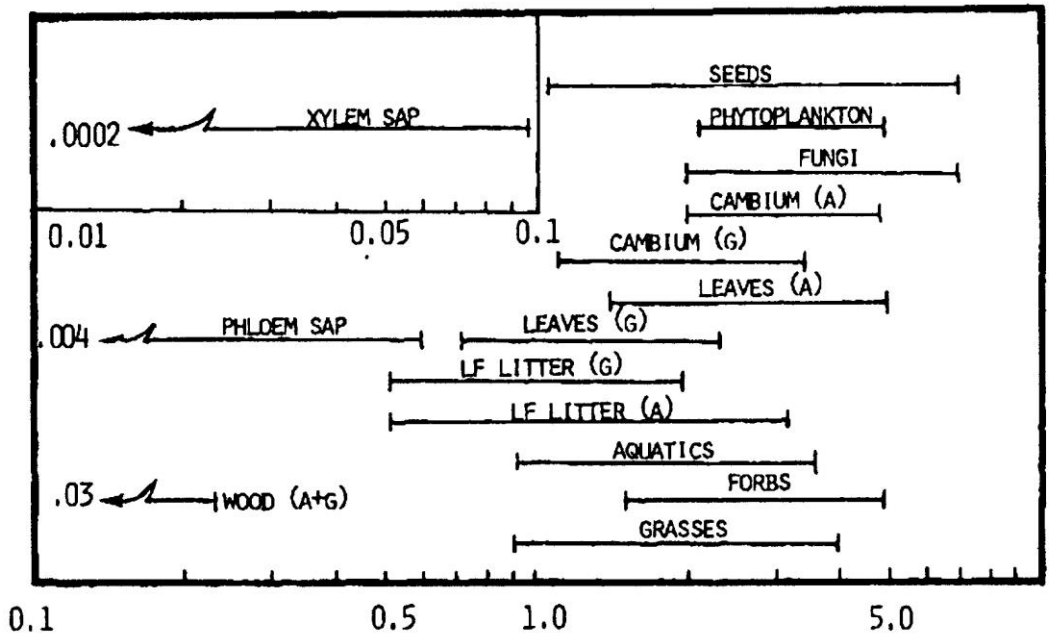


Karley et al (2005) J Insect Physiol 51,1313-1319

Plant tissue nitrogen concentrations are low

Plant tissue structure is predominantly carbohydrate (<7% N by weight)





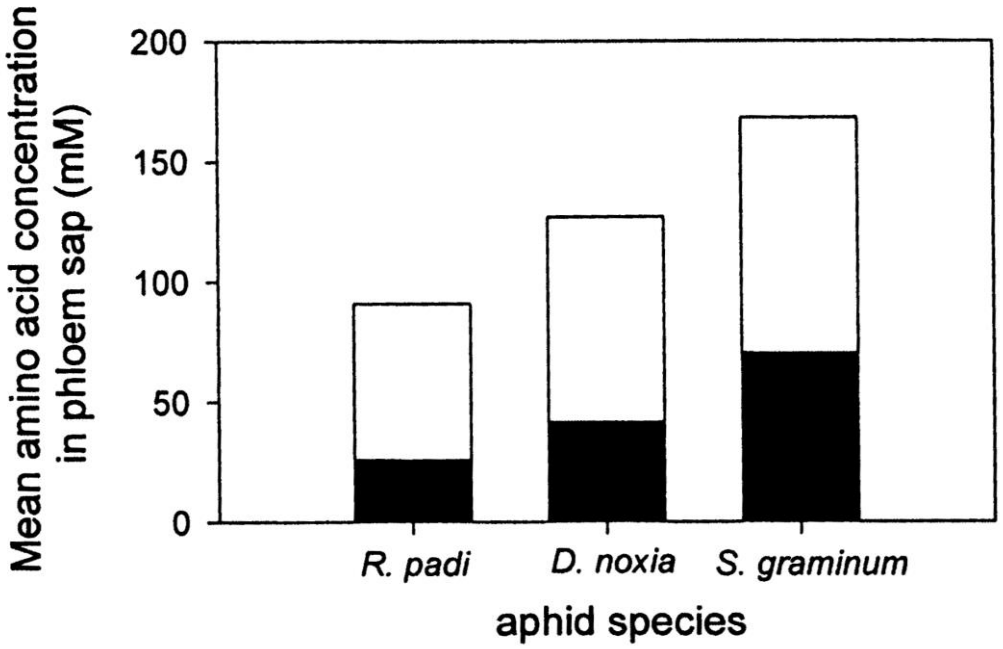
Mattson (1980) Ann. Rev. Ecol. Syst. 11, 119.

Animal tissue structure is >50% protein

(7-14% N by weight)

Herbivore responses to low N: manipulate plant chemistry

Insect salivary secretions promote plant growth or remobilisation of nutrients



Cereal aphids: increased amino acid concentrations of phloem sap

Galling insects: remobilisation of nutrients to feeding site

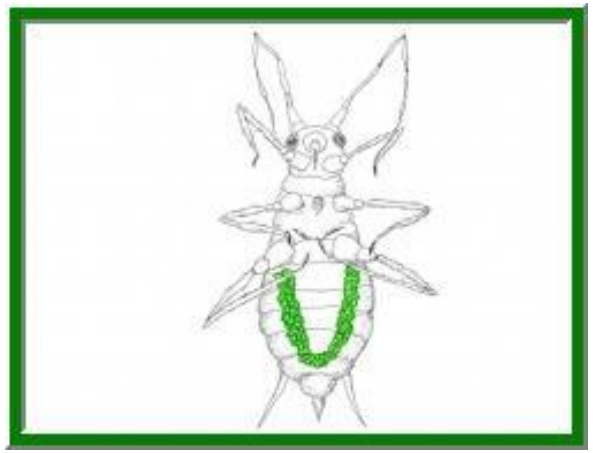
Cytokinin production by leafminer caterpillars maintains the nutritional quality of green islands

Sandstrom et al (2000) J Insect Physiol 46, 33
Sandstrom & Moran (2001) Phsiol Entoml 26, 202

Giron et al (2007) Biol. Lett. 3, 340

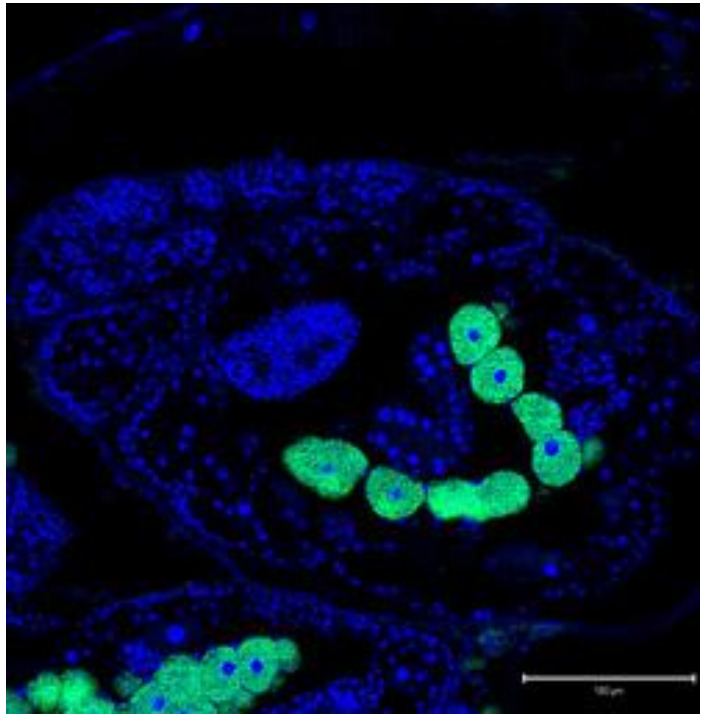
Aphid secret weapon: obligate bacterial endosymbiosis

Buchnera aphidicola, an obligate nutritional endosymbiont of aphids



Location of bacteriocytes containing *Buchnera* in aphid tissues

Symbiosis evolved 150-250 Mya



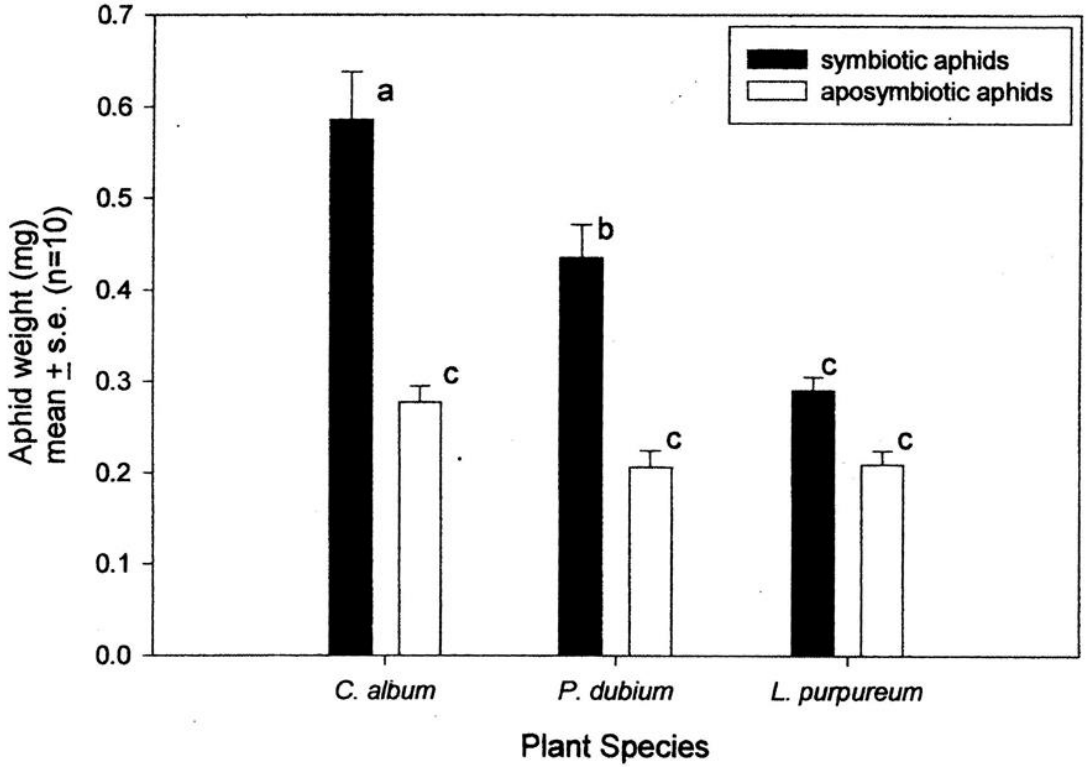
Aphis fabae section fluorescently-labelled with *Buchnera*-specific 16S rDNA probe (green).

The mycetocyte nucleus and other aphid nuclei are stained with DAPI (blue).

(Micrograph of S. Chandler)

Nutrient provision to aphids by *Buchnera*

- Elimination of *Buchnera* from black bean aphids by antibiotic feeding or injection
- Aphids deprived of bacterial endosymbionts show impaired performance



https://influentialpoints.com/Gallery/Aphis_fabae_Black_Bean_aphid.htm

Wilkinson et al (2001) J Exp Biol 204, 3027-3038

Most common aphids on potato

Peach-potato aphid, *Myzus persicae*

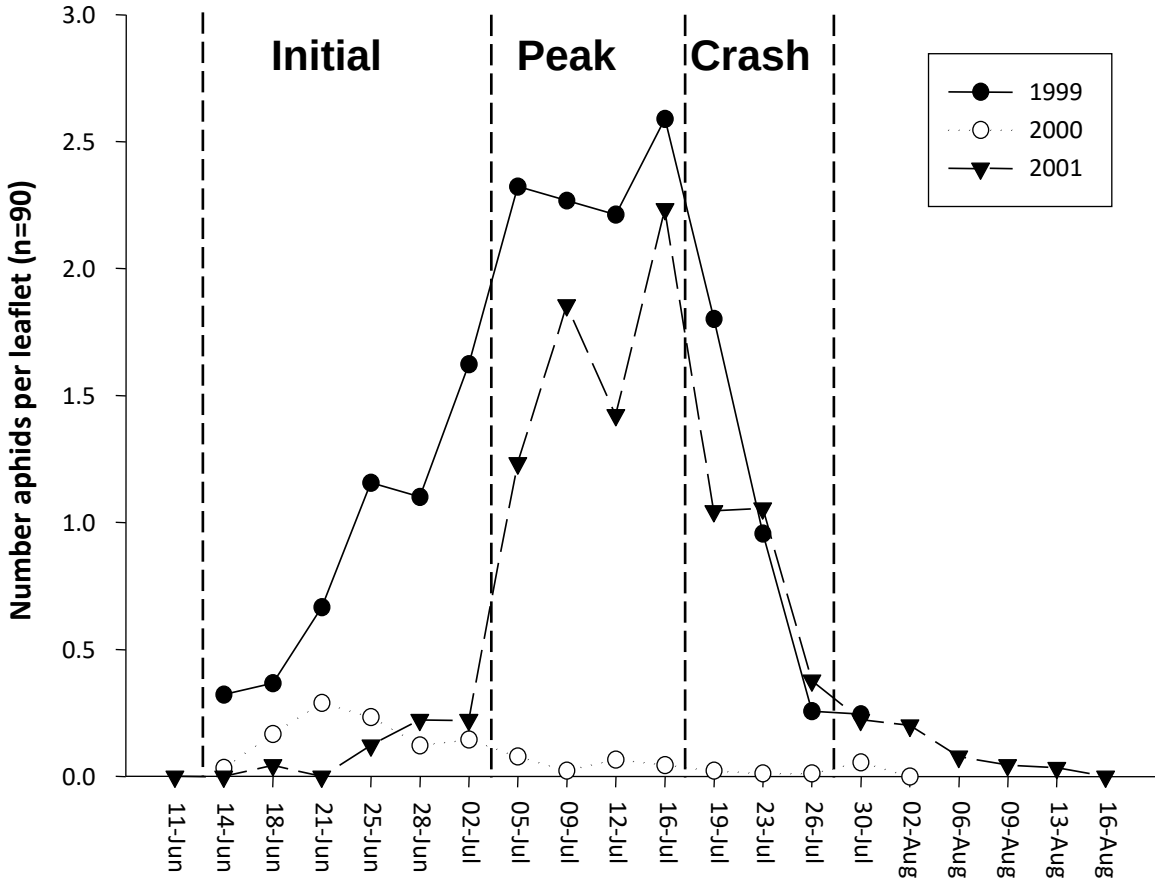
- Global distribution
- Highly polyphagous, attacking >400 plant species
- Transmits >100 viruses to economically important crops
- Efficient vector of PVY, moderately efficient vector of PVA
- Considered an efficient vector of PLRV

Potato aphid, *Macrosiphum euphorbiae*

- North American origin, present in UK since early 1900s
- Polyphagous, feeding on 200 plant species in >20 plant families
- Direct feeding damage and virus transmission
- Low (PVY) or moderate (PVA) efficiency of virus transmission
- Transmits PLRV, although considered less efficient

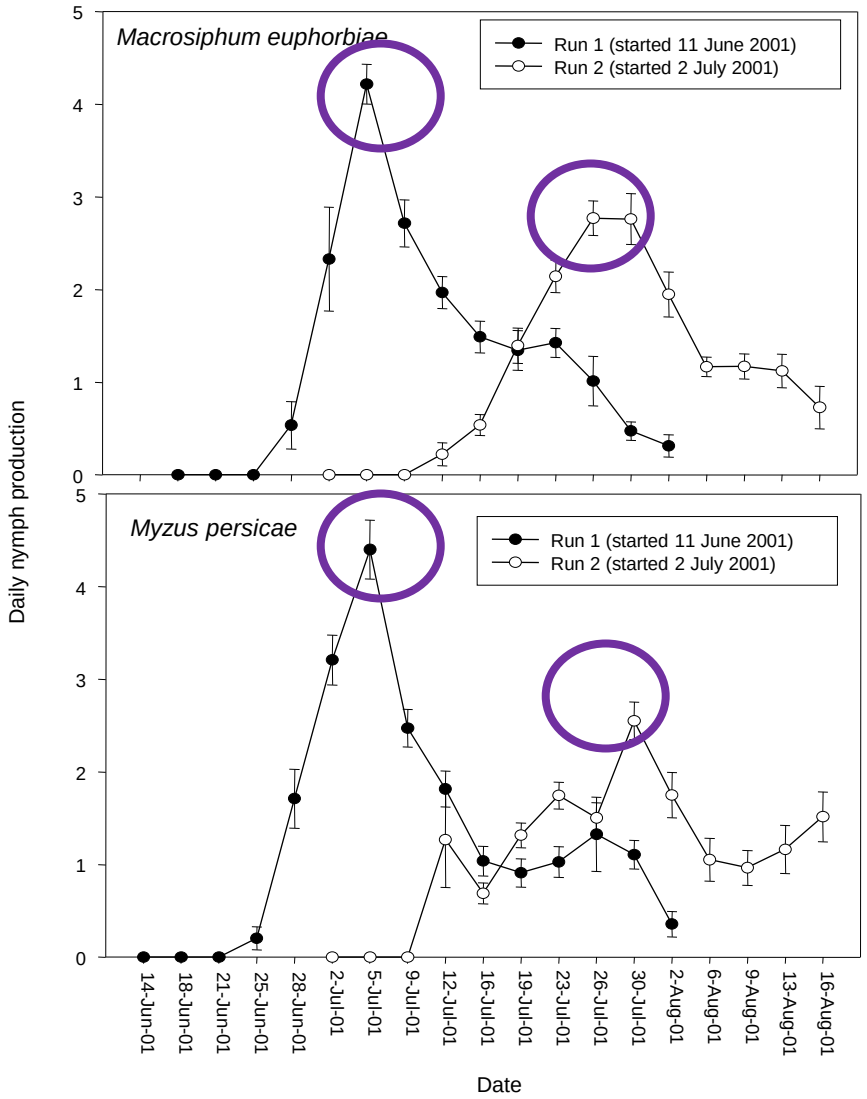
Summer aphid population dynamics on potato crops

Mid-summer aphid population crash occurs in crop and native vegetation

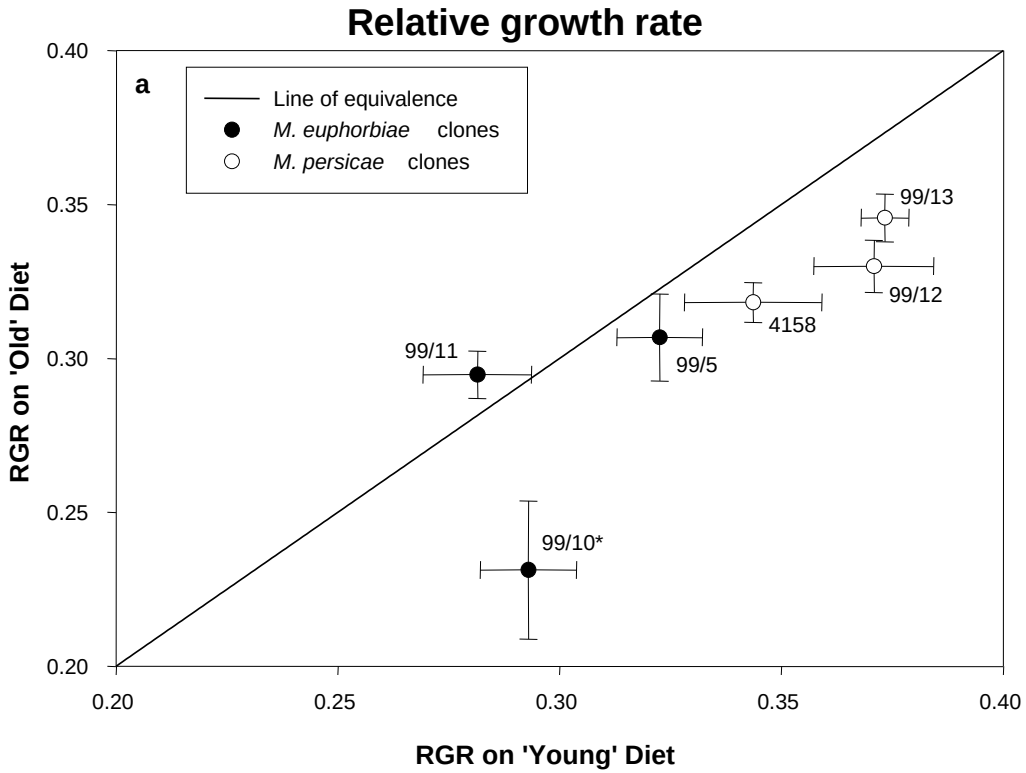


Karley et al (2003) Bull .Ent. Res . 93, 425-437

Phloem amino acid composition alters aphid growth

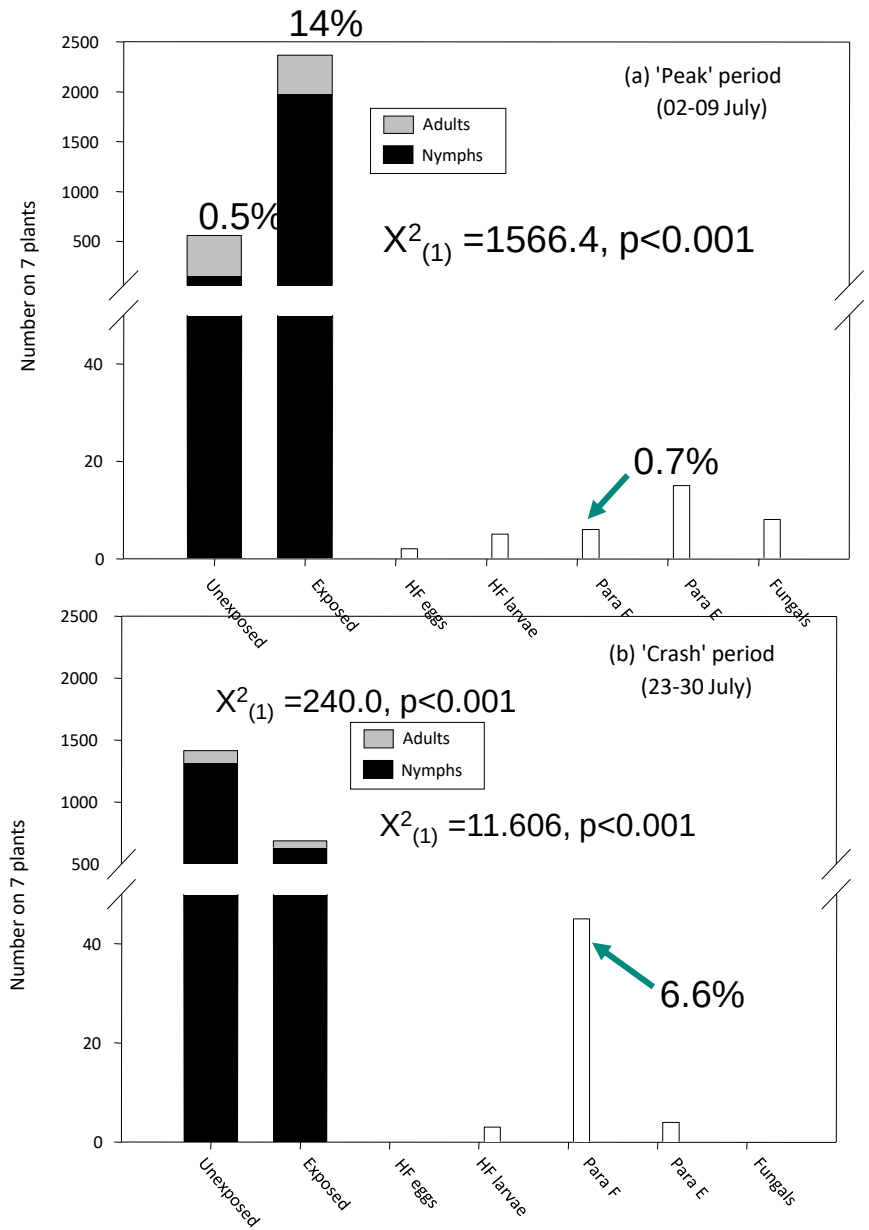


- Aphids perform better on developmentally ‘young’ plants
- Poor quality amino acid composition in ‘old’ plants



Karley et al 2002 J Exp Biol 205, 3009-3018

Aphid and natural enemy dynamics



nymph recruitment increases at 'peak'

proportion of winged adults increases

adult and nymph numbers reduced by exposure in 'crash'

parasitism increases after decline

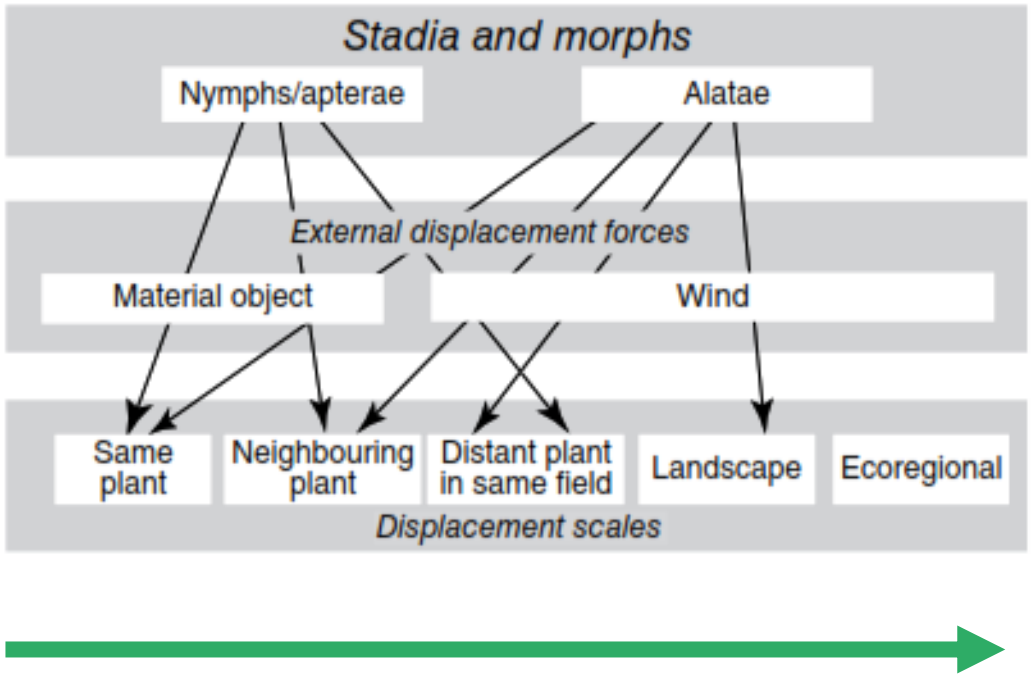
Immigration and reproduction

Emigration and mortality

Karley et al (2003) Bull .Ent. Res . 93, 425-437

Aphid movement – mechanisms and scales

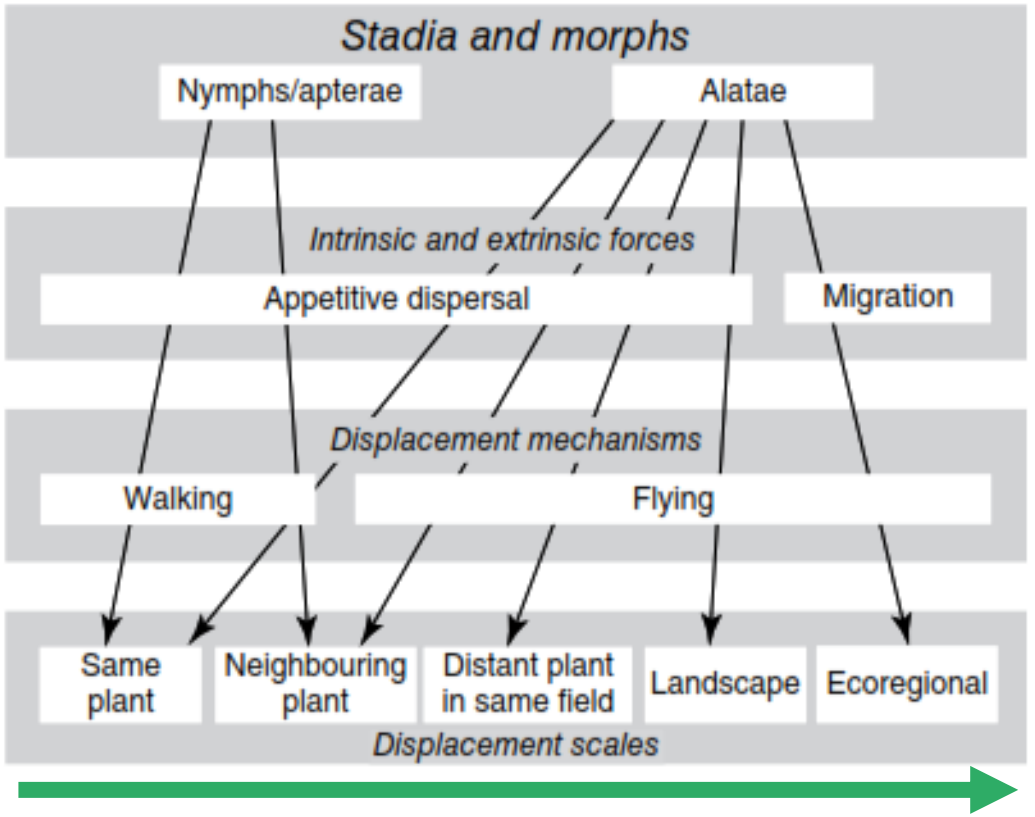
Inadvertent displacement



Fast (sec-min)
Short distances (cm-m)

Slow (month-year)
Long distances (m-Km)

Intentional displacement



Fast (sec-min)
Short distances (cm-m)

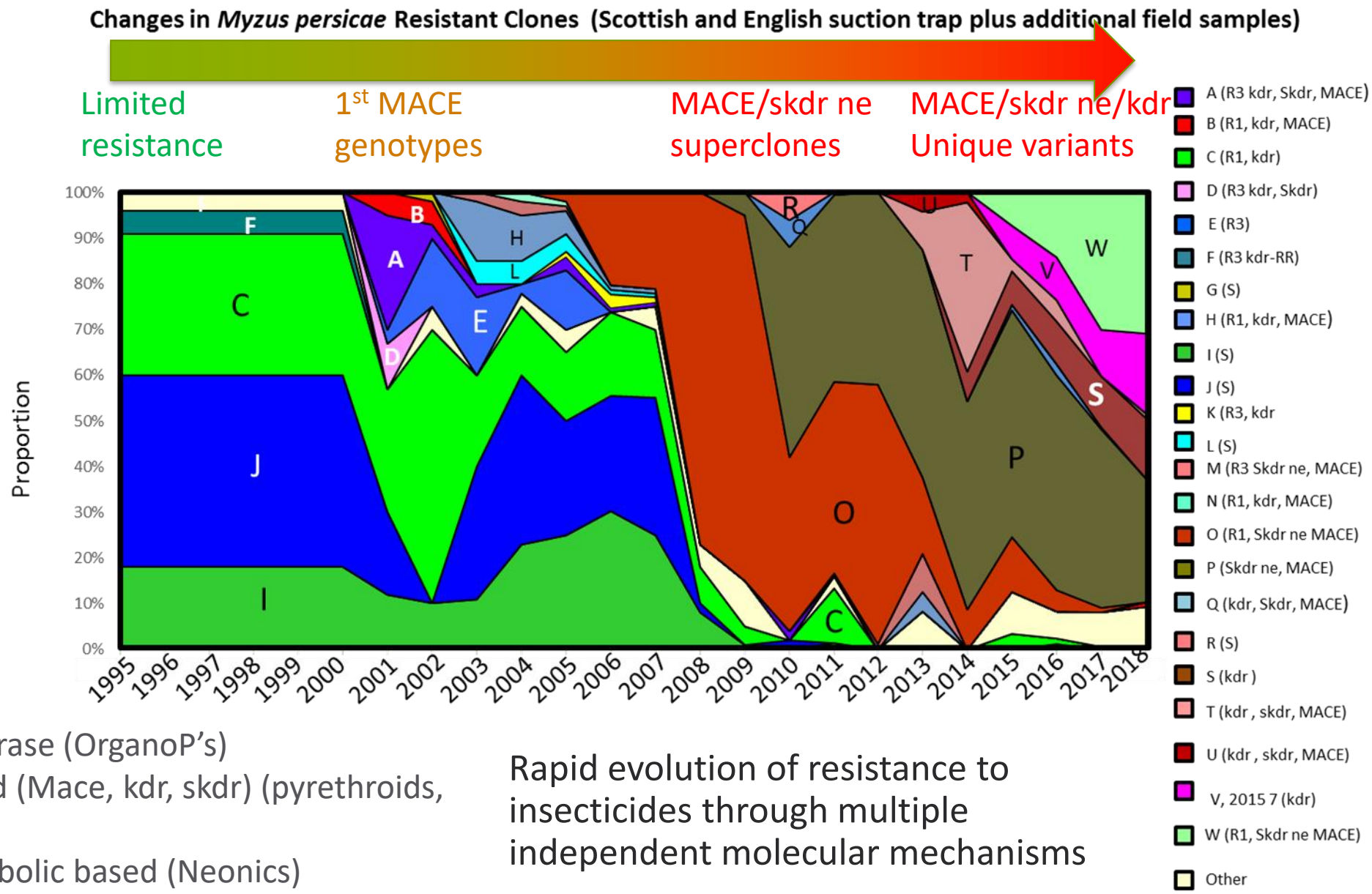
Slow (month-year)
Long distances (m-Km)

Plant viruses can directly and indirectly affect winged aphid production

Rozo-Lopez & Parker, 2023 https://doi.org/10.1111/imb.12860

Ferres et al (2017) Chapter 10, Aphids as crop pests, CABI

Pesticide resistance



Pesticide resistance

- Metabolic - esterase (OrganoP's)
- Target-site based (Mace, kdr, skdr) (pyrethroids, carbamates)
- Target and metabolic based (Neonics)

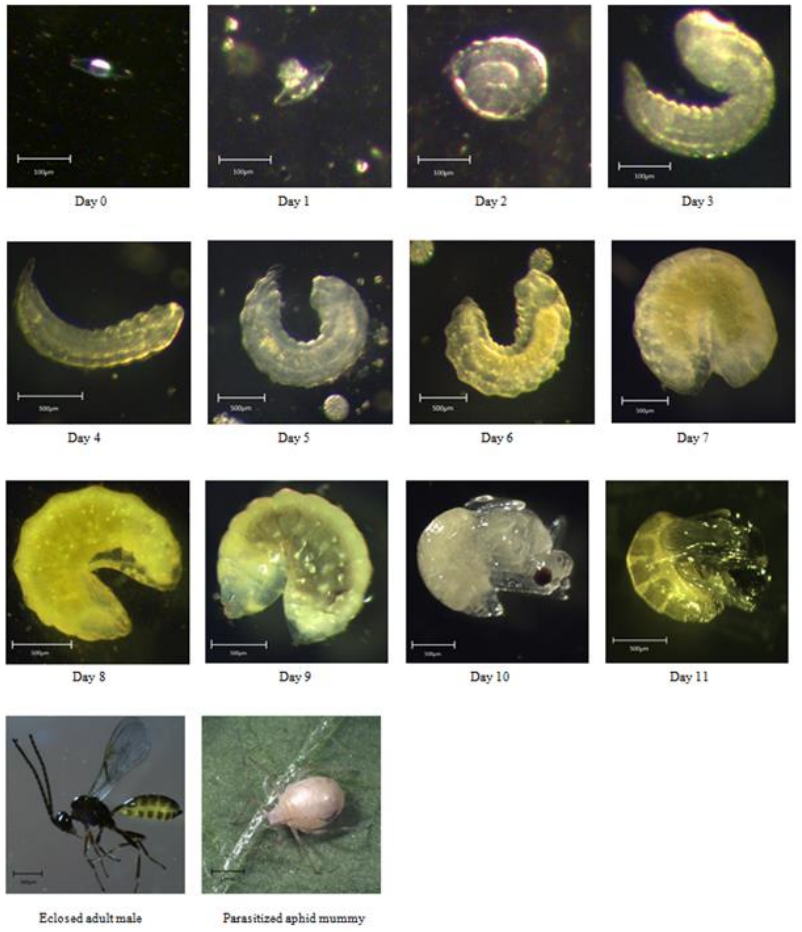
Rapid evolution of resistance to insecticides through multiple independent molecular mechanisms

Natural enemies of aphids

- **Predators**: ladybirds adults & larvae, syrphid larvae, chrysopid larvae, generalist predators
- **Parasitic wasps**: parasitoids and hyperparasitoids
- **Entomopathogenic fungi**: *Beauveria bassiana, Verticillum lecanii, Neozygites fresenii, Pandora neoaphidis*

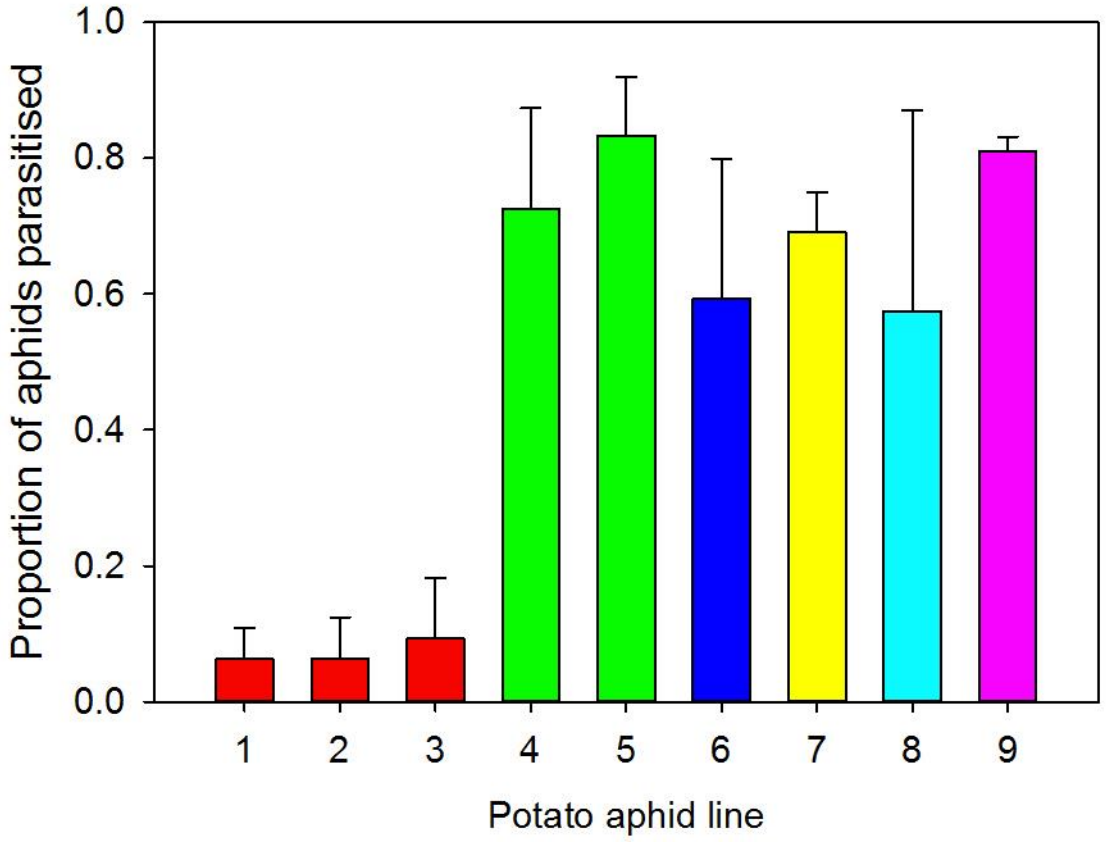
Natural enemy control of aphid populations: parasitism by braconid wasps

Aphidius ervi – common generalist parasitoid of aphids



Aphid resistance to parasitism

Potato aphid genotypes vary in susceptibility to *Aphidius ervi*

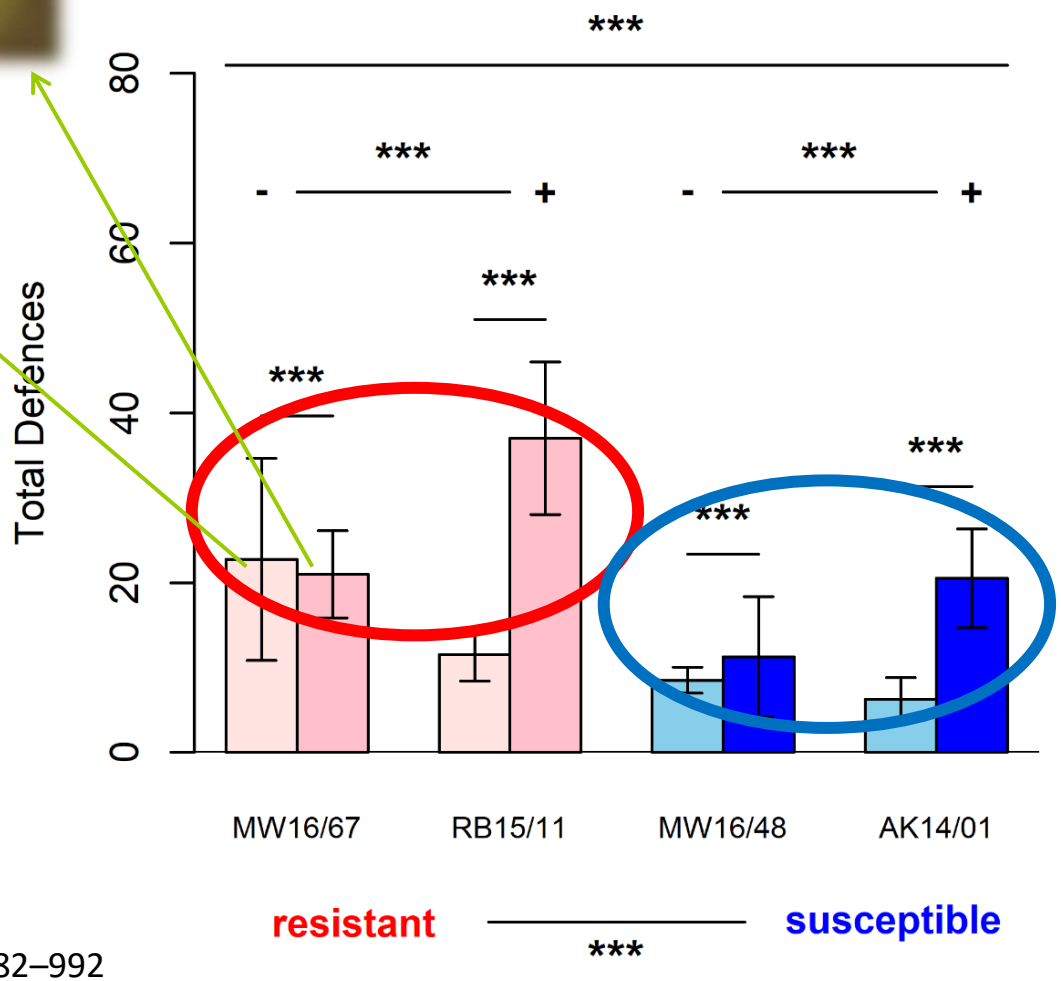


Parasitoid-resistant aphid genotypes have rapid development, high fecundity and long survival

Clarke et al. (2016) Entomologia Experimentalis et Applicata 162, 148-158. doi:10.1111/eea.12516

Interactions with aphid predators

Parasitoid-resistant potato aphid genotype more likely to defend against lacewing and ladybird attack



Behaviour/defence
No reaction
‘Shift’
Kick
Back-up/walk away
Drop

Humphreys et al (2022) Ent. Exp. Appl. 170, 982–992
https://doi.org/10.1111/eea.13223

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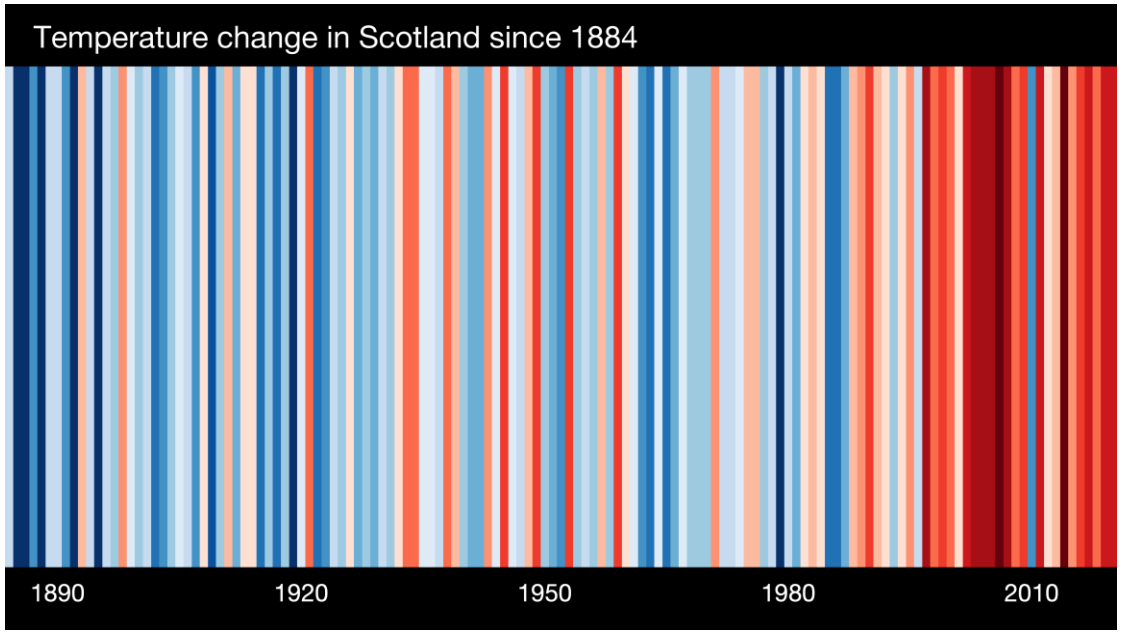
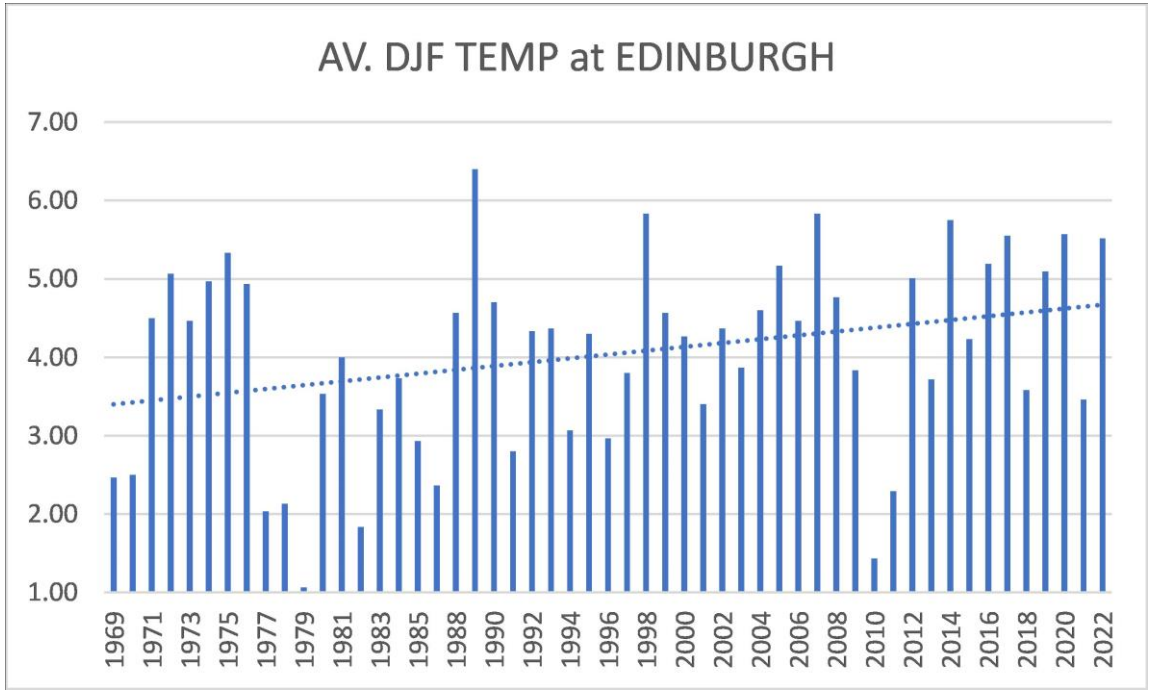
Aphids in a changing climate

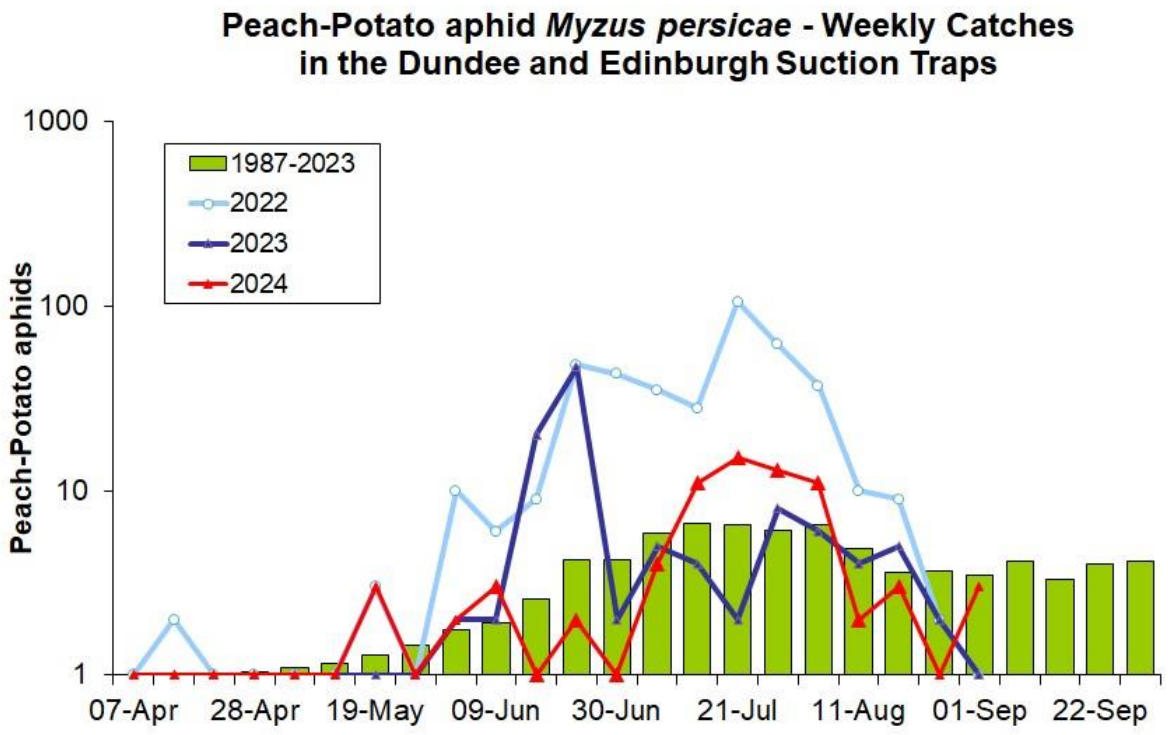
Increasing aphid pressure due to milder winters and warmer summers

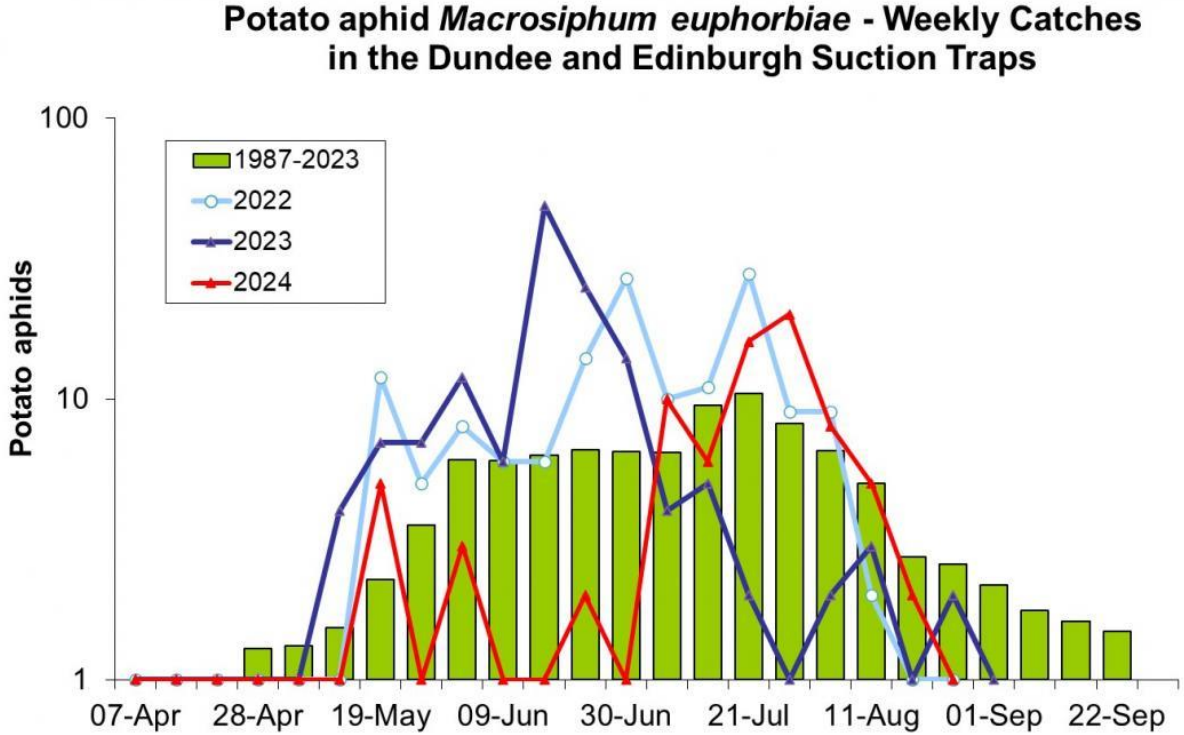




Aphids in a changing climate

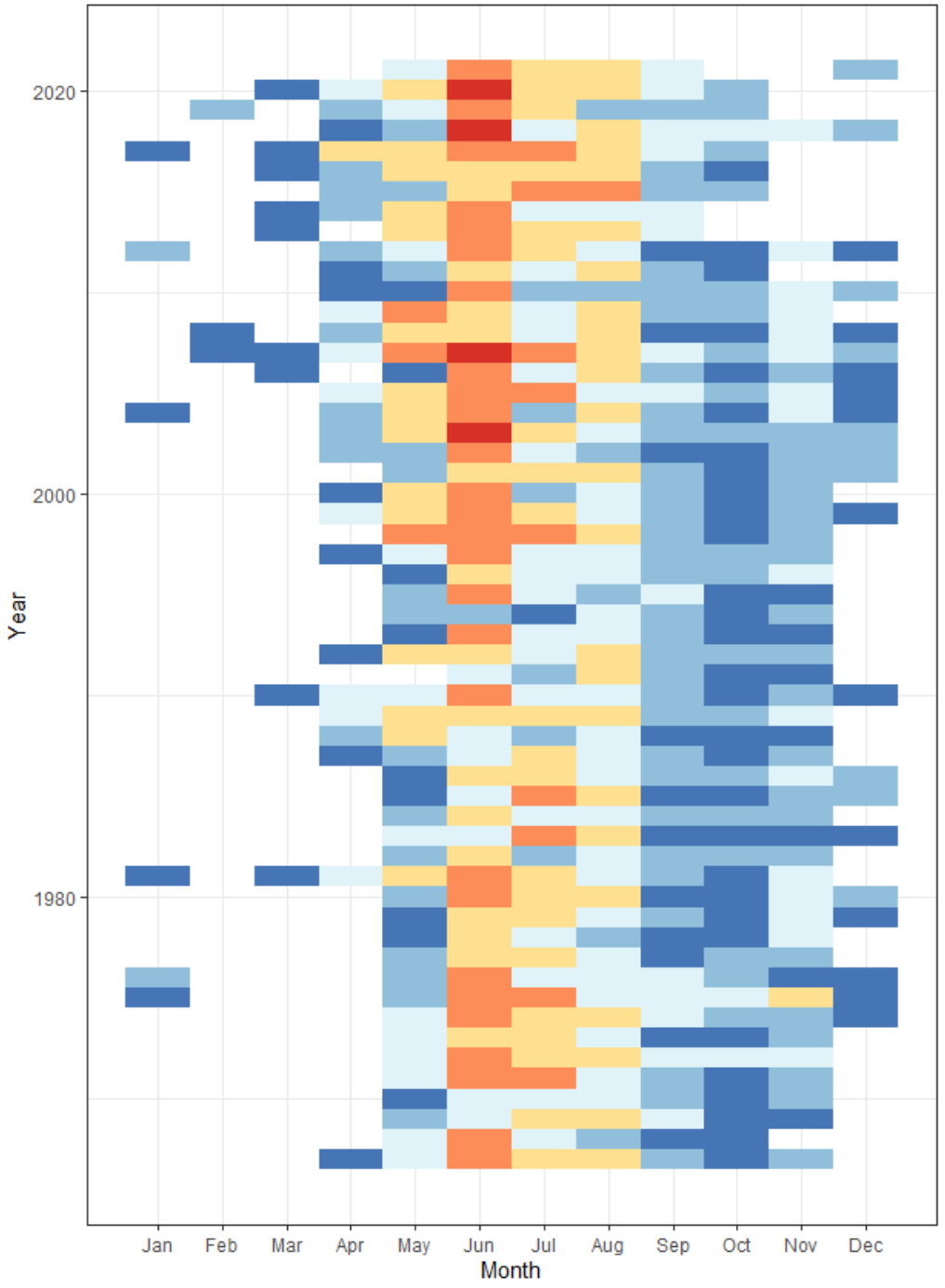
Increasing aphid abundance in recent years

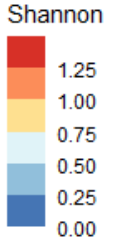


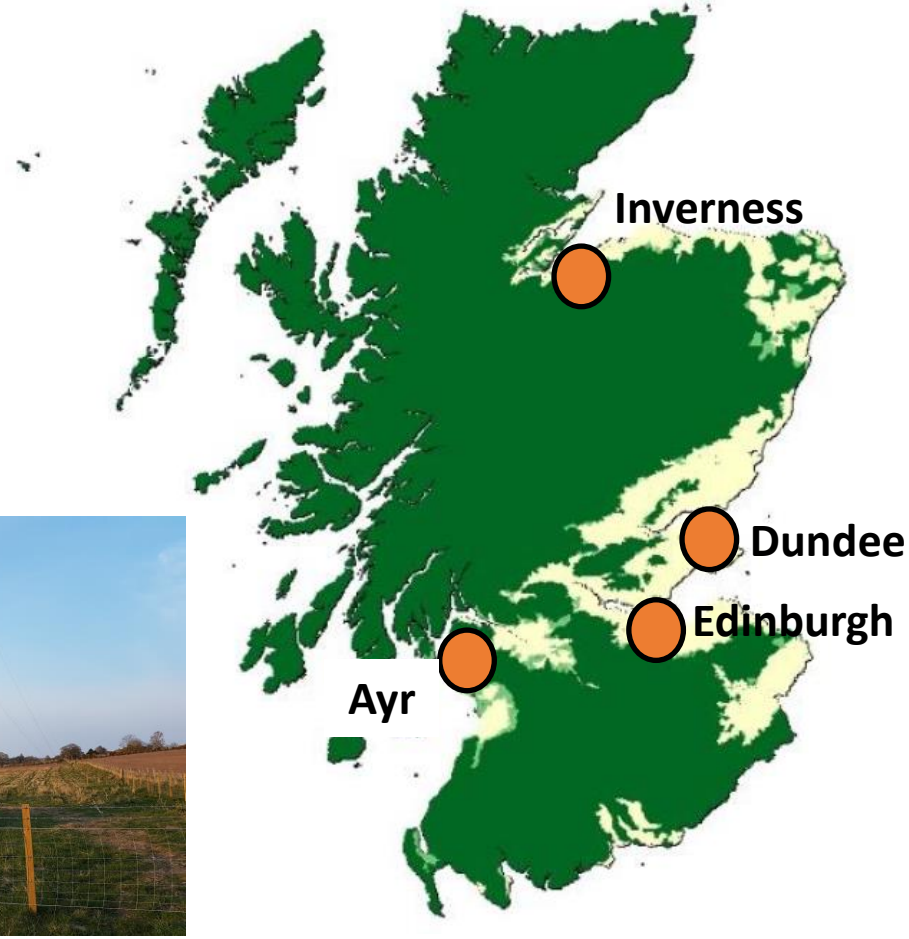


Source: https://www.sasa.gov.uk/wildlife-environment/aphid-monitoring/

Aphid diversity is increasing





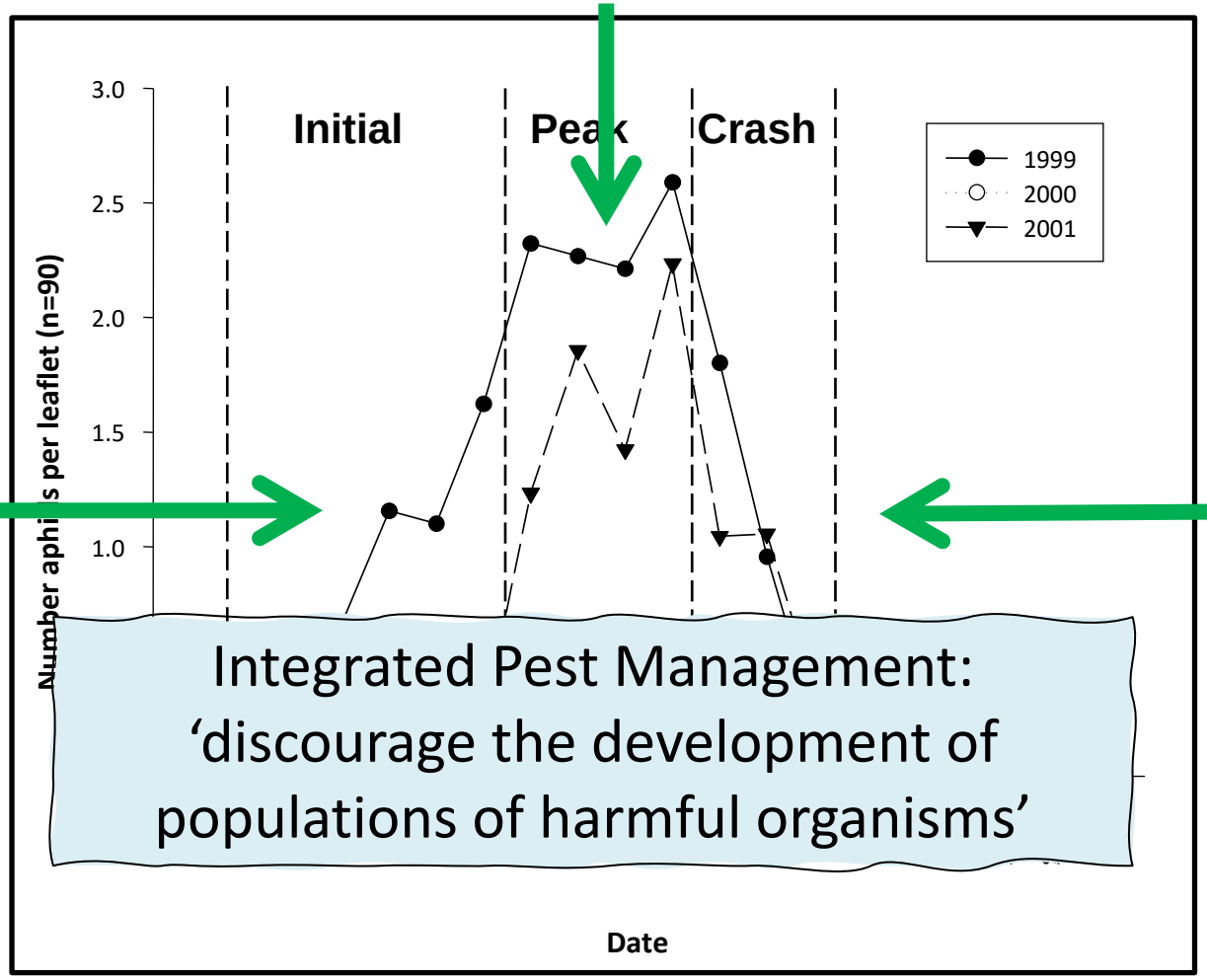


Factors regulating potato aphid abundance

High fitness of aphids colonising good quality immature plants (nutritional and physical traits)

Low natural enemy activity

Aphid recruitment (nymph production, winged aphids) continues up to peak



Integrated Pest Management: 'discourage the development of populations of harmful organisms'

Reduced aphid fitness on poorer quality mature plants (nutritional and physical traits, MPR)

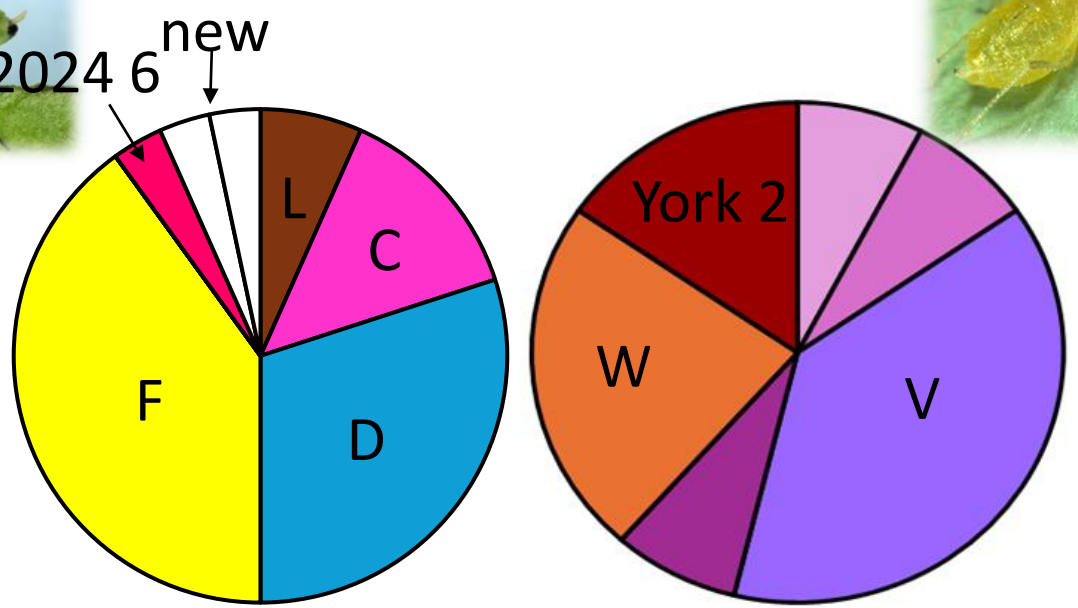
Increased natural enemy activity

Karley et al. (2003) Bull. Ent. Res. 93, 425-437

Field trials of IPM practices

Multi-year trial at Balruddery Farm Centre for Sustainable Cropping to investigate the efficacy of alternative agronomic measures for aphid control

- Co-crop (pea,vetch,rye) sown with the tubers
- Pest monitoring, aphid genotyping
- 3 year trial (each year = 1 replicate)



Summary: aphid dynamics and IPM

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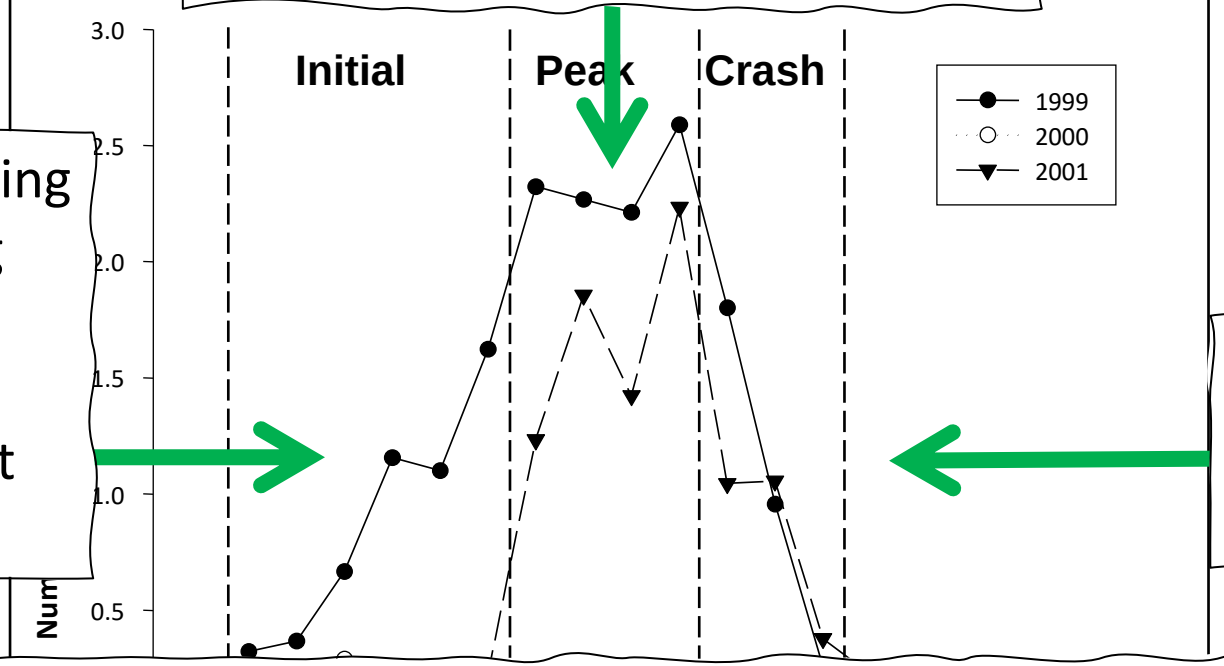
Monitor aphid population composition (species, phenotype)
Pesticide alternatives

Variety choice and breeding to deter aphid settling

Soil microbiome management to attract natural enemies



Mature plant resistance
Enhance natural enemy activity

Warmer, drier summers affect aphid abundance and species composition
Destabilising effects on natural enemy control(?)
Impact on virus control?

Thanks to funders and people

Hutton colleagues
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Ailsa Smith
Susan Verrall
Alon Zuta
Pete Skelsey
Katharine Preedy
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Andrew Christie

Research students
Hannah Clarke
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Many summer students

University collaborators
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Jeremy Pritchard (University of Birmingham)
Steve Hubbard (University of Dundee)
Steve Foster (Rothamsted Research)
Graeme Ruxton (University of St Andrews)

Other collaborators
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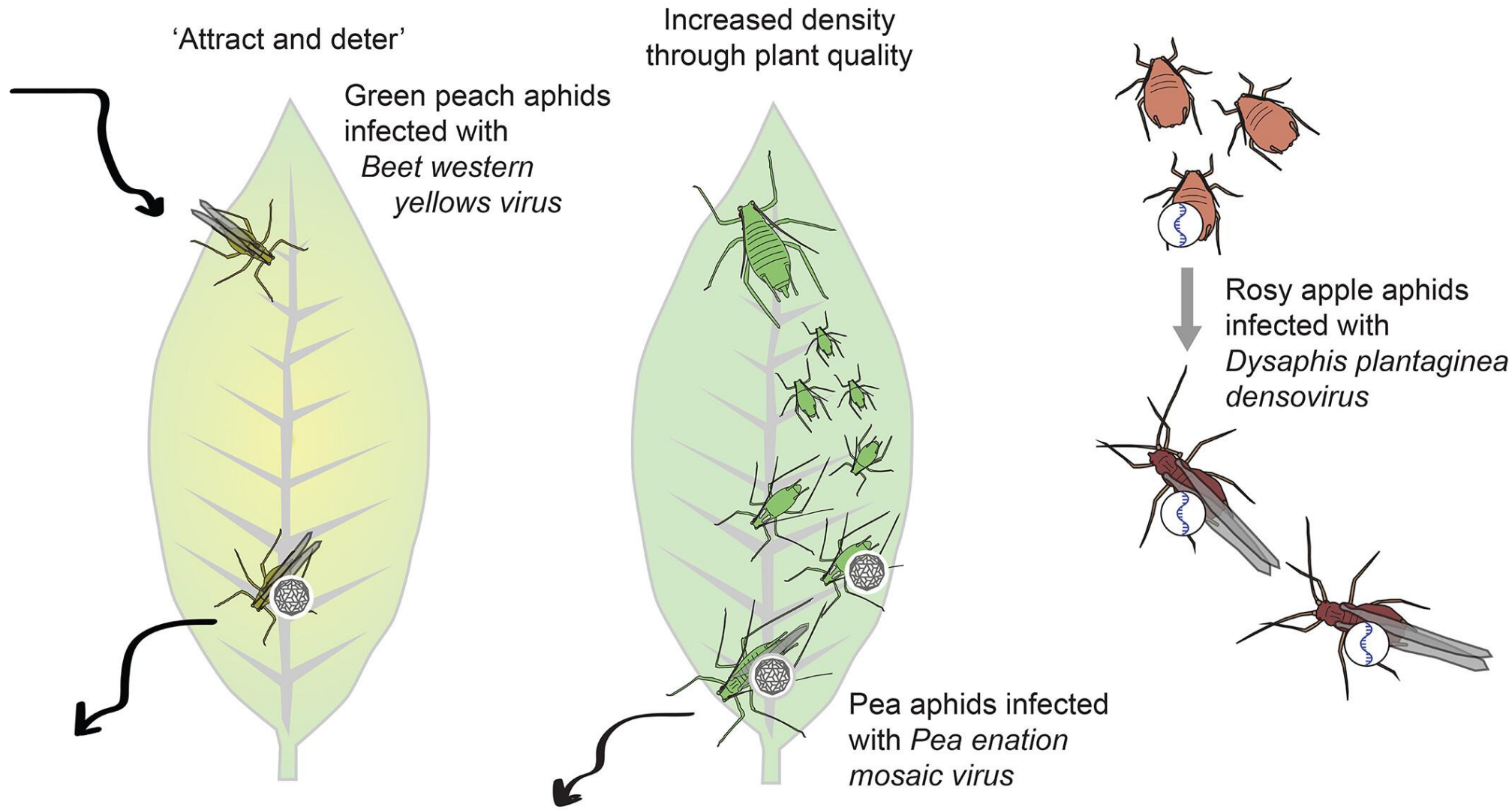
Christophe Lacomme, Fiona Highet (SASA)
Steve Foster (Rothamsted Research)
Scottish Aphid Borne Virus working group

Thankyou for listening

Questions?

(a) **Indirect interactions with winged aphids via host plant**

(b) **Direct wing induction**



VOCs and color of infected plants attract winged aphids; low plant quality causes migration after infection

Viral infection increases host plant quality for aphids; increased density leads to winged aphid production

Viruses directly induce winged aphid formation in infected aphid hosts