

Common resistance mechanisms are deployed by plants against sap feeding herbivorous insects

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Importance of sap-feeding insects

- Sap-feeding insects are a significant problem in food production systems
- Sap-feeding insects are vectors of plant viruses
- Yield losses can exceed 80% if viruses are transmitted
- Recent estimations: for every 1°C rise in temperature yield loss will increase 10%







Image credit: whitefly (Planet Natural); brown planthopper (IRRI)

Protecting plants against sap-feeding insects

- Management options often rely on pesticide applications
- Growing environmental, ecological, and public concerns over pesticide use
- Resistant plant types represent an option for sustainable insect management
  - Many resistant plants described
  - Resistant plants detected for multiple sap-feeding insect species

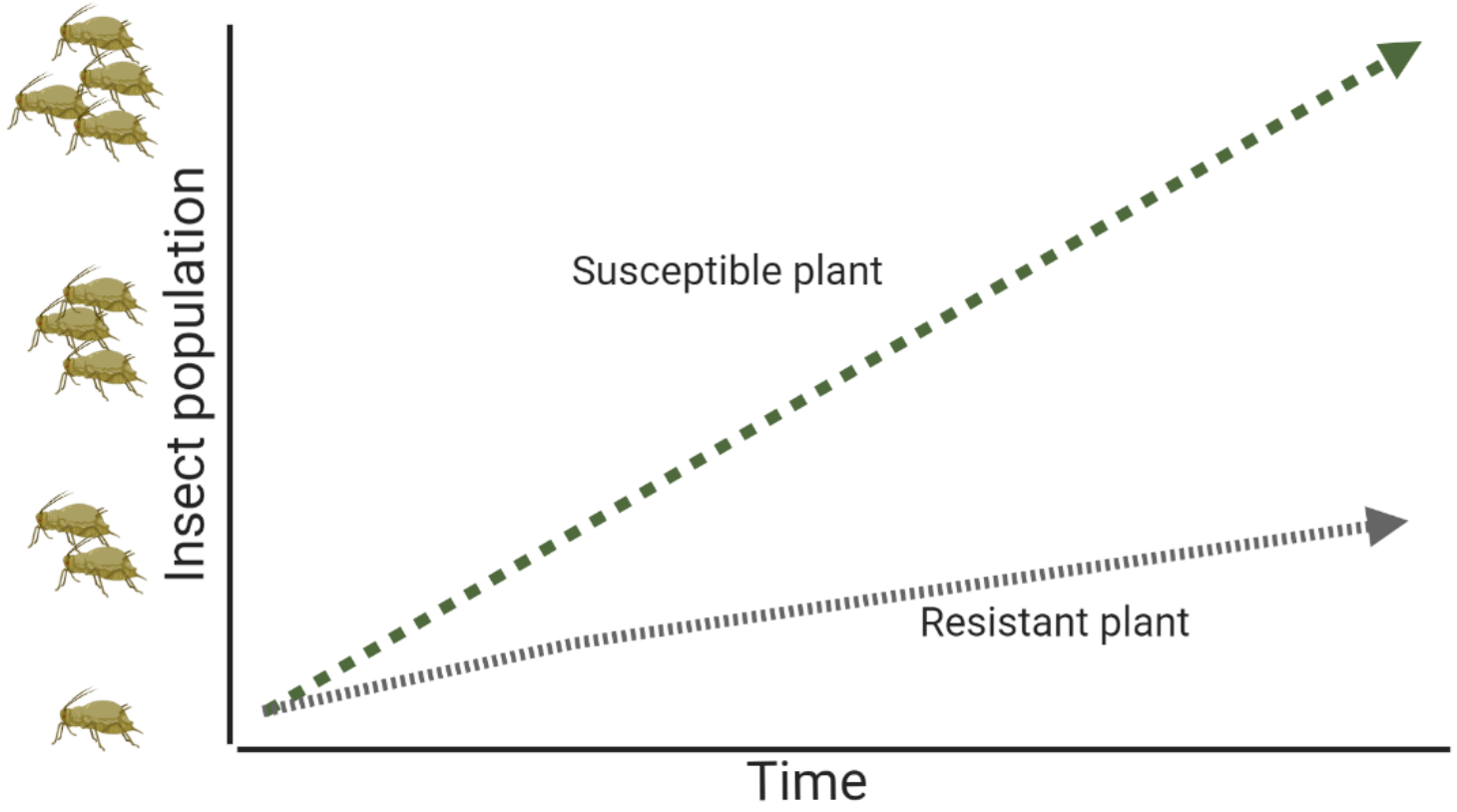






Image credit: whitefly (Planet Natural); brown planthopper (IRRI)

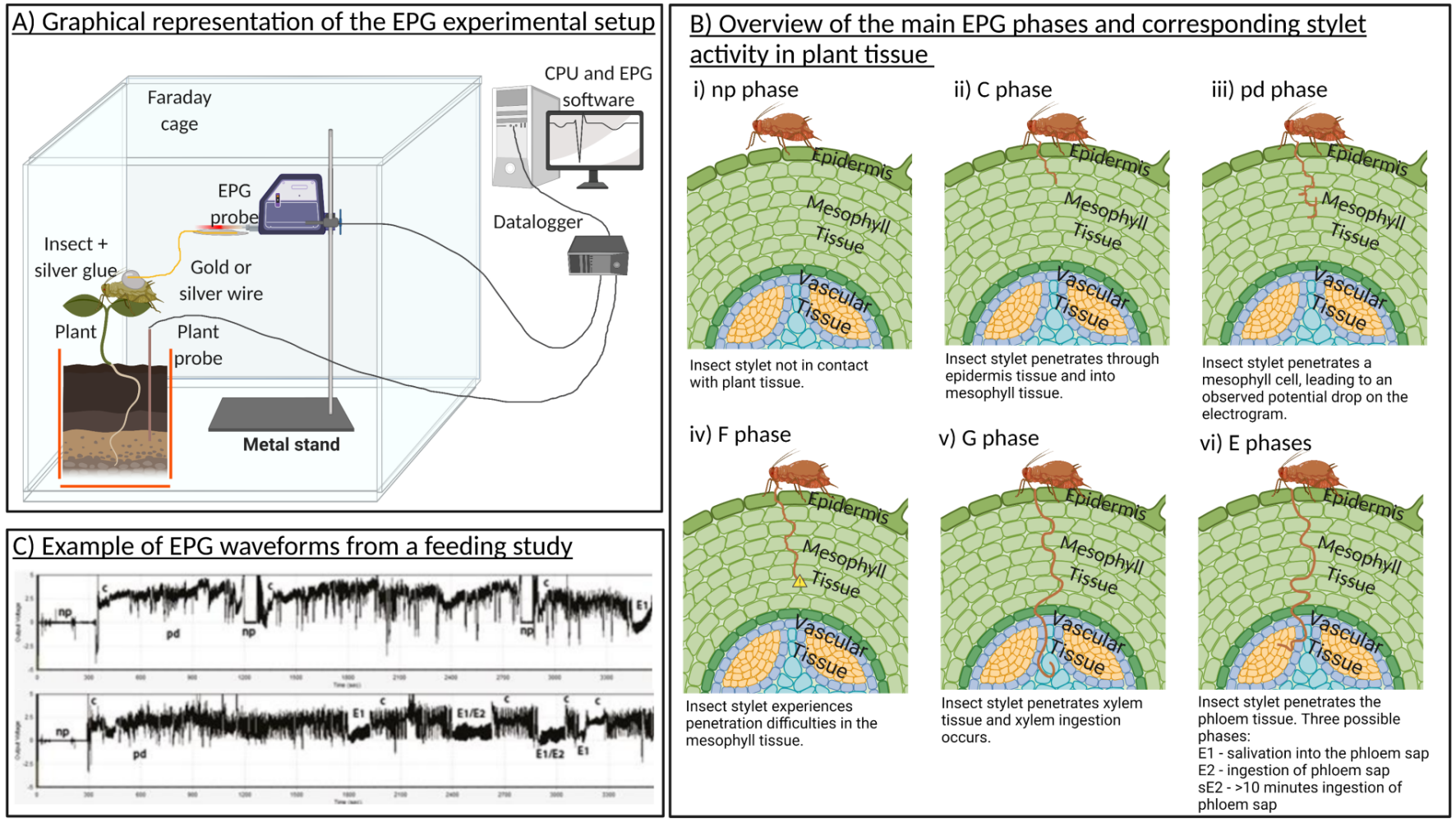
Identifying resistant plants and resistance mechanisms



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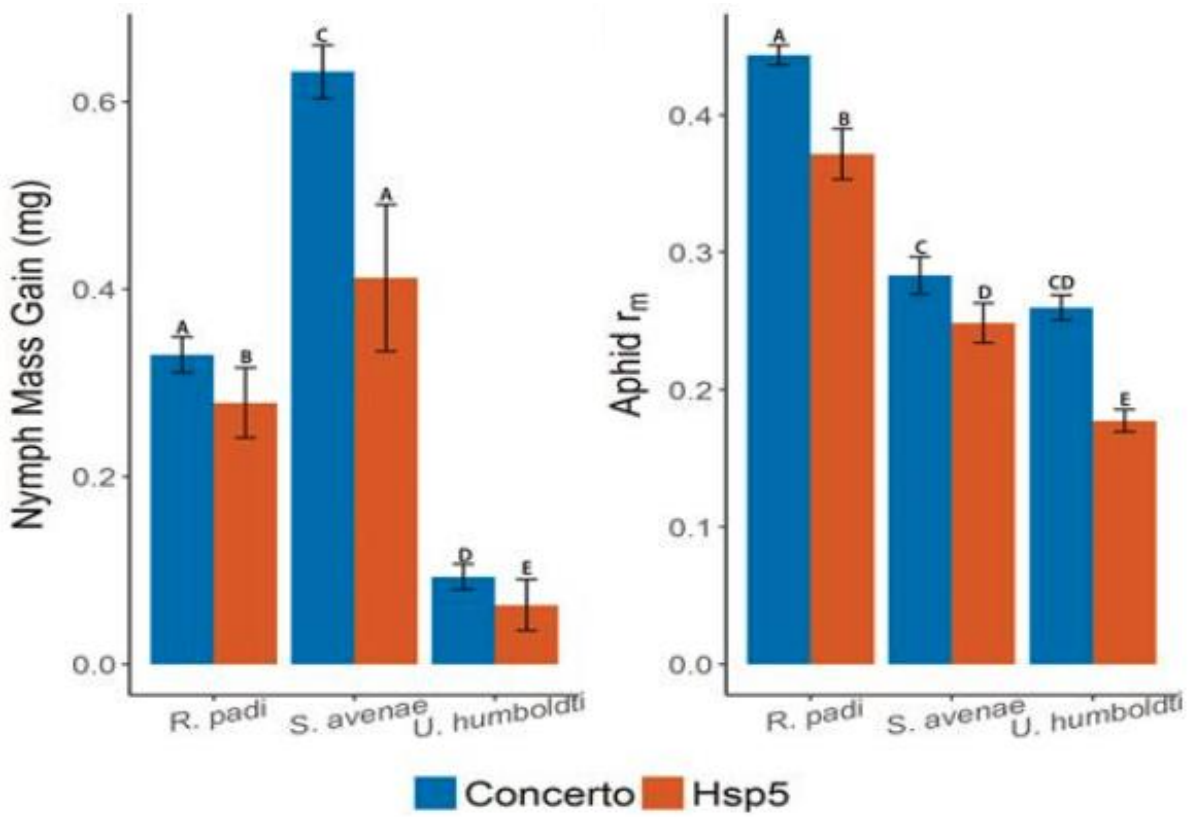
Identifying resistant plants and resistance mechanisms



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Aphid resistance in wild barley

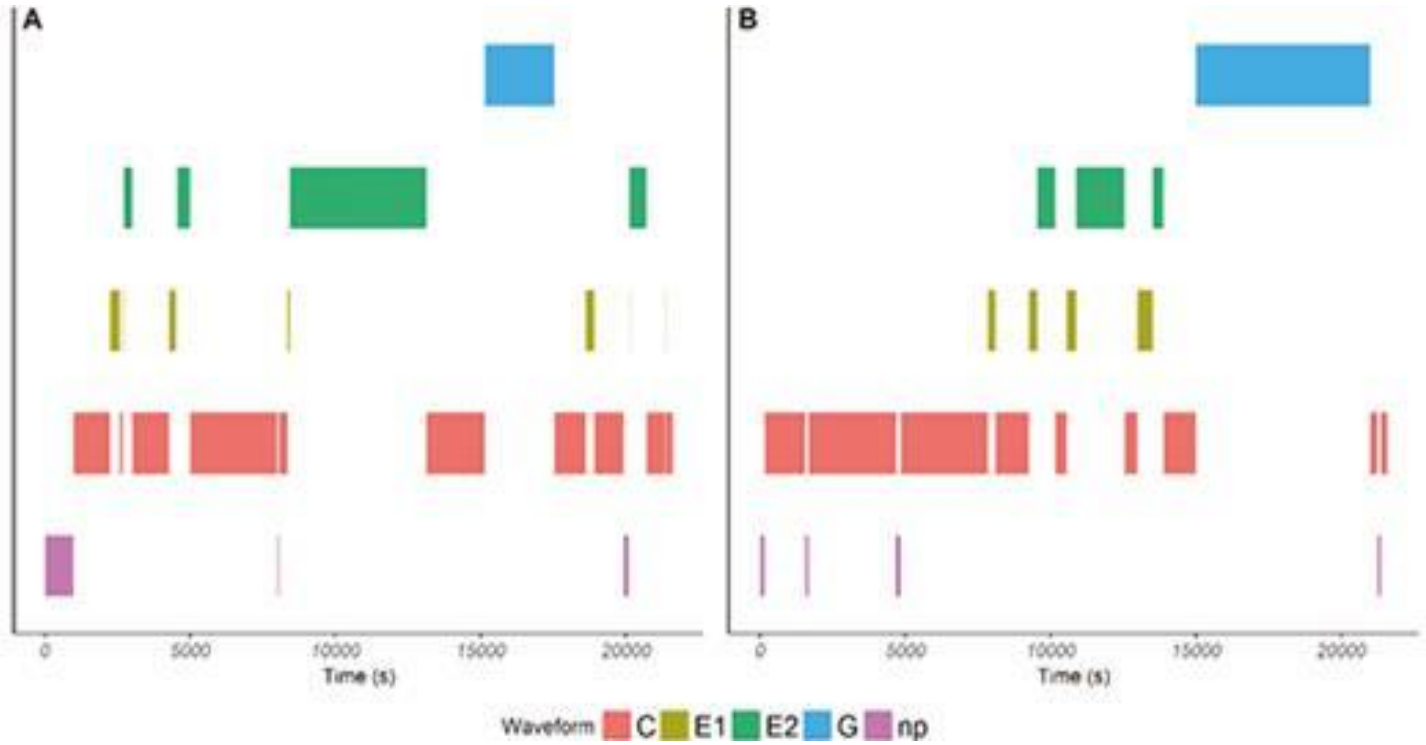


Leybourne et al., 2019; *Journal of Experimental Botany*

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Aphid resistance mechanisms in wild barley

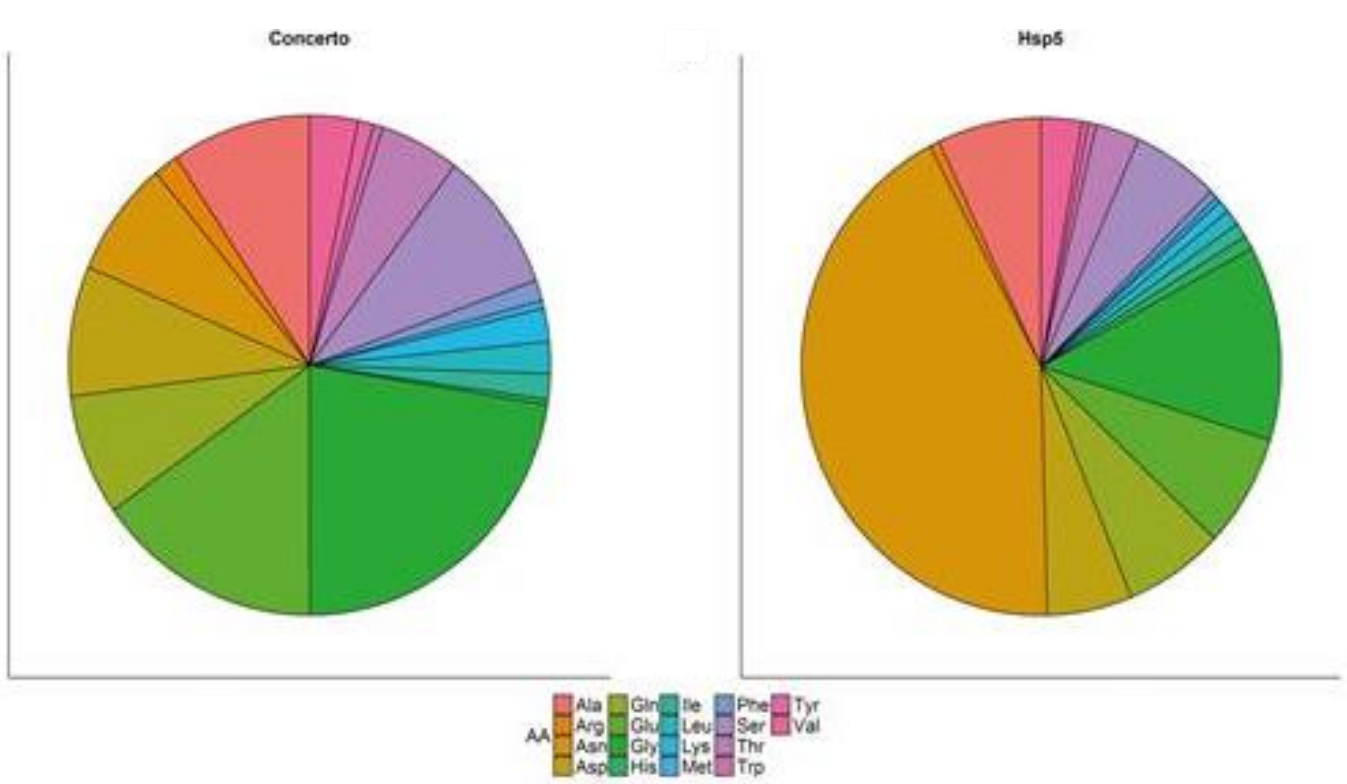


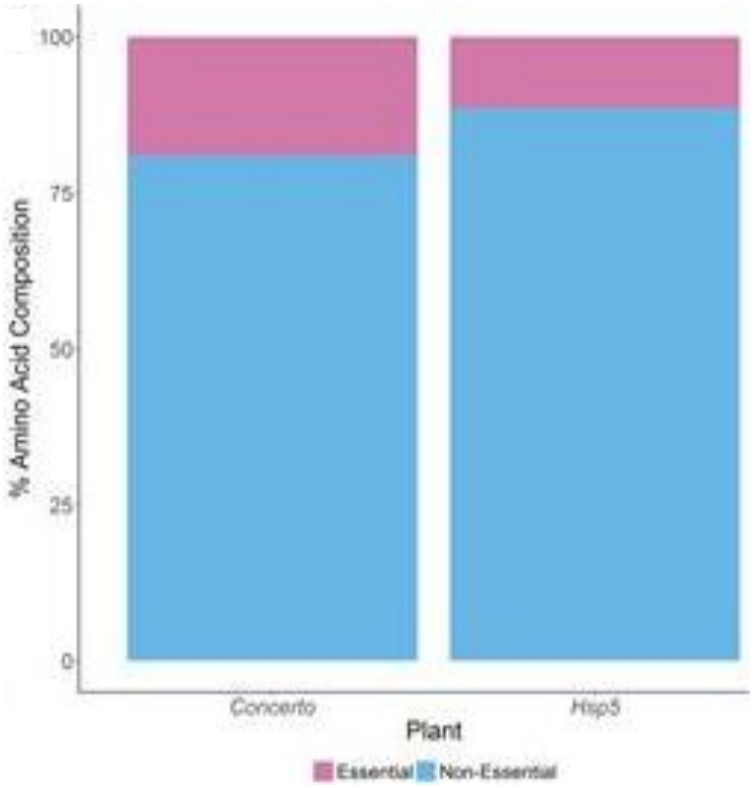
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Aphid resistance mechanisms in wild barley



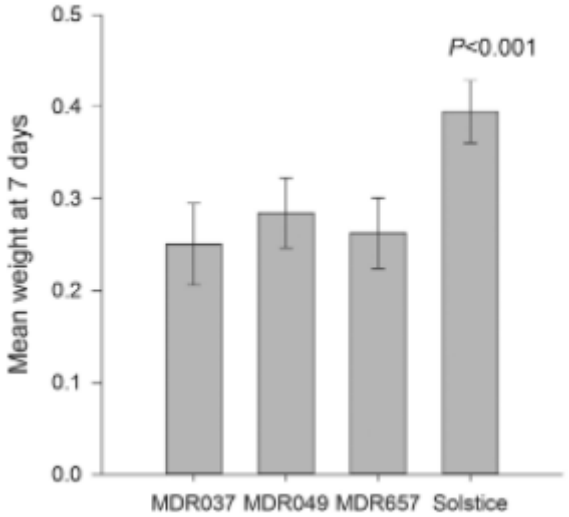


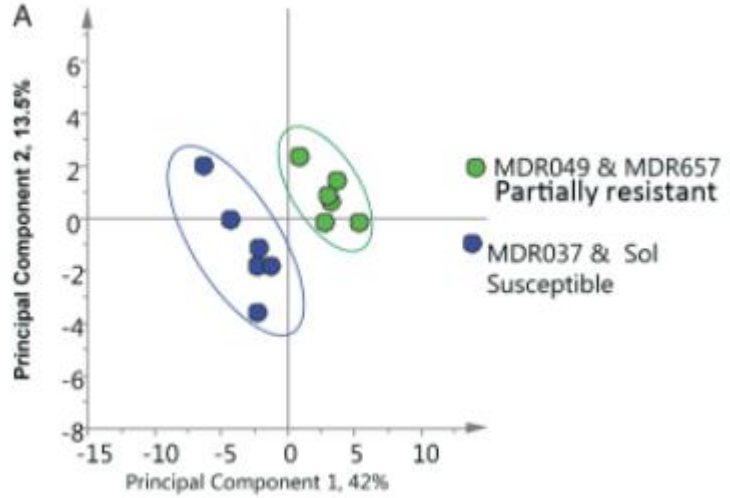
Leybourne et al., 2019; *Journal of Experimental Botany*

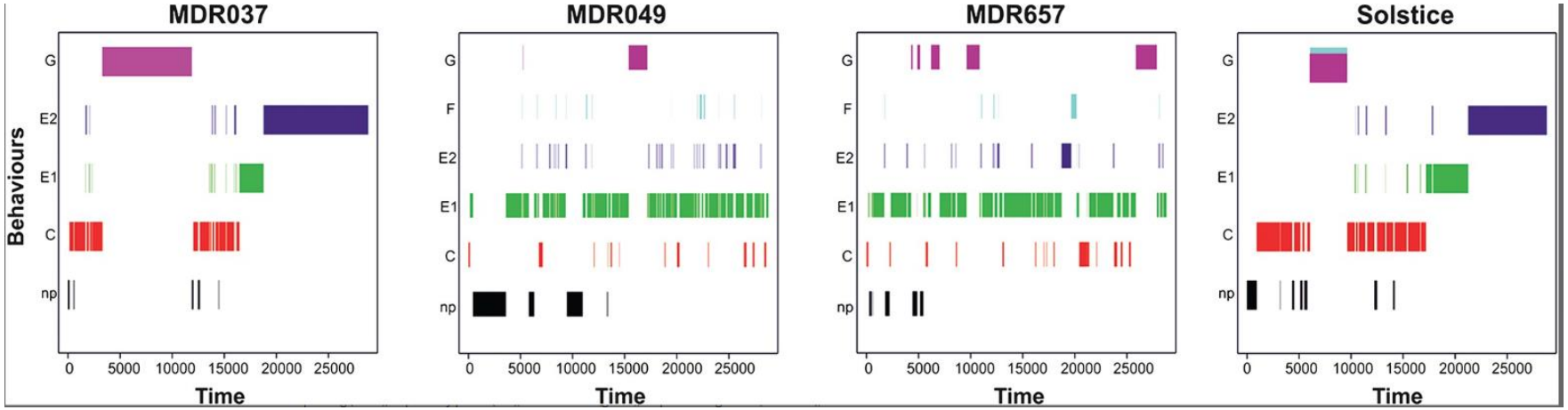
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Similar observations in aphid resistant wheat ...

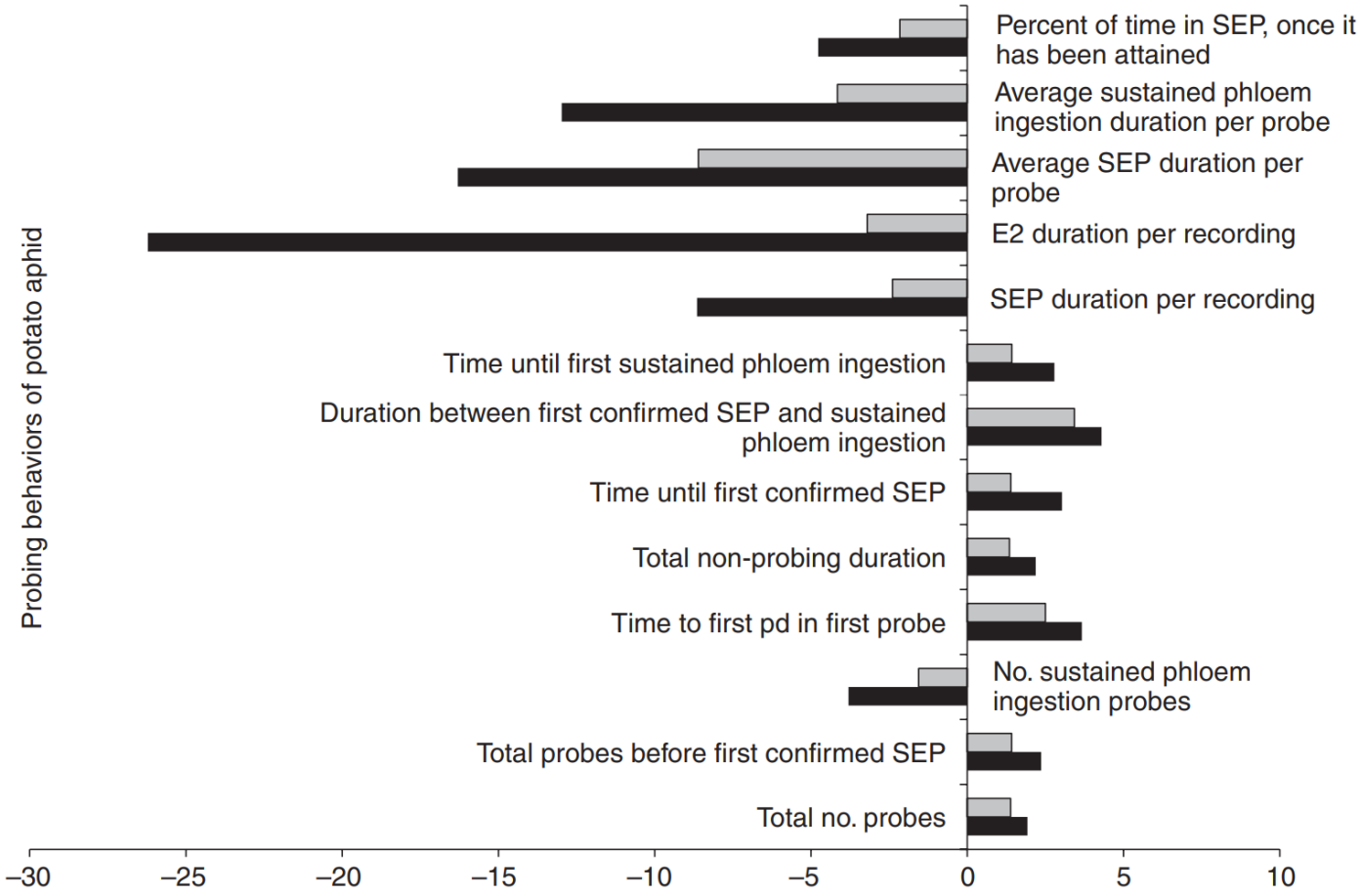






Greenslade *et al.*, 2016; *Annals of Applied Biology*

Similar observations in aphid resistant wheat and tomato ...

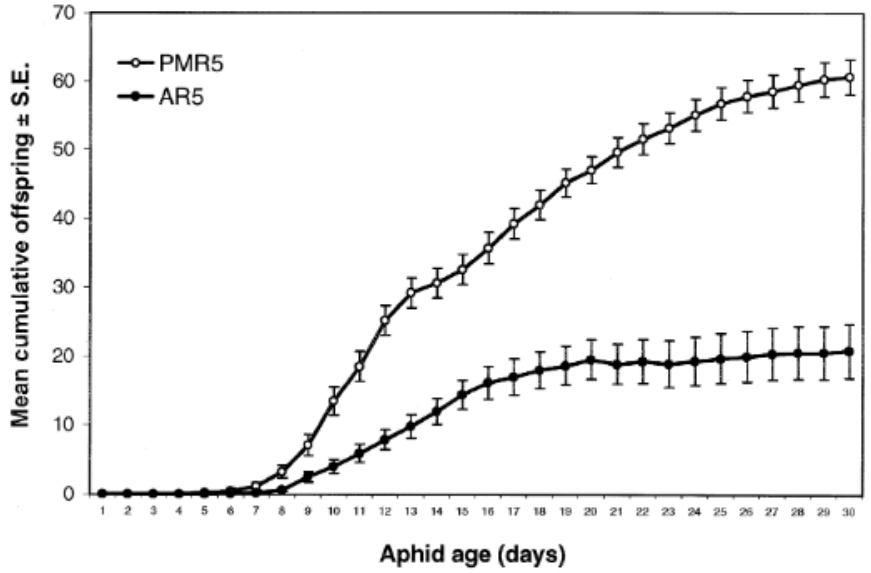


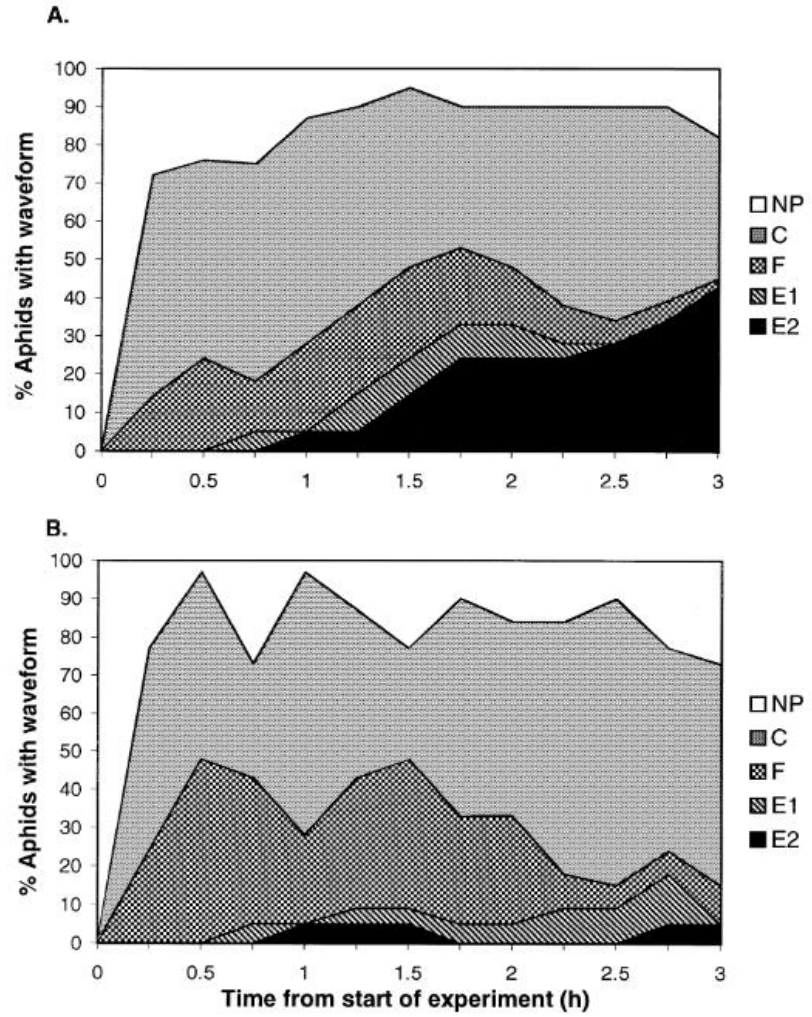
Pallipparambil *et al.*, 2010; *Entomolgia Experimentalis et Applicata*

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Similar observations in aphid resistant wheat and tomato and melon ...





Klingler *et al.*, 1998; *Entomolgia Experimentalis et Applicata*

Similar patterns are observed in other sap-feeding insects

- Brown planthopper resistance in rice
- Tea green leafhopper resistance in tea
- Whitefly resistance in tomato
- Whitefly resistance in Brassica
- Whitefly resistance in alfalfa





Image credit: whitefly (Planet Natural); brown planthopper (IRRI)

Questions arising

1. How common are aphid resistance mechanisms?
2. Is this similar to resistance in other sap-feeding insects?
3. Are the underlying resistance traits similar?

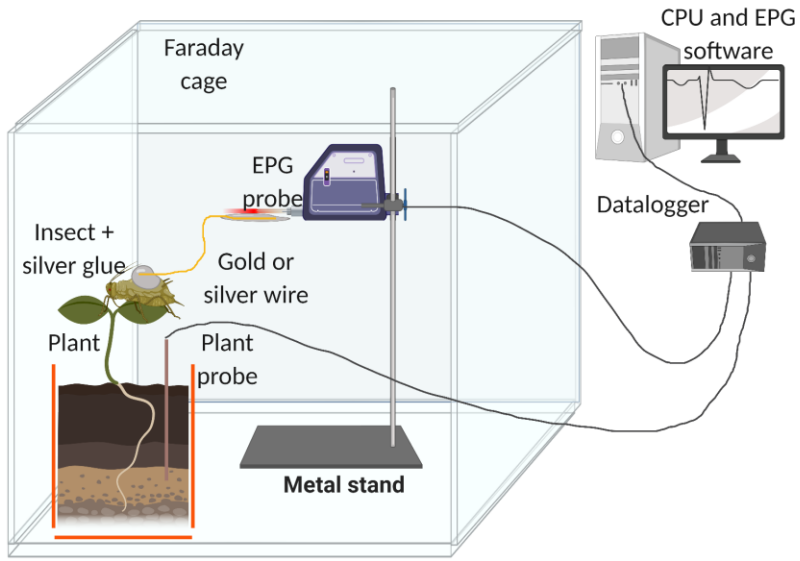


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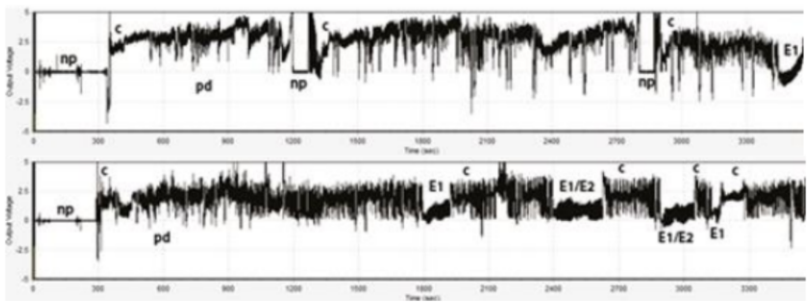
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How can we identify commonalities?

A) Graphical representation of the EPG experimental setup

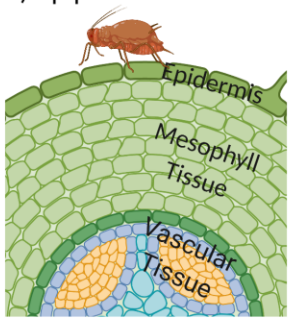


C) Example of EPG waveforms from a feeding study



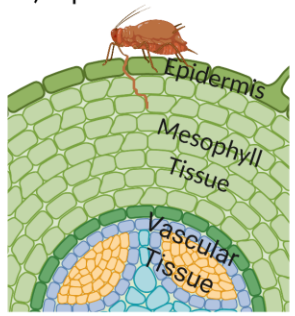
B) Overview of the main EPG phases and corresponding stylet activity in plant tissue

i) np phase



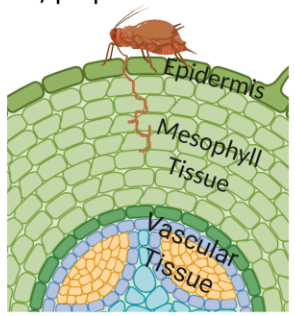
Insect stylet not in contact with plant tissue.

ii) C phase



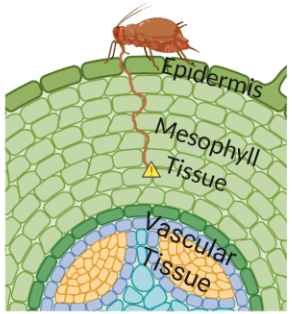
Insect stylet penetrates through epidermis tissue and into mesophyll tissue.

iii) pd phase



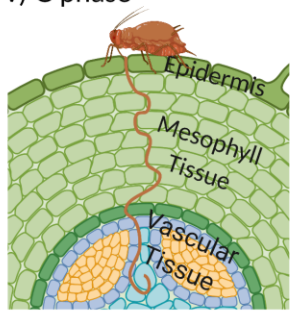
Insect stylet penetrates a mesophyll cell, leading to an observed potential drop on the electrogram.

iv) F phase



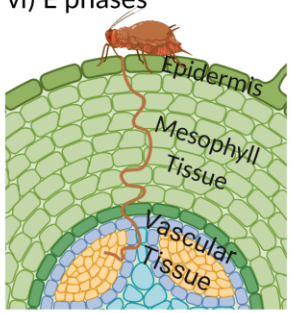
Insect stylet experiences penetration difficulties in the mesophyll tissue.

v) G phase



Insect stylet penetrates xylem tissue and xylem ingestion occurs.

vi) E phases

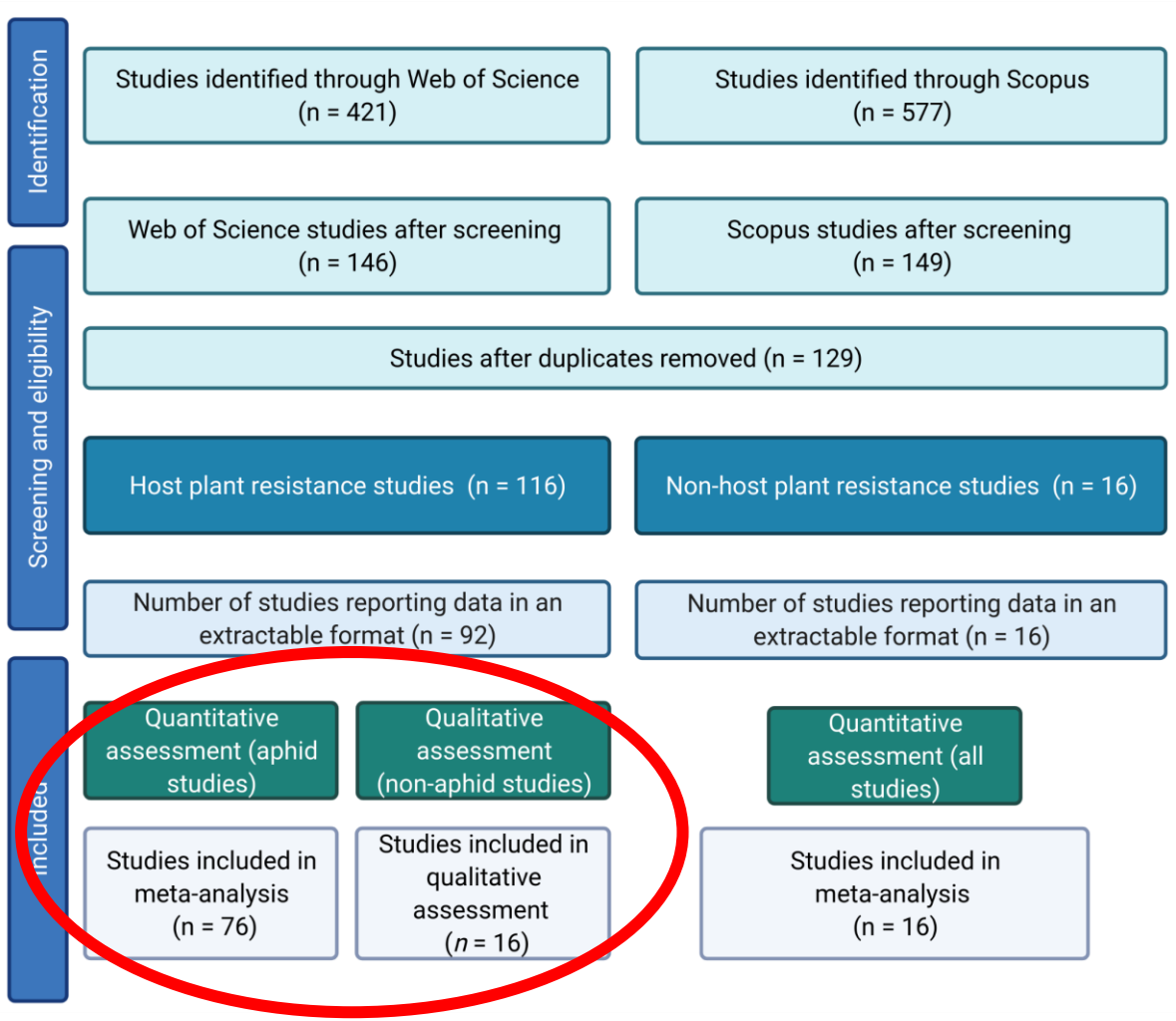


Insect stylet penetrates the phloem tissue. Three possible phases:
E1 - salivation into the phloem sap
E2 - ingestion of phloem sap
sE2 - >10 minutes ingestion of phloem sap

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Quantitative and qualitative synthesis



Data collection

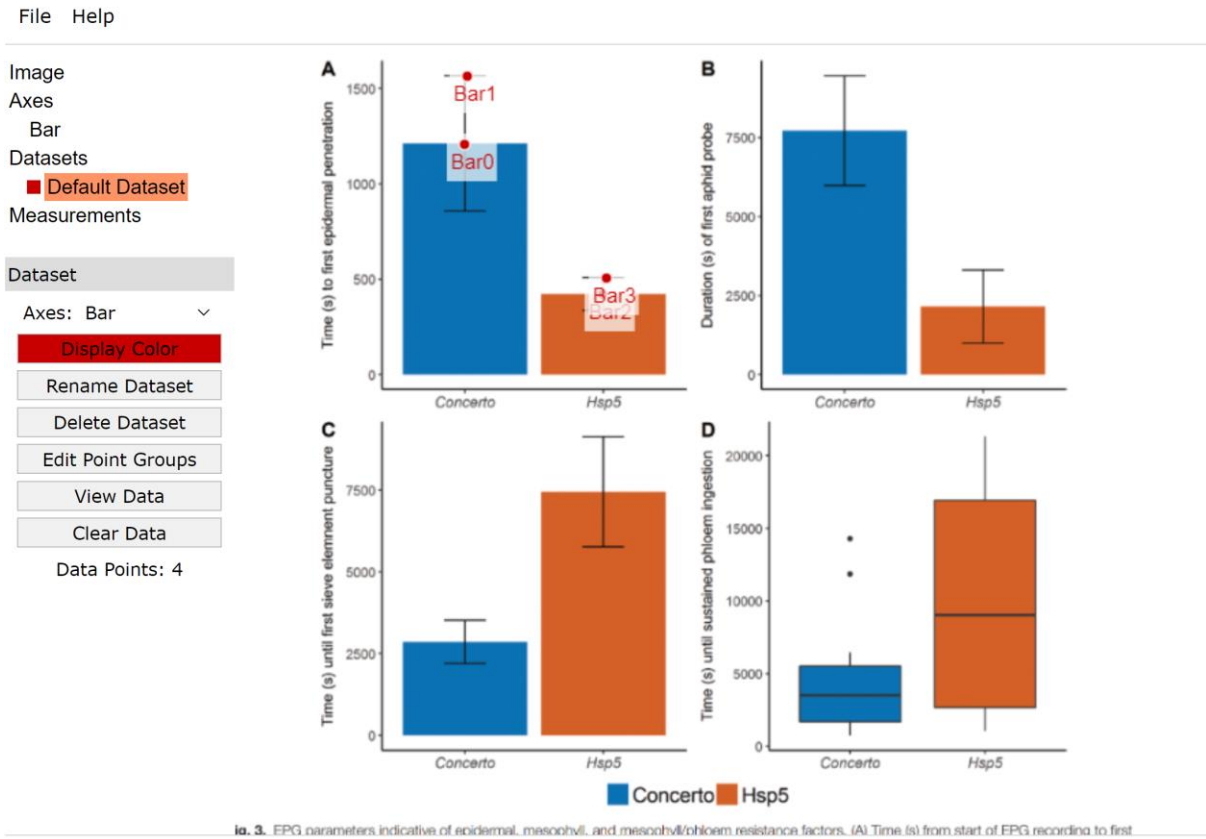
EPG data were extracted for:

- The total waveform duration
- The time until first waveform observation

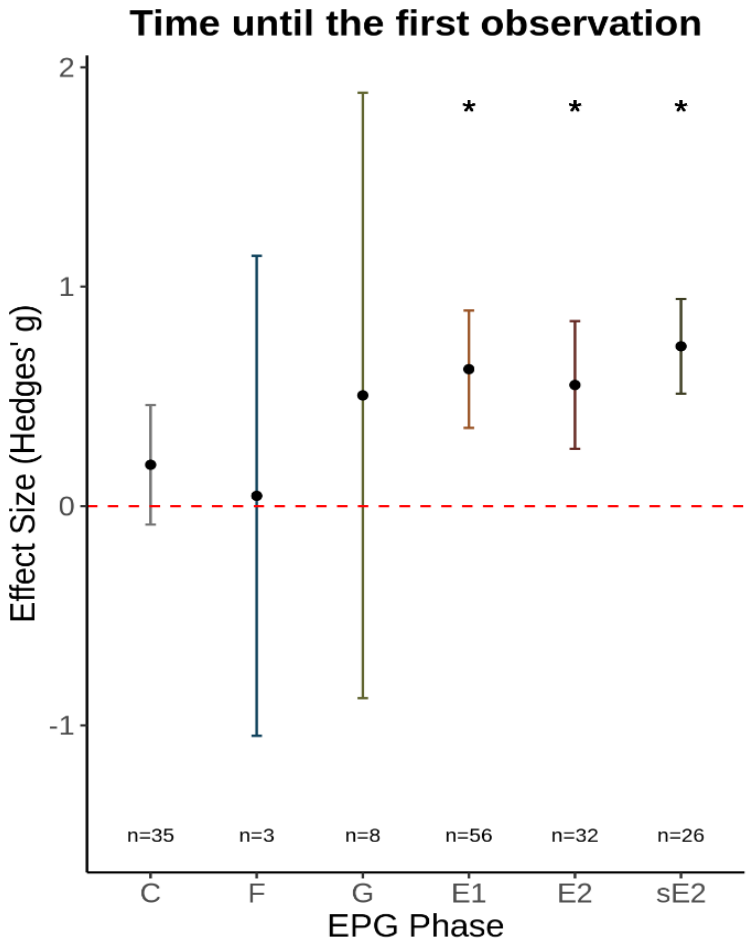
An effect size was calculated for each plant species examined per study

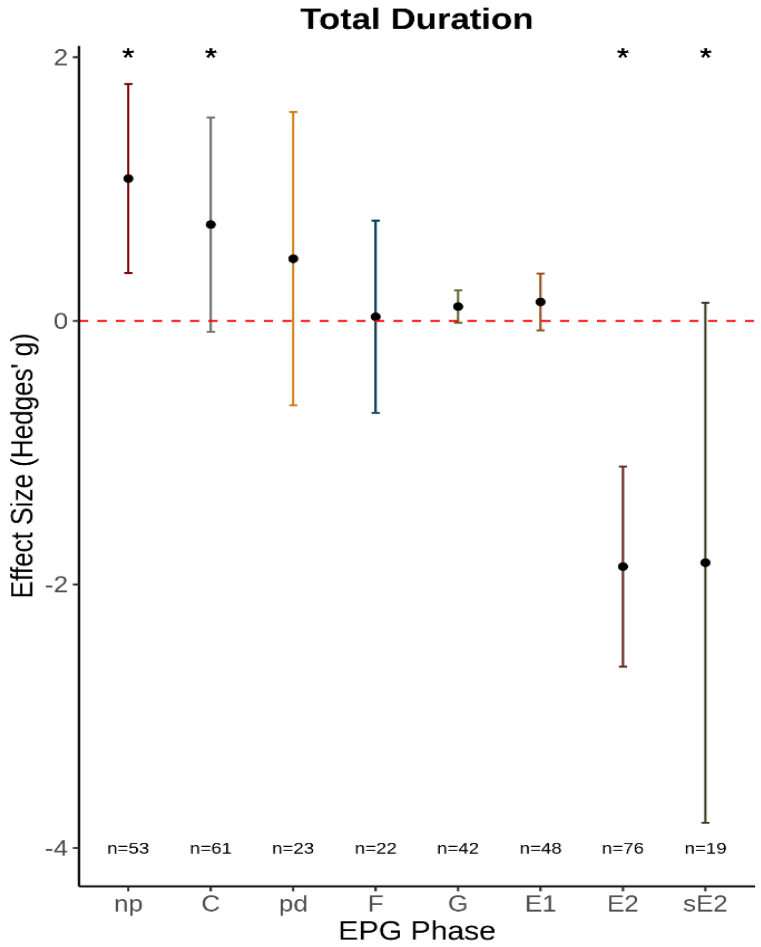
Data grouping:

- Plant family
- Aphid specialism



Common aphid resistance mechanisms



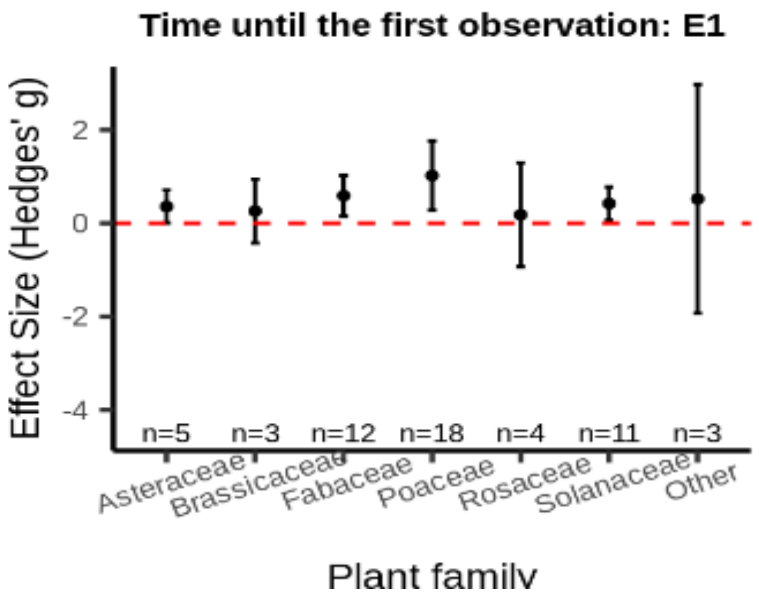




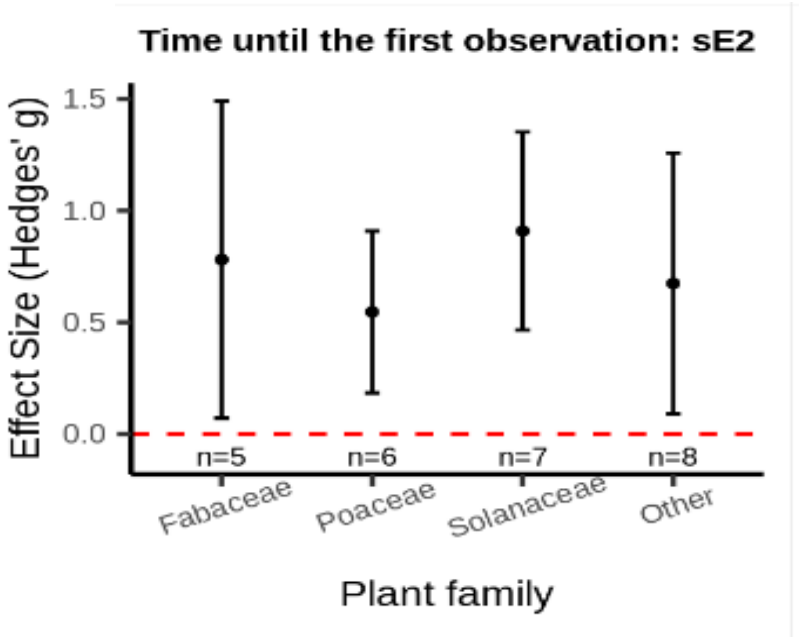
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No difference between plant family





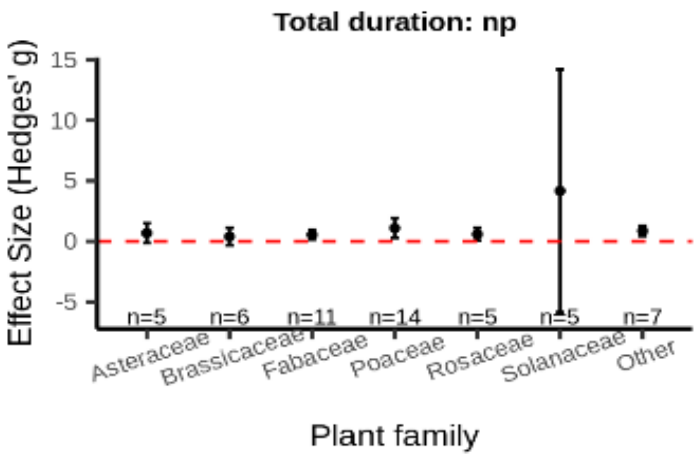


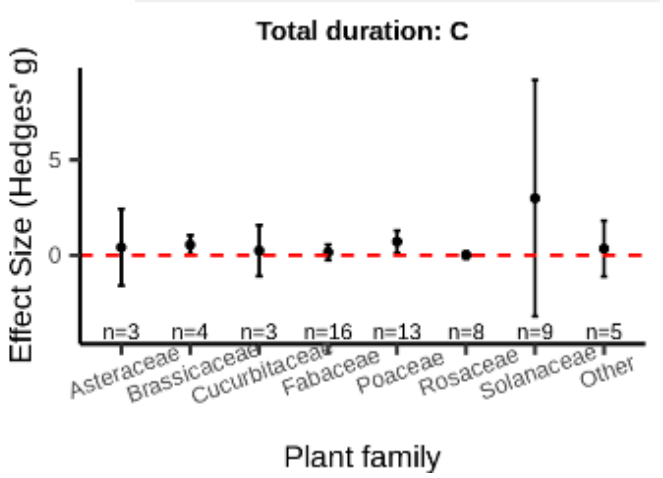


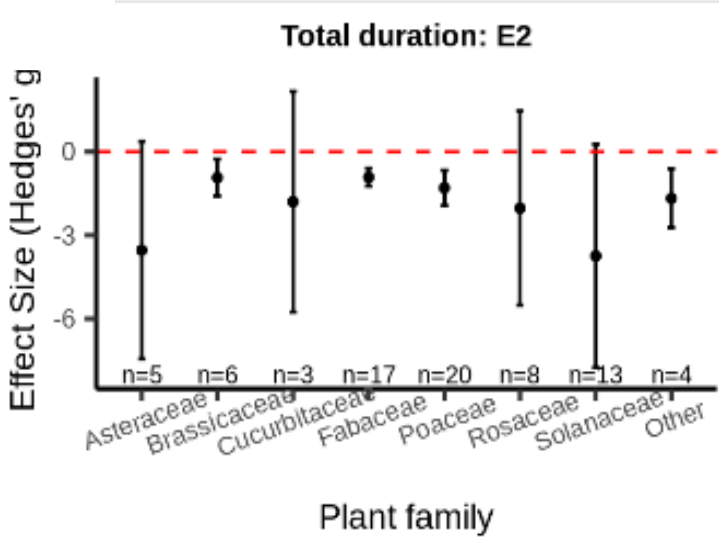
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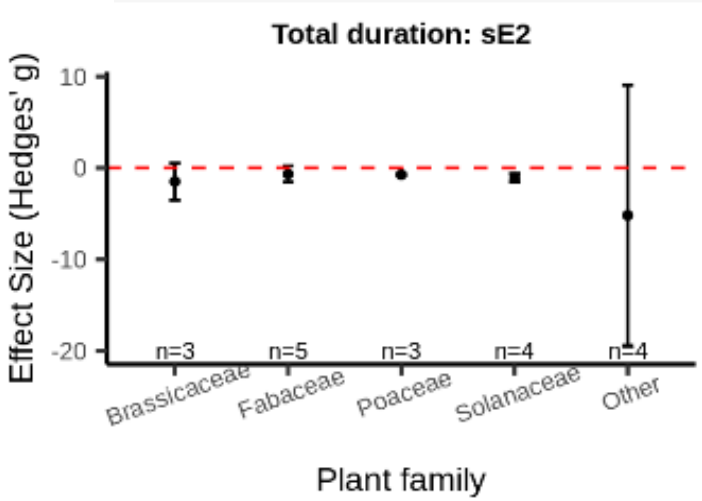
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No difference between plant family







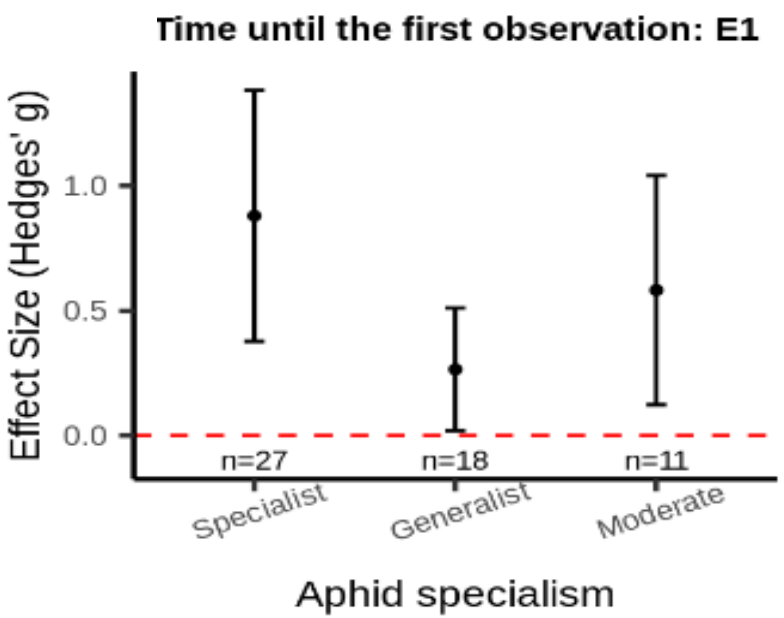


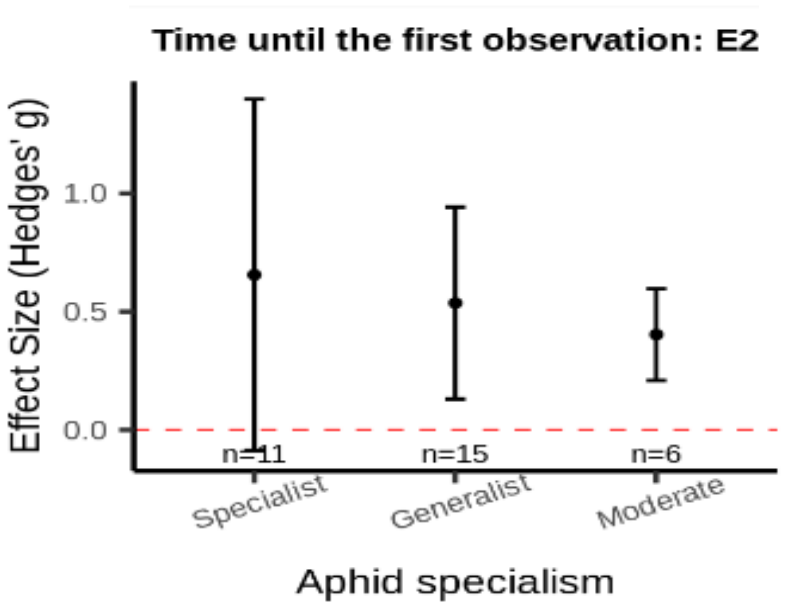


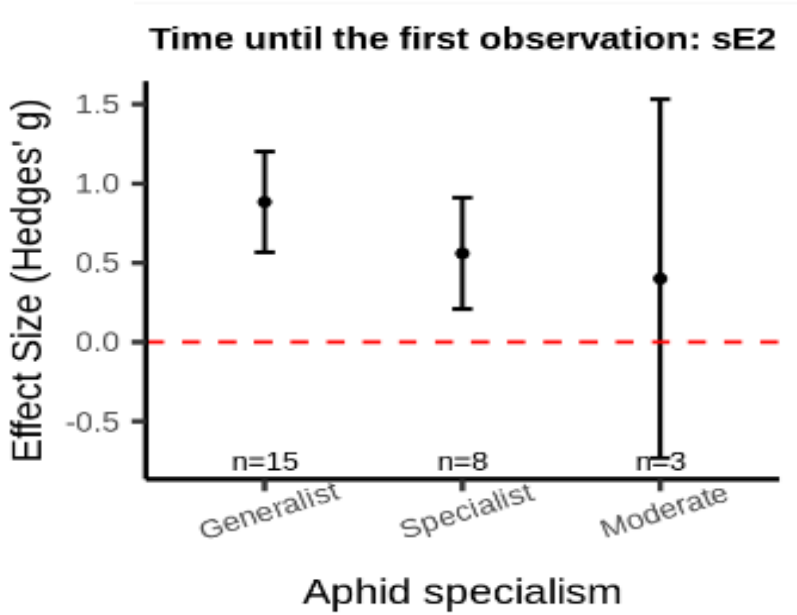
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No difference between aphid specialism





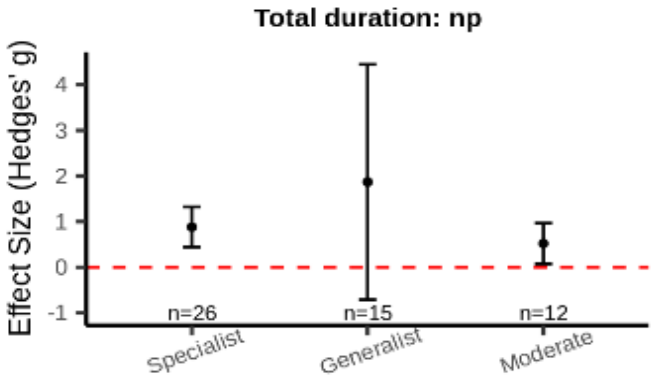


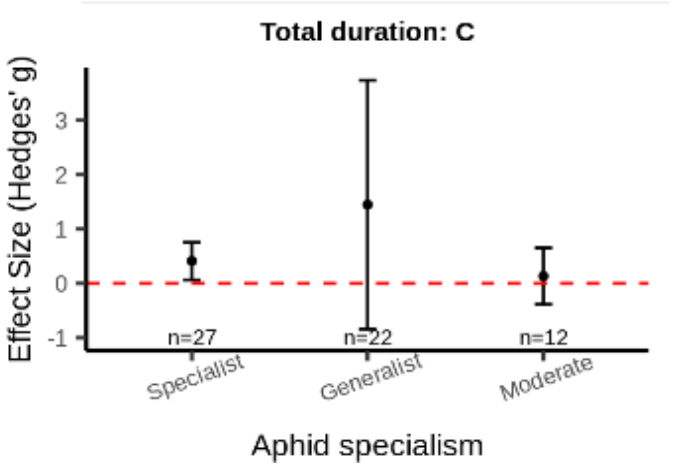


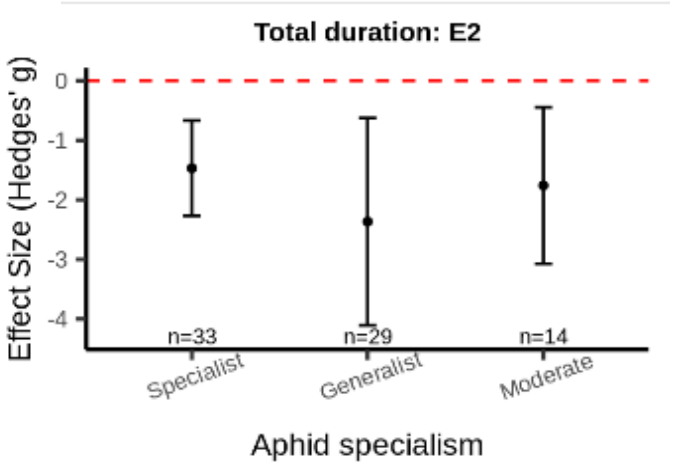
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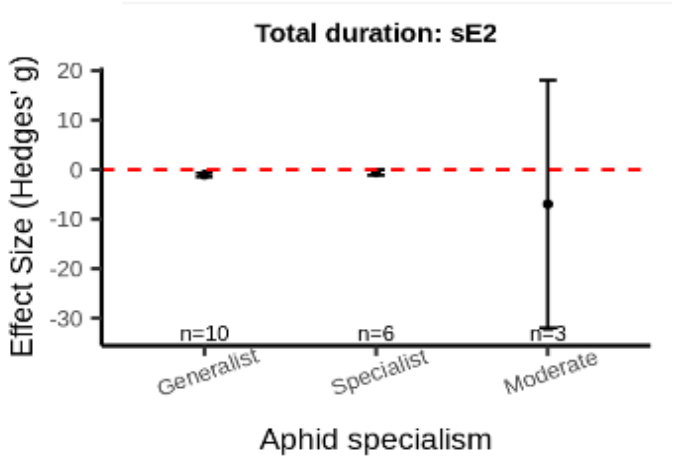
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No difference between aphid specialism











Aphid conclusion

- Restricting access to the phloem and limiting sap ingestion common aphid resistance mechanisms
- Deterring probing and increasing mesophyll contact also important
- Similar results across plant families
- Specialists and generalists impacted similarly



Leybourne & Aradottir, *bioRxiv*

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Common resistance mechanisms

Insect feeding behaviour	Chinch bug	Leafhopper	Planthopper	Psyllid	Whitefly	Aphid
	n = 1	*n* = 3	*n* = 4	*n* = 1	*n* = 7	*n* = 77
Non-probing	Duration ↑	Duration ↑	Duration ↑	Duration ↑	Duration ↑	Duration ↑
Tissue probing	Duration ↑	Duration ↓	Duration ↑	Duration ↑	Time to First ↑ Duration ↓	Time to First — Duration ↑
Salivation into the phloem	Duration —	Duration ↑	Time to First ↑ Duration —	Time to First ↑	Time to First ↑ Duration ↓	Time to First ↑ Duration —
Sap ingestion from phloem	Duration ↓	Duration ↓	Time to First ↑ Duration ↓	Time to First ↑ Duration ↓	Time to First ↑ Duration ↓	Time to First ↑ Duration ↓
Sap ingestion from Xylem	Duration ↓		Duration —	Time to First ↑ Duration ↓	Duration ↑	Time to First — Duration —







Leybourne & Aradottir, *bioRxiv*

Image credit: whitefly (Planet Natural); brown planthopper (IRRI)

What are the resistance traits?

- From 92 studies 23 identified (some) of the resistance traits
- Grouped traits into categories:
  - Chemical (most common trait)
  - Nutritional
  - Physical
  - Molecular
  - Combined/multi-faceted



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Take-home message

- Resistance commonly involves restricting access to the phloem and limiting sap ingestion
- Deterring insect probing and increasing mesophyll contact are important resistance mechanisms
- Mechanisms similar across plant families
- Specialist and generalist insects impacted similarly
- Similar trends observed in multiple sap-feeding groups
- Some common underlying resistance traits







Image credit: whitefly (Planet Natural); brown planthopper (IRRI)

Acknowledgements

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Laura Cooper (Undergraduate student; study screening for meta-analysis)

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Non-host resistance results

