Pesticide use and the origin of crop pests: theory and a test with pests of California crops

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Outline:

I. What are the main drivers of pesticide use in California crops?
- economic drivers
- ecological drivers

→ *Key question: are farmers good profit maximizers?*

II. What shapes the community of pests found on a crop?
- introduced versus native pests
- host shifts and phylogenetic isolation of the crop plant from the native plant community

→ *Key goal: building a conceptual framework for biological control*

Understanding the main drivers of pesticide use

Key goal of much of biocontrol research: reduce reliance on pesticides

Can we use California's Pesticide Use Reporting database to study the main drivers of pesticide use?

Theory from agricultural economics

- Agricultural economics theory is generally based on the assumption that farmers are profit maximizers
- A corollary: crop value is a central determinant of pesticide use
- Although it is considered a “textbook example” of profit maximization, there are few tests

Theory from agricultural entomology

- Core tenet of IPM: only apply pesticides when:

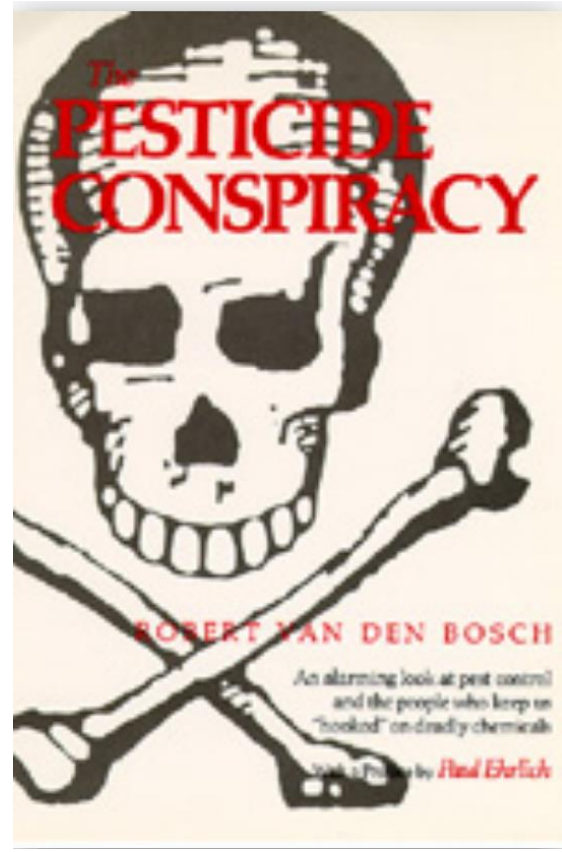
$$\begin{pmatrix} Value\ of\ the\ crop \\ damage\ that\ is\ prevented \end{pmatrix} > \begin{pmatrix} Cost\ of\ the\ pesticide \\ application \end{pmatrix}$$

-- This is the basis of the Economic Injury Level (EIL)

-- This is essentially a re-statement of the idea that farmers should be profit maximizers

Theory from sustainable agriculture/agroecology:

- Many factors make it hard for farmers to achieve the profit-maximizing optimum
- Robert van den Bosch, *The Pesticide Conspiracy*:
  - -- Farmers are misled
  - -- Most pest control advisors are chemical company representatives → conflicts of interest
  - -- Pesticides are overused, misused
  - -- pest problems are self-generated ("pesticide treadmill")



Theory from sustainable agriculture/agroecology:

- Biological features of the crop-pest interaction may also shape pesticide use

  Hypothesis 1: belowground crops may receive fewer pesticide applications (arthropods)

  Hypothesis 2: perennial crops may receive fewer pesticide applications than annual crops (arthropods; pathogens)

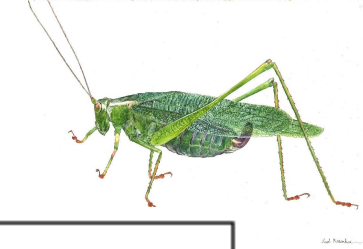
  Hypothesis 3: processed crops may receive fewer pesticide applications than non-processed crops (arthropods; pathogens)

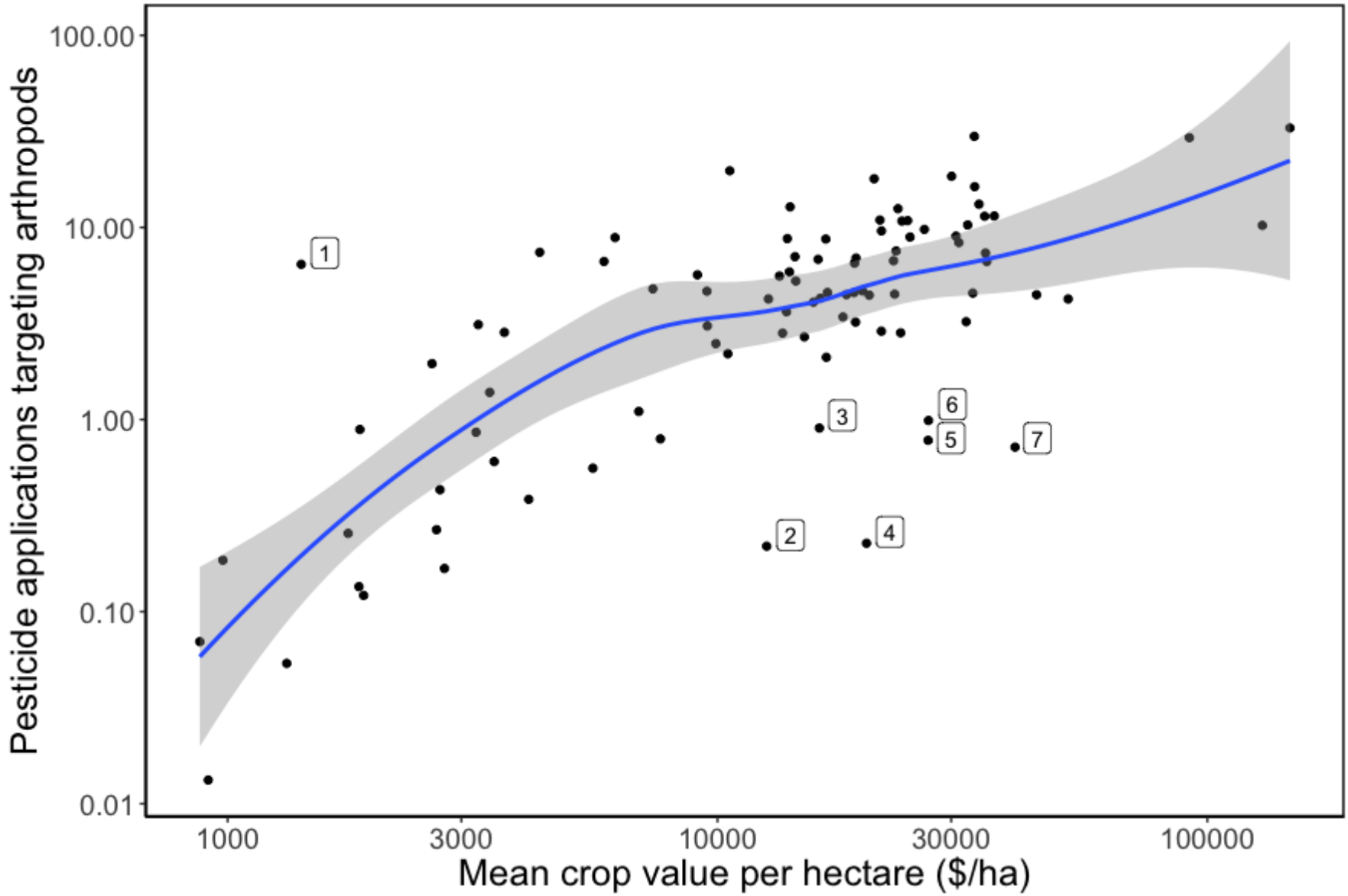
Data:

1. California's Pesticide Use Reporting database
   - 2011-2015, state-wide
   - 93 crops
     -- comparative analysis across all crops
     -- contrasts within plant species, but between crops
   - arthropods; plant pathogens; weeds
2. Crop value: California Department of Food and Agriculture
3. Crop traits: published literature

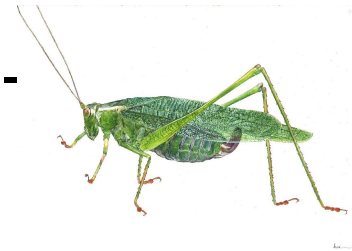
Arthropod pests

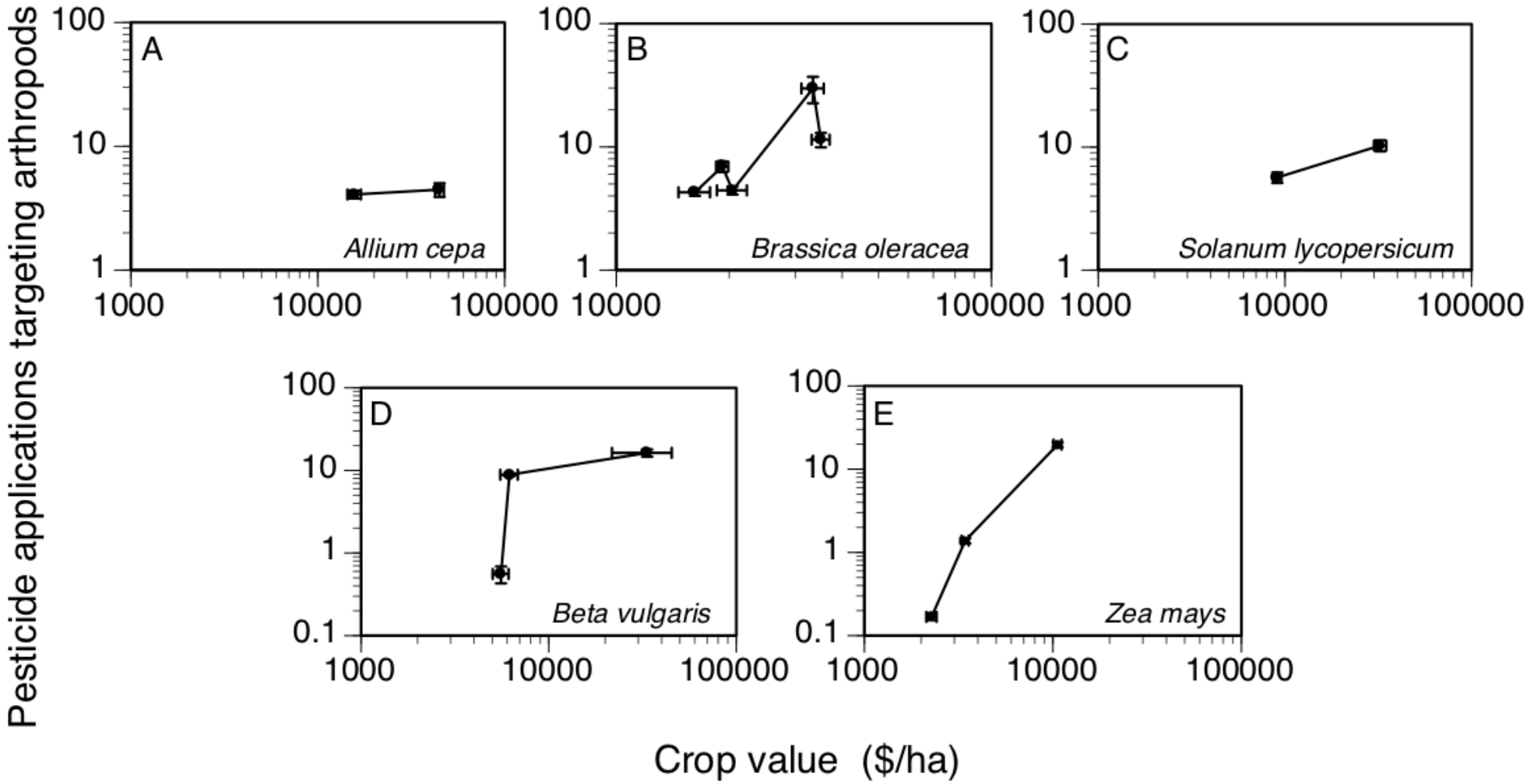
Economics: crop value shapes insecticide use

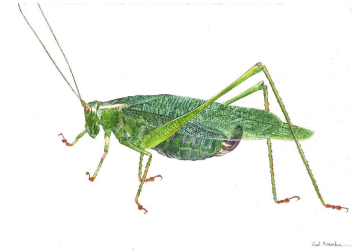




Economics: crop value shapes insecticide use - contrasts within crop plant species





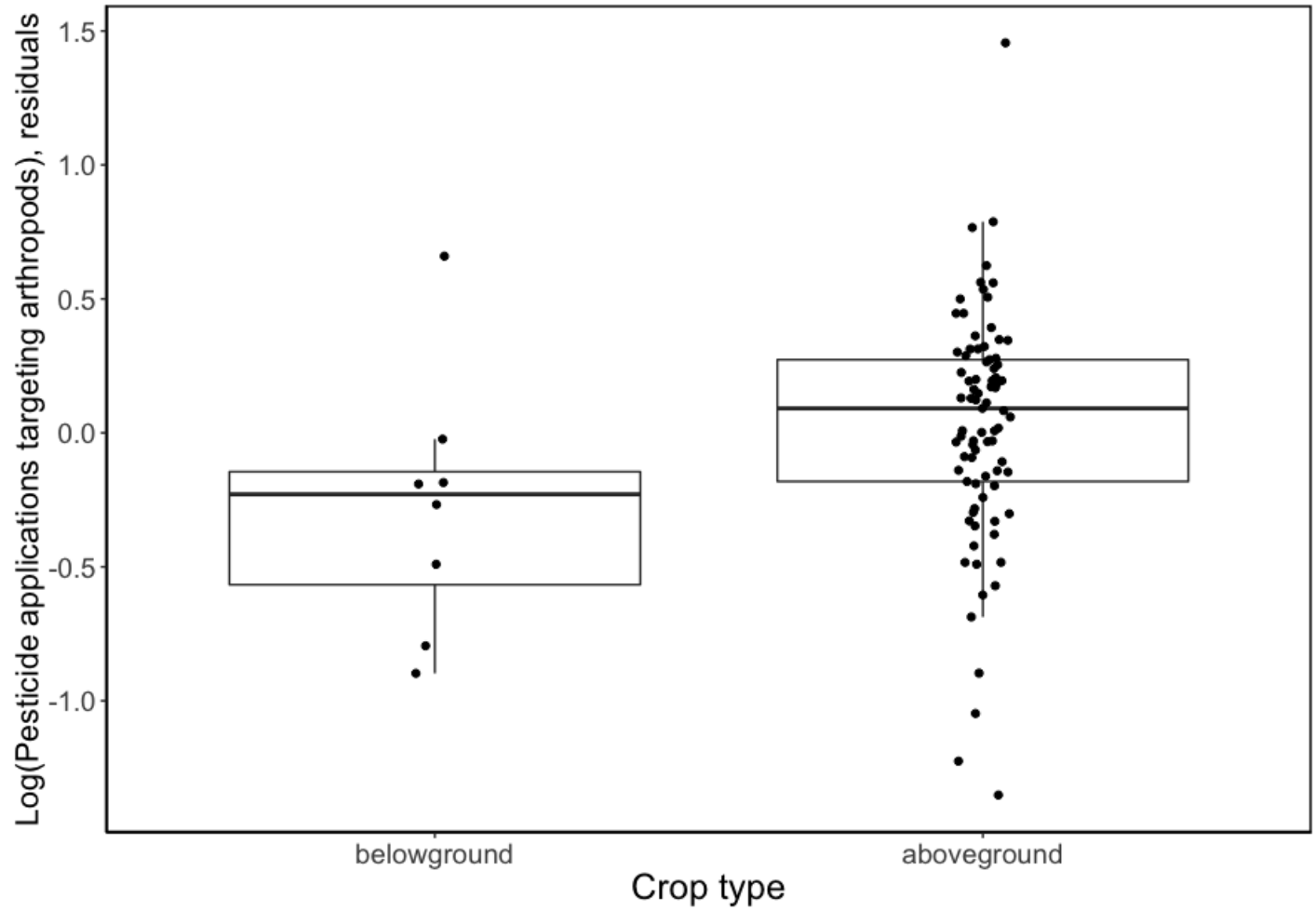


Ecological drivers of pesticide use?

Hypothesis 1:
above- vs. below-ground crops ✔☐

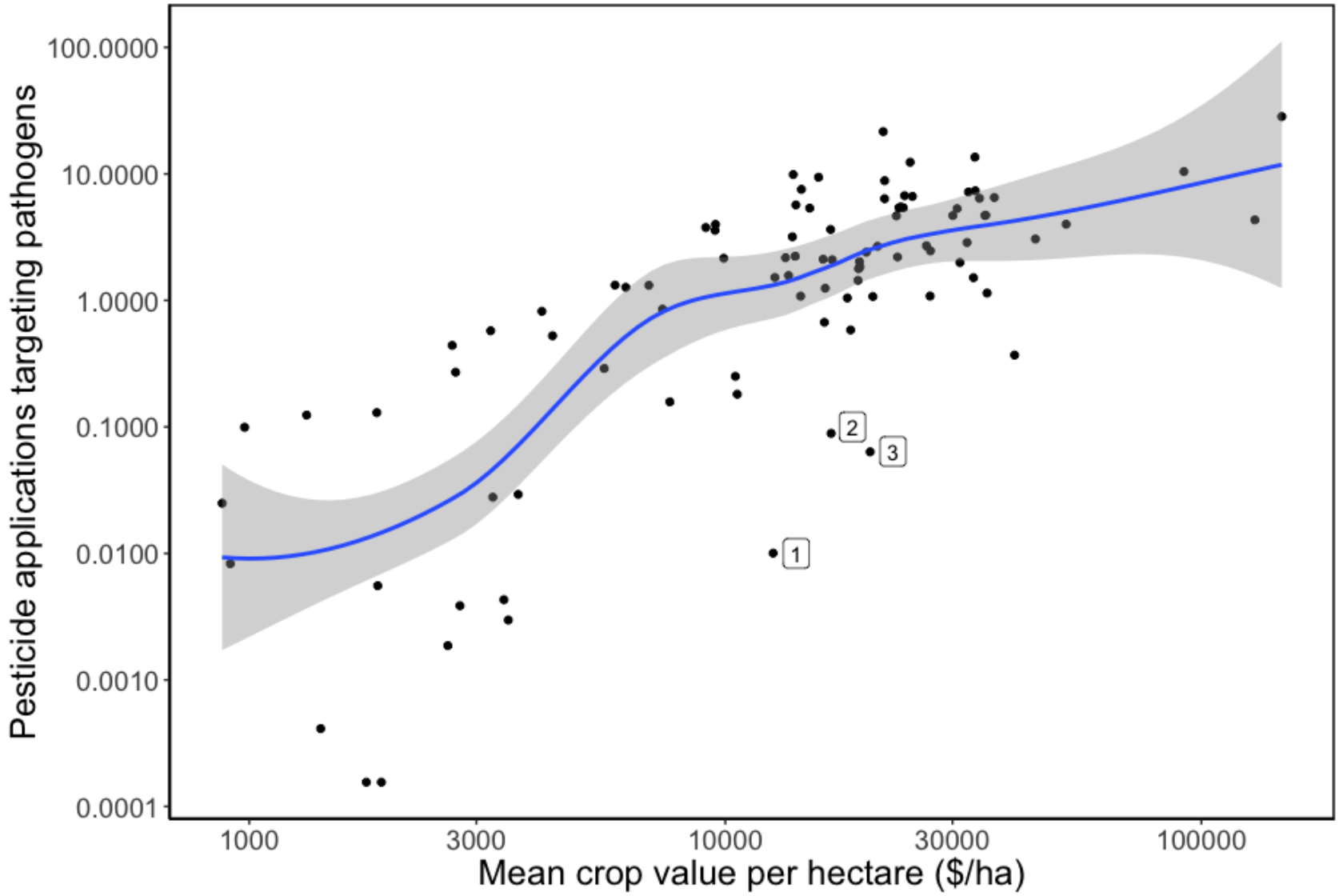
Hypothesis 2:
annual vs. perennial crops ✘

Hypothesis 3:
processed vs. unprocessed crops ✔☐

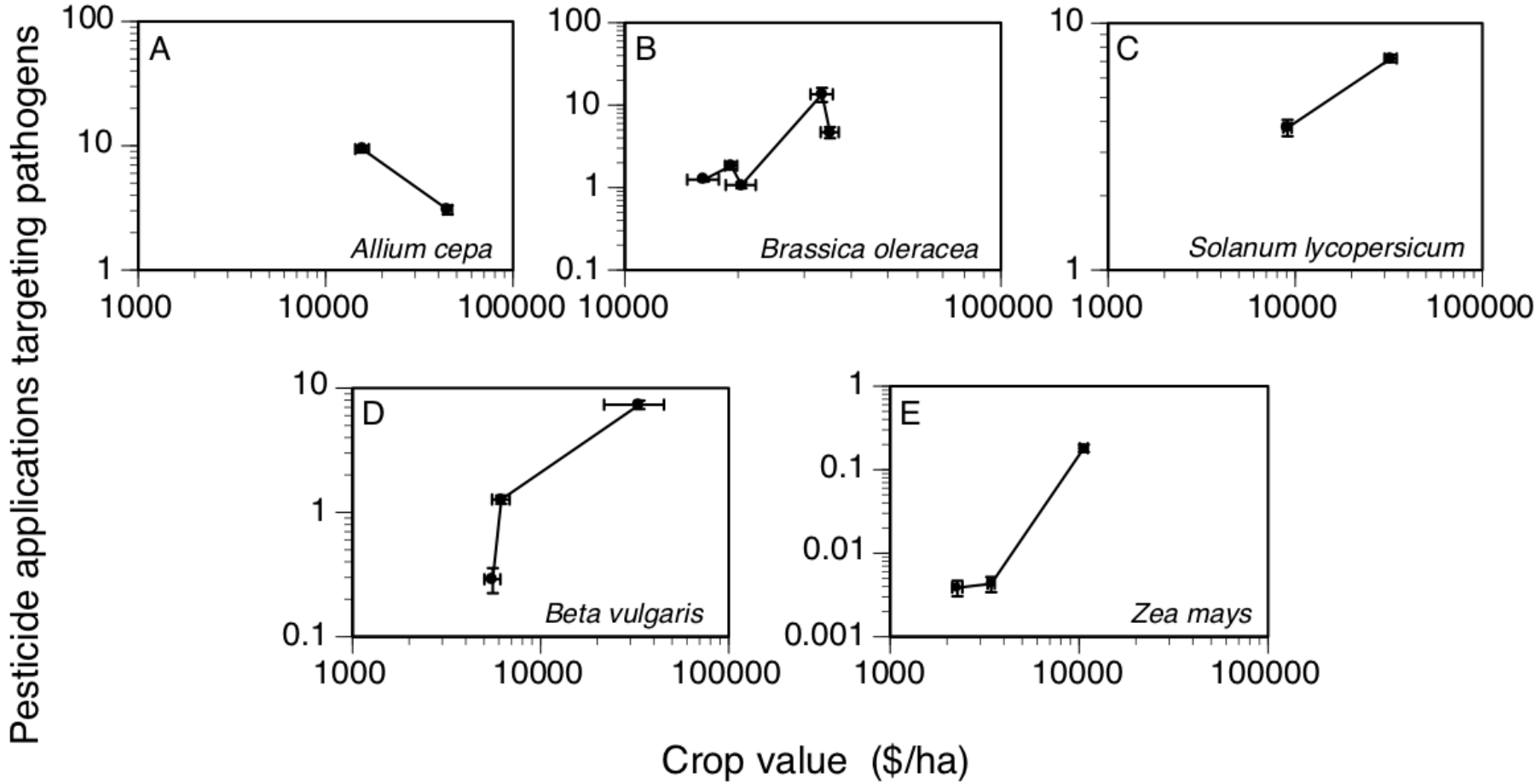


Plant pathogens

Economics: crop value shapes pesticides used against pathogens



Economics: crop value shapes pesticides used against pathogens – contrasts within crop plant species



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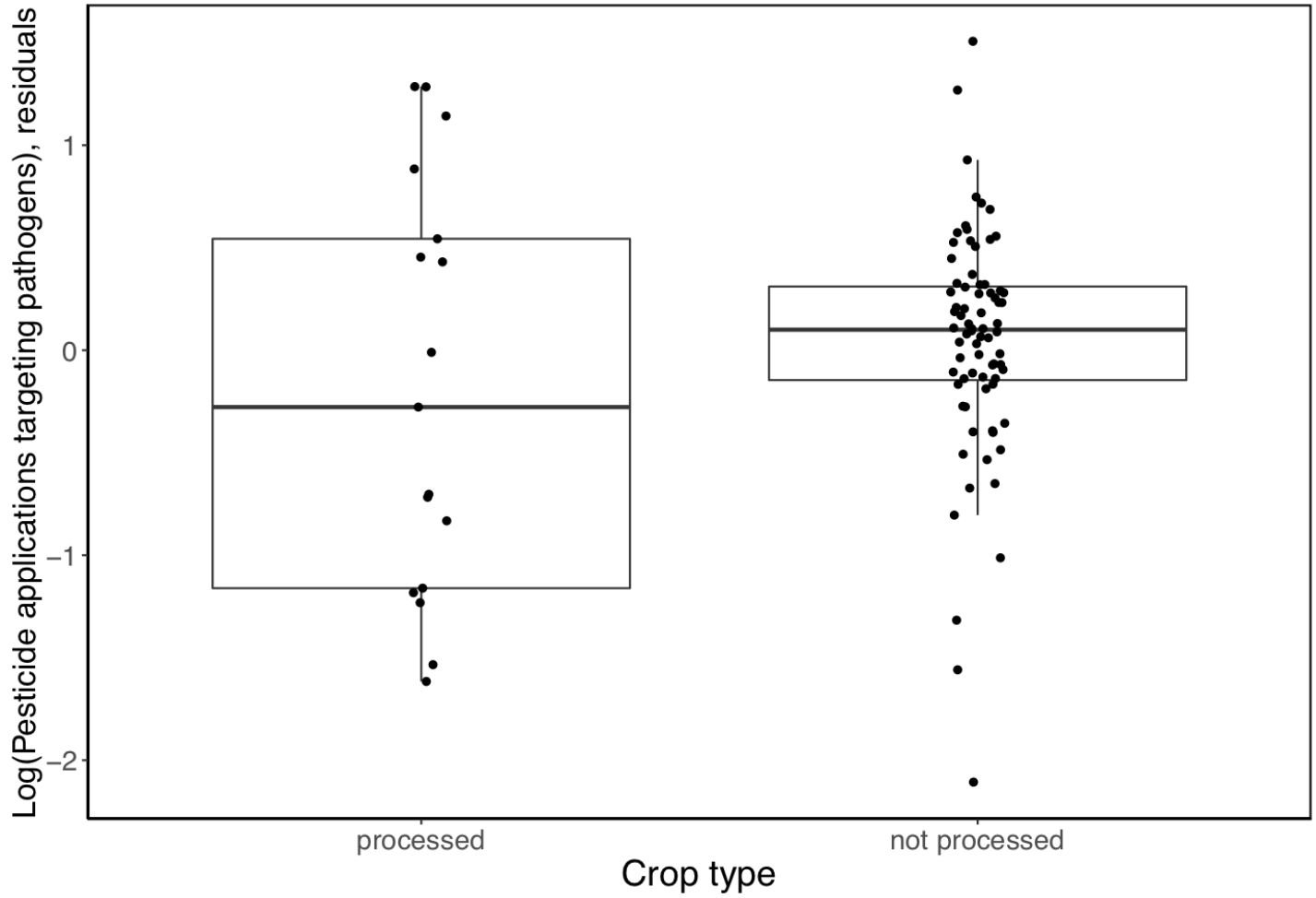
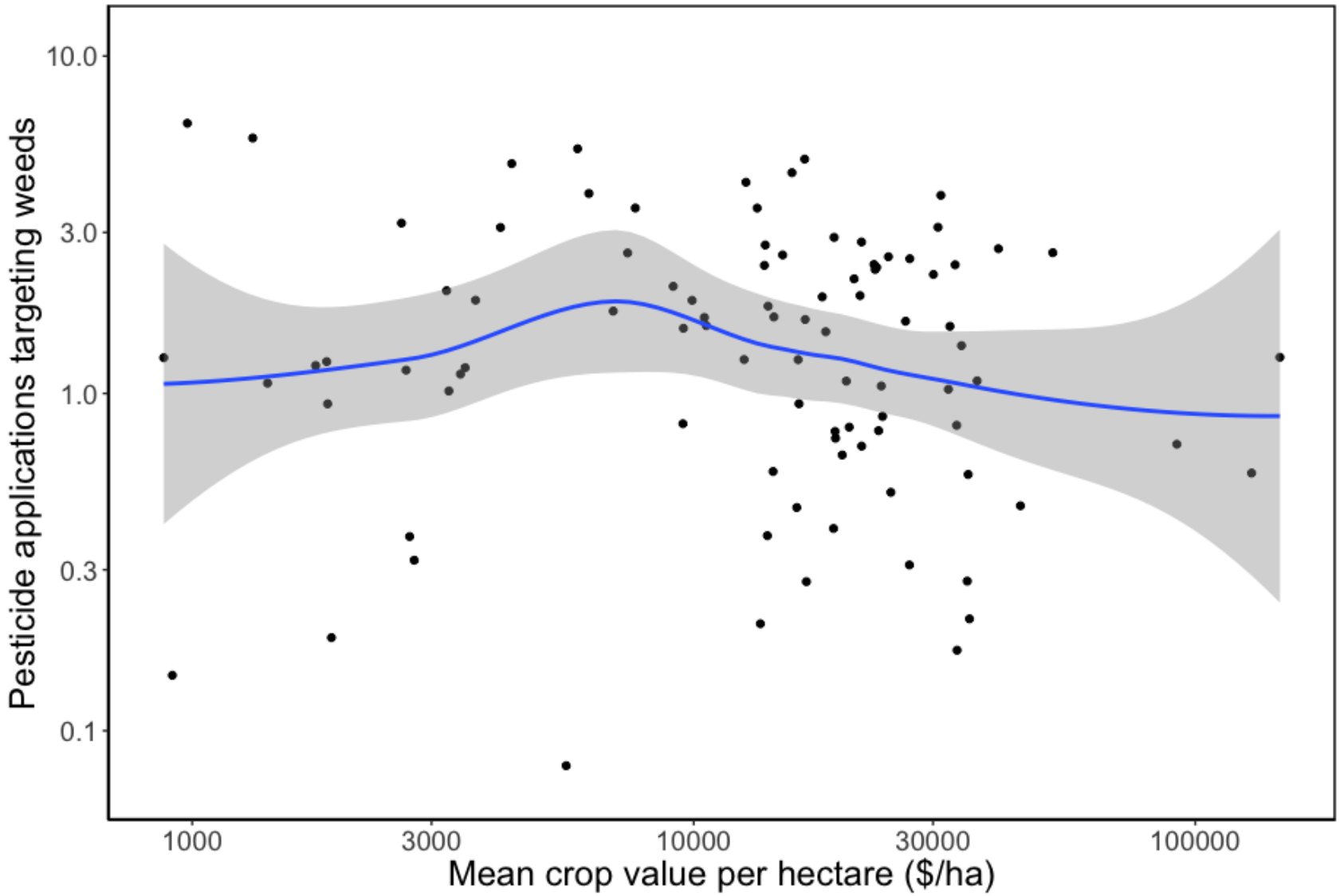


Weeds

Economics: crop value does NOT shape herbicide



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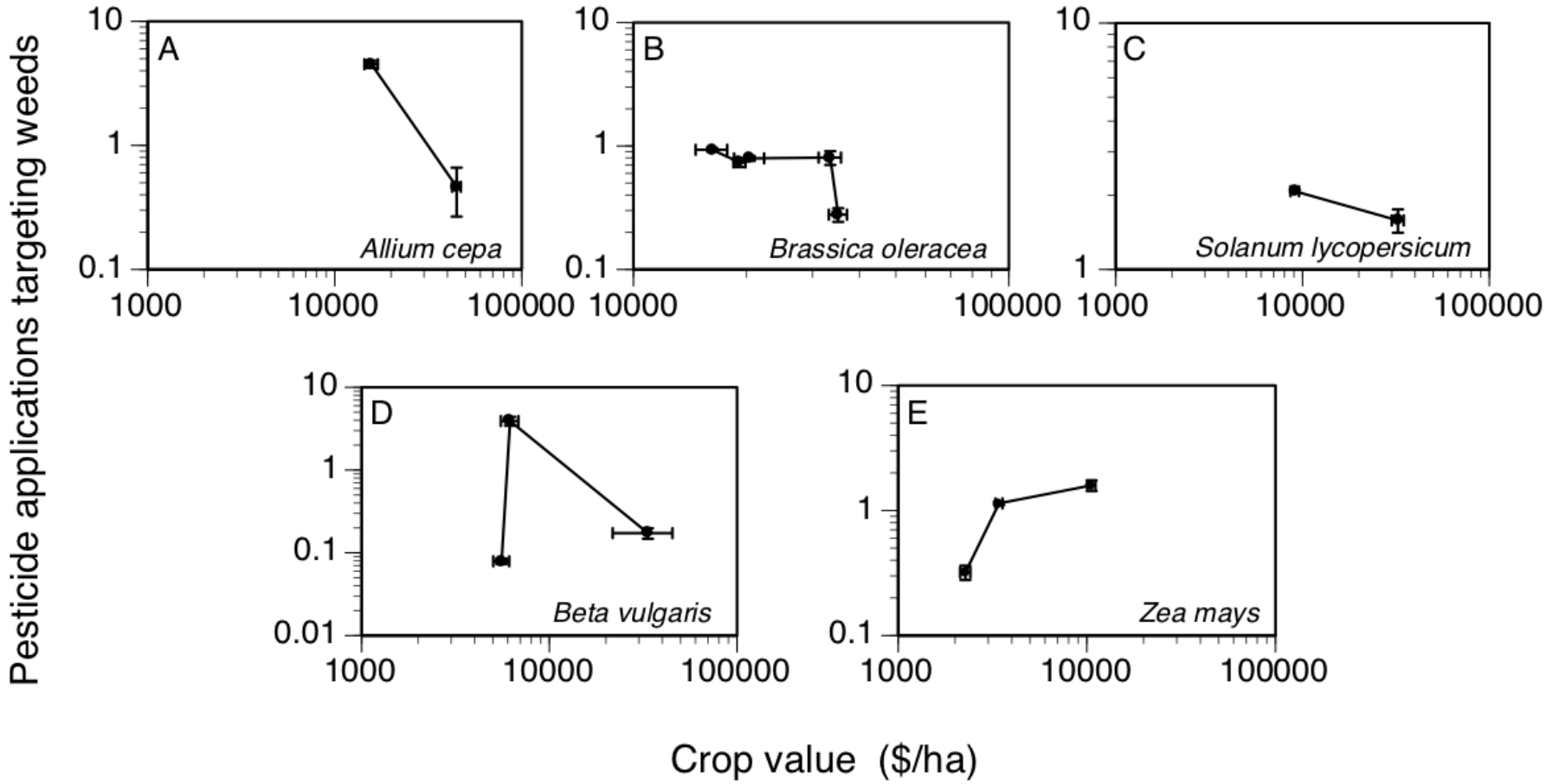

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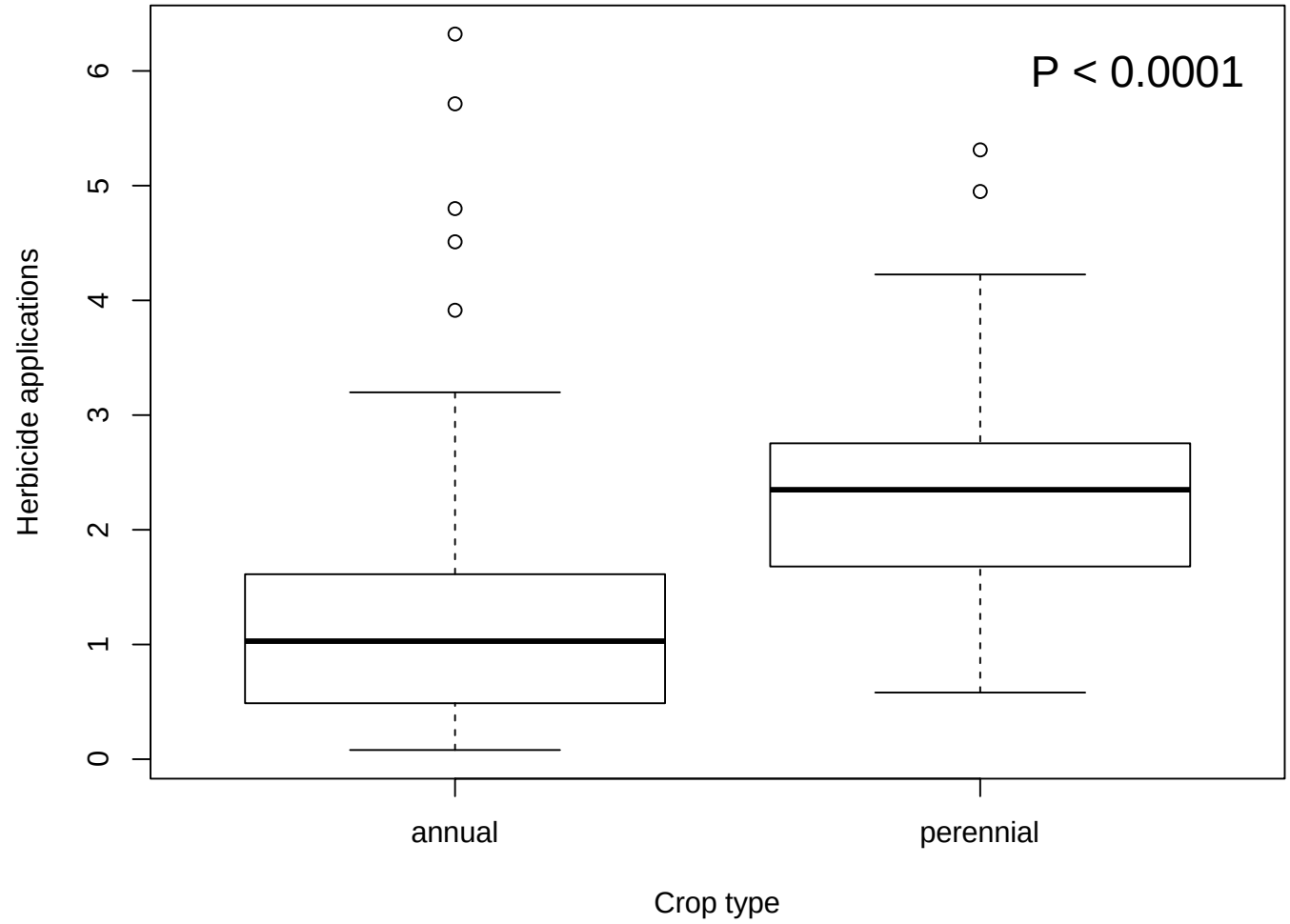


Summary, part I:

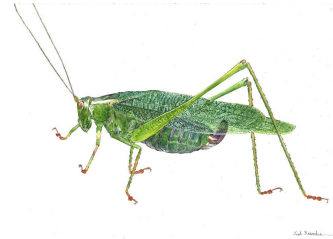
- Economics is a key driver of pesticide use in agriculture

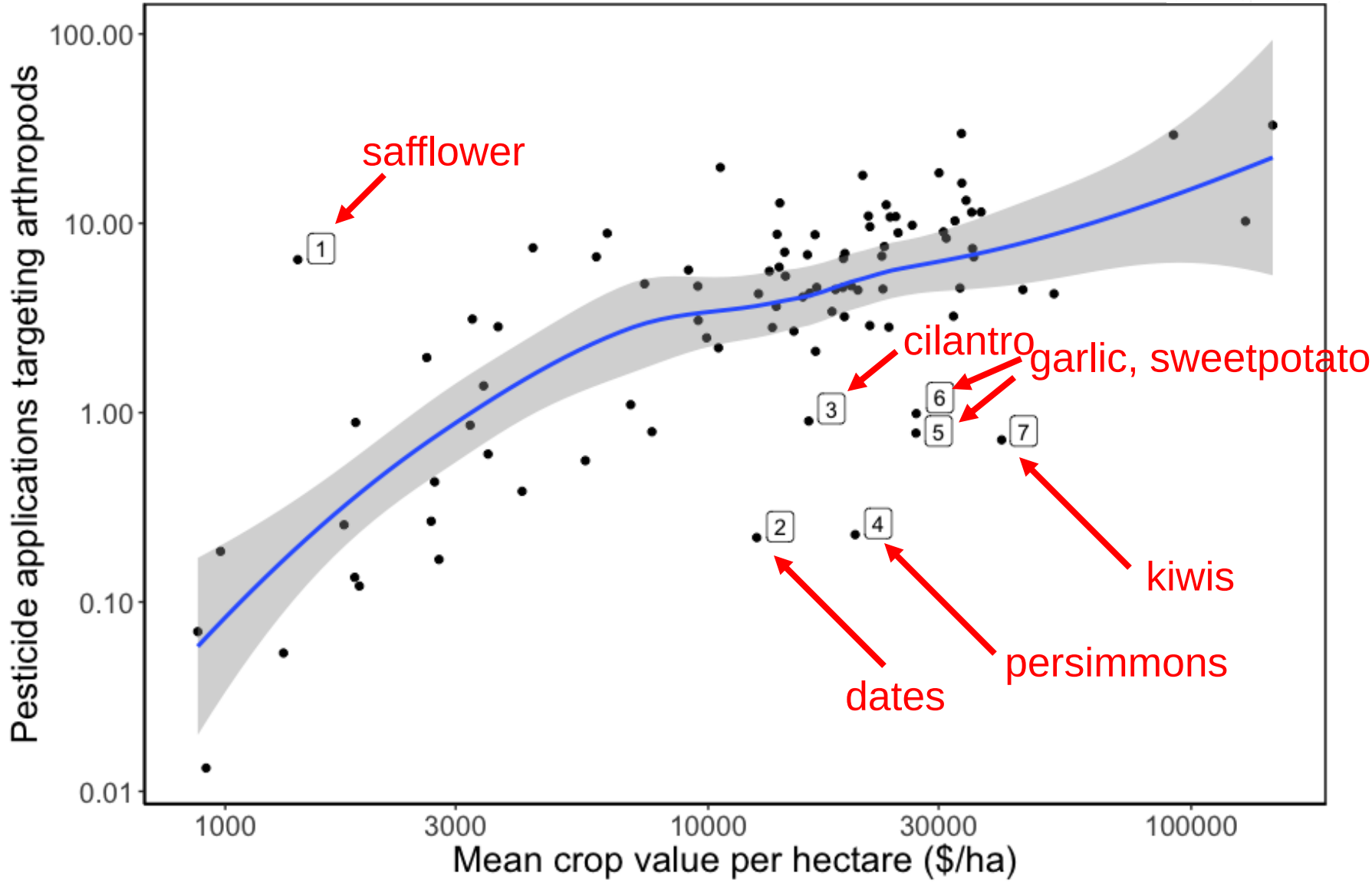
  Crop value explains much of the variation in use of pesticides against arthropods (56%) and plant pathogens (66%), but not weeds

- Ecology is important too; less pesticide use for:
  - Insects attacking belowground crops
  - Insects and pathogens attacking processed crops
  - weeds in annual crops

→ Farmers appear to be good profit maximizers!

Can we explain the outliers?





Low-pesticide use crops have few pest species:

- cilantro: 4 pest species
- dates: 4 pest species
- kiwis: 8 pest species
- persimmons: 6 pest species

All other crops (*N* = 43): 24.5 ± 12.0 pest species (SD; range: 2-59)

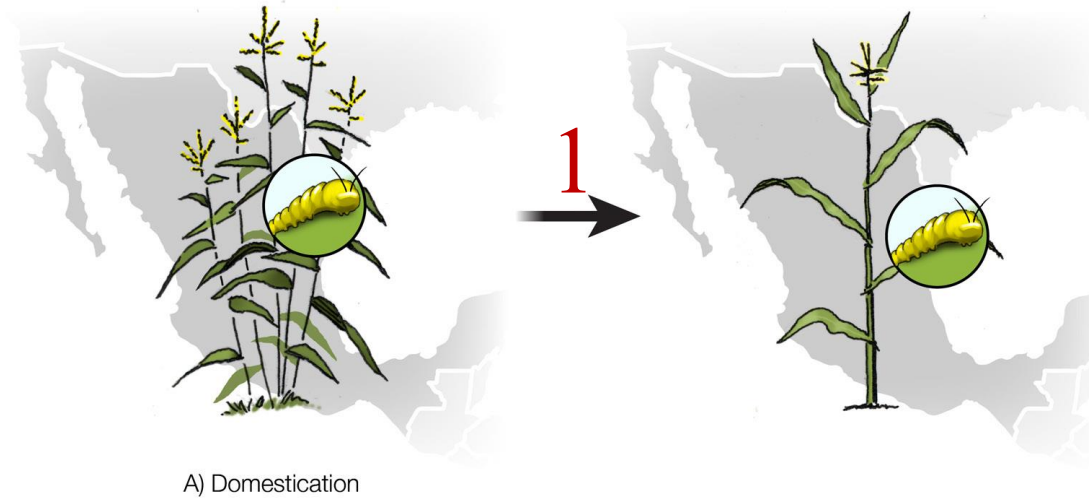
→ *Farmers are seizing opportunities to save money on pest control when the risk of crop damage is reduced*

Why do some crops have depauperate pest communities?

Yolanda Chen (2016): three pathways to the origin of a crop pest:

Path 1: native insect tracks a native plant through domestication (no host shift)

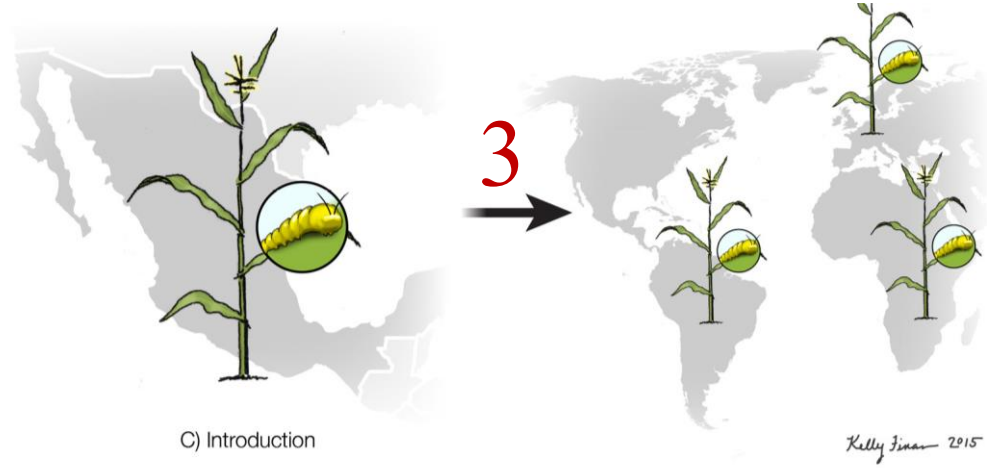
Path 2: native insect ‘jumps’ from a native host plant onto an introduced crop (host shift)



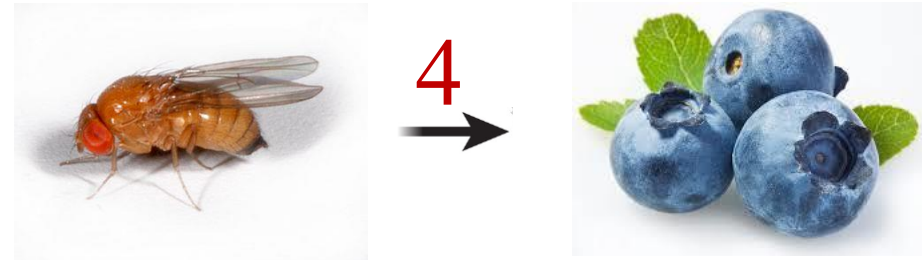
Why do some crops have depauperate pest communities?

Yolanda Chen (2016): Four pathways to the origin of a crop pest:

Path 3: pest introduced with its host plant to new region (no host shift)



Path 4: pest introduced to new region, associated with new host plant (host shift)



Japan

North America

Relevance to biological control:

Pathway to pest status	Host shift involved?	Type of biological control most appropriate
1. Native pest coevolves with native host plant during domestication	No	Conservation, augmentation
2. Native pest shifts to novel, introduced crop	Yes	Conservation, augmentation**
3. Introduced pest, coevolved with crop, invades	No	Classical
4. Introduced pest not coevolved with crop, invades	Yes	Classical**

560 pest-crop combinations

539 pest-crop combinations

Why do some crops have depauperate pest communities?

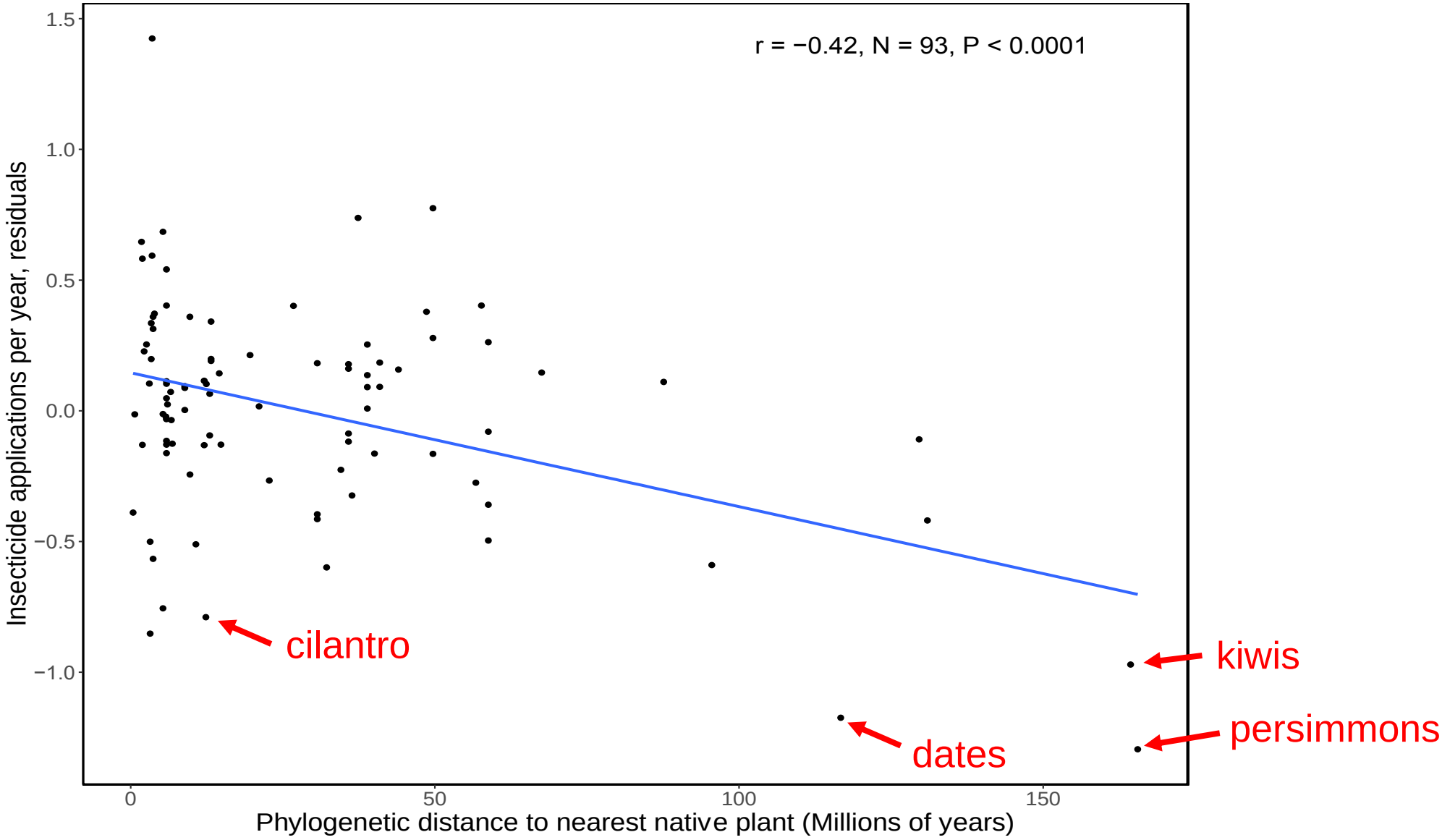
- Many pests (both native and introduced) have to switch hosts to exploit a crop plant

- Evolutionary ecology theory for both arthropod pests and plant pathogens predicts that phylogenetic isolation could be important

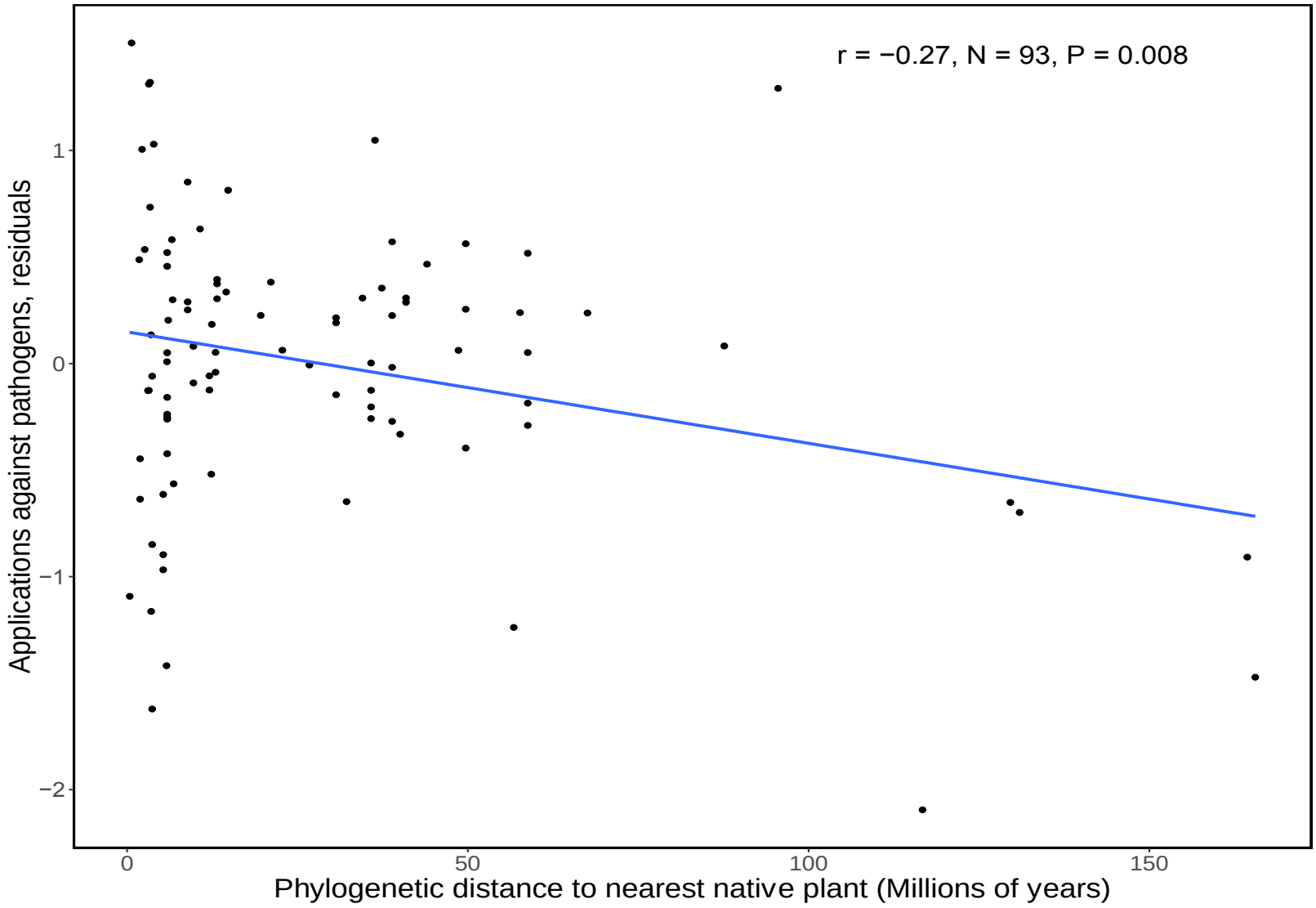
- It's hard for plant parasites to "jump" onto a distantly-related host plant

→ Test this prediction with the pesticide use data (Ian Pearse)

Crop phylogenetic isolation shapes insecticide use:



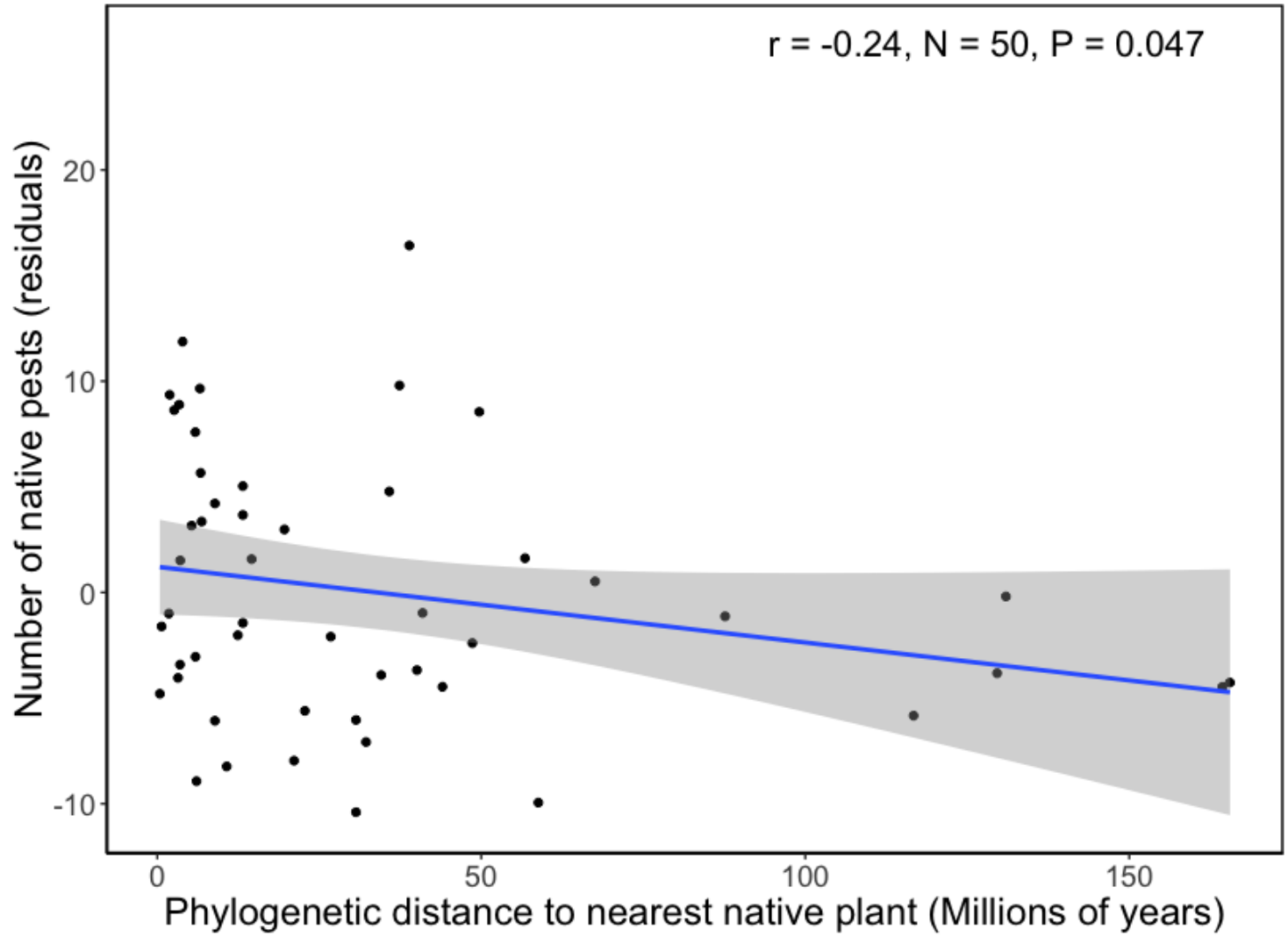
Crop phylogenetic isolation shapes pesticides directed against pathogens:



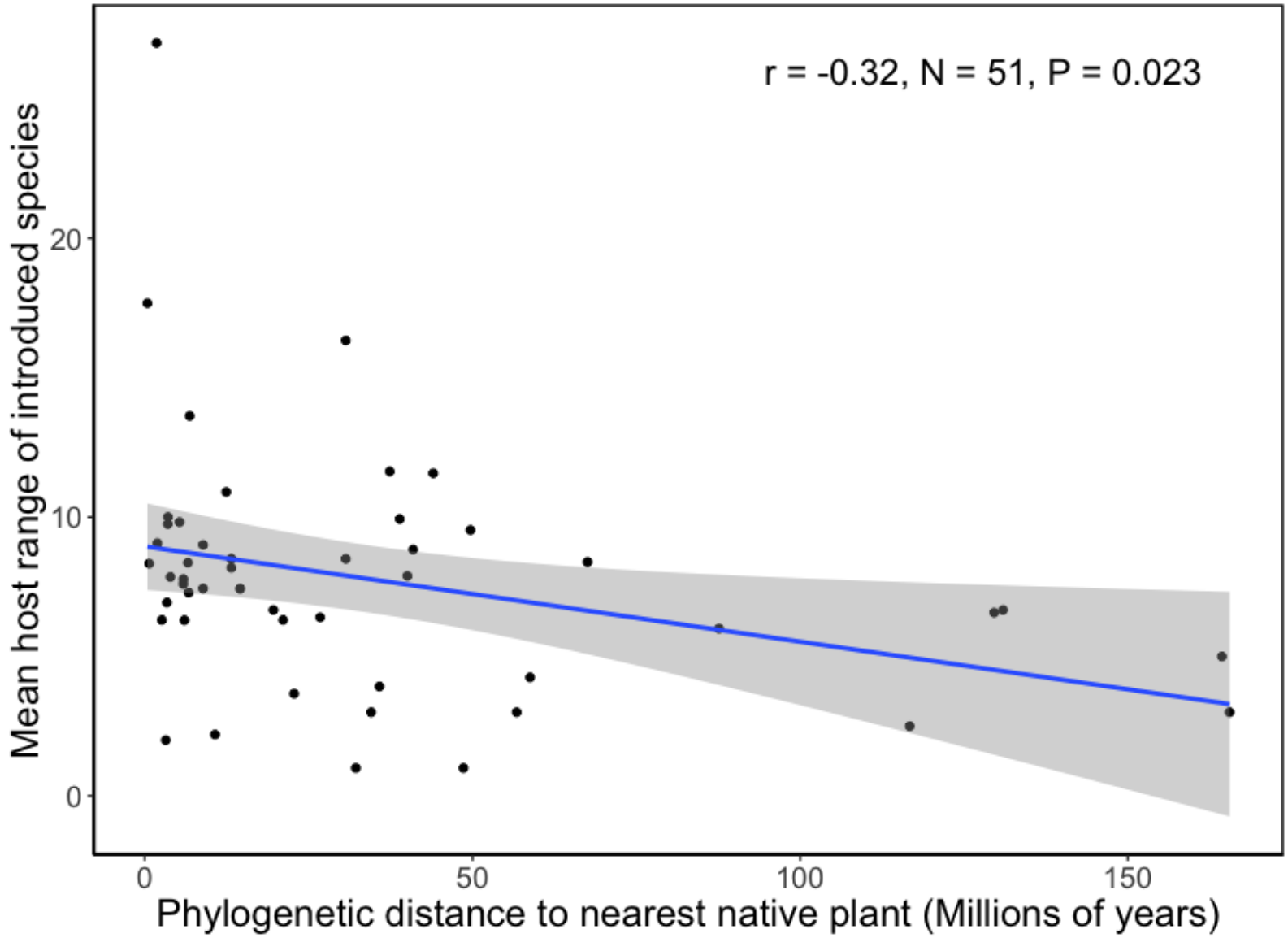
Do we see signals of phylogenetic isolation in the pest community?

- use only those crops (*N* = 50) for which we have unique lists of pest species
- estimate diet breadth as the number of crops where the pest is found
- correct statistically for crop area (hectares grown) and value
- data are noisy!

Phylogenetically isolated crops have fewer native pests



Phylogenetically isolated crops have introduced pests with narrower host rang



Summary, part II:

- The phylogenetic isolation of a crop plant influences pesticide use (against arthropods and plant pathogens)
- This is *likely* caused by the difficulty of host switching onto a distantly related host plant, for both native and introduced insects

Summary, part II:

- Native pests are a major part of our pest community, suggesting that conservation and augmentation biocontrol have a large role to play
- Biocontrol of pests that switch hosts to attack crops may be challenging, if it is hard for natural enemies to also switch host plants