Exploring the Ecological Interactions of the Traditional Milpa Intercropping System

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(Assistant Prof, Converse University 2024)


@ilan_pin

Vavilov Canters of diversity and domestication

3 sisters shared co-evolutionary history

Vavilov Canters of diversity and domestication

<u>Complementary traits</u>:
facilitation & reduction competition

Nice Complementarity

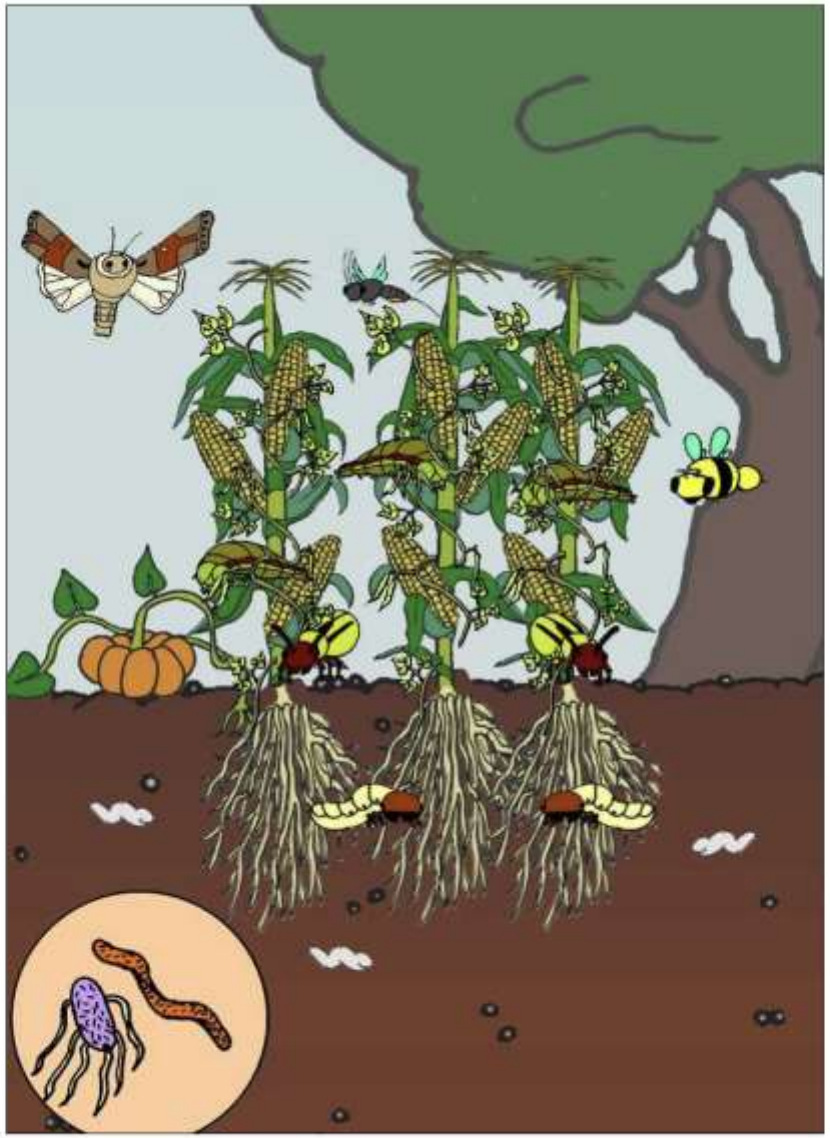
3 sisters shared co-evolutionary history

Dr. Betty Benrey, University of Neuchâtel, Switzerland

Important traits associated with the Milpa crops

Maize

- Provides structure for climbing beans
- Direct defenses
  - Benzoxazinoids exudates
- Indirect defenses
  - HIPVs known to attract parasitoids



Schematic representation on the Milpa agricultural system with the three sisters: maize, beans and squash, and the above and belowground communities associated with this system. Made by Nicolas Marguier

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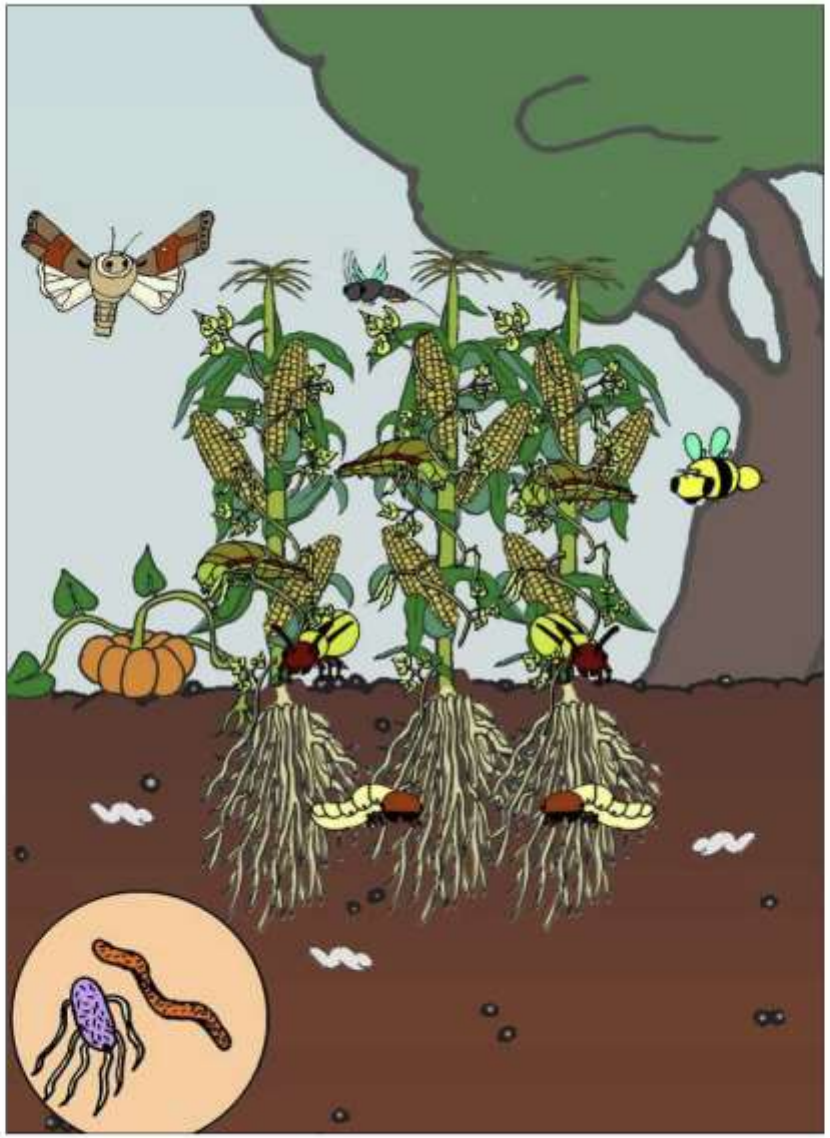

Beans

- Symbioses with nitrogen-fixing rhizobia
- Indirect defense
  - Extrafloral nectar that attracts ants, parasitoids and other 'bodyguards'

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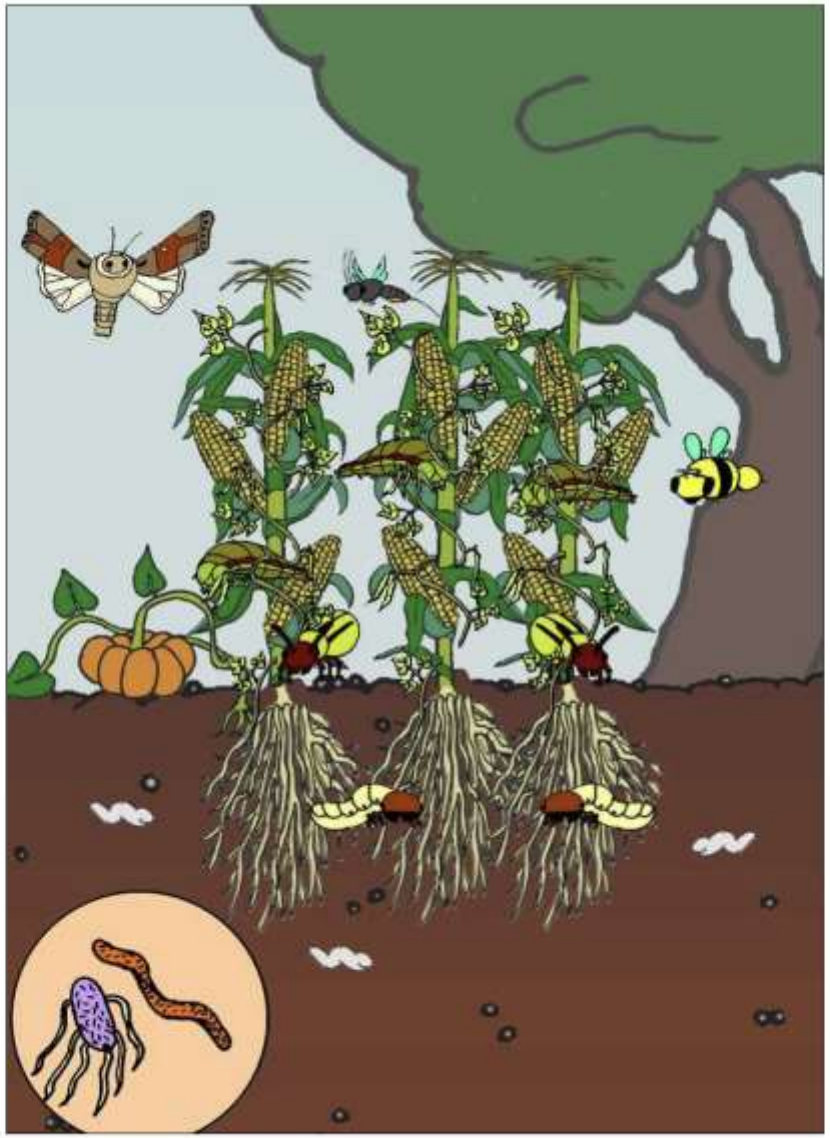

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Squash

- Large leaves that help retain soil moisture and reduce weed growth
- Direct defenses
  - Trichomes
  - Cucurbitacins

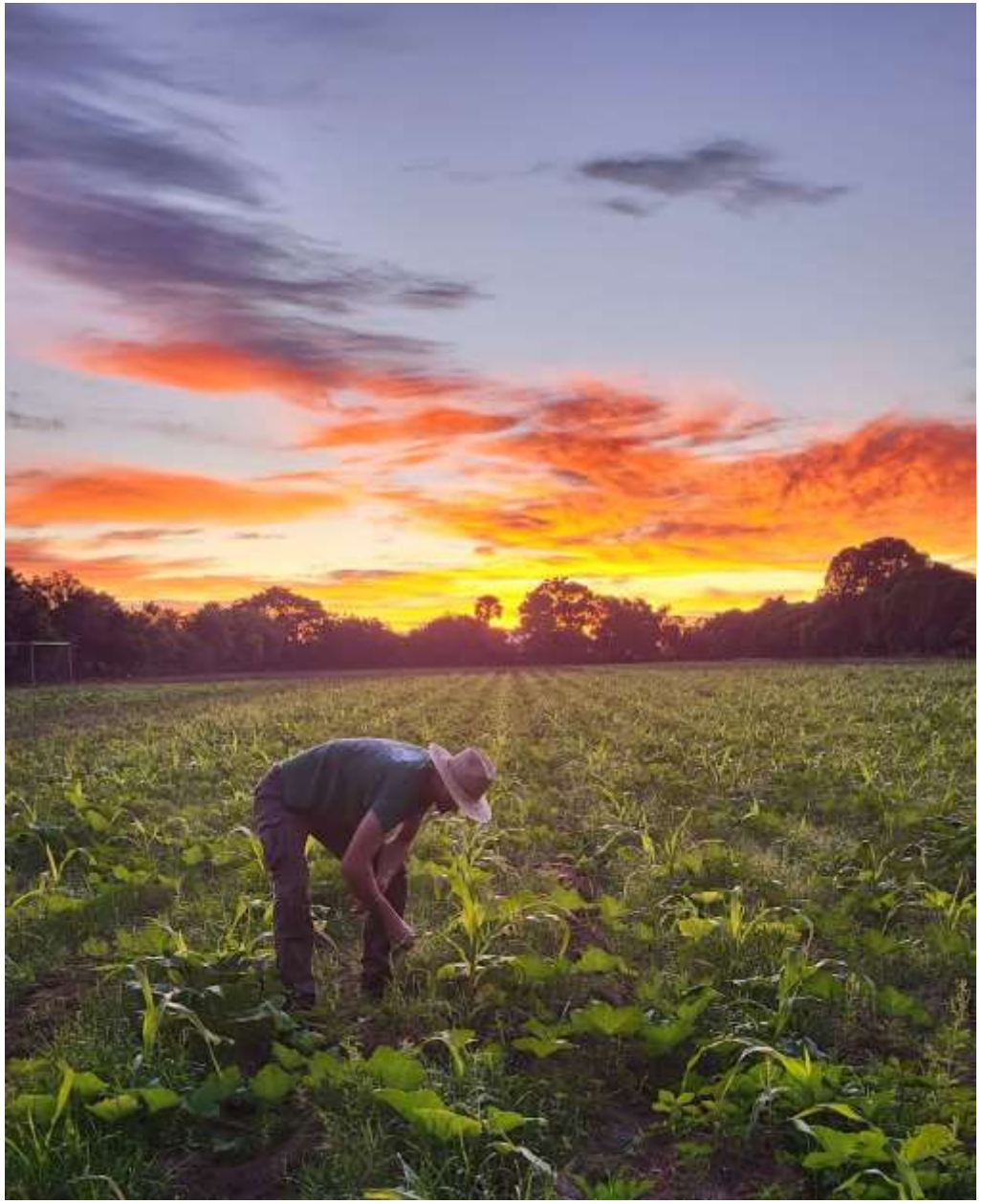
Schematic representation on the Milpa agricultural system with the three sisters: maize, beans and squash, and the above and belowground communities associated with this system. Made by Nicolas Marguier

Primary Questions

1. What is the effect of crop diversity on yield?

2. What is the effect of crop diversity on the abundance and diversity of the insect community?

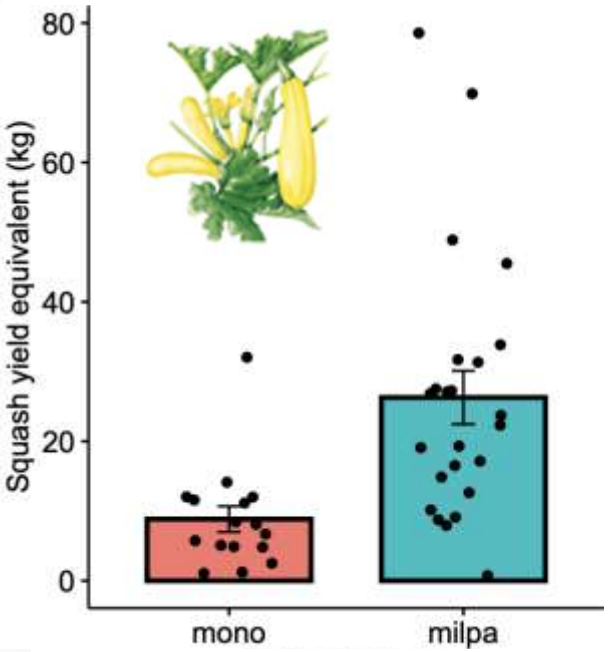
3. What are some mechanisms underlying these patterns?

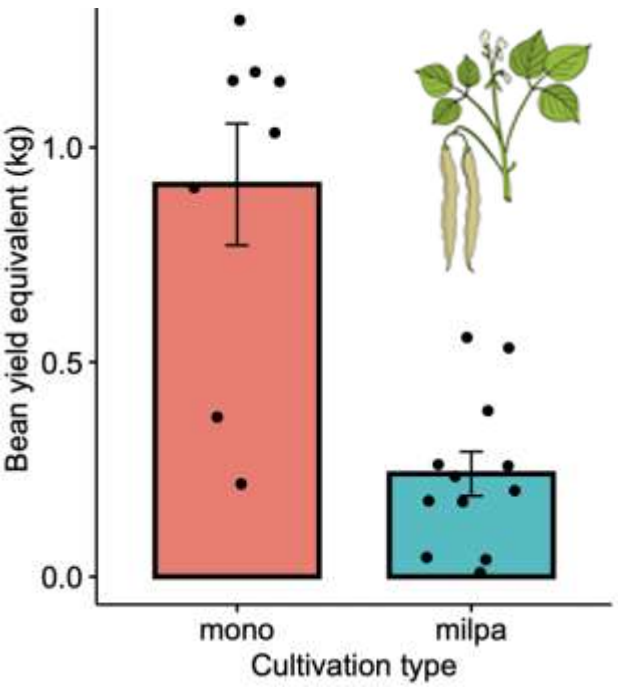


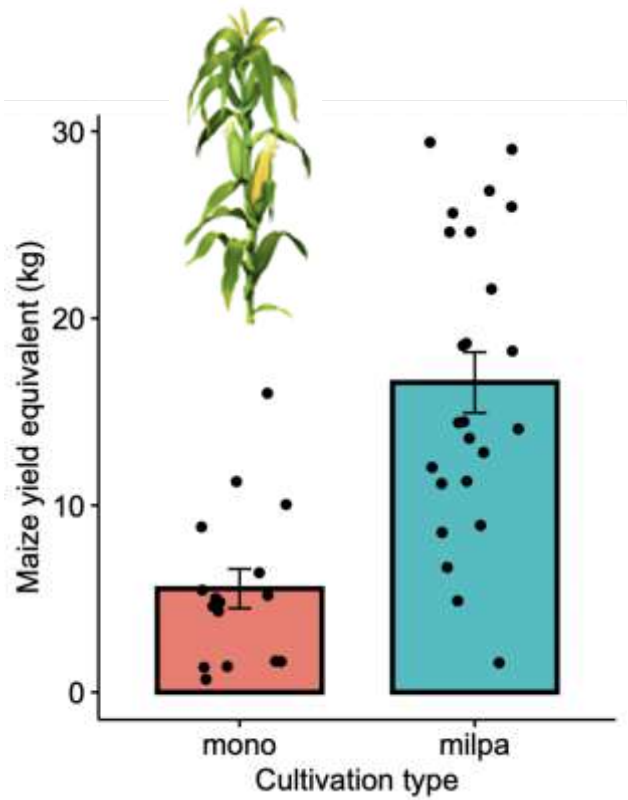

Milpa field site
Puerto Escondido Mexico

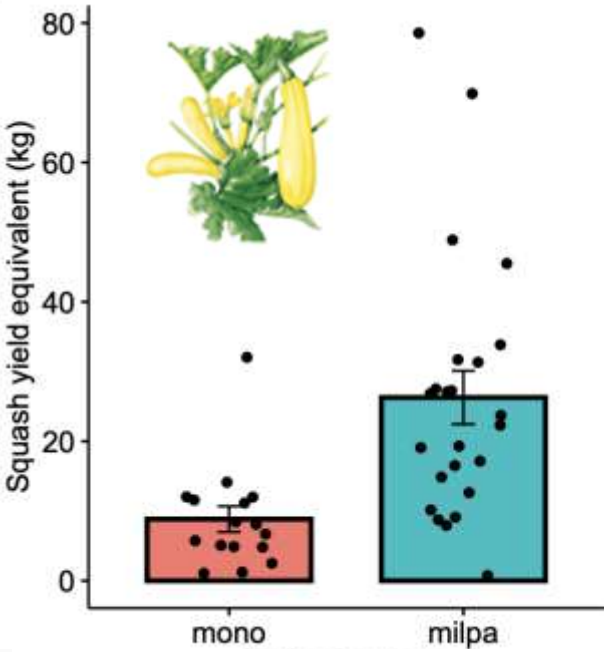

San Antonio
Houston
Monterrey
Mexico
Guadalajara
Mexico City
Guatemala
Honduras

What is the effect of crop diversity on yield?


Squash yield equivalent (kg)
80
60
40
20
0
mono
milpa


Bean yield equivalent (kg)
1.0
0.5
0.0
mono
milpa
Cultivation type


Maize yield equivalent (kg)
30
20
10
0
mono
milpa
Cultivation type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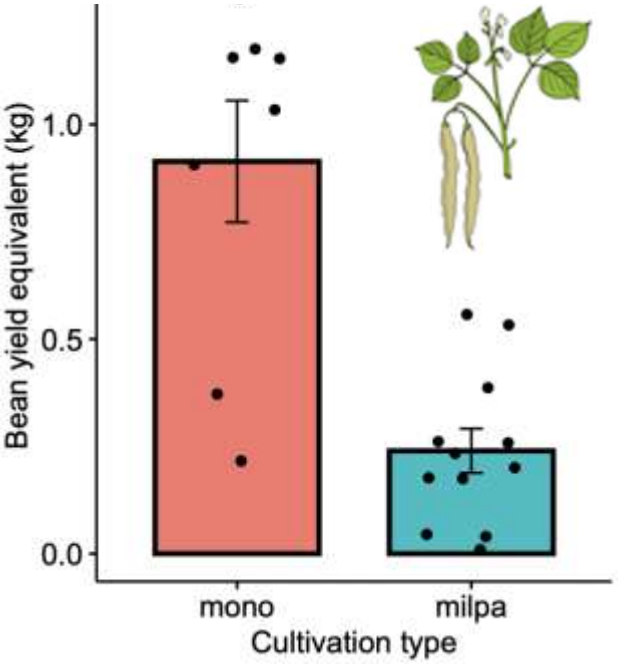
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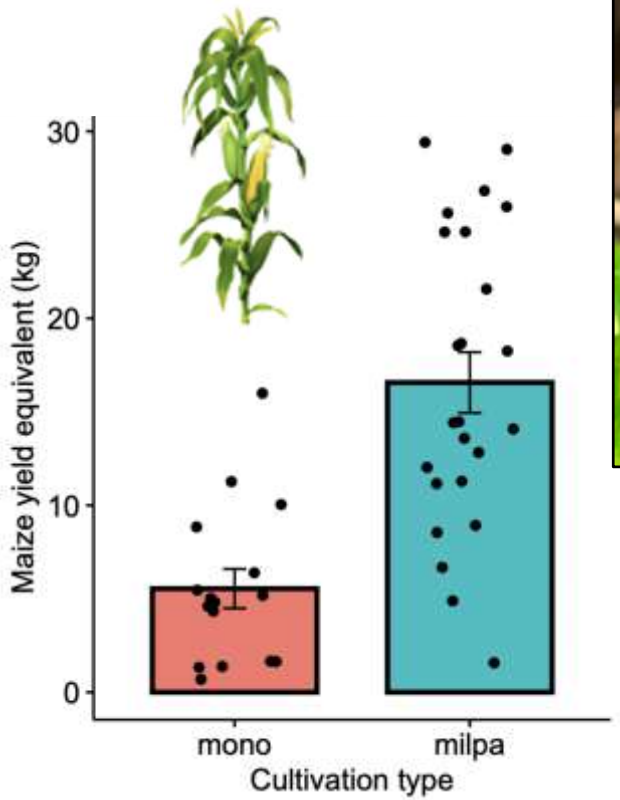
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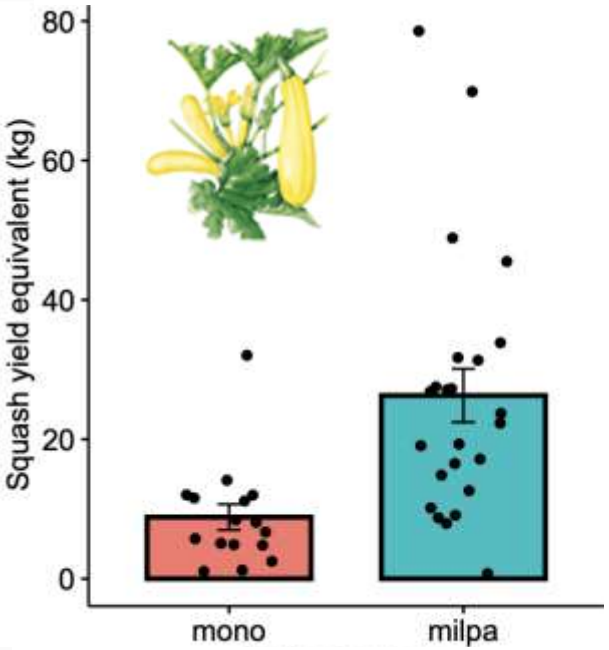
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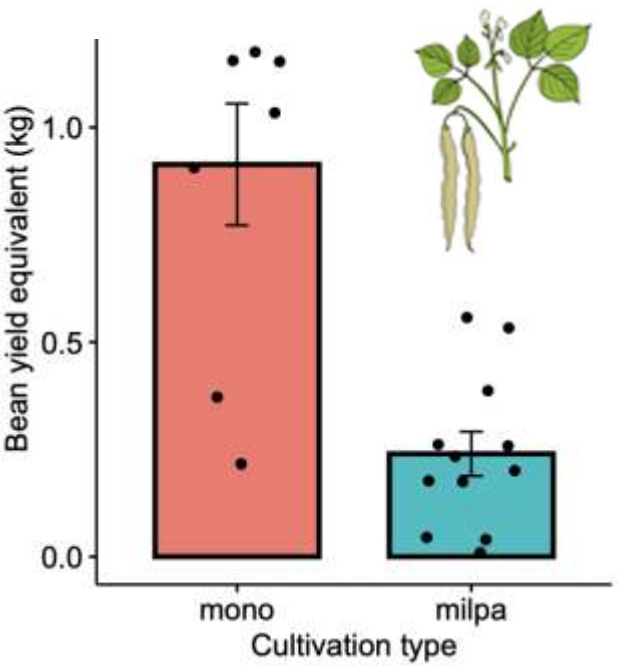
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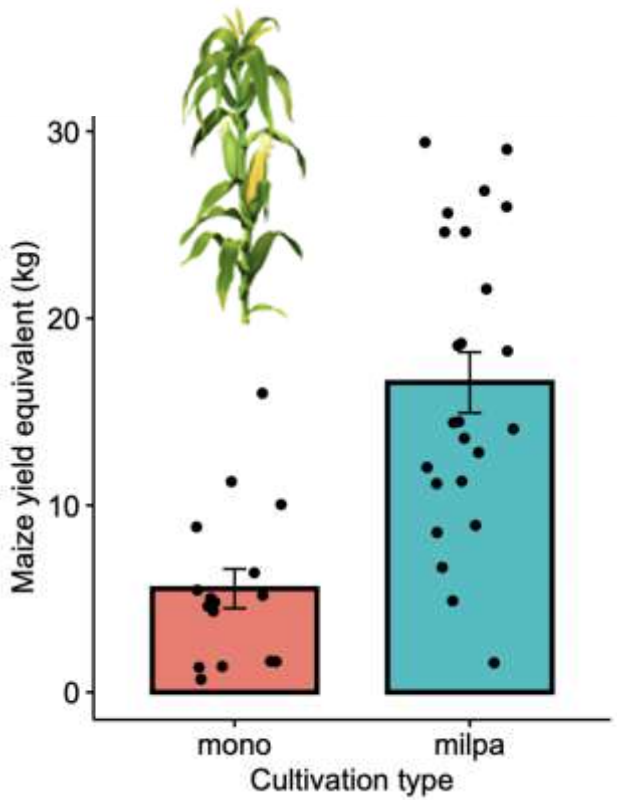
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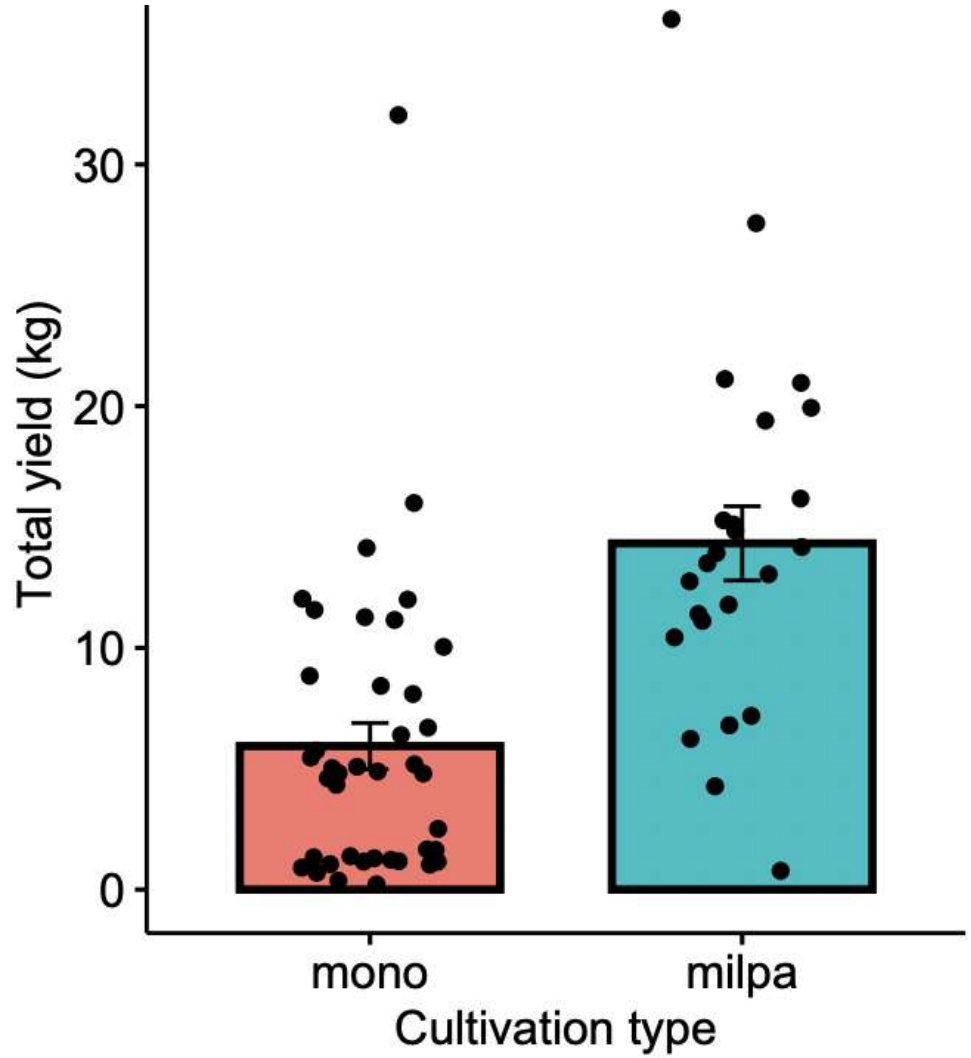
Total yield (kg)
30
20
10
0
mono
milpa
Cultivation type

What is the effect of crop diversity on yield?

Conclusion:

Overall milpa was more productive than monocultures

What is the effect of crop diversity on the abundance and diversity of the insect community?

Predictions regarding effects of crop diversification

1. Fewer herbivores, more natural enemies in polycultures

2. Greater diversity in polycultures

Matia Haïm Muller

Raul Gonzalez

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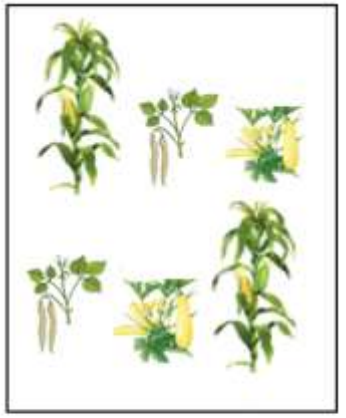
Experimental design



Milpa Triculture

Matia Haïm Muller

Raul Gonzalez

Monocultures

Predictions regarding effects of crop diversification

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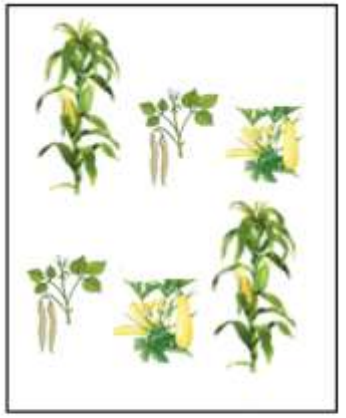
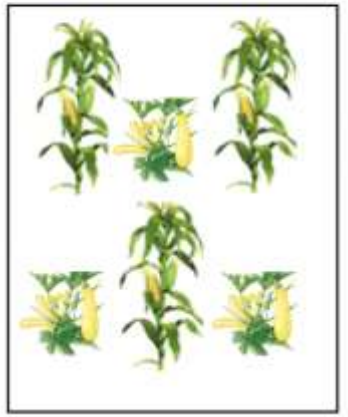
Experimental design

Maize-Bean Biculture



Milpa Triculture

Monocultures



Maize-Squash Biculture

Matia Haïm Muller.

Raul Gonzalez

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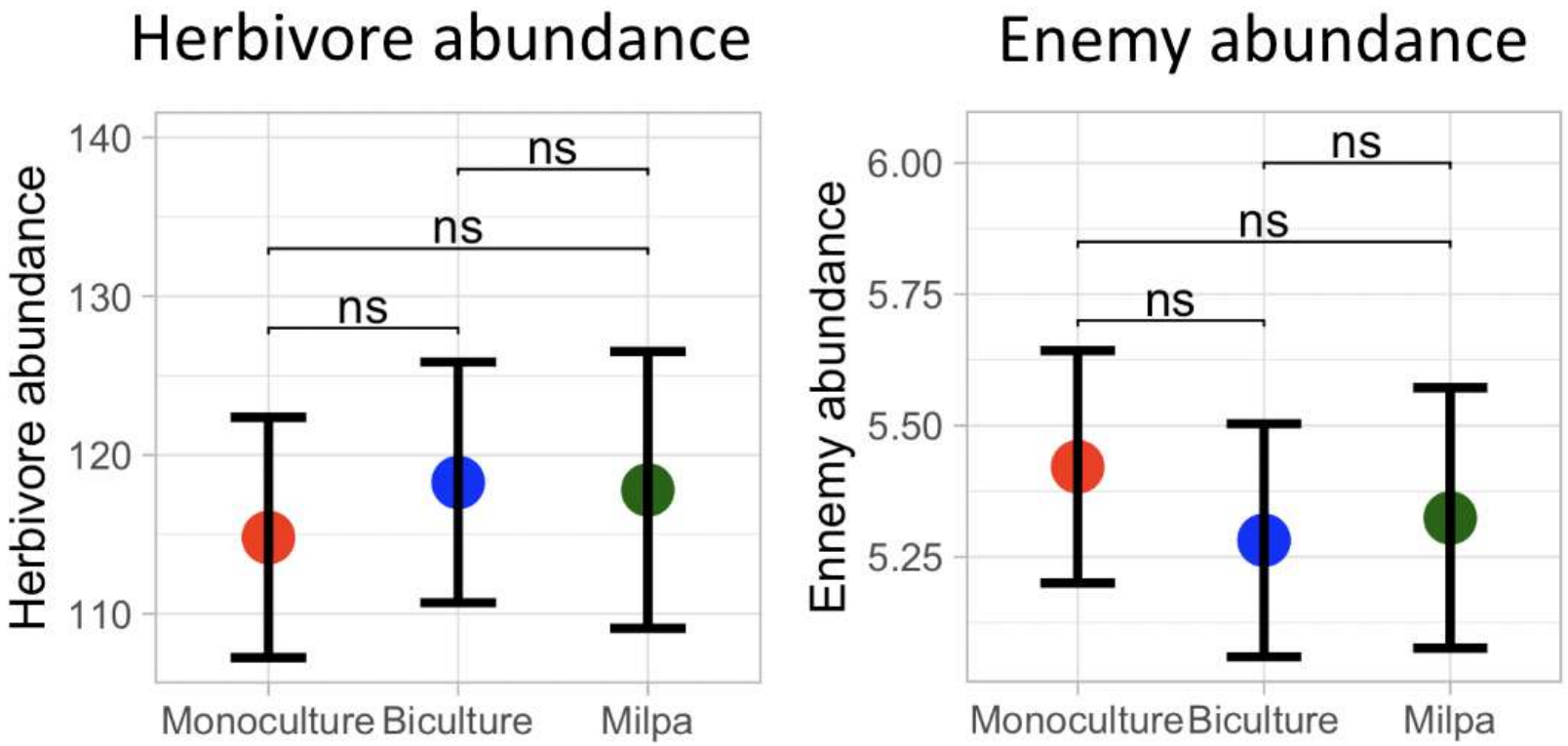
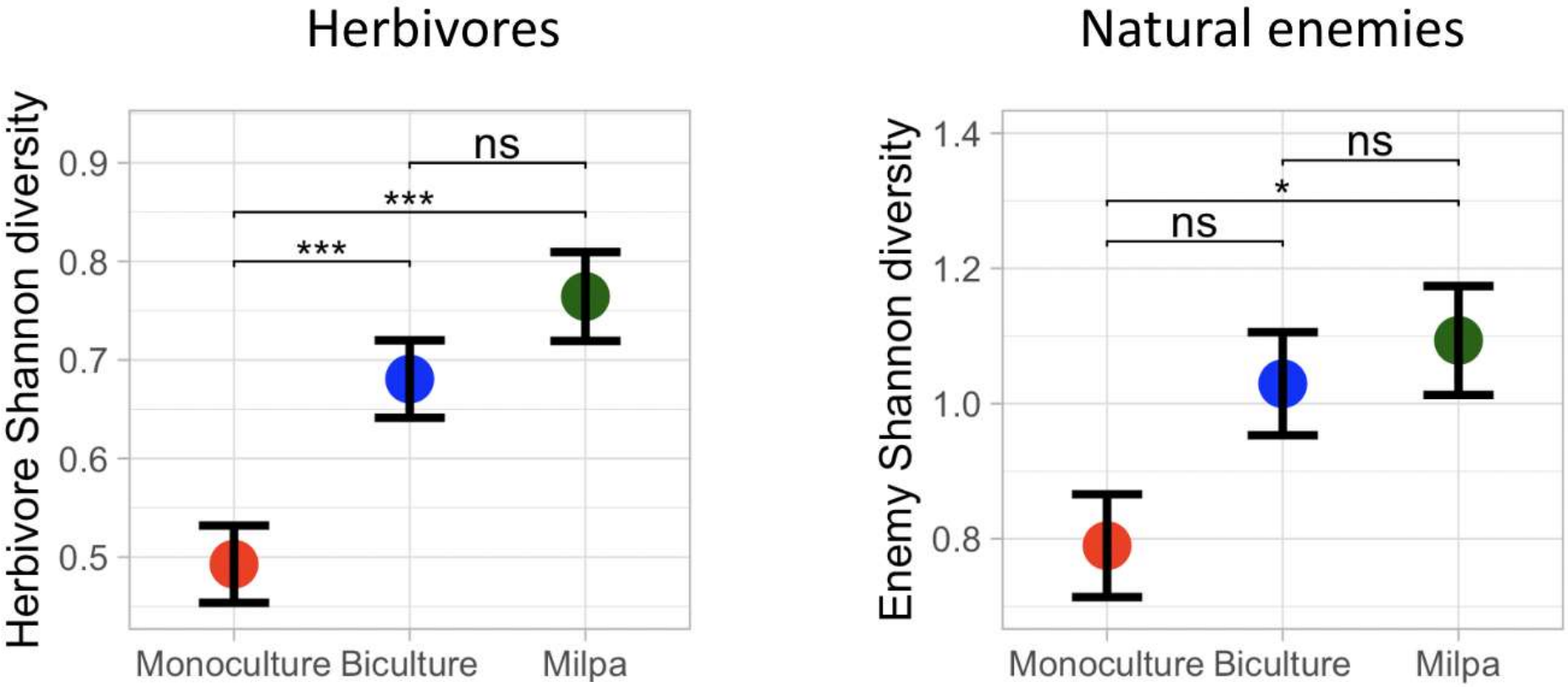


Predictions regarding effects of crop diversification

2. Greater diversity in polycultures



Grof-Tisza and Muller et al. In revision *Agriculture Ecosystem and the Environment*

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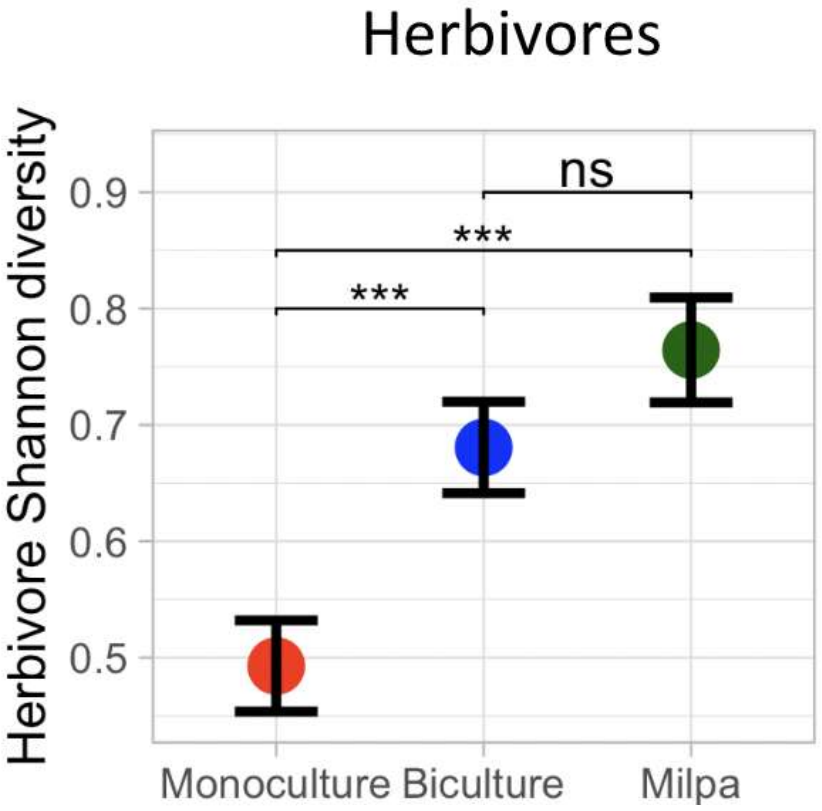
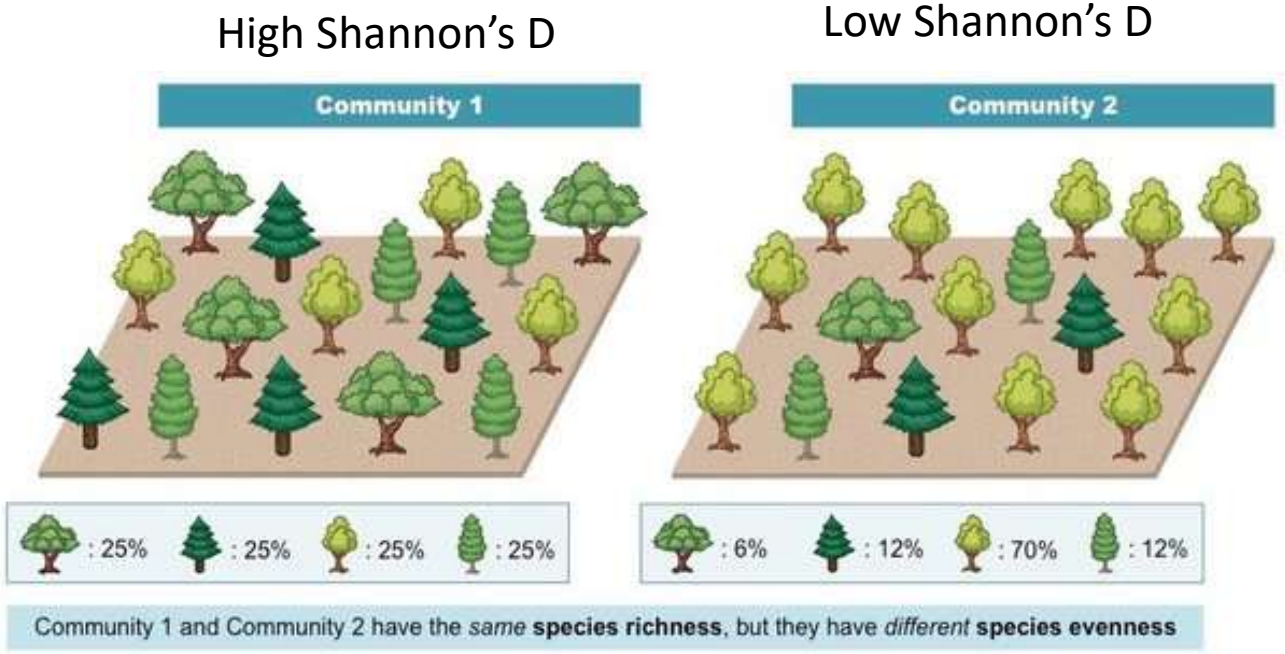


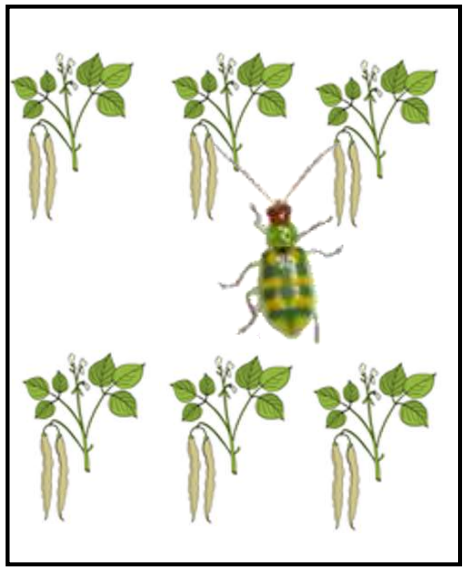


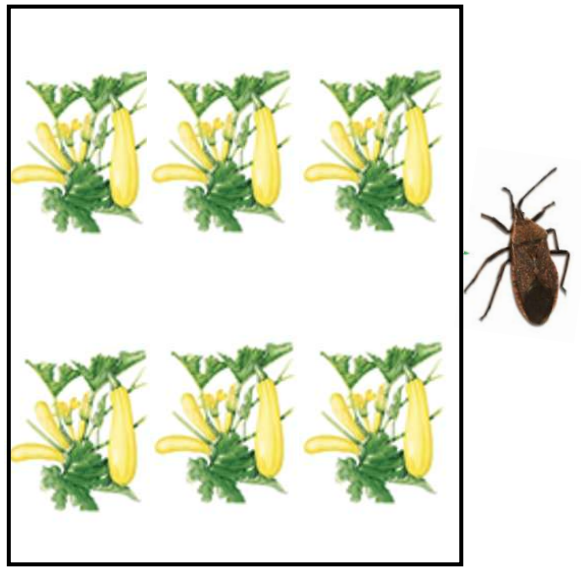
Grof-Tisza and Muller et al. In revision *Agriculture Ecosystem and the Environment*

What is driving this diversity?

More diversity because of

1) Independent effects from each crop

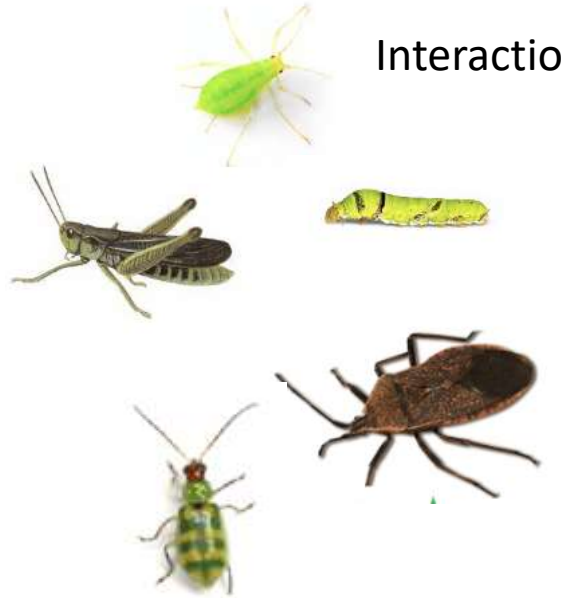




What is driving this diversity?

Positive additivity

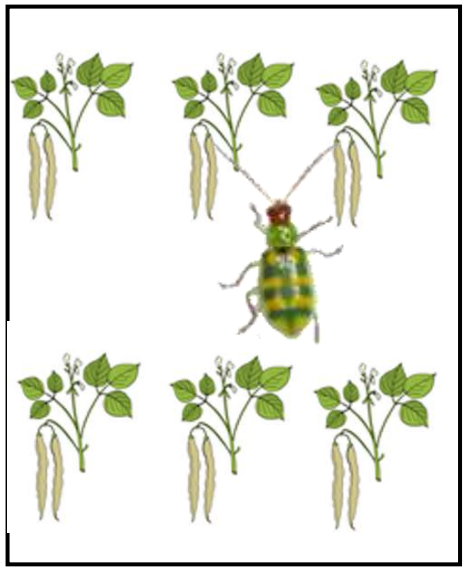
Interactions

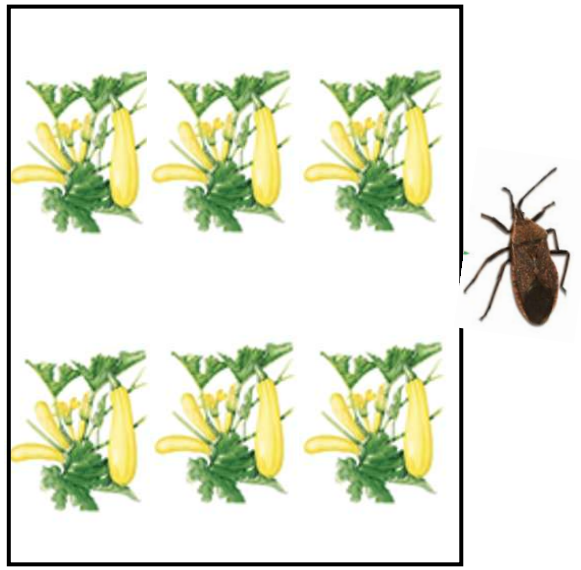


More diversity because of

1) Independent effects from each crop

2) Effects of interactions between crops (non-additivity)





What is driving this diversity?

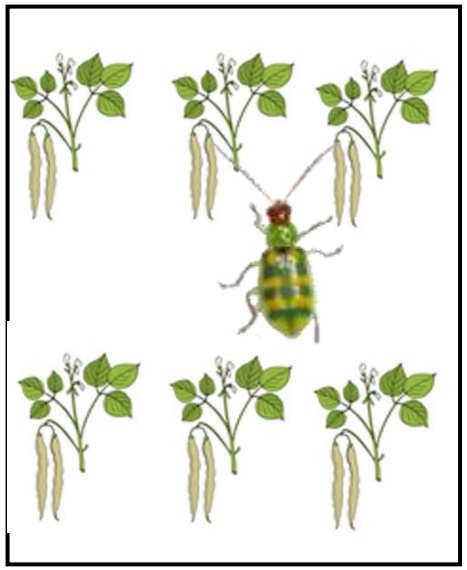
Negative additivity

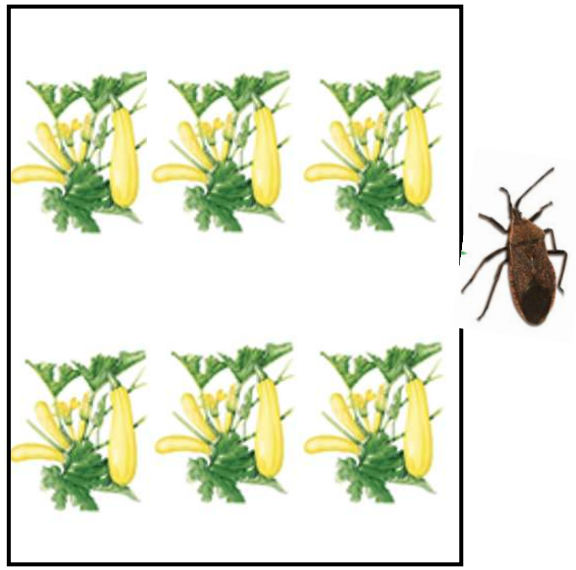
Interactions

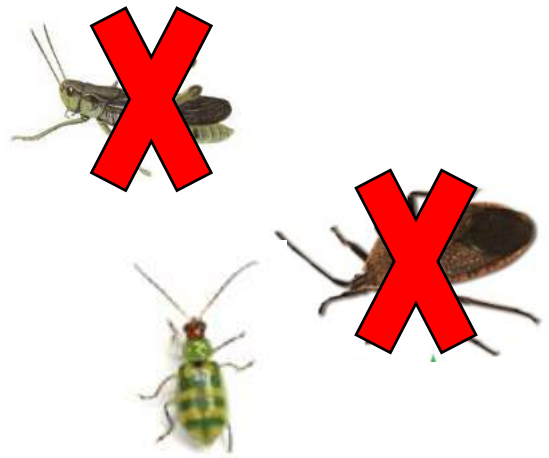
More diversity because of

1) Independent effects from each crop

2) Effects of interactions between crops (non-additivity)

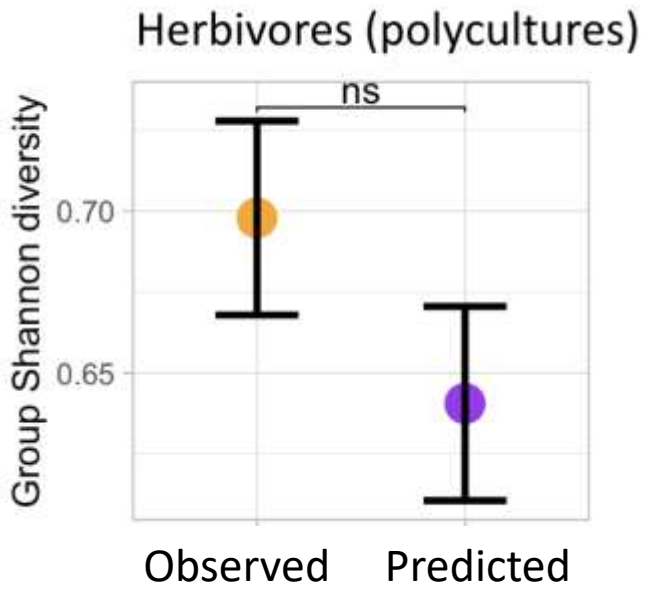






What is driving this diversity?

Moderately insignificant effect of positive non-additivity for herbivores



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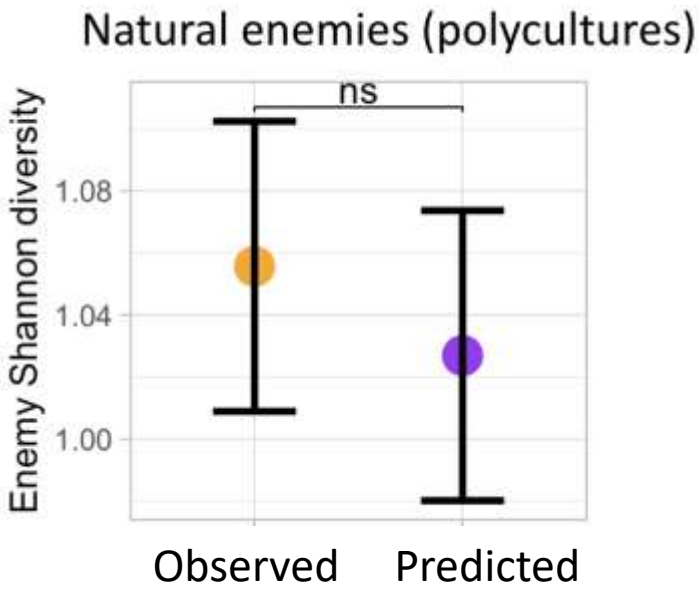
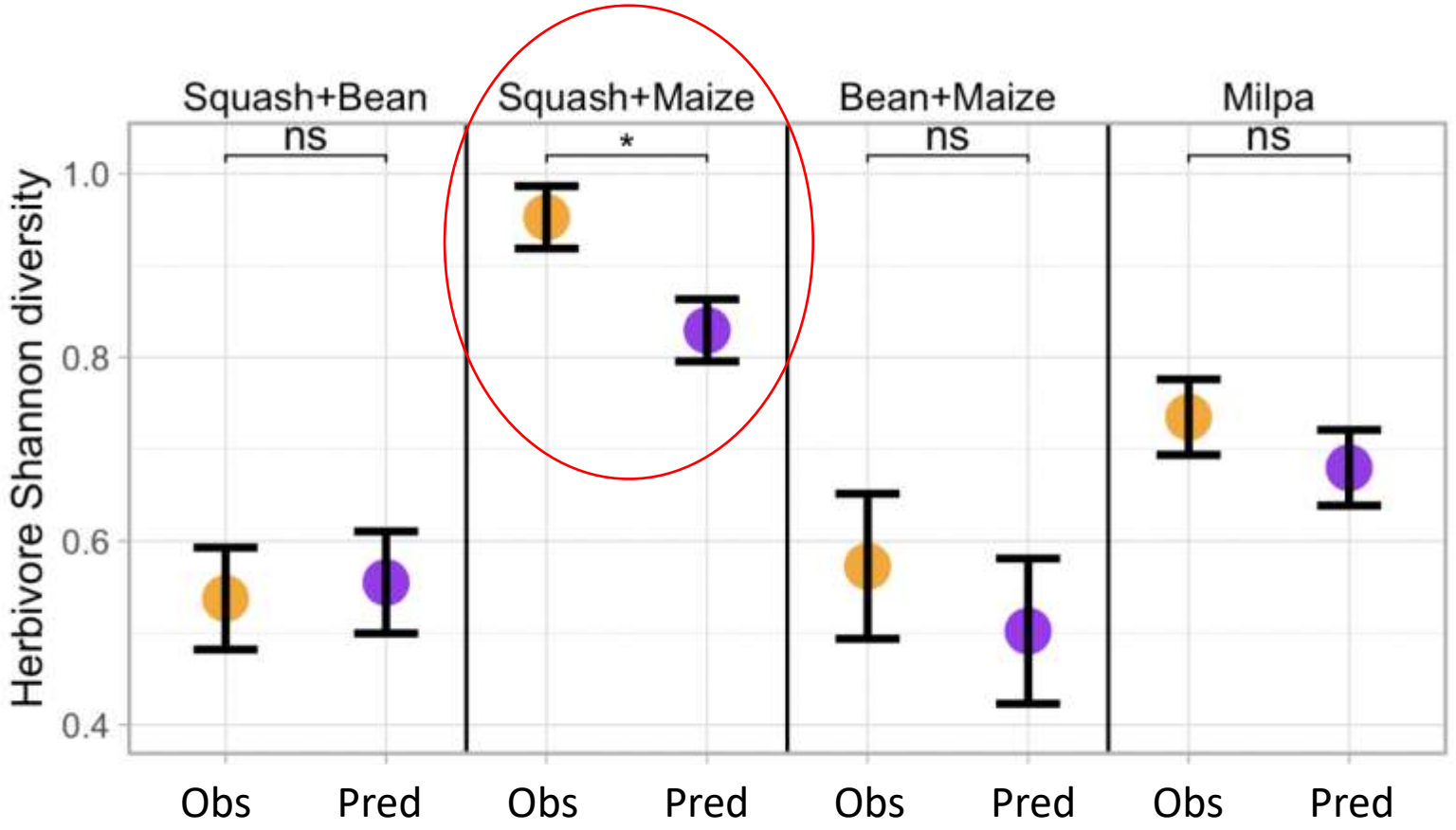
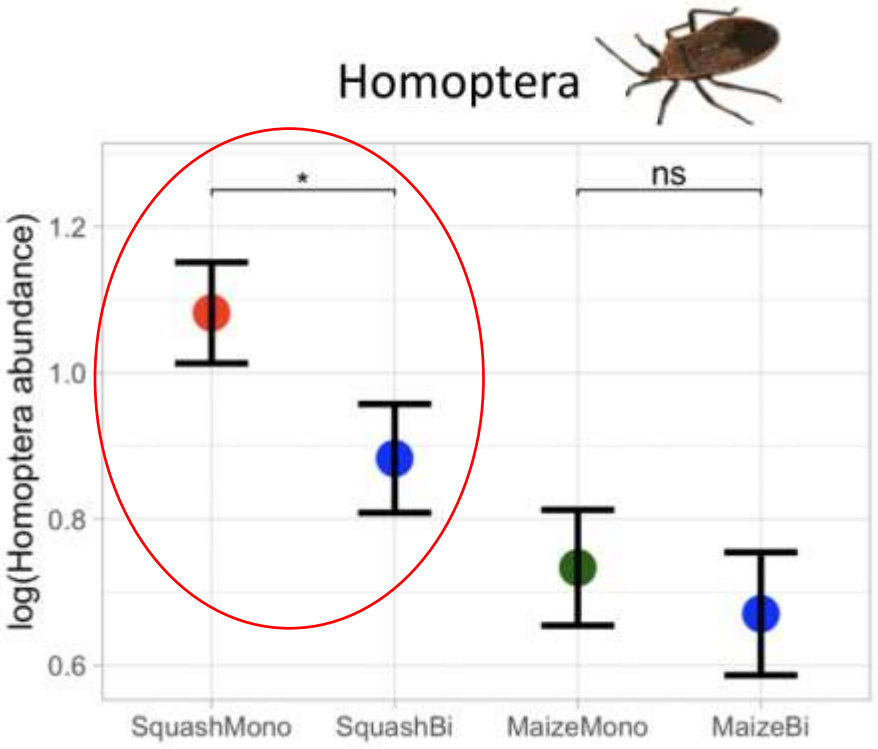


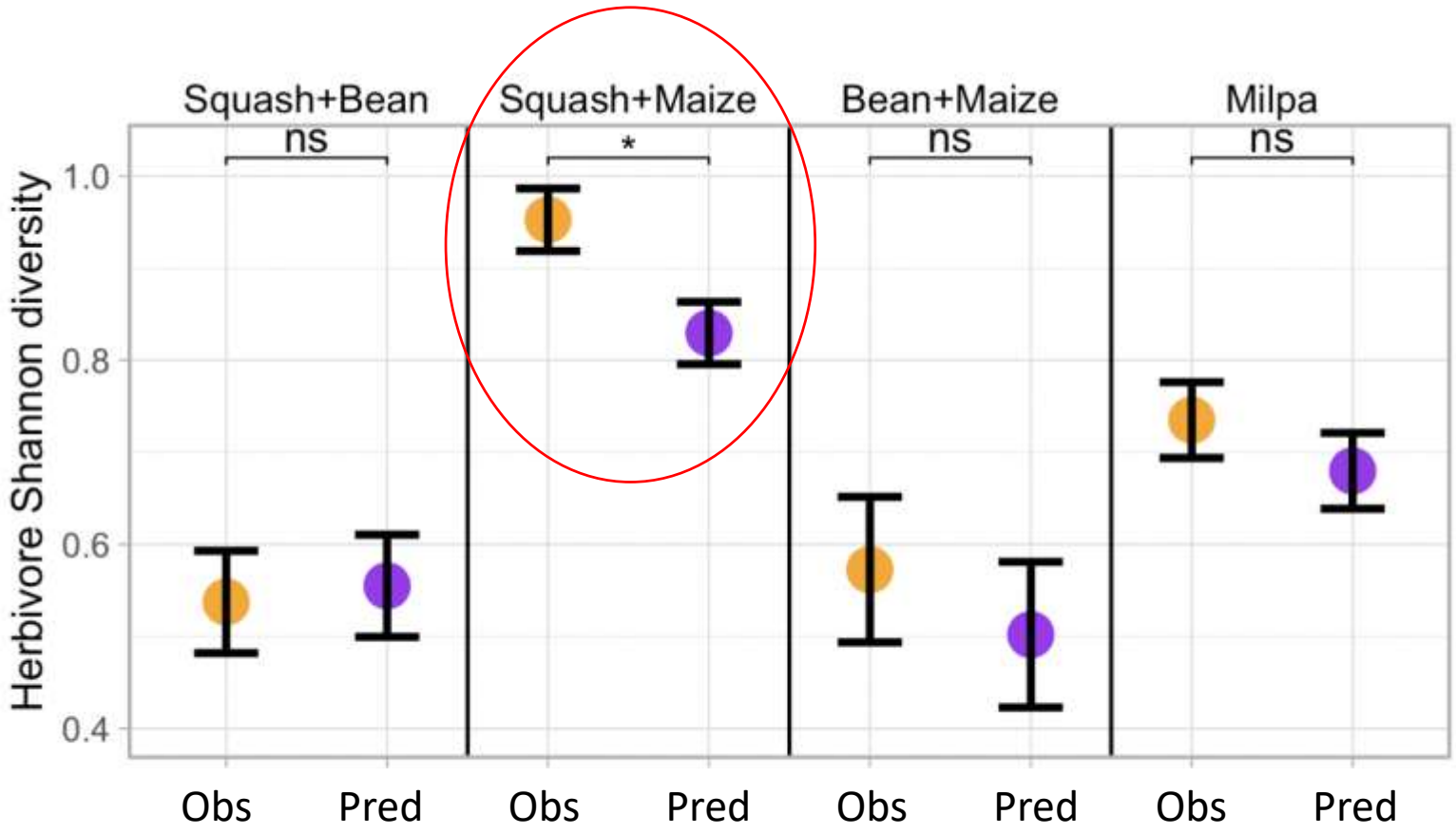
Predicted = Predicted polyculture based on observations of monocultures

More diversity than predicted

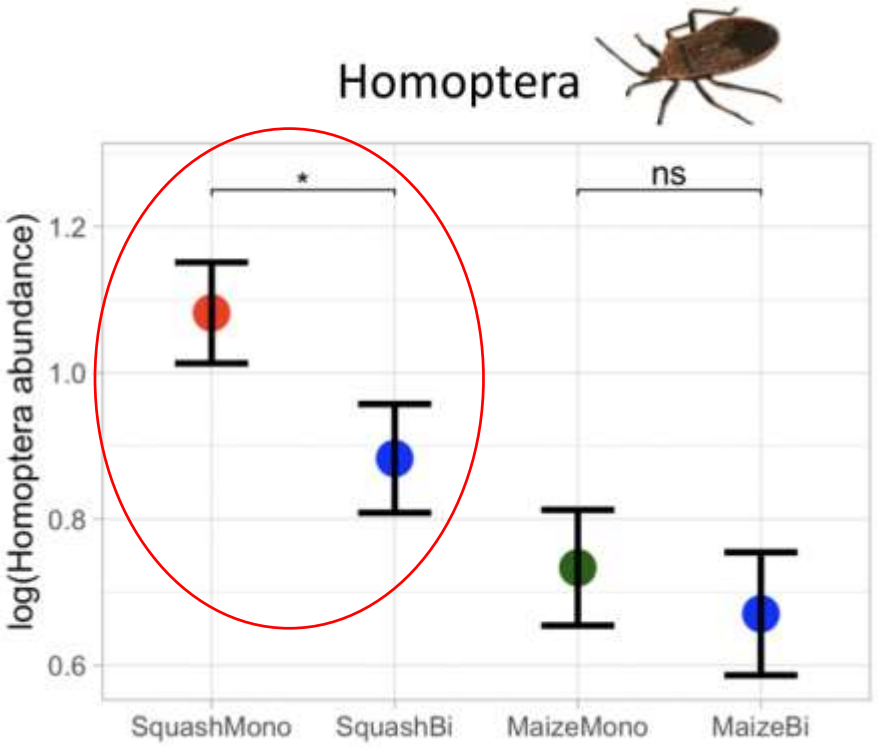
Evidence of positive non-additive effects

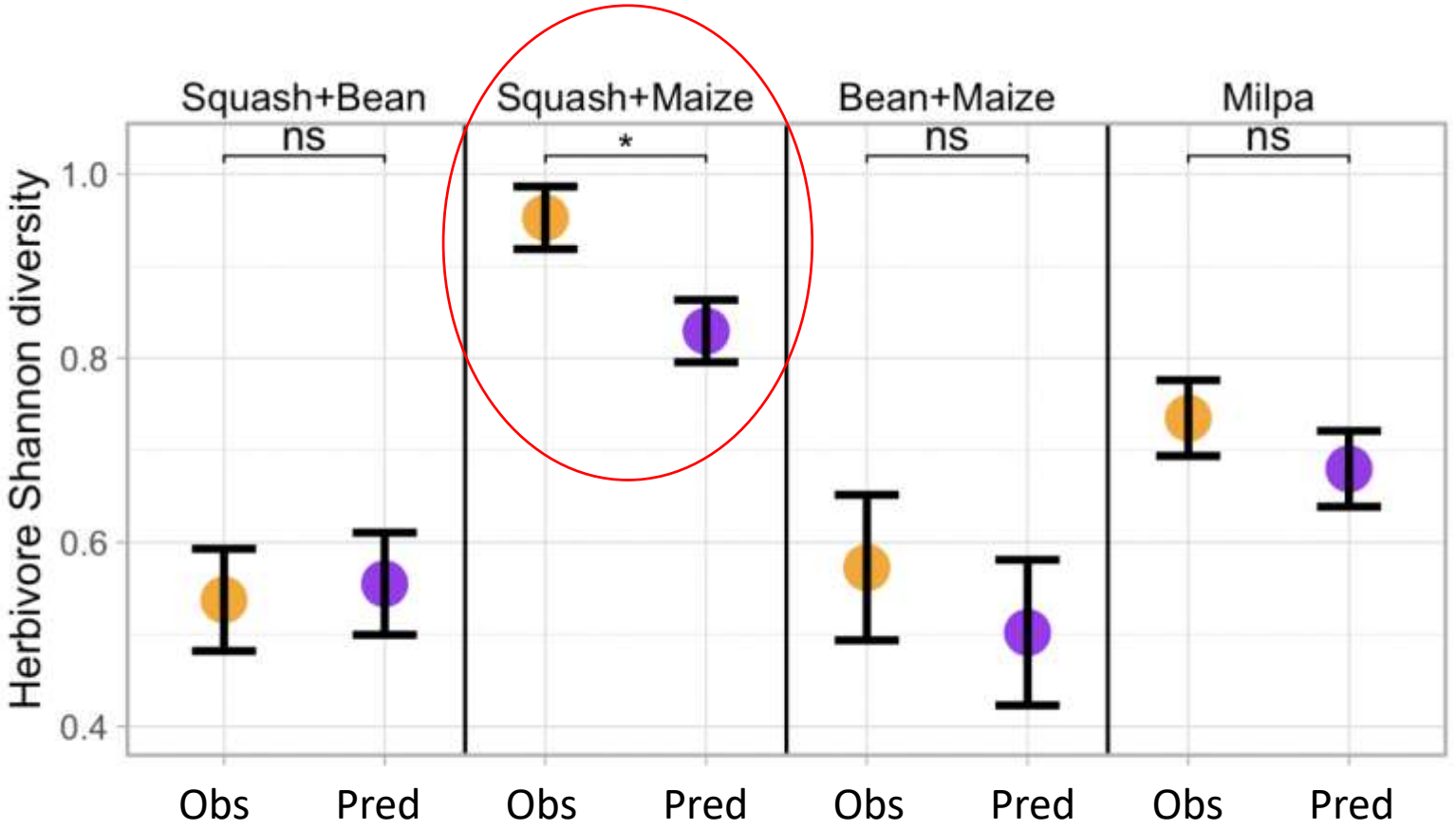



Homoptera
log(Homoptera abundance)
1.2
1.0
0.8
0.6
*
ns
SquashMono
SquashBi
MaizeMono
MaizeBi


Squash+Bean
Squash+Maize
Bean+Maize
Milpa
ns
*
ns
ns
Herbivore Shannon diversity
1.0
0.8
0.6
0.4
Obs
Pred
Obs
Pred
Obs
Pred
Obs
Pred

Potential example of associational resistance: In the presence of maize, fewer homopteran pests on squash





Reduction of dominant pest in biculture = Higher Shannon's diversity (evenness)

What is the effect of crop diversity on the abundance and diversity of the insect community?

Conclusion:

Greater diversity for both natural enemies and their herbivores – even more than predicted

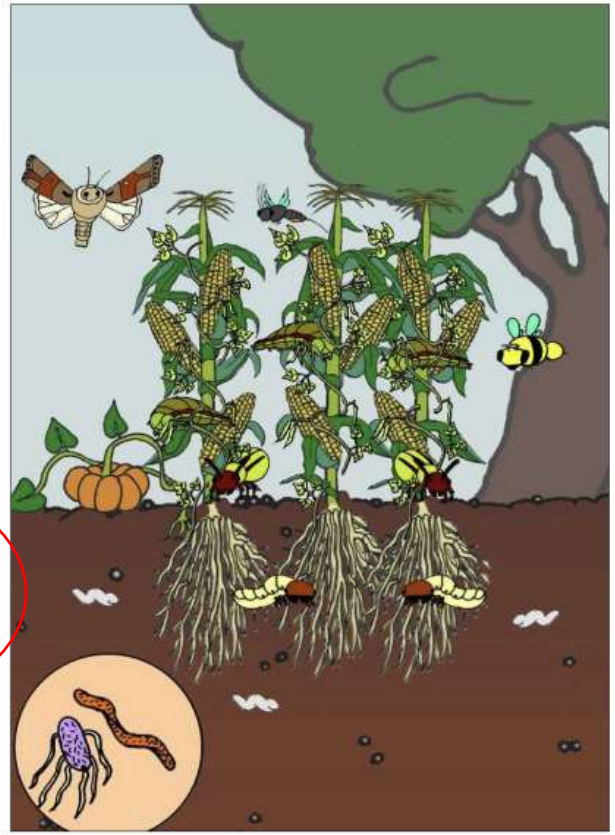
One example of associational resistance were the presence of one crop reduced the vulnerability of another

↑ diversity of predators = ↑ pest regulation

(Crowder et al. 2010 Nature)

What are some mechanisms underlying these patterns?

Important traits associated with the Milpa crops



Maize

- Provides structure for climbing beans
- Direct defenses
  - Benzoxazinoids exudates
- Indirect defenses
  - HIPVs known to attract parasitoids

Beans

- Symbioses with nitrogen-fixing rhizobia
- Indirect defense
  - Extrafloral nectar that attracts ants, parasitoids and other 'bodyguards'

Squash

- Large leaves that help retain soil moisture and reduce weed growth
- Direct defenses
  - Trichomes
  - Cucurbitacins

Schematic representation on the Milpa agricultural system with the three sisters: maize, beans and squash, and the above and belowground communities associated with this system. Made by Nicolas Marguier

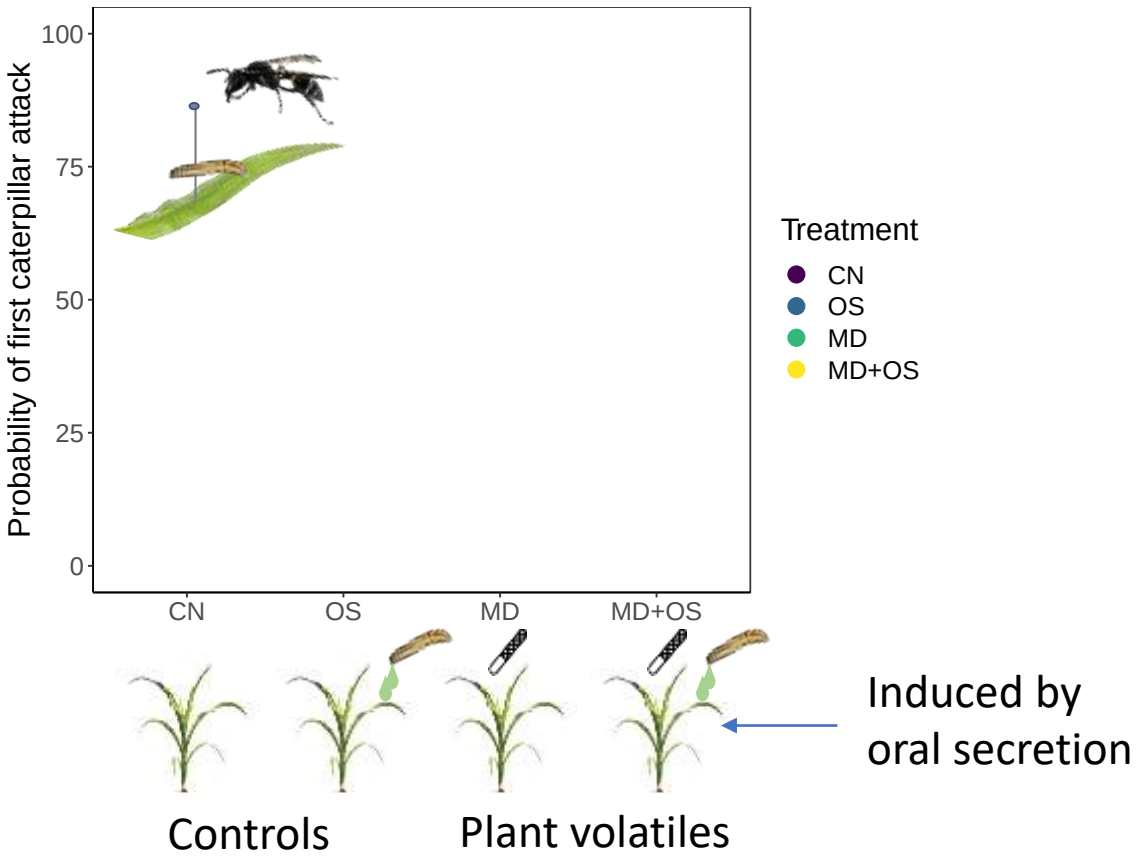
Do predatory wasps use maize odors to locate prey?

Dr. Ted Turlings
University of Neuchâtel

Dr. Carlos Bustos-Segura

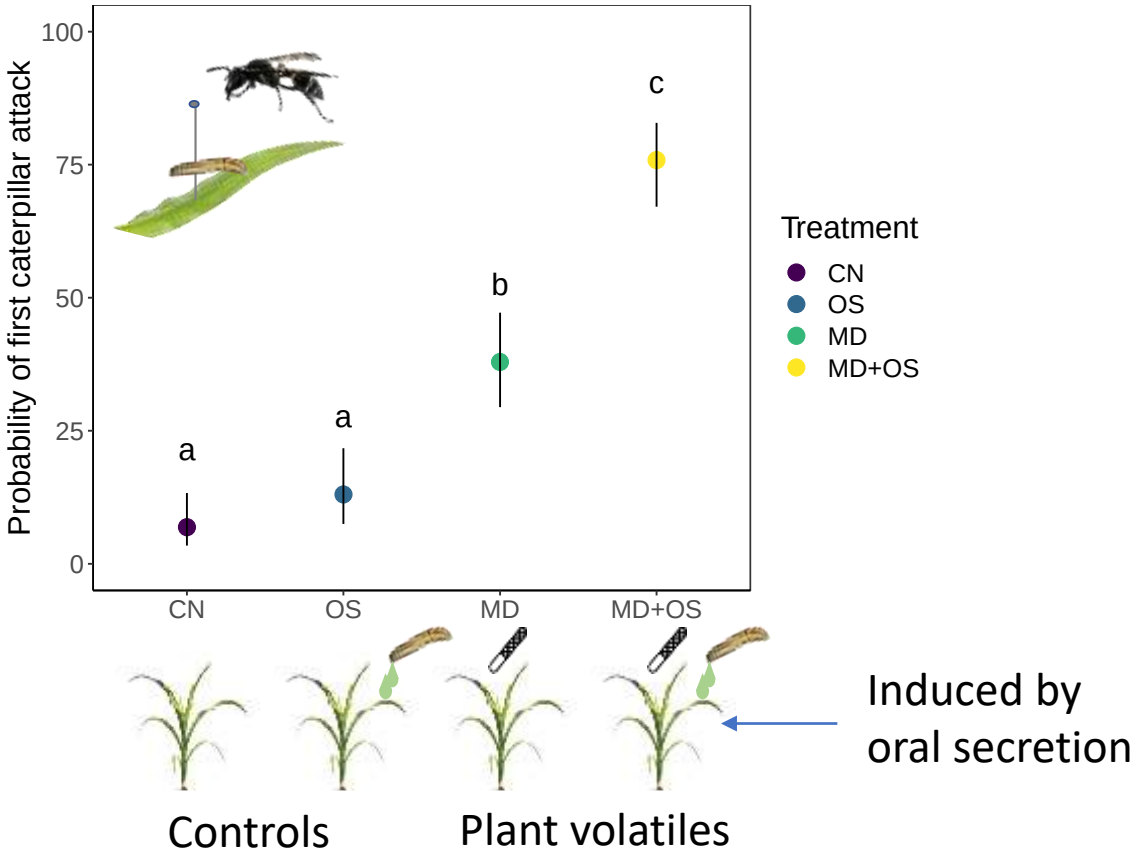
Attraction to herbivore induced plant volatiles (HIPVs) is well established in parasitic wasps (Turlings et al. *Nature* 1990, 1992).

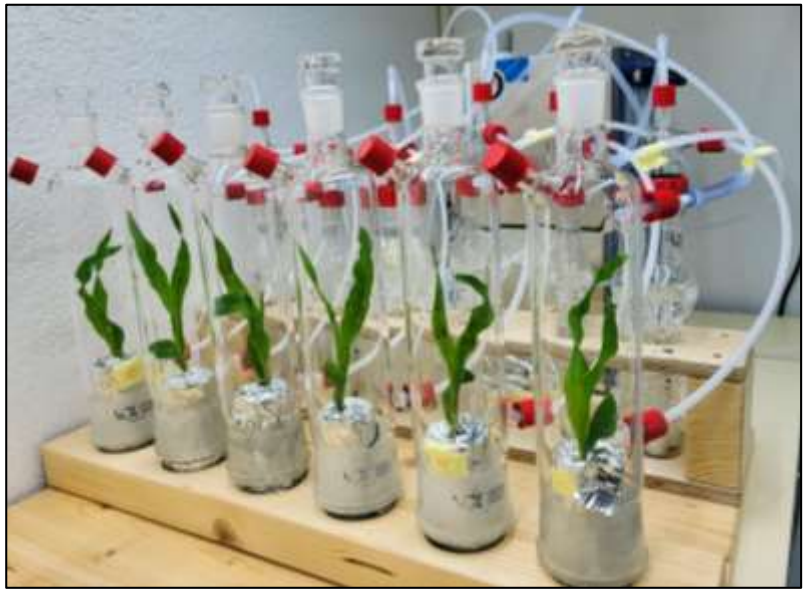
Odors and predatory wasps



Grof-Tisza et al. In review *Functional Ecology*

Odors and predatory wasps



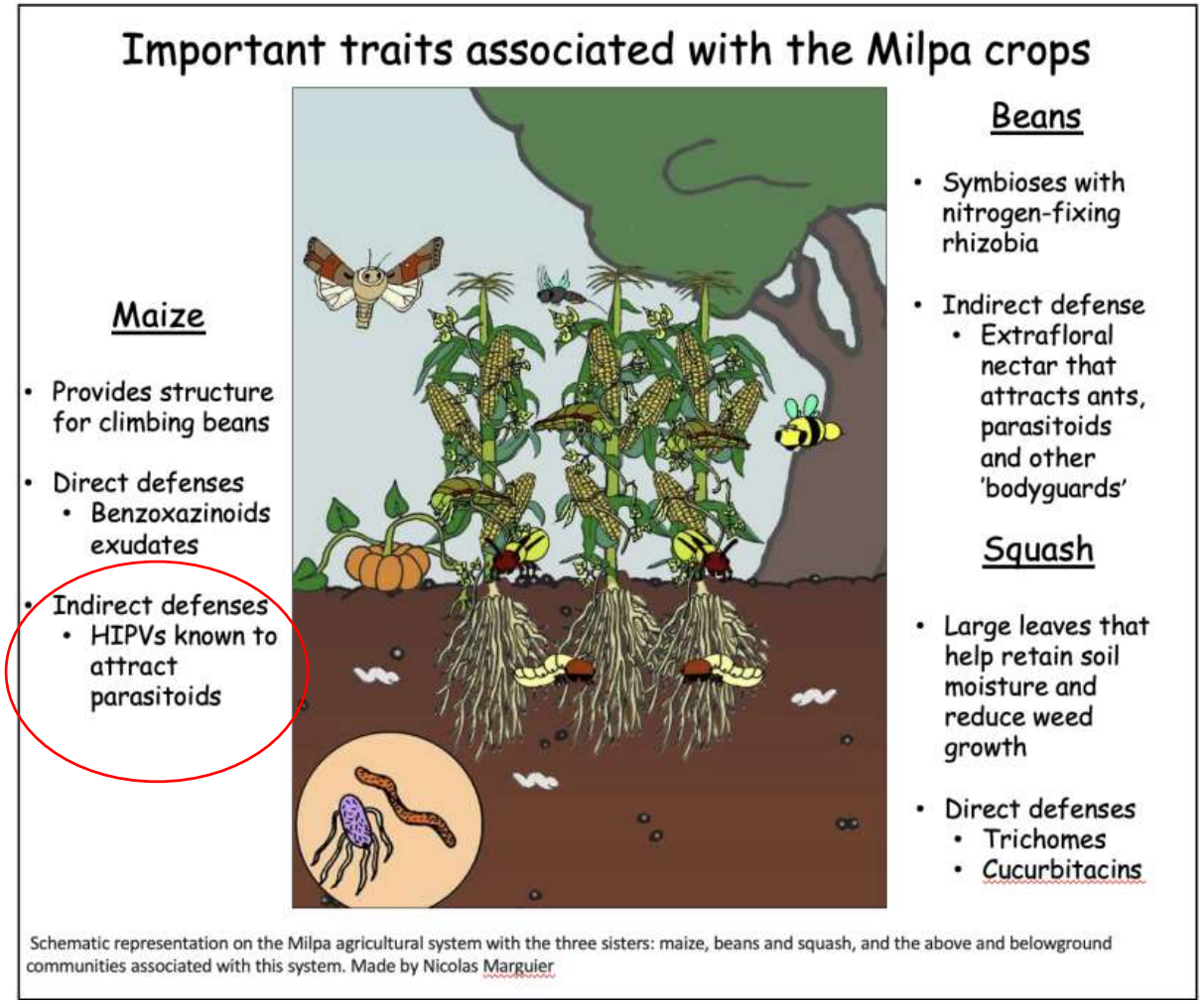


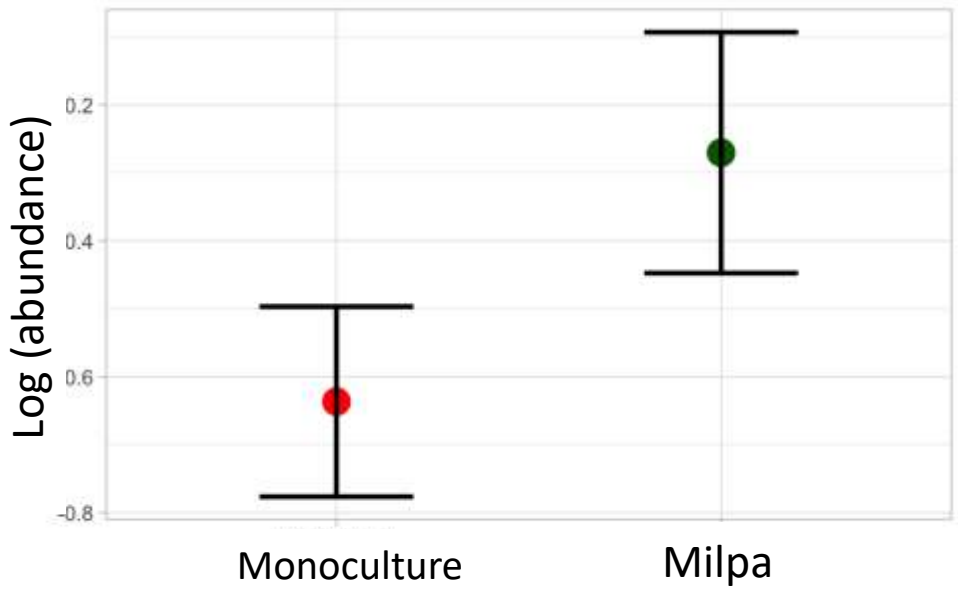
Collection of maize volatiles

Predatory wasps use HIPVs to locate prey

Grof-Tisza et al. In review *Functional Ecology*

What are some mechanisms underlying these patterns?

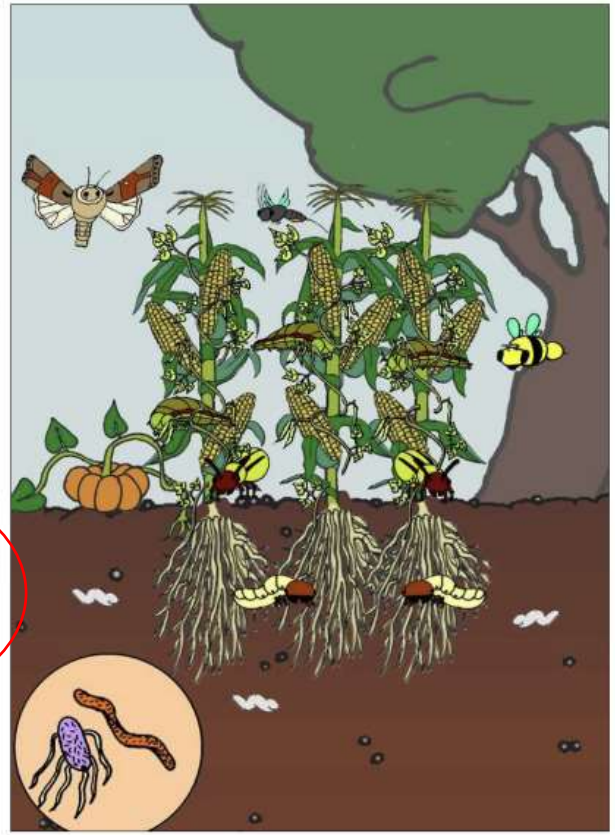




Important traits associated with the Milpa crops

Maize

- Provides structure for climbing beans
- Direct defenses
  - Benzoxazinoids exudates
- Indirect defenses
  - HIPVs known to attract parasitoids



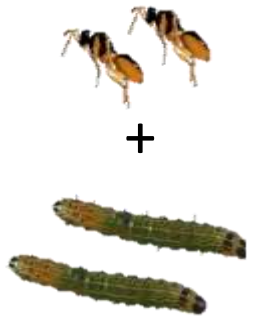
Beans

- Symbioses with nitrogen-fixing rhizobia
- Indirect defense
  - Extrafloral nectar that attracts ants, parasitoids and other 'bodyguards'

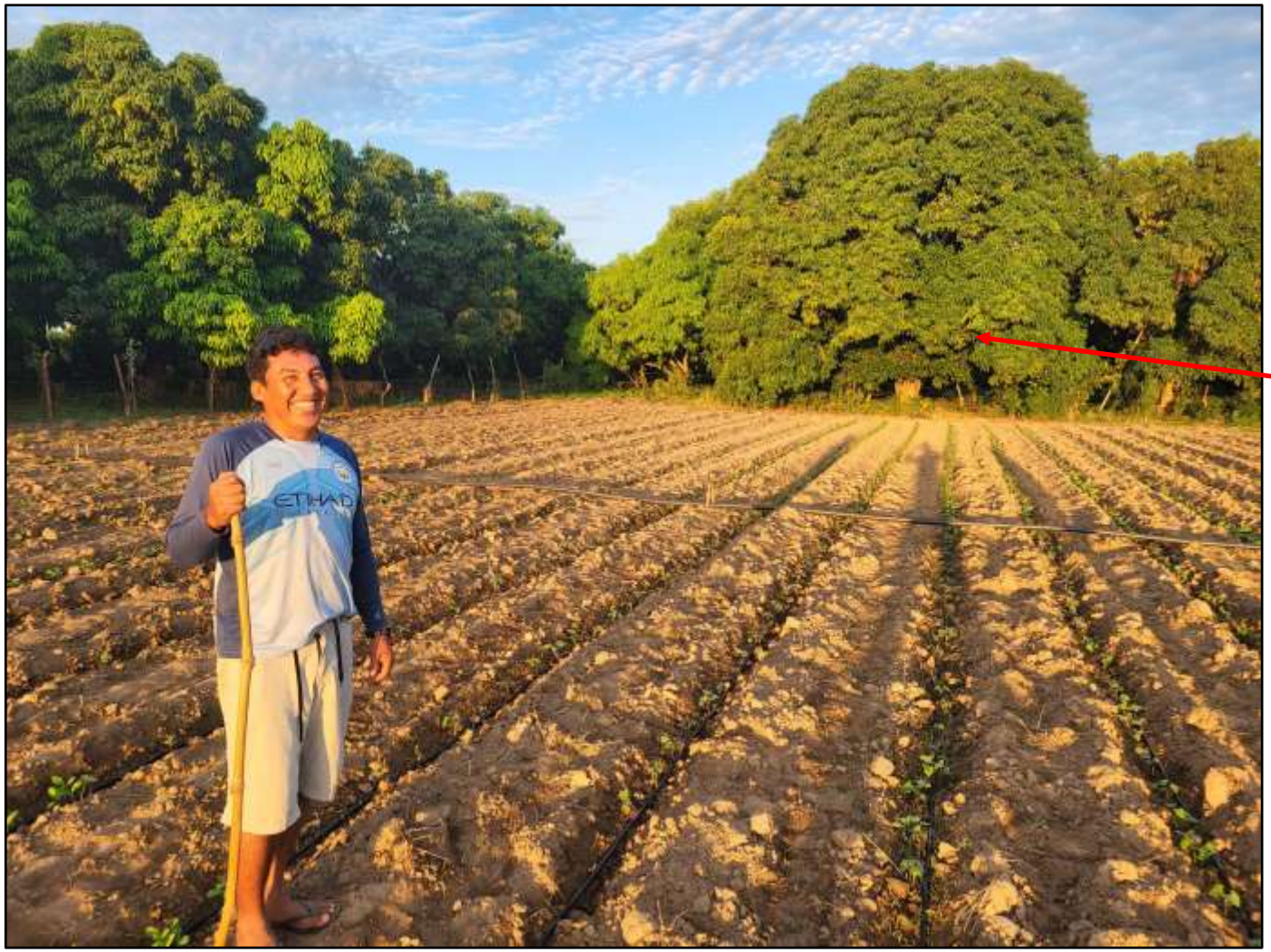
Squash

- Large leaves that help retain soil moisture and reduce weed growth
- Direct defenses
  - Trichomes
  - Cucurbitacins

Schematic representation on the Milpa agricultural system with the three sisters: maize, beans and squash, and the above and belowground communities associated with this system. Made by Nicolas Marguier



Importance of agroforestry: Indirect defenses of milpa depend on trees!



What are some mechanisms underlying these patterns?

Conclusions: many mechanisms are consistent with patterns at larger scales and those predicted by long-held hypothesis

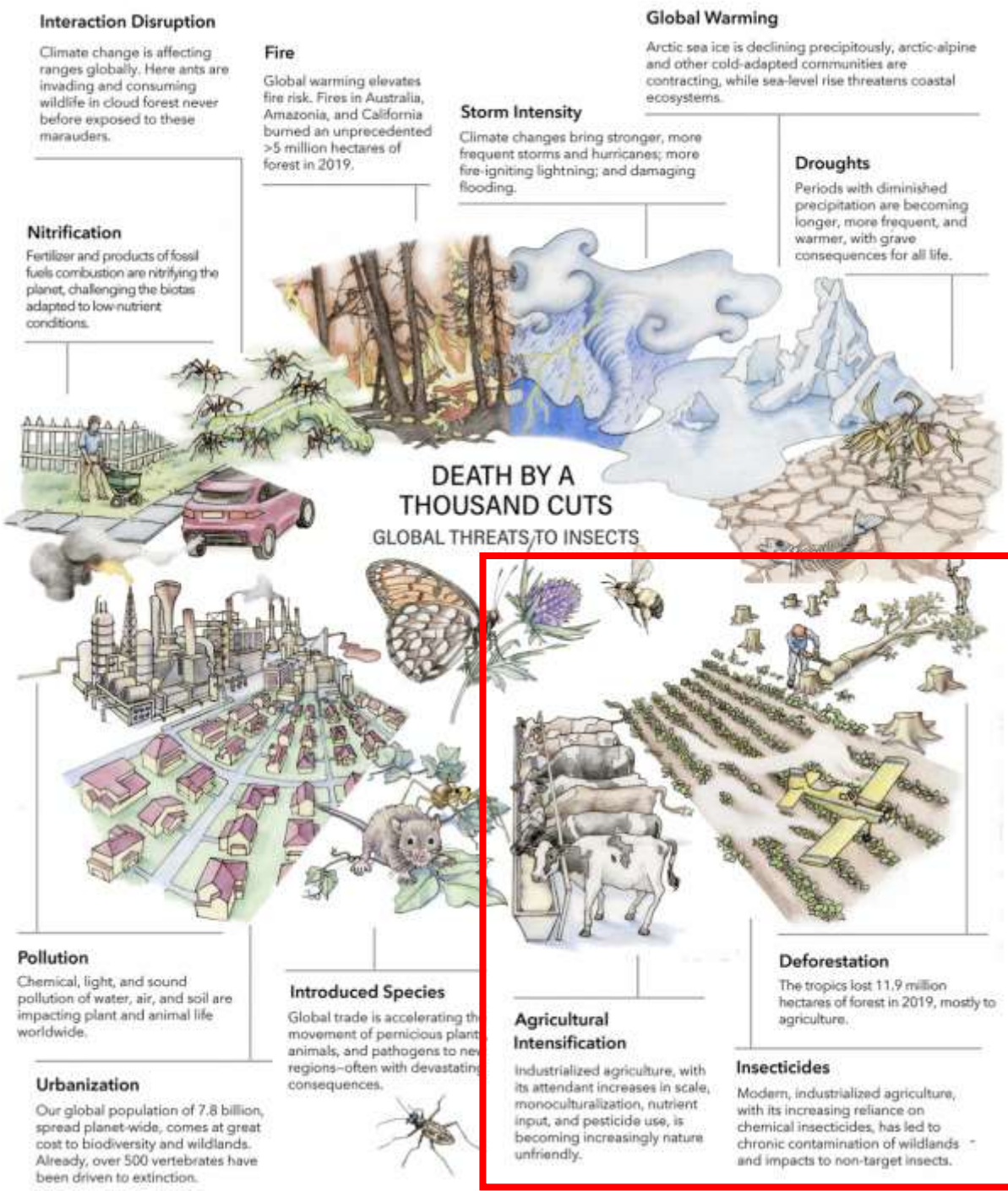
Additional mechanisms to test!

Broader Implications

Insects have declined by 75% in the past 50 years

30% of crop production on 24% of agricultural land is comprised of small-holder agriculture

The preservation of low-input polycultures and small-holder agroforestry systems as a strategy to sustain biodiversity while leveraging natural pest control



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Thanks, Gracias, Danke, Merci

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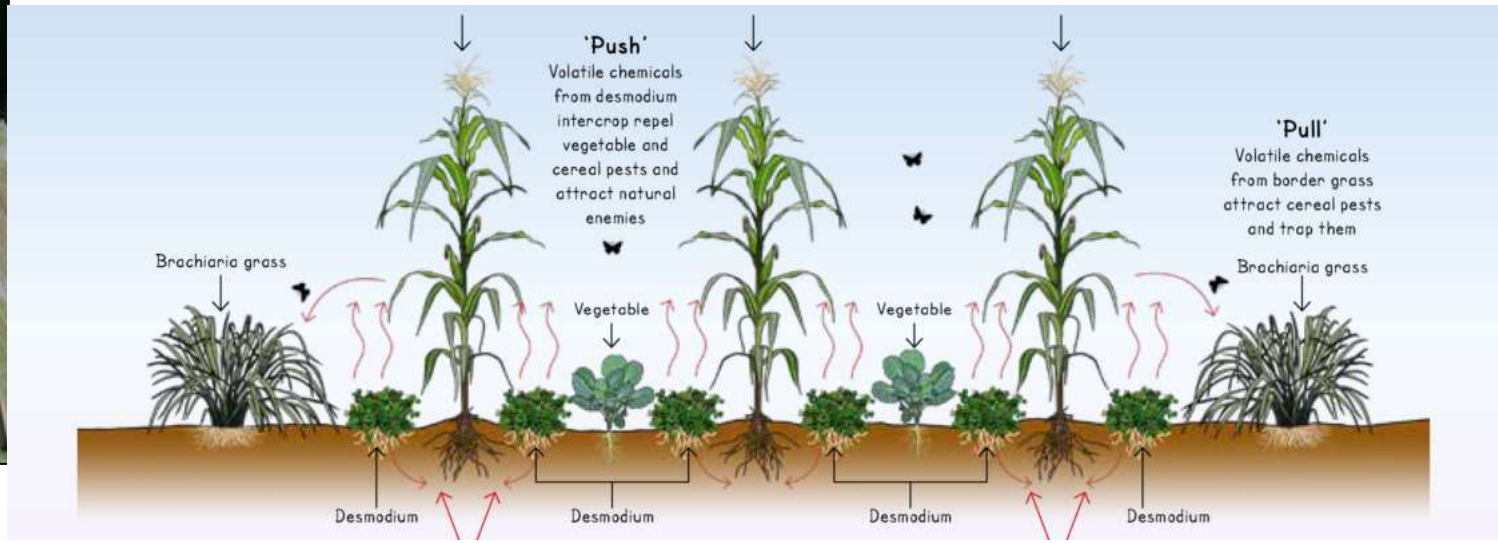
Neuchatel platform of analytical chemistry (NPAC)

Why should we care about plant communication and induced-defenses?

Application?

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