Give predators a complement: balancing positive and negative diversity effects

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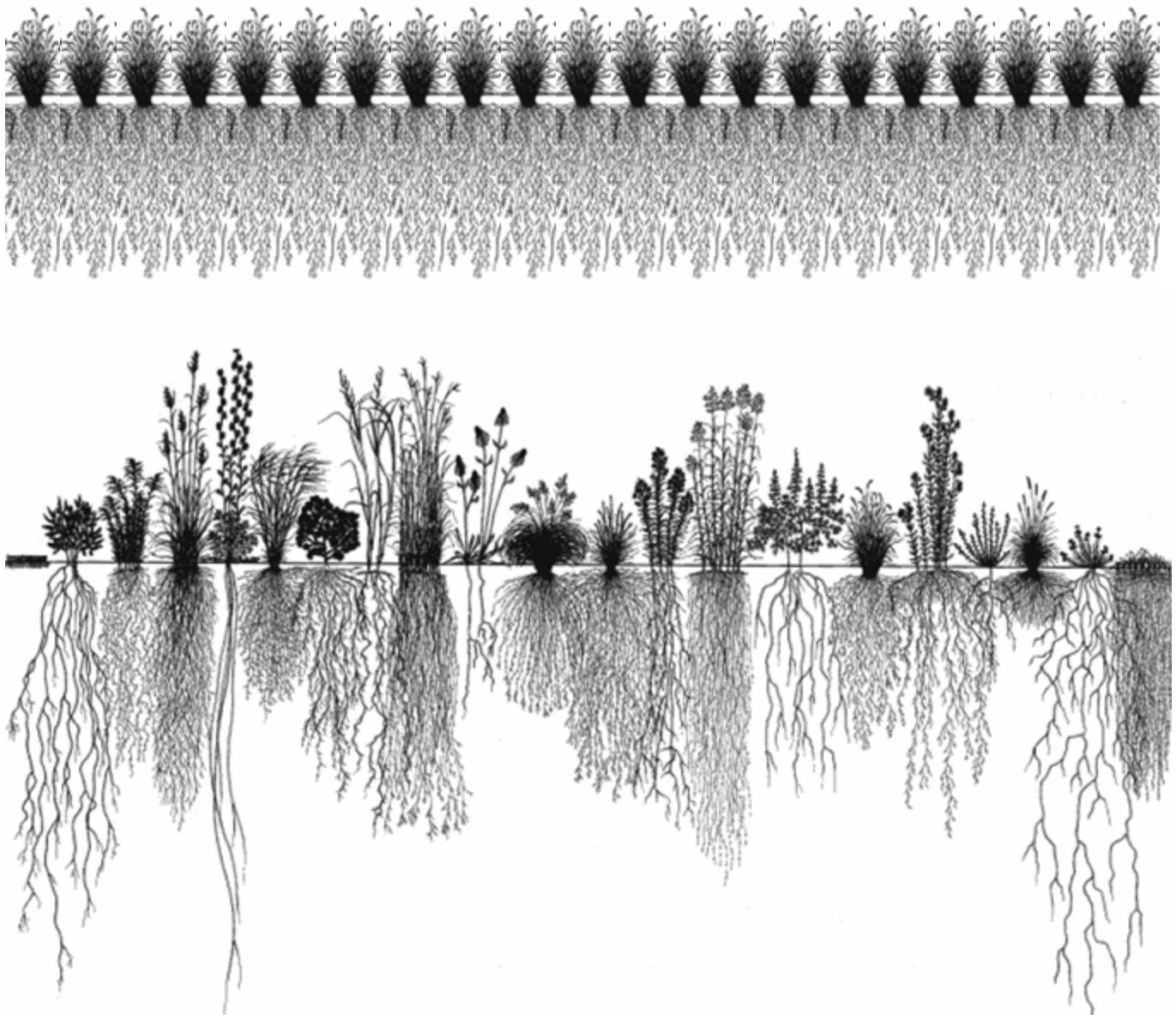
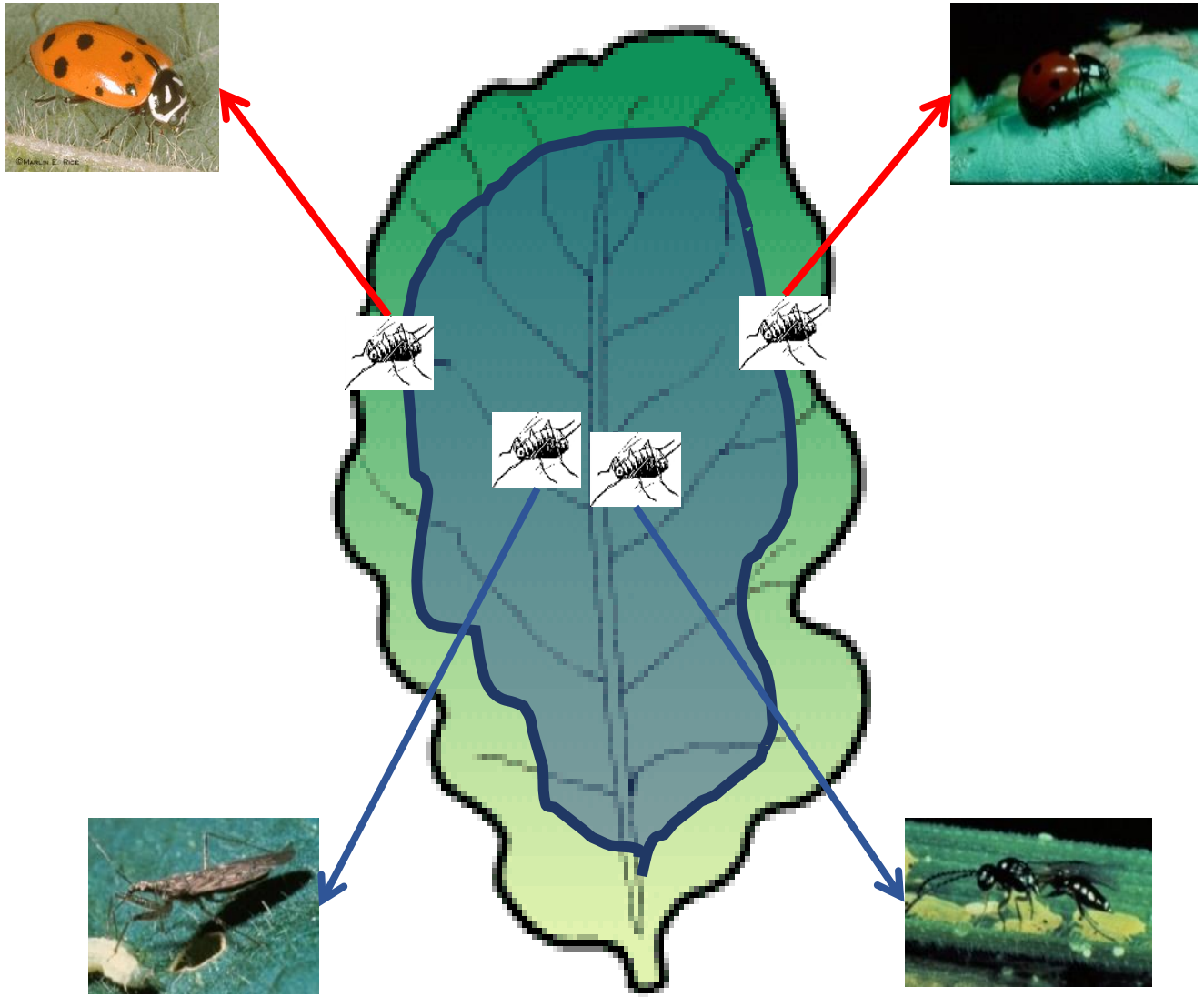
Pimentel 1961, *Annals of the Entomol. Soc. Am:*
"*Considerable evidence in the literature suggests that the lack of species diversity [in] communities modified by cultivation…may be responsible for the outbreaks which are so typical of these simplified communities*"

Biodiversity benefits biocontrol.

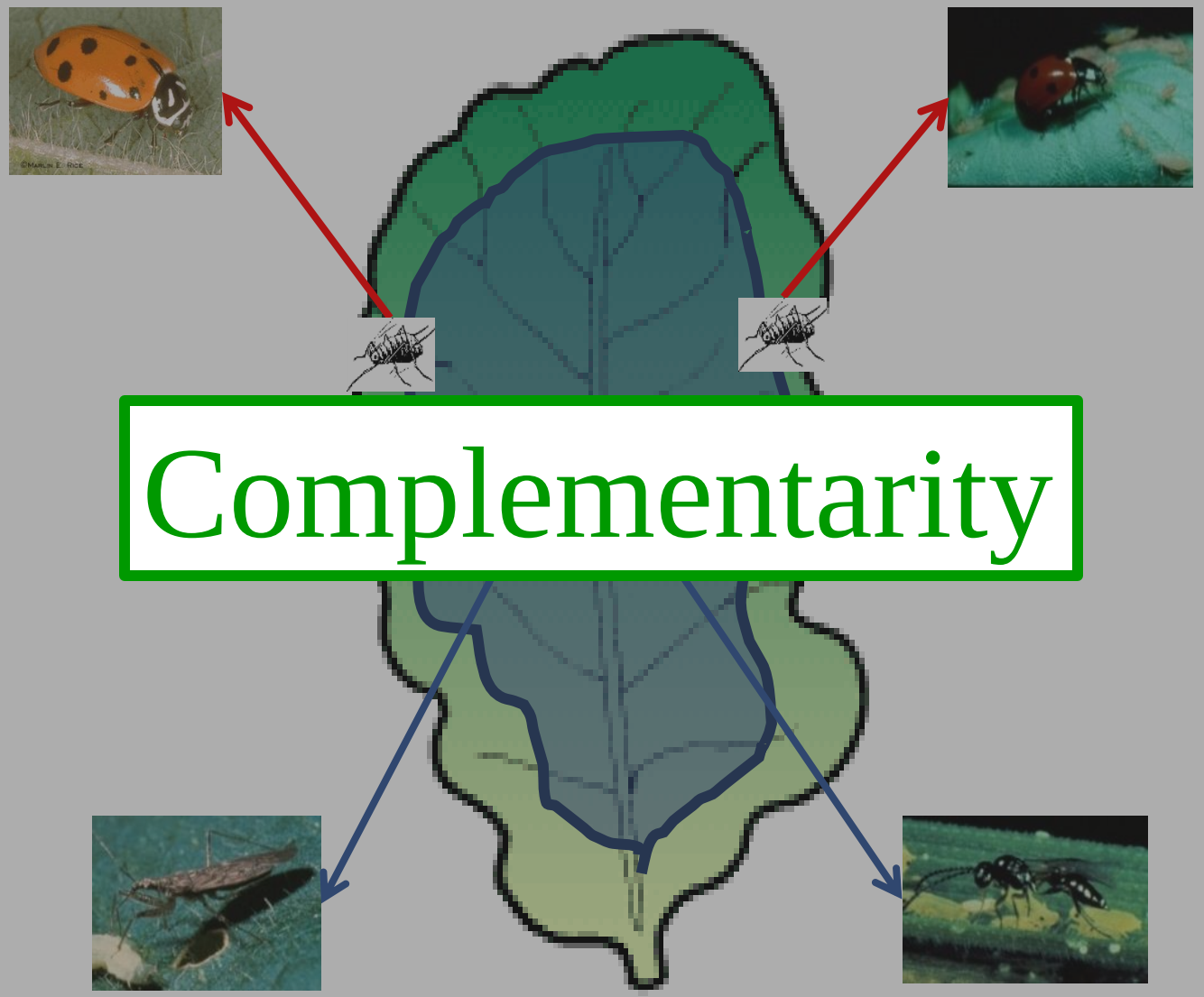

Biodiversity is good.

Different species “complement” one another





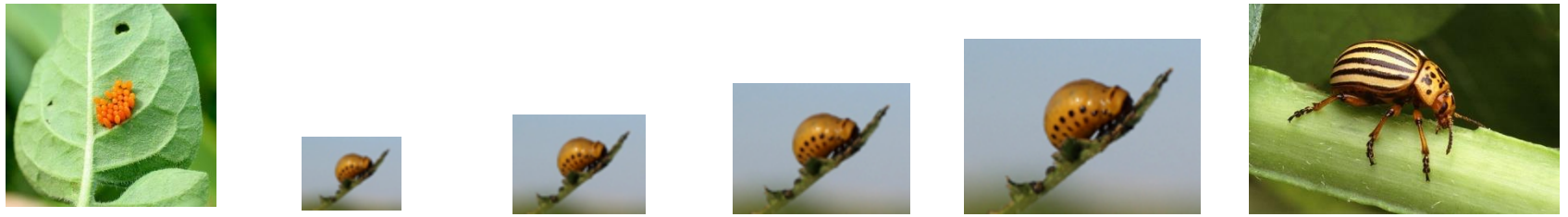
Straub and Snyder 2008, *Ecology*



Straub and Snyder 2008, *Ecology*

Colorado potato beetle,
Leptinotarsa decemlineata

Colorado potato beetle: complex life cycle



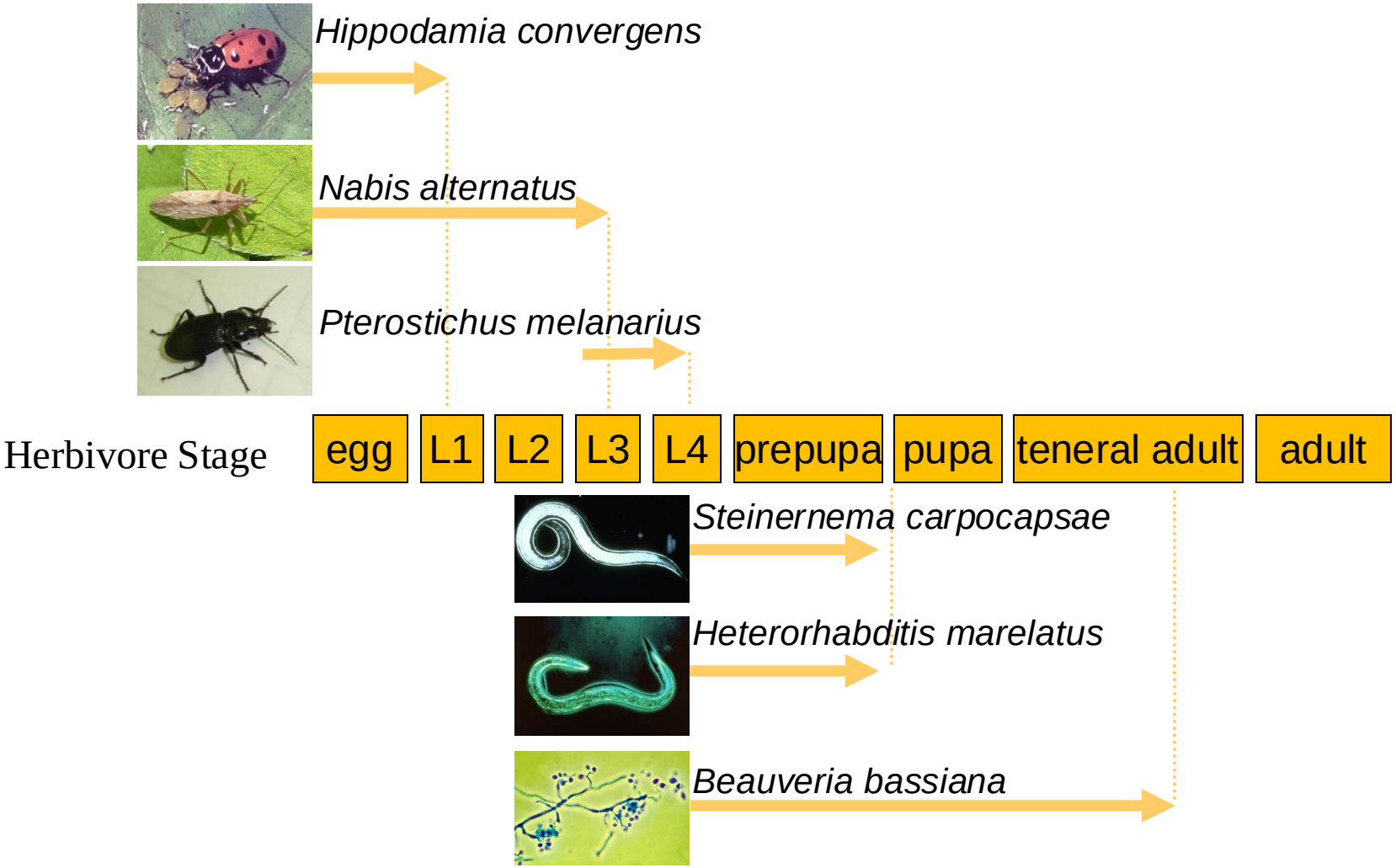
Egg → L1 → L2 → L3 → L4 → Adult

Aboveground

Belowground

Pre-pupa → Pupa → Teneral Adult

Predators above... pathogens below.



Losey and Denno 1998, *Ecology*

- Coccinellids forage for pea aphids in the foliage, but aphids drop to escape
- Carabids are voracious aphid predators, but few opportunities to encounter these prey
- When these predators co-occur, positive synergism?

Losey and Denno 1998, *Ecology*

Facilitation

- Coccinellids forage for pea aphids in the foliage, but aphids drop to escape
- Carabids are voracious aphid ut few opportunities to hese prey
- When these predators co-occur, positive synergism?

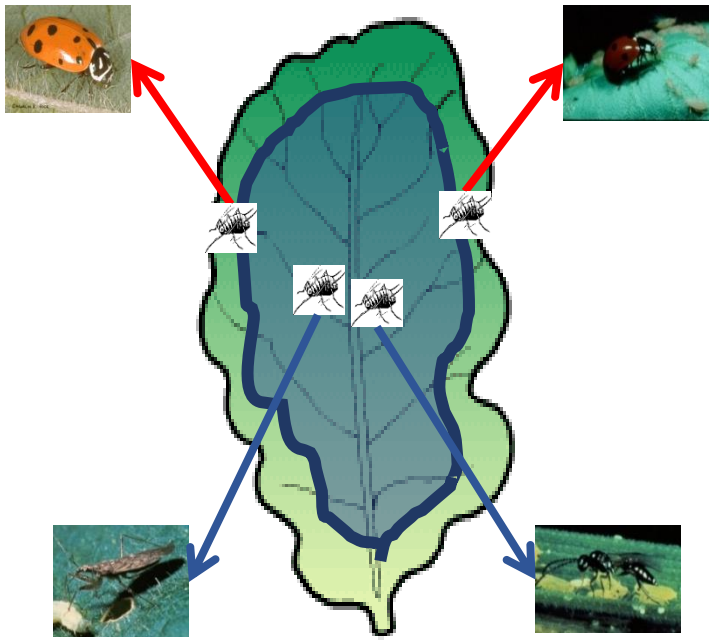
Predators that hunt in different places, at different times, or in different ways can complement one another…

…so this is really simple,
and biodiversity is always good!

Interference

"Intraguild predation", Polis et al. 1989;
Finke and Denno's 2004 *Nature* paper

Does higher predator biodiversity lead to stronger herbivore suppression?



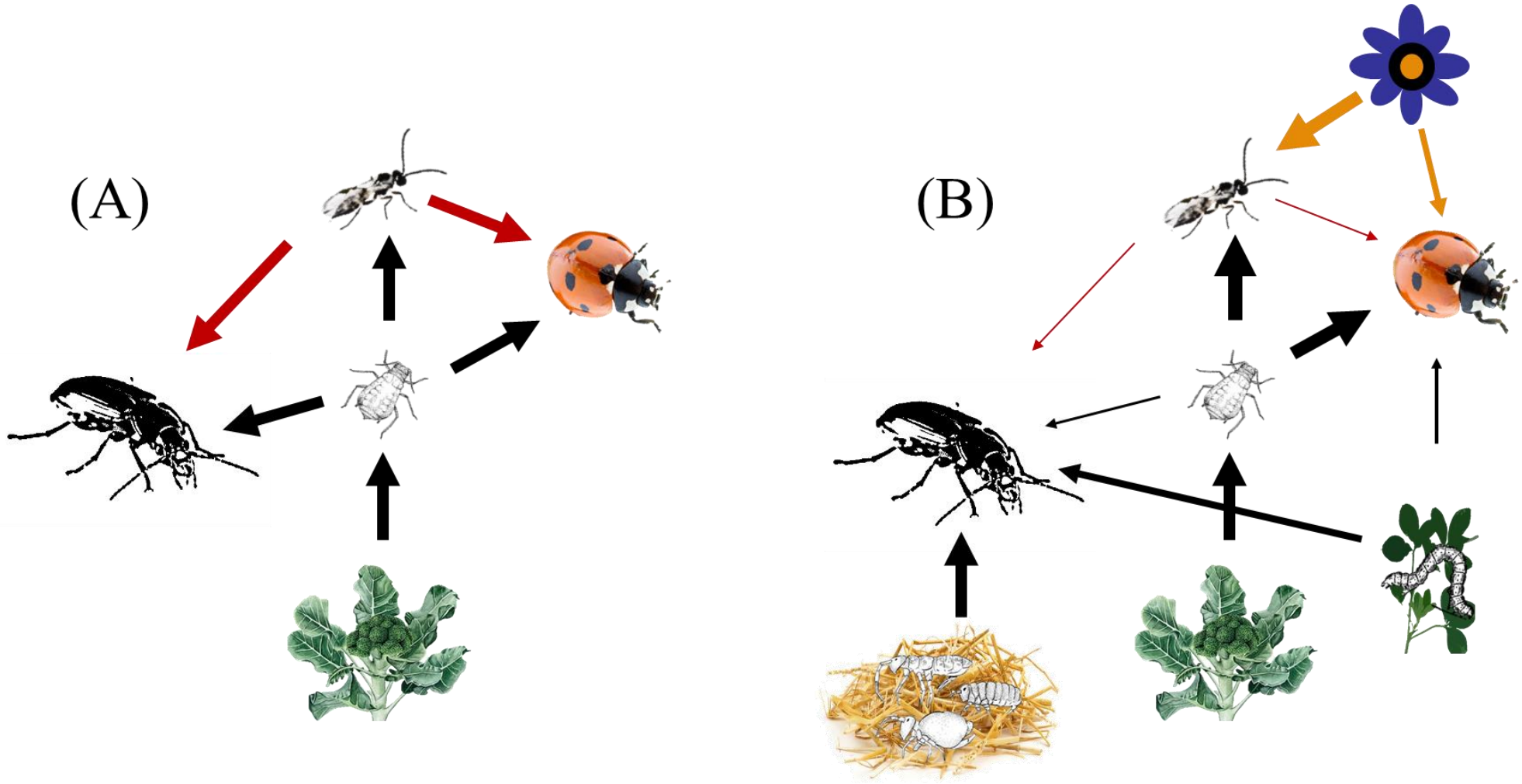
vs

e.g., Straub and Snyder 2008, *Ecology*

e.g., Polis et al. 1989 AREES;
Finke and Denno 2004 *Nature*

How can we change farming practices to encourage niche complementarity?

Complementarity-interference can rebalance?



Summary

1. Predator species complement one another by filling different niches.

2. But, predators sometimes feed on one another.

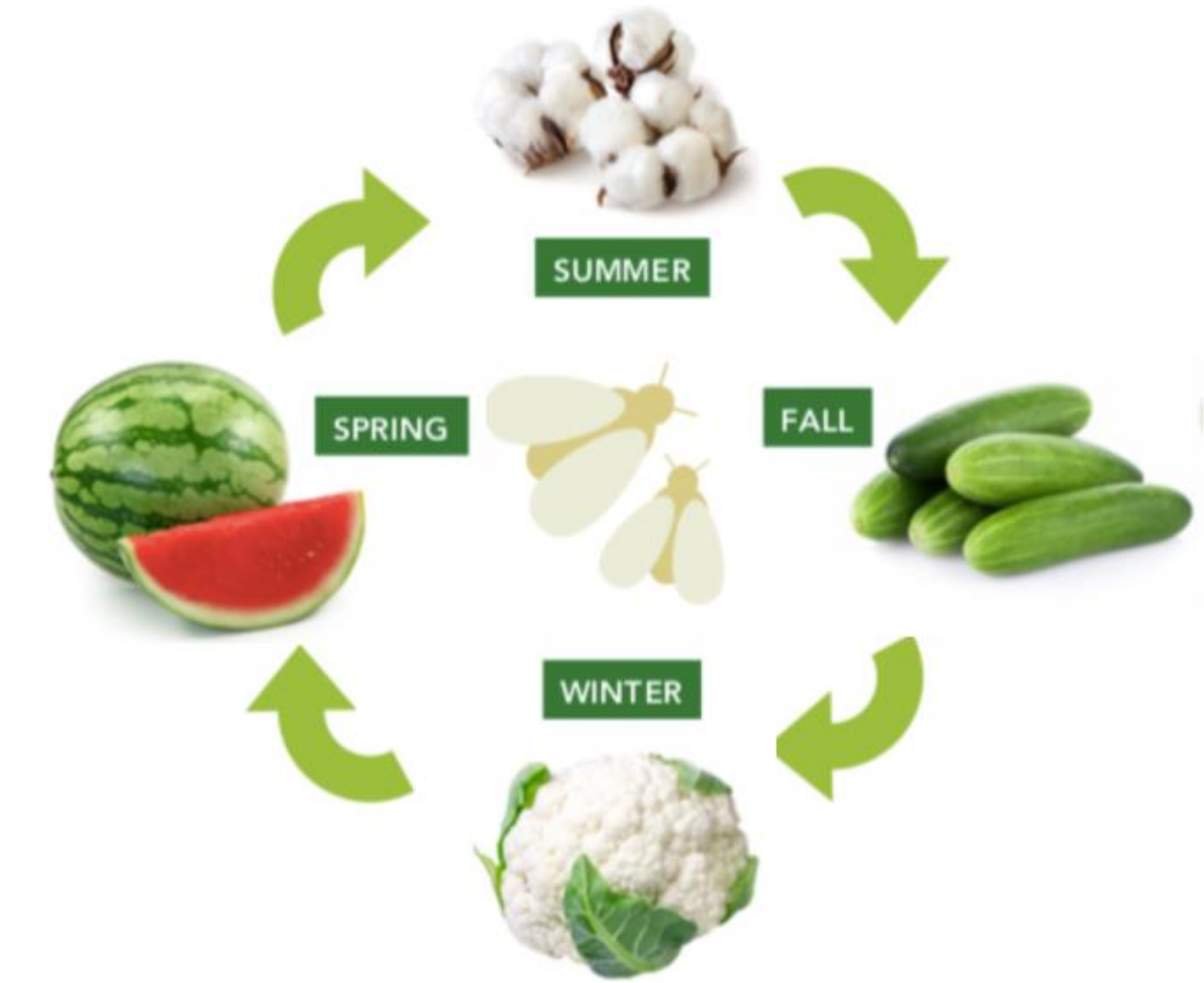
3. **Increasing field and farm complexity might enhance complementarity while reducing interference.**

From southeastagnet.com, Clint Thompson

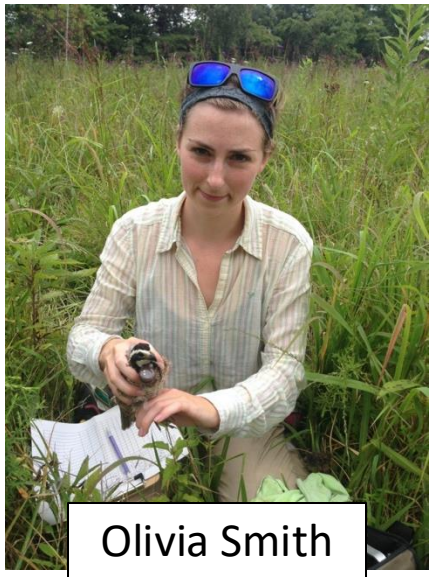
2016-17 emergence of *Bemisia tabaci* as key pest in S GA:

- Long a minor pest
- Sudden eruption
- First outbreak years were the **hottest, driest** ever recorded

Whiteflies move among crops each year



Mike Crossley
UGA postdoc



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Apurba Barman
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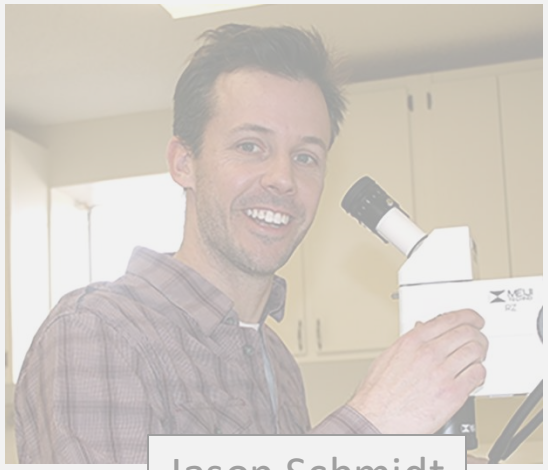

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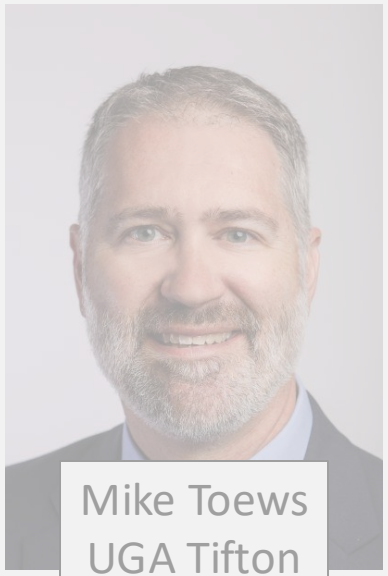
UGA Tifton

Phillip Robers
UGA Extension



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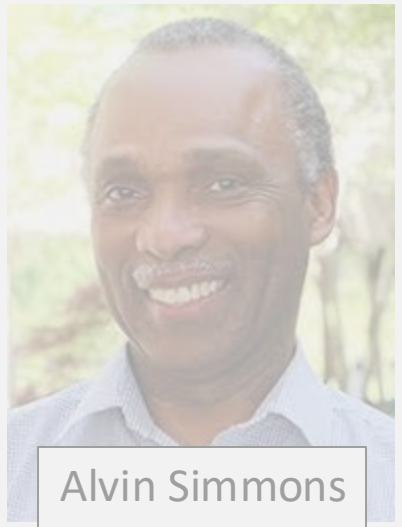
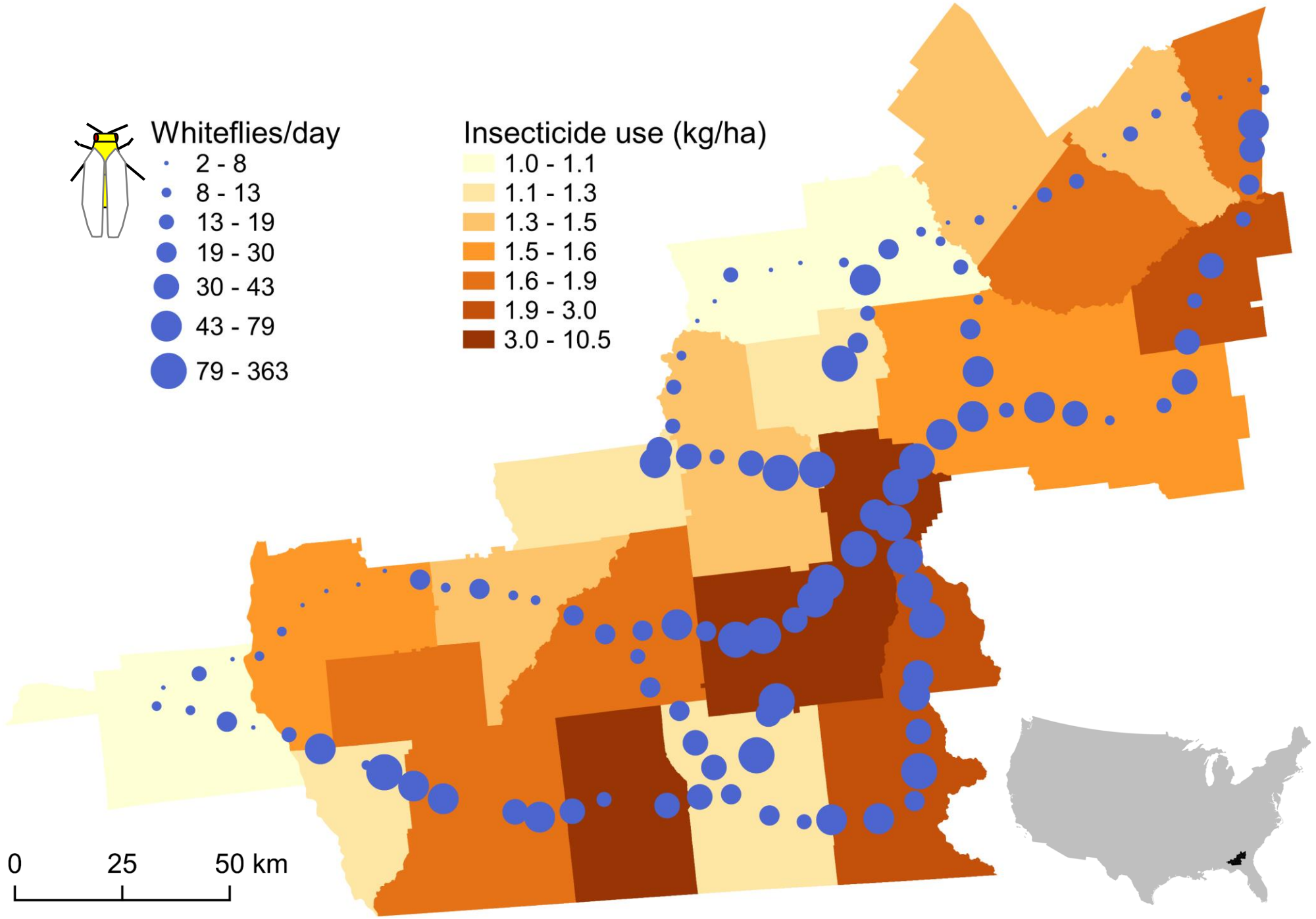


Alvin Simmons
USDA-ARS


Whiteflies/day
2 - 8
8 - 13
13 - 19
19 - 30
30 - 43
43 - 79
79 - 363
Insecticide use (kg/ha)
1.0 - 1.1
1.1 - 1.3
1.3 - 1.5
1.5 - 1.6
1.6 - 1.9
1.9 - 3.0
3.0 - 10.5
0
25
50 km

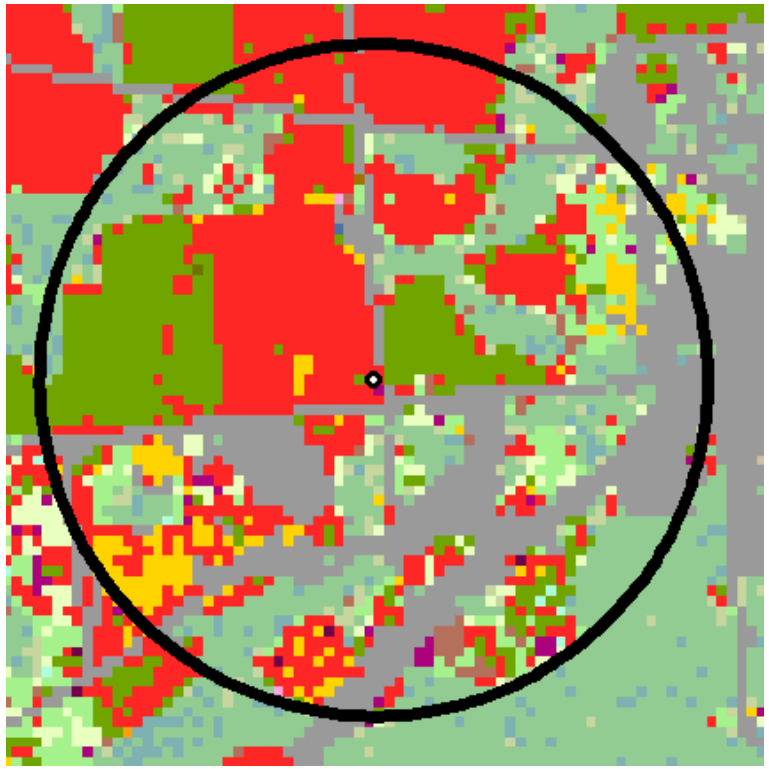
Modelling approach:

Generalized linear mixed-effects models
Model selection using AICc

Included Year fixed effect
Observation-level random effect
Exponential spatial error structure

Covariates

Insecticide use (kg/ha)
% Cotton
% Vegetables
% Seminatural
Brassicas present vs absent
Crop patch richness
Crop edge density
Cold days (Below 0°C)
Growing degree days



Cotton	Brassica	Seminatural	Cotton edge
27.72	0	22.49	2.23

Crop_PR	Crop_SHDI
9	1.076

Crossley et al. 2023, Pest Management Science, in press

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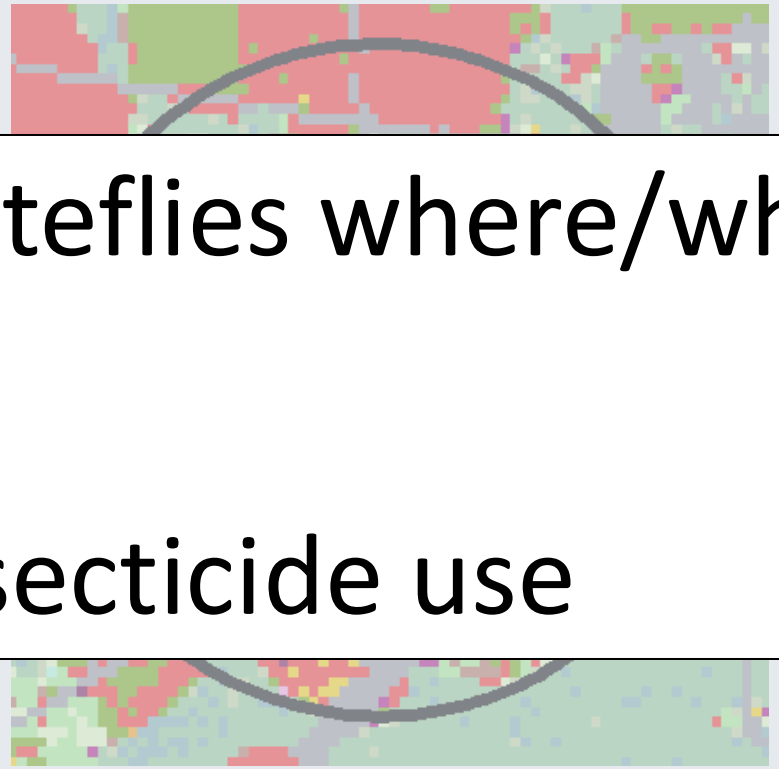
Consistently, more whiteflies where/when:

1) Hottest and driest
2) Highest regional insecticide use



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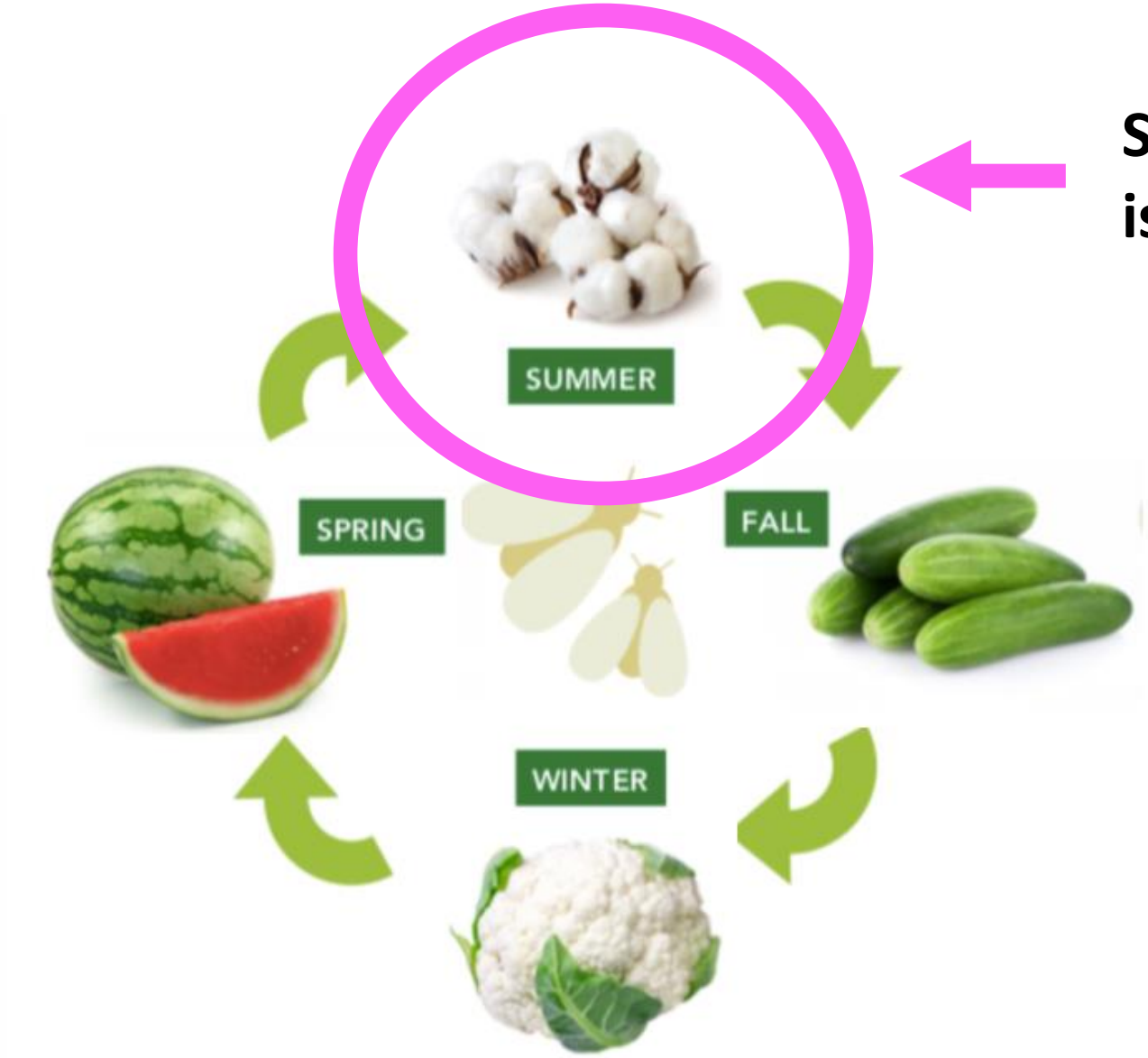
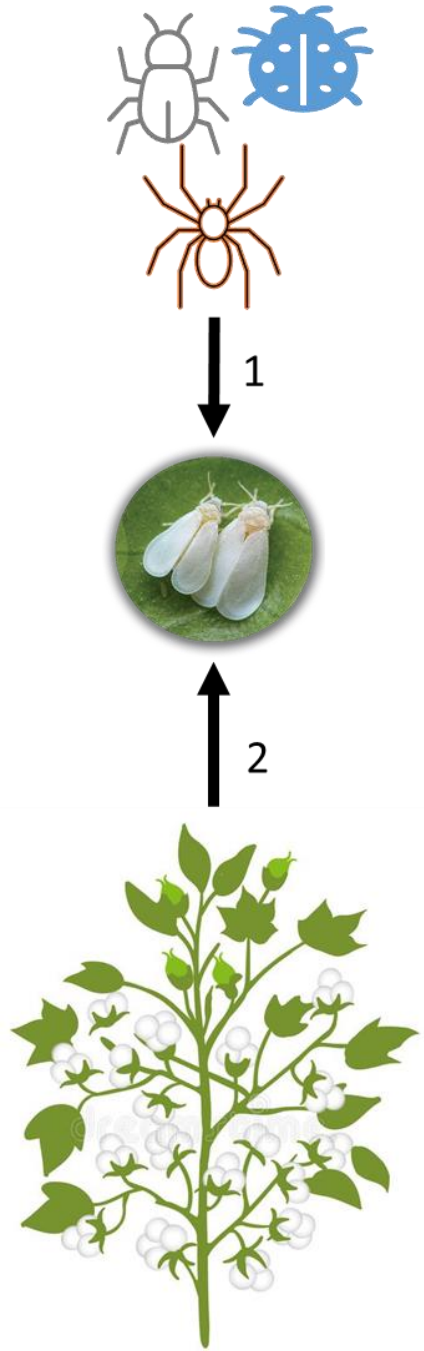


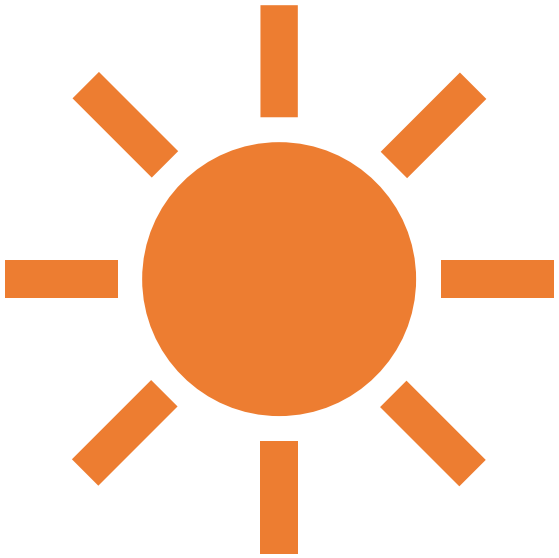
Summer cotton is the key

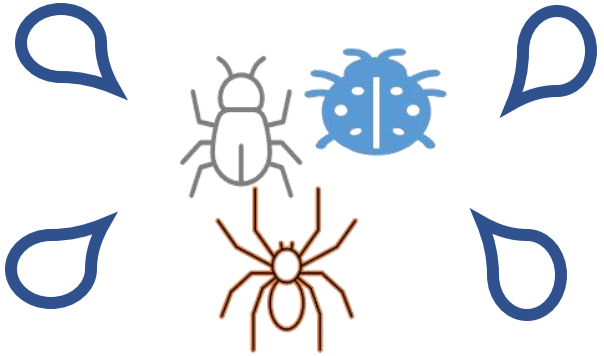
Why might extreme heat and drought (+ insecticides) make a pest problem worse?

Normal biocontrol



Hot biocontrol

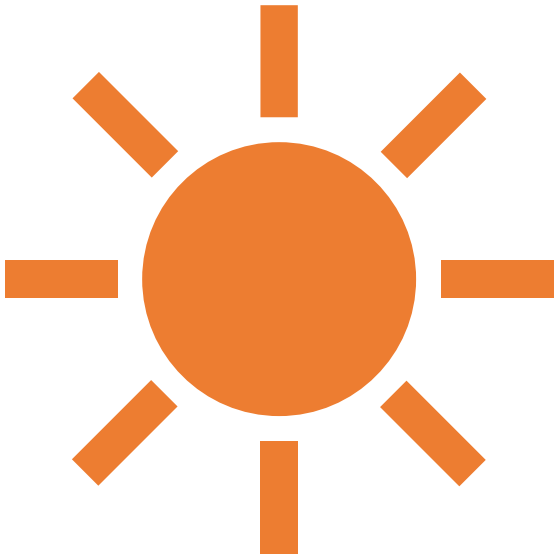


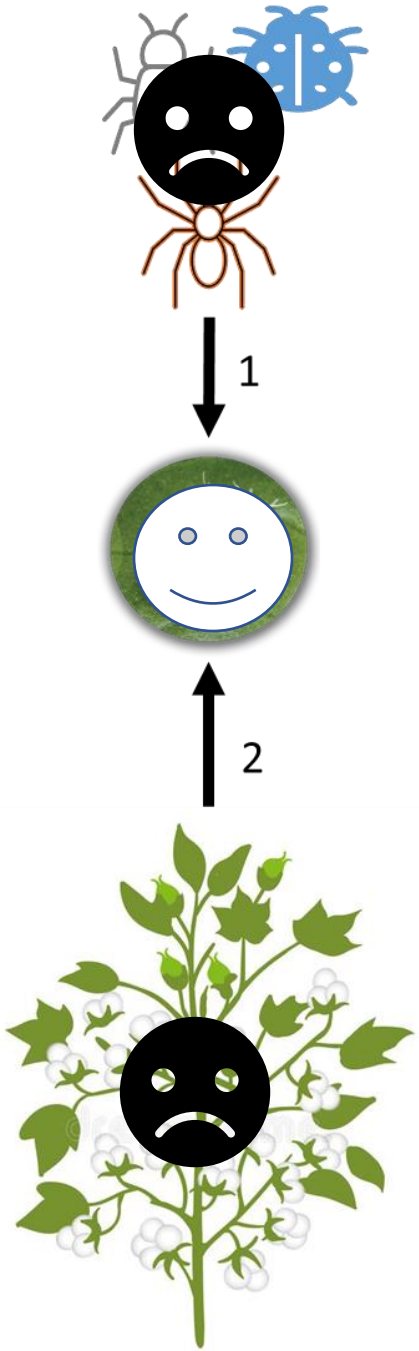


1

2

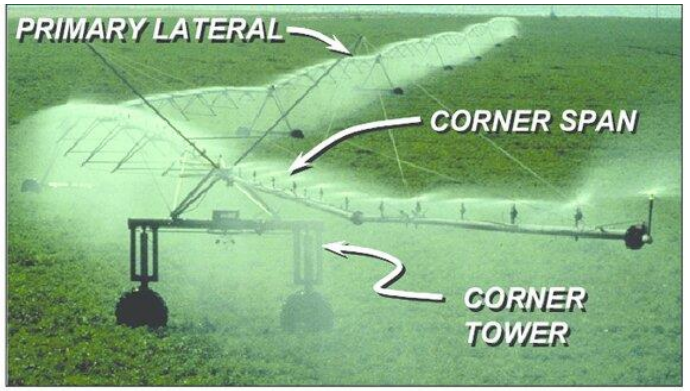
Hot biocontrol





Drought manipulation "natural experiment"

- Center pivot irrigation provides wet vs. dry treatments at each site
- Visited 20 cotton fields in July, August, September
- Collected whiteflies and their predators
- Cotton leaves collected for chemical analyses



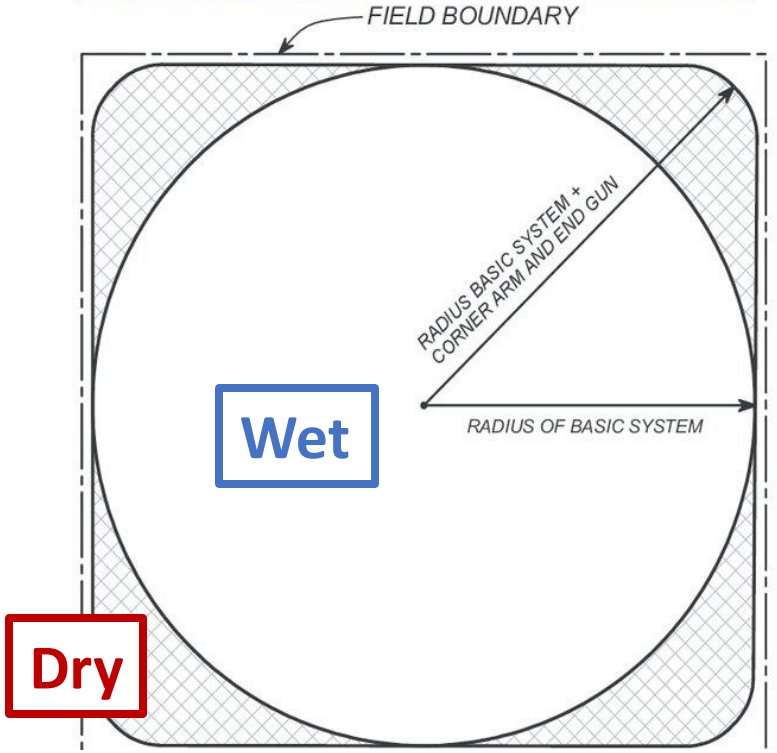
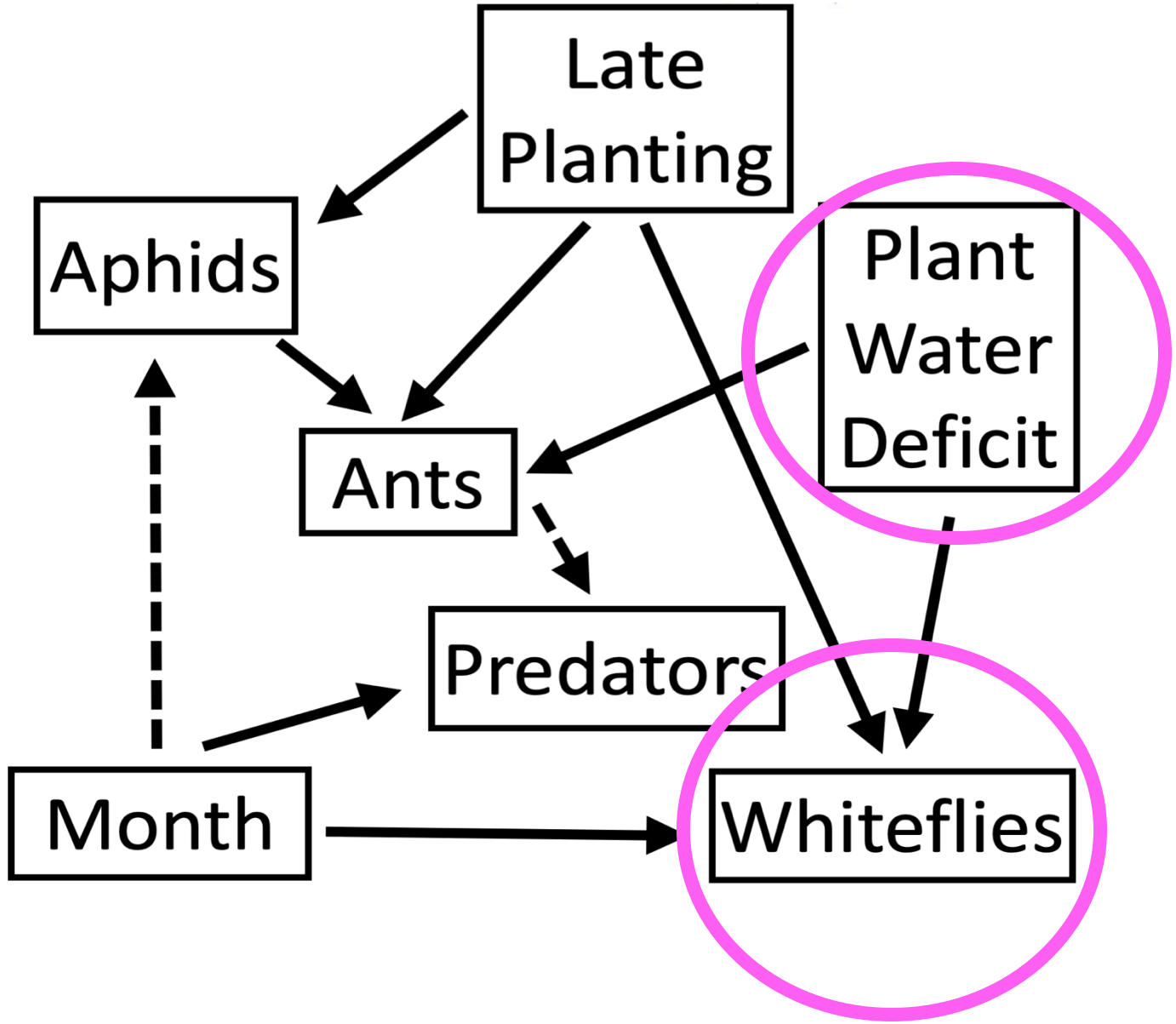


Fig. from Martin, Kincaid and Lyle 2007

The “Dvac” bug vacuum

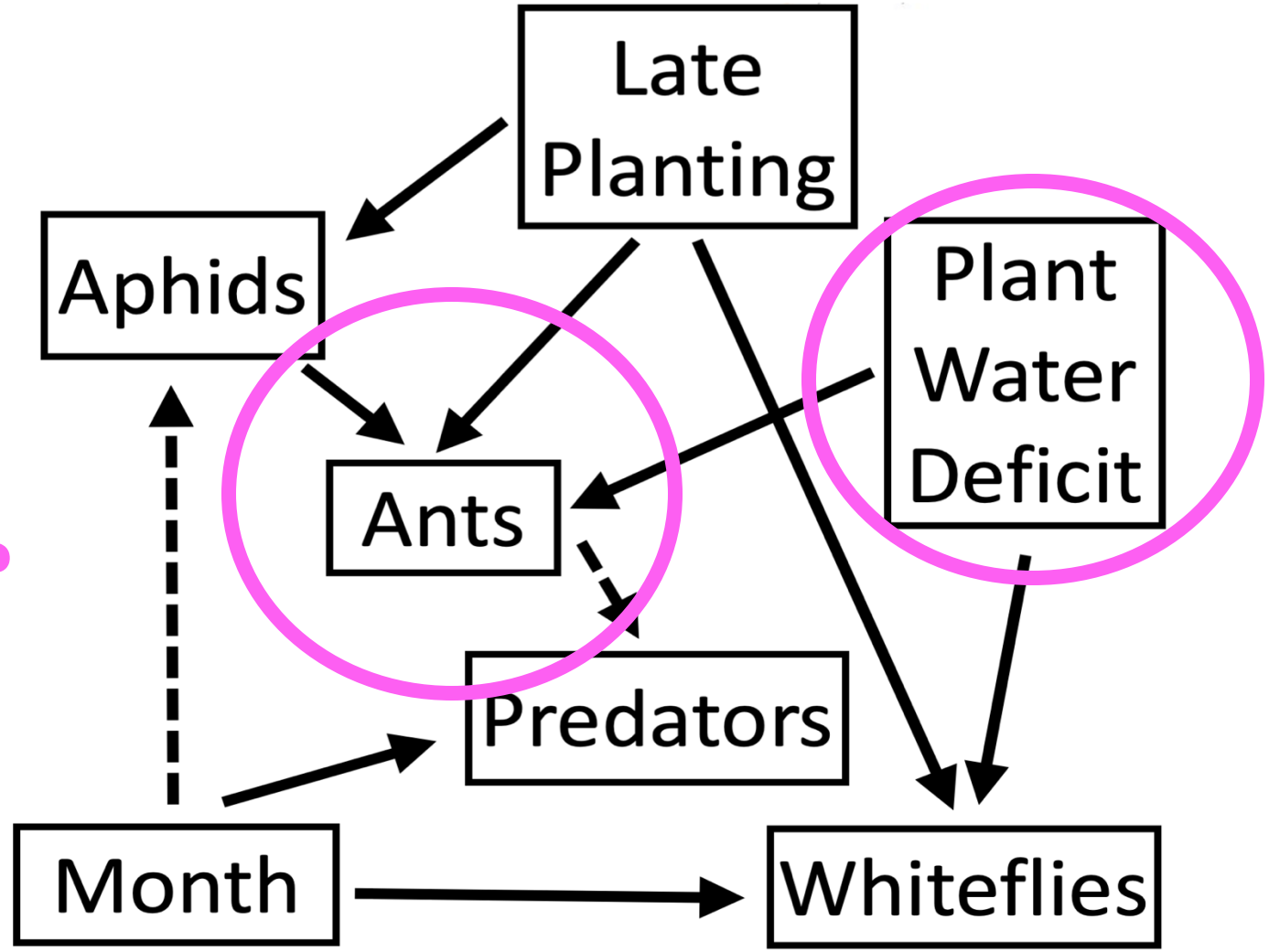
Structural Equation Modeling (SEM):

Statistically fits network of relationships among complex sets of variables (e.g., path analysis). In our case, what appears to contribute to top-down and bottom-up whitefly suppression?

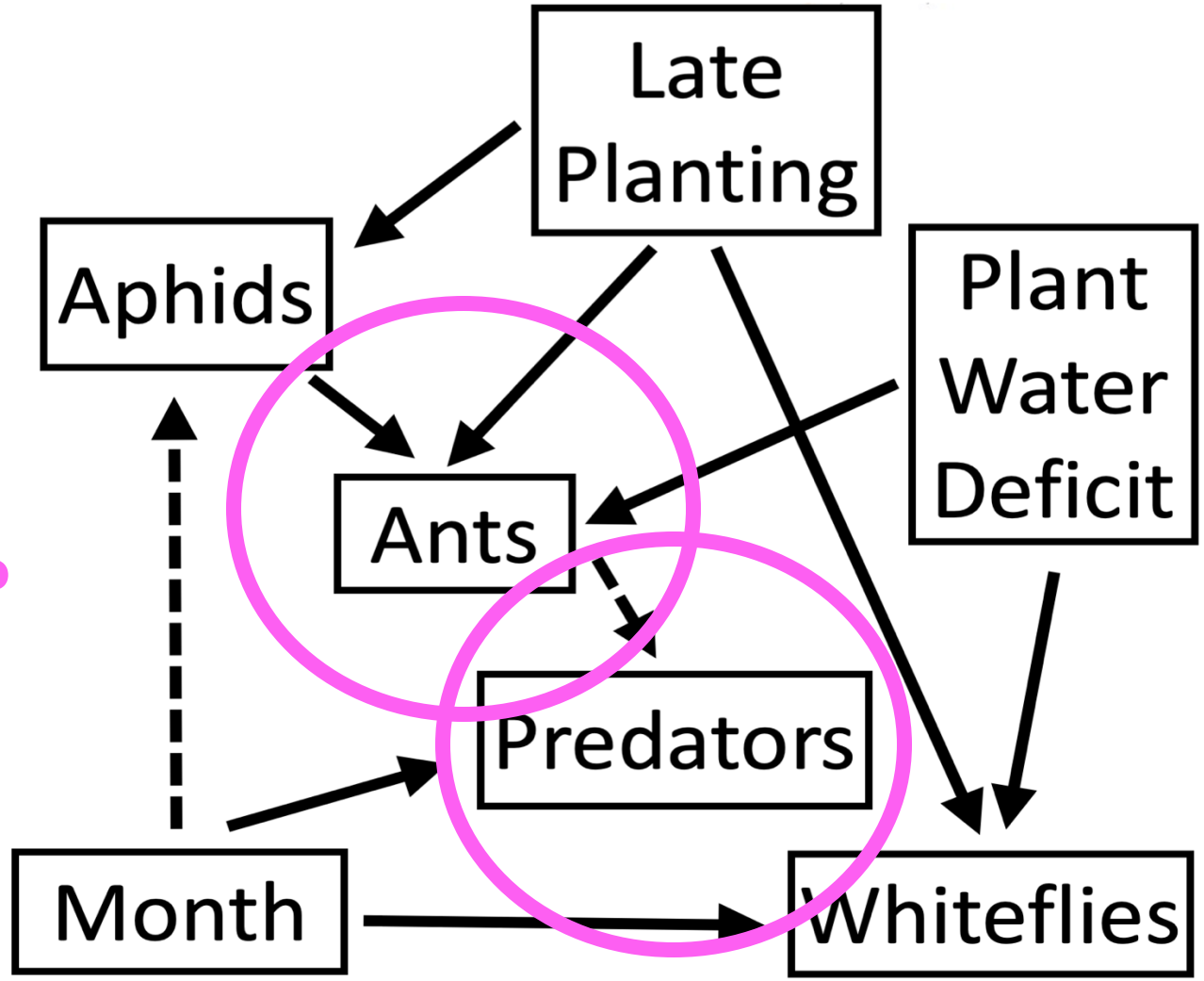


Weakened plant defenses?

Disrupted biocontrol?



Disrupted biocontrol?



Summary

1. More whiteflies on drought stressed plants

2. Drought stress = more ants = fewer other predators

3. **Is there some way to undo the harm of drought stress on plant health and natural enemies?**

Adding structural complexity – mulch or reduced tillage

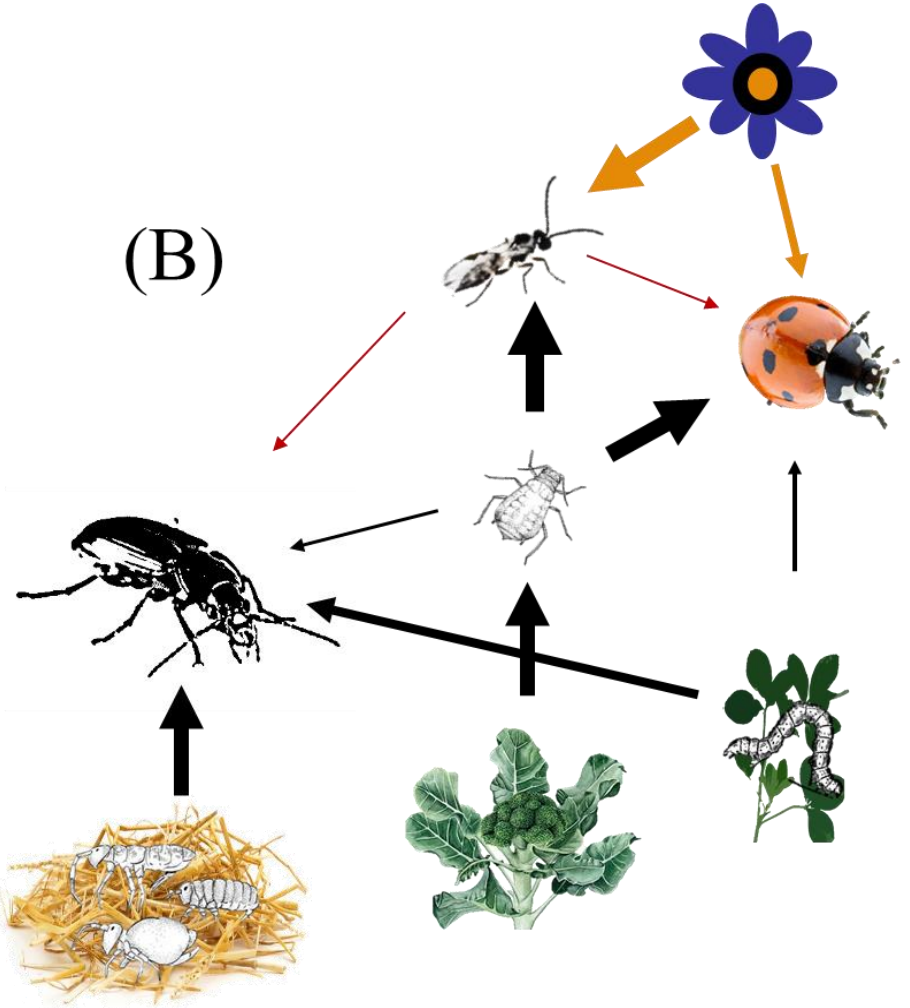

Normal tillage


Cover crop + reduced till

Ecological advantages of reduced tillage:

(A)

(B)



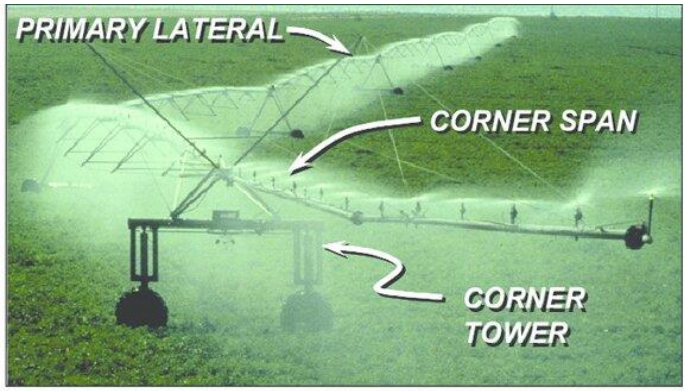
Jordan Croy
Postdoc

Pedro Rodrigues
Postdoc

Krishna Patel
PhD student

Drought manipulation “natural experiment”

- Cotton fields vary in being under irrigation or not
- **Fields also vary in tillage (normal versus reduced)**
- Visited 20 cotton fields in July, August, September
- Collected whiteflies and their predators
- Cotton leaves collected for chemical analyses



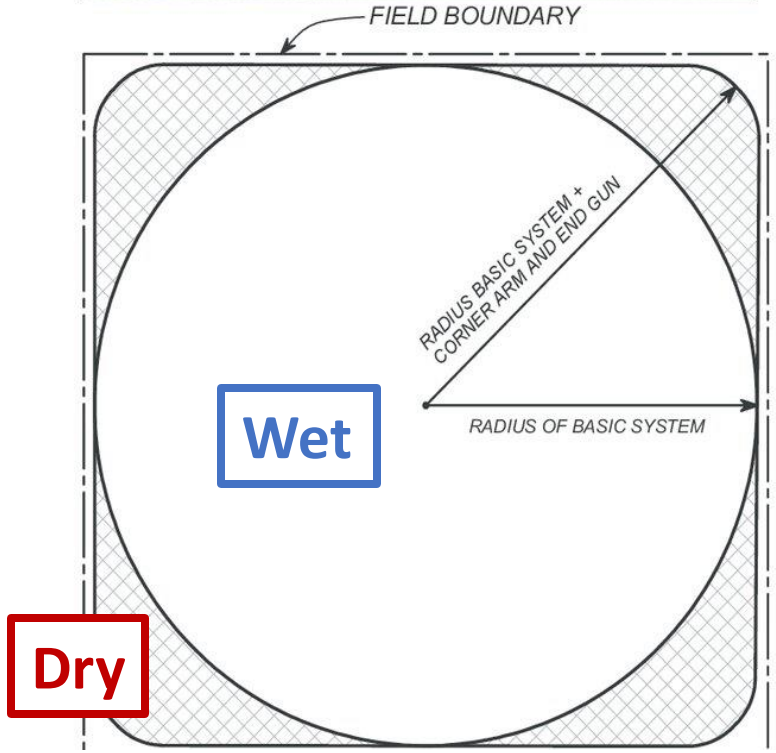
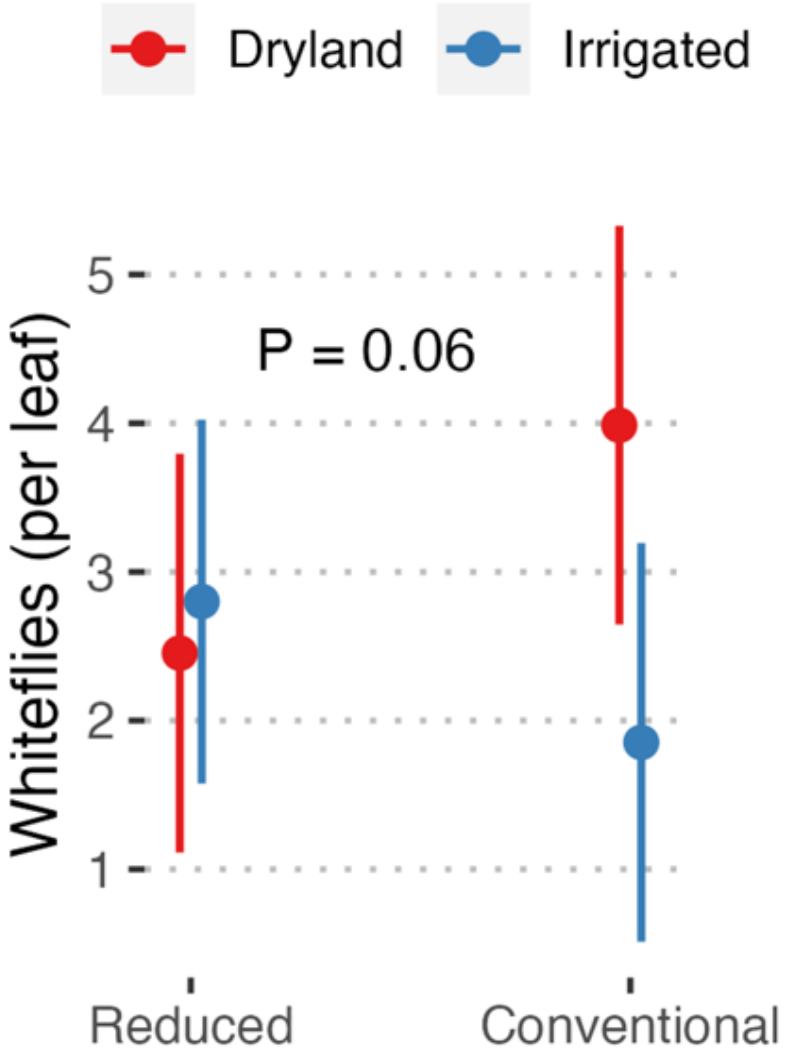


Fig. from Martin, Kincaid and Lyle 2007

Reduced tillage stops whitefly outbreaks in dry fields



Summary

1. Whitefly outbreaks correlate with growing drought and weakened biocontrol

2. Drought stress = more ants = fewer other predators

3. **Does reduced tillage rebalance natural enemy communities, while strengthening plant defenses?**

Conclusions

- Predator species complement one another by filling different niches, but can interfere when in same niche
- Increasing field and farm complexity might enhances complementarity while reducing interference
- **Diversified farming systems can enhance beneficial natural enemy biodiversity & biocontrol**

Acknowledgements

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United States Department of Agriculture
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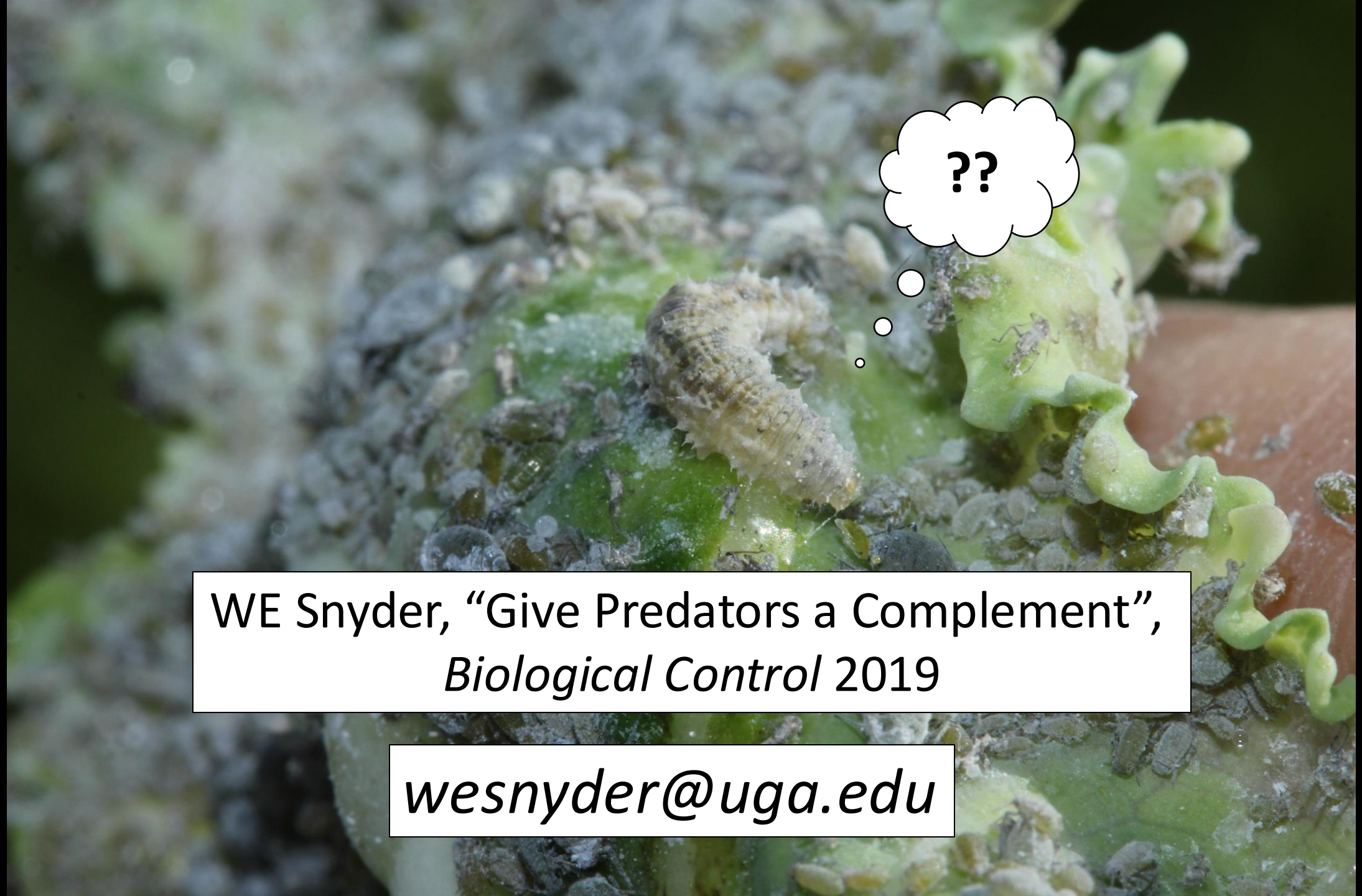

WE Snyder, “Give Predators a Complement”, *Biological Control* 2019

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