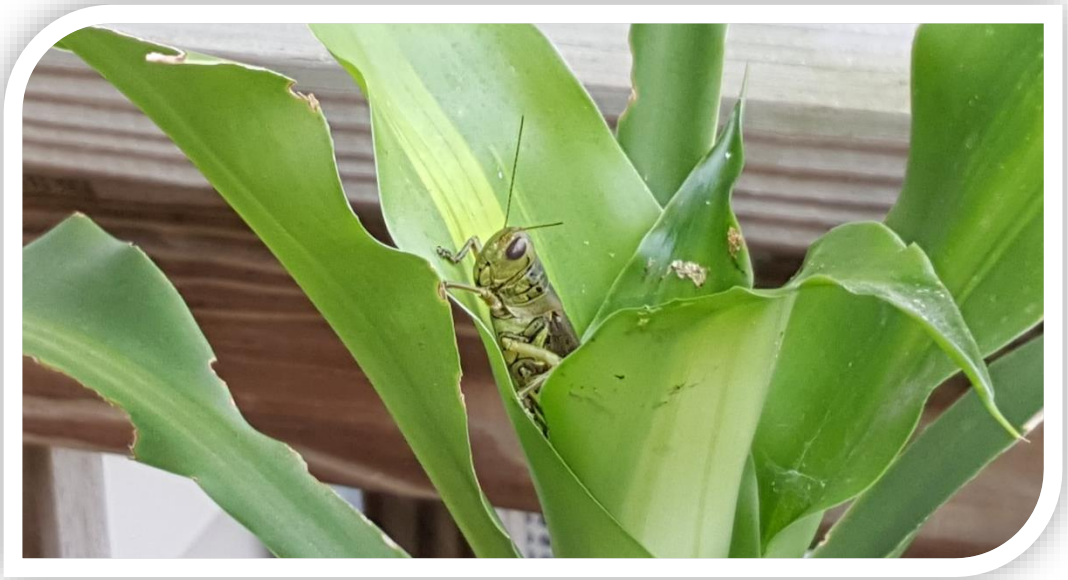
Invasion Ecology



Week 9

Narrowing down the focus: novel plant-insect interactions

Learning Outcomes

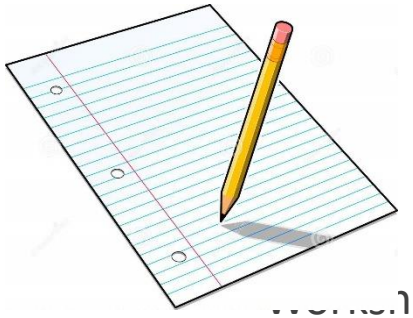
By the end of today's introduction lecture <u>you will know</u>:

- ❑ what novel species associations are
- ❑ what mechanisms underlie novel plant-insect interactions

By the end of today's introduction lecture <u>you will be able to</u>:

- ❑ recognize novel species associations
- ❑ give at least two examples of novel plant-insect associations

Class Activities



Worksheet

Small group discussion

All-class-discussion

In-class ungraded quizzes

Novel Plant-Insect Associations

- a combination of resident (native) and non-resident (exotic) plant or insect species "in which at least one species has little or no experience with relevant ecological traits of its interaction counterpart" (Saul and Jeschke, 2015).

Introduced plant's native range

Lack of coevolution

Introduced plant

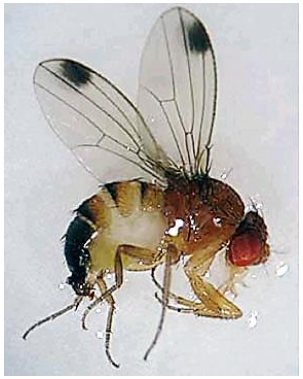
Native insect

Native community

Diversity of non-native insect and plant species: forest and crop pests

- Gypsy moth

- Emerald Ash Borer



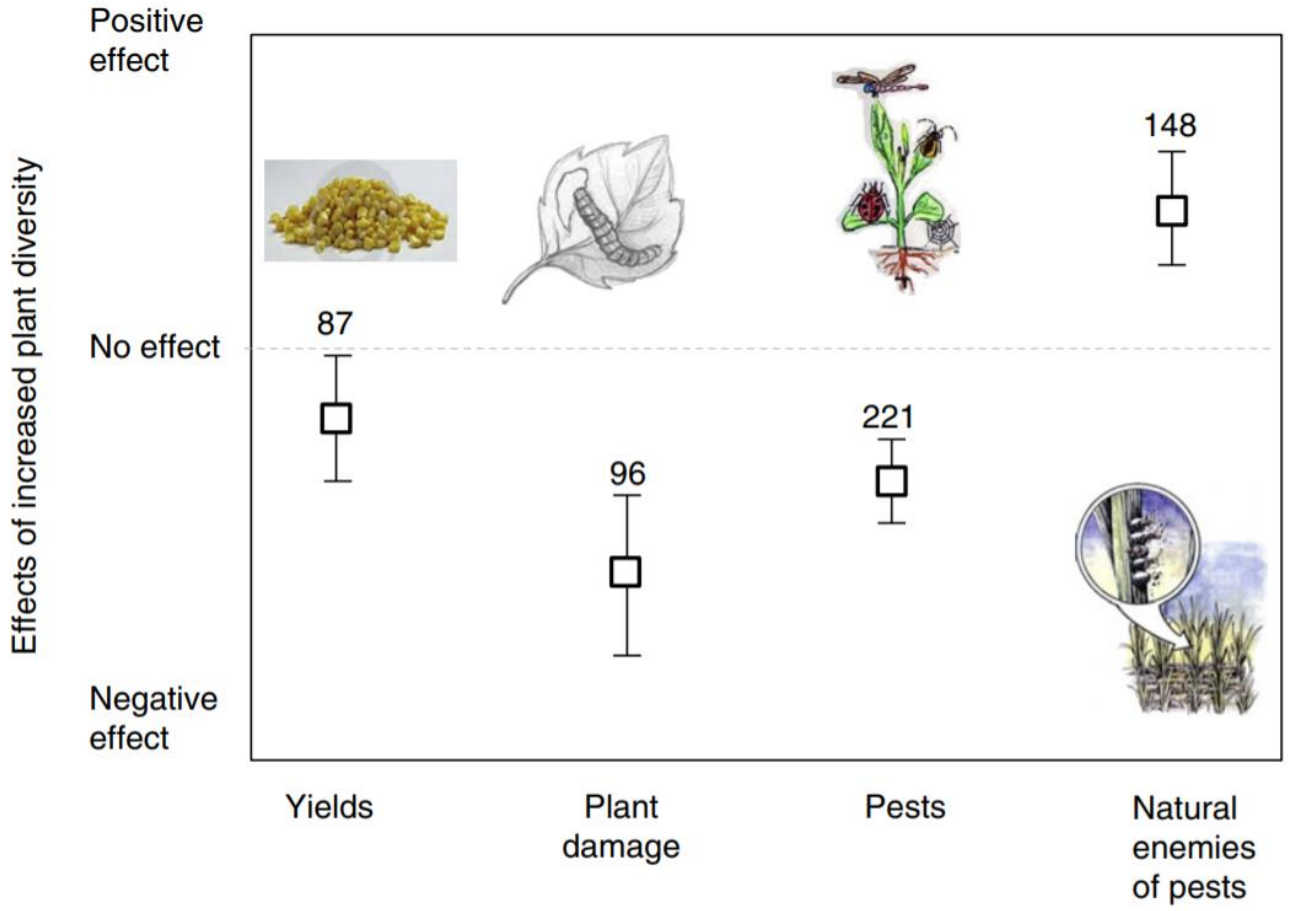
- Spotted Wing Drosophila

- Sirex Woodwasp

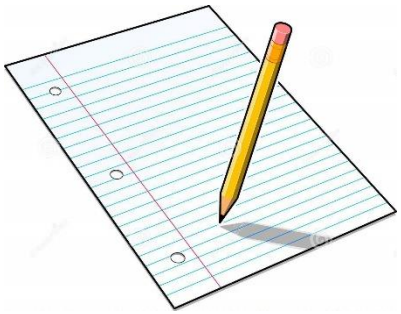
Resource: Maryland Cooperative Extension; fact sheet 242 by M. J. Raupp, J. A. Davidson, F. E. Wood

Discussion

What do you see?

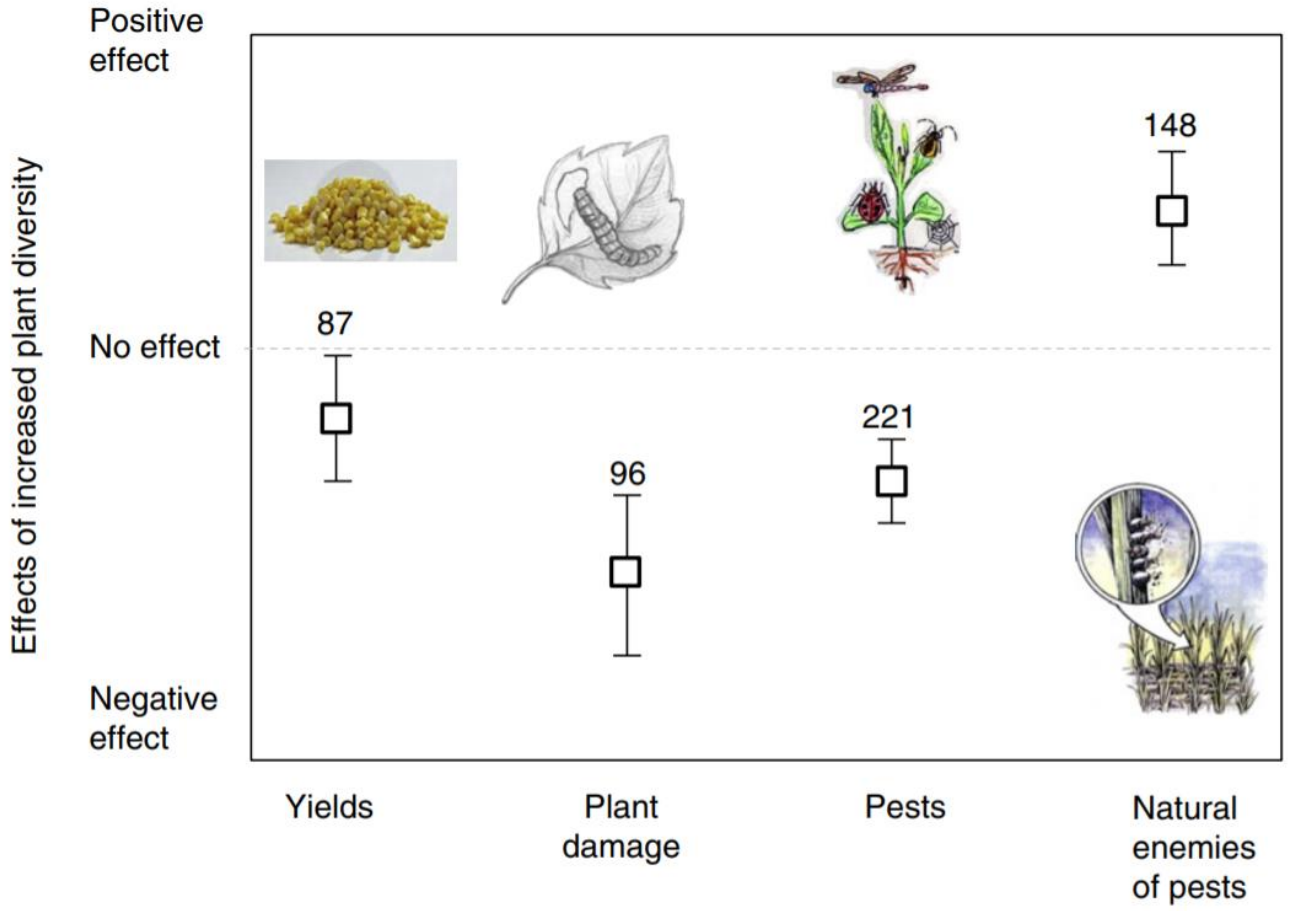


Quijas and Balvanera 2013

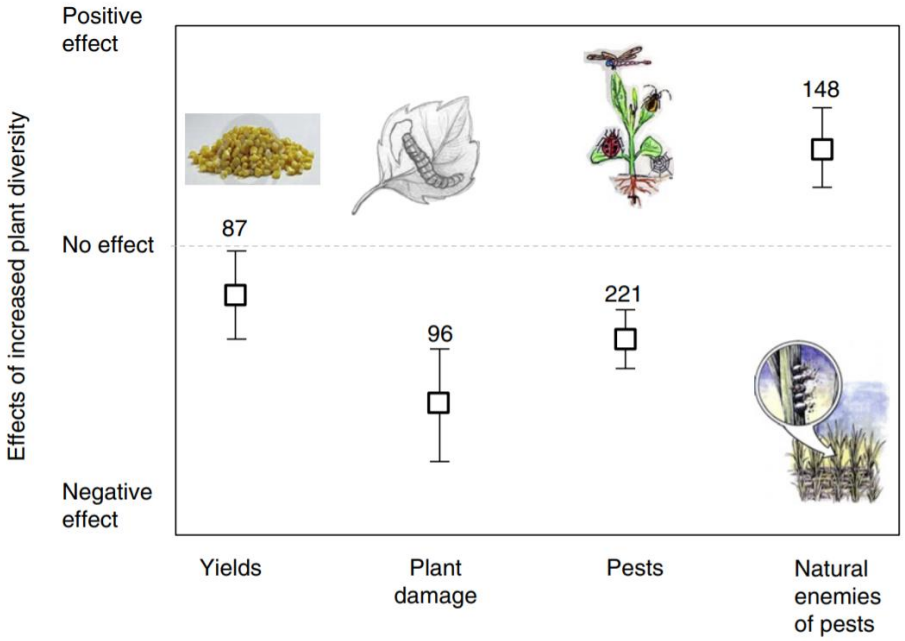


Worksheet Part 1.

What does it mean?



What does it mean?



Effects of biodiversity:

- lower/high abundance of pests (herbivores) (Yes/No)
- lower/higher abundance of natural enemies of such pests (predators and parasites) (Yes/No)
- Increased/decreased damage by pests (Yes/No)
- Reduction/increase in crop yield (Yes/No)

PNAS

Tree diversity regulates forest pest invasion

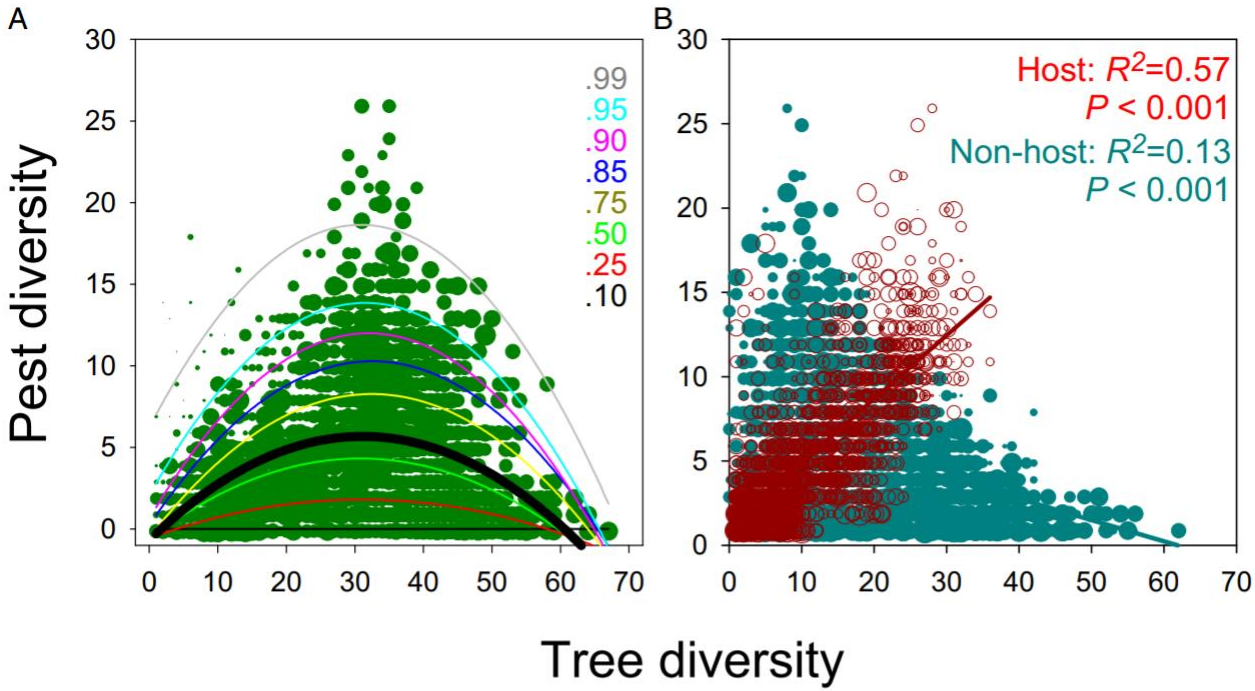
Qinfeng Guo[a,1], Songlin Fei[b,1], Kevin M. Potter[c], Andrew M. Liebhold[d,e], and Jun Wen[f]

[a]US Department of Agriculture Forest Service, Southern Research Station, Eastern Forest Environmental Threat Assessment Center, Research Triangle Park, NC 27709; [b]Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47907; [c]Department of Forestry and Environmental Resources, North Carolina State University, Research Triangle Park, NC 27709; [d]US Department of Agriculture Forest Service, Northern Research Station, Morgantown, WV 26505; [e]Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, CZ 165 21 Praha 6-Suchdol, Czech Republic; and [f]Duke Clinical Research Institute, Duke University, Durham, NC 27705

Edited by Rodolfo Dirzo, Department of Biology, Stanford University, Stanford, CA, and approved March 5, 2019 (received for review December 10, 2018)

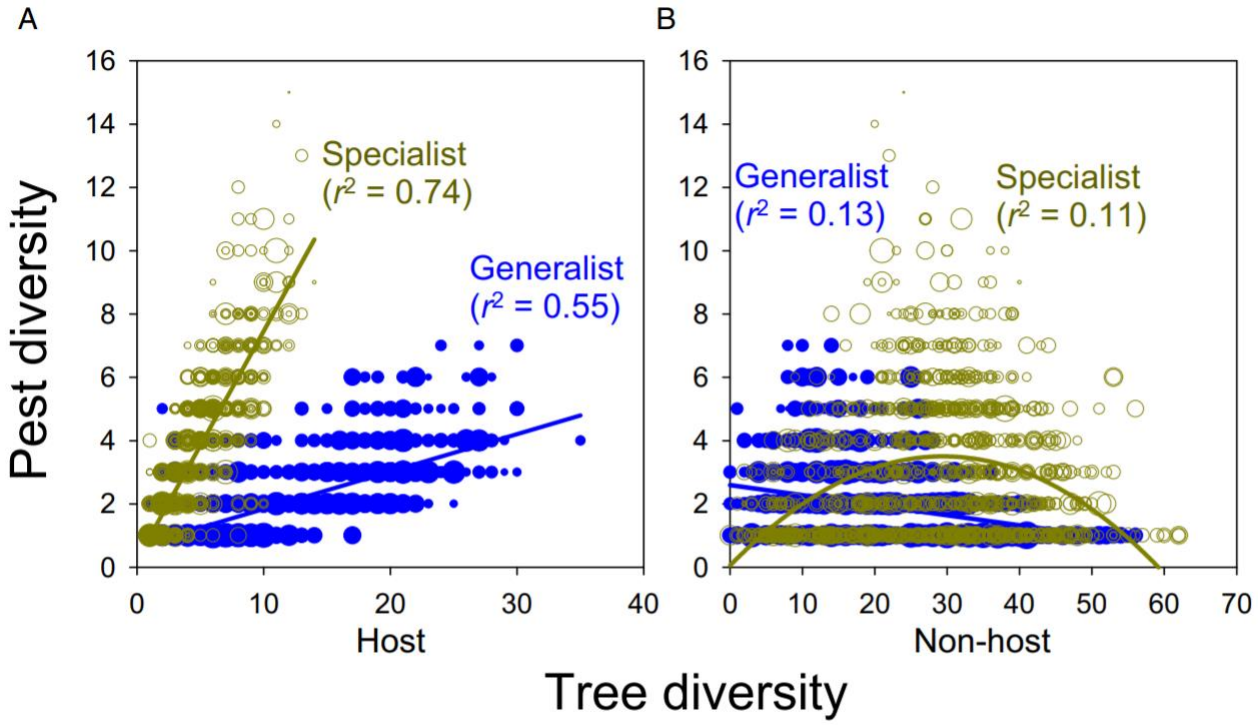
Nonnative pests often cause cascading ecological impacts, leading to detrimental socioeconomic consequences; however, how plant

are (e.g., host vs. nonhosts and their relative proportions), as well as on the direct and indirect interactions among neighboring



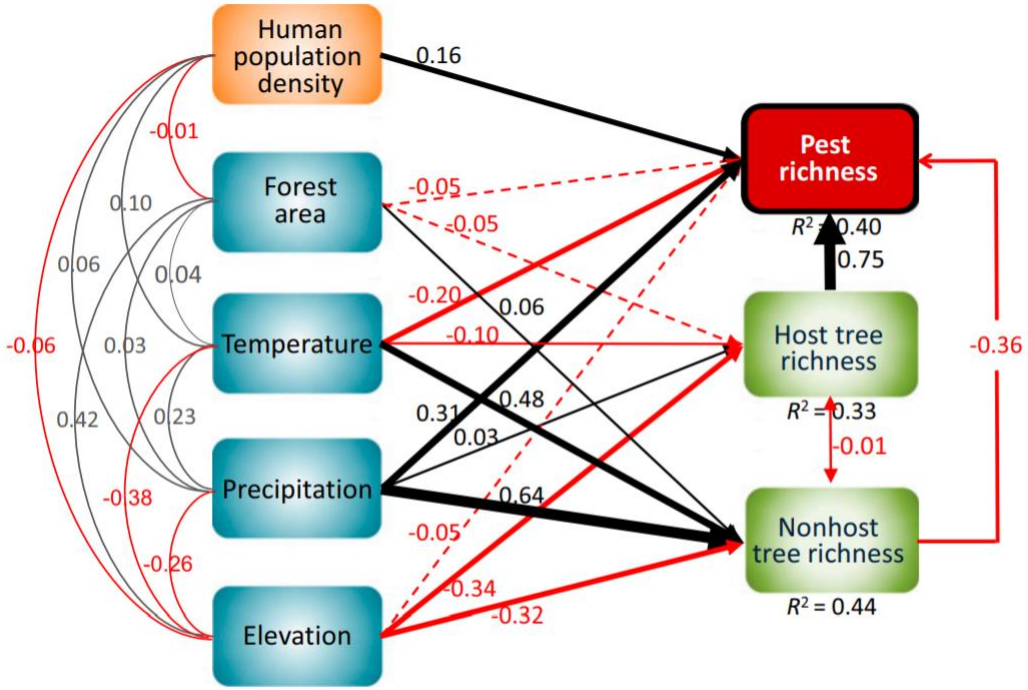
Guo et al. 2019

Native host/nonhost diversity and the diversity of specialist and generalist nonnative invasive pests in forest ecosystems



Guo et al. 2019

The effects of selected physical and human factors on pest diversity



Guo et al. 2019

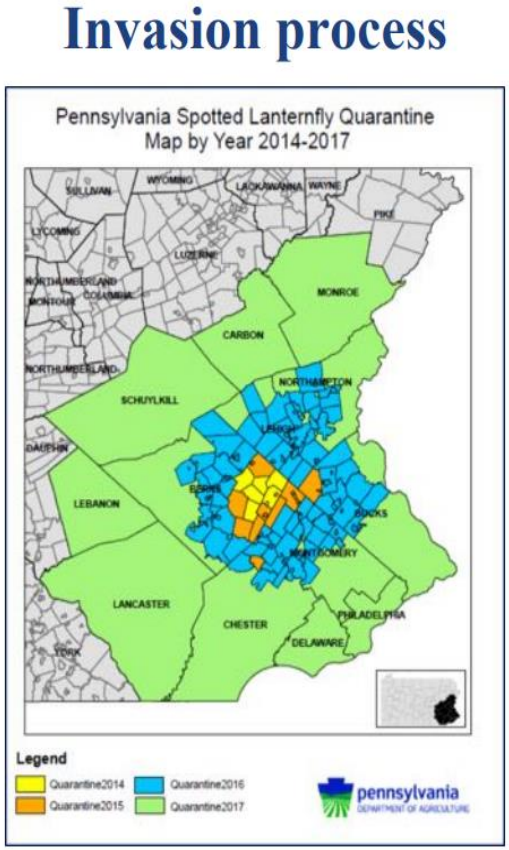
Quick Review (true/false)

- Novel plant-insect associations are the ones between invasive insects and native plants only Yes/No
- Plant diversity increases the number of natural enemies Yes/No
- Tree diversity affect generalist insects only Yes/No
- Temperature doesn't affect invasive pest diversity Yes/No

Interactions between native and invasive species and their ecological impact: a case study

- **The spotted lanternfly**
- An emerging highly invasive insect pest
- Native to China
- Invaded Korea in 2004
- Detected in Berks County, PA in 2014

Where is spotted lanternfly in the US and how fast will it spread?



Pennsylvania – Berks (2014) now in 13 counties, established

Delaware – New Castle (2017), established

New Jersey – Hunterdon, Mercer and Warren Counties (2018) established

New York – Albany, Suffolk and Yates (2018)

Virginia - Frederick County (2018), established

Massachusetts (2019)

PennState

Life stages of spotted lanternfly

Eggs

1st instar

2nd instar

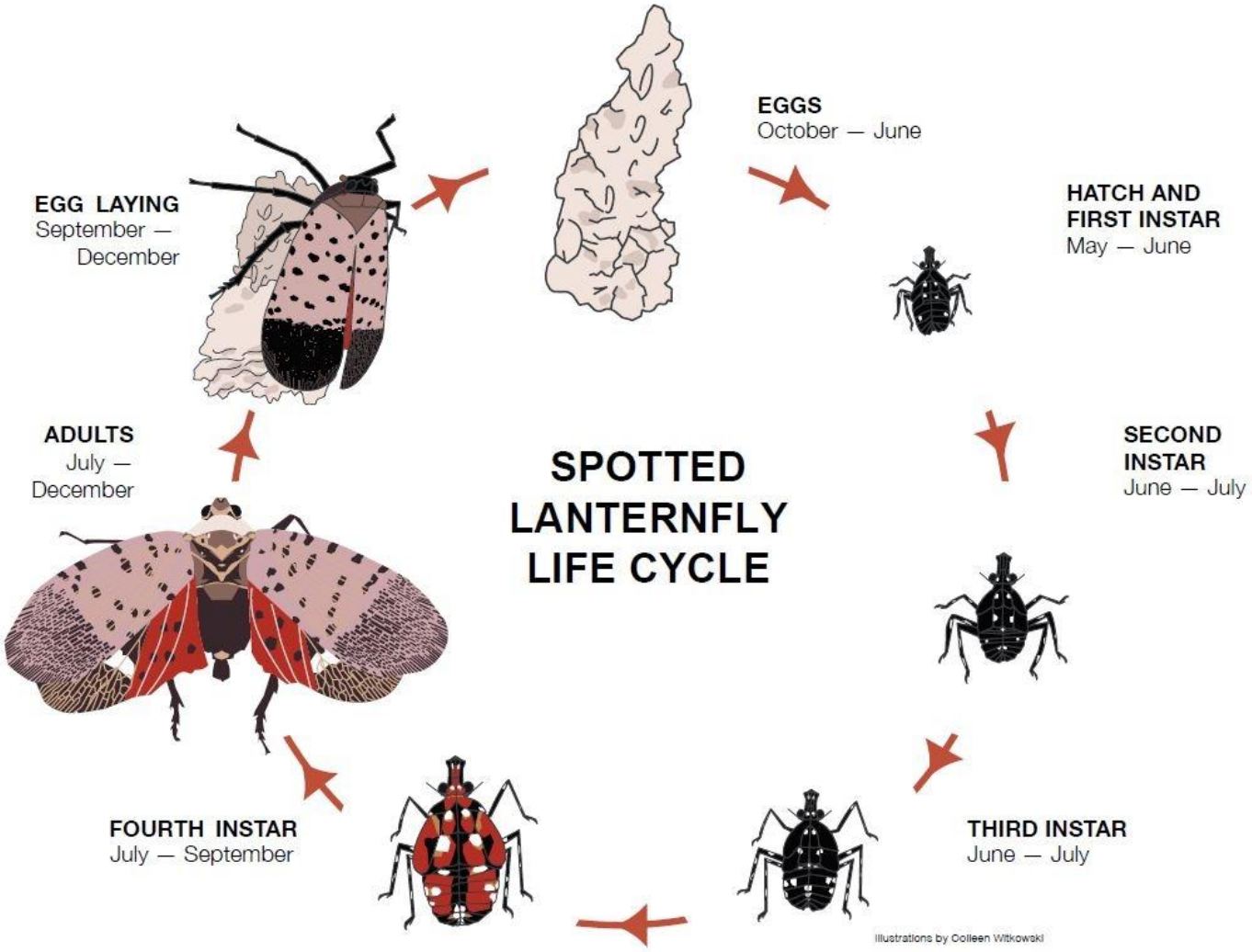
3rd instar

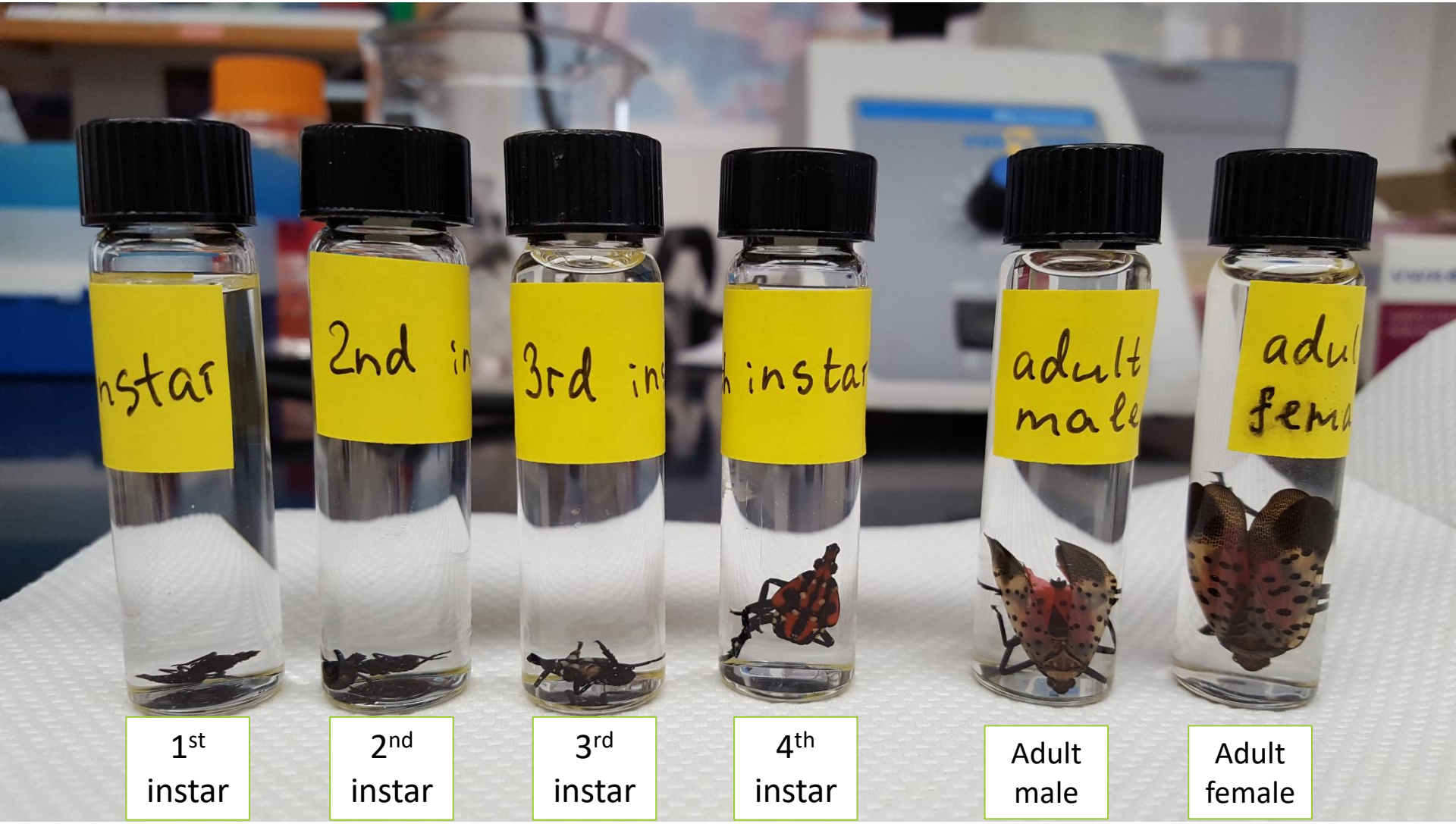
4th instar

Adult

Dara et al., 2015

Life cycle of spotted lanternfly





1st instar | 2nd instar | 3rd instar | 4th instar | Adult male | Adult female

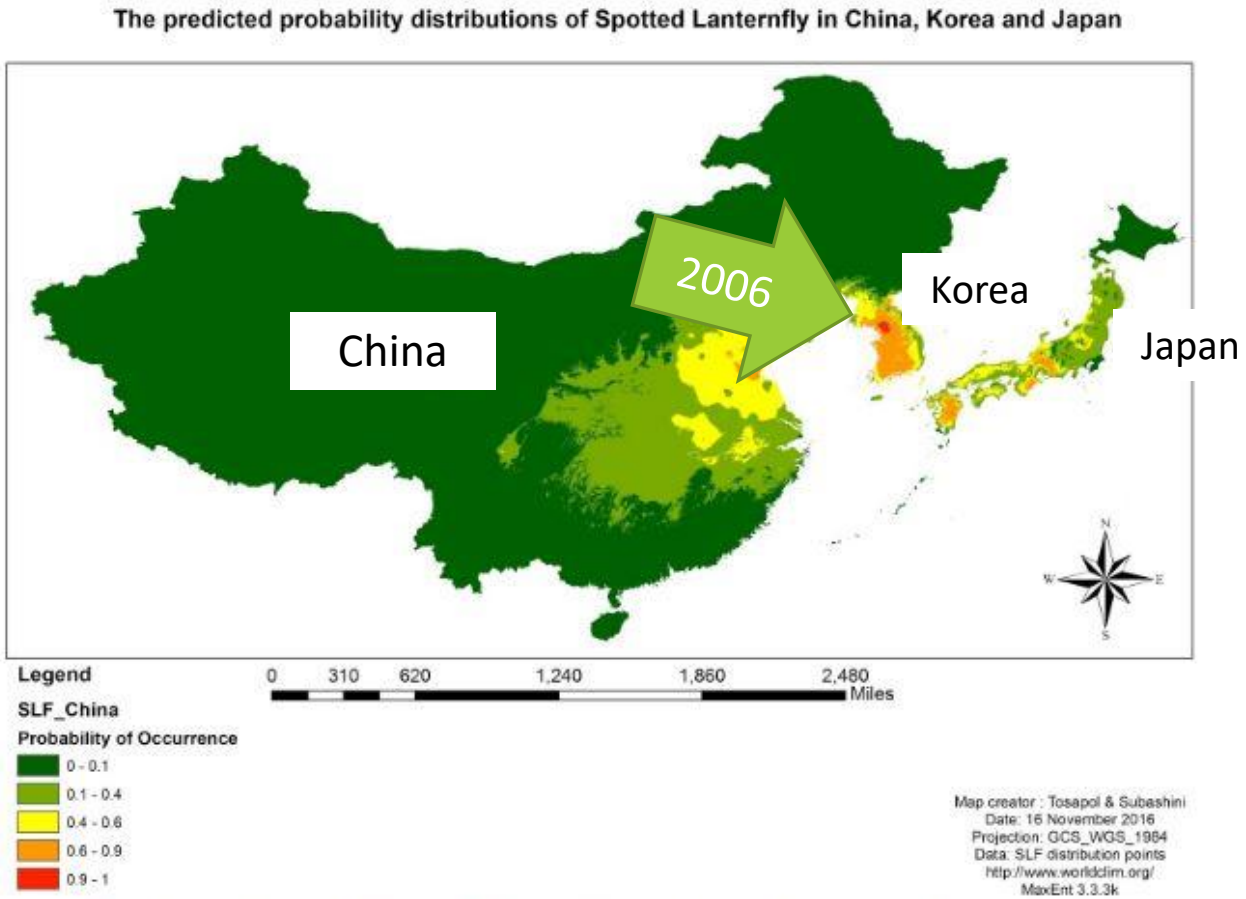
Modes of SLF dispersal

- One of the most aggressive leaf-hopping pest in Mid-Atlantic region
- Very high potential to breed and increase its population size
- It can be spread long distances by any material (including manmade material) containing egg masses:
  - trunked tree
  - stones
  - vehicles
  - yard furniture
  - farm equipment, etc.

What are the native and invaded ranges of spotted lanternfly in Asia?

Native to China

Invasive in Korea, Japan, Taiwan, and Vietnam



Map: The predicted probability distributions of Spotted Lanternfly in China, Korea and Japan

Host plants in China

Chinese mahogany

Tree-of-heaven

Manchurian catalpa

'Chinese Elm'

- Ornamental and fruit trees
- Soybean and some agricultural crops

Soybean plants

Host plants in Korea

Tree-of-heaven

Manchurian walnut

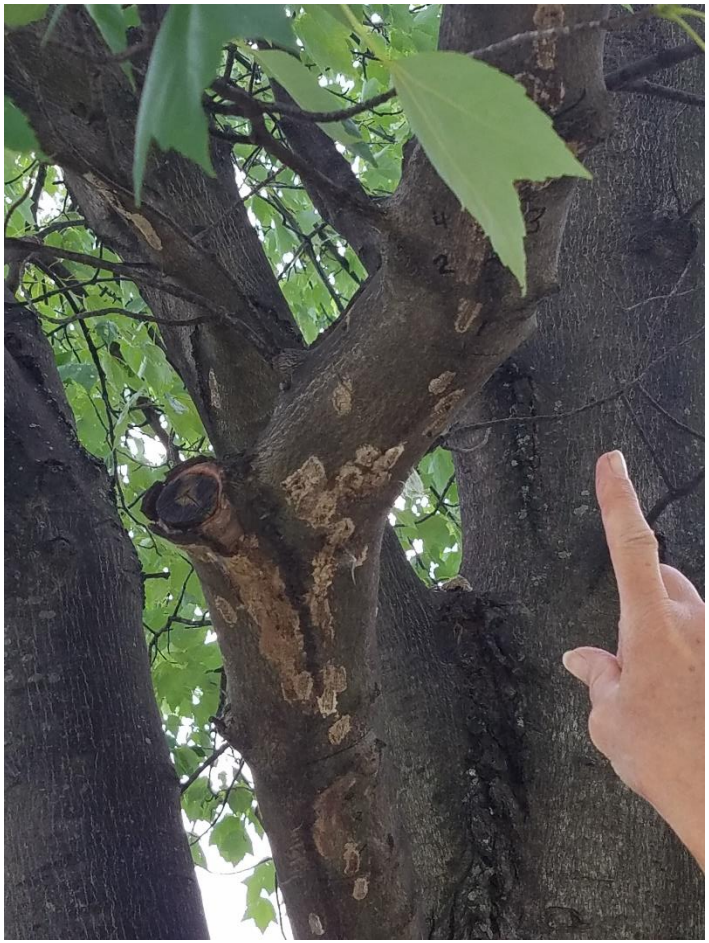
Amur grape

Chinese mahogany

Korean Evodia

- Ornamental and fruit trees
- Herbs

Egg masses



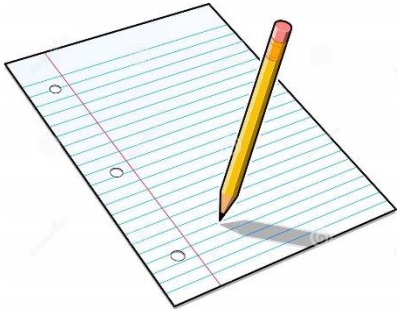
PA, July 2018

Host plants

Sap-feeder

SLF can utilize over 70 host plants:

- **Apple**
- Plum
- Cherry
- Peach
- Apricot
- **Grape**
- Pine
- Tree of heaven (preferred tree host)
- ……. and many many others….



Worksheet Part 2.

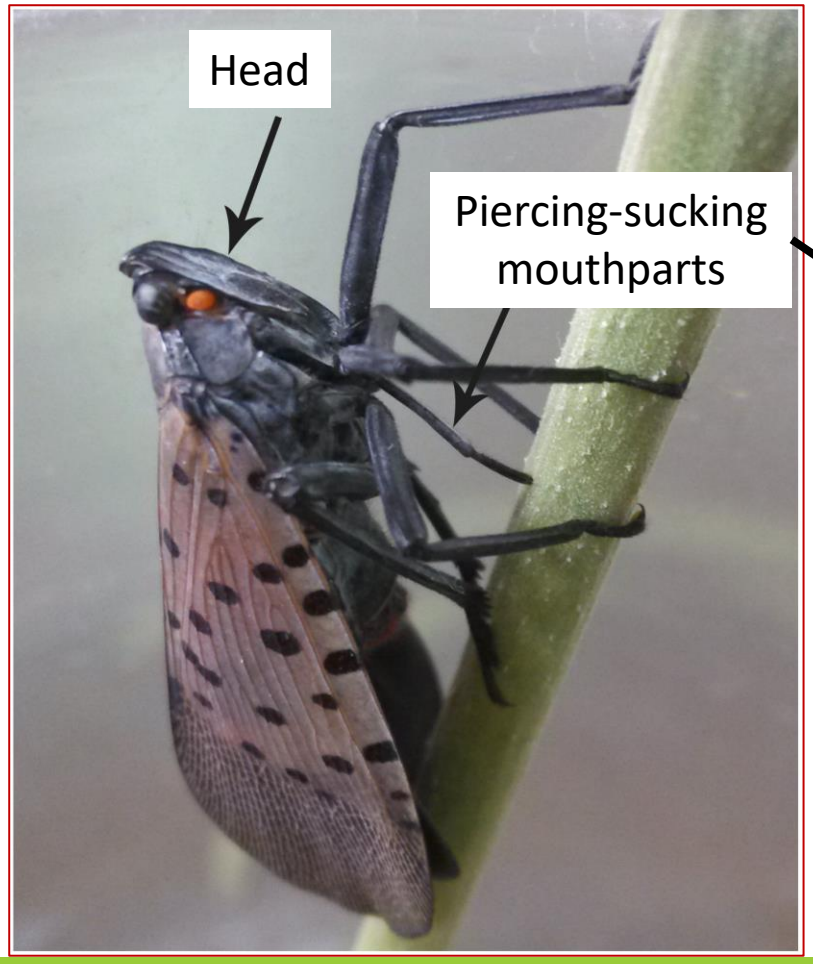
Please list 2 native and 2 novel host plants for the spotted lanternfly

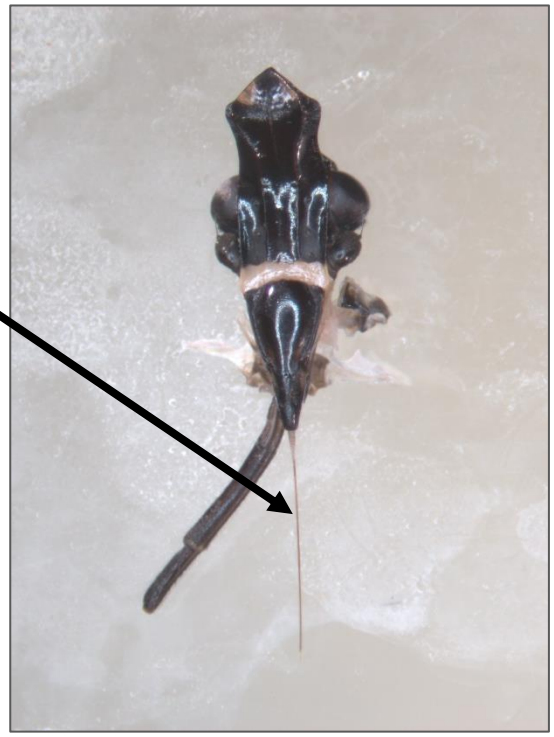
(1-2 min)

Please compare your lists in pairs and create a combined list

(1-2 min)

How does the lanternfly eat and damage plants?





Sap- feeders

Hao et al., 2016

Avanesyan et al. Plos One, 2019

Plant damage

Consumes phloem sap

- Reduction in photosynthesis
- Weeping wounds
- Decreasing plant's growth

PennState

Plant damage

Create a sugary substance (honeydew)

- Attract other insects - ants, wasps, etc.
- Colonized by sooty mold -> blackening of parts of the plant

Photo: M. J. Raupp

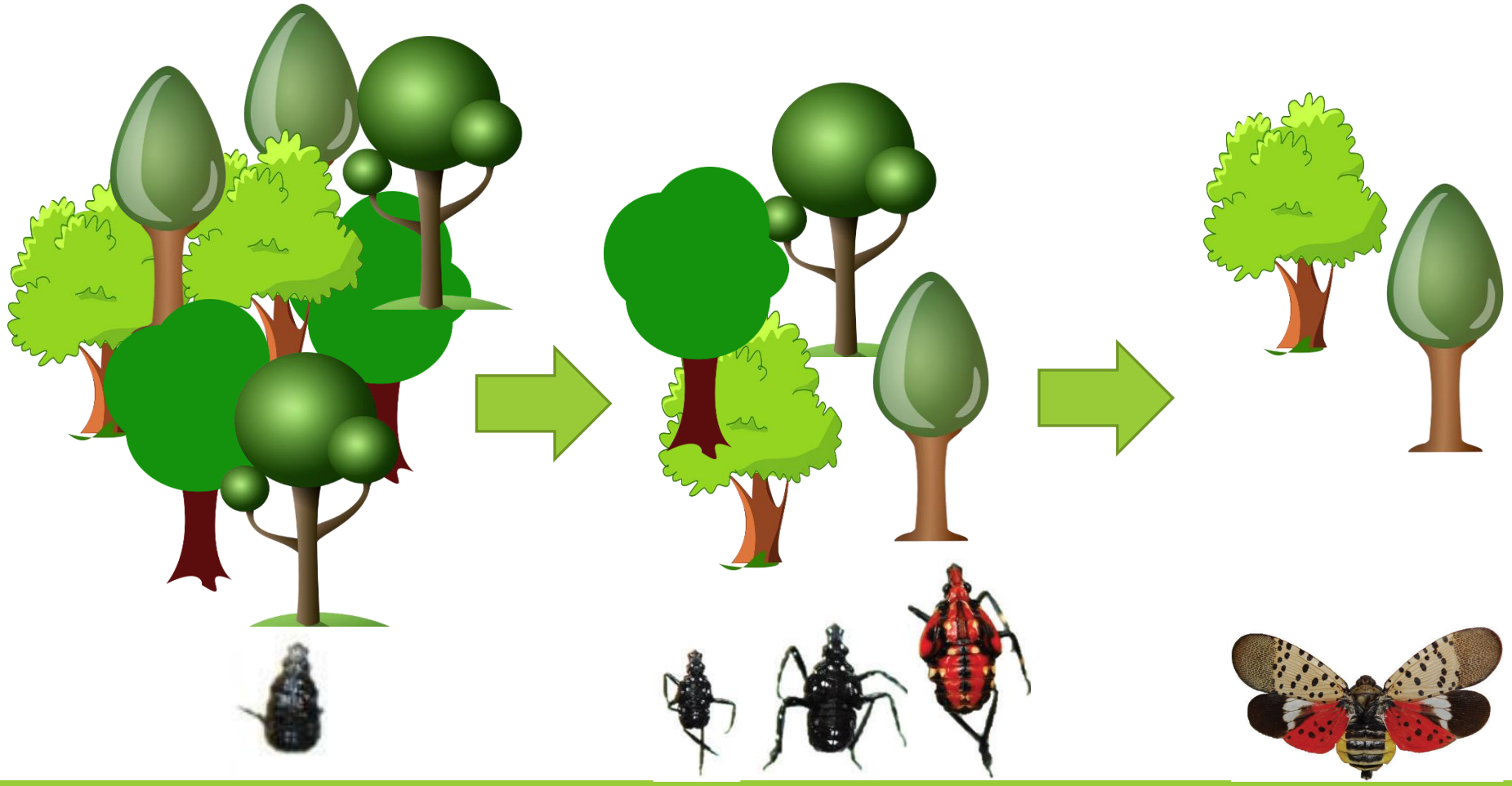
PA, July 2018

https://www.youtube.com/watch?v=vE1QJ4ADV7c

PennState

Behavior on host trees

Seasonal behavior



May-June June-August September-December

Behavior on host trees

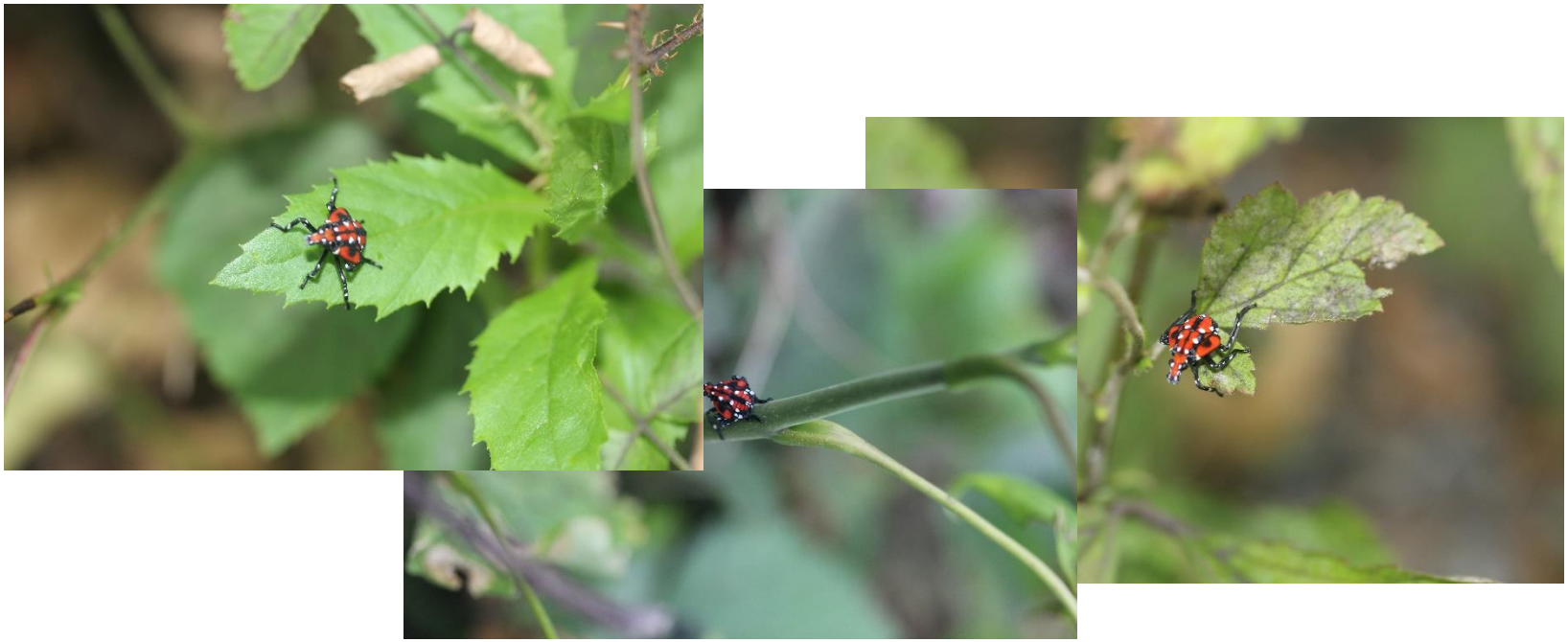
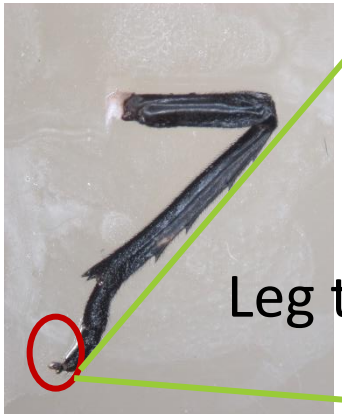
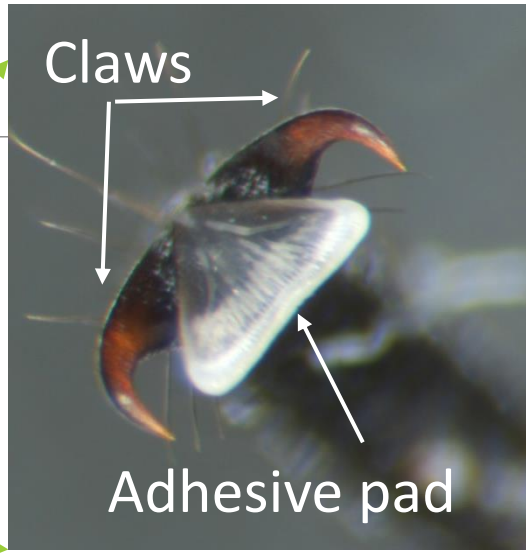


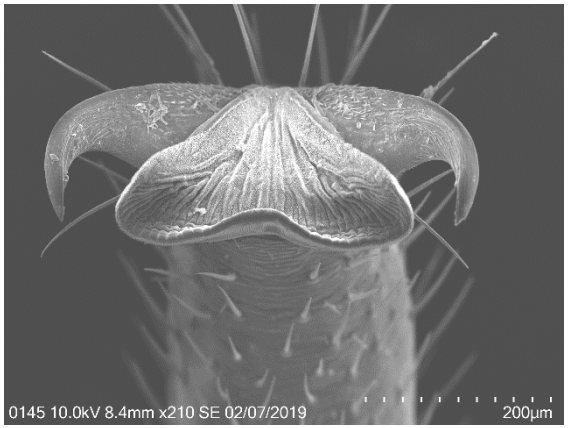
Photo: Bill Lamp; PA, July 2018

Behavior on host trees

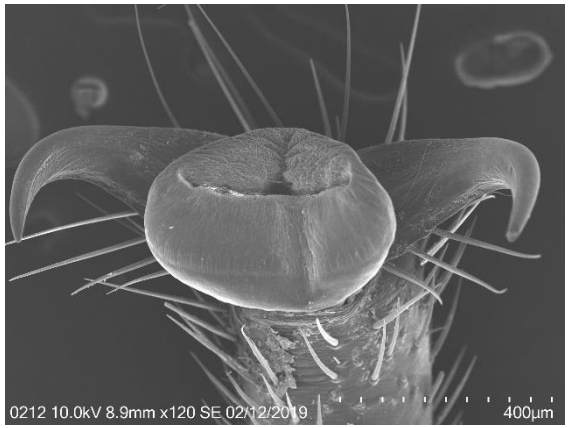
Holding on to the host trees







Lanternfly resting



Lanternfly moving

Avanesyan et al. 2019

Quick Review

- In the introduced range, does the spotted lanternfly feed on host plants present in its native range only? Yes/No
- Adaptations to feeding on novel host plants?
  - seasonal behavior Yes/No
  - morphological adaptations Yes/No
  - nymphal coloration Yes/No

Management strategies in PA

PennState

Band trees to catch nymphs

PennState

PennState

Scrape eggs

Eggs should be scraped off of trees, posts, stones, houses, and anywhere else you find them!

Use a plastic card, putty knife, or stick to scrape eggs downward into a bottle or bag.

Eggs can then be killed by putting them in rubbing alcohol, smashing them, or burning them.

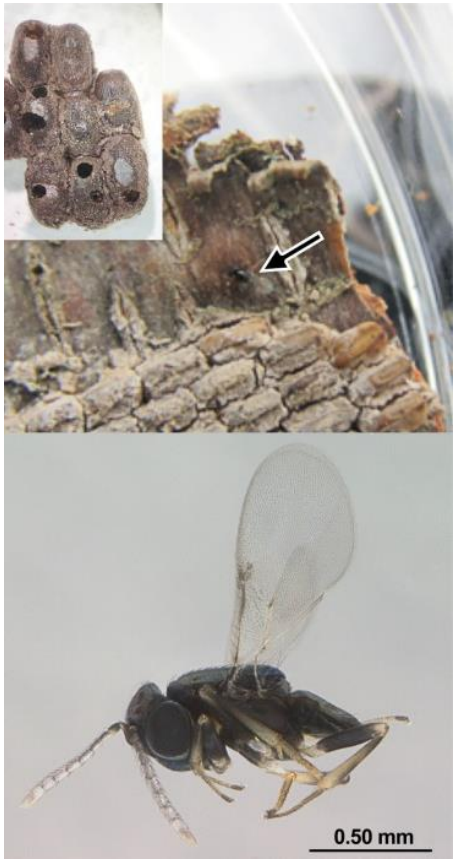
Removes 30-50 eggs per mass

Link to video:
https://extension.psu.edu/how-to-remove-spotted-lanternfly-eggs

PennState

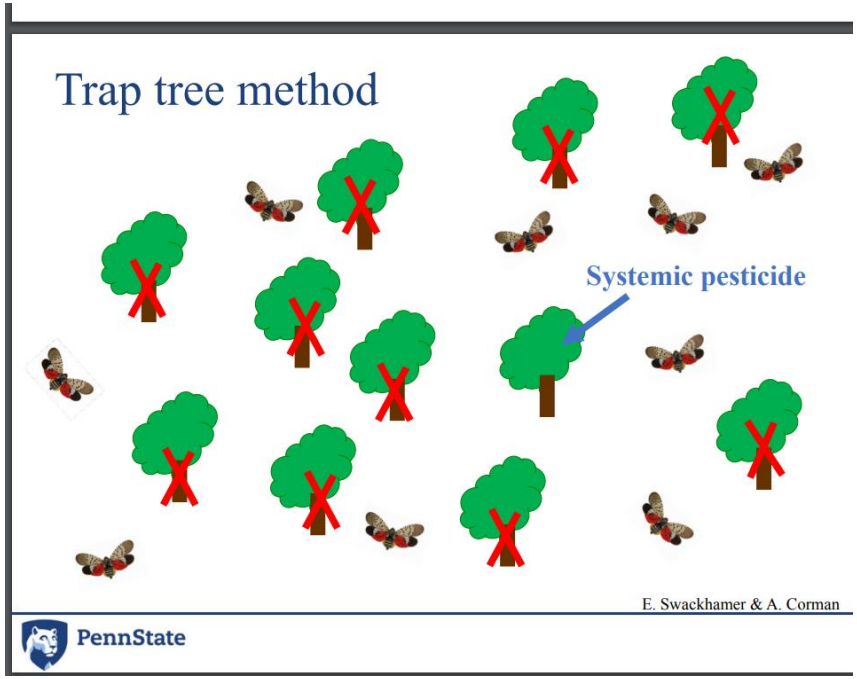
Biological control

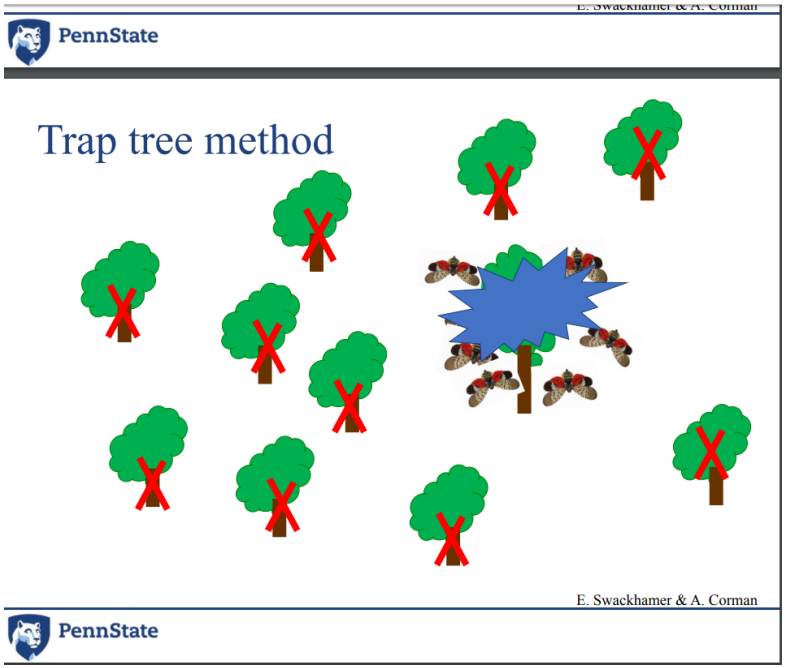
Indigenous natural enemies including spiders, mantises, and assassin bugs are now attacking and killing lanternflies



A tiny wasp called *Ooencyrtus kuvanae was* imported in 1908 to control gypsy moth. It was taken a liking to spotted lanternfly and now parasitizes and kills eggs of the lanternfly.

Use trap-trees to reduce populations





Use trap-trees to reduce populations

PA, July 2018

Monitoring and scouting

Egg masses: on tree trunks, stones, etc.

Adults: in clusters on tree trunks

2-4th instars: plant leaves, stems, tree trunks

1st instar: close to the ground, plant shoots, stems, etc.

May -> June -> July -> August -December

Insecticidal control

Synthetic pyrethroid - deltamethrin 1% EC
Organophosphate - fenitrothion 50% EC
“Quick and strong insecticidal activity against the 2nd-3rd nymphs”

Neonicotinoids - imidacloprid 4% SL and clothianidin 8% SC “showed 100% insecticidal activity at 24h after treatment”

Park et al. 2009

Pyrethrum, Sophora, and neem extracts (at 1,000 fold dilution) killed95% of adults within 48 h, but the extracts tended to be less effective against nymphs in some tests

Dara et al. 2015

What can be done to assist with management of lanternfly?

Pennsylvania Department of Agriculture and Penn State web sites assist citizens with identification of this new pest, learning how to destroy egg masses, and for reporting sightings in general.

https://extension.psu.edu/spotted-lanternfly

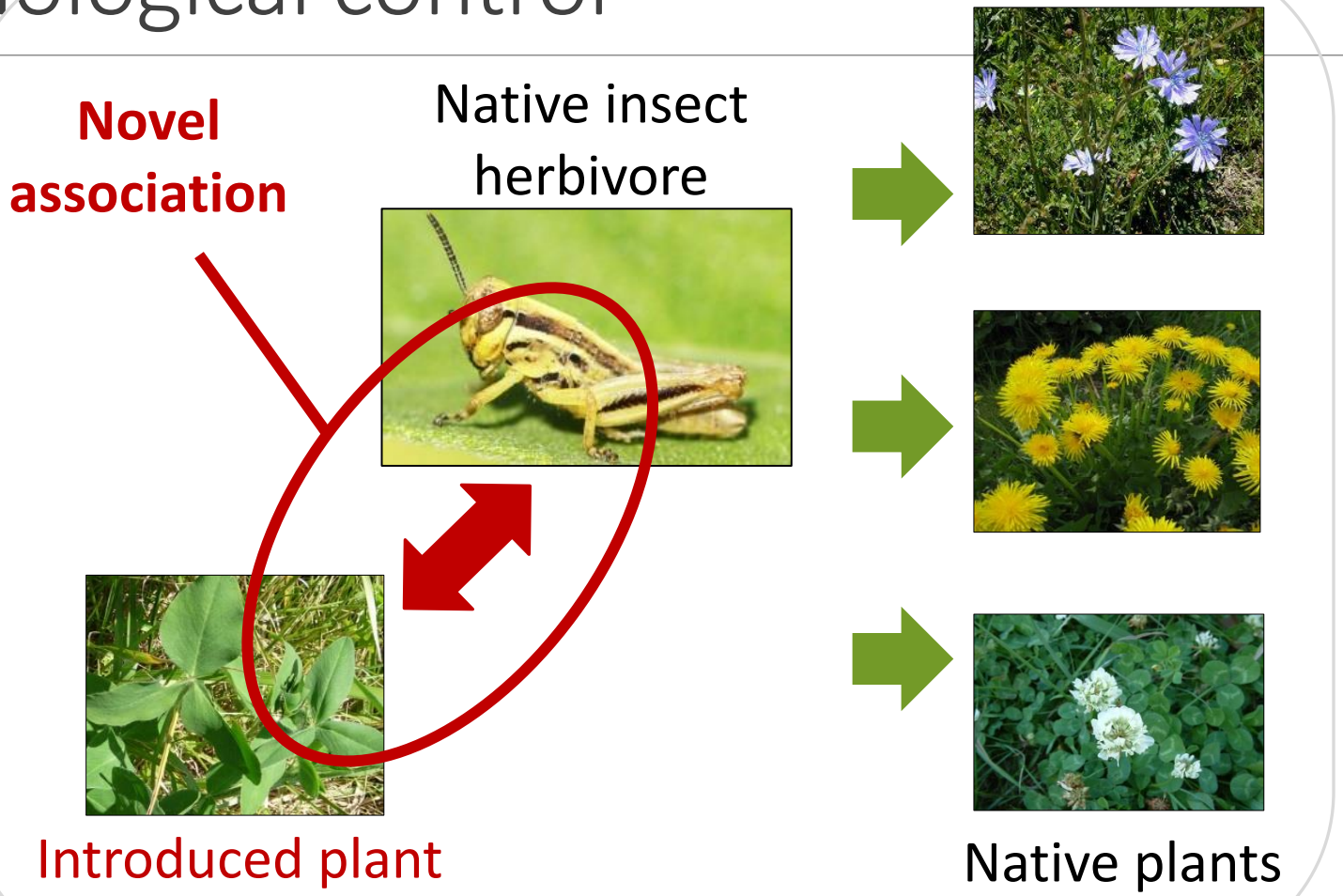
If you discover an egg mass, nymphs, or adult lanternflies, report to your University Extension Service or State Department of Agriculture.

http://extension.umd.edu/hgic/topics/spotted-lanternfly

Quick discussion (3 min)

Can you predict how other invasive insects might adapt to their novel host plants?

Novel plant-associations: implications for co-evolution, biotic resistance, and biological control



In the introduced range…

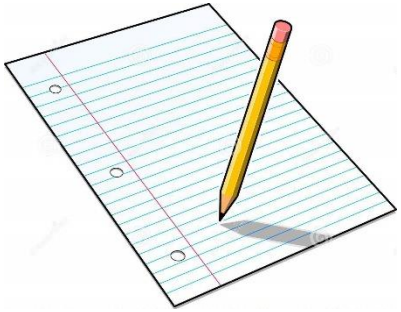
Establishment → Spread → Impact

Introduced species

Species invasion

Fail to establish

Native community



Worksheet Part 3.

Why do introduced species fail to establish in a new range?

Quick discussion (3 min)

Why do introduced species fail to establish in a new range?

Biotic resistance

- "the ability of resident species in a community to reduce the success of exotic invasions" (Levine et al., 2004) – i.e. competition, parasitism, herbivory, or predation, etc.

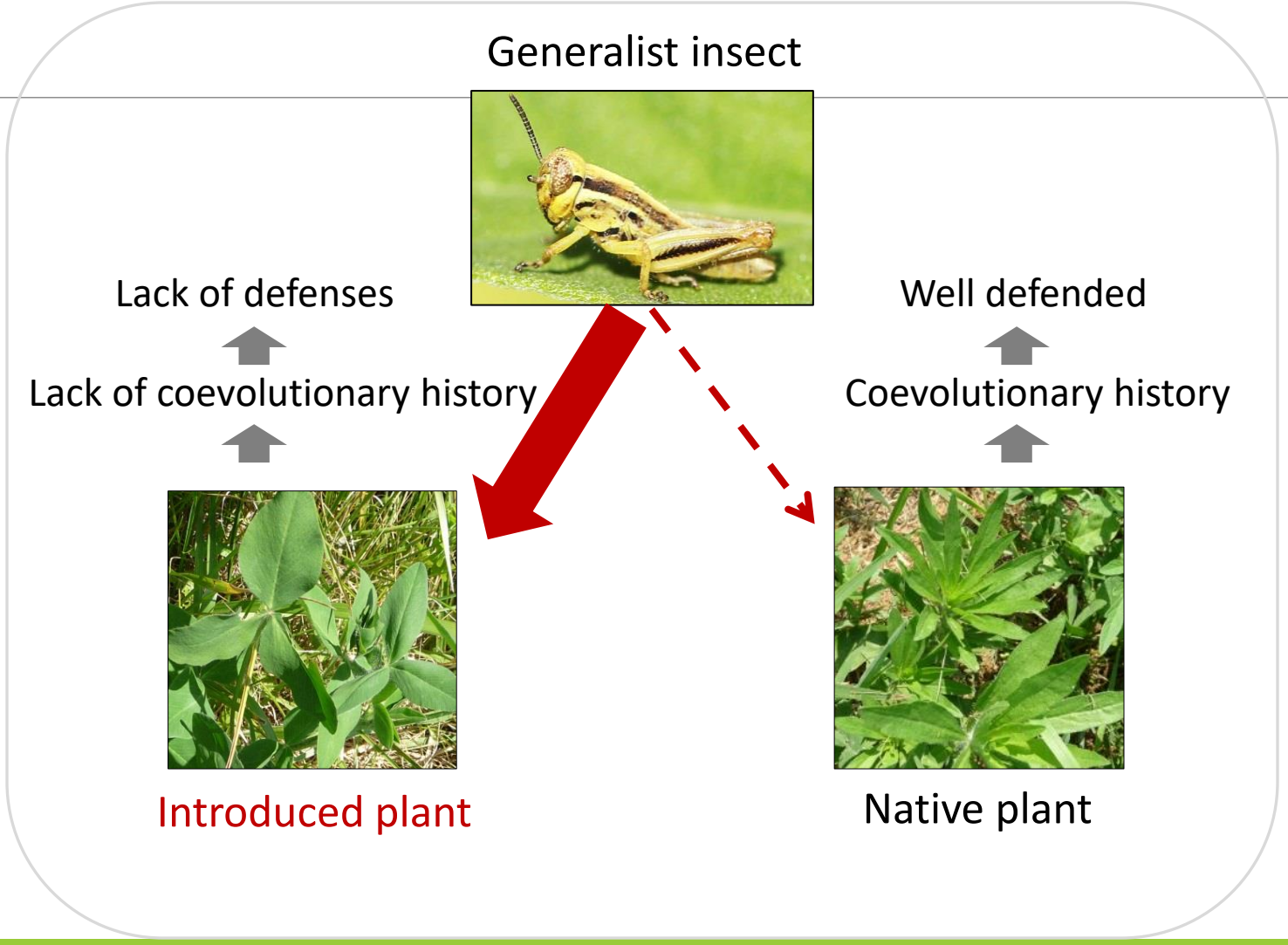
Establishment → Spread → Impact

Species invasion

Stop!

Native community

Biotic Resistance Hypothesis



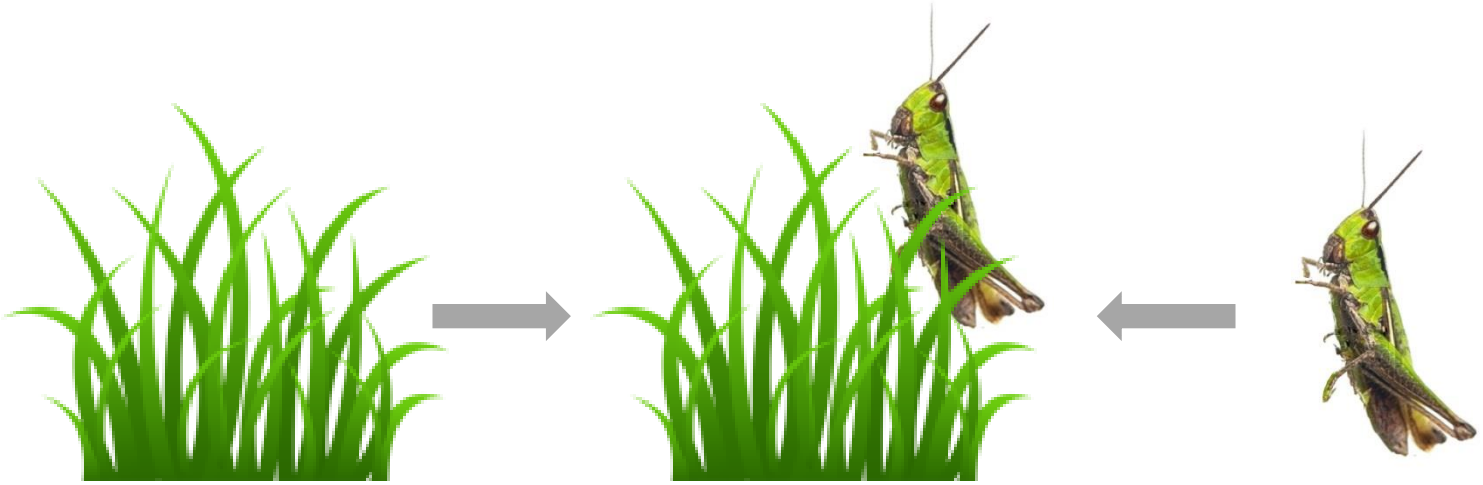
Why do introduced species fail to establish in a new range?

Novel species interactions

- How do insect herbivores respond to their novel host plants?

- How do plants respond to their novel insect herbivores?

The Interaction between Generalist Insect Herbivores and Their Host Plants



Plant perspective

Insect perspective

Plant perspective

- Plant resistance to insect herbivory
- Plant tolerance to insect herbivory

Plant Resistance

- **The ability of a plant to decrease herbivore damage**

  Price et al., 2011

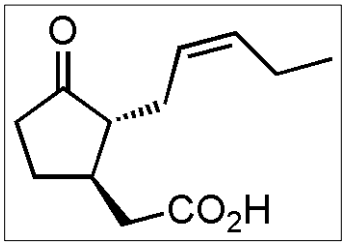
- "A resistance trait is any plant character that influences the amount of damage a plant suffers"

  Rausher, 1992

Wax

Spines

Trichomes



Jasmonic acid

- **Leaf damage** is one of the commonly used measurements for plant resistance
- Plants with more damage from herbivores are generally considered to have a lower level of resistance to herbivory

  Mauricio 2000, Zou et al. 2008

Plant Tolerance

- **The ability of a plant to maintain fitness while sustaining herbivore damage**

  Price et al., 2011

- Physiological components of plant tolerance:
  growth rate, storage capacity, photosynthetic rates, nutrient uptake etc.

  Rosenthal & Kotanen 1994

- **Plant compensatory growth in terms of aboveground plant biomass** is one of the fundamental and commonly used measurements for plant tolerance to herbivory, especially in grasslands

  Rosenthal & Kotanen 1994; Atwood & Meyerson 2011; Leis & Morrison 2011

- Estimating biomass should be **non-destructive**, accurate, and easy to implement

  Redjadj et al. 2012

Insect perspective

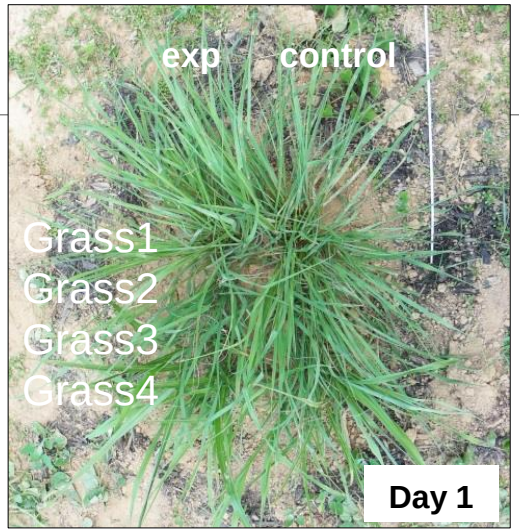
How do we know?

- behavioral approach (feeding activity, consumption, assimilation)
- molecular approach (DNA barcoding of ingested plant material)

Insect perspective

behavioral approach (feeding activity, consumption, assimilation)

Feeding Trials: Field

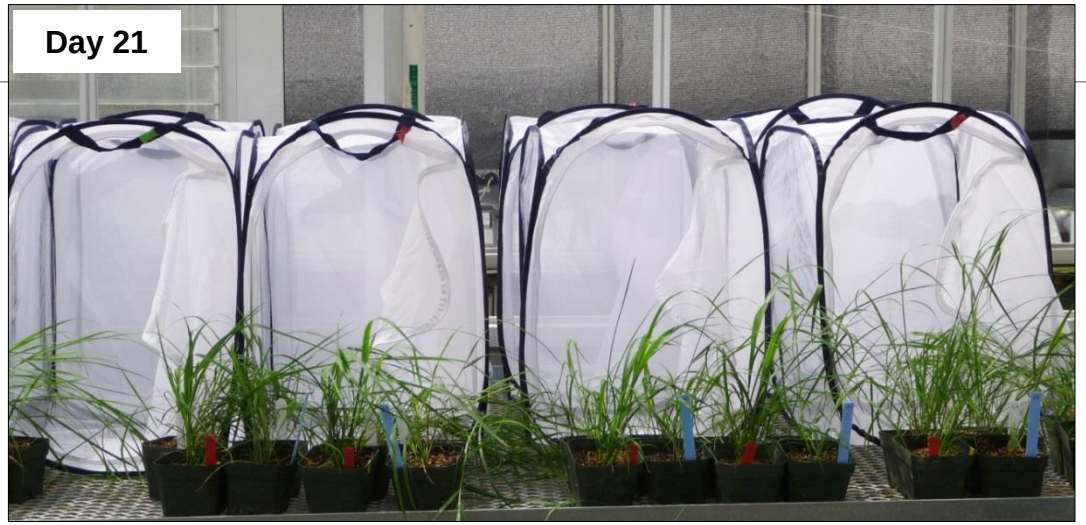


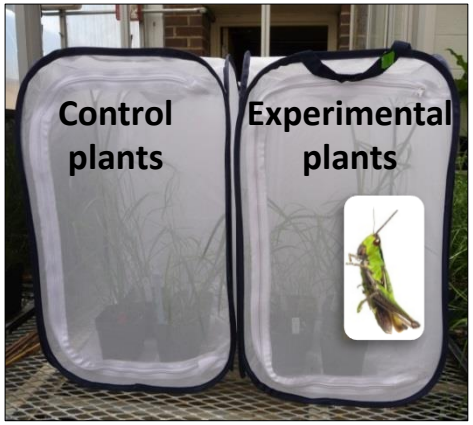
Plant growth / Grasshopper feeding

Plant regrowth

Avanesyan and Culley (2017), *J. Torrey Soc.*

Feeding Trials: UC Greenhouse



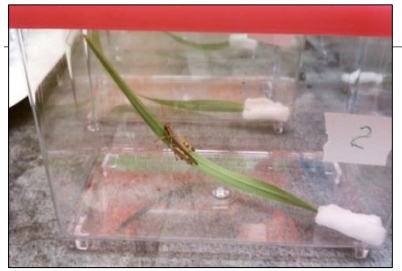


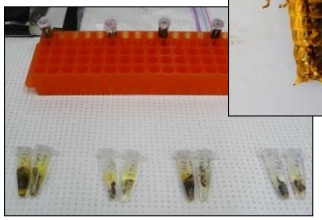
Lab Assays (Leaves)

Insect perspective

molecular approach (DNA barcoding of ingested plant material)

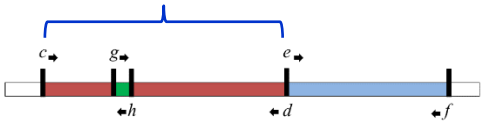
Molecular Confirmation of Diet

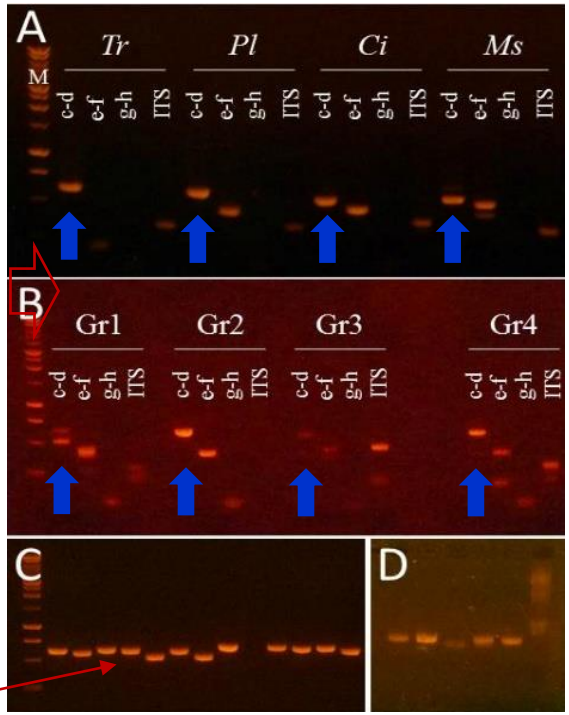




Chloroplast *trn*L (UAA) intron

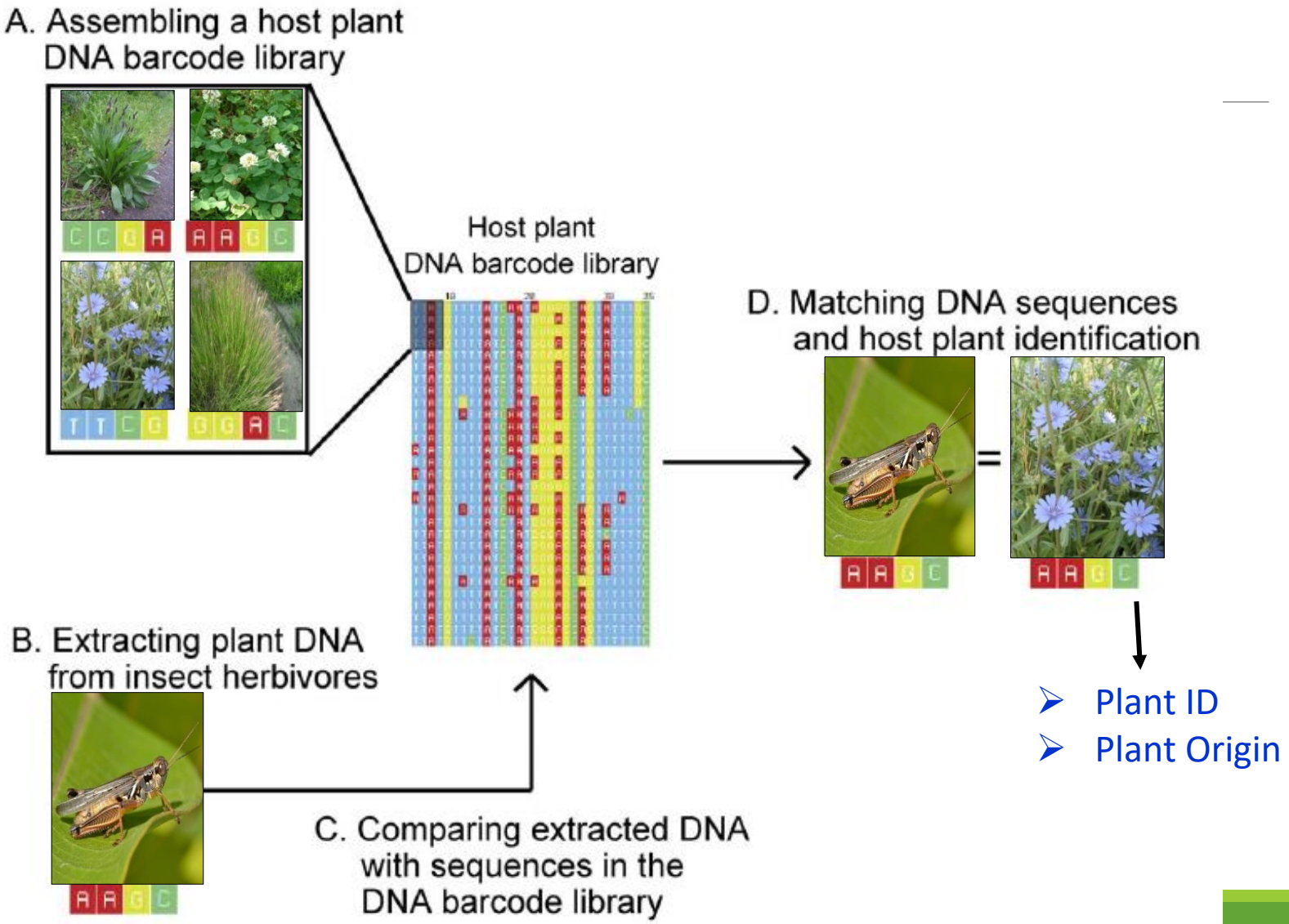
~ 550 bp





Avanesyan 2014, *Application in Plant Sciences*

Host Plant Identification



- Plant ID
- Plant Origin

Modified from García-Robledo et al. (2013)

Application to Biotic Resistance

Establishment → Spread → Impact

Plant invasion

Stop!

Native community

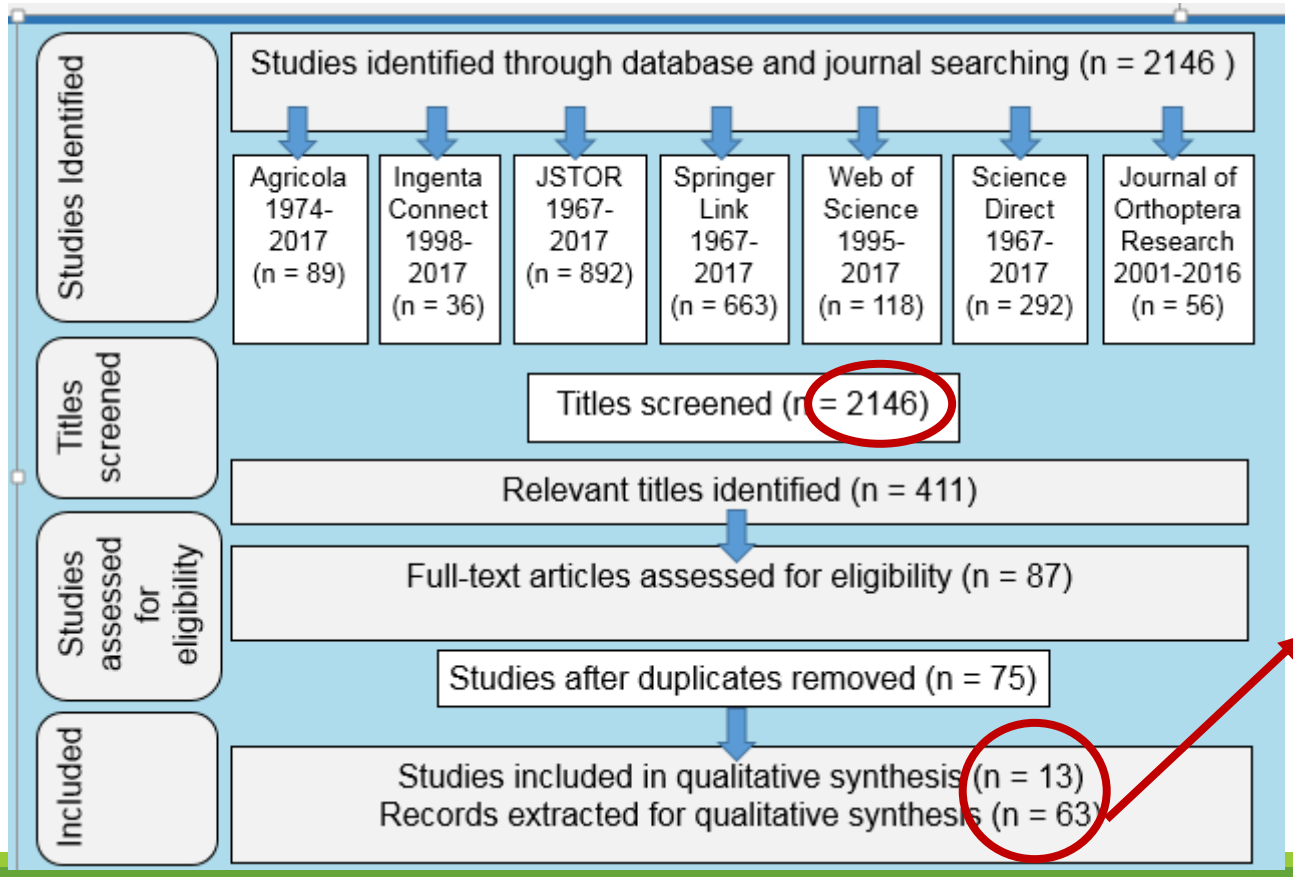
Quick Review

- Can we determine insect feeding preferences for native vs. novel host plants? Yes/No
- Does biotic resistance refer to native species? Yes/No

Quick discussion (3 min)

If we know a feeding response for one insect species, does it mean all the insects in this genera/family, etc. have the same responses?

Should I Eat or Should I Go? Acridid Grasshoppers and Their Novel Host Plants: Implications for Biotic Resistance



for 28 North-American grasshopper species

Avanesyan 2018, *Plants*

Systematic Review and Meta-analysis

Herbivory of native and exotic North-American prairie grasses by nymph *Melanoplus* grasshoppers

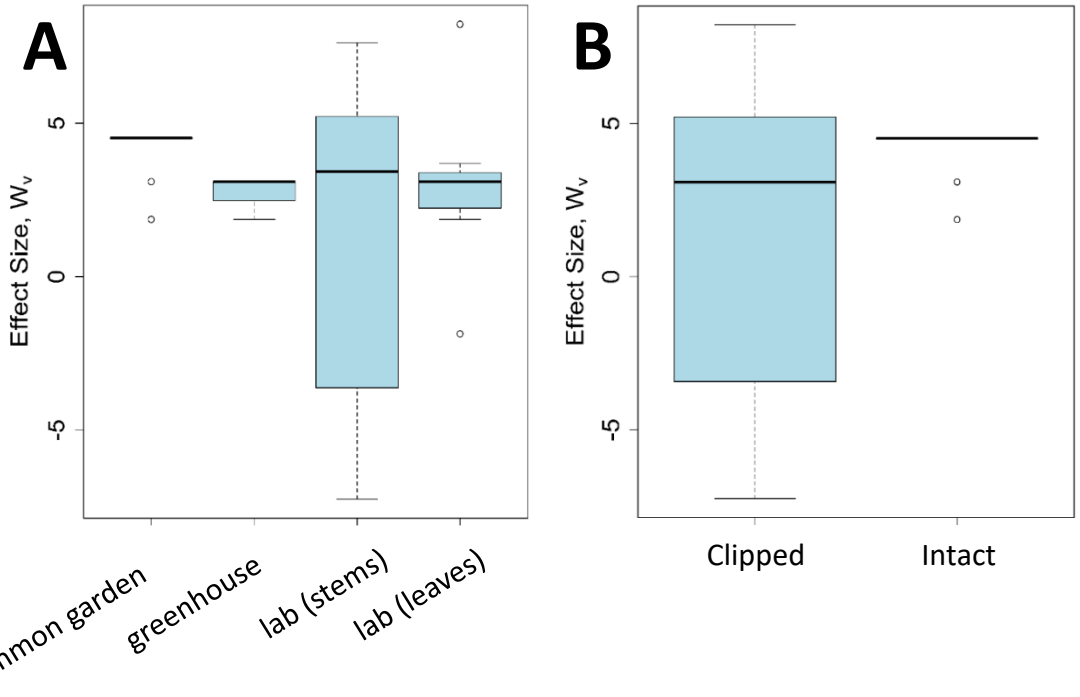
Alina Avanesyan · Theresa M. Culley

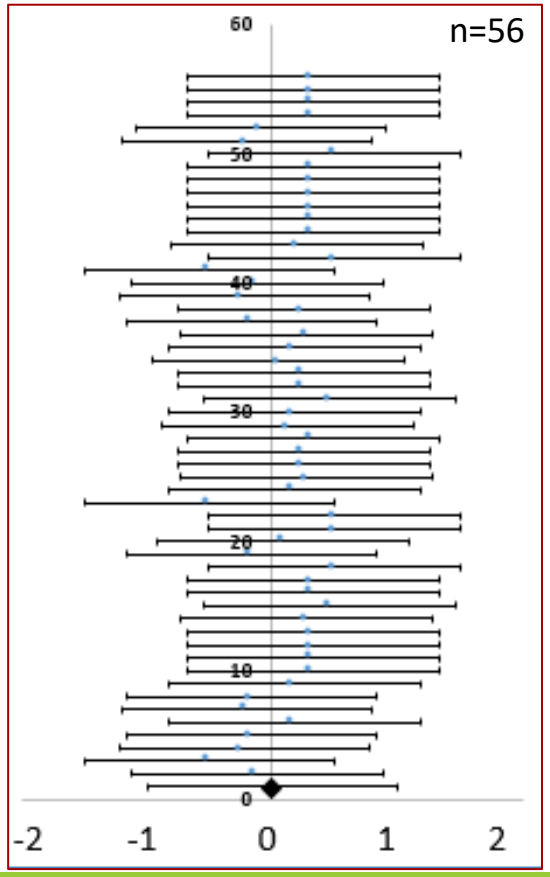
The authors used a very wide range of experimental conditions and measurements to assess grasshopper preferences

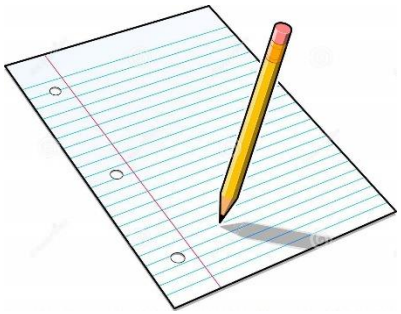
- **4 experimental environments**: common garden, greenhouse, lab (leaves), lab (stems)
- **3 types of feeding trials**: no-choice, choice (2 plants), choice (plant mixture)
- **2 types of plant material**: intact plants, clipped plant parts
- **Different stages**: adults, nymphs, mix
- **35 measurements** of feeding preferences!

Discussion

What do you see?

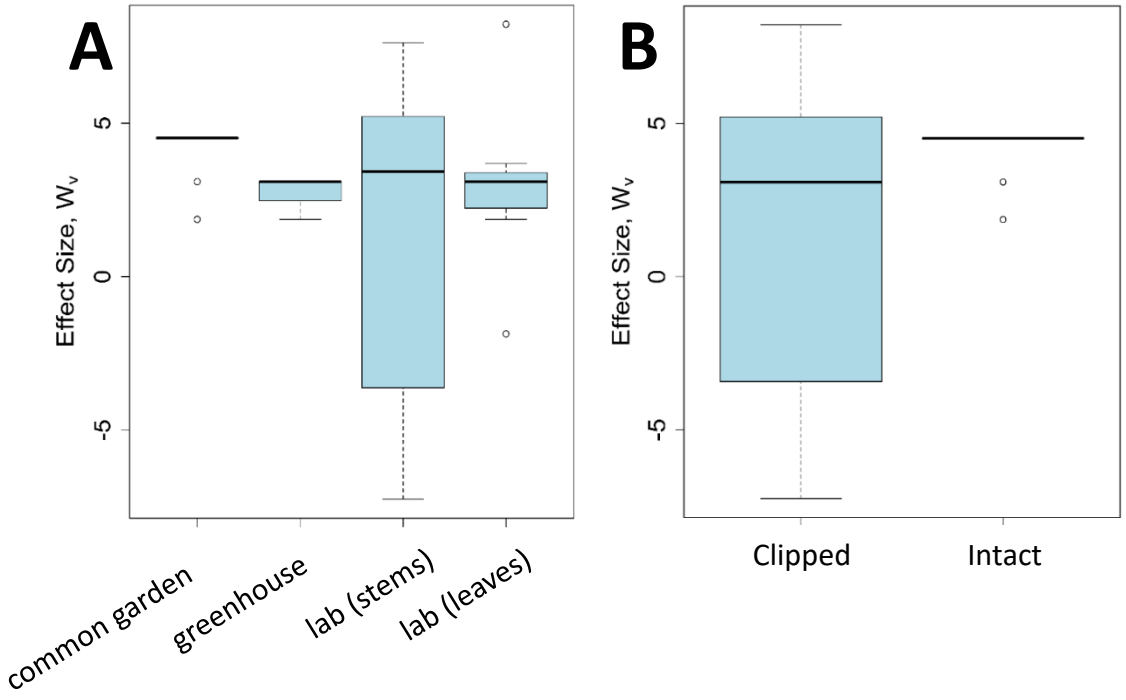


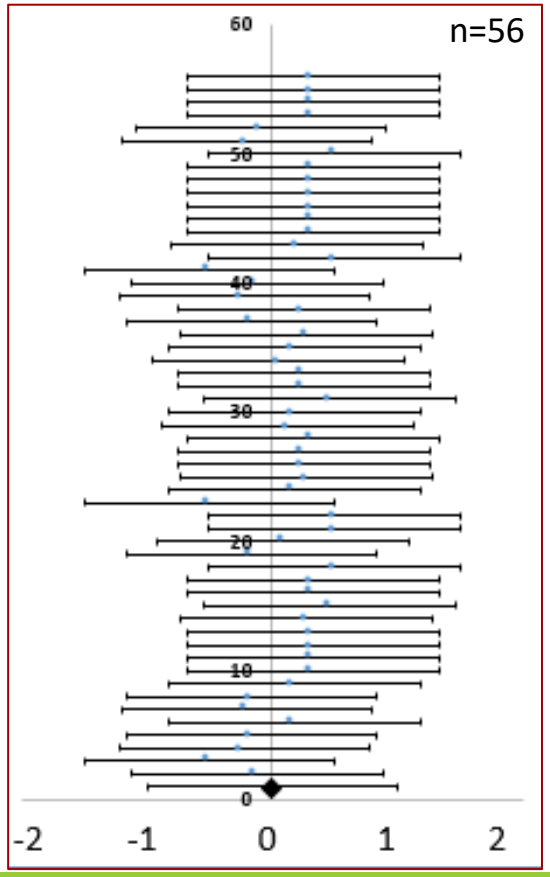




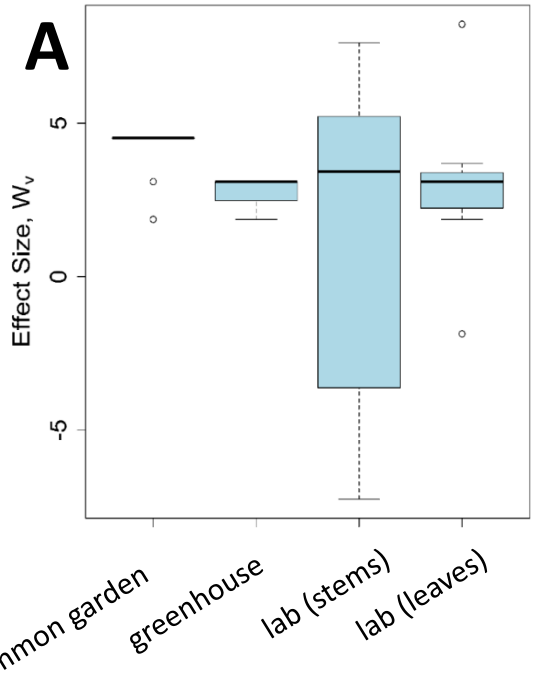
Worksheet Part 4.

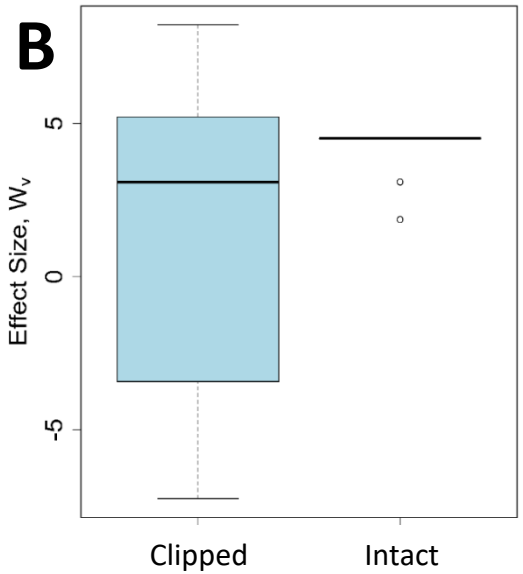
What does it mean?

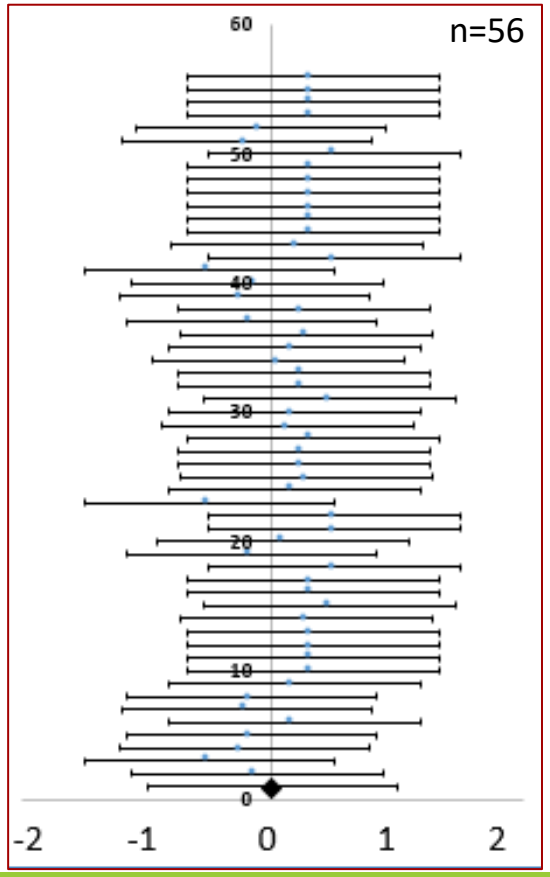




What does it mean?

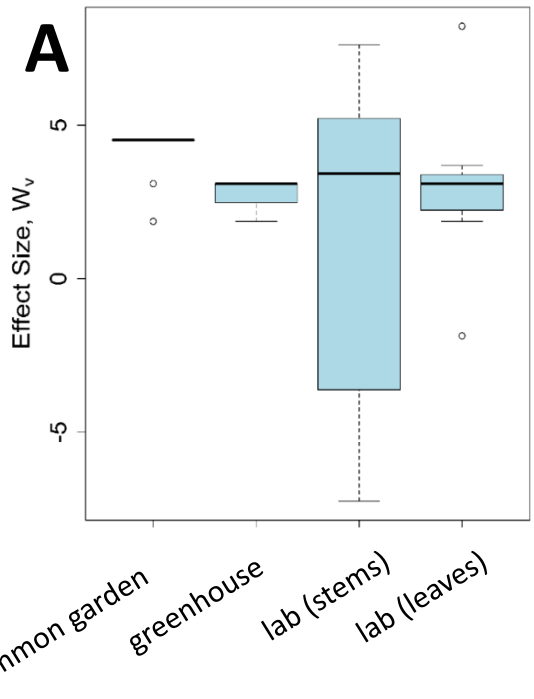


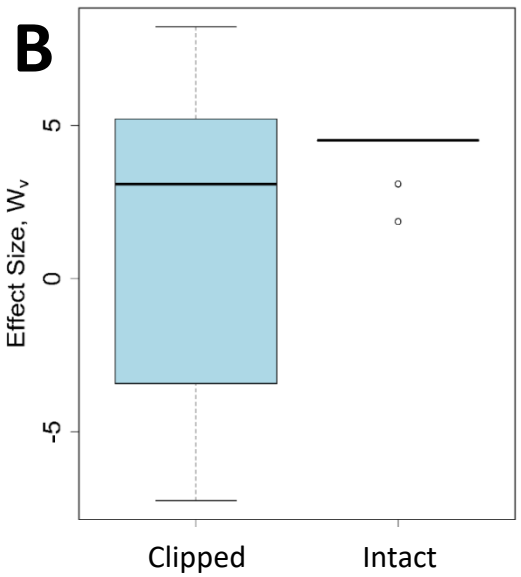


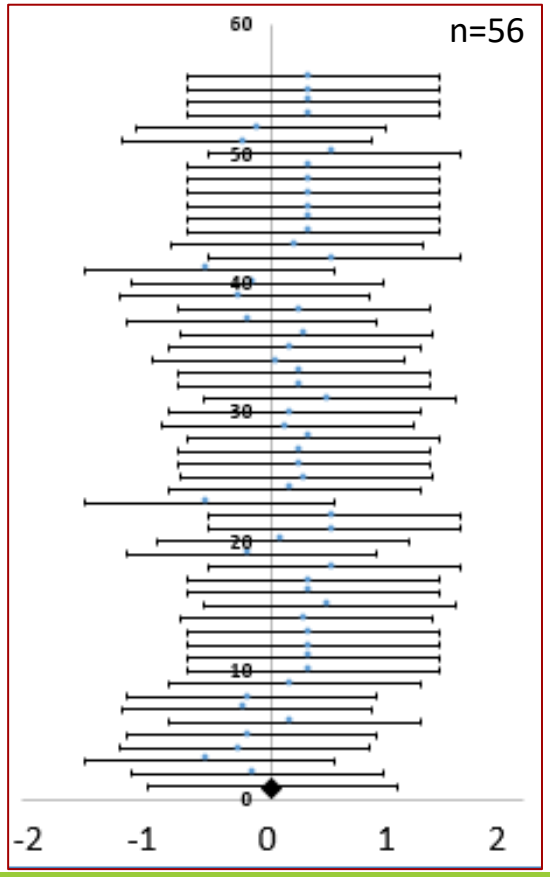


$$\text{Preference Metric} = \frac{n_{\text{most preferred exotic plant species}} - n_{\text{most preferred native plant species}}}{n_{\text{total plant species offered}}}$$

Acridid grasshoppers prefer to feed on introduced plants regardless the experimental conditions or plant material offered







$$\text{Preference Metric} = \frac{n_{\text{most preferred exotic plant species}} - n_{\text{most preferred native plant species}}}{n_{\text{total plant species offered}}}$$

Most of the preferred plants are highly invasive

- 20 introduced plant species (out of 22) were reported as “the most preferred”
- 12 species showed high or middle invasive rank
- *Bromus inermis* (smooth brome) and *Schedonorus arundinaceus* (tall fescue) are among the most preferred (for 50% grasshopper species)

Application to Biotic Resistance

Establishment → Spread → Impact

Plant invasion

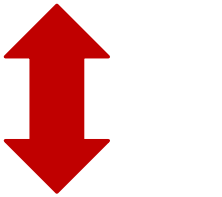
Stop!

Native community

Summary

Why do introduced species fail to establish in a new range?

Native insect herbivore



Introduced plant

- Phylogenetic relatedness

Native plant

- Behavioral mechanisms
- Morphological adaptations
- Plant chemistry
- Insect seasonal phenology
- ….many other mechanisms

Native community

Quick Review

- Can insect feeding behavior serve as a mechanism of biotic resistance? Yes/No
- Do all the introduced plants establish in the introduced range? Yes/No

The End

Please name at least one

novel plant-insect association

Image credits and resources

USDA

Maryland Cooperative Extension

https://www.nhbs.com/the-ecology-of-invasions-by-animals-and-plants-book

http://www.socialstudiesforkids.com

https://oceanservice.noaa.gov

https://www.ecori.org/natural-resources/2015/6/23/gypsy-moth-caterpillars-take-ri-by-storm

Louis-Michel Nageleisen, Département de la Santé des Forêts, Bugwood.org

http://bugoftheweek.com/blog/2017/4/29/good-bye-ash-trees-of-the-potomac-emerald-ash-borer-eab-iagrilus-planipennisi