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The invasion of the Spotted Lanternfly and its impact on horticultural crops

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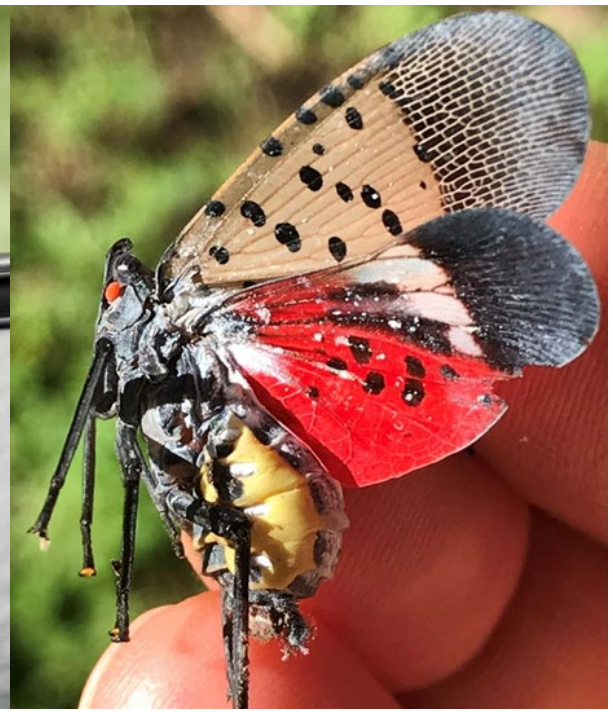

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StopSLF.org

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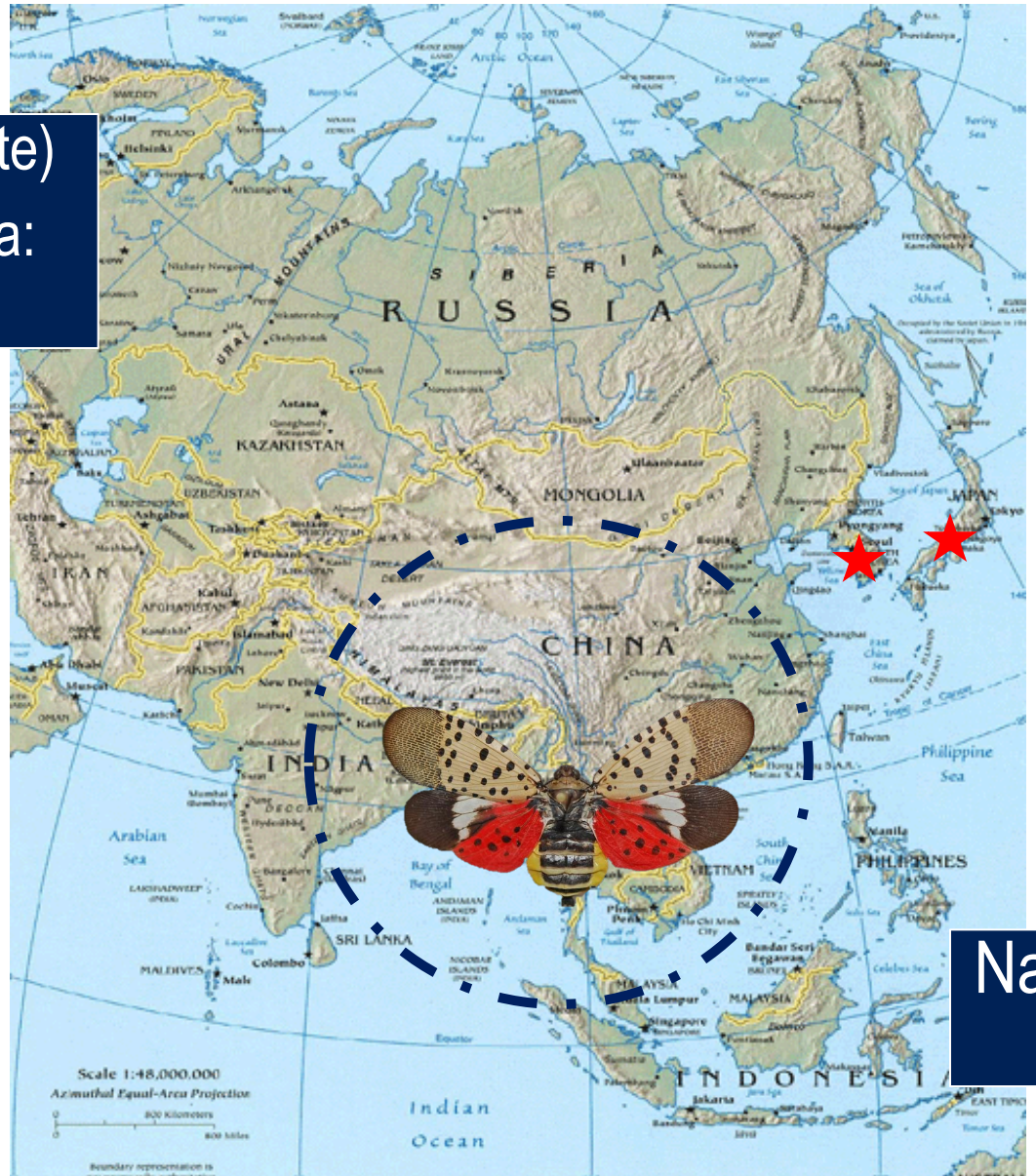
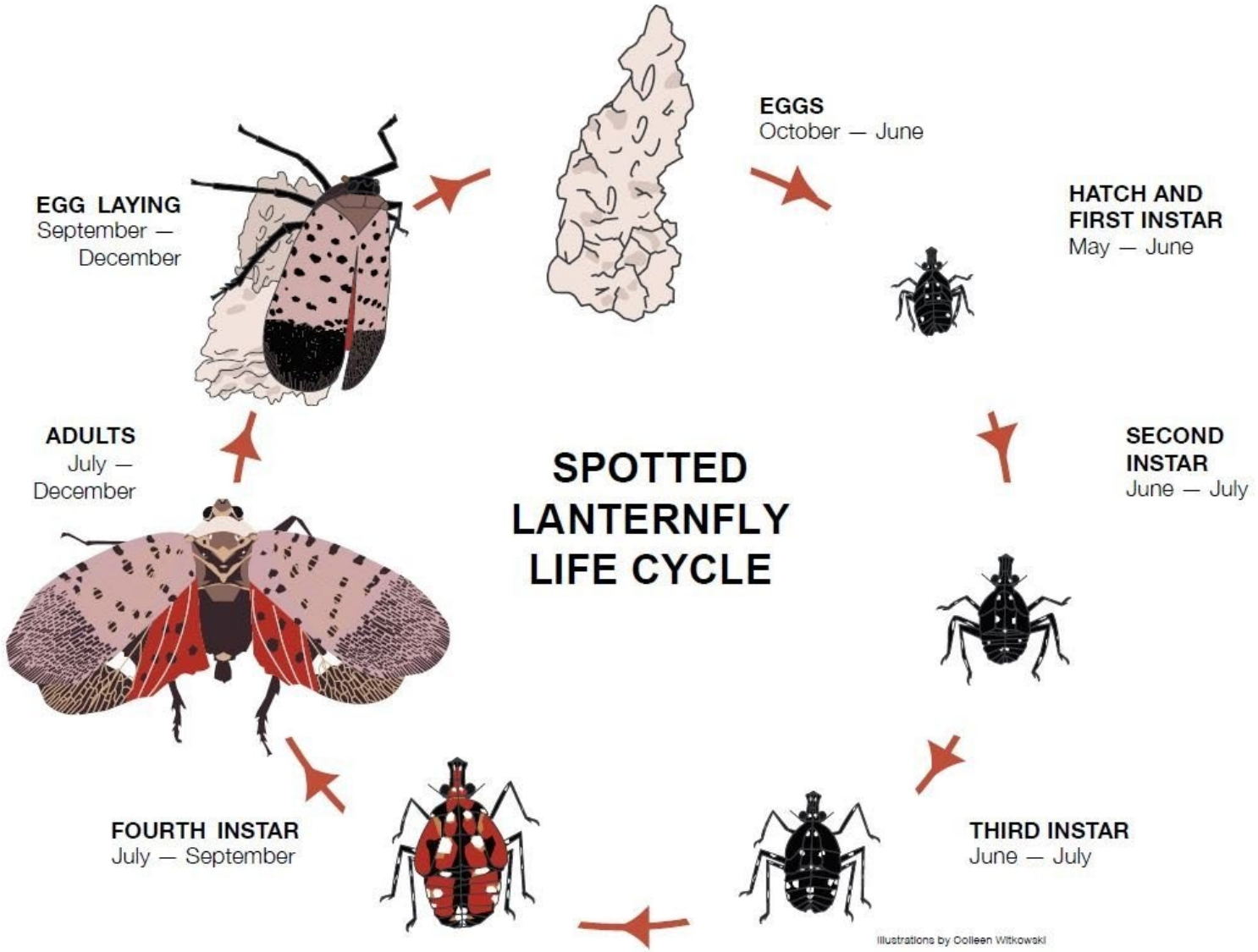
SLF is an Invasive Species in the USA, South Korea and Japan

Lycorma delicatula (White)
(Hemiptera: Fulgoroidea: Fulgoridae)



Native to China, India, and Vietnam

SLF Life History



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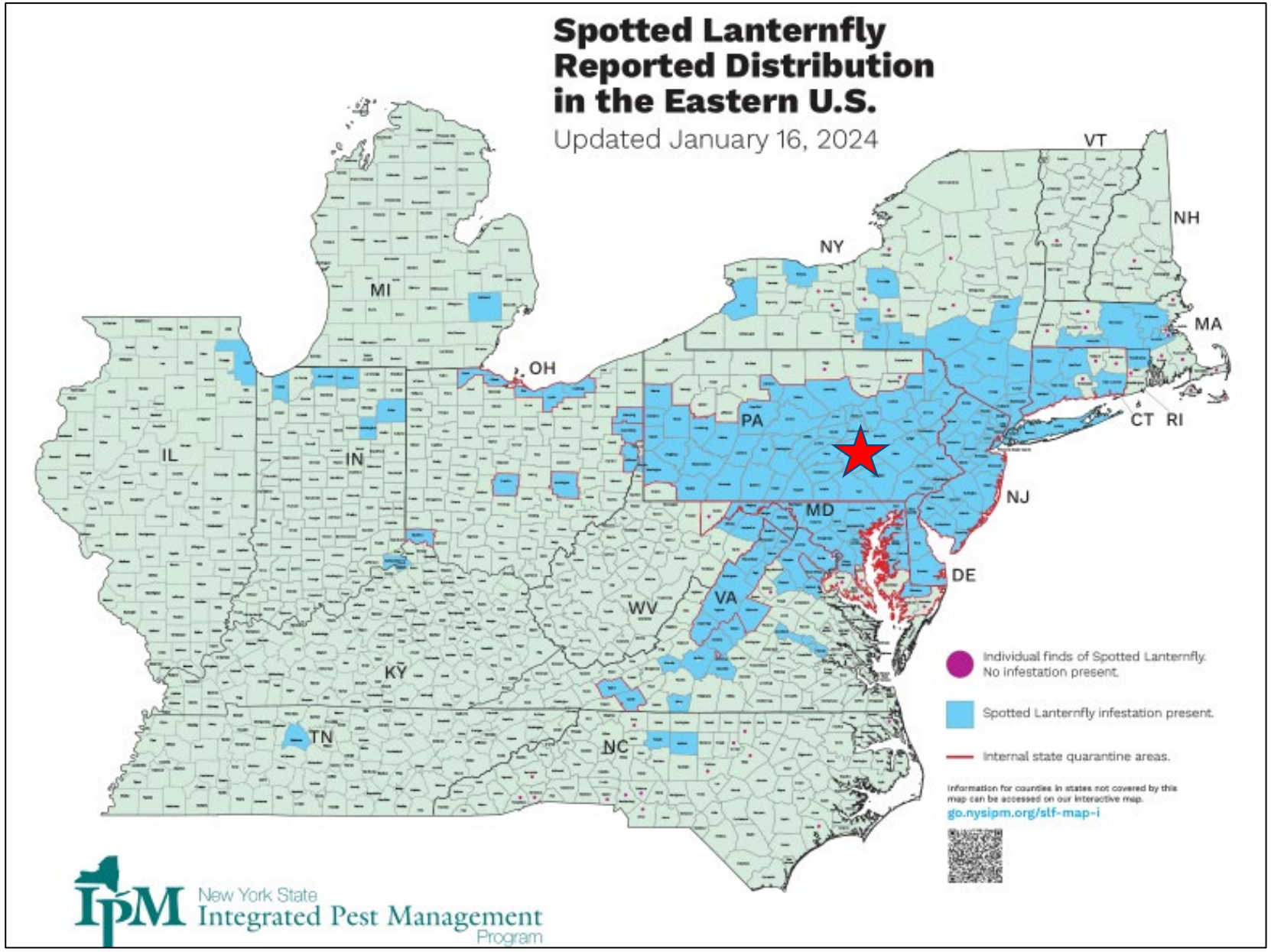
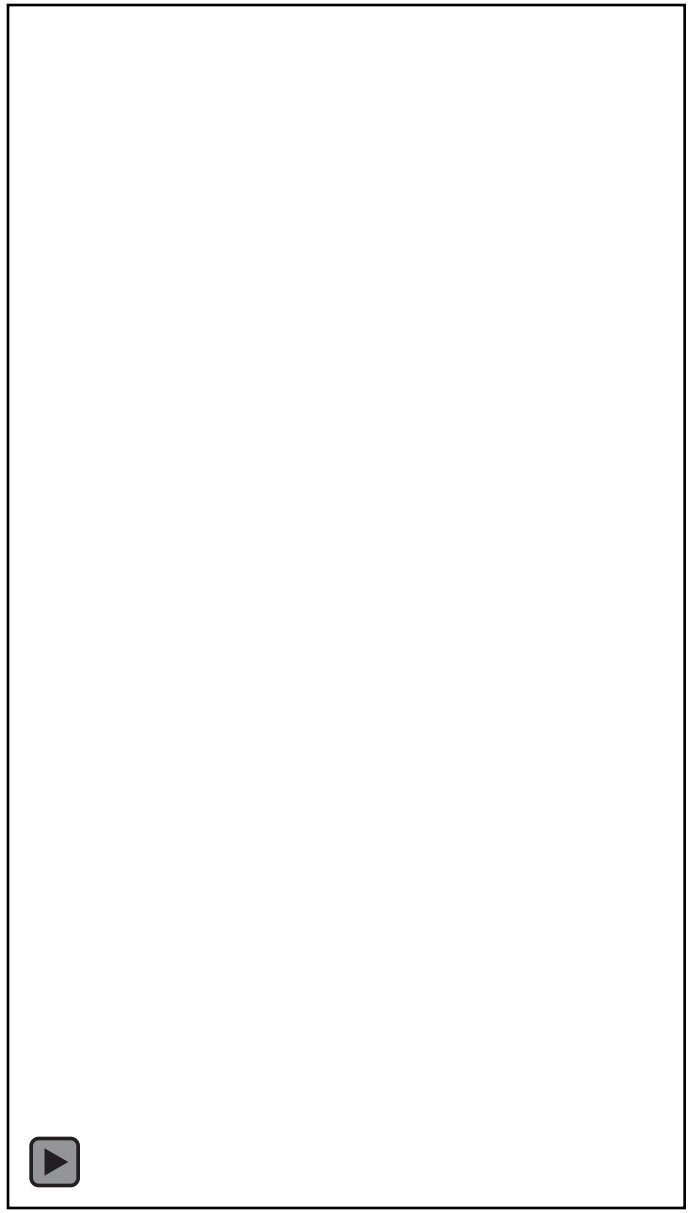
Current Known Distribution of SLF in the USA



Outline For Today's Talk

- Information and Unanswered Questions from South Korea
- Host plants/vulnerable crops in the USA
- Human-assisted Dispersal
- Monitoring Tools
- Next Steps/More to Do



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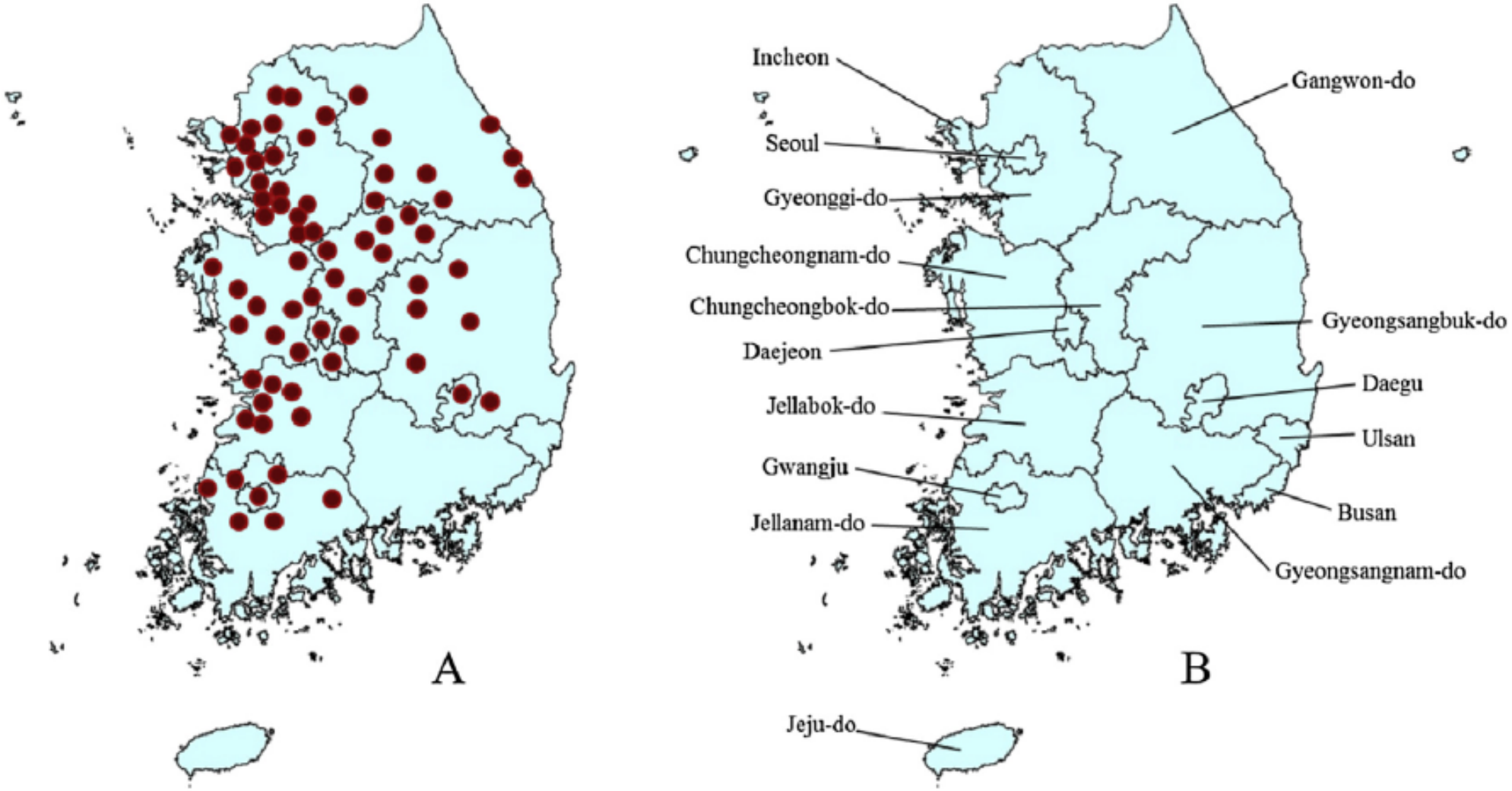
Distribution in South Korea



1. A, Distribution map of Lycorma delicatula consulted to KFS 2013; B, administrative districts in Korea including eight provinces and seven major cities. KFS ¼ Korea Forest

Potential Crops and Commodities at Risk

- **Direct effects**
  - Projected to become a serious pest of timber, ornamental trees, tree fruit, stone fruit, grapes, hops and small fruit such as blueberries.
  - Feeding could potentially shock trees and cause decline

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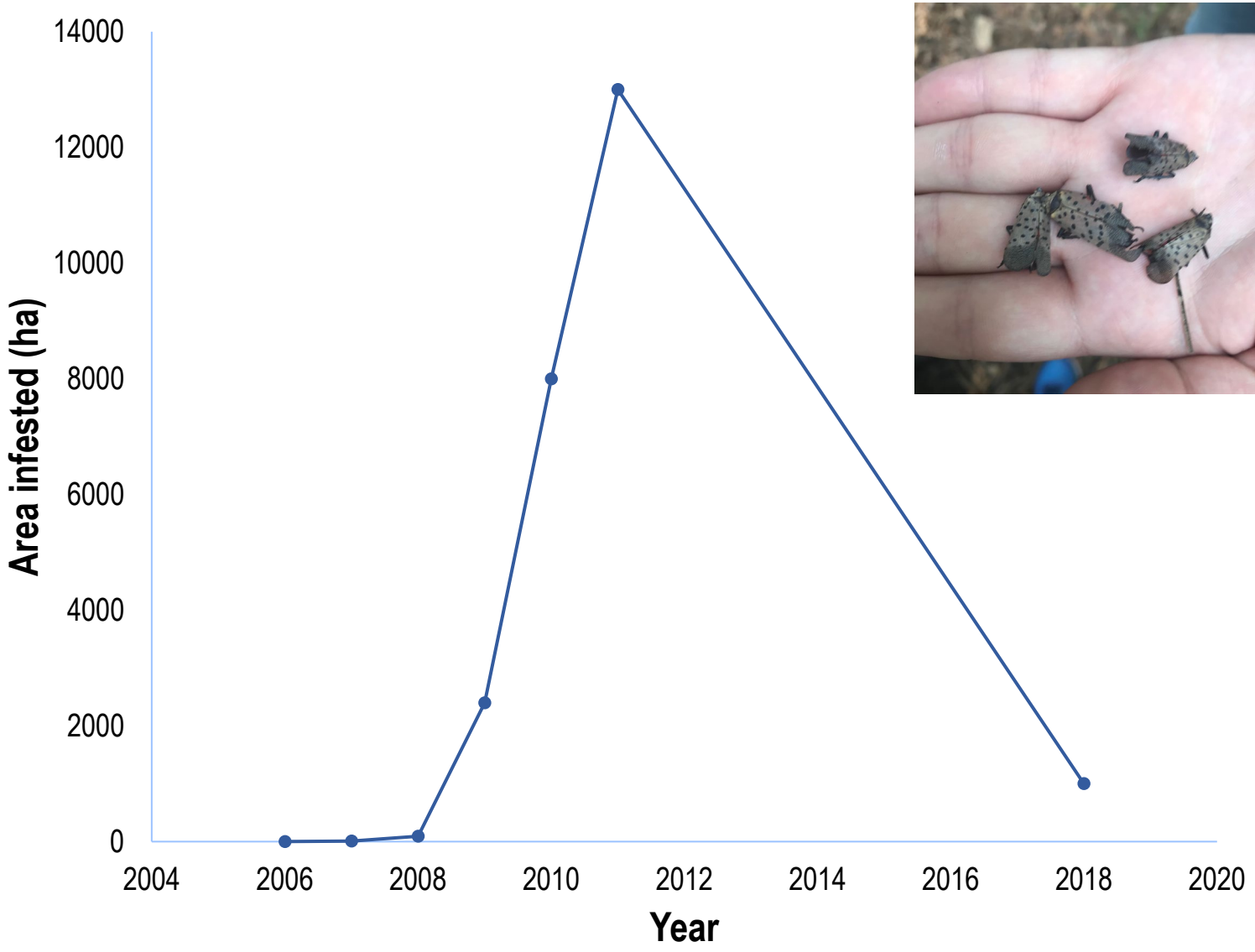
Impacts in South Korea

Feeding on vines caused wilting, stunting and sooty mold growth

Feeding caused dieback and decline

SLF Populations in South Korea



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What is Not Known About Hosts of SLF in the USA

- What specialty crop and common wild host plants bordering specialty crop production support development and survivorship of SLF?

- How could the landscape mosaic that is common in Mid-Atlantic agroecosystems contribute to SLF pest pressure in vulnerable specialty crop hosts?

SLF Host Plants in the USA

Tree of Heaven

- Native to China, highly invasive in continental USA, especially in Eastern US and California.
- Considered a favored host in the native range. Same in USA.

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Question: *What single specialty crop and wild host plant diets can support SLF over a two-week time period?*

- Evaluated two-week survivorship for 50 early (1st and 2nd) and 25 late (3rd and 4th) instar nymphs and 10 adults per cage on single host diets.

- Potted host plants were grown under greenhouse conditions.
- Hosts included:
  - Tree of Heaven (TOH), *Ailanthus altissima*
  - Black Cherry, *Prunus serontina* Ehrh.
  - Black Walnut , *Juglans nigra* L.
  - Black Locust, *Robinia pseudoacacia* L.
  - Common Hackberry, *Celtis occidentalis* L.
  - Sugar Maple, *Acer saccharum*
  - White Oak, *Quercus alba* L.
  - Mulberry, *Morus alba* L.
  - Apple, *Malus domestica*
  - Peach, *Prunus persica*

- Conducted all trials in 2019 and 2020 in quarantine greenhouse at USDA-ARS, Fort Detrick, MD.

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Two-Week Survivorship



Host Plant	Early Instar % Survivorship	Late Instar % Survivorship	Adult % Survivorship
Tree of Heaven	82.0 a	88.0 a	85.0
Black Cherry	2.0 b	16.0 bc	0
Black Locust	1.3 b	21.0 bc	2.5
Black Walnut	42.3 ab	56.9 ab	0
Common Hackberry	4.0 b	31.0 bc	0
Mulberry	5.0 b	11.0 bc	0
Sugar Maple	11.0 b	7.0 bc	0
White Oak	0.0 b	6.0 c	0
Apple	1.3 b	17.0 bc	0
Peach	8.6 b	15.0 bc	0

Main Findings:

- Nymphs survive on a broader host range than adults.
- ToH supports highest survivorship.
- Black walnut supports high nymphal survivorship, but not for adults.

Nixon, L. J., Jones, S. K., Tang, L., Urban, J., Felton, K., & Leskey, T. C. (2022). Survivorship and development of the *invasive Lycorma delicatula* (Hemiptera: Fulgoridae) on wild and cultivated temperate host plants. Environmental entomology, 51(1), 222-228.

Question: *How effectively does SLF complete development on cultivated specialty crop and wild host plants?*

- Each cage provisioned two single or one of each plant species for mixed diet plants and 30 newly hatched first instar SLF added to each cage. Tracked development and survivorship.
- Conducted in 2019 and 2020 in quarantine greenhouse at USDA-ARS, Fort Detrick, MD.

Single Host Diets

Tree of Heaven (TOH)

Black Walnut

Apple

Peach

Grape, *Vitis rotundifolia, var.* Carlos

Mixed Host Diets

- ToH + Black Walnut
- ToH + Apple
- ToH + Peach
- ToH + Grape

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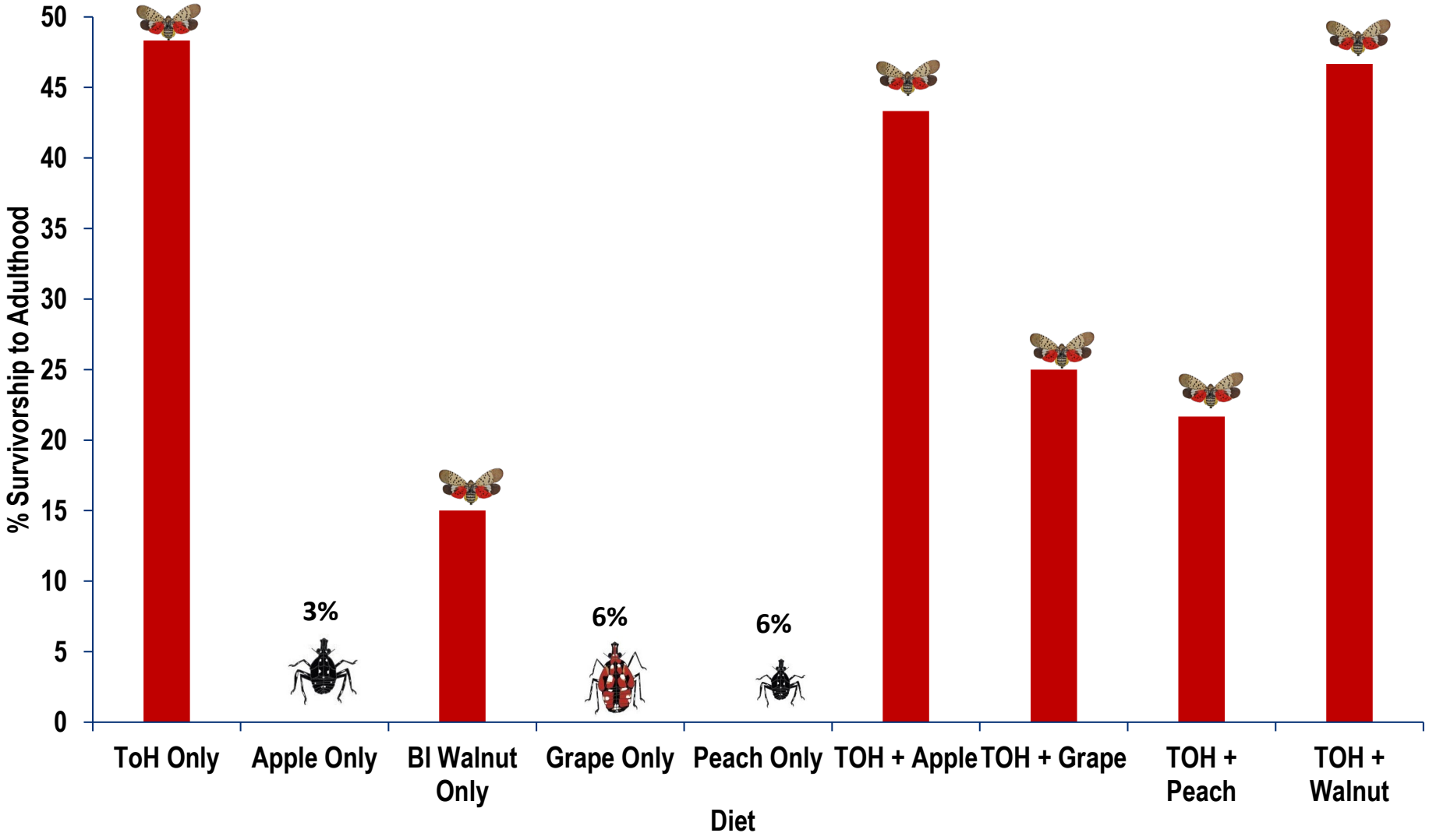
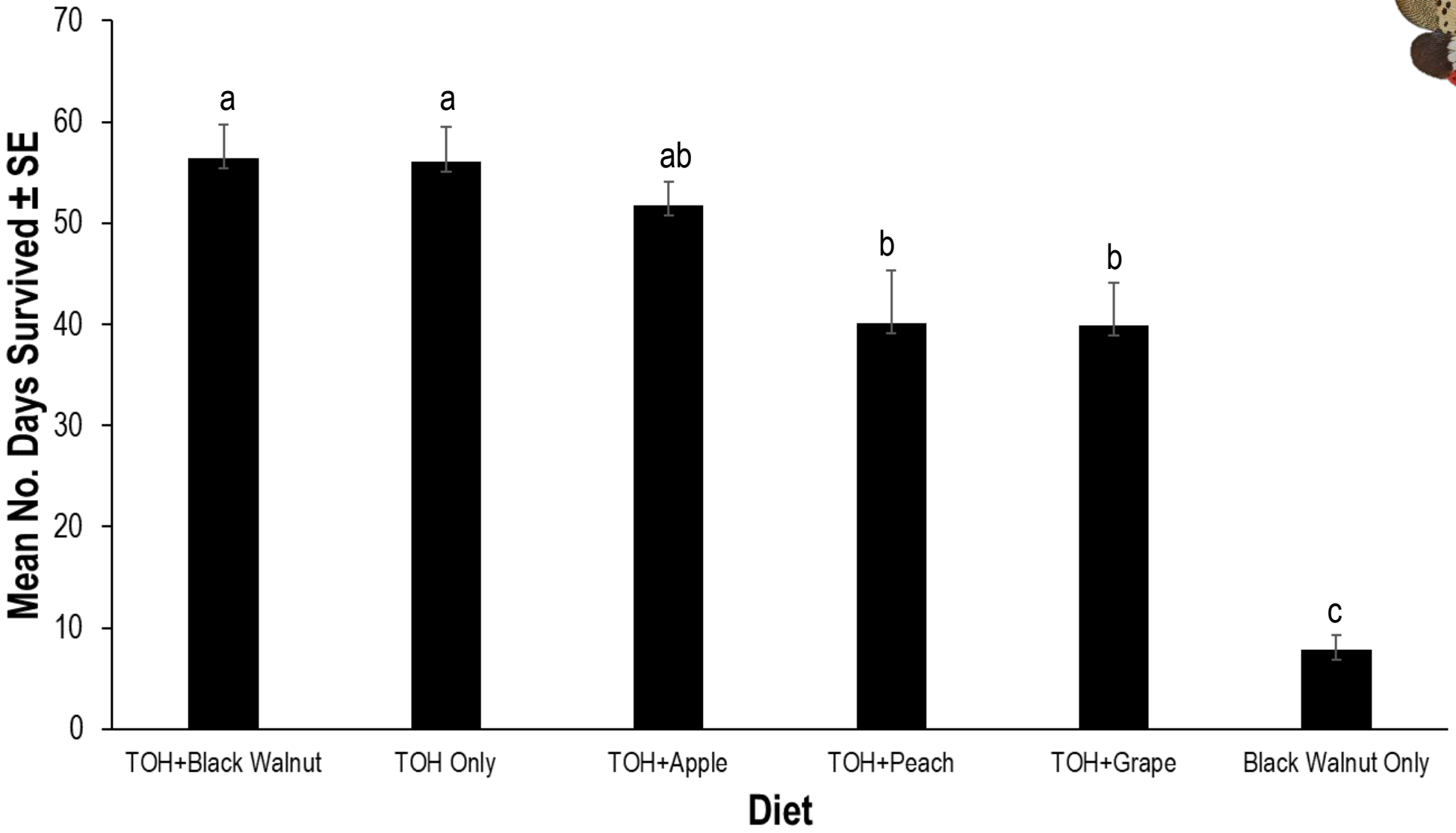
SLF Completed Development on TOH, TOH-mixed diets and Black Walnut



Adult Survivorship Period Significantly Lowest on Black Walnut



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- Conducted in 2021 in quarantine greenhouse at USDA-ARS, Fort Detrick, MD.

Grape-Based Host Diets

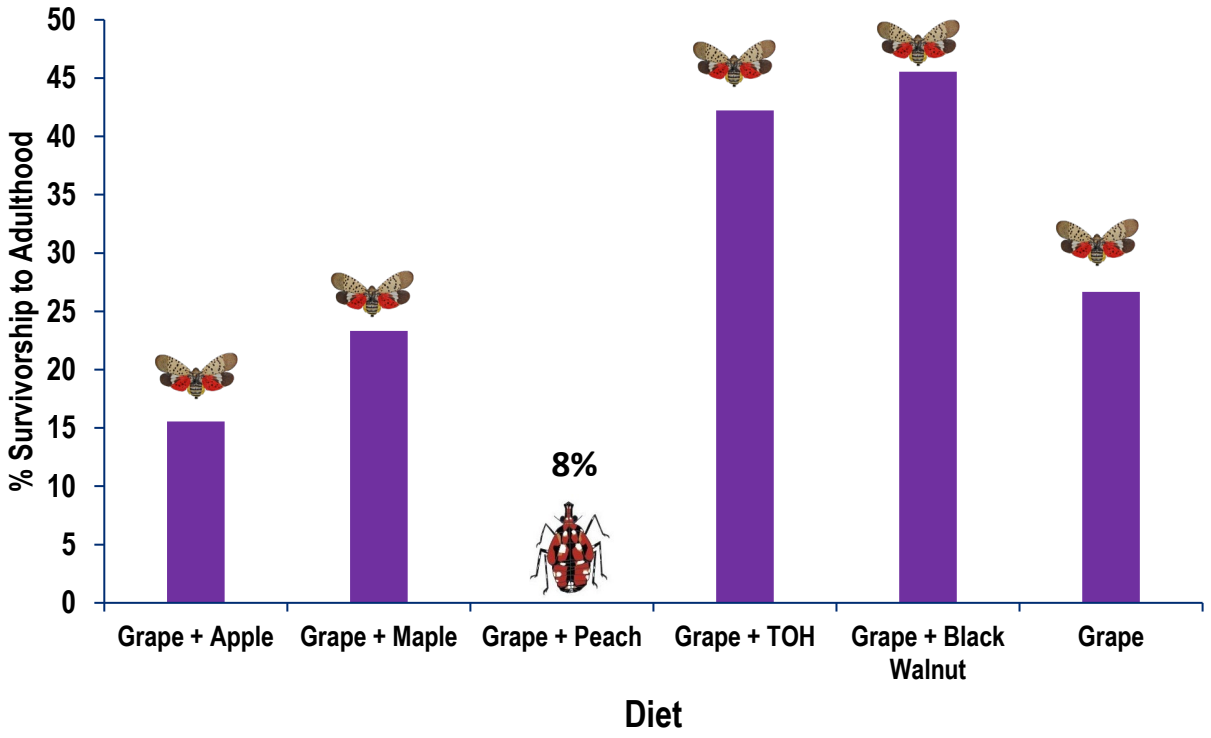
- Grape, *Vitis vinifera, var.* Riesling
- Grape + Apple
- Grape + Peach
- Grape + Black Walnut
- Grape + Silver Maple, *Acer saccharinum*
- Grape + TOH

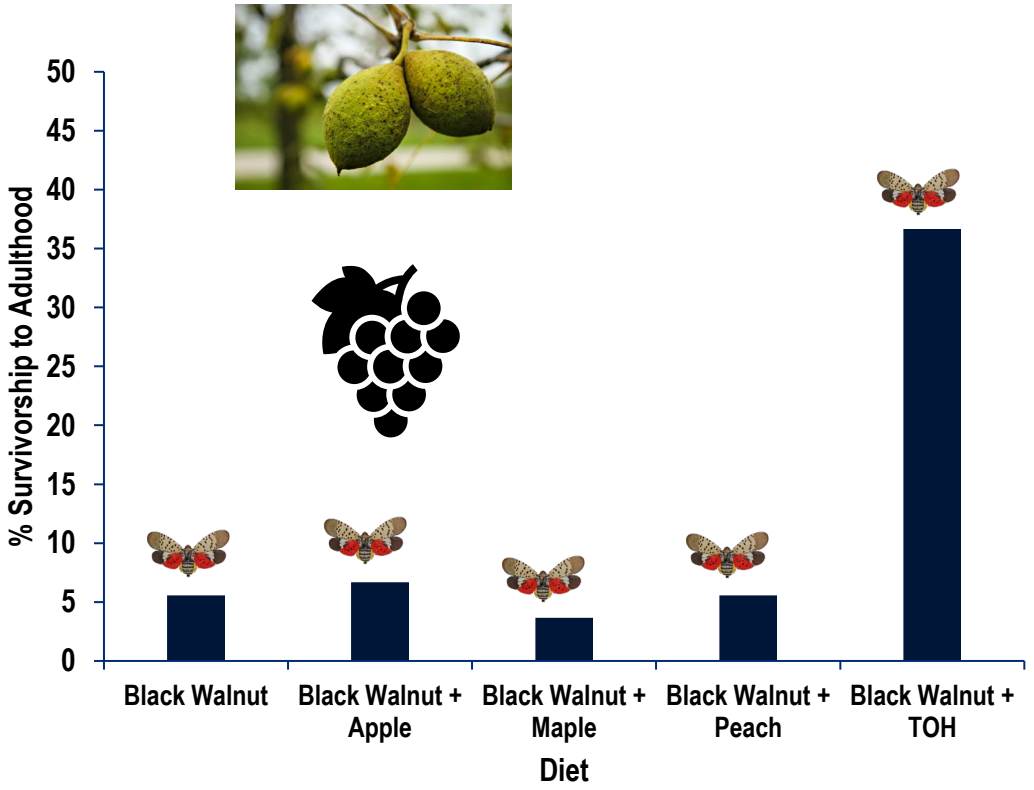
Black Walnut-Based Host Diets

- Black Walnut
- Black Walnut + Apple
- Black Walnut + Peach
- Black Walnut + Silver Maple
- Black Walnut + TOH

Combining Grape (*V. vinifera*) or Black Walnut as the 'primary host' with specialty crop or forest hosts resulted in development to the adult stage in the absence of TOH in nearly all cases.

V. vinifera appears to support development better than *V. rotundifolia.*





Question: How effectively does SLF complete development on various *Vitis* spp?

- Each cage provisioned two plants species for mixed diet plants and 30 newly hatched first instar SLF added to each cage. Tracked development and survivorship. Five replicates.
- Conducted in 2022 in quarantine greenhouse at USDA-ARS, Fort Detrick, MD.

Grape-Based Host Diets

- *Vitis vinifera, var.* Chardonnay (white wine variety)
- *Vitis vinifera, var.* Pinot Noir (red wine variety)
- *Vitis riparia,* riverbank grape
- Vitis labrusca, juice grape
- Vitis rotundifolia, var. 'Carlos', (muscadine grape)
- Tree of Heaven – positive control

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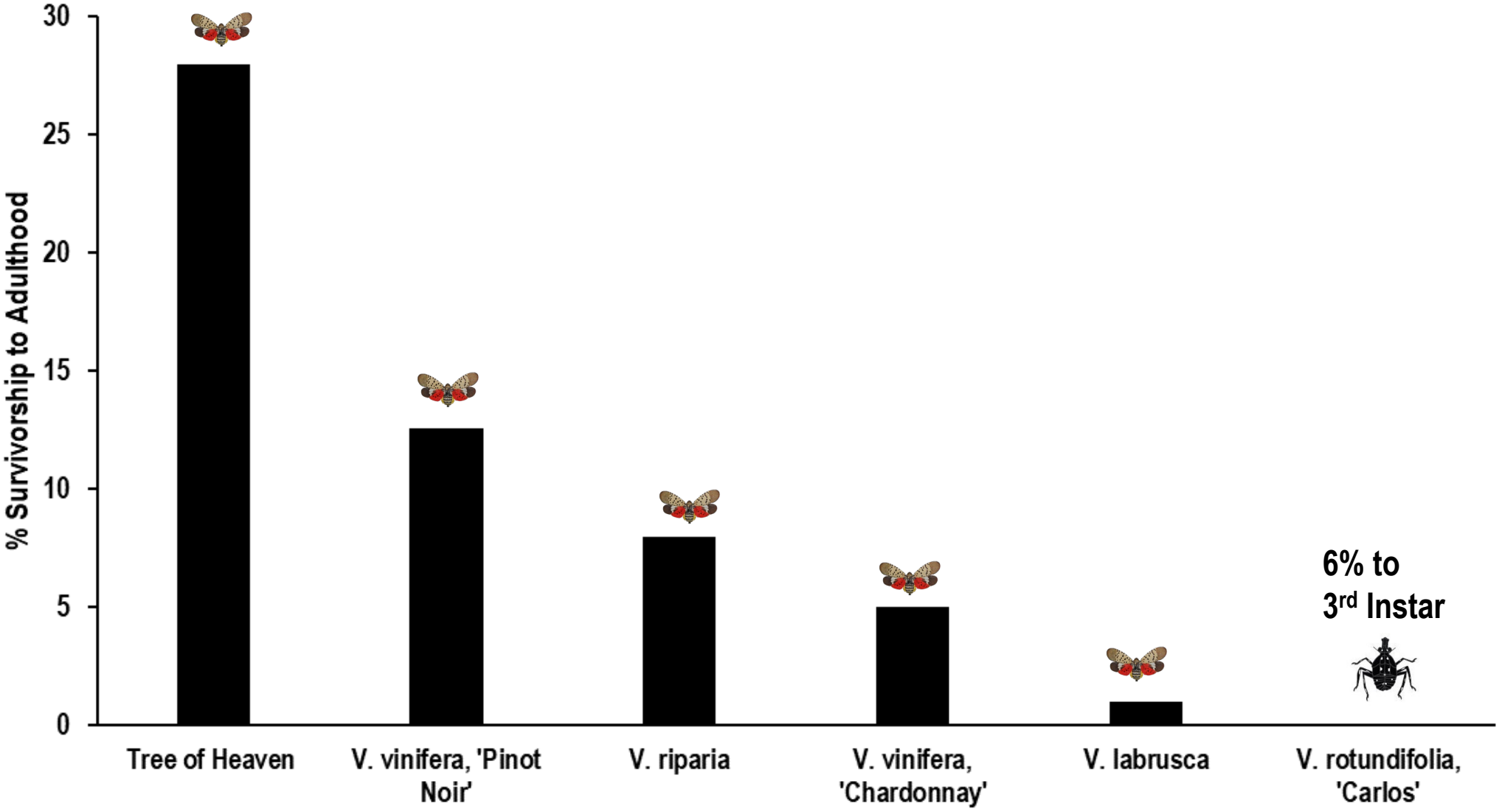
TOH, *V. vinifera* and *V. riparia* supported SLF developm[illegible] to adul[illegible] stage. *V. labrusca* and *V. rotundifolia* appear to be poo[illegible]



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Question: Does SLF feeding impact young apple and peach trees?

2nd-leaf peach and apple

2 treatments alternated among the cages (n = 45)

2021: Jun, Jul, Aug, Sep, Oct
2022: Mar, Apr, May, Jun, Jul, Aug, Sep
Spring 2023

SLF-infested: Early instar → Late instars → Adults

Control: *No SLF present*


All tree planted in field blocks in Oct 2021

Data collection
Weekly SLF survivorship
Monthly tree growth and photosynthesis attributes

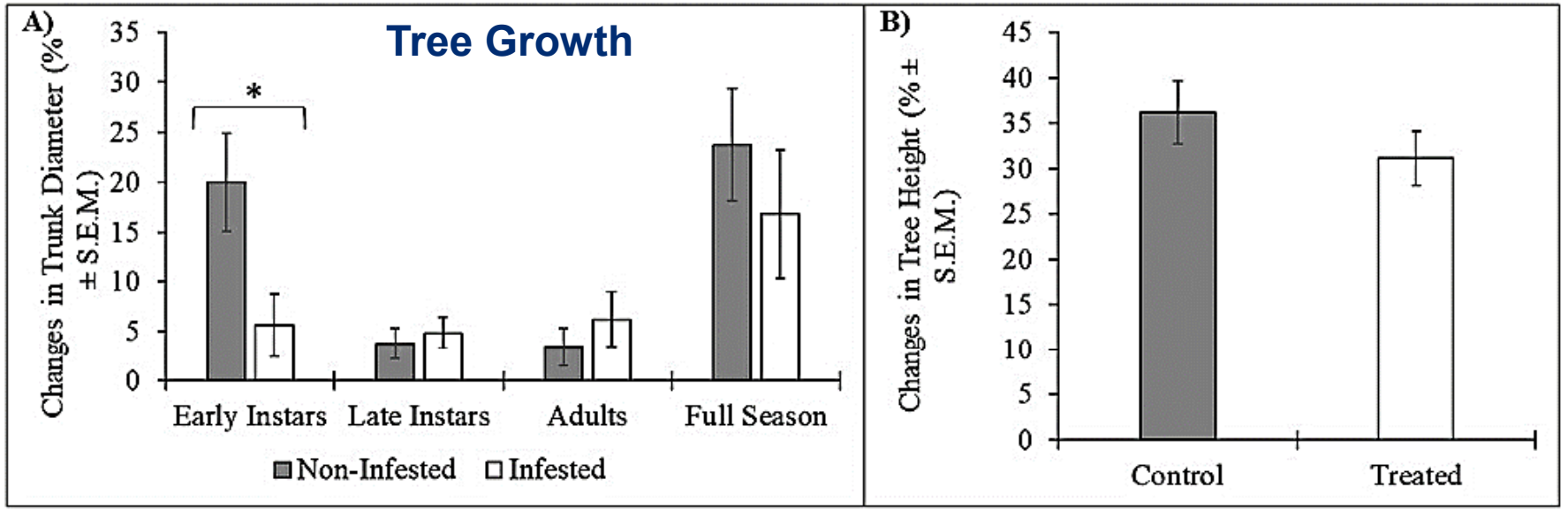
Frost damage evaluation
Dates of different bud/flowering stages

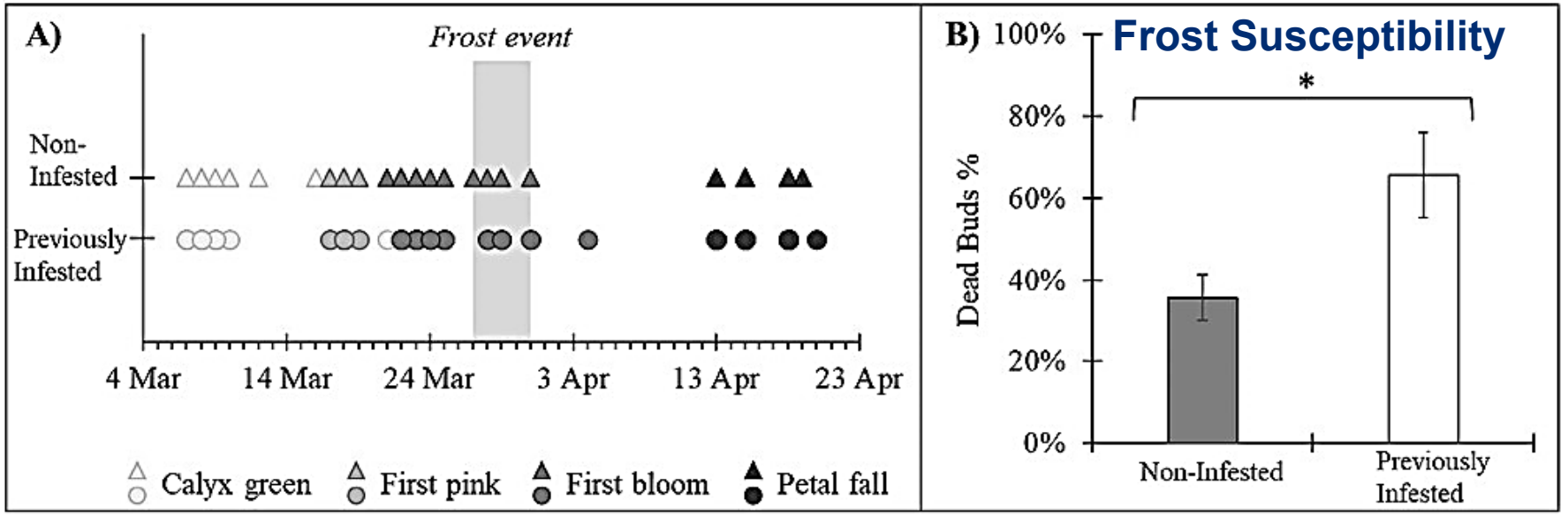
Tree growth and photosynthesis measurements

Frost damage evaluation

Spring Phenology

No Impacts on Apple, but Reduced Growth and Frost Susceptibility on Peach

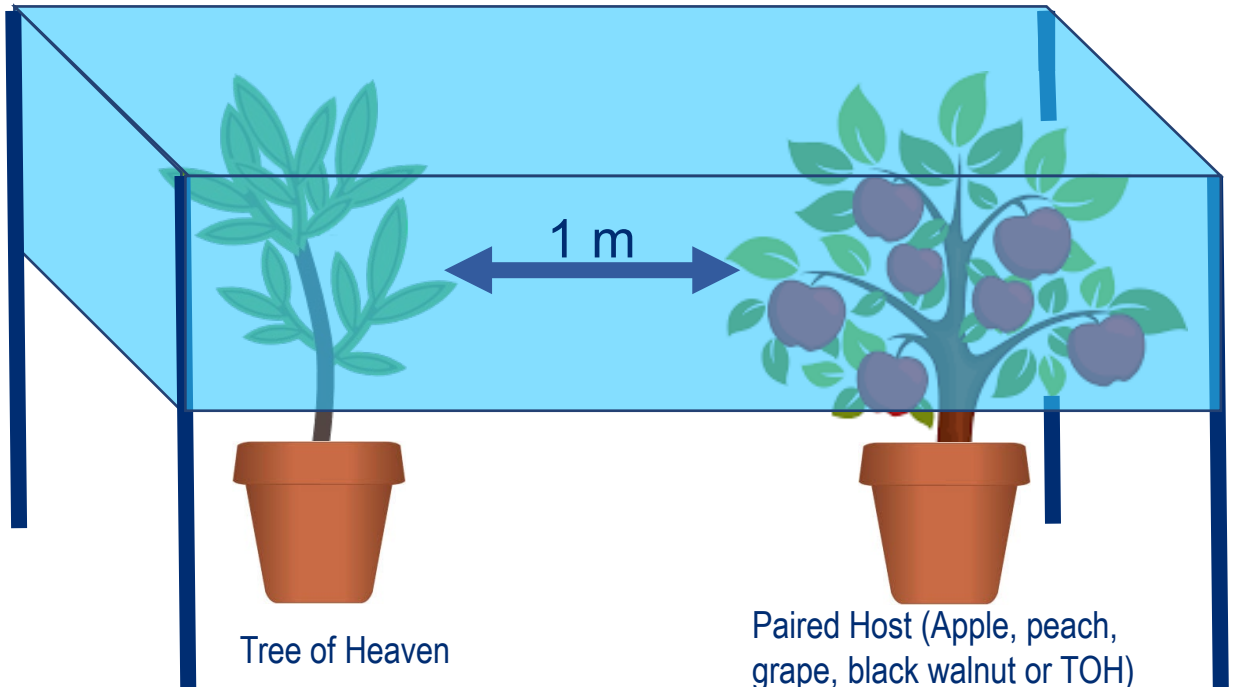




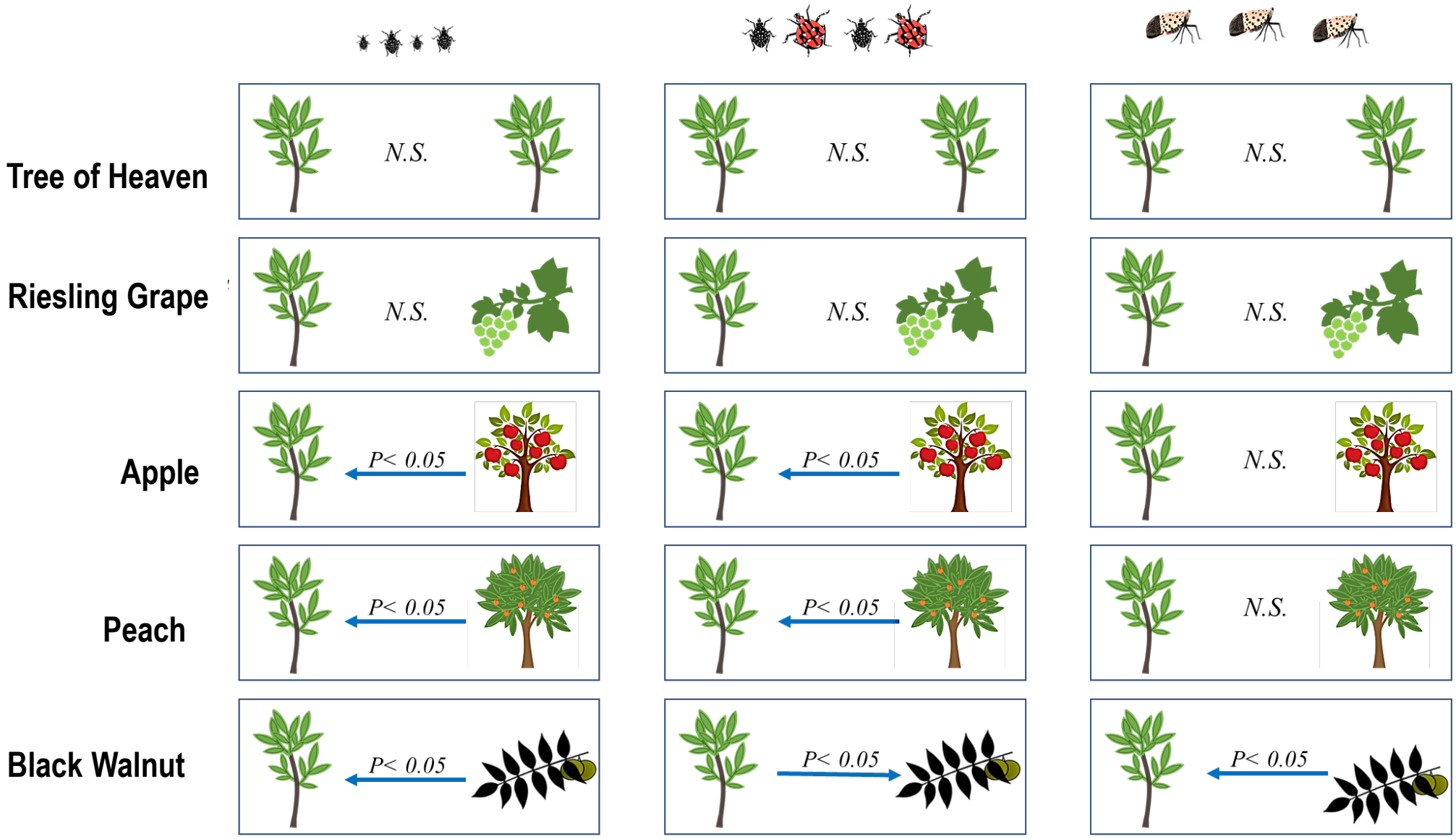
Nixon, L.J., C. Barnes, C. Wilson, A. Rugh, L. Carper, **T.C. Leskey** and L. Tang. 2023. **S**hort- and long-term effects of season-long infestation of *Lycorma delicatula* (Hemiptera: Fulgoridae) on young apple (*Malus domestica*) and peach (*Prunus persica*) trees. **Journal of Economic Entomology.** 11: 2062-2069.

Question: *How acceptable are key wild and cultivated host plants to SLF?*

- Double-sized shade cloth tents constructed.
- Host + TOH placed under the same tent, 1m apart.
- 15 SLF marked different colors released at the base of each.
- Retention on and movement between hosts measured at 1, 2, 4, 6, and 24 hrs.
- Evaluated early instars, late instars, and adults.



RESULTS

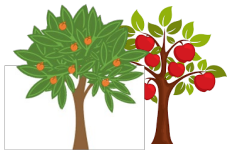

Tree of Heaven
Riesling Grape
Apple
Peach
Black Walnut
N.S.
P< 0.05

Host Plant Conclusions

- Tree of heaven is a highly acceptable host across all lifestages.

- *Vitis vinifera* is a highly acceptable host and vulnerable crop. *Vitis riparia* is a good host as well. *V. rotundifolia* is not.

- Overall, black walnut is a very suitable host for nymphal lifestages and a preferred host for late instars. Adults disperse from this host and do not survive well on it.



- Apple and peach trees are not particularly acceptable hosts for SLF, although all lifestages can be observed feeding on these plants.

- Overall, the mid-Atlantic landscape and host plants likely has favored establishment and spread.

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Spotted Lanternfly (SLF) Is An Invasive Landscape Level Pest

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Strong Dispersers: Potential For Human-Assisted Transport of Eggs

DO YOUR PART TO HELP STOP THIS INVADER!

Look before you leave! Please confirm that you have inspected any of these items and related objects that appear on the list below before traveling or transporting them from the quarantine area (check all that apply).

❑ **Vehicle**
- Bumpers and wheel wells
- Under and inside vehicle
- Windshield wiper area

❑ **Recreational or Camping Items**
- Backpacks
- Bicycles
- Boats/boat trailers
- Campers
- Ice chests
- Motor homes
- Motorcycles
- Recreational vehicles
- Snowmobiles
- Sports equipment
- Tarps
- Tents
- Other_____

❑ **Children's Playthings**
- Bicycles, scooters
- Kiddie pools
- Playhouses
- Sandboxes
- Yard games
- Other_____

❑ **Outdoor Household Items**
- Barrels
- Cardboard or wooden boxes
- Firewood
- Outdoor furniture/lights
- Outdoor poles
- Plant containers
- Propane or oil tanks
- Refrigerators/freezers
- Shutters
- Storage sheds
- Storm/screen doors and windows
- Trash cans
- Window awnings
- Other_____

❑ **Building Materials**
- Brinks/cinder blocks
- Cement mixing tubs
- Lumber
- Pipes
- Roofing materials
- Skid steers/forklifts
- Tools and toolboxes
- Workbenches
- Other_____

❑ **Yard and Garden Items**
- Backhoes
- Barbecue grills
- Carts
- Cold frames
- Dog houses, rabbit sheds, chicken coops, etc.
- Fencing
- Garden tillers
- Garden tools
- Lawnmowers
- Sign and posts
- Storage sheds
- Tractors and trailers
- Trees, shrubs, and plants
- Yard decorations
- Other_____

Check yourself before getting into any vehicle to make sure there are no spotted lanternfly nymphs or adults on you.

If you find any life stage of spotted lanternfly, destroy them immediately. For egg masses, be sure you crush all eggs evenly. Alternatively, all life stages of spotted lanternfly can be placed permanently in a container with rubbing alcohol or hand sanitizer to destroy them.

By signing this checklist, I am confirming that I have inspected my vehicle and those items I am moving from the spotted lanternfly quarantine area, and I do not see any spotted lanternfly egg masses or other life stages in or on anything I am moving.

SIGNATURE _____ DATE _____

ADDRESS _____

Please sign, date, and keep this checklist in your vehicle, and use it each time you need it. For more information and to see the latest map of quarantined counties, visit **agriculture.pa.gov/spottedlanternfly**.

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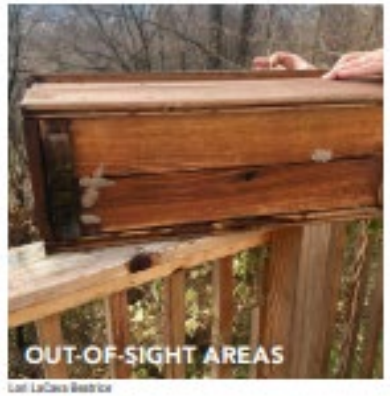

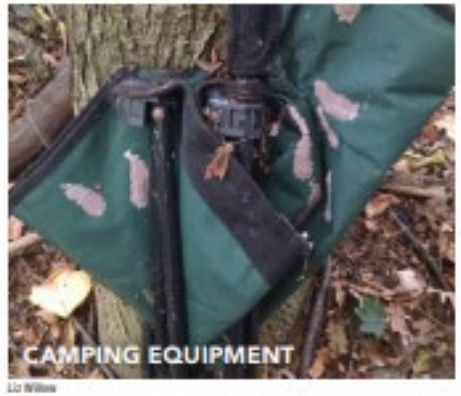

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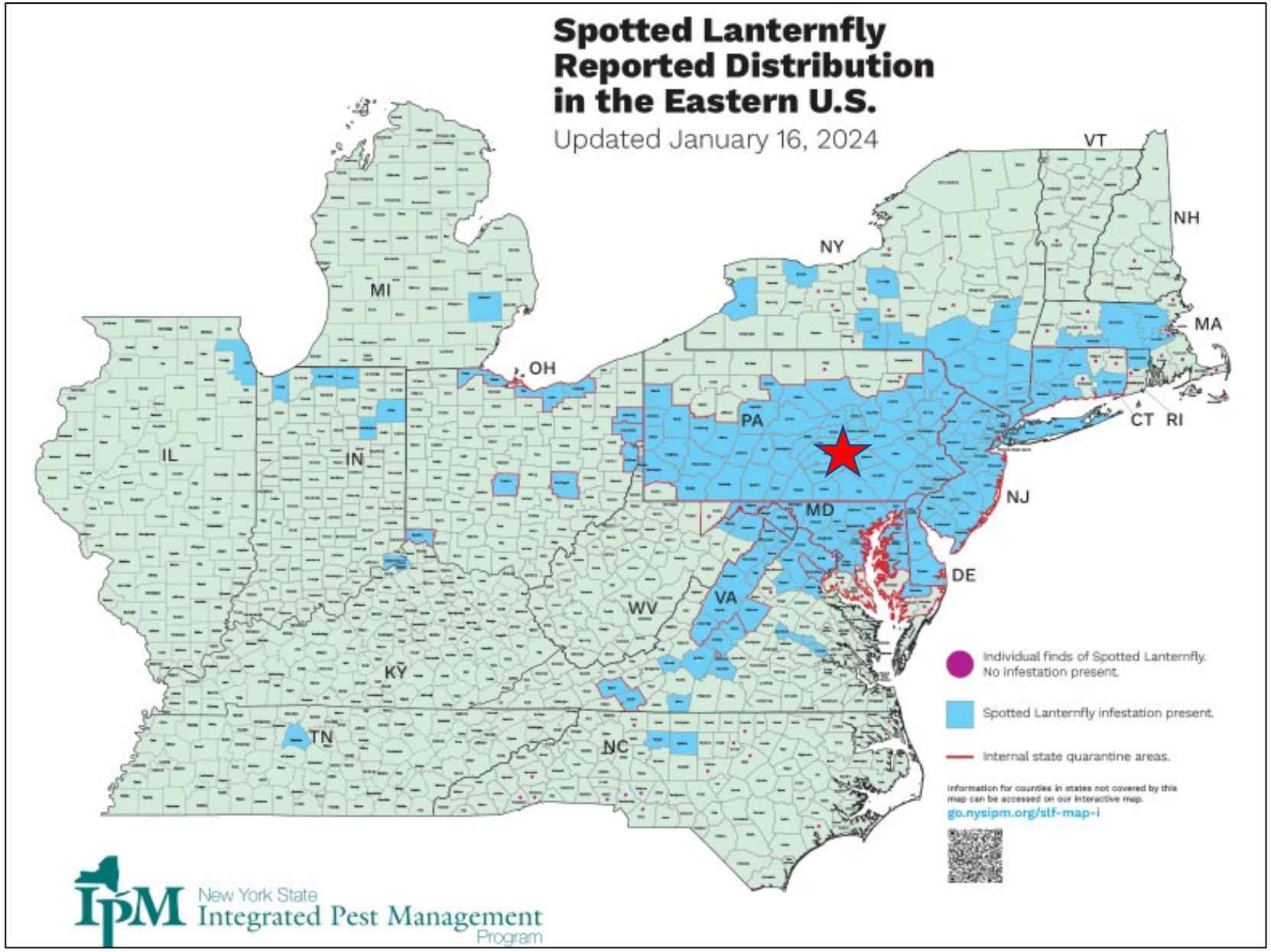
Current Known Distribution of SLF in the USA



- Distribution and spread following major highways, interstates and railroads.
- New populations often detected in urban centers.

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Threat from Mobile Lifestages: Presence of Adults at Local Railroad

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Human-Assisted Dispersal of Invasive Insects

- Long historical record of human-assisted dispersal in cargo, plant material or as passengers on planes, trains, ships and vehicles.

- Examples such brown marmorated stink bug, emerald ash border, spongy moth, and Asian long-horned beetle.

OUR KEY QUESTION Could accidental hitchhiking by SLF on vehicles be an important dispersal mechanism and pathway for spread?

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Development of Human Assisted Dispersal Bioassay

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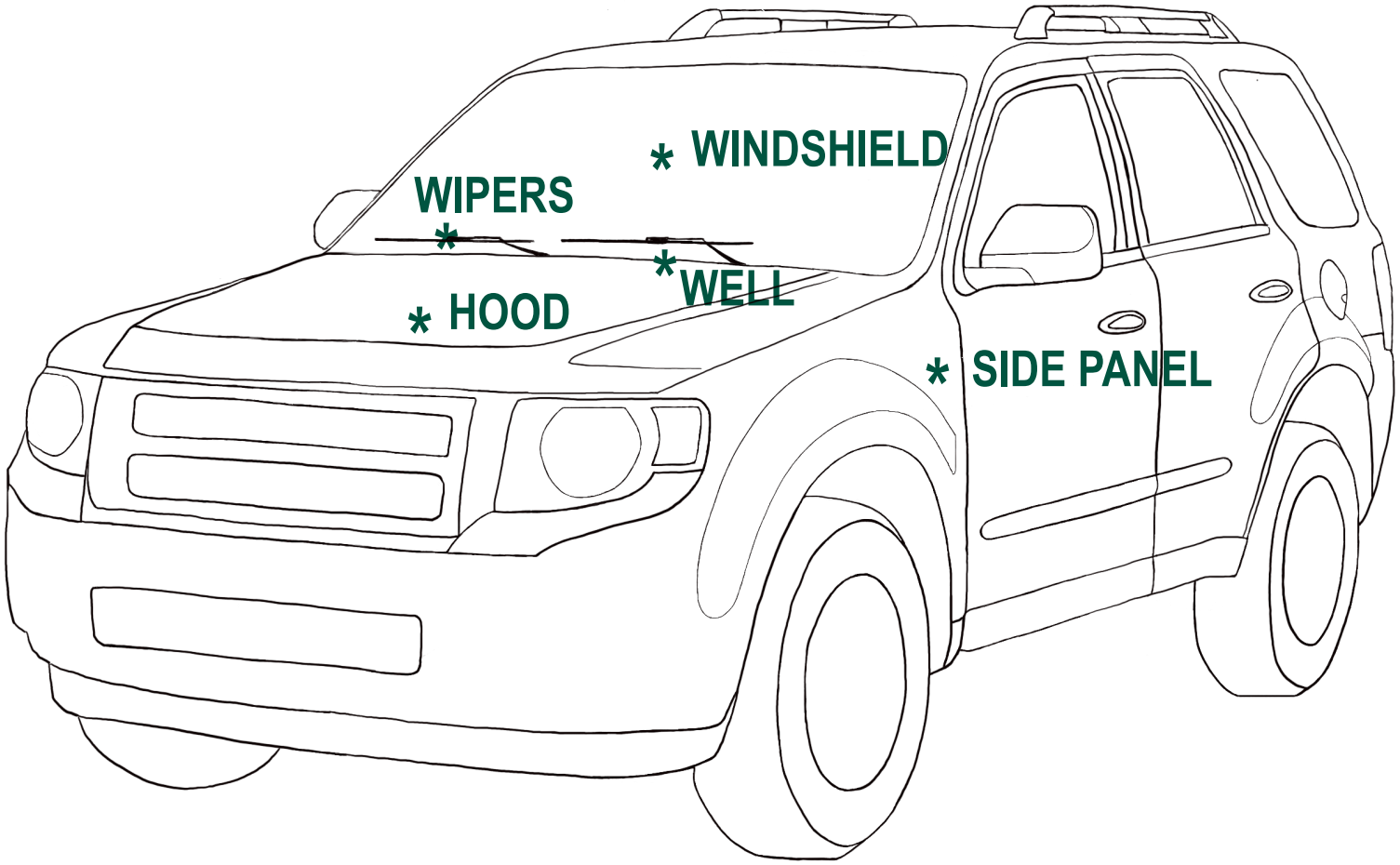
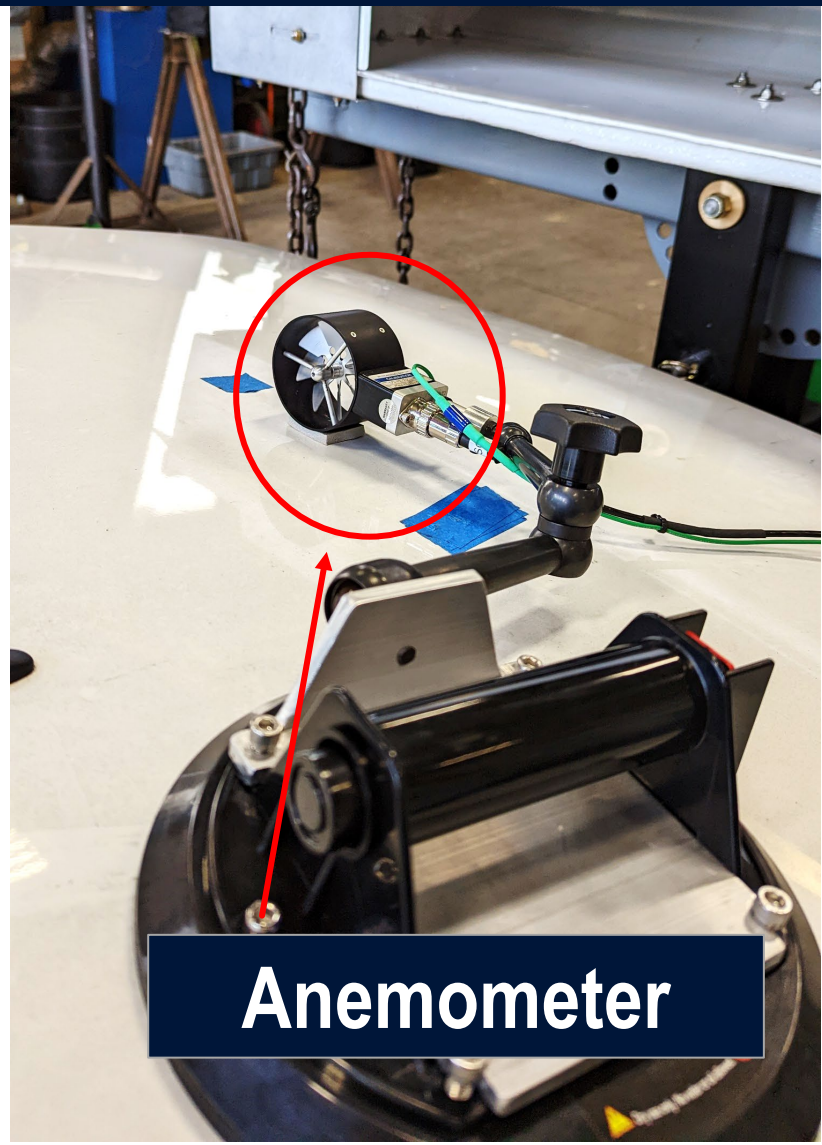
Question: Can we create a system that will enable us to understand the impact of hitchhiking, i.e., human-mediated dispersal, on spotted lanternfly spread? Can we measure adhesion and dislodgement by hitchhikers?





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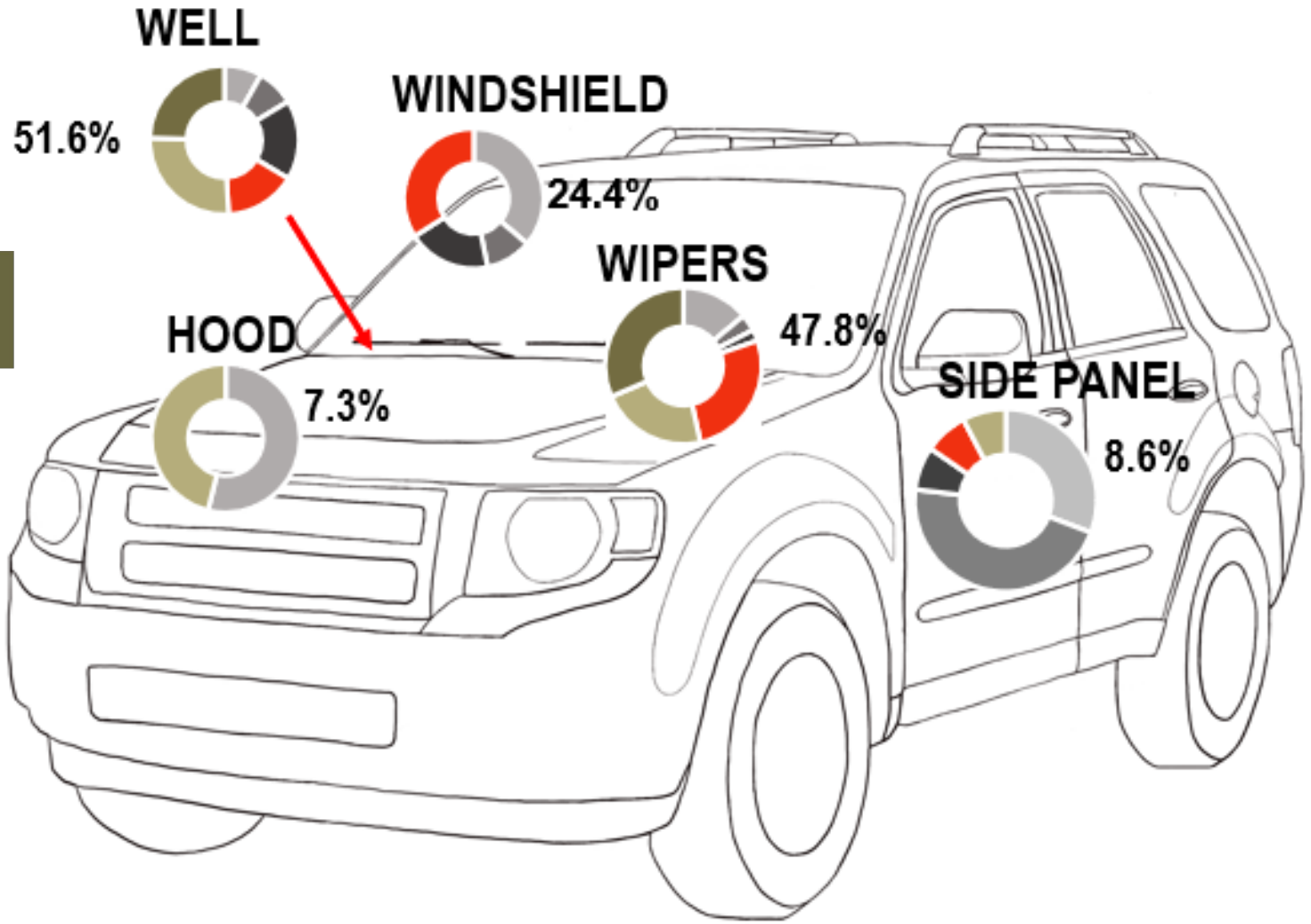
Percent of Each Lifestage Reaching Max Wind Speed

1ST 2ND 3RD 4TH Early Adult (August) Late Adult (October)

Nymphs



Tentative Conclusions

- All life stages were able to reach maximum wind speed at some locations on the vehicle. Human-assisted transport a likely mode of long-distance dispersal.

Elsensohn Johanna E., Wolford Scott, Tabb Amy and Leskey Tracy 2024 Experimental evidence supports the ability of spotted lanternfly to hitchhike on vehicle exteriors as a mechanism for anthropogenic dispersal R. Soc. Open Sci.11240493

Need for Sensitive Monitoring Tools

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Trapping Studies Conducted in VA and PA

Question: ***Based on their negatively gravitactic dispersal behavior, can we identify a trap type that reliably captures SLF adults and nymphs and the fewer non-targets than standard sticky bands when deployed on SLF host trees?***

Standard Sticky Band	Circle Trap Designs		
			
	Polyester Screen Base and Small Collection Device (Small Circle)	Polyester Screen Base Large Collection Device (Modified Circle)	Wire Screen Base and Large Collection Device (TR290)

Nixon et al. 2020. Environ Entomol. 49:1117–1126.

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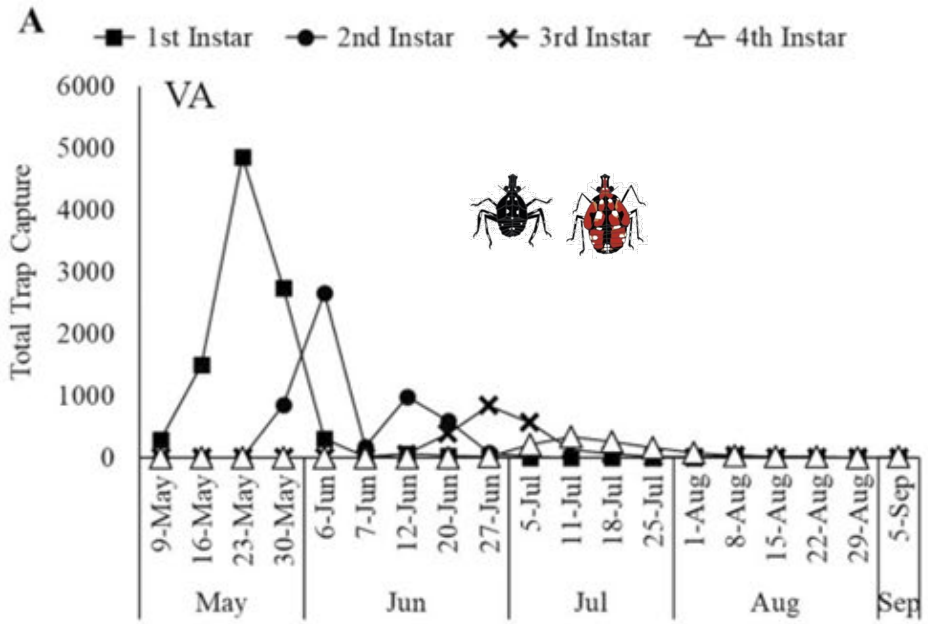
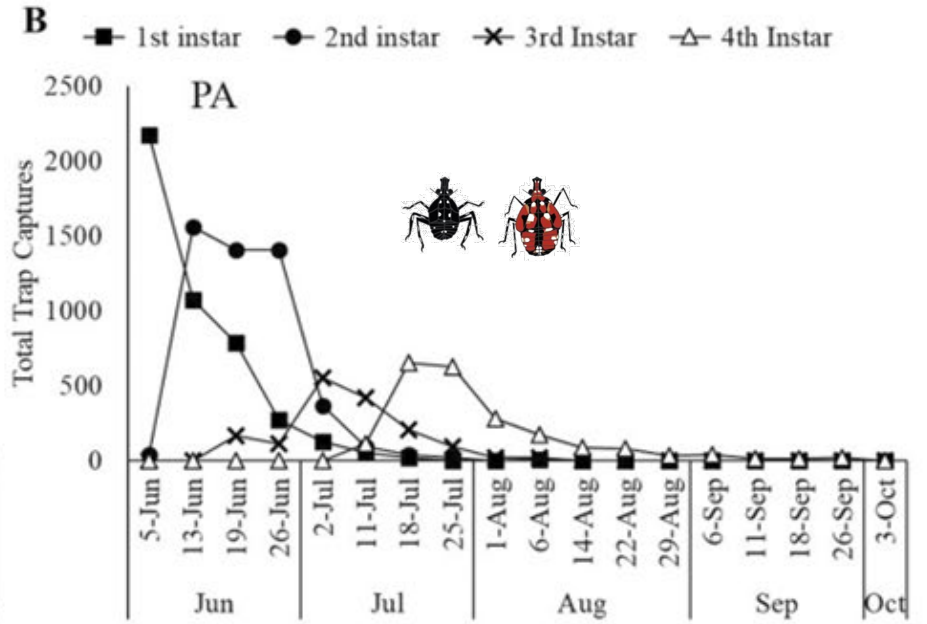
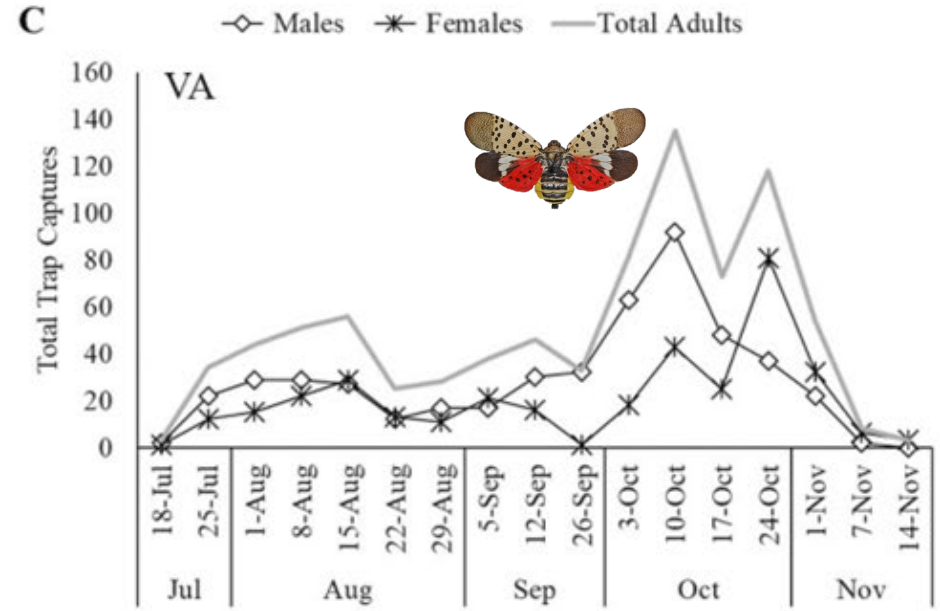
Phenology of Total Trap Captures

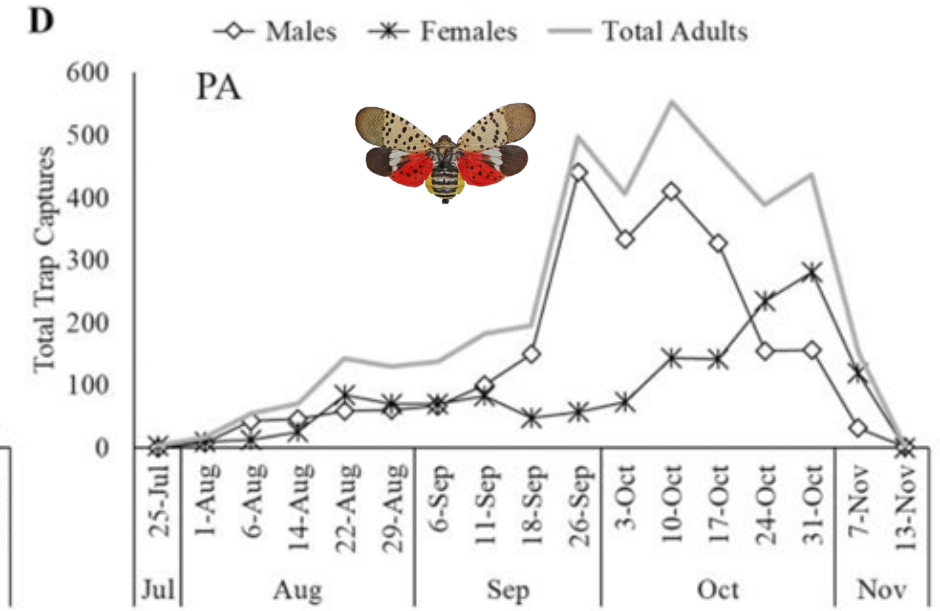
Key Results and Implications: Nymphal presence detected from May-August and adult presence from late July-November. With each progressive lifestage, captures decline.

When SLF are present, unbaited traps do provide information on relative density and phenology.









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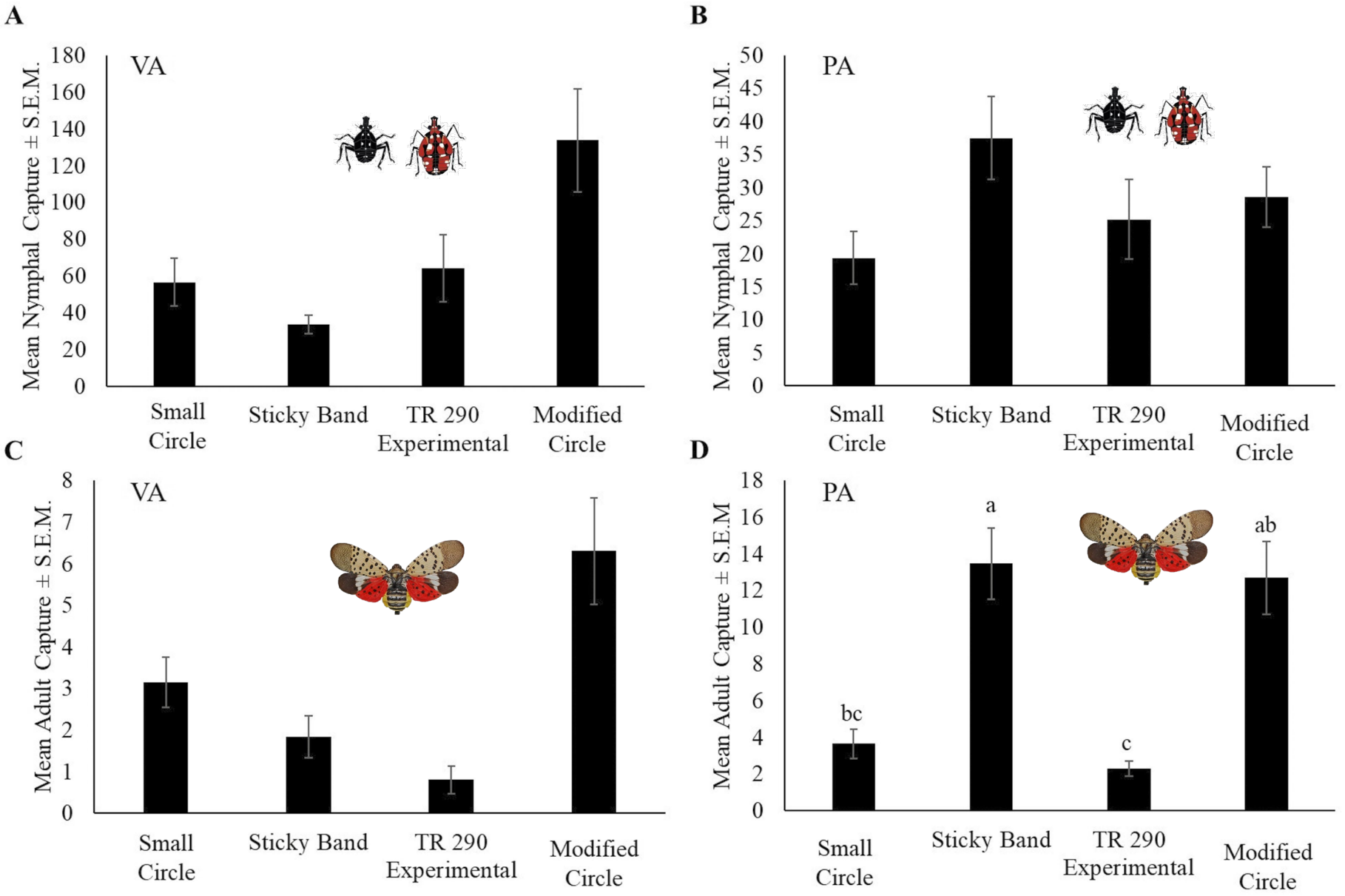
SLF Captures By Trap Type

Key Results and Implications: All trap types captured both nymphs and adults, but greatest captures generally with modified circle trap with larger collection device and sticky band.

Circle traps with large collection device worked best.



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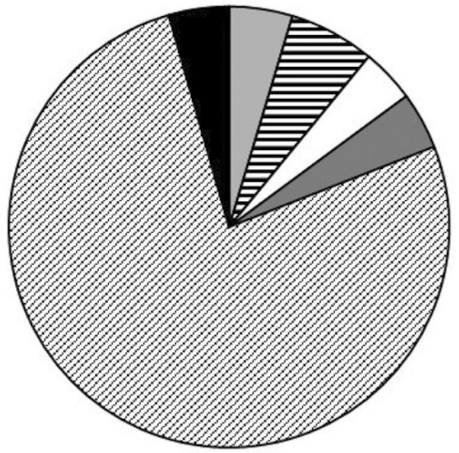
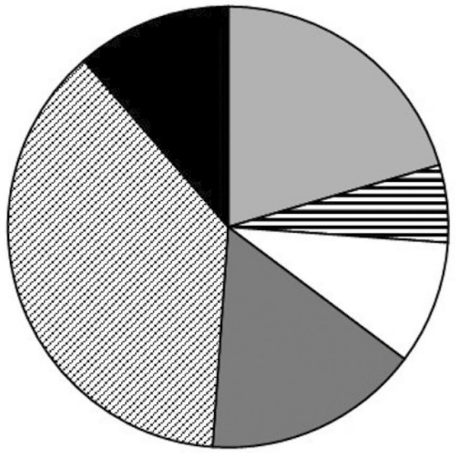
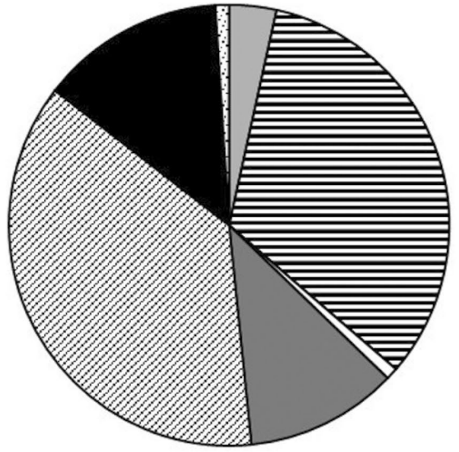
Non-Target Captures By Trap Type

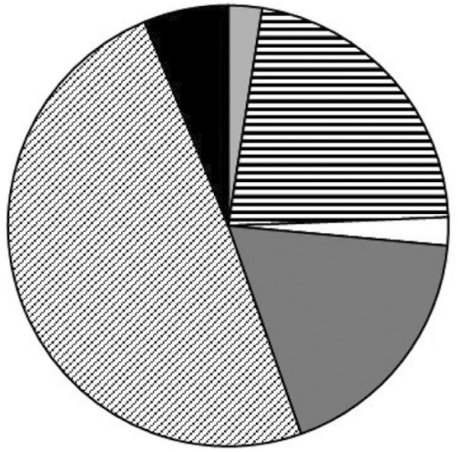
Key Results and Implications:
Sticky bands captured greatest non-target captures.

To reduce non-target captures, deploy circle traps.



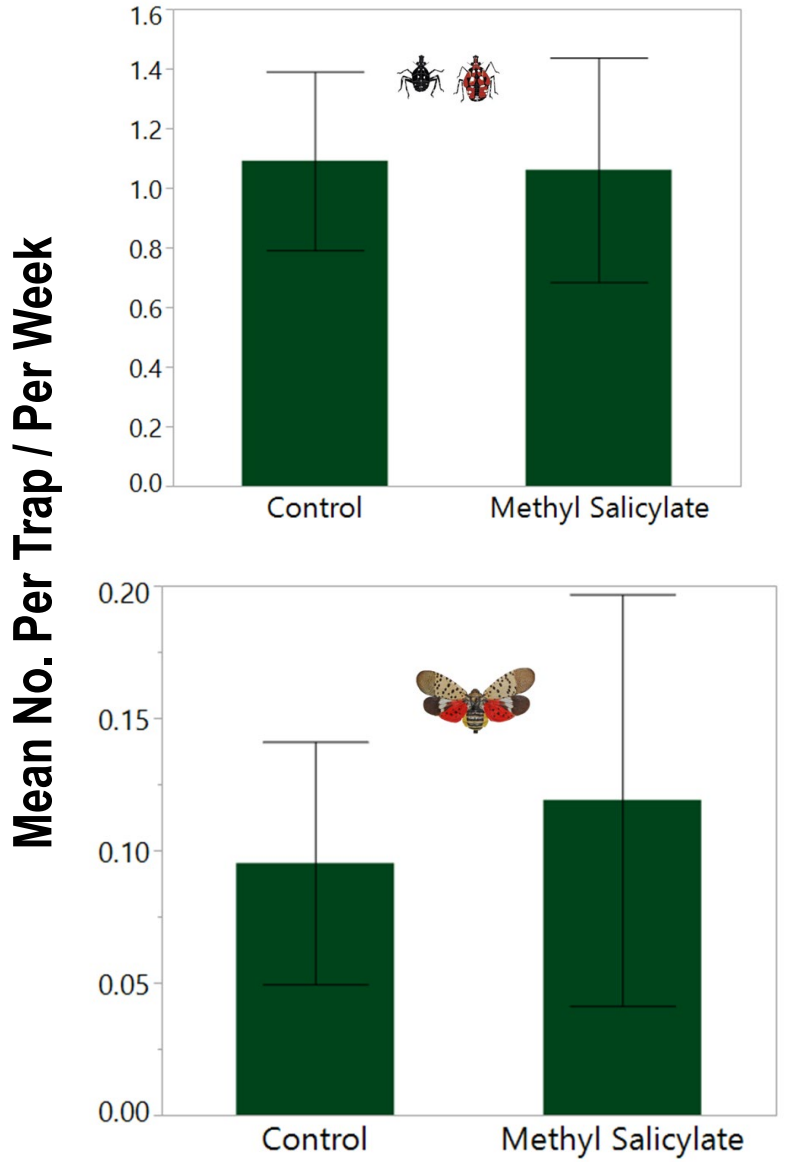






Coleoptera Diptera Lepidoptera Hemiptera Hymenoptera Arachnids Vertebrates

Commercially Produced Circle Traps Available But No Attractants Available



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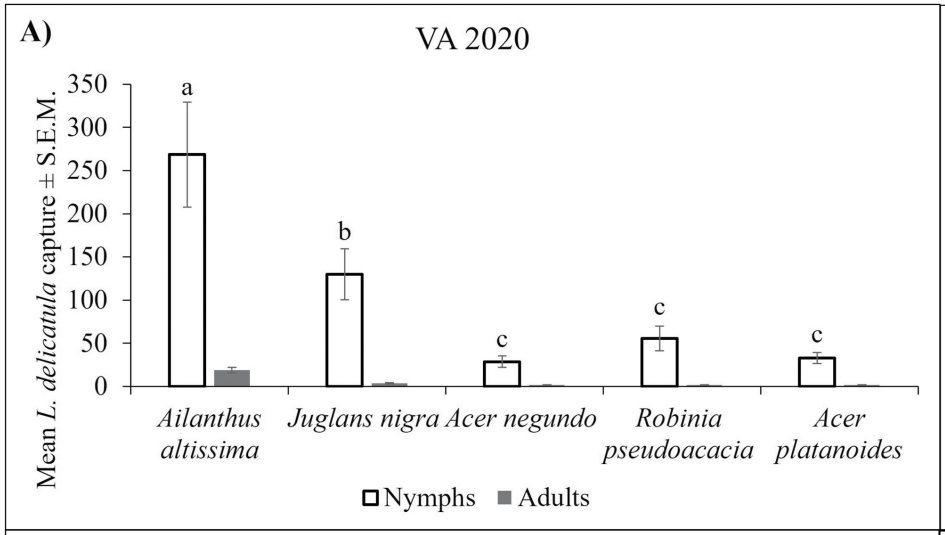
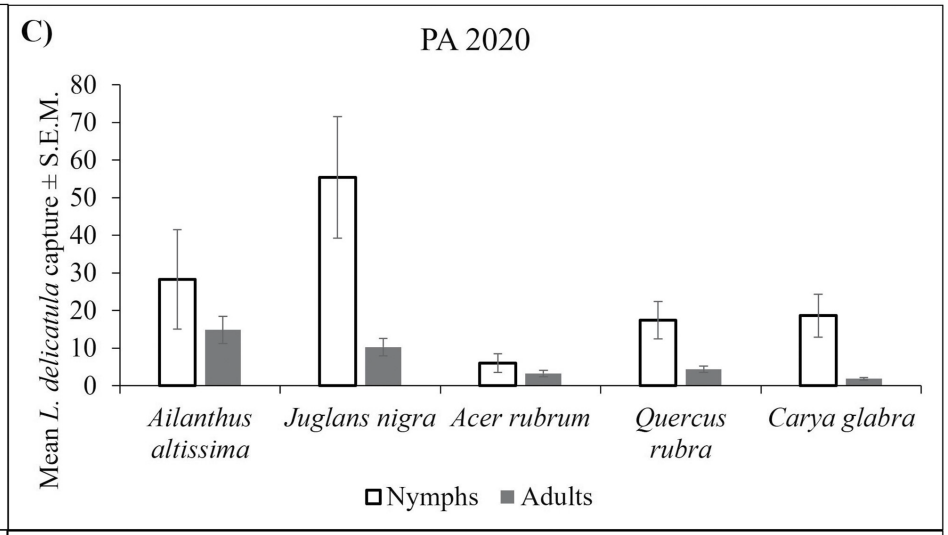
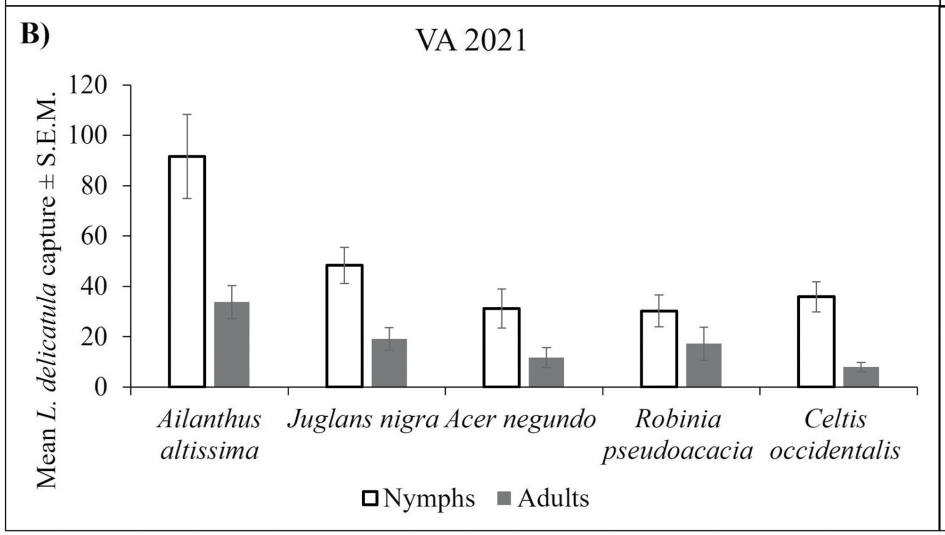
Host Tree Deployment

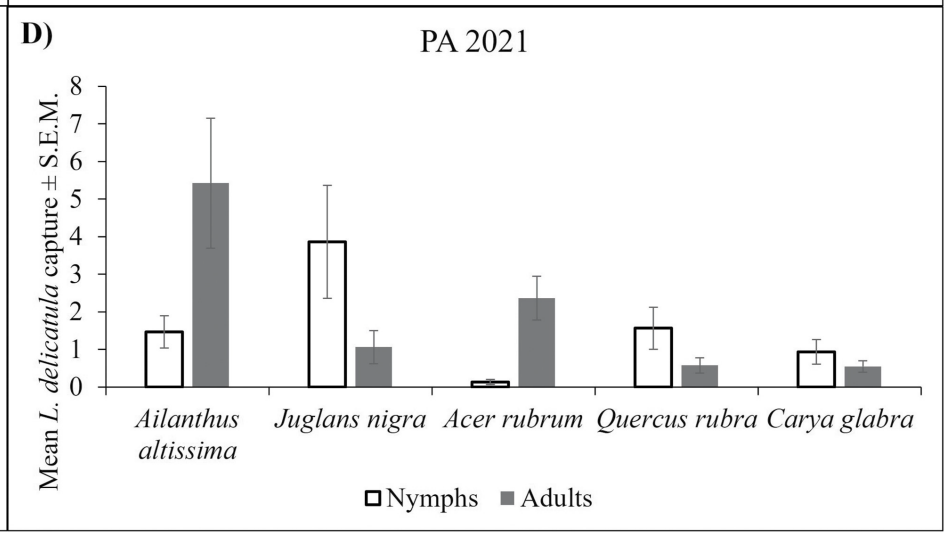
Key Results and Implications: All hosts captured some SLF nymphs and adults, but tree of heaven and black walnut were generally best.

If available, deploy on tree of heaven followed by black walnut for greatest likelihood of SLF captures.



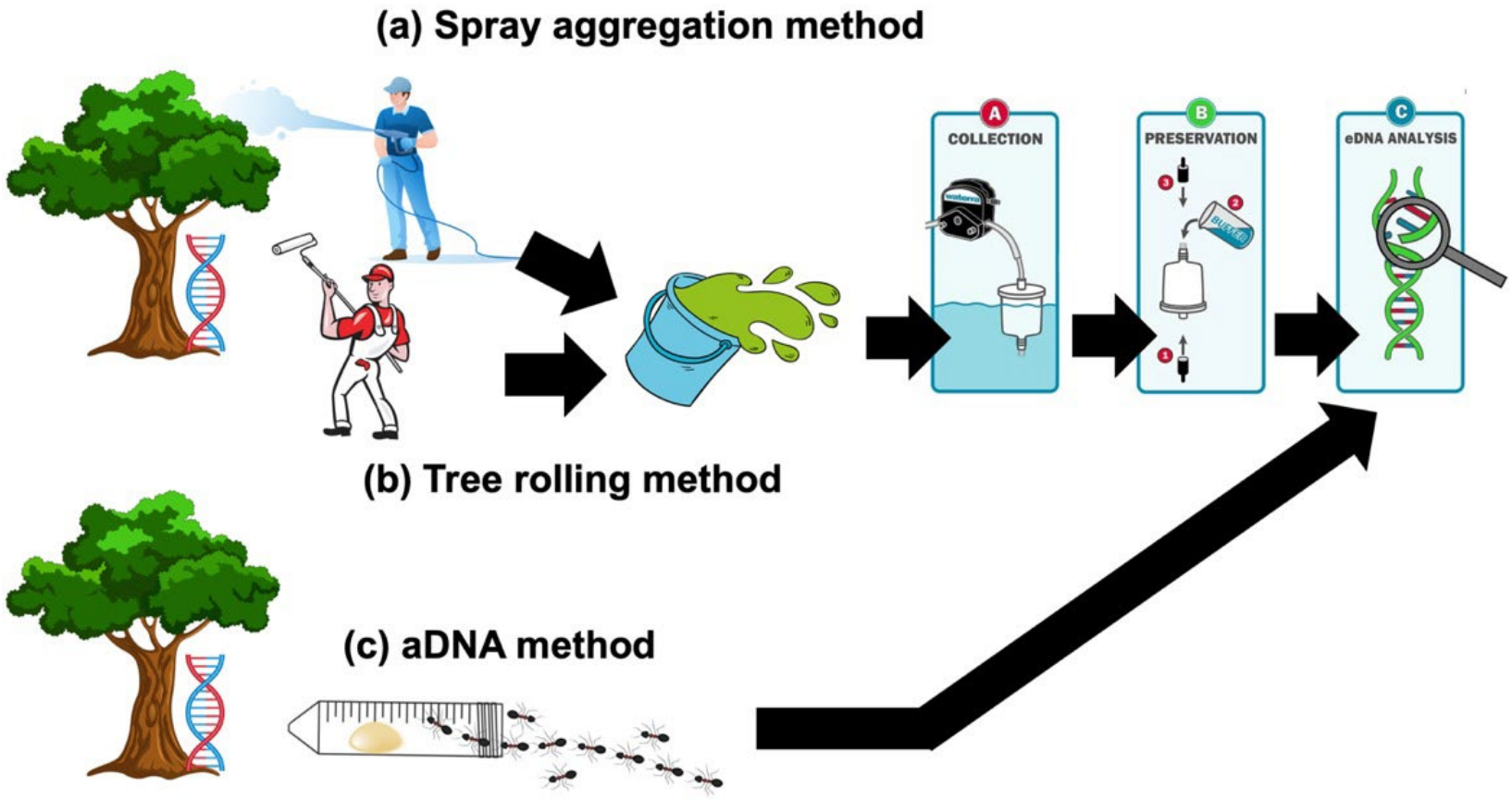






Using Environmental DNA Left Behind by Target Organism For Detection

Environmental DNA (eDNA) left behind by foraging SLF is collected by rinsing plant where low levels of DNA may be present, concentrating the DNA for extraction, qPCR and Nextgen sequencing. But, easily degraded by abiotic factors and very labor-intensive. Using ants and their honeydew feeding has led to new method referred to as aDNA.



Yang et al. unpublished

Results of Vineyard Monitoring with eDNA, Visual Survey and Traps

Timeline of Infestation of Experimental Vineyard at AFRS, Kearneysville, WV

1 Dead SLF

2019

+eDNA samples
-trap samples
-visual samples

2020

+eDNA samples
+trap samples
+visual samples

2021

+ Very Conspicuous SLF Populations in Unmanaged Areas

2022

2023

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Native and Classical Biological Control

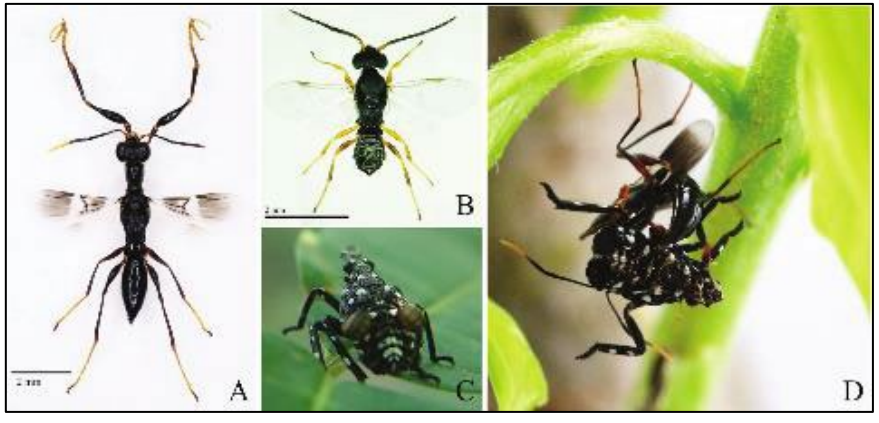
Life History and Rearing of *Anastatus orientalis* (Hymenoptera: Eupelmidae), an Egg Parasitoid of the Spotted Lanternfly (Hemiptera: Fulgoridae)

FREE

Hannah J Broadley ✉, Juli R Gould, Liam T Sullivan, Xiao-yi Wang, Kim A Hoelmer, Mauri L Hickin, Joseph S Elkinton

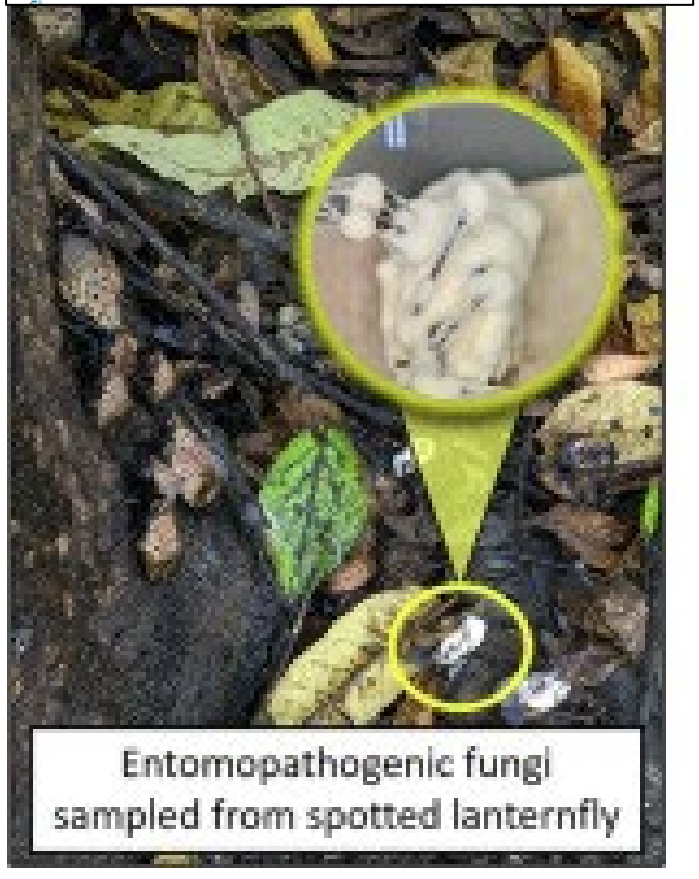
Exploratory Survey of Spotted Lanternfly (Hemiptera: Fulgoridae) and Its Natural Enemies in China

Bei Xin, Yan-Long Zhang, Xiao-Yi Wang, Liang-Ming Cao, Kim A. Hoelmer, Hannah J. Broadley, Juli R. Gould



Discovery of two hypocrealean fungi infecting spotted lanternflies, *Lycorma delicatula*: *Metarhizium pemphigi* and a novel species, *Ophiocordyceps delicatula*

Eric H. Clifton [a], ✉, Louela A. Castrillo [b], Ann E. Hajek [a]

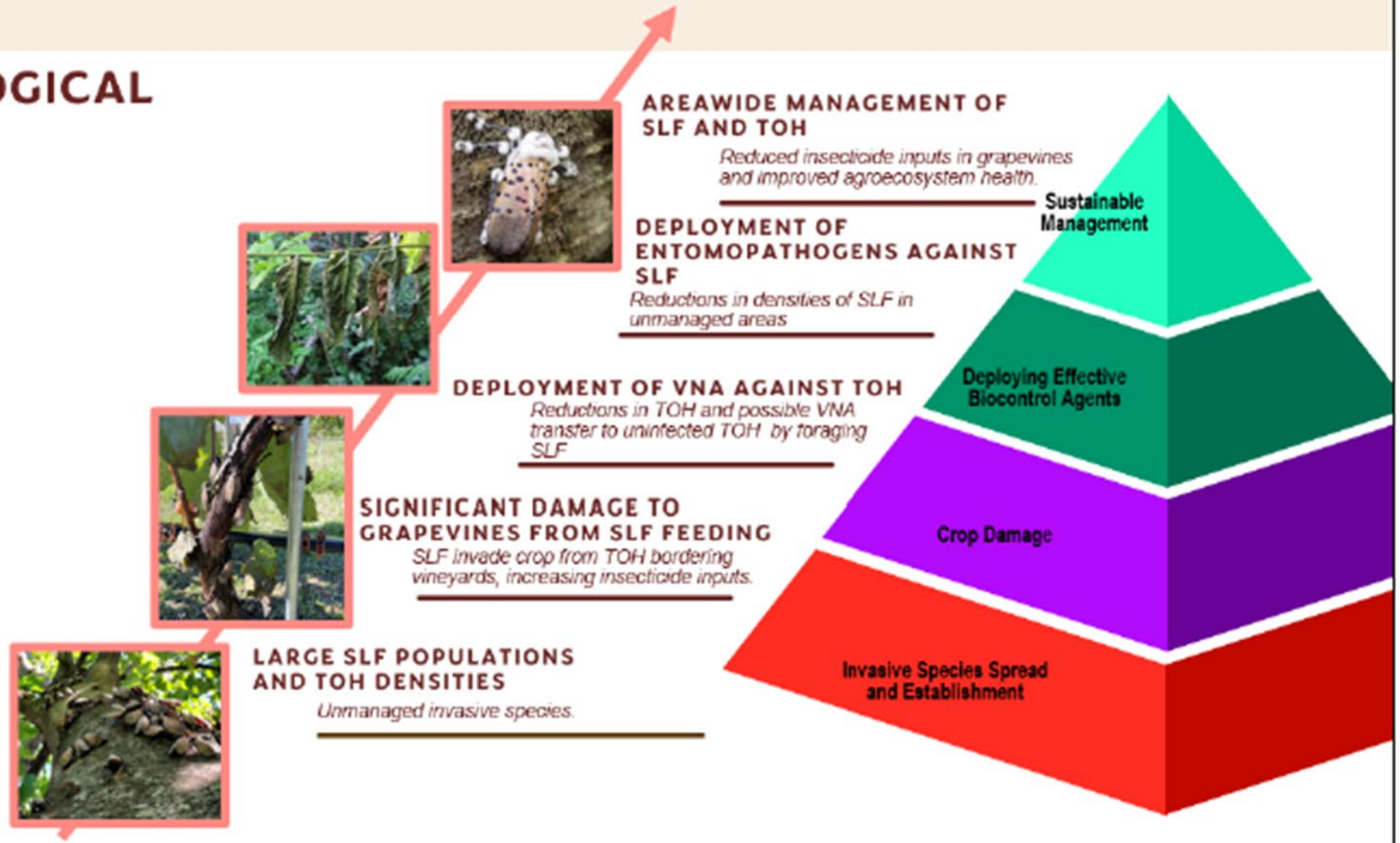


Areawide Management of TOH and SLF

LEVERAGING BIOLOGICAL CONTROL ACROSS TROPHIC LEVELS

PROBLEM: SLF utilizes TOH as a host. Because TOH is already widely distributed, SLF is rapidly invading new regions, establishing and causing significant damage to grapevines.

SOLUTION: Leverage VNA against TOH, and entomopathogens against SLF to simultaneously use biocontrol across two trophic levels and reduce populations of both invasive species.



Tentative Conclusions and Next Steps

- Circle traps can be used to detect SLF presence and relative abundance with less impact on non-targets. But no attractants available currently. aDNA looks promising
- Biocontrol and Areawide management for SLF and TOH are active areas of research.
- We still need tools for management of SLF in vulnerable crops like grape. However, stone fruit not vulnerable.
    - Currently evaluating nymphal and adult thresholds using visual counts on grapevines. Already seeing yield declines.

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Acknowledgements

Thanks to Leskey Lab, USDA-ARS Project #8080-21000-032-000D, USDA-APHIS PPA 7721 and USDA-NIFA SCRI 2019-51181-30014

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