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2024 Spotted Lanternfly Research & Technology Development Meeting

October 16-17, 2024
Wooster, Ohio

Compiled by Gregory Parra, Phillip Lowe, and Judy Mannix

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2024 SPOTTED LANTERNFLY RESEARCH & TECHNOLOGY DEVELOPMENT MEETING

October 16 & 17, 2024

Ohio Agricultural Research and Development Center
Wooster, Ohio

Sponsored by

The Ohio State University
and
U.S. Department of Agriculture
Animal and Plant Health Inspection Service

Compiled by

Gregory Parra[1], Phillip Lowe[1], and Judy Mannix[2]

[1]USDA Animal and Plant Health Inspection Service (APHIS),
Plant Protection and Quarantine (PPQ), Raleigh, North Carolina
[2]USDA Forest Service, Milwaukee, Wisconsin

FORWARD

The spotted lanternfly (SLF), *Lycorma delicatula* (White, 1845), a fulgorid phloem feeder, was discovered in Berks County, Pennsylvania, in September 2014. As of 2024, SLF also occurs in 17 other states: New York, New Jersey, Virginia, Maryland, Delaware, West Virginia, Connecticut, Massachusetts, Ohio, North Carolina, Rhode Island, Indiana, Michigan, Illinois, Tennessee, Kentucky, and Georgia.

As funding from various sources became available for SLF technology development and research, several Federal, state, provincial, and university groups became involved. The meeting in Wooster, Ohio, was an effort to pull together the many groups involved, including U.S. Department (USDA) Animal and Plant Health Inspection Service (APHIS) Plant Protection and Quarantine (PPQ) field staff and state cooperators, in a forum where they could share research and technology development outcomes and interact. The purpose of the meeting was to address Goal 2 of the SLF Strategic Plan: Support continued scientific research toward practical management and risk mitigation; Objective 2: Enable communication and information sharing on key SLF research efforts to deliver practical tools for use. The abstracts in this report represent a robust response by the scientific community to the challenges offered by this invasive pest. In the future, this response aims to address the SLF problem effectively and equip operations with practical tools to reduce long-distance spread and manage SLF.

Matt Travis
USDA APHIS PPQ
Emergency and Domestic Programs

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PRESENTATIONS

IMPACTS TO U.S. AGRICULTURE AND NATURAL RESOURCES

What Would Spotted Lanternfly (*Lycorma delicatula*) Life History Look Like if it Established in Stockton, CA?

Melody A. Keena

USDA Forest Service, Northern Research Station
51 Mill Pond Road, Hamden, CT 06514

melody.keena@usda.gov

ABSTRACT

Spotted lanternfly (*Lycorma delicatula*) is an invasive insect from Asia that was first found in the U.S. in Pennsylvania in 2014 and has since spread to 16 other states. Some of this spread is natural as the insect disperses to new areas adjacent to where it is already established, but every year there are new regulatory incidents that are not adjacent to current infestations. These long-distance movements typically occur when eggs are laid on vehicles (trains, cars, etc.) or materials that are stored outdoors and moved. Spotted lanternfly has had major impacts on Pennsylvania grape vines and there is a great concern that it will eventually be introduced to California where grapes are a major crop. Previous work on the thermal responses of spotted lanternfly has suggested that it may experience mortality and adverse effects if exposed to temperatures over 35℃ for extended periods of time. This study mimicked 2022 climate conditions in Stockton, CA, to estimate the effects of a warmer, drier climate (where grapes are grown) on spotted lanternfly. Nymphs were provided Concord grape vine and tree of heaven to feed on and were checked daily for molts or death. Adults were held four pairs (4 males and 4 females) to a large cage and provided maple bolts for oviposition. The spotted lanternfly successfully completed development in the Stockton, CA, climate regime. Nymphs went through the instars fairly quickly with mortality highest in the first and fourth instars. Weight at molt was comparable to what is seen under milder climatic conditions. The first adults were seen in June and adults lived an average of 58.0 and 69.0 days, for females and males respectively. The oldest female of the 60 individuals that were followed died at 102 days and the oldest male of the 53 that were followed died at 101 days. Oviposition began in late August and continued into November. Seventy percent of females laid an egg mass, and 32% of females laid more than one egg mass (up to 4 egg masses). The egg masses that were laid began to hatch March 25. First laid eggs hatched before later laid egg masses. Egg masses laid before or during the week-long heat wave with a 40℃ maximum temperature had lower percentage hatch than those laid later. The progeny that hatched were viable and were successfully reared to adult under the Stockton, CA, regime for use in another study. Because adults lived a long time and some females laid multiple egg masses, spotted lanternfly has the potential to increase in numbers more quickly in warmer climates like this where a fall freeze does not kill the adults before they would naturally die. The week-long heat wave that was simulated (40℃ maximum temperature) did not have a significant impact on survival but did appear to reduce egg hatch for eggs precent during that week, so the Stockton, CA, climate appears to be acceptable for spotted lanternfly establishment. Most of the oviposition occurred during the same time of year as it does where spotted

lanternfly has already established, so completing more than one generation in a single year is unlikely. Some precocious hatch did occur in November, but the fate of these first instars is uncertain.

Observations on Regional Variation in Spotted Lanternfly Female Reproductive Development

Julie M. Urban, Elena Gomez, Teresa Kaveney, and Holly Shugart

Department of Entomology, The Pennsylvania State University
501 Agricultural Science and Industries Building, University Park, PA 16802

jmu2@psu.edu

ABSTRACT

As the spotted lanternfly (*Lycorma delicatula*) expands its range in the Eastern U.S., it is encountering temperatures that are potentially beyond the range of those used to date to model its seasonal activity (e.g., Calvin et al. 2023). That is, our current understanding of spotted lanternfly phenology is based primarily on field studies conducted in eastern Pennsylvania (where spotted lanternfly has been present the longest), which use accumulated growing degree day estimations based on temperatures observed in that region to predict life stage transitions. Because spotted lanternfly's patterns of host plant use vary across its nymphal and adult life stages, expansion of its range into warmer regions and an associated increased rate of insect development are likely to result in patterns of host plant use that are similarly temporally shifted, compared to its current range. Particularly the late season movement of adult spotted lanternfly into vineyards (Leach and Leach 2020) or onto other hosts, upon which it appears to feed heavily and become reproductively mature (Calvin et al. 2023), may occur earlier in warmer regions. As such, we hypothesize that in warmer regions, heavy feeding and reproductive maturation are likely to occur earlier than in cooler regions, and that this could translate into greater impact on host plants due to longer, heavier feeding. We also hypothesize that in cooler regions, reproductive maturation is likely to occur later than in warmer regions and could translate into less impact on host plants due to shorter durations of cumulative feeding.

To test these hypotheses, we collected ~50 female adult spotted lanternfly from each of four collection sites across the northern/southern extent of its current U.S. range at multiple time points in the 2024 field season.

Collection Location	Collection Date (n = number of female insects collected)		
Kernersville, NC	July 9 (n=60)	Aug. 2 (n=53)	Aug. 28 (n=53)
Nashville, TN	July 7 (n=61)	Aug. 3 (n=51)	Sept. 5 (n=55)
Lewistown, PA		Aug. 11 (n=52)	Sept. 11 (n=54)
Rochester, NY		Aug. 16 (n=52)	Sept. 20 (n=51)

Note: no adult spotted lanternfly were collected in Lewistown, PA, or Rochester, NY, in July because field reports at those sites indicated adult emergence had not yet occurred or had only been recently observed with insufficiently high enough numbers of adults present to

warrant travel to the site to sample. Attempts were made to sample each site at approximately similar time points at ~ 1-month intervals, to the extent other time constraints allowed.

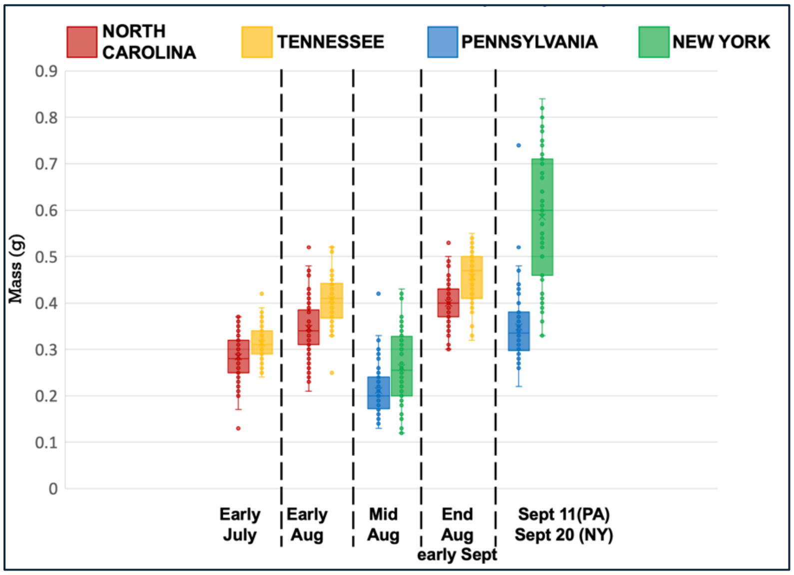

FIGURE 1. Box and whiskers plots showing female spotted lanternfly mass (mean depicted as line within box, and box showing 25th – 75th percentiles of distribution).

The live mass of each collected female spotted lanternfly was recorded and specimens were collected into ethanol, with each individual stored in its own separate vial in order to associate mass with subsequent dissections. In the present study, dissections have not yet been conducted. As such, the mass of the collected female adults serves as a proxy for relative degree of reproductive maturation and is also interpreted as somewhat of a proxy for relative degree of impact (i.e., reflecting cumulative amount of feeding or host depletion) on host plants at that site.

As expected, mean female mass (shown with its distribution in the box plots below per site and collection event) was higher in the southern sites (NC and TN) than in the northern sites (PA and NY) earlier in the season.

However, in the later season, the higher mean mass shown by females at the Rochester, NY, site was unexpected and counter to our hypothesis that in cooler regions, reproductive maturation (i.e., our proxy of increasing female mass) occurs later than in warmer regions. In order to better understand the observed mass distributions in light of accumulated growing degrees, the latter were estimated for each site and collection event using the U.S. Pest degree day calculator at: https://uspest.org/dd/model_app, using the simple average growing degree day calculation, general purpose degree-day calculator selecting the closest station to the collection site, a base threshold temperature of 10.4℃, and summing all growing degree days from Jan. 1, through the date prior to the collection date.

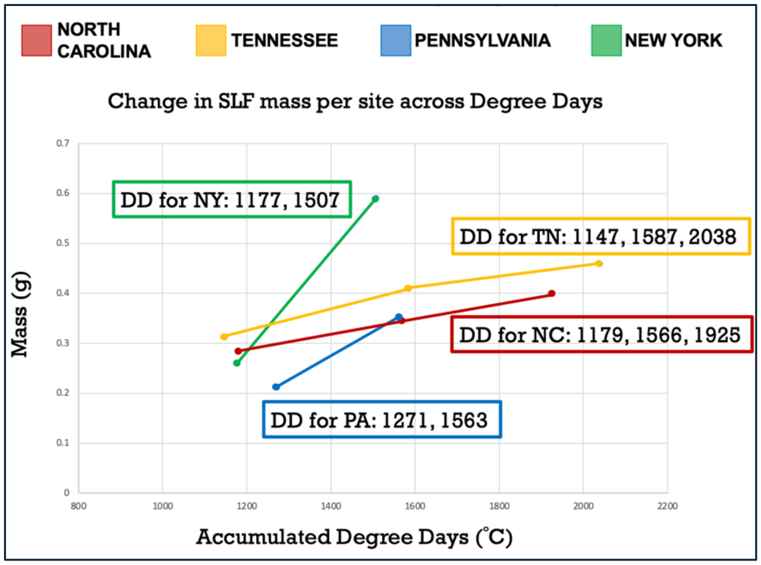

FIGURE 2. Rate of change in female mean mass by accumulated growing degree days.

The relatively steep slope shown for the Rochester, NY, sampled females, and the overall lower growing degree days accumulated at this site, even for the latest sampling date (Sept. 20) rejects our hypothesis that female development would be slowest at this site. Taken together, these preliminary results suggest that while cumulative feeding in warmer, more southern sites might be associated with larger impacts (resource depletion) in host plants than on hosts in the insect's current range where it has been studied most (i.e., in Pennsylvania), additional data are needed to further confirm this hypothesis. Preliminary results from Urban (2023, in preparation) show that the mass of female spotted lanternfly collected from the Kernersville, NC, site in 2023 continued to increase over time and females sampled later in that season (Sept. 16) were significantly heavier than those collected at that same site one month earlier (Aug. 20). As such, additional sampling is planned for the Nashville, TN, site in mid-October. Observed results from the Rochester, NY, population, however, were unexpected based on current models of spotted lanternfly phenology, and demonstrate the need for further work seeking to field-validate model predictions as its range continues to expand. Subsequent dissections will contribute further insights into the timing of spotted lanternfly mating and internal reproductive development from the insects sampled in the current study.

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Adult Spotted Lanternfly Weight is Correlated with Survival on Specialty Crops, Including Sauvignon Blanc var. Grapevine, Hops, Citrus, Avocado, and Fuzzy Kiwi

Holly Shugart, Teresa Kaveney, and Julie Urban

Department of Entomology, The Pennsylvania State University
501 Agricultural Science and Industries Building, University Park, PA 16802

Hxs5534@psu.edu

ABSTRACT

The invasive planthopper, spotted lanternfly (SLF, *Lycorma delicatula*), has expanded its range to 18 states (https://www.stopslf.org/where-is-slf/slf-map/), recently invading into the Midwest and as far south as Georgia. Spotted lanternfly is highly polyphagous, and as it expands to new habitats, it will encounter new cohorts of host plants. How SLF will interact with these new hosts will impact SLF survivability and the risk of establishment, as well as influence risks to forests, managed landscape, and a variety of specialty agricultural crops. As such, we are trying to learn as much as we can about which specialty crop hosts might be important for establishing new populations and which are at risk of damage from SLF feeding.

We tracked survivorship and adult female weight on two species of grapevine, *Vitis. Vinifera* var. Sauvignon Blanc and *V. rotundifolia* var. Black Beauty; fuzzy kiwi, *Actinidia deliciosa* var. Hayward; two varieties of hops, *Humulus lupulus* vars. Cascade and Centennial; citrus, *Citrus sinensis* var. Valencia; avocado, *Persea americana* var. Hass; and tree of heaven, *Ailanthus altissima*. Adult female SLF survived longest on grapevine, *V. vinifera* (26 days), fuzzy kiwi (26 days), and tree of heaven (22 days). Adult female SLF survived for significantly shorter durations on all other tested hosts; 3 days on avocado, Muscadine grapevine and Centennial hops, 5 days on citrus, and 8 days on Cascade hops.

We tracked the changes in SLF weight over time of adult females during the observation period better understand the interactions between SLF and their hosts more deeply than can be determined from observations of survival alone. In order to track the weight of individual female SLF over time, we first needed to uniquely identify each individual. Using the large size of the insect to our benefit, we simply wrote numbers (1–50) duplicated on each of their wings just in case the number became illegible on one of the wings. We used Sharpie™ oil-based paint markers. Both fine point and extra fine point worked for this purpose. Numbers were touched up as needed during weighing throughout the experiment. Once individually marked, we tracked the live weight of 50 young, field-collected females during the exposure and survival time on each host. Weights were taken every 2–3 days, during which time SLF were handled very delicately, and after which they were returned to their respective hosts. The mean starting weight of adult females used for survival and suitability tests was 0.289g. Adult females gained weight on only 2 hosts, tree of heaven (+0.069g), and *V. vinifera* grapevine (+0.062g). Adult females maintained their weight with no change

over the observation period on Muscadine grapevine. Adult female SLF lost weight on all other tested hosts, including fuzzy kiwi (-0.008g), hops var. Centennial (-0.032g), hops var. Cascade (-0.040g), citrus (-0.116g), and avocado (-0.040g). We found that weight changes in adult SLF measured while feeding on hosts, is directly correlated with survivorship on that host. Our data line up with the results from other studies in finding grapevine and tree of heaven to be the most suitable hosts as adult female SLF lived longest and gained weight on both hosts. Fuzzy kiwi is an example of a host on which SLF survive well, but are not thriving, and lose weight while feeding on the host (-0.008g). On all other hosts, we find that adult female SLF survive poorly and lose weight.

We assessed nymphal survival and development on citrus and avocado, as well as the resulting damage from SLF nymphal feeding. We collected early first instar SLF nymphs and caged 50 nymphs per tree. We used 8 experimental trees and 4 control trees for the citrus and avocado tests. Citrus trees were 5–6 ft tall, while avocado trees were 6–7 ft tall. Nymphal SLF survived 11 days on avocado trees, and 93 days on citrus. The citrus finding was unexpected, as this was the first documented case of nymphs completing their development on this host. A single previous study documents SLF nymphs surviving to early 3rd instar. In our observations on citrus, young nymphs fed voraciously and developed quickly. They then slowed down and were long-lived as 4th instars. Only a single adult male developed on our experimental citrus trees. At the end of our observations of SLF nymphs on citrus, the plants were very sticky and coated in copious quantities of honeydew. This could be of concern to growers if SLF arrives in areas growing citrus, such as California. Simultaneously, we tracked same-aged nymphs collected at the same time and caged on tree of heaven. We observed 4 cages of nymphs on tree of heaven. The tree of heaven cages contained more nymphs per cage compared to the citrus and avocado experimental trees, with 300–400 nymphs per tree. The tree of heaven trees were also much larger than the experimental tree. The comparison was made to track the rate of development on the experimental trees and have frame of reference to compare. We know that SLF nymphs develop well, complete their life cycle on tree of heaven, and survive and gain weight as adults on this host. Comparing tree of heaven and citrus, the first SLF 2nd instar emerged after 6 days on both hosts, the first 3rd instar emerged at 19 days on citrus and 16 days on tree of heaven, the first 4th instar emerged at 28 days on citrus and 34 days on tree of heaven, the first SLF adult emerged on citrus at 66 days and on tree of heaven at 43 days. Comparing SLF nymphal development on citrus and tree of heaven, we found that early instars develop slightly faster than on tree of heaven, but that diverges at the 4th instar, where it takes 23 more days on citrus to develop to an adult compared to nymphs developing on tree of heaven.

We have also had recent success in rearing SLF across generations in a quarantine greenhouse setting. To determine the vigor of female lanternflies held in greenhouse conditions, we collected adult female spotted lanternflies weekly beginning on Sept 7 and ending on Oct 26, 2023, from the same site in Pittsburgh, PA, and tracked mean changes in weights over time in a greenhouse environment. Insects were held on tree of heaven saplings with a mean trunk diameter of 4.665 cm. Though only female data is presented here, males and females were tracked, allowed to mate, and were given collected wood for deposition of egg masses. Resulting egg masses were collected, chilled at 5℃, then allowed to hatch. Offspring (F1- male and female) were marked once adult and individually tracked during the 2024 season. For 2023 cohorts, the mean weight was 0.331g, maximum weight was 0.577g, and the minimum weight was 0.163g. Females laid 168 egg masses in colony, with a mean of 31.5 number of eggs per mass. Greenhouse reared (F1) insects emerged as adults beginning on Apr. 23 and were heavier than similarly aged field-collected insects throughout the season. Greenhouse reared insects were longer lived compared to field-collected insects, with the oldest insect living 172 days as an adult. We found that spotted lanternfly can be successfully maintained and reared under greenhouse conditions, that insects will mate and lay eggs, and that these eggs can be hatched to develop into healthy and long-lived insects appropriate for use as laboratory specimens.

BIOCONTROL TECHNIQUES

Rearing, Life History Evaluations, and Host Range Testing of *Dryinus sinicus*, a Promising Biocontrol Agent of Spotted Lanternfly

Steven Sipolski[1], Corrine Losch[1], Devan Driscoll-Roach[1], Xiao-yi Wang[2], Liang-ming Cao[2], Xingeng Wang[3], Juli Gould[1], and Hannah Broadley[1]

[1]USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Science and Technology (S&T), Forest Pest Methods Laboratory Buzzards Bay, MA, U.S.A.

[2]Research Institute of Forest Ecology, Chinese Academy of Forestry Beijing, China

[3]USDA Agricultural Research Service (ARS), Beneficial Insects Introduction Research Unit Newark, DE, U.S.A.

steven.sipolski@usda.gov

ABSTRACT

Spotted lanternfly is an invasive species with a broad host range but is a particular pest of grapes. It was first detected in the United States in 2014 and since has spread to 16 additional states. Toward developing a management tool, the Forest Pest Methods Laboratory is evaluating the promising candidate classical biological control agent *Dryinus sinicus* (Hymenoptera: Dryinidae), a univoltine nymphal parasitoid of spotted lanternfly that is native to China. Our work is focused on developing and optimizing rearing methodology of *D. sinicus*, evaluating its life history characteristics, and testing its host range. To establish a colony of *D. sinicus*, we developed a multifaceted rearing strategy in which we propagate host plants (*Ailanthus altissima*), rear SLF nymphs from field collected egg masses to 2nd or 3rd instar nymphs to serve as hosts, and mate and rear *D. sinicus* parasitoids in our insect containment facility through their life cycle. We have been able to extend the *D. sinicus* rearing period from one generation a year with adults emerging only in early summer to three generations reared from February to November. Unfortunately, in 2024 large portions of subsequent generations of parasitoids entered a diapause which we are still working to better understand and break. However, we were still able to maintain a strong colony and produce over 1,000 cocoons this year. We have made significant progress toward evaluating the host range of *D. sinicus*. At the conclusion of 2024 we have completed no-choice testing on nine species of non-targets with six additional species in progress. No-choice tests have shown that many species experienced no non-target attack, although some species of planthoppers did experience some lower levels of host feeding (Table 1). We have not seen any parasitism or reproduction on a non-target to date. All species of non-targets that were attacked in no-choice testing will undergo choice testing, and in preliminary results we are seeing a decrease in non-target attack. Host range testing will continue into next year to acquire sufficient data to submit a petition for release.

Non-target species	Family	Group name	Status
Anasa armigera	Coreidae	Seed bug	No attack
Anasa tristis	Coreidae	Seed bug	No attack
Chinavia hilaris	Pentatomidae	Stink bug	No attack
Podisus maculiventris	Pentatomidae	Stink bug	No attack
Graphocephala atropunctata	Cicadellidae	Leafhopper	No attack
Paraulcizes irrorata	Cicadellidae	Leafhopper	No attack
Microcentrus perditus	Membracidae	Treehopper	No attack
Rhyncomitra microrhina	Dictyopharidae	Planthopper	Low rates of host feeding
Scolops sulcipes	Dictyopharidae	Planthopper	Low rates of host feeding
Acanalonia bivittata/conica	Acanaloniidae	Planthopper	Some host feeding
Flatormenis proxima/Metcalfa pruinosa	Flatidae	Planthopper	Low rates of host feeding
Poblicia fuliginosa (later instar)	**Fulgoridae**	Planthopper	No attack
Poblicia fuliginosa (1st-2nd instar)	**Fulgoridae**	Planthopper	Low rates of host feeding
Scaralina aethrinsula	**Fulgoridae**	Planthopper	Low rates of host feeding
Scaralina cristata	**Fulgoridae**	Planthopper	Low rates of host feeding

Table 1: This table lists the species of non-targets that have undergone no-choice host range testing, and the level of attack experienced by each non-target species.

Evaluation of Fabric Bands to Disseminate the Fungal Pathogen, *Beauveria bassiana*, for Biological Control of Spotted Lanternfly (*Lycorma delicatula*)

Emily Russavage[1], Melissa Benzinger McGlynn[2], Emily Wallis[2], Michael Raupp[1], Phil Lewis[2], and Paula Shrewsbury[1]

[1]Department of Entomology, University of Maryland
College Park, MD, U.S.A.

[2]USDA Animal and Plant Health Inspection Service (APHIS) Forest Pest Methods Laboratory
Buzzards Bay, MA, U.S.A.

phillip.a.lewis@usda.gov

ABSTRACT

Since its' discovery in 2014, the spotted lanternfly (*Lycorma delicatula,* SLF) has spread to 16 other states and caused millions of dollars in economic damages to nurseries, landscapes, and vineyards. This invasive pest feeds on plant sap and excretes sticky honeydew, which can lead to sooty mold growth, increased stinging insect activity, yield loss, reduced marketability, and in some cases plant death. Currently, growers heavily rely on chemical insecticides to control SLF, since other control methods like economic thresholds, lures, and classical biological control are still under development. To reduce grower exposure to chemical insecticides, mitigate development of insecticide resistance in insect populations, and improve the sustainability of pest management, we must find and implement alternative pest control tactics. In our recent studies, we evaluated different applications of a commercially available biopesticide containing the fungal pathogen *Beauveria bassiana*. While this product can be applied using conventional sprayers, we also investigated another, novel application method we call "fungal bands." Fungal bands are fabric strips containing millions of fungal spores. Once attached to a tree, pests that walk across the fabric pick up spores, ultimately leading to infection and death. In 2024, we developed fungal band formulations and tested their efficacy in the laboratory against 2nd, 3rd, and 4th instar SLF. In the field, we quantified the length of time that bands are effective against SLF adults. Our promising results indicate that this control method may be useful against SLFs. However, further work must be done to quantify non-target effects and how to maximize their effectiveness in the field.

Efficacy of Indigenous Predators of Spotted Lanternfly

Kelli Hoover

The Pennsylvania State University
University Park, PA

Kxh25@psu.edu

ABSTRACT

Spotted lanternfly (*Lycorma delicatula*) is an invasive and highly polyphagous planthopper that feeds on many economically important plants. Among its hosts, spotted lanternfly shows a preference for tree of heaven (*Ailanthus altissima*), with which it coevolved in Asia. Spotted lanternfly is capable of sequestering toxic compounds, such as quassinoids, from tree of heaven, which it can use for defense against predators. Thus, we were interested in 1) identifying predators that were feeding on spotted lanternfly in North America, 2) determining if access to tree of heaven affected the palatability of spotted lanternfly to its major predators, and 3) assessing promising predators for potential use in conservation and augmentation biological control.

To identify predators of spotted lanternfly in the United States, we used a community science project where we asked for reports from the public of what they saw feeding on spotted lanternflies through social media. This was largely through a Facebook page which we shared through Penn State Extension, several media outlets, and various other organizations. We received nearly 1300 reports of predation events between 2020 and 2022, with arthropods and birds being the most reported groups of predators.

We tested if birds would show a preference for spotted lanternfly nymphs that had or had not fed on tree of heaven by providing them to nesting house wrens in feeding cups on top of nest boxes. We found that the birds ate or fed to their chicks a significantly greater proportion of the spotted lanternfly reared without access to tree of heaven at all nymphal instars. To determine if birds would show a similar preference with adult spotted lanternflies, we made suet that contained adult spotted lanternflies that had been reared with or without access to tree of heaven and counted the number of times the birds pecked each type of suet. We found that the birds pecked the suet containing spotted lanternfly reared without access to tree of heaven significantly more. This suggests that spotted lanternfly can sequester compounds from tree of heaven that act as a successful deterrent to predatory birds.

We also tested to see if a variety of predatory arthropods showed a preference between spotted lanternflies that did or did not have access to tree of heaven. We performed choice and no choice tests with 10 different predatory arthropod species, giving them spotted lanternflies that had access to tree of heaven, those that hadn’t, or one of each. We found that there was no significant difference in the proportion of spotted lanternflies eaten by any predator in the choice or no choice tests. This suggests that defenses sequestered by spotted lanternflies from tree of heaven are not effective against arthropod predators.

We then tested commercially available or easily collected arthropod predators to see if any would be effective at reducing spotted lanternfly populations over a week caged on potted grapes in a greenhouse. We found that spined soldier bugs were consistently the best predator for reducing spotted lanternfly populations at all nymphal and adult life stages.

Through this work, we discovered that many generalist predators in the U.S. are feeding on spotted lanternflies, defenses sequestered from tree of heaven can be a successful deterrent against some predators (notably birds), and native natural enemies show promise for future use in conservation and augmentation biological control.

Safety of *Verticillium nonalfalfae*, a Bioherbicide Agent to Control *Ailanthus Altissima*: Results of Host Range Studies

Raghavan "Charu" Charudattan[1], Erin Rosskopf[2], Sara Houpt[2], Anton Baudoin[3], Carrie Fearer[3], Scott Salom[3], Timothy Shively[3], Brian Smith[3], Harrison Miles[3], Matthew Kasson[4], Kristen Pierce[4], and Maria del Mar Jiménez Gasco[5]

[1]BioProdex, Inc.
Gainesville, FL 32609

[2]USDA Agricultural Research Service (ARS), U.S. Horticultural Research Laboratory
Fort Pierce, FL 34945

[3]Plant and Environmental Sciences, Entomology, and Forest Resources and Environmental Conservation, Virginia Tech
Blacksburg, VA 24061

[4]Division of Plant and Soil Sciences, West Virginia University
Morgantown, WV 26505

[5]Plant Pathology and Environmental Microbiology, The Pennsylvania State University
University Park, PA 16802

rcharudattan@bioprodex.com

ABSTRACT

Our objective has been to develop EPA-required host-range data to register *Verticillium nonalfalfae* as a biological control agent, specifically as a bioherbicide, to control *Ailanthus altissima,* the tree-of-heaven (ToH). We hypothesize that any reduction in the population density of ToH, the preferred host to spotted lanternfly (SLF, *Lycorma delicatula*), will help towards integrated management of SLF. *V. nonalfalfae* is a native fungal plant pathogen that causes Verticillium wilt of ToH. In 2000, an epidemic of the disease was discovered in Pennsylvania causing widespread wilting and death of mature ToH trees. Subsequently, it was also found in Virginia and Ohio. An isolate of the fungus recovered from an epicenter of ToH wilt in Pennsylvania and designated as VnAa140 was studied extensively by Professor Donald Davis and his students at Pennsylvania State University who proposed it as a biological control agent of ToH. The fungus was initially placed in *V. albo-atrum.* Following a taxonomic revision of wilt-causing *Verticillium* spp. (Inderbitzin et al. 2011), the ToH-isolate was reassigned to the newly created species of *V. nonalfalfae.* The isolate VnAa140 has been used in eight host range studies. Results from four of the studies have been published in peer-reviewed journals while the others are awaiting publication. The latter include studies in Florida (on native and crop species), Virginia (apple, cherry, grape, and peach), West Virginia (kiwifruit and Solanaceous spp.), and Pennsylvania (potato cultivars).

The host range was determined by inoculating test species with VnAa140 with appropriate controls, replications, and repeats. The inoculations were done using suspensions of VnAa140 spores (vegetative, conidia) harvested from plate cultures grown on plum extract agar. The spores were washed with sterile water or 0.1% peptone, counted with a hemocytometer, and standardized to 1 x 10^7 spores per ml (the standard inoculum). Controls of test species were mock inoculated with sterile water using similar methods. ToH seedlings/saplings were included in every batch of screening as a positive control to assure infectivity of the inoculum and disease development.

Seedlings or small saplings of test species were screened in the greenhouse. Mature trees and shrubs were screened at field sites. Inoculation in the greenhouse was done by dipping washed roots of test species in the standard inoculum for 30 min (the root-dip method) and transplanting the seedlings/ saplings in pots containing pasteurized potting soil. Larger saplings and mature trees of ToH and test species were inoculated by a slash-and-squirt method or a stem-infusion method. The former is akin to chemical herbicide applications where the stem/trunk is slashed with a hand-held axe deeper past the bark into the wood and a suitable amount of spore suspension squirted or sprayed into the cut. Alternatively, a volume of spore suspension is infused into the stem/trunk by impaling a woodworking gouging chisel into the stem and letting the inoculum to be pulled into the stem. In addition to such direct inoculation of trees and shrubs, nontarget plants growing at Verticillium wilt epicenters were monitored for wilting or death from natural spread of VnAa140 from infected TOH trees.

Susceptibility of ToH and test species was determined from typical symptoms of Verticillium wilt. In greenhouse trials, plants that developed chlorosis, vein-clearing, and necrosis of leaflets, abscission of leaf and leaflets, wilting, and stem death, as illustrated below. Since transplanted seedlings may develop leaf chlorosis and necrosis and die from physiological stress, only symptoms in the younger/newer leaves were considered. Reisolation of the pathogen from wilting and dying plants and morphological comparison of the reisolate with the culture used for inoculation were used for disease confirmation. As needed, gene sequences of the reisolate were compared with diagnostic sequences for *V. nonalfalfae* in the GenBank.

Top row, left two, epinasty & chlorosis, third, chlorosis, and right, chlorosis & vein clearing. Bottom, left to right, chlorosis & necrosis, leaf & leaflet abscission, and wilting & death. Right, a healthy control.

On mature trees, the first symptoms of disease are the thinning of the canopy from leaf abscission, barren branches, and opening in the canopy as illustrated below. The trees eventually die over several months after inoculation. Discoloration of the vasculature and stem from fungal invasion is another diagnostic symptom of Verticillium wilt. However, while stem discoloration (illustrated below) is an important diagnostic feature, it is not conclusive of the causal pathogen as wilt-causing fungi, including VnAa140, can invade and colonize nontarget species without causing disease (asymptomatic hosts).

Symptoms of Verticillium wilt of mature ToH trees inoculated with VnAa140 at a field site in PA. Left to right: Leaf fall, barren branches, and opening in the canopy of inoculated ToH trees; a dead ToH tree, a healthy (left) and an infected tree (right), the latter showing vascular discoloration, and a stem discoloration in a VnAa140-infected ToH.

Relying on the symptoms, reisolation, and molecular confirmation as needed, to date 97 nontarget species in 72 genera belonging to 42 families have been screened against VnAa140 of which 82 (85%) were immune or resistant, 3 (3%) tolerant, and 12 (12%) susceptible. *V. nonalfalfae* is a known pathogen of golden kiwifruit (*Actinidia chinensis*, Actinidiaceae) in Chile, hops (*Humulus lupulus,* Cannabaceae) in Europe, and some potato cultivars (*Solanum tuberosum,* Solanaceae) in China. However, these plants have not been reported as hosts to *V. nonalfalfae* in the United States, and a recent search of the National Plant Diagnostic Network (https://www.npdn.org/, accessed Nov. 2, 2024) by RC did not reveal any record of *V. nonalfalfae* in the United States as a pest of these or any other nontarget species. Red kiwifruit (*A. polygama)* and hops were screened in Florida and rated as resistant to VnAa140. Studies in Virginia indicated apple, cherry, grape, and peach to be resistant while two potato cultivars were reported from Pennsylvania to be resistant.

Published results by Kasson et al (2015) have identified *Acer pensylvanicum* (striped maple, Sapindaceae) and *Aralia spinosa* (devil's walkingstick, Araliaceae), both native plants that may co-occur with ToH, as susceptible to VnAa140. These plants, upon inoculation or from natural infection in the field developed wilting, vascular discoloration, and death, and *Verticillium* was reisolated from symptomatic plant tissues. However, in the field, these two species as well as *A. altissima* had been attacked by *Euwallacea validus*, an ambrosia beetle, which might have transmitted VnAa140 or other wilt-causing fungi.

In addition, the following nine species are tolerant or possibly susceptible to VnAa140: *Acer palmatum* (Japanese maple)*, A. platanoides* (Norway maple), both in Sapindaceae, *Catalpa speciosa* (northern catalpa, Bignoniaceae), *Carya* sp. (hickory, Juglandaceae), *Cercis canadensis* (eastern redbud, Fabaceae), *Elaeagnus umbellata* (autumn olive, Elaeagnaceae), *Leitneria floridana* (corkwood, Leitneriaceae), *Robinia pseudoacacia* (black locust, Fabaceae), and *Sassafras albidum* (sassafras, Lauraceae). When inoculated in the field, these native species developed vascular discoloration but did not die. Without inoculation, they remained asymptomatic even when occurring near inoculated, diseased ToH. It is well established that VnAa140 can spread from infected to healthy ToH through root grafts.

Cross pathogenicity tests with *V. nonalfalfae* strains from different geographic locations and host plants in studies by Pierce and Kasson (2024) have shown that isolates were more virulent in their respective hosts of origin than in other known hosts, providing further evidence of host adaptation within the species. Strains from non-*Ailanthus* plants were not pathogenic or mildly pathogenic to ToH. Thus, our conclusion is that *V. nonalfalfae*, isolate VaNn140, is host-specific to ToH and it can be used safely as a bioherbicide to manage ToH.

Toxicity of Milkweed to Spotted Lanternfly

Kelli Hoover and Anne Johnson

The Pennsylvania State University
University Park, PA

aej5228@psu.edu

ABSTRACT

Spotted lanternfly (*Lycorma delicatula*) is an economically important invasive species with a wide host range. While many pesticides are effective against spotted lanternfly, the potential for resistance to develop makes finding alternative control methods crucial. Observations by members of the general public have led to the suggestion that feeding on milkweed will kill spotted lanternfly and thus planting it could offer a potential management strategy. In order to assess the validity of this idea, we needed to determine 1) if feeding on milkweed will kill spotted lanternfly and 2) if spotted lanternfly will feed on milkweed in the presence of other hosts.

To determine if spotted lanternfly will die from feeding on milkweed, we performed no choice tests on spotted lanternflies throughout their life cycle where they were given either a grape plant (*Vitis vinifera*) or a common milkweed plant (*Asclepias syriaca*) to feed on. Spotted lanternflies were then checked after 24 hours to see how many died. From this, we found that mortality was significantly higher on common milkweed than grape for all nymphal instars and adult spotted lanternflies, often in the range of 60-80% of the spotted lanternflies on milkweed dying within 24 hours compared to 0-30% of those on grape dying within 24 hours. This suggests that feeding on milkweed can kill spotted lanternflies.

Next, we performed choice tests to determine if spotted lanternfly would feed on milkweed in the presence of other hosts. This involved placing a lanternfly in the center of an enclosure with a grape plant at one end and a common milkweed plant at the other. Checks were made at 1, 2, 4, 6, and 24 hours to see if the lanternflies were still alive, which plant they were on, and if they were feeding. We found that there was some mortality in the later checks for all life stages and that every life stage could be observed feeding on the common milkweed. There was no significant preference for one host plant over the other at any check for any nymphal instar, but adult spotted lanternflies did show a preference to be on grape during the 4-, 6-, and 24-hour checks. However, as mortality continued to rise at these checks and no spotted lanternfly adults had died on grape in the no choice experiments, it is possible that adults were feeding on milkweed when we were not observing them.

Overall, this work suggests that feeding on milkweed can lead to spotted lanternfly mortality and that they will still feed on milkweed in the presence of other hosts. Future work into how different species of milkweed affect spotted lanternflies, the mechanism through which spotted lanternflies are killed, the behavior of lanternflies in the presence of other alternative hosts, and how effective planting milkweed is at controlling spotted lanternfly populations in the field is underway.

CHEMICAL AND MICROBIAL CONTROL

A Comparison of Potential Ovicides for Spotted Lanternfly

Jason Bielski and Douglas G. Pfeiffer

Department of Entomology, Virginia Tech
170 Drillfield Drive, Blacksburg, VA 24061

dgpfeiff@vt.edu

ABSTRACT

Spotted lanternfly (SLF, *Lycorma delicatula*) overwinters in egg masses for approximately eight months a year, representing the longest individual life stage. Therefore, the inactive egg mass life stage constitutes a good candidate for management practices. Egg masses were collected from various locations in Winchester, VA, and stored in climate-controlled incubators simulating winter conditions (25℃, 65% relative humidity, and a 16:8 light-to-dark ratio). The egg masses were treated at three periods during the overwintering phase: winter, early spring, or late spring. We conducted bioassays across 3 years (2021–2023) utilizing 13 insecticides, across multiple modes of action, compared to untreated and water checks. Egg mass hatch reduction was analyzed to determine the efficacy of the various treatments and application timings. In all bioassays, there were strong reductions in survivorship from malathion and chlorpyrifos. Other pesticides tested in laboratory bioassays demonstrated varying, lesser hatch reductions across application timings and years.

In 2023, a field trial using malathion against an untreated check was carried out. In this field trial, malathion provided a high degree of ovicidal efficacy against SLF egg masses.

Controlling Spotted Lanternfly Using TyraTech Formulation

Tadeh Issaian and Spencer Walse

USDA Agricultural Research Service (ARS), San Joaquin Valley Agricultural Sciences Center
Parlier, CA

spencer.walse@usda.gov

ABSTRACT

Spotted lantern fly (SLF), *Lycorma delicatula* (White) (Hemiptera: Fulgoridae), is an invasive insect first introduced to the United States in 2014. Approaches are critically needed to control this pest infesting commodities and consignments that must be moved through quarantines. Of particular concern is the overwintering egg life stage, which is laid in clusters on the surface of logs, sawn timber, and other outdoor items. Microscopic investigations revealed chorionic microstructures permeable to both gas and liquids. Conventional fumigants (methyl bromide, sulfuryl fluoride, or phosphine) can be used to limit its spread in commercial channels of regulated articles. Non-fumigation control measures are also needed, particularly for homeowners and business owners without access to fumigation. Various TyraTech formulations, using insecticides exempt from the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registration under the 25(b) authorization, were evaluated to address this need. These formulations target the tyramine receptors with promising efficacy toward all life stages, including eggs. The applied formulations resulted in the complete mortality of all egg masses subject to the treatment. In total, 231 SLF eggs remained unhatched using the commercially available formulation and 3,219 SLF eggs remained unhatched using the non-commercially available formulations, which will commercially marked in the near future.

Exploring Long Lasting Insecticidal Net (LLIN) for SLF Monitoring and Control

Allan Mortenson[1] and Brian Walsh[2]

[1]Vestergaard, Switzerland

[2]Penn State Extension, Berks County, PA

brw5318@psu.edu

ABSTRACT

Insecticide treated nettings are produced around the world for a variety of uses. The insecticides used in these nets are generally considered safe for mammals but deadly for insects. These products are commonly used for commodity storage protection, clothing treatments to repel biting arthropods such as ticks, and bed netting used to kill mosquitos that vector pathogens. Since 2019, we at PSU Extension have been working with a variety of insecticide treated nettings from multiple manufacturers exploring the efficacy of the various materials against spotted lanternflies (SLF) and how they might be used to kill SLF passively (without applying insecticide to the ecosystem beyond what is contained in the treated netting) in a variety of situational applications.

Our work has included bioassays to establish the efficacy of various active ingredients (tested against all SLF life stages), developing protocols that engage SLF behaviorally to contact the netting where it is deployed (primarily through attraction to vertical silhouettes), evaluating the durability and product label legality for situational use of the material with SLF. Of all the materials tested, one product has emerged as a clear front runner that (once re-registered for sale in the U.S. through EPA) has a strong potential for employment for monitoring and possible control applications with SLF in a variety of scenarios. Vestergaard's deltamethrin impregnated netting is an LLIN that is manufactured with yarns impregnated with the active ingredient and stabilized for U.V. exposure to slow breakdown of the netting and deltamethrin when left exposed to the elements outdoors.

Testing with Vestergaard's Perma-net 2.0 has indicated that its 0.4% strength of deltamethrin caused 100% mortality of adult SLF within 96 hours after as little as one minute of contact exposure. Five minutes of contact exposure led to 100% of the insects being moribund within one hour with 100% mortality by the end of the 96-hour trial period. Trials included developing several styles of traps for deployment on posts, utility poles and in vineyards that utilize the LLIN netting as a kill mechanism that does not need servicing through the season due to accumulation of dead SLF. Further testing indicated that deltamethrin strength retention in the netting after 36 months of continuous environmental exposure was ~85%, indicating that if used for traps, efficacy of several years could be expected before needing to reapply new treated netting.

Further use of this netting has been delayed by EPA re-registration of the product for use in the US, but once re-registered, this netting has the potential for use against many arthropod pests of agricultural production.

DEVELOPMENT OF TOOLS FOR EARLY DETECTION, SURVEY, TRAPPING

Spotted Lanternflies Respond to Their Own Chemical Signals Used in Lures in Field Studies – Improving Traps for Spotted Lanternflies by Exploiting Their Own Signals

Miriam F. Cooperband and Kelly M. Murman

USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Science and Technology (S&T), Forest Pest Methods Laboratory
1398 W. Truck Rd. Buzzards Bay, MA 02542

Miriam.F.Cooperband@usda.gov

ABSTRACT

Behavior of spotted lanternfly (SLF), *Lycorma delicatula* (Hemiptera: Fulgoridae), is mediated by multimodal sensory inputs composed of semiochemicals (from host plants, their own body volatiles, and honeydew), visual cues, and substrate vibrations. Although over 78 semiochemicals have been identified so far, and we have tested more than 45 of these in various formulations in the field, we have not yet identified a more potent semiochemical lure than methyl salicylate, which can improve trap capture under certain conditions, but which cannot outcompete the attraction of large host trees or naturally occurring aggregations of SLF.

Without knowledge of the optimal blend and ratio of compounds required by SLF, we first tested semiochemical lures composed of their own natural volatiles collected from their bodies (extract) and their honeydew for attraction in the field. SLF honeydew and SLF for making extract were collected at high-SLF-density sites and SLF extract and honeydew as lures were deployed in low-SLF-density trapping sites. Each trapping site block had three *Ailanthus altissima* trees of equal size (DBH) baited with either a combination of extract and honeydew, extract alone, or hexane controls. Ten blocks were serviced on Mondays, Wednesdays, and Fridays for 12 weeks, therefore, each trapping period lasted 2-3 days. On those days, we changed trap bags, diffuser lures, and honeydew-laden burlap ribbons, and the amount of extract (or hexane in controls) emitted from each diffuser lure over each period was recorded and plotted against the number of SLF captured during each period for each lure.

In controls, no significant relationships were found between amount of hexane emitted and SLF caught. In the absence of honeydew, no positive relationships were seen between SLF captured and amount of SF extract emitted, but sometimes a negative relationship was seen. In the presence of honeydew, the amount of SLF extract emitted was significantly positively correlated to capture of SLF during peak mating (males) and oviposition (females) times. The positive dose response suggests the combination of volatiles from their honeydew and bodies worked synergistically to produce a positive dose-response not seen in controls or body extract alone.

In another experiment, we redesigned SLF circle traps in a way that utilized captured SLF as living lures by replacing the plastic collection bag with a mesh collection bag, and attaching the mesh to the tree trunk enabling captured SLF to continue to live, feed, produce body volatiles, honeydew, and substrate vibrations. Blocks each had two *A. altissima* trees of equal size (DBH). Each tree had a circle trap and either a standard plastic collection bag (control) or a mesh collection bag attached to the tree trunk to allow captured SLF to feed through it. This enabled captured SLF to continue to live and feed, and produce chemical and acoustic signals that attract other SLF for aggregation and mating. Traps were serviced and rotated every two weeks for 12 weeks in 2022, 2023, and 2024.

Significantly more SLF were captured in mesh bags than in plastic bags, particularly prior to mating. In total, in 2022 and 2023, combined, attached mesh bags caught 34% more total SLF than plastic bags in low density sites. The strongest responses were in 4th instars, Early-1 adults, Mid adults, and Late-1 adults.

Early-2 and Late-2 adults did not show a significant difference in 2022 and 2023 combined, and only data prior to mating in 2024 had been analyzed by the time of this report. SLF circle traps with mesh bags were more effective than those with plastic bags in 2022 and 2023 combined. In 2024, results so far continue to trend the same way in Early-1, with mesh bags performing significantly better than plastic bags in capturing fourth instar and adult SLF.

Lessons Learned from Seven Years of Circle Traps: Observations and Analyses

Joseph A. Francese[1], Sarah M. Devine[1,2], Everett G. Booth[1], Kelly M. Murman[1,3], and Miriam F. Cooperband[1]

[1]USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Science and Technology (S&T), Forest Pest Methods Laboratory
1398 West Truck Road, Buzzards Bay, MA 02542

[2]Department of Biology, Xavier University
3800 Victory Parkway, Cincinnati, OH 45207

[3]USDA APHIS PPQ S&T, East Stroudsburg Field Station
East Stroudsburg, PA 18301

joe.francese@usda.gov

ABSTRACT

Over the last 7 years, and with the help of many collaborators, circle traps for SLF have been developed, modified, tested and improved. Prior to the development of the circle trap, only glue-coated tree banding wraps were available for the survey of SLF. These traps are messy, can be clogged with debris, and are prone to nontarget bycatch including vertebrates. Initial studies found that Bug Barrier bands, which differ in that they face in toward the tree trunk, catch less falling debris and are more efficient at capturing SLF (Francese et al. 2020). In 2018, we modified a plum curculio circle trunk trap by replacing the small cup with a larger 1.89L plastic jar. This trap would also exploit the behavior of SLF to climb host trees by funneling them up and into the jar containing a pesticide strip. This circle jar trap caught more SLF nymphs and adults than BugBarrier in paired trapping comparisons on tree-of-heaven (TOH). While the circle trap was successful, the jar presented an issue in high-density populations as the copious amounts of honeydew coated the jar, decreasing sample quality and by the end of the season very little light could enter the jar. This may have influenced SLF behavior to climb the trap and enter the receptacle. Traps were later fitted with plastic bags as receptacles for capture and compared with jar traps. Bag-fitted traps caught significantly more SLF than jar-fitted traps at almost every life stage. Additionally in multi-state detection tools comparisons conducted in 2020, detection rates (ability of a trap to capture at least one target) were comparable across all life stages, and this version of the trap was adopted by the PPQ program for use in detecting new populations.

With a reliable trap in hand, the next goal was to improve survey methods and to potentially develop visual attractants. Requests from state cooperators and from PPQ Field Operations to remove the Dichlorvos insecticide strips from the traps led to a study in 2021 that found that presence of the pesticide strip did not significantly increase catch. However, more live insects were found inside traps during collection periods. A field assay investigating the ideal the timing between trap checks showed that the optimal check frequency was every 2-3 weeks or earlier. Traps left in the field longer than this resulted in significant degradation

of samples and longer processing time. Circle traps on the trunk of host trees were also found to be more effective at capturing SLF than other trap designs suspended in the canopy. However, many SLF were observed in the canopy above the circle trap. Additionally, studies were conducted to determine if visual cues could be incorporated into traps to increase their effectiveness. Electroretinogram assays showed that SLF adults are potentially sensitive to wavelengths in the 460nm (blue) range of the visible spectrum. In two assays, circle traps were 1) painted in 3 shades of blue and 2) fitted with white and blue lights. Control traps caught more SLF than treatment traps in both assays. In 2023, additional trapping assays investigating trapping on non-preferred hosts, showed that maple and black walnut can be used as additional trap hosts in the absence of TOH. A final comparison showed that placing methyl-salicylate lures on these traps was not necessary for improving trap catch or detection.

A final study was conducted over 2 years in 2022 and 2023 in Indiana, Connecticut, and New York to assess the efficacy and impacts of using large numbers of circle traps to reduce SLF populations within sites. To answer this question, treatment plots were setup where every live tree stem larger than 5cm diameter had a trap placed on it. Every 2 weeks visual surveys were paired with trap catch to determine if the traps were reducing the population. After both years, generally trap catch, and visual survey counts suggested that populations were still increasing despite the thousands of SLF removed from the sites. Despite many SLF being taken out of the system by the trap, however many remain above the trap and move in from surrounding areas. The circle trap is a passive trap that can only intercept the SLF that are walking on the individual tree. Without a more effective lure, the trap doesn’t have any additive pull beyond that of the host tree on which the trap is placed. Through the numerous years of trapping studies, we’ve improved the overall trap design, limited nontarget bycatch, improved surveying methods and techniques, and have investigated the uses and limitations to improve overall SLF trapping recommendations.

Characterizing the Metabolite Profile of *Ailanthus altissima* (TOH) Phloem

Amanda Davila-Flores[1], Kimani Hamilton-Wray[2], Amanda M. Koenig[2] Susanne Hoffmann-Benning[2], and Phillip A. Lewis[1]

[1] USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Science and Technology (S&T), Forest Pest Methods Laboratory Buzzards Bay, MA

[2]Michigan State University, Department of Biochemistry and Molecular Biology East Lansing, MI

amanda.m.davilaflores@usda.gov

ABSTRACT

Tree of heaven (TOH) (*Ailanthus altissima*), a disturbance-adapted species native to China and Taiwan, is a key host for Spotted lanternfly (SLF) (*Lycorma delicatula*), an invasive insect native to Taiwan and China that has spread throughout Pennsylvania and surrounding states since its first detection in 2014. Interestingly, in stands of tree-of-heaven, some trees may seem ignored by spotted lanternfly while adjacent trees can be covered with SLF aggregates, a phenomenon referred to as “hot” trees. Some hot trees even appear to be attractive year to year. These observations suggest a preference for certain trees that could be more attractive to SLF by offering a feeding advantage through quantity or qualitative phloem characteristics. However, it is currently unknown why one tree is selected over another. This study aims to understand if changes in the metabolite profile between TOH plants may explain SLF aggregation on certain TOH.

Between 2019 and 2022, phloem samples were collected via a stylectomy method from trees that showed both high and low SLF densities. This method involved cutting the stylet of the SLF while the SLF was actively feeding on TOH. Turgor pressure then slowly expelled phloem through the stylet, then the droplet was collected with a capillary tube. Samples were later analyzed using gas chromatography mass spectrometry (GC-MS).

Over 70 metabolites including sugars, amino acids, organic acids, and other metabolites have been identified. These include chlorogenic acid, quininic acid, gallic acid, and pinitol, all compounds that are known to have insecticidal properties or are induced in response to stress. Preliminary multi variate analysis shows compounds grouping by year likely due to environmental effects, however within each year, samples also appear to show separation. More analysis is needed to investigate if this is related to the hot tree effect.

Because of the mobility of the SLF adults and their egg-laying habits, there is a high likelihood this pest will continue to spread. It is therefore important to develop new tools to detect and control expanding populations to limit further spread and to reduce populations in the currently infested areas. Information from this study will add to our understanding of each step driving SLF to form aggregations and inform on mechanisms that may be exploited in the development of control tools.

Understanding Spotted Lanternfly Infestation Through Egg Mass Distribution

Houping Liu

Pennsylvania Department of Conservation and Natural Resources
400 Market Street, Harrisburg, PA 17105

hliu@pa.gov

ABSTRACT

Spotted lanternfly (SLF) (*Lycorma delicatula* (White) [Hemiptera: Fulgoridae]) a pest of tree of heaven (TOH) (*Ailanthus altissima* (Mill.) Swingle [Sapindales: Simaroubaceae]) from China, Taiwan, and Vietnam (White 1845, Liu 1939, Zhou 1992), was recently found in Pennsylvania (Barringer et al. 2014). As a polyphagous pest, its recorded hosts include >100 species of trees, woody plants, vines, and weeds worldwide (Zhou 1992, Kim et al. 2011, Dara et al. 2015, Liu 2019). Current distribution in the U. S. includes17 states from New York to South Carolina and Massachusetts to Illinois (NYS IPM 2024), posing serious threats to the multibillion-dollar fruit, nursery, landscape, and hardwood industries in the United States (USDA APHIS 2018).

SLF completes one generation a year and overwinters as eggs on the surfaces of various plants and nonliving materials. In North America, egg hatch starts in early May. Nymphs pass through four instars to become adults in late July. Early instar nymphs feed on plants close to oviposition sites while late instars move to a narrowed down list of host plants centered around TOH (Song et al. 2018, Liu 2019, Derstine et al. 2020, Dechaine et al. 2021). Adults feed aggregately and mate on TOH between early August and early September before dispersing to other preferred hosts for supplemental feeding and egg-laying in late September (Liu 2019, 2020, Keller et al. 2020a, Dechaine et al. 2021, Keller and Hoover 2023). Eggs are usually laid in masses covered by gray wax and arranged in a single layer of several rows with multiple eggs in each row (Liu 2019, 2022).

We conducted field surveys to better understand SLF infestation through egg mass distribution by examining 1) oviposition preference, 2) temporal/spatial patterns, 3) impact factors, 4) predictive models, 5) role of TOH, 6) possible mechanisms, and 7) management implications.

SLF oviposition preference was first examined by visually survey surfaces of all potential substrates (trees, shrubs, vines, stones, fence posts, etc.) below 2 meters through random transecting at 14 infested sites (6 man-hours/site) in Berks County, Pennsylvania between late March and late April in 2016 and 2017. Results showed that of the 24 types of substrates recorded, TOH, black cherry (*Prunus serotina* Ehrh. [Rosales: Rosaceae]), black birch (*Betula lenta* L. [Fagales: Betulaceae]), and sweet cherry (*Prunus avium* L. [Rosales: Rosaceae]) were preferred by the females to lay eggs, accounting for 62.5% substrates used and 68.5% egg masses found, respectively (Liu 2019). Further surveys on the entire trees at 28 fixed-radius (100 m^2) plots at seven sites in 2020 produced similar results, with 80.5% egg masses found on Norway maple (*Acer platanoides* L. [Sapindales: Sapindaceae]), TOH, black birch, tulip tree (*Liriodendron tulipifera* L. [Magnoliales:

Magnoliaceae]), and American beech (*Fagus grandifolia* Ehrh. [Fagales: Fagaceae]) (Liu and Hunter 2021).

TOH and black walnut (*Juglans nigra* L. [Fagales: Juglandaceae]) trees were felled in 2019 for within tree distribution of SLF egg masses in the field. No significant difference in egg mass number was found for different cardinal directions and tree species. Egg masses were found from the ground to the top of the tree for both species, with more egg massed found between 8-10 m and 4-6 m above ground for TOH and black walnut, respectively (Liu and Hartlieb 2020). Significantly more egg masses were also found on branches compared to trunk for black walnut while egg masses were equally split between trunk and branches on TOH (Liu and Hartlieb 2020).

Visual survey from the ground was also used to study egg mass spatial distribution in fixed-radius (100 m^2) plots. Results showed that there was no significant difference between different cardinal directions, but significantly more egg masses were found on the upper trunk and first order branches (Liu and Hunter 2021). Females tend to lay eggs on the same or nearby substrates (trees) over the years (Liu unpublished data).

Factors impact SLF egg mass distribution in the field were also investigated, with plot type (with or without TOH), plot basal area (m^2/ha), tree species (TOH vs others), tree diameter, position within the tree (height), and distance to dominant TOH in the plot identified (Liu and Hartlieb 2020, Liu and Hunter 2021, Liu and Julian 2024, Liu unpublished data). More egg masses were found on TOH trees in the field, with positive correlation between density (abundance) and tree diameter (basal area) (Liu and Hunter 2021, Liu and Julian 2024). More egg masses were also found on tree of other species in plots with TOH trees (Liu and Julian 2024). The higher the plot basal area /the larger the tree/the closer the tree to dominant TOH, the more egg masses it attracted (Liu and Hunter 2021, Liu and Julian 2024, Liu unpublished data).

N-mixture models were fit with egg mass survey data of 28 fixed-radius (100 m^2) plots in 2021 to test the accuracy of visual survey from the ground. These models use repeated count data to estimate population abundance (λ) based on detection probability (p) with the assumptions of equal occupancy and detectability in a demographically closed population with no double counting (Royle 2004). Results showed that detection probability increased with sample period but negatively correlated with tree diameter, ranged from 0.516 to 0.614 between the 1st and 3rd sample period. On the other hand, population abundance was positively correlated with basal area of the sample unit (Liu and Julian 2024).

The importance of TOH in SLF infestation cannot be overestimated since it's the primary host of this pest. To study this, 18 plots at four infested sites in Swatara State Park were selected in 2022. A dominant TOH tree was first identified to serve as the center of each plot. All trees (> 2.5 cm in diameter) within 15 m to the dominant TOH (or the closest TOH when multiple TOH trees present) were georeferenced before visually searched for SLF egg masses (new and old) from two directions (north and south). Results of inverse distance weighted (IDW) interpolation showed that more egg masses were found on TOH or other trees close to the dominant TOH tree in all plots (Liu unpublished data). In addition, number of egg masses on each tree was negatively correlated with its distance to the dominant TOH tree, with >80% egg masses found within 20 m from the dominant TOH tree two years after initial infestation (Liu unpublished data).

Oviposition strategies adopted by insects (e.g., habitat selection, substrate preference, egg size, clutch size, structure, arrangement, parental care) are critical to the survival and development of their eggs (Fatouros et al. 2020). The preference-performance hypothesis (optimal oviposition theory) predicts correlation between oviposition preference by females and host suitability for offspring development (Jaenike 1978). However, it does not work well for species with adults feed on different hosts from the immature life stages (Fujiyama 2008). Alternatively, the optimal foraging theory anticipates maximized female fitness through the optimization of adult performance (longevity and fecundity) on its preferred hosts, even at the expense of the offspring (Scheirs et al. 2000, Mayhew 2001, Adar and Dor 2018). Either theory could not fully explain the oviposition and development patterns demonstrated by SLF in the field as both nymphs and adults feed on a wide range of hosts.

The proximity to suitable habitat for the offspring hypothesis states that oviposition

decisions by females have a great impact on larval defense sequestration, predation evasion, mixed nutrient acquisition, host synchronization, and interspecific competition (Refsnider and Janzen 2010). It fits well with SLF as TOH contains large amount of quassinoids, a group of compounds with antifeeding and insecticidal properties that are crucial for the color change of SLF in the 4^{th} instars (Song et al. 2018). SLF can disperse a maximum of 65 m from release point as nymphs (Keller et al. 2020b) and up to 1,740 m as adults although mostly under 60 m (Wolfin et al. 2019, Jung et al. 2022). With TOH in the suitable habitats, nymphs hatched from egg masses laid on various substrates can feed on a mixed diet first before congregating on nearby TOH trees for defense sequestration as late instars. Matured adults then disperse to other preferred species (e. g, TOH, maples) for supplemental feeding and egg deposition to complete the life cycle (Liu 2019, Cooperband and Murman 2022, Nixon et al. 2023).

SLF infestation in the field can be interpreted more efficiently through egg mass distribution since it remains stationary on the substrates and persists for a few seasons after being laid (Liu and Hunter 2021). SLF females choose to lay eggs on TOH and other preferred species in the habitat. As an invasive tree capable of clonal growth of more than 27 m in the field (Kowarik and Säumel 2007), TOH can start isolated clusters from single introductions. Plot type, basal area, tree species, tree diameter, and distance to dominant TOH all play a role in the spatial/temporal distribution of SLF egg masses in the field. Visual survey from the ground can be effective when impact factors and sample period are considered. While removing TOH alone is unlikely to eliminate SLF from the habitat instantly, it’s impact on the long-term population reduction could be profound and long-lasting. It is therefore imperative to focus on the dominant TOH tree in the forest based on egg mass survey results for the integrated management of this pest in North America.

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Spotted Lanternfly Spread in the United States 2014 Through 2023, a Multi-Scale Analysis

Joseph Keller and Matthew R. Helmus

Department of Biology, Temple University, Philadelphia, PA

joseph.keller0002@temple.edu

ABSTRACT

The spotted lanternfly (*Lycorma delicatula*) has spread rapidly in the United States since its first detection in Berks County, PA in 2014. Understanding the rate at which this pest is spreading can guide improved management, but arriving at accurate estimates can be difficult because the spatial scale used in analysis influences rate estimates and because spread rates change over time. The spotted lanternfly invasion in the U.S. has been highly documented by government surveyors and by community scientists. We gathered and integrated >900,000 records of spotted lanternfly occurrence in the *lydemapr* database, which contains anonymized records and is freely available online. We based our analyses on government survey points, and used biological year rather than calendar year, reflecting spotted lanternflies' univoltine life cycle with years turning over around the time of the emergence of first–instar nymphs (1 May–30 April). We analyzed these data to resolve the following questions:

1. How does the spatial scale used in analysis affect the estimated spread rate?
2. What scale parameters result in the best performance based on cross validation?
3. Has the spotted lanternfly spread rate varied predictably over time, with slow initial spread?

To assess the influence of spatial scaling on spread rate estimates, we used square-root area regression, which is based on tracking change in the area of the invasion over time. We measured the area of the invaded range in each year of the invasion using two methods. First, we intersected presence records with a grid overlaid on the landscape such that cells holding presence records were designated invaded, while those holding no presence records were not. Second, we derived the α-convex hull around all presence points. These hulls bounded presence points while allowing for range discontinuities, and this approach has been used in the past to estimate the range size of threatened and endangered species as well as other spreading invasives. Both of these approaches require the selection of a spatial scaling parameter. For grids, one must choose the cell edge length, while for α-convex hulls, one must set the parameter α, which controls the resolution of the boundary. We evaluated a range of values for each of these parameters and found that the resulting spread rate estimate was substantially influenced by the choice of spatial scale. Using a cell edge length of 1 km, for example, resulted in an estimated spread rate of 6.5 km yr^{-1}, while a coarser cell edge length of 20 km resulted in a faster spread rate estimate of 26 km yr^{-1}. Spread rate estimates based on α-convex hulls followed a similar pattern, with coarser boundaries resulting in faster spread rate estimates.

We used 5-fold cross validation to identify scaling parameter values that resulted in invaded range boundaries that best captured spotted lanternfly occurrence patterns. We scored different parameters' ability to accurately bound the invaded range using the F_β score, which weighs precision (the proportion of all points within the designated invaded range that were truly presences) and recall (the proportion of all presence points that were accurately captured within the designated invaded range). With this metric, the relative importance placed on recall and precision can be tuned by altering the parameter β. We tested βs ranging from 1 to 4, reflecting potential greater emphasis on recall over precision because invasive species managers likely value capturing all locations where the targeted pest is present more highly than they do narrowly specifying where within the invaded range spotted lanternflies may or may not occur. We found that α-convex hulls generally outperformed grid-based boundaries. Increased emphasis placed on recall favored the use of coarser scaling. We identified α = 19.7 km as a suitable value for use based on averaging performance across years and using a β value of 2.

To evaluate change in spotted lanternfly spread rate over time, we measured annual boundary displacement around each distinct population identified using the alpha convex hull with optimal alpha value described above. Spread rate around the primary invasion has varied over time. In 2015, the median annual boundary displacement was 6.5 km. This rate accelerated to 20.7, 20.3, and 20.5 km in 2017, 2018, and 2019 respectively. In recent years, though, spread at the margins of the primary invasion has apparently slowed, with median displacement of 5.2, 7.6, and 4.4 km in 2021, 2022, and 2023 respectively. This trend follows the expected slow-fast-slow spread pattern projected by theory, but the causes of the apparent slowdown are unresolved and there are many possible contributors including weather, land use, and reporting differences. In addition to the primary invasion, we also measured spread around 29 distinct invasion epicenters with sufficient sampling effort (≥20 absences within 5 km in each year of observation). Generally, spread around outbreaks in the first year after they were first detected was relatively slow, with most having median boundary displacement under 8 km. Taken together, these results show that spatial scaling and temporal variation can influence our understanding of invasive species spread. Also, continued sampling is necessary to evaluate temporal variation in spread rates.

An Effective Trap for Spotted Lanternfly Egg Masses

Phil Lewis, Emily Wallis, and Amanda Davila-Flores

USDA Animal and Plant Health Inspection Service (APHIS), Forest Pest Methods Laboratory
Buzzards Bay, MA 02542

phillip.a.lewis@usda.gov

ABSTRACT

Spotted lanternfly (SLF) (*Lycorma delicatula* (White)), an invasive planthopper discovered in Pennsylvania, USA in 2014, continues to spread and is now present in 14 states with substantial infestations present in seven states. Population projections using adult SLF trapping or visual counts are not reliable due to the transient, migratory behavior of the adults which make population forecasts difficult. Another approach to population monitoring is utilization of the stationary egg mass stage but counting small cryptic egg masses throughout the canopy of large trees in dense woodlots is arduous and prone to error.

After several field seasons testing various trapping configurations and materials, we have identified an efficient, simple, low-cost trap termed a 'lamp shade trap' that is attached to the lower trunk area of an SLF host tree. SLF females readily enter the trap and lay eggs on the thin, flexible trap surface. A vertical trap orientation was superior, and the most productive woodlots yielded an average of 47 and 54 egg masses per trap, and several traps had over 100 egg masses.

There were 1,943 egg masses tallied from 105 traps placed at six locations in two states. Egg mass counts in the area above and below the traps and on nearby control trees yielded very few egg masses in comparison. Selection of trees 15 to 20 cm in diameter for trap placement is most efficient, yielding good egg mass abundance while minimizing the amount of trap material used.

The lampshade trap has potential as an effective tool to identify SLF in new areas, gauge SLF population levels in woodlots and can also be used to collect and monitor egg masses for research purposes. Step-by-step instructions, pictures on LST construction and a materials list are available at: https://www.stopslf.org/stopslf/assets/File/LST-Construction-for-SLF-Egg-Masses.pdf. Source for the Journal article: https://doi.org/10.3389/finsc.2023.1154510.

Roadside Environmental DNA Surveys Provide Efficient and Sensitive Early Detections of Spotted Lanternfly Spread

Christopher Eddy, Mario Hernandez, Anthony Vastano, Mariel Vandegrift, Michael Allen, and Julie Lockwood

Department of Ecology, Evolution, and Natural Resources, Rutgers University
14 College Farm Road, New Brunswick, NJ 08901

Julie.lockwood@rutgers.edu

ABSTRACT

Roadways are a primary pathway for *Lycorma delicatula*, or Spotted lanternfly (SLF), spread especially along major interstates and highways where SLF often establish satellite populations after 'hitch-hiking' on cars and trucks. Working with the New York State Department of Transportation (NYSDOT), we developed an environmental DNA (eDNA) roadside survey protocol based on previous methodology used to successfully detect SLF within vineyards and urban forests. This protocol involves aggregating DNA from the surfaces of host trees using commercially available paint rollers and processing these samples with quantitative Polymerase Chain Reaction (qPCR) within an eDNA lab to discern if SLF DNA was present within each field sample. Our field survey required two crew members working from a light-duty truck, where this crew completed site survey protocols within 30 to 45 minutes. We targeted our surveys so that we preferentially included rest, text, or truck stops along I-90, I-86, I-81, I-87, and I-495. We visited 83 roadside sites in September and October across two years, 2022 and 2023.

We detected SLF DNA at 64 of the 83 sites (77%), whereas we had visual detections of SLF at only 4 of the sites (4%). We detected SLF presence at survey sites beyond the previously known invasion front, extending up to the Canadian border on I-87 and along Lake Erie near the Ohio border on I-86. We found that, overall, eDNA has a 50% probability of detecting SLF when present, and that five eDNA sampling occasions were sufficient to reach a 95% confidence of presence. We found no evidence that the probability of detecting SLF in eDNA surveys differed by survey month (September and October). We did find that the probability of detecting SLF in eDNA surveys was higher in 2022 than in 2023, reflecting our selection of survey sites in 2023 that were well outside of the known geographical range of SLF in New York (more difficult to detect). When we compared eDNA detection rates to those calculated for circle traps we found that eDNA had three-times higher probability of SLF detection and required a fraction of the survey effort needed to have high confidence in SLF presence at a site.

These results indicate that eDNA surveys perform very well in early detection and rapid response programs. Finally, although from a limited set of data, we confirm through our eDNA surveys that SLF are more likely to establish satellite populations along major interstates and highways than they will along less active roadways. In total, we surveyed approximately 900 miles of roadways in New York State spanning urban and rural forest

settings (e.g., areas near New York City and within the Adirondack Park) in about 6 weeks. Lab processing times averaged around 8 days for 100 field samples. Our data has been integrated with New York State SLF trapping information making it available for use by state and national agencies in their response effort. We suggest that eDNA surveys are a highly cost-effective, efficient, and sensitive way to inform SLF early detection and rapid response efforts across North America.

RISK ASSESSMENT MODELS AND PRIORITIZATION TOOLS

Invasion Risk of *Lycorma delicatula* to the Lake Erie Grape Belt

Matthew R. Helmus

Department of Biology, Temple University
1925 N. Broad Street, Philadelphia, PA 19122, USA

mrhelmus@temple.edu

ABSTRACT

Pests spread rapidly when inadvertently transported among properties that act as invasion hubs—locations where vehicles, goods, and people converge, facilitating the movement of invasive species across regions. Interactive and accessible decision support mapping tools can help stakeholders identify and manage these high-risk properties to control nascent populations early. However, such applications are only useful if there are workflows for leveraging them to support integrated pest management questions. Here, I present a four-step workflow to address the question of where proactive surveys should be conducted at hub properties to find nascent populations of *Lycorma delicatula* (SLF; spotted lanternfly). I used decision support mapping applications developed by Temple University that are publicly available on the *Lycorma delicatula* Integrated Pest Management (IPM) Dashboard (slf.iecolab.org, Figure 1). The workflow presented here supports optimal decision-making by state and federal agency operations teams and can be adapted for any future pest.

1. Define the limits of the invasion risk assessment.

Grape is a highly suitable host for SLF, and invaded vineyards have experienced production losses and increased management expenditures. SLF presents an extremely high risk of transport and invasion into important grape-growing regions worldwide. The first globally important grape region SLF is likely to invade is the Lake Erie Grape Belt, which is a designated American Viticultural Area (AVA). Located in northwestern Pennsylvania (Erie County) and southwestern New York (Chautauqua County), the Erie AVA is the largest grape production region east of the Rocky Mountains and the largest and oldest Concord grape-growing region in the world (Figure 2).

This invasion risk assessment for the Erie AVA was conducted in 2024, based on data from 2014–2023, and is valid for management and surveys occurring in 2025. Due to the randomness of transport events, it is possible that a property not identified in this risk assessment will be the first to have an established population of SLF. Therefore, surveys should be performed at as many hub properties as possible. Extension campaigns should focus on increasing awareness among workers at all hub properties in the region. Additionally, because initial SLF detections often occur at non-hub properties, outreach should engage the public, who are more likely to find SLF at such locations.

2. Assess establishment potential of the pest in the region of interest.

Based on species distribution and population dynamics models, the establishment potential of SLF across the Erie AVA is high, and the environment is unlikely to limit this pest's invasion of the region (Figure 3). Therefore, assessing transport risk is warranted.

3. Assess past and forecasted spread of the pest.

Based on the past spread of SLF, transport into the Erie AVA is likely to occur from the south through Pennsylvania rather than through New York (Figure 4). SLF was first detected in Berks County, PA, in 2014 (Figure 4A). By 2020, it had spread west through PA counties that follow major rail and interstate road transport corridors (Figure 4B). By 2023, it had spread north along the western PA border and established in Mercer County, south of Erie County (Figure 4C). Erie County has also had several public reports of SLF, while Chautauqua County has had none (Figure 4D). Finally, a spread forecasting model indicates that SLF is likely to establish in Erie County before Chautauqua County (Figure 5).

4. Identify hub properties likely to transport the pest.

SLF lays eggs on a variety of surfaces—including plants, stones, vehicles, pallets, and railcars—which allows it to readily hitchhike to new locations. Spatial data across the U.S. were collected and harmonized on hub locations from various sources, including proprietary databases and open-access repositories. The focus was on properties such as rail yards, distribution centers, and landscaping companies that are likely to facilitate the pest's spread through human-mediated transport. These data are mapped within interactive decision support tools called pestHubMap apps, developed by Temple University for multiple states and regions across the U.S.

Based on assessment with the Erie County pestHubMap app and its provided data layers (railroads, transport risk, satellite imagery, Figure6), the following hub properties and their surrounding areas should be prioritized for surveys in 2025:

Auction Center: 12141 US-6, Corry, PA 16407

Campgrounds (multiple): 352 Holliday Rd, Erie County, PA 16430

Campgrounds: 13939 Crosscut Rd, Corry, PA 16407

Campgrounds: 12681 PA-89, Wattsburg, PA 16442

Campgrounds: 9640 Findley Lake Rd, North East, PA 16428

College Campus and Stadium Parking: 4701 College Drive, Erie, Pennsylvania 16563-0001

Distribution Center: 1520 Downing Ave, Erie, PA 16511

Distribution Center: 7500 Birkmire Dr, Fairview, PA 16415

Distribution Center: 2200 W 50th St, Erie, PA 16506

Distribution Center: 1702 Pittsburgh Ave, Erie, PA 16505

Distribution Center: 8115 Wattsburg Rd, Erie, PA 16509

Distribution Center: 4800 Loomis St, North East, PA 16428

Distribution Center: 2600 Hirtzel Rd, North East, PA 16428

Fairgrounds and nearby rail: 30 Academy St, Albion, PA 16401

Fairgrounds: [13993 State Hwy 8, Wattsburg, PA 16442]

Landscaper: [429 State St #2, Erie, PA 16501]

Landscaper and nearby properties: [2520 Manchester Rd, Erie, PA 16506]

Rail Yard: [2962 Mechanic St, Lake City, PA 16423]

Rail Yard: [1114 Mechanic St, Girard, PA 16417]

Rail Yard: [1520 Downing Ave, Erie, PA 16511]

Rail Yard: [2602 Pearl Ave, Erie, PA 16510]

Truck Rental: [13250 US-6, Corry, PA 16407]

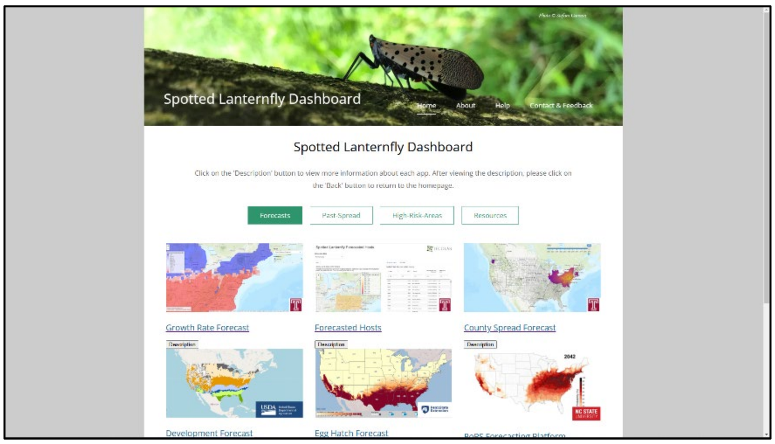

FIGURE 1. Integrated pest management (IPM) decision support tools for *Lycorma delicatula* are available on the Spotted Lanternfly Dashboard (link). Apps from this dashboard were used to estimate the invasion risk of the Erie AVA.

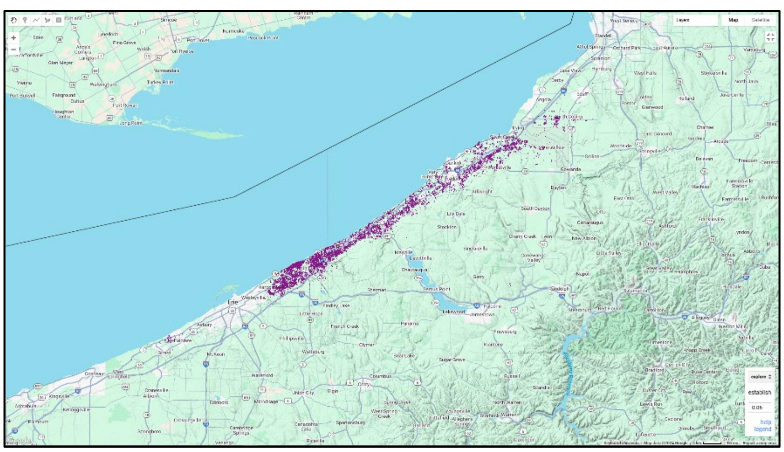

FIGURE 2: The largest and oldest Concord grape growing region in the world is the Lake Erie Grape Belt, an American Viticultural Area (AVA) on the SE shore of Lake Erie in NW Pennsylvania and SW New York USA. Image from the *Lycorma delicatula* global invasion risk map app (link).

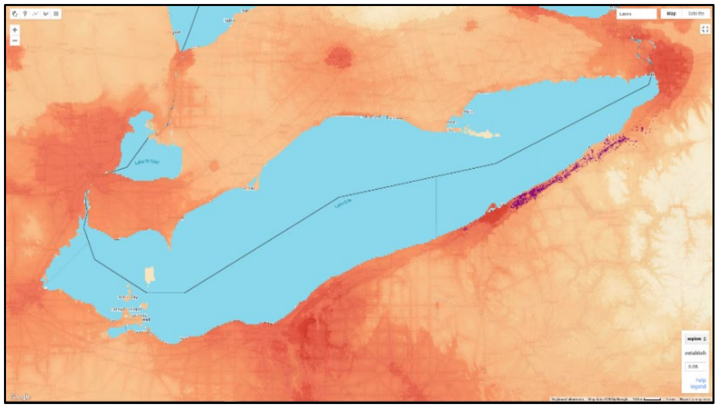

Figure 3: Establishment potential is high across the Lake Erie Region. All areas shaded light to dark red are above the minimum threshold of environmental suitability for SLF. Image from the *Lycorma delicatula* global invasion risk map app (link).

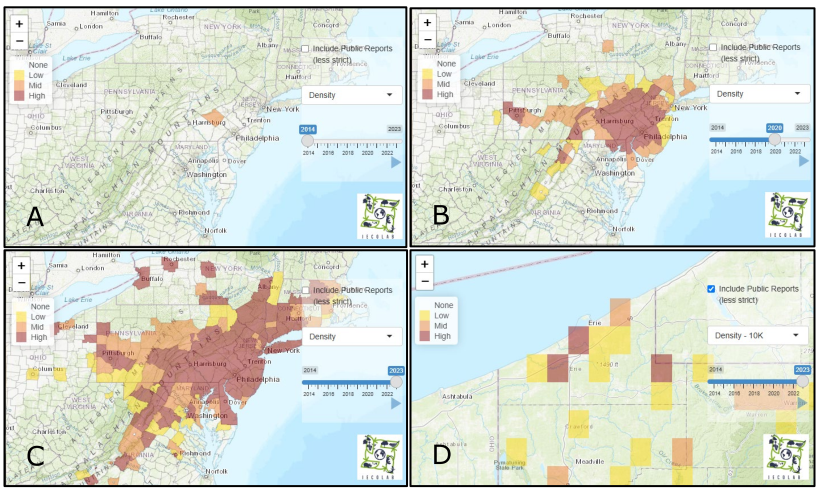

FIGURE 4: Past spread of SLF in 2014 (A), 2020 (B), and 2023 (C). Public reports of SLF in the Lake Erie region (D). By 2023, no confirmed established populations have been found. All public reports were followed up by agency personnel and were considered regulatory incidents that did not lead to established populations. Images from the *Lycorma delicatula* U.S. invasion timeseries app (link). Data from lydemapr database.

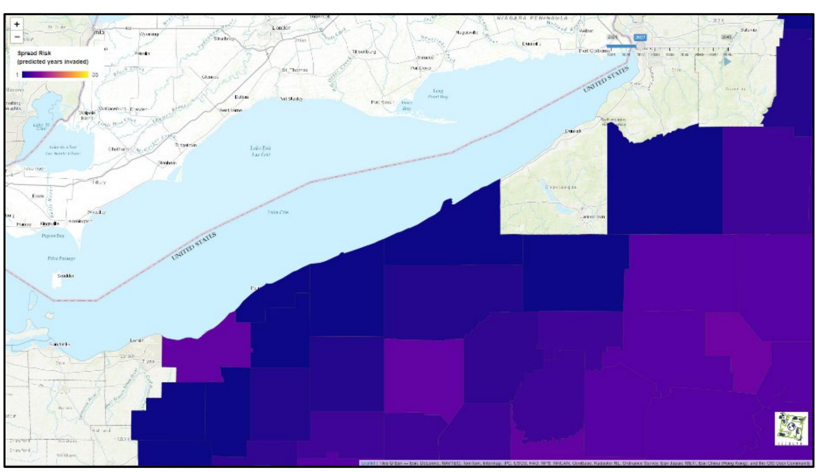

FIGURE 5: SLF spread model forecasting indicates that Erie County, PA, will likely have an established population of SLF before Chautauqua County, NY. Images from the *Lycorma delicatula* county spread forecast app (link).

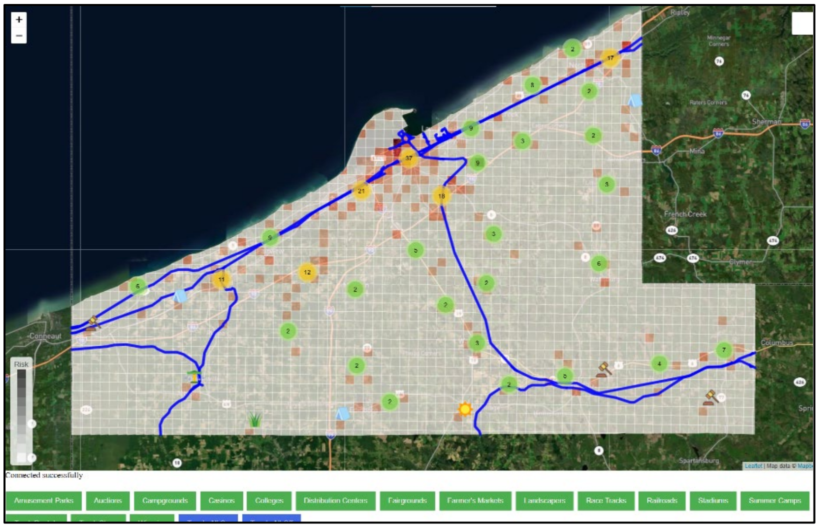

Figure 6: The Erie County, PA, pestHubMap app is an interactive mapping application for identifying invasion hub properties likely to transport SLF (link).

Real-time Mapping of Phenology and Climate Suitability for Spotted Lanternfly

Brittany Barker[1,2] and Len Coop[1,2]

[1]Oregon IPM Center
[2]Department of Horticulture
Oregon State University
2701 SW Campus Way, 2215 Cordley Hall, Corvallis, OR 97331

brittany.barker@oregonstate.edu

ABSTRACT

An improved understanding of both when and where to expect invasive species can support early detection programs and other efforts to control invading populations. We developed and evaluated the predictive performance of a model for spotted lanternfly (SLF), *Lycorma delicatula*, for use in the DDRP (Degree-Days, Risk, and Pest event maps) platform. DDRP was designed to produce timely predictions of the phenology and risk of establishment (based on climatic suitability) of invasive insect pests. We are using DDRP to produce regularly updated forecasts for 18 invasive insect species including SLF for the continental U.S. (CONUS), available at USPest.org (https://uspest.org/CAPS). The objective of this study was to provide accurate and timely forecasts of establishment risk and the appearance of SLF nymphs and adults to help guide decision-making related to surveillance and management.

Developmental temperature thresholds, stage durations, and the timing of phenological events used in the DDRP model for SLF were estimated by re-interpreting temperature vs. development rate data from several laboratory studies and monitoring studies of this pest. Phenological observations from China and North America in the iNaturalist database were used to evaluate the accuracy of predicted dates of events. The climatic suitability model was developed using eco-physiological information and presence records from China, and then validated using presence records from CONUS. We demonstrated the model using a phenological event map of first adult emergence for SLF for CONUS for 2024. Additional details about the DDRP model are available in a technical white paper at https://uspest.org/CAPS.

Predictions of first adult emergence for SLF in 2024 for CONUS varied substantially by latitude (Figure 1). First adult emergence occurred as early as June in southern parts of SLF’s current distribution (North Carolina), compared to late September in areas close to its northern range edge (New York). An inability for SLF to complete its life cycle may reduce the likelihood of establishment for cooler areas, such as high-elevation parts of the western U.S. (Figure 1). DDRP predicted that first adult emergence of SLF occurred prior to the observation date of adults for 96.5% (10535/10649) records in the iNaturalist database. Thus, the model potentially over-predicted adult emergence for only 3.5% of the records. Cold stress excluded SLF from parts of the upper Midwest and northern New England for several modeled years between 2004 and 2023, whereas heat stress excluded the pest from hot areas of the Southwest and California (Central Valley) (Figure 2). The model correctly

included presence records from North America in the potential distribution for SLF for each of 20 modeled years.

The DDRP model for SLF can help decision-makers understand both when and where to conduct surveillance for this invasive pest. Forecasts can be accessed at USPest.org as well as the USA National Phenology Network at https://www.usanpn.org/data/forecasts, where end-users may interact with maps and submit phenological observations to help us further improve the model.

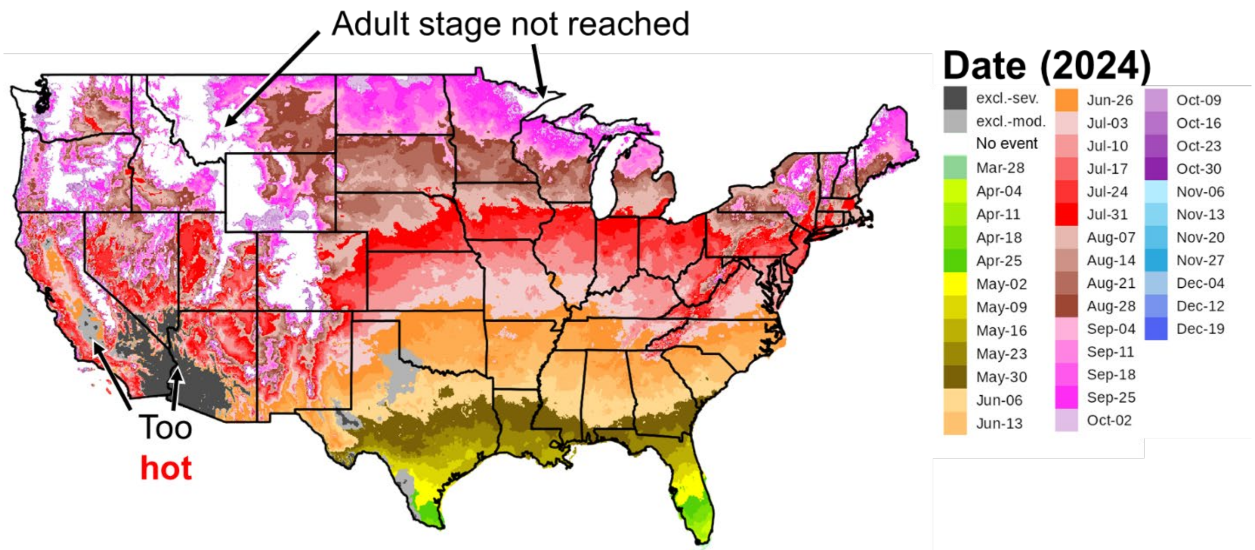

FIGURE 1. Map depicting the average date of first adult emergence of SLF with severe and moderate climate stress exclusions (based on cold and heat stress units) for 2024 produced by DDRP.

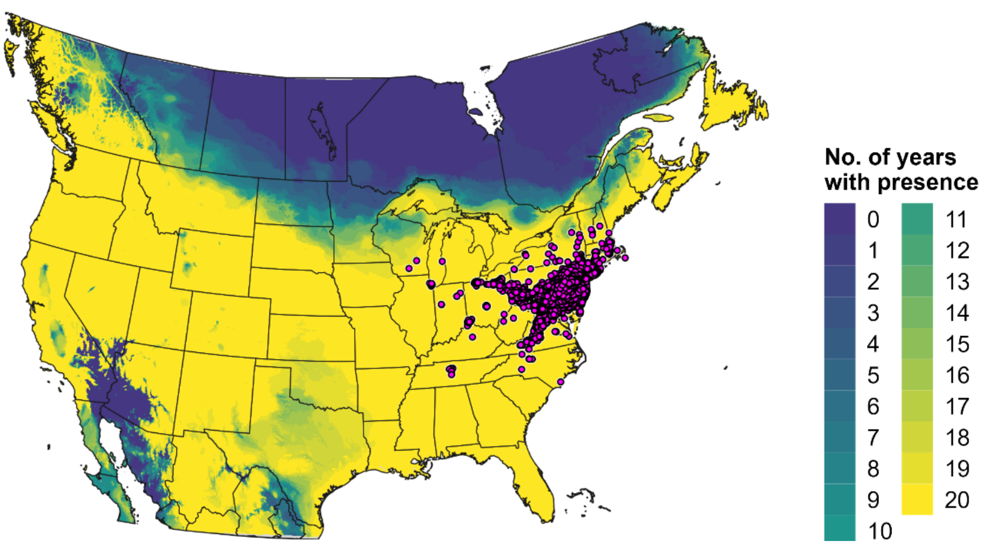

FIGURE 2. The modeled potential distribution for SLF in North America (CONUS, southern Canada, and northern Mexico) according to DDRP runs for 20 recent years (2004−2023). Yellow areas were included in the potential distribution for all 20 years, whereas areas with cooler colors were excluded by climate stress for one or more years. Pink circles depict the approximate geographic location of presence records used to validate the climatic suitability model.

Modeling the Life Cycle and Spread of the Spotted Lanternfly in the U.S.

Daniel Strömbom

Department of Biology, Lafayette College
Easton, PA 18042

stroembp@lafayette.edu

ABSTRACT

In the spring of 2020, students enrolled in Biological Modeling (BIOL285) at Lafayette College unanimously decided that the topic for the semester-long research project should be the spotted lanternfly. This elective course is designed for biology majors that found the mathematics and modeling part of the required Quantitative Biology BIOL113 course interesting and want to learn more advanced modeling techniques and how to use modeling in practice. In particular, learn how to identify questions that modeling may be useful to address and how to set up and refine models based on available biological information. To practice this on the course the class selects a topic of current interest that neither I or anyone in class have extensive knowledge about. The idea being that we will start from scratch and proceed in an exploratory fashion and adapt to whatever situation we find ourselves in to learn how to actually model.

Once the class had selected the topic, the next step was to come up with questions about the lanternfly. Some of the questions that turned out to lead somewhere were: How fast are lanternfly populations growing? Are effective control measures available? Where will it spread to next? What drives the spread?

Then we proceeded to see if we could find answers to these questions in the literature and determine if there were any issues or gaps that we may be able to address using modeling. Below is a summary of what we found for each of these questions in Spring 2020.

- How fast is the US lanternfly population growing?

The consensus is that the population growth rate is rapid, but no population level estimate is available. We conclude that we should try to estimate it.

- Are there effective control measures available?

The literature says yes, and reports that some are even 100% effective! However, we note that the published studies were conducted on short timescales where population dynamics is not operating, and often effectively all lanternfly available in the study could be found and treated with the control. We conclude that modeling may be useful to generalize the results in these empirical studies to include population dynamics and/or incomplete delivery.

- Where will it spread to?

Published model forecasts suggest that the lanternfly will eventually occupy a substantial proportion of the US. We note that the current infestation only occupies a tiny part of the

forecasted maximal distribution and conclude that if we could forecast how it will spread from the current distribution to the maximal forecasted one, perhaps we can stop it before it gets there.

- What drives the spread?

The literature suggests many driving factors, e.g. host plant availability, human activity in general, certain business activities, vehicular transport, population etc. However, we cannot find any statistical evidence in the literature that any of the proposed factors are indeed associated with the spread and/or settlement of the lanternfly in the U.S.

Based on these findings we planned two projects:

Project 1. Find/Create a population dynamics model for the spotted lanternfly that can be completely parameterized using the current literature and then use it to

- Estimate the population growth of the lanternfly in the U.S.
- Assess the efficacy of the control measures presented in the literature when population dynamics and incomplete delivery are taken into account.

Project 2. Determine whether statistical evidence to support that the proposed drivers mentioned in the literature are indeed associated with lanternfly infestation in the US. Prioritizing factors and drivers that "we" may be able to affect. Then construct a spread model based on the factors/drivers found to be associated with infestation and assess its accuracy using past data. If it is reasonably good, use it to forecast the spread in the coming years, and if possible use it to identify, and assess proposed, management efforts.

Neither of these projects were completed by the end of the course, but two students continued to work on them through summer research and subsequent independent research courses. For Project 2 we eventually had to recruit five more independent research students to help us complete it, several of whom were in the BIOL285 class where the project was initiated.

Project 1 resulted in the introduction of a simple population dynamics model parameterized using available information in the literature model that was used to 1. Estimate the annual growth rate of the SLF population in the U.S. to be 5.47, 2. Establish that only three out of six proposed control measures considered have the potential to decrease the population even if we can find and treat each SLF in every stage, and 3. That even with a combined strategy involving the most effective proposed control measures, about 35% of all SLF in the relevant stages must be found and treated to turn population growth into decline. More details about this work can be found in Strömbom, D. and Pandey, S., 2021. Modeling the life cycle of the spotted lanternfly (*Lycorma delicatula*) with management implications. Mathematical biosciences, *340*, p.108670. https://doi.org/10.1016/j.mbs.2021.108670. This project also led another student to create an online game where players are invited to try to control/eradicate a lanternfly population that grows at a rate of 5.47. Play it here: https://lafcollanternflies.github.io.

Project 2 resulted in establishing that there is statistical evidence to suggest that four specific human activity-related factors are associated with infestation and the introduction of a network model based on these factors. This model was found to reproduce key features of the spread 2014 to 2021. In particular, the growth of the main infestation region and the opening of spread corridors in the westward and southwestern directions that are consistent with data and the model accurately forecasts the correct infestation status at the county level in 2021 with 81% accuracy. The model was also used to forecast the spread up to

2025 in a larger region and those predictions are relatively accurate even now in 2024. More details about this project can be found in Strömbom, D., Sands, A., Graham, J.M., Crocker, A., Cloud, C., Tulevech, G. and Ward, K., 2024. Modeling human activity-related spread of the spotted lanternfly (*Lycorma delicatula*) in the US. Plos one, *19*(8), p.e0307754. https://doi.org/10.1371/journal.pone.0307754.

The work presented here was the starting point for the spotted lanternfly research track in my lab and we have since then developed it further in several directions, of which some has already been published (Strömbom et al. 2024. Royals Society Open Science 11(2), 231671. https://doi.org/10.1098/rsos.231671), and several are ongoing. This has not only contributed to the spotted lanternfly literature, but also provided meaningful in-class and individual modeling-related research experiences for many undergraduate biology majors at Lafayette College. Without these students, their ideas and hard work, these papers would not exist and many of the results they contain would likely remain undiscovered.

Iterative Forecasting Leads to a Better Understanding of SLF Spread Patterns

Chris Jones, Brit Laginhas, Shannon Jones, Ben Seliger, and Ross Meentemeyer

North Carolina State University
Raleigh, NC 27695

cmjone25@ncsu.edu

ABSTRACT

Forecasting newly emerging pests like spotted lanternfly can be challenging early in the invasion as little is known about how the species responds to its new environment. Iterative forecasting allows us to look at how updating model parameters over time improves model performance and how a new understanding of the species' biological tolerances can improve model performance. We use a spatially and temporally dynamic spread model called the Pest or Pathogen Spread (PoPS) model to iteratively update model parameters through calibration and validation and to include new data on temperature tolerances, spread via railroad networks, and SLF phenology. Specifically, we use new data collected through annual surveys to update our calibration using the latest observational data to improve model parameters for forecasts. We updated our temperature tolerances as the average across lifespans based on Kreitman et al. 2021 data. We updated the model to account for long-distance dispersal along rail networks, and we used a phenology model to control the timing of emergence and spread within the model. Our results show that iteratively updating model parameters can significantly impact our model performance, and an improved understanding of spread dynamics and biological tolerances can have a major impact on model performance. Throughout our study, from 2017 to 2023, model performance improved from 0.6125 MCC to 0.8725 MCC, see Figure 1. Iteratively updating parameters improved model performance by 0.12, adding the network improved the model by 0.075, adding the updated temperature tolerances improved the model by 0.05, and adding in the phenology model improved the model by another 0.015.

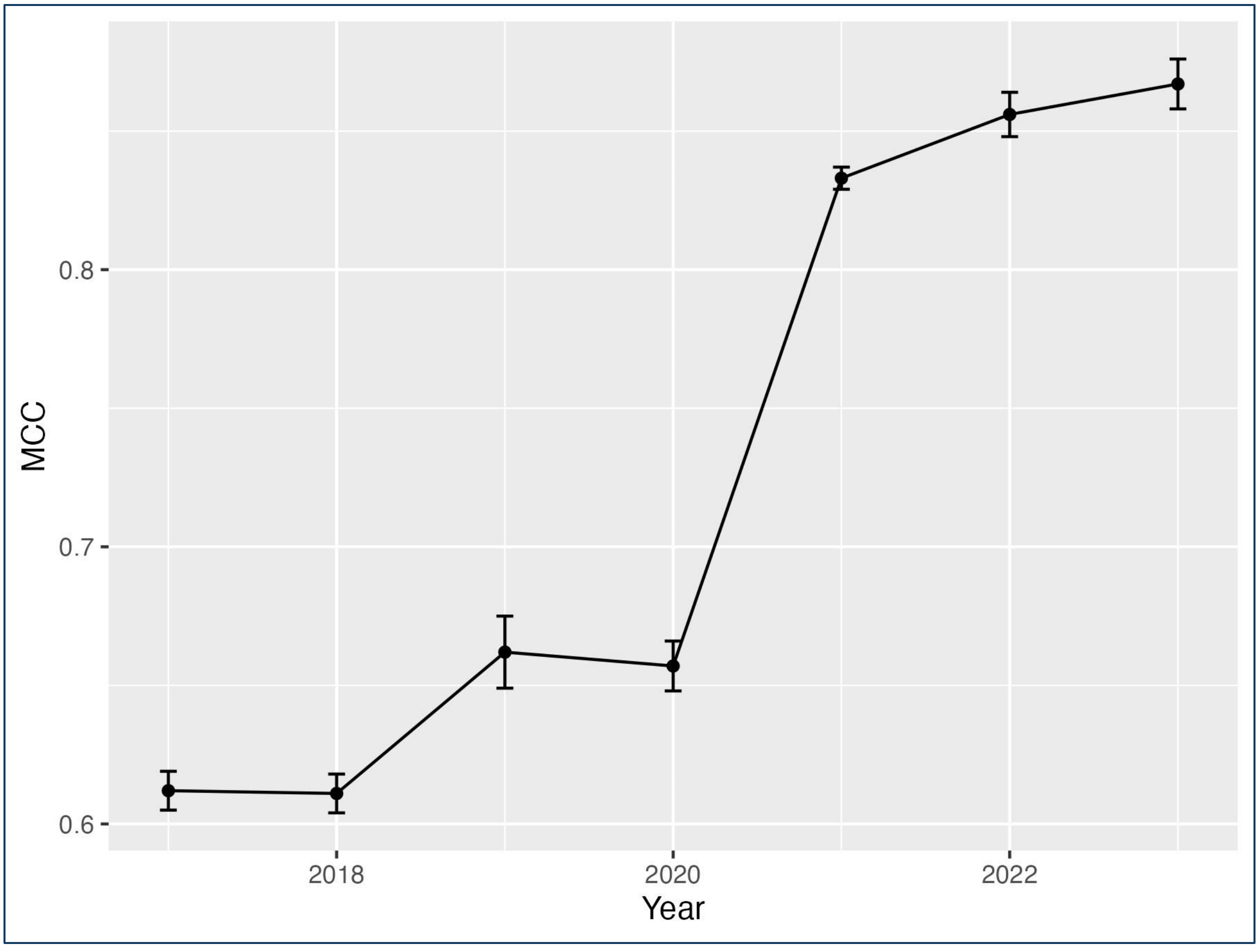

FIGURE 1. Total improvement in MCC over time. From 2020 to 2021, the network model and the updated temperature tolerances were added to the model, and the phenology model was added in 2023.

Mathematical Framework for Modeling the Movement of Adult Spotted Lanternfly into Vineyards and Application for Optimal Control

Jacob Woods[1], Fatma Seker[2], Benjamin Seibold[1], and Matthew R. Helmus[2]

[1]Department of Mathematics
[2]Department of Biology
Temple University, 1805 North Broad Street Philadelphia, PA 19122

jacob.woods@temple.edu

ABSTRACT

The spotted lanternfly (*Lycorma delicatula*, SLF) is a plant hopper that primarily feeds on hosts such as the tree of heaven and grape vines. Hosts may succumb and die from the infestation, posing a significant concern for the agricultural industry in particular vineyards are at great risk. SLF can damage and even kill vines throughout a season this coupled with the emergence of adults, the time when SLF are most mobile, coinciding with grape harvest makes the control of SLF very challenging in these landscapes. The SLF has been observed participating in a gliding-ascending cycle where the SLF ”jumps” or is knocked off a host and moves randomly away for some time, eventually seeking out a new host, then finds a host and climbs up and repeats the cycle.

We construct a model based on the gliding-ascending cycle of the SLF to capture how agents would move around in a landscape of hosts. This model utilizes experimental data to help parameterize model functions describing the movement and preferences of SLF. Further, we reduce the model using assumptions based on the SLF behavior to a Markov model for how SLF hops from host to host. We model the SLF movement in three stages:

- Feeding Stage: Here is where SLFs spend most of their time on hosts feeding.
- Gliding Stage: Here SLF glide pseudo-randomly away from hosts.
- Seeking Stage: Here SLF will head towards the most attractive host they see based on their current location.

We assume that SLF glide away from a host on average a distance proportional to the height with a fixed variance and that a host’s attractiveness at a given location is based on its height, species, and how far away from the host the location is. This allows us to construct a host hopping model on given an arrangement of hosts only parameterizing the preference for each host type in the model, the gliding variance, and the mean gliding distance. Using satellite data and data from the NEON SERC database we apply our host hopping model to the Vineyards at Dodon a Maryland-based vineyard seen in Figure 1.

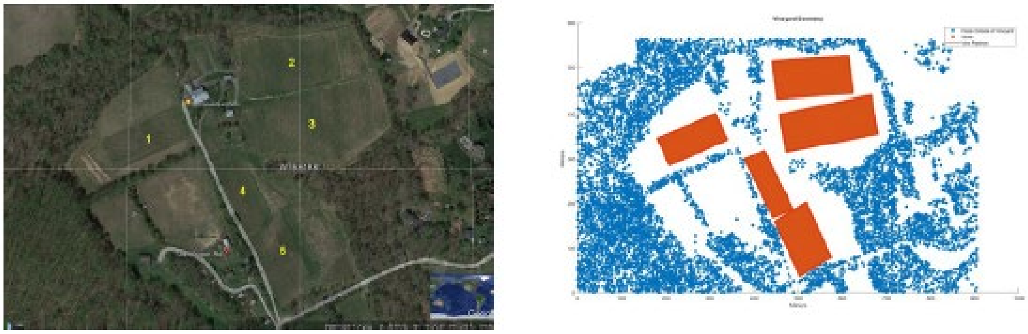

FIGURE 1. GPS imagery marking 5 patches of vines labeled (left). Model hosts in blue being forest trees and hosts in red being vines in vineyard (right).

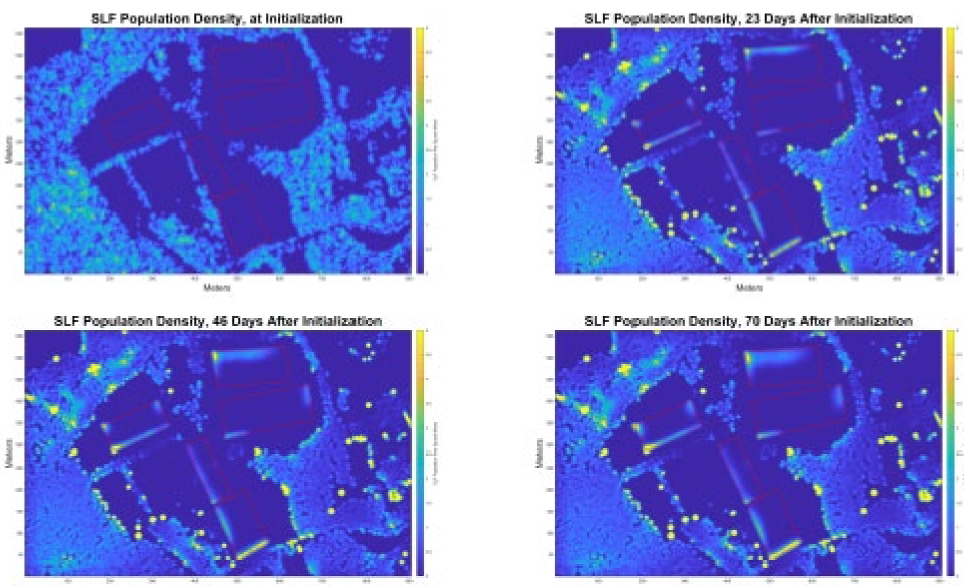

FIGURE 2. Simulation of SLF host hopping model on the vineyards at Dodon. SLF initialized population uniformly spread in the forest.

We run our host hoping model on the Vineyards at Dodon landscape digitized as seen in Figure 1 for 70 days, representing the time from adult emergence till harvest of grape. Compared to field observations we see qualitatively similar distributions of SLF with the population quickly invading and occupying the edge of the vineyard but rarely moving deeply into it.

We then look at control actions based on thresholds for a fixed initial population looking at how various thresholds affect the population over time in the vineyard in Figure 3. We see that thresholds too low miss out on control of SLF moving into the vineyard late in the season and thresholds too high miss out on preventing damage done by SLF that move into the vineyard early. All thresholds are tested for two different initial conditions and we observe which threshold maximizes the damage reduction in the vineyard when compared to no control action plotted in Figure 4 for both initial populations. We see for a given geometry the relationship between threshold and damage reduction is non-trivial for our different initial conditions this relationship looks qualitatively different. This indicates that the optimal choice of threshold for when to administer control actions may be context-dependent.

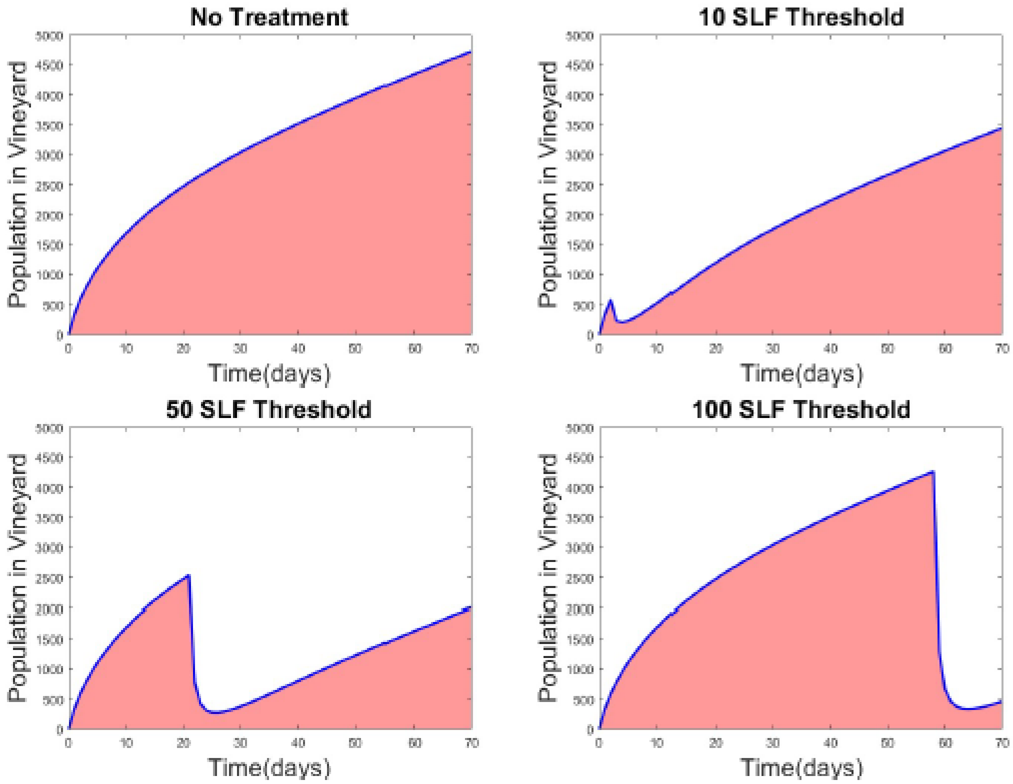

FIGURE 3. SLF population as a function of time for no treatment and three different treatment thresholds for and initial population evenly distributed in the forest. The area of the pink region represents the number of SLF*days spent on vines in the vineyard. For a threshold of 10 SLF there is a 38.5% reduction of SLF days, for a threshold of 50 there is a 60.8% reduction, and for a threshold of 100 there is a 23.2% reduction.

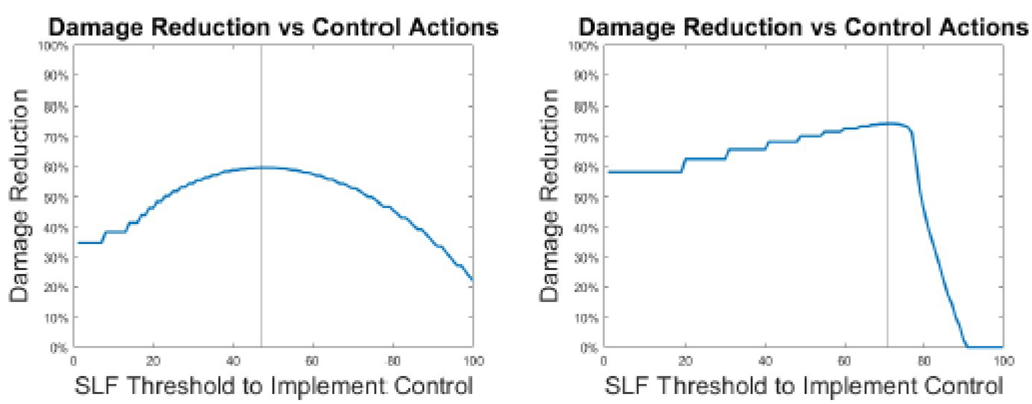

FIGURE 4. Percent damage reduction as a function of SLF threshold for two different initial SLF populations.

Quantifying Spotted Lanternfly Establishment Risk and Resistance Based on Principled Life Cycle Models

Benjamin Seibold[1] and Matthew R. Helmus[2]

[1]Department of Mathematics
[2]Department of Biology
Temple University, 1805 N. Broad Street, Philadelphia, PA 19122, USA

seibold@temple.edu

ABSTRACT

Observational understanding about the spotted lanternfly (*Lycorma delicatula*), an invasive species in the Eastern United States, has been established both at local and at global scales. Principled mathematical models establish connections between these two scales, and thus can serve (i) as predictive tools for future spread and establishment, (ii) to establish counterfactuals (e.g., what would the establishment be in the absence of control measures), and (iii) to build and falsify hypotheses (e.g., a hypothesized local behavior can be falsified if it must lead to global features that are not in agreement with observations). Here, the "local scale" refers to insights about the individual behavior and collective development, survival, and spread in one location, obtained via field studies and laboratory experiments; and "global scale" refers to information on regional (e.g., US East Coast) scales, e.g., establishment maps.

A mathematical model for the spotted lanternfly life cycle, dominated by a local temperature profile over time, $T(t)$, is outlined. The model captures the co-existence of agents at all possible life stages and all developmental ages, including multiple possible developmental pathways (diapause, see below). The life cycle is divided into four life stages: non-diapause eggs, diapause eggs, post-diapause eggs, and motiles. Each is equipped with a function $\rho(a,t)$, representing the density of agents at developmental age $a \in [0,1]$ on that stage, and at time t. On each of these four domains, agents possess a uniform developmental rate, death rate, and age distribution widening. Assuming that Allee and overpopulation effects are secondary, a linear partial differential equation describes the temporal development of the age-density,

$$\frac{\partial}{\partial t}\rho + \nu\frac{\partial}{\partial a}\rho = -m\rho + \xi\nu\frac{\partial^2}{\partial a^2}\rho\,,$$

where $\nu(T)$ is the developmental rate, $m(T)$ the death rate, and ξ a parameter that captures the widening of age-distributions (e.g., for motiles, even if all agents were to hatch at the same time, later there would be a co-existence of multiple instars). The four stages are coupled via flux conditions, so that diapausing transitions into post-diapause, and both non-diapause and post-diapause transition into motiles. Finally, an egg laying kernel yields an in-flux into the non-diapause or diapausing domains, based on the motile age-density at later age values, and affected by diapause, assumed here to be triggered by photoperiod. See Figure 1 for a visual depiction of the cycle. All model parameters are calibratable via

local-scale field and laboratory data. Moreover, the model framework is readily adaptable to different principles, e.g., alternative mechanisms for diapause could be captured.

Given a temperature profile over the course of a year, the model induces a one-year development operator that maps the system state, captures by the four age-density functions, one year into the future. Assuming a periodic profile $T(t)$, e.g., obtained via a 10-year average, the long-term local species development is captured by an annual growth factor R_0, i.e., the population size one year into the future divided by the population size now. The dominant eigenvalue, λ_1, of the one-year development operator is a proxy for R_0.

Predictive results of the annual growth factor, obtained by simulating the calibrated model for all counties in northern Pennsylvania and Southern upstate New York, are shown in Figures 2 and 3 (from the authors' SLF dashboard `iecolab.org/slfDashboard`). For each county, the local climatic 10-year average temperature profile is used. Intense blue represents reliably no establishment potential ($R_0 < 0.7$), while intense red represents strong growth potential ($R_0 > 3$). Less intense colors represent the intermediate regimes. Figure 2 shows the results for a model calibrated with the assumption that spotted lanternfly have ample access to tree of heaven (*Ailanthus altissima*), the spotted lanterfly's preferred host. In contrast, the results in Figure 3 assume limited access to tree of heaven and only access to maple, manifesting in reduced development rates. These model results can guide agencies and stakeholders in their planning efforts for future control actions, and they provide counterfactuals for certain past control actions such as removal of tree of heaven. Moreover, predictions on the pest's establishment potential under expected future climate change can be carried out.

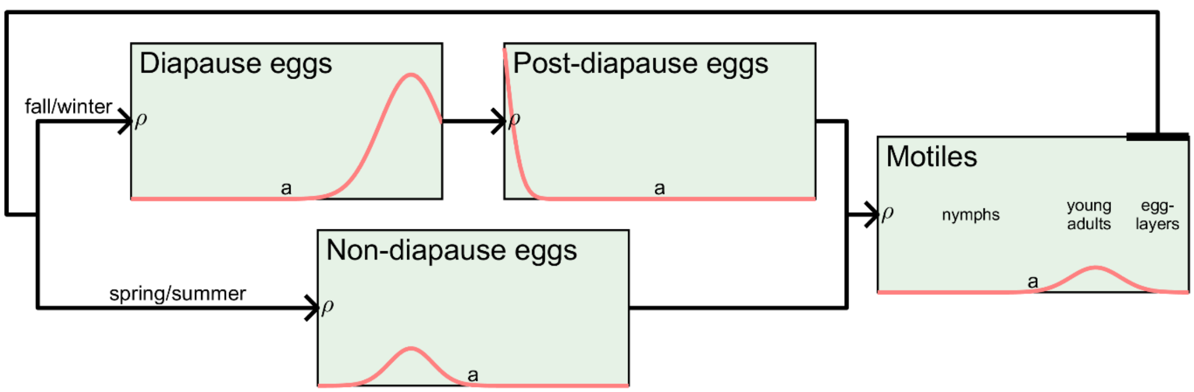

FIGURE 1: Domains for spotted lanternfly life cycle model, allowing for co-existence of life stages/ages and multiple developmental pathways.

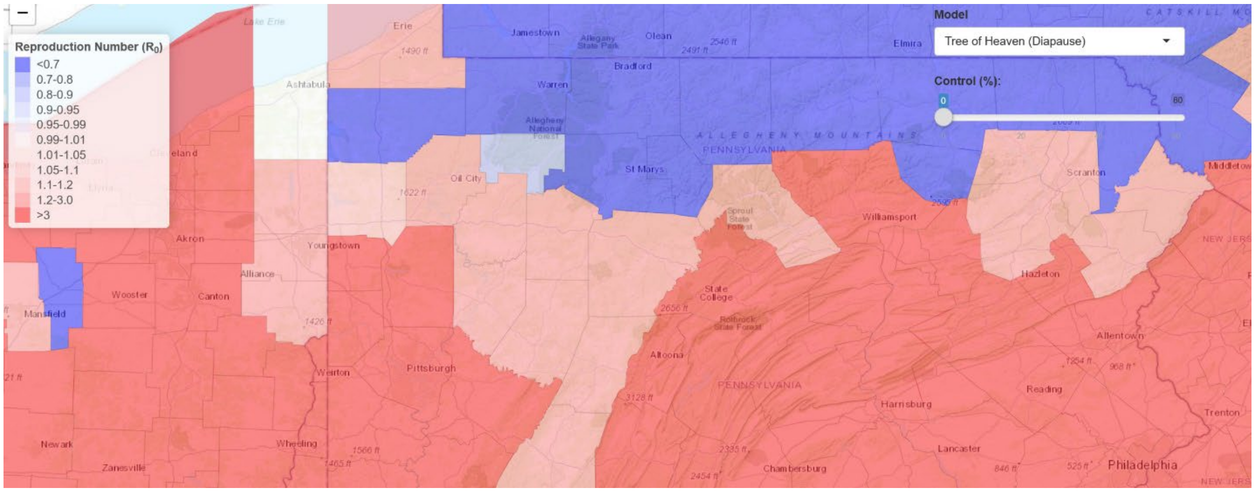

FIGURE 2: Model predictions for annual growth factor of spotted lanternfly, assuming access to tree of heaven.

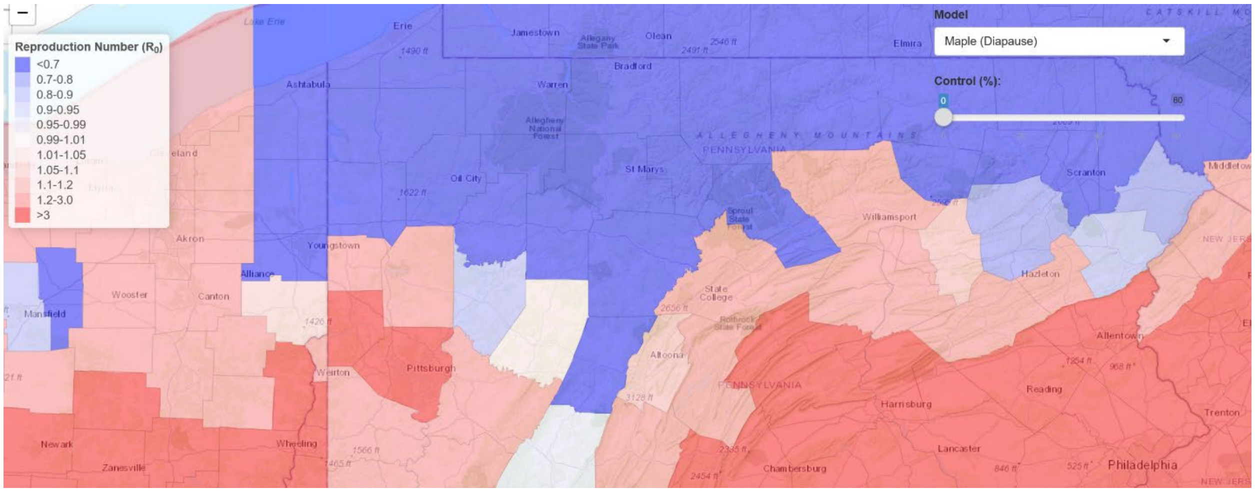

FIGURE 3: Model predictions for annual growth factor of spotted lanternfly, assuming no access to tree of heaven, only to maple.

RISK MITIGATION AND PRACTICAL MANAGEMENT

Development of Action Thresholds for Managing Spotted Lanternfly in Winegrapes

Flor E. Acevedo, Michela Centinari, Sukhman Singh, Taran Rowless, Andrew Harner, Misha Kwasniewski, Jack Dwenger, and Claudia Schmidt

Penn State University

fea5007@psu.edu

ABSTRACT

The Spotted lanternfly (SLF), *Lycorma delicatula* is an invasive insect that threatens the U.S. grape and wine industry. SLF suppresses photosynthesis, sap flow, and carbohydrate storage in grapevine roots. Economic losses are associated with reductions in yield, increased use of insecticides, and vine death. Grape growers are educated on SLF scouting, identification of life stages, and use of insecticides to control this insect. However, critical research on SLF action thresholds is lacking and urgently needed to prevent economic loss. The goal of this study is to estimate economic thresholds for SLF when feeding on *Vitis vinifera* cv. Cabernet Franc. Our objectives are to determine 1) the effect of various SLF densities on plant yield and juice chemistry and 2) the SLF density that should trigger management actions. To accomplish these objectives, we enclosed 20-year-old grapevines in mesh cages and infested them with 15 SLF densities (0, 1, 2, - 15 individuals per shoot). We tested the effect of nymphs and adults on yield loss and juice chemistry for two consecutive years and the effect of adult feeding for an extra year. We found no effect of SLF feeding (nymphs or adults) on yield during the first year of infestation, but there was a reduction in grape juice PH, total soluble sugars (TSS), phenolics, and tannins with the higher adult densities (> 6 insects/shoot). Feeding by nymphs also reduced TSS, but did not affect the remaining parameters tested. During the second year of consecutive SLF infestation, there was a reduction in yield, PH, and TSS with adult densities higher than six insects/shoot. During the third year of consecutive adult infestation, we found a sharp decrease in yield with adult densities higher than four insects/shoot. These preliminary results suggest that adult SLF feeding affects juice chemistry parameters within a single season and decreases yield after the second year of infestation. However, nymphs don't seem to be as damaging as adults; feeding by nymphs did not decrease yield or have consistent undesired effects on juice chemistry in old vines at the densities used in our experiments. These results, along with information on SLF management costs that will be collected from grape growers and crop value, will help us estimate economic thresholds for SLF management in *V. vinifera*.

Threshold-based Sprays for Management of Spotted Lanternfly in Vineyards

Laura J. Nixon, Lisa Tang, Faith Ketterman, Cara Hodge, Taylor Lucas, Annette Martenot, and Tracy C. Leskey

USDA Agricultural Research Service (ARS), Appalachian Fruit Research Station
Kearneysville, WV, USA

laura.nixon@usda.gov

ABSTRACT

Spotted lanternfly (SLF) is an invasive phloem feeder with a broad host range; over 100 host plant species have been reported. Tree of heaven is a primary host for SLF feeding and development, however, in the US, economic damage has been reported on commercial grapevines; indeed, among *Vitis* species, *Vitis vinifera*, best supports SLF development and survivorship. To help address the needs of winegrape growers, we conducted a preliminary study (Fall 2023-Fall 2024) to establish the impact invading SLF nymphs and adults on grapevine health and yield. In this study, there were two treatments: 1) insecticide treatments applied to vines when weekly counts of SLF reached either 150 nymphs or 80 adults per vine (thresholds were based on densities found to be injurious to grapevines in studies by Harner et al. 2022); and 2) untreated control vines (though weekly counts of SLF nymphs and adults were made) to quantify field-based impacts of invading SLF and their feeding on vines. Adults were present in this vineyard for the first time in Fall 2023, at which point the study was initiated with vines in the treatment group sprayed with an insecticide and those in the untreated group left unmanaged. Vine health measurements taken from vines in June 2024 when nymphs were present showed a significant decrease in leaf water potential in control vines; though these measurements were still within the normal range, it is still concerning considering adults were present only for a brief period in Fall 2023 and nymphs (present on vines in Spring 2024) have been thought not to be damaging to vines. Moreover, yield data from the 2024 season showed a significant decrease in average cluster weight from berries harvested from untreated Cabernet Franc vines and a significant decrease in total vine yield from Traminette vines in untreated vines. In total, four insecticide sprays were applied in 2024 to target SLF in the threshold blocks. Collectively, our results point to the possibility that SLF can affect vine health and yield within one year of infestation, and that time targeted sprays can assist in management.

Novel Technology and Biological Target for Spotted Lanternfly Control

Man-yeon Choi[1] and Gregory Parra[2]

[1]USDA Agricultural Research Service (ARS), Horticultural Crops Disease and Pest Management Research Unit
3420 NW Orchard Ave, Corvallis, OR 97330

[2]USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Science and Technology (S&T)

man-yeon.choi@usda.gov

ABSTRACT

Invasive insect pests often expand their populations rapidly because there are few or no competitors and natural enemies in the new ecosystem. It can result in a huge economic impact, so a quick response to controlling pests is critical. The most recent threatening invasive insect pest in the United States, the spotted lanternfly (SLF), *Lycorma delicatula*, is no exception. Most of the primary control options for SLF rely on synthetic chemical insecticides, despite many adverse environmental and human health, and developing insecticide resistance in the future. Therefore, the heavy reliance on chemical options should be replaced or at least complemented by species-specific management strategies using biological targets that focus on less toxic and more environmentally friendly alternatives.

The discovery of new insecticides, biopesticides, in particular, is a time-consuming process with high risks and low chances of success. Despite the wealth of information on integrative pest management (IPM), the use of biopesticides to control insect pests is still limited. With the rapid increase in molecular biology tools and information, the development/application of advanced molecular methods to develop new control options is becoming a reality in entomology.

Insect neuropeptides (NPs) and their G protein-coupled receptors (GPCRs) are potential biological targets for the development of new insecticides, because they are involved in many key biological processes in insects. Recently, we have developed a novel receptor-based insecticide discovery method to identify bioactive peptides to control target-specific pests (1,2). The first proof-of-concept for the technology using the fire ant model is called Receptor interference (Receptor-i) (3,4).

The advantage of Receptor-i is that millions of short peptides that block a specific GPCR system can be rapidly screened. Thus, novel insecticides can be quickly available for new or established invasive pests. In this study, we extended Receptor-i technology to identify bioactive peptides to develop biologically-based and target-specific practices for SLF. We focused on the species-specific CAPA system of SLF, which is involved in a variety of biological functions: muscle contraction, feeding, and cuticle melanization for various life stages. The outcomes of this research are expected to address fundamental requirements for the application of biological tools for controlling SLF.

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Fumigation to Slow the Spread of SLF via Commercial Consignments

Austin P. Lourie and Spencer Walse

USDA Agricultural Research Service (ARS), San Joaquin Valley Agricultural Sciences Center
Parlier, CA

spencer.walse@usda.gov

ABSTRACT

Phytosanitary treatments to limit the spread of spotted lanternfly (SLF) (*Lycorma delicatula*) (Hemiptera: Fulgoridae) may be required by importers to minimize interceptions on various non-horticultural consignments, including a myriad of forest products, construction materials, and vehicles that can harbor egg masses. SLF egg masses contained in gas-permeable cages were fumigated with key fumigants across a range of applied doses and treatment durations in laboratory-scale chambers at 10.0 ± 0.5℃ ($\overline{x} \pm 2s$). Fumigant (sulfuryl fluoride, methyl bromide, propylene oxide, hydrogen cyanide) exposures, expressed as concentration (*C*) × time (*t*) products (*Ct*), were calculated, the *Ct* exposure-mortality regression was modeled for multiple durations, and exposures required to control 50 to > 99% of egg populations were predicted, $(Ct)_P$. In addition, confirmatory studies were conducted for sulfuryl fluoride and methyl bromide. We detail progress toward the development of a postharvest fumigation schedules based on the confirmatory results and the technical and operational features they inform, particularly with respect to labeling, environmental, and regulatory considerations.

The Use of Heat Treatments to Kill the Eggs of Two Invasive Forest Pests, Spotted Lanternfly and Spongy Moth

Nooshin Zandi-Sohani[1,2], Melody A. Keena[2], Michael R. Gallagher[3], and Anthony Cullen[4]

[1]West Virginia University, Department of Geology and Geography
98 Beechurst Avenue, 330 Brooks Hall, Morgantown, WV 26506

[2]USDA Forest Service, Northern Research Station
51 Mill Pond Road, Hamden, CT 06514

[3]USDA Forest Service, Northern Research Station
501 Four Mile Road, New Lisbon, NJ 08064

[4]USDA Animal Plant Health Inspection Service (APHIS)
350 Corporate Blvd, Robbinsville, NJ 08691

melody.keena@usda.gov

ABSTRACT

The spotted lanternfly (SLF), *Lycorma delicatula* (White), and the spongy moth (SM), *Lymantria dispar* L., are two introduced pests into the eastern United States that spread along human transportation corridors by ovipositing on vehicles and cargo. In this study, we investigated the impact of heat treatments on SLF and SM egg masses in 2023 and 2024 to determine whether heat can effectively kill the eggs. The egg masses of SLF were collected from multiple sites in October and November in both years. The SM egg masses were obtained from laboratory colonies of European and Asian sponge moths. In the first year of the study, the heat treatments applied (using a Fisher Isotemp chamber) were between 35 to 70℃ for 15 to 120 minutes, and all treatments were applied in the spring. In the second year, the treatments were changed based on the first year's results and applied in both fall and spring. Only 50℃ was applied to SM eggs for 15 to 75 minutes, and 45 to 60 °C was applied to SLF egg masses for 15 to 135 minutes. All egg masses were held in an alternating temperature regime that mimicked the Scranton, PA climate before undergoing heat treatments. After treatment, they were transferred to a growth chamber at 25℃ and 60% RH for hatch in 2023 and returned to the same alternative regime in 2024 until hatch. In the first year, SLF eggs exposed to 45℃ for 120 minutes or 50℃ for all durations showed significantly reduced hatching compared to the control. No eggs hatched at temperatures ≥ 55℃. For SM, over 90% of egg masses hatched at all temperatures below 50℃. However, at 50℃, the percentage hatch of eggs decreased by more than 30% and 70% in both 15- and 30-minute treatments. Only a few eggs hatched at 55℃ when subjected to 15 minutes of heat, and no eggs hatched when subjected to temperatures >55℃. In the second year, the season in which heat treatments were applied had no significant effect on the SLF egg mass hatch, but it had a significant effect on the SM egg mass hatch, and the percentage

hatch of SM egg masses decreased at a higher rate in spring treatments than in fall treatments. There was no hatch of SLF eggs after 120, 45, and 15 minutes of exposure to 45, 50, and 55℃, respectively. A few SM eggs hatched when exposed to 50℃ for 60 minutes in the fall and 45 minutes in the spring, and no eggs hatched at longer exposure times. These results suggest that the heat treatment regime required to kill the eggs of SLF and SM is comparable to the regime specified in ISPM 15 for killing wood-boring insects in solid wood packaging material. Note that solid wood packaging material certified to be treated under ISPM 15 would need to be retreated to kill eggs that are deposited by these insects when it is stored outside where females could lay on it.

Leveraging Biological Control Agents to Simultaneously Reduce Populations of Spotted Lanternfly, *Lycorma delicatula*, and Tree of Heaven*, Ailanthus altissima* at an Areawide Scale

Tracy C. Leskey and Laura J. Nixon

USDA Agricultural Research Service (ARS), Appalachian Fruit Research Station
Kearneysville, WV, USA

tracey.leskey@usda.gov

ABSTRACT

Tree of Heaven (TOH), *Ailanthus altissima,* an invasive species introduced into the US in the late 1700s, is now present in much of the US. This invasive tree species thrives in poor soil in disturbed areas, grows clonally and produces large numbers of samaras (seeds) for further spread. Unfortunately, TOH also support survivorship and development of a recently introduced invasive planthopper, spotted lanternfly (SLF), *Lycorma delicatula.* SLF first arrived in eastern PA in 2014 and has since spread to 16 additional states throughout the eastern half of the US. This invasive insect prefers TOH as a feeding host season-long, is more fecund when TOH is part of their diet, and is often present in extremely high densities on trunks, leading to a large pest reservoir in unmanaged habitats. Unfortunately, SLF will disperse from TOH, especially when trees become less acceptable due to intense feeding leading to reduced tree vigor, to feed on other hosts including wine grapes, *Vitis vinifera*. SLF dispersal into vineyards has resulted in increased insecticide inputs, reduced yields, and increased winter injury. Because of the close insect-plant relationship between SLF and TOH, the opportunity to manage both invasive species simultaneously across the landscape using compatible biological control agents and reducing the spread of SLF is very compelling. Here, we propose to use the principles of Areawide Management to: 1) deliver *Verticillium nonalfalfae* (VNA) to TOH under field conditions, and document potential spread of VNA by SLF; 2) deliver promising commercially-available entomopathogens, *Beauveria bassiana* fungus and entomopathogenic nematodes (EPNs), to suppress SLF in the field; and 3) conduct field-based evaluation of complementary biological control agents against TOH and SLF at an Areawide scale. To ensure we do not encounter barriers to adoption, this project has been designed to fully integrate a sociologist/communication specialist and an applied economist to provide expertise on communicating benefits and generating economic return of the Areawide program, respectively. Our goal is to suppress populations of both invasive species to increase ecosystem health, reduce insecticide inputs against SLF in vineyards and mitigate yield losses, and alleviate impacts on native pollinators and plant species.

OUTREACH AND EDUCATION

Utilizing 3D Printing: Improving Outreach and Extension

Natalie Constancio[1], Andrew Michel[1], Amy Stone[2], and Ashley Leach[1]

[1]Department of Entomology, The Ohio State University
250 Wooster Science Building, Wooster, OH 44691

[2]The Ohio State University Extension
5403 Elmer Dr, Toledo, OH 43615

constancio.2@osu.edu

ABSTRACT

Spotted lanternfly (SLF; *Lycorma delicatula)* is an invasive species that was recently identified in Ohio, USA in 2020. Since the initial discovery, SLF has spread to 12 different counties within the state as of 2024. This rapid spread is particularly concerning for grape (*Vitis vinifera)* growers, as SLF has been reported as a major insect pest of grapes in Pennsylvania. In response to increased spread, growers are encouraged to be vigilant and monitor their vineyards for signs and symptoms of SLF infestations, as proper identification and management may delay infestations. However, scouting for SLF is difficult for many reasons, including: 1) egg masses are particularly difficult to identify due to their cryptid nature, and 2) training is nearly impossible with live specimens outside of the known distribution range. Therefore, 3D printing SLF life stages provides tangible and highly specialized products that can improve an individual's ability to identify SLF egg masses.

To train individuals to identify SLF egg masses, we created 3D printed models and developed an interactive learning program to enhance scouting ability. The training program begins with a 20-minute power point reviewing SLF life stages, and their distinct features. After the power point presentation, there is a short scavenger hunt to find the 3D printed egg masses, to allow participants to practice scouting. The egg masses are hidden in places where SLF has been shown to oviposit, including on trashcans, trees, and buildings. To record individuals' ability to scout SLF, a Qualtrics survey is used, and participants are required to submit a photo of each egg mass they find. By submitting the photos, we can gain an understanding of the biases' participants exhibit while scouting, and we can alter our training program to address those biases.

Post training program, individuals demonstrated are significant improvement in their ability to identify SLF egg masses, with more than 95% being identified during the scavenger hunt. The Qualtrics survey also highlighted a scouting bias, indicating that individuals were most likely to identify egg masses that were at eye level when compared to egg masses below the knee, or above the head. Finally, at the end of the training program, participants were asked about their satisfaction with the program, and most reported they strongly agreed that they: 1) learned new information, and 2) are planning to use the information they learned.

Overall, our work with the 3D printed models highlights that grower education remains a critical component of monitoring the SLF invasion. Moreover, 3D printing provided an

experiential learning opportunity for growers and improved their ability to correctly identify SLF egg masses. Finally, these results showcase the promise of 3D printing to engage stakeholders in unique and novel ways to improve extension programs.

POSTERS

BIOCONTROL TECHNIQUES

Development of Treatment and Infection Detection Methods Using Mycoinsecticide (*Beauveria bassiana*) Products on Spotted Lanternfly (SLF, *Lycorma delicatula*)

Emily Wallis, Melissa Benzinger McGlynn, Phillip Lewis, Paula Shrewsbury, and Emily Russavage

USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Forest Pest Methods Laboratory with the University of Maryland
Buzzards Bay, MA 02542

Emily.Wallis@usda.gov

ABSTRACT

Three products containing *B. bassiana* (BotaniGard 22WP, BotaniGard ES (BG-ES) & BioCeres WP) and water (control) were tested as biocontrol agents on early through late-phase SLF adults in 2022. Bugs were placed in cups with mesh coverings and sprayed with ~ 3.5 mL of solution per treatment type and caged on *A. altissima* and held for assessments. Two infection detection methods were tested; half the specimens were assessed visually 2-weeks post treatment for fungal growth emerging from SLF, and the other half assessed 4–5-day post-treatment by microscopic evaluation by hemolymph staining to identify fungal hyphae. BG-ES had the highest percent mortality and fungal body detection after 2 weeks, but results were not consistent between SLF life stages. In general, hyphae detection in hemolymph proved to be a problematic method with desiccated cadavers and other issues resulting in low occurrence of detections.

Only the BG-ES formulation was tested in 2023. Two treatment methods were used; hand-held sprayers to directly spray SLF nymphs, and *A. altissima* foliage and bark surfaces sprayed and 4th instars/adult SLF caged 24-hours later on the treated, dry surfaces (Figure 1). For evaluations, specimens were placed on agar plates and checked for evidence of infection, signified by thick white fungal outgrowth emerging from segments and joints. We found low average adult SLF infection rates as well as high control mortality.

FIGURE 1. Mesh cages attached to *A. altissima* to assess SLF assessments.

A new treatment method in 2024 utilized fungal bands soaked in a solution of BG-ES and a petroleum oil product. Two concentrations of bands were laboratory tested on nymphs in petri dishes. Insects were allowed to contact bands for 30-seconds and then caged on squash plants or *A. altissima* clippings, then plated on agar for infection determination. High concentration bands and water bands were tested in the field on 4th instar and adult SLF. Bands were secured below circle traps and insects allowed to walk over the bands and up into mesh bags. Specimens were transferred to *A. altissima* plants or tree trunks and then plated on agar for infection detection. Most SLF nymphs that walked over high concentration bands in the lab study became infected while mortality was similar regardless of fungal load on the bands. Most SLF that contacted fungal bands in the field became infected with *B. bassiana*, while lower infection rates were seen using bands that had been aged.

Modeling the Emergence of Social-Bird Biological Controls to Mitigate Spotted Lanternfly Infestations

Jackie Brochu and Daniel Strömbom

Department of Biology, Lafayette College
Easton, PA 18042

brochuj@lafayette.edu

ABSTRACT

The spotted lanternfly (*Lycorma delicatula*) is an insect pest that is currently invasive in Japan, South Korea and the United States. Due to a lack of effective natural enemies where it is invasive, human intervention is required. Extensive management has been applied but the spread continues. This suggests that exploring more unconventional management approaches may be useful.

Recently, the idea of bird-based biological controls has re-emerged and shown to be effective in studies involving solitary birds and other types of pests. While their effectiveness has not been investigated for control of the spotted lanternfly, there are numerous anecdotal observations of individual birds eating lanternflies in the US. This suggests that perhaps birds could contribute to dealing with the lanternfly. However, it is questionable if birds are able to effectively control unfamiliar and occasionally toxic invasive pests in short timeframes. Unless, perhaps, the birds are effective social learners and toxicity of the invaders is rare. Interestingly, some of the birds that have anecdotally been observed to eat lanternfly in the U.S. are social birds, such as Starlings (*Sturnus vulgaris*) and Black-capped Chickadees (*Poecile atricapillus*).

Here we introduce a mathematical model for social learning in birds to investigate conditions for the emergence of a collective biological control of a pest that is occasionally toxic, like the lanternfly. We find that the social observation rate relative to the proportion of toxic lanternfly dictate when collective biological controls will emerge. We also implement the social learning model into a model of collective motion in bird-like animals, and find that it produces results consistent with the mathematical model.

Our work suggests that social birds may be useful in managing the spotted lanternfly, and that removing the toxicity-inducing preferred host of the lanternfly should be a priority to facilitate this. More broadly, given the extraordinary foraging effectiveness of social animals, including social birds, in other contexts, we propose that effort go into exploring the potential of social/collective biological controls to be part of integrated pest management programs.

Survey for Parasitoids of Native Hoppers in Rhode Island and Implications for Spotted Lanternfly Biocontrol

Daniel Farnworth[1], Nicholas Durinzi[2], Dana Terrill[3], Lexi Johnson[3], and Lisa Tewksbury[3]

[1]URI Coastal and Environmental Fellow

[2]Environmental Science and Forestry
SUNY

[3]Plant Sciences and Entomology Department
University of Rhode Island

lisat@uri.edu

ABSTRACT

The pincer wasps (Hymenoptera: Dryinidae) are a family of parasitoids that specialize in hoppers (Hemiptera: Auchenorrhyncha). The USDA Forest Pest Method Lab is currently evaluating a wasp in this family, *Dryinus sinicus,* as a means of classical biological control of spotted lanternfly (*Lycorma delicatula*). As part of our native host rearing for the USDA's non-target host range testing for their biocontrol program, the University of Rhode Island Biological Control Lab conducted hopper field collections over a two-year period. During these collections we detected parasitism by dryinid species in our native hoppers.

FIGURE 1. *Acanalonia bivittata* nymph with thylacium.

In 2023 and 2024, immature stages of native hopper species represented by five families were collected weekly from multiple field locations in RI and screened for signs of parasitism. Of the families collected, acanaloniids showed the highest rates of parasitism,

with 36 out of the 182 (19.8%) hoppers collected in 2024 being parasitized, and in 2023 percent parasitism of acanaloniid hoppers was 19.3%. Flatid hoppers had moderately high rates of parasitism, with 15 of the 191 nymphs (12.7%) being parasitized in 2024, and five of the 47 flatid nymphs parasitized in 2023 (9.4%). Other families that were observed to be parasitized by dryinid wasps included Cicadellidae, Issidae, and Dictyopharidae.

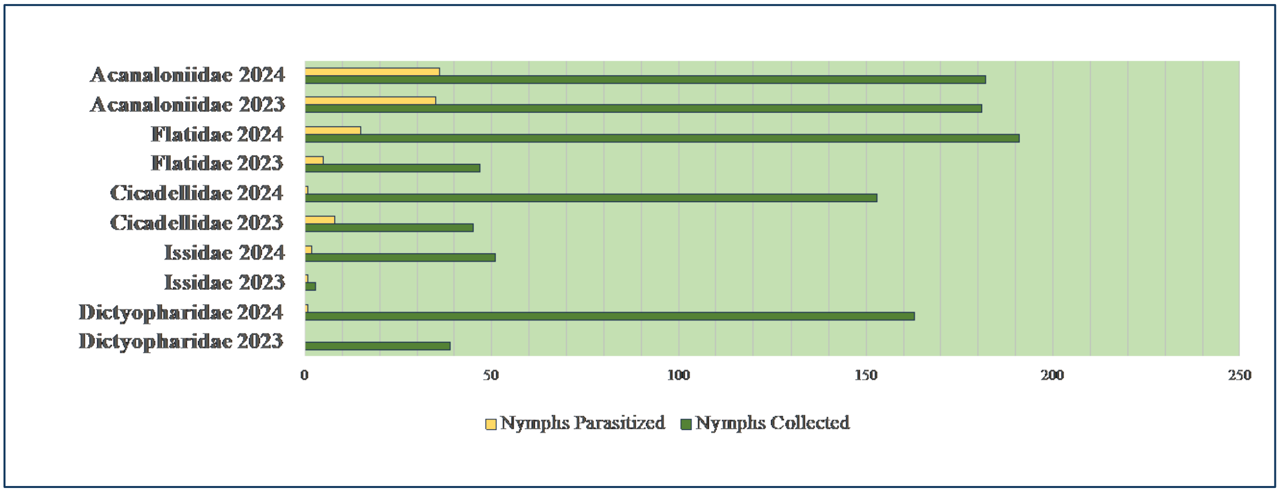


FIGURE 2. Relative proportion of parasitized to collected hopper nymphs by hopper family in 2023 and 2024.

The dryinid larvae that emerged from their thylacia in 2024 haven't eclosed from their cocoons, so we do not have species identifications. However, some wasps from 2023 emerged in the fall of 2023 and others in July and August of 2024. Of those wasps, one *Neodryinus typhlocybae* emerged from a flatid nymph, two *D. alatus* and 18 *Gonatopus* sp. emerged from acanaloniid nymphs, and one *Thaumatodryinus perkinsi* emerged from an issid nymph.

For the dryinid parasitoids collected in 2024 we will need to wait for adult emergence in the spring to complete identification to genus and species. Additional surveys could lead to identification of new dryinid species in areas where we have not yet collected.

CHEMICAL AND MICROBIAL CONTROL

Determining Pesticide Impacts on Spotted Lanternfly Egg Masses Using Embryonic Development and Hatch Data

Melissa Benzinger McGlynn, Phillip Lewis, Mauri Hickin, and Megan Doner

USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Forest Pest Methods Laboratory
Buzzards Bay, MA 02542

melissa.benzingermcglynn@usda.gov

ABSTRACT

The Spotted Lanternfly (*Lycorma delicatula*, or SLF), an invasive sap feeding insect originally from southeast Asia, was discovered in Pennsylvania in 2014 and has since expanded its range to 17 U.S. states. One method to decrease the number of emerging SLF nymphs is the use of insecticides like Golden Pest Spray Oil (GPSO) and Bifenthrin (BIFEN). The Lampshade Trap (LST) is a useful tool for congregating and collecting SLF egg masses (Lewis et al. 2023) (Figure 1). Eggs laid on these traps were used for this study.

Hatch of treated and untreated egg masses laid was counted and a sample of the unhatched eggs were also dissected to determine the stage of embryonic development post-treatment. SLF embryonic development was categorized on a ranked scale when eggs were 0-12 days post diapause (Shim & Lee 2015) (Figure 2). LST's deployed in Sept-Oct 2023 were harvested in January 2024, and inner trunk portions of traps with 10+ egg masses were left on trees and treated in March. Egg masses were treated with BIFEN at 3 mL per quart, GPSO at 50:50, or water and left until June, when all SLF egg masses had hatched in PA.

FIGURE 1. Lampshade Trap on tree.

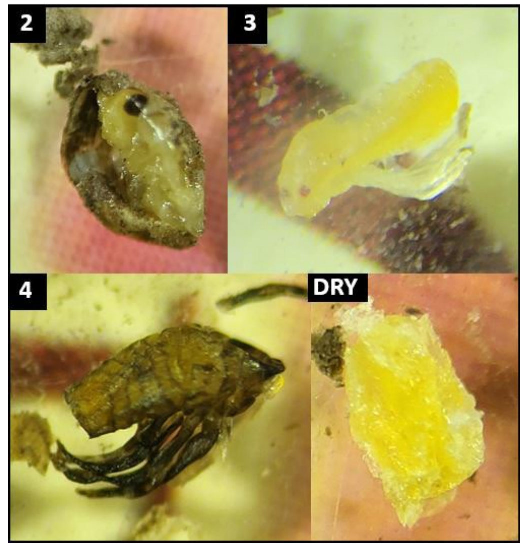


FIGURE 2. SLF embryo development stages.

Upon collection, detailed photos of individual egg masses were taken, and hatch vs total eggs was tallied per egg mass to calculate percent emergence. Evidence of hatch is by a visible, open "trap door", however, this can be tricky to determine without a full dissection of every egg.

A total of 14 egg masses with 405 eggs were individually dissected and embryonic development was recorded. GPSO prevented most development, with 0% hatch and 94.0% ± 0.1% in the dry stage. BIFEN emergence was 4.6% ± 0.1% and differed from the control group with heavy mortality in the 4th (final) stage of egg development. Control emergence was 41.6% ± 0.4% (Figure 3).

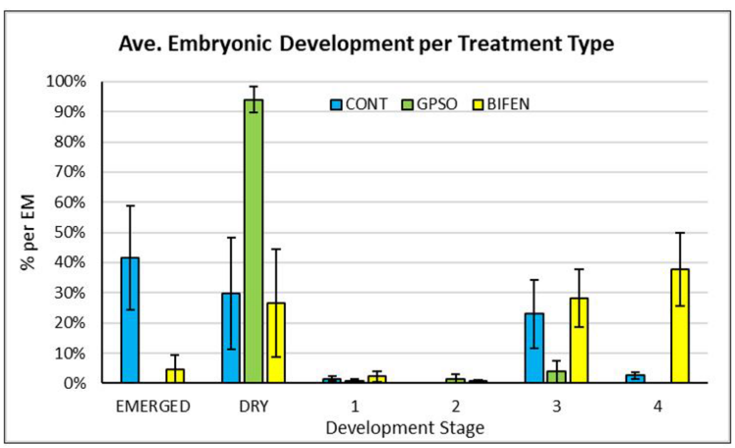


FIGURE 3. Embryonic development stage of dissected unhatched SLF egg masses by treatment type (± SE).

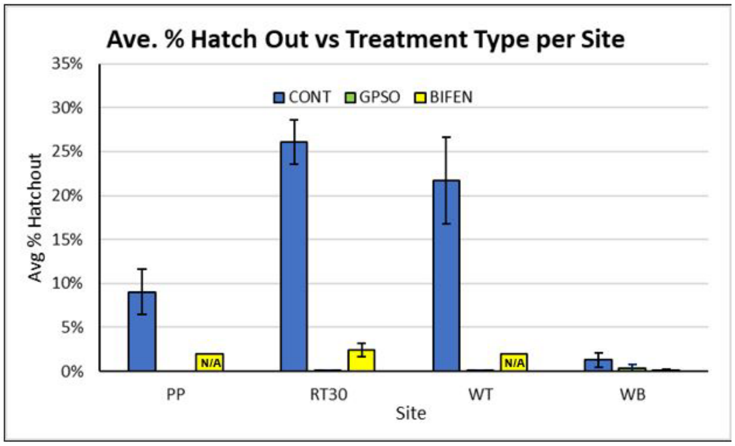


FIGURE 4. Ave. percent hatch by treatment type and study site (± SE).

A total of 290 GPSO, 179 BIFEN, and 188 control egg masses across 34 traps were assessed for hatch and egg masses were tallied that had sloughed off between treatment and collection (Figure 4). Average percent hatch at the 4 study sites was 13.1% ± 0.2% in controls, 0.0% ± 0.0% with GPSO, and 1.0% ± 0.0% with BIFEN. Average percent of egg masses that detached from LSTs was high in all groups. The rough texture of the trap surface seemed to prevent good adhesion of the eggs and led to weathering over time. Combining values for % hatch and % egg detachment of the control group yields hatch values consistent with field observations of 50-70% hatch when comparing to normal egg masses laid on bark.

We found that GPSO is highly effective at disrupting early SLF development while BIFEN disrupts the last stages of embryonic development, but both are effective treatments to prevent nymph egg hatch.

Novel Use of PermaNet Netting for SLF Control Applications

Tie Lan, Sha Fu, and Allan Mortensen

Vestergaard Sàrl, Place Saint-François 1
CH-1003 Lausanne, Switzerland

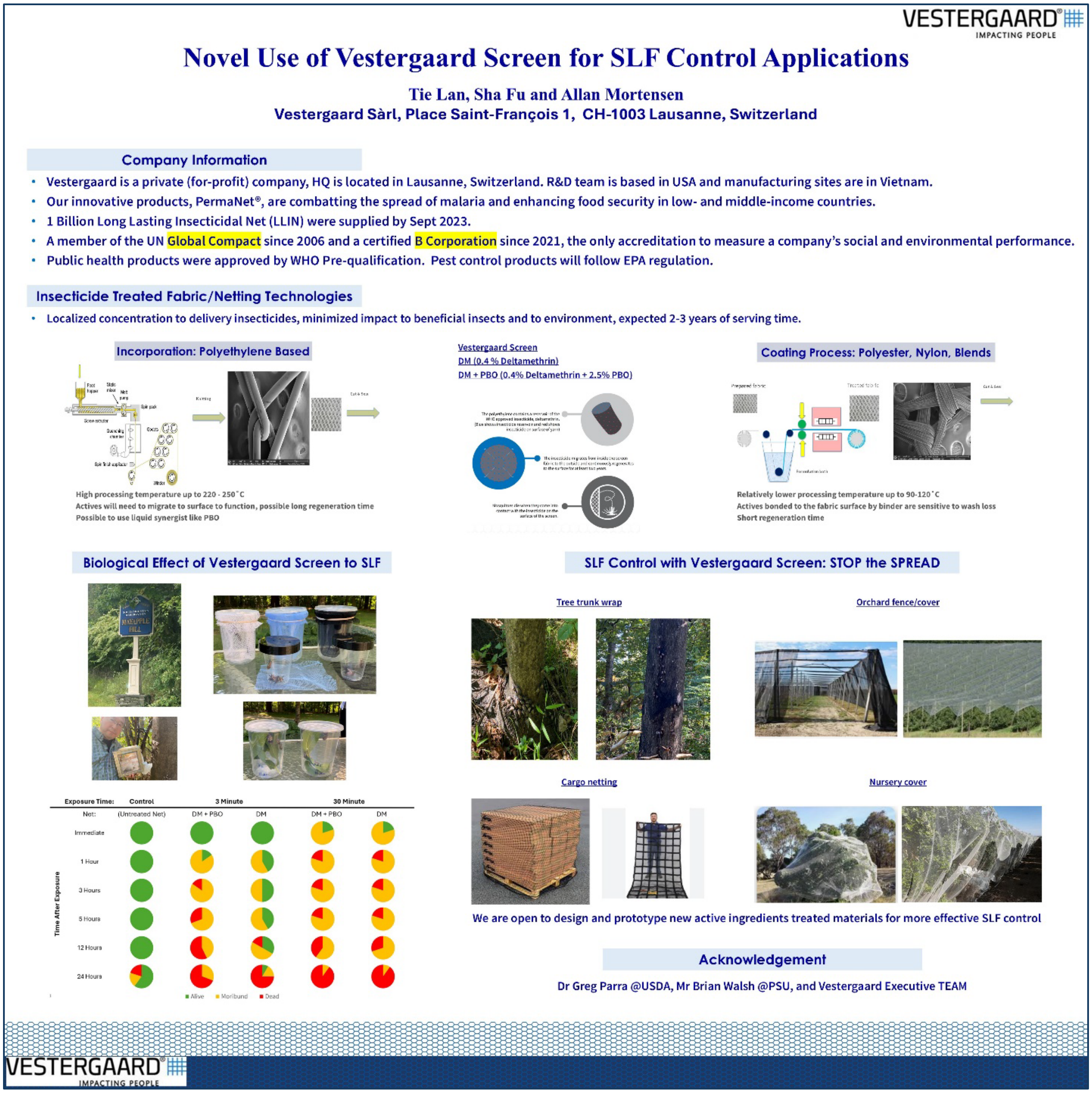
tl@vestergaard.com

ABSTRACT

Vestergaard is the pioneer in developing the Long Lasting Insecticidal Netting (LLIN) for mosquito control to eradicate malaria in Sub-Saharan and Southeast Asian countries. Millions of lives were saved with the introduction of LLIN as intervention tools in the last 20 years. Under WHO's supervision, the LLIN offers enhanced safety for use and handling. The localized concentration of insecticides on the net fabric surface delivers the lethal dose to kill mosquitoes upon contact under the host-seeking behavior of the mosquitoes with greatly reduced impact to beneficial insects and birds comparing with traditional insecticide spray applications. The advanced formulation technology also provides relatively long service life (3 years) as well as stability in the environment.

SLF as an invasive pest was observed in Berks County, PA, 2014. Extensive work has been done by PSU extension in the past years to identify possible tools to monitor/control SLF and stop SLF spreading. Vestergaard's LLIN was one of the promising options to kill adult SLF with very short contact time. Vestergaard R&D team was able to confirm the lethal effect of LLIN to SLF adults in 2024. This will support the development of tree trunk wraps to control SLF nymphs from April to July once the nymphs emerge since the nymphs have much lower body mass compared to adult SLF. The attraction of the vertical surface of the tree trunk and the climbing movement of the nymphs to access to food sources of the tree branches will allow great contact of the nymphs with the net fabric surface to deliver the lethal dose of the insecticides to kill the nymphs to reduce populations of SLF.

The LLIN fabric can also be made into products in other forms to protect nursey stocks during storage and shipping. The shipping pallet netting will prevent adult SLF from accompanying the cargo to spread to new locations. With the addition of certainly synergist, such as piperonyl butoxide or other fast insecticide delivering fluids in the LLIN formulation, the net fabric can deliver greater irritation effect to adult SLF. Thus, the chance for SLF to stay on the cargo surface or laying eggs on the cargo surface can be eliminated. Parameter fences can be used to separate the infested area from others. With the possible discovery of the SLF attractants, design of Attract-and-Kill trap can be also effective tools to control SLF. In addition, biological control agents, such as Fungal Pathogen *Beauveria bassiana,* can also be used to make treated fabrics to disseminate as tree trunk wrap or other types of products. With the expectation of EPA registration in 2025/26, Vestergaard LLIN will be effective tools for SLF and other pest control in the near future.


VESTERGAARD
IMPACTING PEOPLE
Novel Use of Vestergaard Screen for SLF Control Applications
Tie Lan, Sha Fu and Allan Mortensen
Vestergaard Sàrl, Place Saint-François 1, CH-1003 Lausanne, Switzerland
Company Information
• Vestergaard is a private (for-profit) company, HQ is located in Lausanne, Switzerland. R&D team is based in USA and manufacturing sites are in Vietnam.
• Our innovative products, PermaNet®, are combatting the spread of malaria and enhancing food security in low- and middle-income countries.
• 1 Billion Long Lasting Insecticidal Net (LLIN) were supplied by Sept 2023.
• A member of the UN Global Compact since 2006 and a certified B Corporation since 2021, the only accreditation to measure a company's social and environmental performance.
• Public health products were approved by WHO Pre-qualification. Pest control products will follow EPA regulation.
Insecticide Treated Fabric/Netting Technologies
• Localized concentration to delivery insecticides, minimized impact to beneficial insects and to environment, expected 2-3 years of serving time.
Incorporation: Polyethylene Based
High processing temperature up to 220 - 250˚C
Actives will need to migrate to surface to function, possible long regeneration time
Possible to use liquid synergist like PBO
Vestergaard Screen
DM (0.4 % Deltamethrin)
DM + PBO (0.4% Deltamethrin + 2.5% PBO)
Coating Process: Polyester, Nylon, Blends
Relatively lower processing temperature up to 90-120˚C
Actives bonded to the fabric surface by binder are sensitive to wash loss
Short regeneration time
Biological Effect of Vestergaard Screen to SLF
Exposure Time: Control 3 Minute 30 Minute
Net: (Untreated Net) DM + PBO DM DM + PBO DM
Immediate
1 Hour
3 Hours
5 Hours
12 Hours
24 Hours
Time After Exposure
Alive Moribund Dead
SLF Control with Vestergaard Screen: STOP the SPREAD
Tree trunk wrap
Orchard fence/cover
Cargo netting
Nursery cover
We are open to design and prototype new active ingredients treated materials for more effective SLF control
Acknowledgement
Dr Greg Parra @USDA, Mr Brian Walsh @PSU, and Vestergaard Executive TEAM
VESTERGAARD
IMPACTING PEOPLE

DEVELOPMENT OF TOOLS FOR EARLY DETECTION, SURVEY, TRAPPING

Best Practices for Setting and Monitoring Circle Traps for the Spotted Lanternfly (*Lycorma delicatula*)

Everett Booth[1], Sarah Devine[1,2], and Joseph Francese[1]

[1]USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Forest Pest Methods Laboratory
Buzzards Bay, MA, 02542

[2]Department of Biology, Xavier University
Cincinnati, OH, 45207

everett.g.booth@usda.gov

ABSTRACT

Since 2018, with the help of many cooperators, we have collectively set and monitored thousands of spotted lanternfly (SLF) circle traps in various habitat types, on different tree species, and with different build modifications. While results from successful season-long trapping studies have been used to further improve survey methods and the overall trap design, occasionally traps do fail. To further improve overall trapping success, we revisited and cataloged a comprehensive list of previously reported trapping issues over the past five field seasons. The major issues were grouped into six common categories where we offer suspected causes for these issues, as well as possible solutions.

The most frequently reported problem was "trap down" which occurs when the trap becomes detached from the tree. Switching to longer staples (at least 1/2" long) fastened along both the bottom of the trap as well as up inside the trap opening near the plastic cone, usually solves this issue. The second most reported comment was "bag found on ground" which occurs if either the bag is not properly secured to the trap or if the plastic connection has a manufacturing defect and isn't properly glued to the screen. When zip tied, the bag will not easily be pulled away from the cone so testing this connection during trap checks solves this. The connection between the screen and the plastic funnel should be checked prior to setting the trap, and if plastic cone does break away from the trap it can be reattached using a stronger two-part epoxy adhesive. Other less common trapping issues included, "poor sample quality, bag chewed, bycatch, and opening blocked". Many of these issues can be partially attributed to site characteristics and environmental factors. Generally, checking traps more frequently, adjusting trap locations if signs of vertebrate interactions occur, avoiding trapping in wetlands, and clearing out fast growing vegetation near trap positions can all help mitigate some of these challenges.

While sometimes overlooked, one of the major components to any successful trapping program is proper trap installation and maintenance. A poorly set circle trap will likely not last the full trap checking interval and will therefore be less likely to detect new populations of SLF. Taking extra care to properly fasten traps, inspecting for damaged components during setup, and recognizing potential risks before they result in trap failures will help result in a more successful and efficient trapping survey.

Design and Evaluation of *Lycorma delicatula* (Spotted Lanternfly) Traps in Central Virginia

Ainsley John Doczi Darling and Lisa Jordan Powell, Ph.D.

Environmental Science Program and Center for Human & Environmental Sustainability, Sweet Briar College

Lead author: ajdarling4038@sbc.edu
Corresponding author: lpowell@sbc.edu

ABSTRACT

Lycorma delicatula, or spotted lanternfly (SLF), is an invasive species that can inflict damage on vineyards, orchards, and native plant species, in addition to forests and farms more broadly. Different trap types have been designed to help manage the SLF population, though concerns persist about the capture of unintended species (bycatch) with some designs. This research is a preliminary exploration of the effectiveness at capturing SLF while minimizing bycatch of two of the most-used existing trap designs in comparison with two new circle trap designs based on modifications of existing traps. This research primarily observes the traps catching SLF during their nymph stages. All trap study sites were located on the 2847 acre campus of Sweet Briar College in central Virginia. In this study, one of the modified circle trap designs demonstrated high effectiveness at catching SLF, also while having low bycatch numbers.

Introduction

Increasing invasive spotted lanternfly populations have the potential to inflict significant ecological and agricultural damages. SLF wipes out crops by feeding on the sugary sap and depleting plant resources, causing decay [1]. While SLF are consumed by some animals, such as birds, there is not enough interest from predators to bring down the numbers that are currently ravenging the eastern US; use of pesticides, while potentially effective, may negatively impact other species [3]. With increasing numbers and migration throughout the US, other techniques to slow down and cull the population are being investigated, including several types of traps for SLF at their different life stages. A major concern in the use of traps is how they attract bycatch, or other species besides their target. Two existing trap types are sticky traps and cone traps; prior work has indicated that a third category of traps, circle traps, may be more effective at catching SLF than other types [4]. This research aims to design and test modifications of prior circle trap designs and to assess their effectiveness at catching SLF in nymph stage and minimizing bycatch in comparison with other trap types. This work looks at SLF behavior in central Virginia; location does have an effect on this research, as in different climates and regions, SLF act differently [2].

Methods

All traps were installed on *Ailanthus altissima,* or tree of heaven, the main host species of SLF. To properly test and compare the trap designs, there needed to be high SLF concentration and consistency. Across the different plots, trees of heaven of approximately the same size and age were selected for trap installation. All trees selected already had a population of SLF on them.

There were four trap sites across campus, each of which had four trees with one each of the trap designs installed: sticky traps, cone traps, and two newly-designed traps that fully encircle the trees’ trunks, which will be called Circle 1 and Circle 2 trap types (Figure 1). The sticky traps were purchased commercially, and the cone traps were provided by the Virginia Department of Agriculture and Consumer Services. Materials for constructing the Circle 1 and Circle 2 traps designs included items commonly available at hardware stores: metal wire, plastic zip ties, metal mesh screen, one gallon plastic bags, string, and large funnel-type objects for shaping.

The Circle 1 and Circle 2 designs differ from existing circle traps by fully encircling the tree trunk and having removable bags for cleaning (Figure 1). Circle 1 completely encircles the trunk and features a metal mesh cylinder with a metal mesh cone on top that feeds into a plastic bag where SLF get stuck. The tree trunk exits the trap on the side of the metal cone. Circle 2 is similar, but the trunk exits before the start of the metal cone.

Trap data collection occurred twice weekly from 18 June through 5 July 2023; traps were cleaned out after each observation.

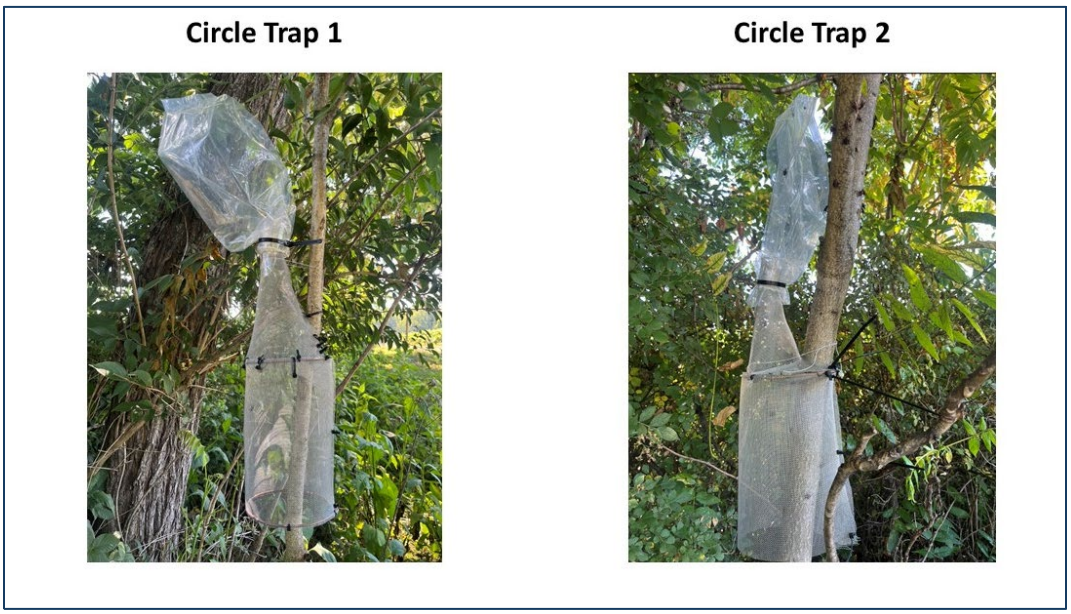


FIGURE 1. Images of Circle Trap 1 and Circle Trap 2.

Results

Circle Trap 2 performed similarly to the sticky traps in catching SLF, but had minimal bycatch (Figure 2). The total catches of this trap include SLF (244), Earwig (10), Beetle (5), Ant (6), Spider (3), Fly (2), Katydid (1) (Figure 3). A drawback of Circle 2 is that it may also be more difficult to install on some tree types and sizes, but the design needs to be tested further to confirm.

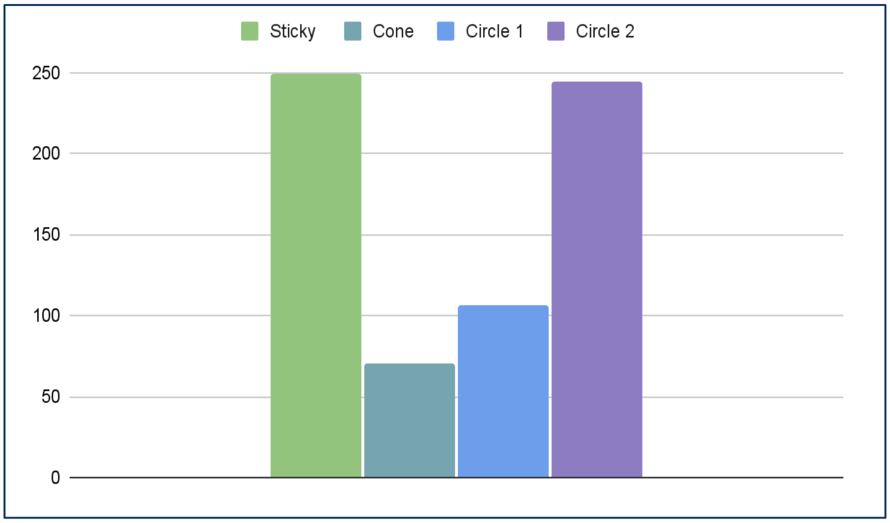


FIGURE 2. SLF Caught in Type of Trap.

Catch Type	Sticky	Cone	Circle 1	Circle 2
SLF	249	70	106	244
Earwig	1604	11	11	10
Gnat		2		
Beetle	9	4	2	5
Katydid		1		1
Moth	1	1		
Fly	41	12	1	2
Ladybug		3		
Ant	71	17	2	6
Stink bug		1		
Spider	12	3	2	3
Webworm	1			
Bee	6			
Tick	2			

FIGURE 3. Total Catch by Trap Type.

Conclusions and Future Work

This preliminary research has provided insight on trap designs that may both be effective at catching SLF while also minimizing bycatch. Design elements of the Circle Trap 2 structure and its installation could present challenges to its widespread use on some trees, e.g. those with larger trunks. The research team plans to expand testing of these designs in the future, while also considering additional elements of trap design, such as materials used and color. With more testing, the designs potentially could be improved upon to make them easier to build and install while maintaining their effectiveness and avoiding bycatch.

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Acknowledgements

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Detecting and Mapping SLF Hosts from Google Street View Imagery

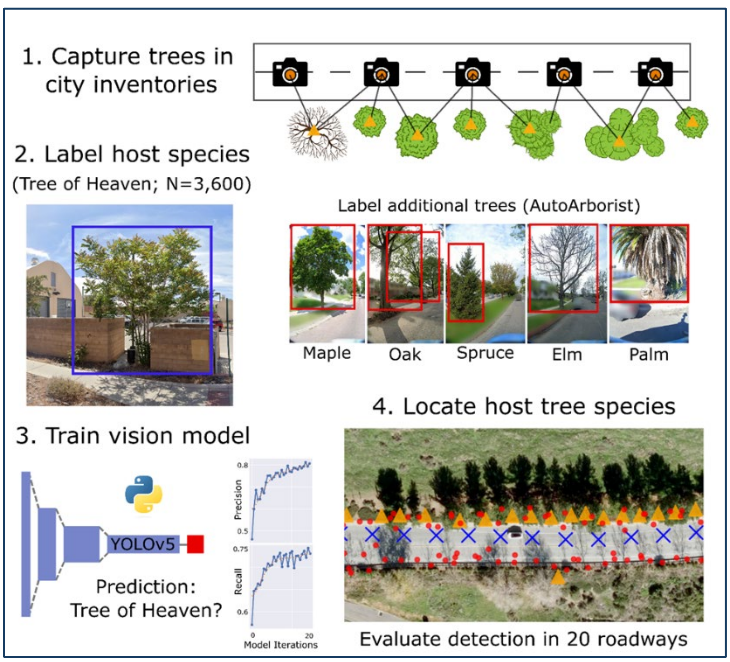
Thomas Lake, Brit Laginhas, Drew Bresingham, Ross Meentemeyer, and Chris Jones

North Carolina State University
Raleigh, NC 27695

cmjone25@ncsu.edu

ABSTRACT

The spread of invasive species is a consequence of global connectivity. However, sparse and outdated information on the location of invasive species limits our ability to anticipate spread. To address this gap, we developed computer vision models using street-view images from Google Street View in an effort to identify the invasive plant, tree of heaven (*Ailanthus altissima*), a crucial host for the invasive spotted lanternfly (*Lycorma delicatula*). We leveraged a dataset containing several million images of trees (i.e., AutoArborist) to train a state-of-the-art object detection model that automatically locates *Ailanthus altissima* along roadsides.



Preliminary results indicate that models detect *Ailanthus altissima* with a high precision (77%) and recall (71%) despite substantial variation in tree growth stage, phenology, and background environment. Visually-similar species explained the majority of false positives, whereas false negatives were driven by obscured trees or those with an unconventional appearance. Our findings support the use of computer vision to automate tree species identification and monitoring, which may be instrumental for foresters and ecologists to anticipate where invasive pests or pathogens may spread. Although street-view images are confined to road networks, our results can: 1) inform sampling design for ground-based studies, 2) mitigate the potential sampling biases associated with citizen science efforts by incorporating new observations, and 3) link newly documented species point data with corresponding detection from remote sensing (e.g., satellite) technologies. As a result, our model provides timely information on *Ailanthus altissima* presences for use in pest forecasting models. More broadly, our results contribute to advancing our understanding of biological invasions in an era of rapid global change.

Detecting SLF Egg Masses with Advanced Imaging Techniques

Rhys Butler[1], Karla Negrete[2], Nicolas Alvarez[1], and Maureen Tang[1,2]

[1]Department of Chemical and Biological Engineering
[2]Department of Mechanical Engineering and Mechanics,
Drexel University
3141 Chestnut Street, Philadelphia, PA 19104

mhtang@drexel.edu

ABSTRACT

The invasive spotted lanternfly (*Lycorma delicatula*, SLF) has spread rapidly from Pennsylvania through neighboring states in part because of its ability to travel long distances and hitchhike by laying eggs on vehicles and cargo. The primary purpose of this project is to develop new technology that can automatically detect SLF egg masses using patterned projection profilometry and angle-resolved reflectance to identify textured objects on smooth (metallic) substrates. These approaches can leverage domain knowledge of SLF egg mass size, shape, and texture for smarter detection compared to conventional computer vision algorithms. If successful, the resulting technology could be used to inspect vehicles and cargo at ports, trainyards, warehouses, or other points of entry into North America or between jurisdictions.

Earlier work applied machine learning and active thermography to early detection of SLF egg masses. Our findings confirmed that these methods are possible, but extremely sensitive to variation in the imaging environment, including temperature, wind, light, and substrate. The sensitivity to environmental parameters means that training data must be obtained on target substrates (containers, storage pods, etc.). Although machine learning tools are powerful and widely used, they require vast amounts of training data for accurate identification of positive and negative images. Operationally, it will be a major challenge to acquire a large number of true positives i.e. actual egg masses deposited on trailers and shipping containers. This finding has motivated our current approach, which instead uses blob detection and connected-component analyses to search for objects of size, shape, height, and texture that match expectations.

In patterned projection profilometry, a series of structured light patterns is projected onto a surface. The patterns projected onto the surface are distorted by the surface topography. A camera captures the reflected images and a computer calculates the 3D profile using a mathematical model. Patterned projection profilometry is frequently used for quality control in manufacturing as it can detect protrusions and other surface topography features. Because SLF always lay a single layer of eggs with relatively constant protrusion height, topography is promising method to identify egg masses. We have built a custom lab-scale profilometer using a micro-projector, camera, goniometer, and controller. Raw images are then converted into topology using a mathematical model. This model compensates for geometric distortions by optics and perspectives, the orientation between the camera and measured object, and optical aberrations. Algorithms based on the resulting topological

image may be as simple as flagging protrusions that match the known height of SLF egg masses.

In an alternative approach, earlier optical experiments found that the angle of incident reflection affected the visible appearance of egg masses. Because eggs are much more textured than metal or even wood, they have higher diffuse reflectance (random scattering) and lower specular reflectance (mirror-like reflection). Thus, at direct angles (0º), eggs reflect less light towards the detector and appear dark. At indirect angles (45º), eggs reflect less light away from the detector and appear bright. We are using this phenomenon to develop a detection method based on egg mass texture. Algorithms based on this approach rely on combining blob detection with pre-existing domain knowledge of typical egg mass size, color, and texture. Blob detection functions by smoothing images, then computing the local curvature of the image to identify edges that form continuous objects. We are imaging egg mass samples in the laboratory to acquire statistical distributions of egg mass area, inertia ratio (which describes if a shape is more like a circle or an ellipse), circularity (the presence or absence of sharp corners), and convexity (the presence or absence of 'missing pieces'). Additionally, the difference in contrast (darker vs lighter) in the angled vs direct images can be used to filter true from false positives. Textural analysis of ordered egg patterns or characteristic ootheca cracking may also provide unique identifiers for automated detection algorithms. Texture is quantified through Fast Fourier Transform (FFT) calculations of intrinsic properties such as contrast, visual appearance, spatial alignment, orientation, and angular distribution. Utilizing FFT to analyze detected egg masses within images generates a unique frequency spectrum and may provide a rapid way of filtering egg masses from both videos and static images, without the need for a prior knowledge of egg mass parameters.

Effectiveness of Citizen Scientist Dog Teams in Detecting Spotted Lanternfly (*Lycorma delicatula*) Egg Masses

Sally Dickinson[1], Nathaniel Hall[2], Edgar Aviles-Rosa[2], Mizuho Nita[3], and Erica N. Feuerbacher[1]

[1]Virginia Polytechnic and State University, School of Animal Sciences
Litton-Reaves Hall (0306), 175 West Campus Drive
Blacksburg, VA 24061 (Corresponding Author)

[2]Canine Olfaction Lab, Department of Animal and Food Sciences
Texas Tech University, Box 42141
Lubbock, TX 79409

[3]School of Plant and Environmental Sciences, AHS Jr. Agricultural Research and Extension Center
595 Laurel Grove Road
Winchester, VA 22602

enf007@vt.edu

ABSTRACT

The Spotted Lanternfly (*Lycorma delicatula*, SLF) is an invasive pest species first detected in Pennsylvania in 2014. SLF targets critical crops such as grapevines, apples, and hops, causing millions of dollars in annual agricultural losses. Effective mitigation of SLF spread relies on early detection and eradication of their egg masses, a process currently hindered by reliance on human visual inspection, which is inefficient and prone to high false negative rates. Detection dogs have demonstrated high accuracy in identifying SLF egg masses while discriminating against environmental distractors. However, the limited availability of trained canine teams within governmental agencies necessitates alternative approaches to scale detection efforts. We explored the feasibility of utilizing citizen scientist handler-dog teams to detect SLF egg masses.

We recruited 182 handler teams across the United States and provided them with devitalized SLF egg masses for training. Training protocols, overseen by local canine trainers, were flexible and adapted to participants' diverse geographic locations, schedules, and resources. After 12 -18 weeks of preparation, teams underwent an odor recognition test and a field evaluation to assess detection accuracy in simulated field conditions. Of the teams that completed the field evaluation, we evaluated whether the dog could transition to live eggs, having been trained on devitalized eggs.

The Odor Recognition Test (ORT) consisted of a 10-trial evaluation, during which the handler-dog teams were given 90 seconds per trial to evaluate an array of six identical boxes. Each trial was conducted double-blind, with randomized odor placements. The test array contained zero to one SLF egg mass and five to six ecologically and experimentally

relevant distractor odors, including bark, grass, clean SLF packaging material (match blank), and clean medical gloves.

Teams were given three attempts to achieve the minimum passing score of 80%. Of the 182 teams enrolled in the study, 68 met this threshold. Across all the ORT individual trials, the sensitivity (True positive / (True positive + False negative)) was 80%, and the specificity (Correct rejection / (Correct rejection + False positive)) was 58%. While there is no official detection standard for conservation detection dogs, a sensitivity of 80% demonstrates the dogs can discriminate the SLF egg masses from relevant distracting odors in a controlled environment. The specificity of 58% suggests that dogs are less capable of indicating an absence of the target odor when no SLF eggs are in the array (i.e., blank trial). A subset of 49 of these teams advanced to the Field Evaluation (FE), a double-blind, single-trial evaluation in a naturalistic setting with between three and five SLF egg masses. Each team was allotted 5 minutes to detect the placed samples in a 25-meter x 25-meter area. Across all the FE trials (pass or fail), the sensitivity was 58%, suggesting that the target was more challenging for the dog to locate in a non-controlled environment.

The Live Egg Transition ORT consisted of a double-blind, five-trial ORT, with each trial having one live SLF egg sample and five distracting odors. Of the 29 teams that attempted the live egg transition ORT, 22 were successful, and the calculated sensitivity was 89%. This suggests that teams trained on devitalized eggs can transition to live versions of the egg.

This proof-of-concept study highlights the scalability and feasibility of participatory science detection programs as a community-driven approach to invasive species management. Additionally, we saw a high generalization rate to live eggs, suggesting we can train dogs on devitalized eggs and deploy them to detect live eggs. By harnessing the power of trained volunteers and their dogs, local communities can proactively mitigate SLF's ecological and economic impacts. Citizen scientist dog teams offer a cost-effective and accessible solution for early detection of SLF egg masses, empowering local communities to participate actively in agricultural biosecurity.

Influence of Alternative Hosts on Trap Catch and Detection of Spotted Lanternfly

Joseph A. Francese[1], Sarah M. Devine[1,2], Everett G. Booth[1], Kelly M. Murman[1,3], and Emily K.L. Franzen[2,4], Miriam F. Cooperband[1]

[1]USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Science and Technology (S&T), Forest Pest Methods Laboratory
1398 West Truck Road, Buzzards Bay, MA 02542

[2]Department of Biology, Xavier University
3800 Victory Parkway, Cincinnati, OH 45207

[4]USDA APHIS PPQ S&T East Stroudsburg Field Station
East Stroudsburg, PA 18301

[4]USDA APHIS PPQ S&T Bethel Field Station
222 West Plane Street, Bethel, OH 45106

joe.francese@usda.gov

ABSTRACT

Circle traps have been shown to be an effective tool for spotted lanternfly (SLF) trap catch and detection. The recommended host for trap placement is SLF's preferred host, *Ailanthus altissima*, tree of heaven. As SLF spreads through the North American landscape, and utilizes new hosts, being able to detect it with circle traps in areas where tree of heaven is limited would be beneficial to detecting new outbreaks. Murman et al. (2020) showed that significantly more adult SLF were captured on tree bands placed on tree of heaven than on other species. However, catch of earlier instars was not significant. Of the species tested in those studies, black walnut, *Juglans nigra*, and maple, *Acer* spp. showed potential for serving as alternative hosts, and would possibly be available throughout the targeted survey areas. Multi-state assays were conducted in 2021 (5 states – MD, NJ, NY, PA, WV) and 2022 (3 states - IN, NJ, WV) comparing trap catch and detection (at least one SLF caught in a trap) rates of circle traps placed on tree of heaven with black walnut (2021) and with maple (2022). All traps were baited with methyl salicylate (a host volatile) lures. In 2021, overall adult SLF catch was higher on tree of heaven than on black walnut, however, there was no difference in detection between species at any stage among all replicates. While in 2022, overall trap catch and detection of nymphs and adults were similar between both tree of heaven and maple. There was also no difference in detection rates at low, medium or high density between the hosts. In the absence of tree of heaven, black walnut and maple would serve as suitable hosts for circle trap placement.

I See Trees of Green and Spotted Lanternfly Too: An Overview of WSDA's Proactive Approach

Joshua M. Milnes[1], Sven-Erik Spichiger[2], Wendy DesCamp[2], Karla Salp[2], and Cassie Cichorz[2]

[1]Washington State Department of Agriculture – Department of Plant Protection
21 North 1st Avenue, Suite 103, Yakima, WA 98902

[2]Washington State Department of Agriculture – Department of Plant Protection
WSDA/Natural Resource Building 1111, Washington St. SE, Olympia, WA 98504

JMilnes@agr.wa.gov

ABSTRACT

Washington State Department of Agriculture (WSDA) – Department of Plant Protection is on the lookout for the spotted lanternfly (SLF), *Lycorma delicatula,* a major pest of multiple special crops such as grapes, hops, and fruit trees. Although this planthopper is not currently found in Washington State, there have been multiple "close" calls on the West side of North America. This is very concerning to pest regulators and has led to a call to action across the Pacific coast as SLF continues to move further west. WSDA has been proactive in its efforts to impede any attempts of SLF establishment in the Pacific Northwest specialty crops, which is estimated at over
$3,611,387,000 in production value. WSDA is focusing on four objectives: 1) Development of an SLF response toolkit for state regulators; 2) removal of Tree-of-Heaven at key ports of entry into the state; 3) education and community outreach; and 4) survey of commercial and abandoned vineyards to monitor SLF.

Abundance Trends and Sticky-Trap Monitoring Effectiveness for Spotted Lanternfly Invasion Dynamics in Eastern Ohio

Christopher J. Payne

Department of Biology, Franciscan University of Steubenville
1235 University Blvd., Steubenville, Ohio 43952

cpayne@franciscan.edu
OrcID: 0000-0002-8300-0596

ABSTRACT

The spotted lanternfly (SLF), *Lycorma delicatula*, is an invasive planthopper from China that has spread to seventeen states since being discovered in Pennsylvania in 2014. The insect is both a nuisance pest for property owners and a costly agricultural pest known to feed on more than fifty woody plant species, including grapes, fruit trees, and timber trees. Given Ohio's proximity to Pennsylvania and Ohio's national transportation centrality, a survey program was initiated along the then-known western extent of the SLF invasion in 2021 to monitor for the eventual arrival and spread of SLF into Ohio. Thirteen (2021 – 2022, later twenty in 2023 – 2024) survey sites (each 40 – 4500 m2 and totaling approximately 9.4 hectares) were placed along high-traffic roadways and rail-lines along the Ohio-West Virginia border (Jefferson County in Ohio and Hancock and Brooke Counties in West Virginia) in anticipation of the lanternflies' tendency to hitch rides on vehicles and trains. These survey sites were monitored for 4 years (2021 – 2024), with 4 survey types being employed each year: 1) an initial visual survey of all woody vegetation in each site (approximately 5,250 total stems) in May – June, 2) repeat visual surveys and sticky trap surveys of 6 high host-preference trees (e.g., *Ailanthus altissima*, *Acer* spp., and *Prunus* spp.) in each site every 7 – 14 days from May – November using Web Cote Inc. sticky band traps wrapped in protective poultry-wire cages, 3) incidental visual surveys of non-banded trees every 7 – 14 days from May – November, and 4) a final visual egg-mass survey of the entirety of each site (with use of binoculars for canopies) in December of each year.

The results (as of 2024-10-10) of more than 43,000 surveys (including more than 5,000 sticky-trap surveys) resulted in 1 SLF observed/captured in 2021 (the third ever population documented in Ohio), 31 SLF found in 2022, 8,568 SLF found in 2023, and 106,950 SLF found in 2024 (estimated to reach 150,000 by the end of November). As of 2024-10-10, 2024 data already equates to more than 11,300 SLF per hectare across all sites for the year. Not only did the lanternfly numbers increase across years, but their geographic spread along the Ohio-West Virginia border increased as well. The number of sites with at least 1 observed SLF increased each year: 7.7% (1/13) of sites in 2021, 15.4% (2/13) of sites in 2022, 95% (19/20) of sites in 2023, and 100% (20/20) of sites in 2024. Across sites, the greatest number of observances in 2022 – 2024 each occurred on a college campus, while other sites with substantial numbers of observations typically occurred near rail lines. The survey results of this study suggest rapid infestation of this costly insect only a few years after initial establishment, likely expediting earlier models of rates of spread further into the

Midwest and throughout the U.S. The results also demonstrate the need for thorough monitoring in less-commonly targeted invasion hubs (e.g., college campuses) as well as in previously un-infested high-risk locations to inform quick elimination and control measures.

The results of these survey data also enable an in-field analysis of the effectiveness of sticky band traps for SLF monitoring. 2024 collection data corroborate previous findings that indicate incomplete trapping effectiveness of sticky bands, especially for adults vs. nymphs. Specifically, sticky bands in the current study captured most (90%, 37,586 SLF on band and 4,086 SLF off band) nymphs but fewer (14%, 7,764 SLF on band of a total 55,984) of the observed adults from repeat 7 – 14-day surveying. Additionally, a greater proportion of adults (11.1%, 6,210 of a total 55,984 adult SLF) vs. nymphs (0.7%, 289 of a total 41,672 SLF) were incidentally recorded on non-banded trees throughout the 2024 banding season, though this is undoubtedly in-part due to the greater conspicuousness of adults vs. nymphs. Together, these results suggest that surveying efforts can be performed efficiently by targeting high-preference host species for banding, but that parallel visual surveys can enable sticky-band surveying to be more representative of SLF population dynamics, especially during later life stages of SLF.

Finally, given the rapid establishment, growth, and spread of SLF into Ohio – as well as the known current limitations in eradicating SLF after such thorough establishment across its invaded range – it is proposed that mitigation and control efforts take a dynamic approach. Specifically, the data from this study suggest that monitoring with traps before arrival is an effective tool for capturing local spread dynamics. After any observed establishment, all effort should be made to destroy and eliminate SLF in the observed invaded site(s). If SLF becomes established and their population survives to a second year, elimination is unlikely, and mitigation efforts should be shifted instead to target protection of specific crops as well as regular targeted checking of vehicles, trains, and shipping containers to reduce further spread.

Effectiveness of Sticky-Band Trapping *Lycorma Delicatula* on Wild Grapes (*Vitis* spp.)

Kaylee N. Kirkpatrick and Christopher J. Payne*

Department of Biology, Franciscan University of Steubenville
1235 University Blvd., Steubenville, Ohio 43952

cpayne@franciscan.edu
*OrcID: 0000-0002-8300-0596

ABSTRACT

Lycorma delicatula, the spotted lanternfly or SLF, is an invasive plant hopper from northern China that has quickly spread across the eastern United States since its first detection in Berks County, Pennsylvania in 2014. Since then, SLF have caused millions of dollars in damages, especially to vineyards. SLF are polyphagous phloem-feeders with a wide range of feeding hosts including more than 102 different taxa of plants. Despite their broad palate, SLF demonstrate preference for certain host species including tree of heaven (*Ailanthus altissima*), maples (*Acer* spp.) and grape vines (*Vitis* spp.). Since the arrival of SLF in the United States, there have been many efforts to survey and slow the insects' spread. One example of these efforts has been to trap SLF via the placement of sticky traps around tree trunks. However, much less research exists demonstrating whether trapping on grape vines is also an effective means of monitoring for SLF populations.

This study investigated the efficacy of trapping SLF on a preferred liana host, wild grapes (*Vitis* spp.), compared to more common trapping methods on preferred-host trees (*A. altissima* and *Acer* spp.). It was hypothesized that grapes would be a superior host for trapping SLF given the known preference SLF have for cultivated species of this taxon. To investigate this hypothesis, three research sites with known SLF populations were established in Jefferson County, Ohio, USA. A total of 18 preferred-host trees and 18 grapes (6 of each host type among each of the 3 sites) were selected for sticky trap banding. Web Cote Inc. brand sticky traps were placed around the circumference of each woody stem approximately 1.37 m from the base of each stem, and each sticky trap was surrounded by 2.54 cm poultry wire to reduce vertebrate interactions with traps. The sticky traps were regularly examined and replaced every 10–14 days for the entirety of the SLF's active seasons from 2022-2023 to quantify the number of trapped SLF on grapes versus trees. The location, species, and stem diameter for each host plant were additionally recorded.

A total of 2,831 SLF were caught throughout the study, of which 2,670 were caught on banded trees and 161 were caught on banded grape vines. The difference in captured SLF was in large part due to the difference in stem sizes: the average diameter of banded trees (*A. altissima* and *Acer* spp.) was 25.6 cm, while the average diameter of banded grape vines was only 4.0 cm. A regression analysis was used to further parse out the effect of plant type (grapevine vs tree) after controlling for stem size. After AIC selection of various regression models, a negative binomial random-intercepts regression with plant type, diameter, and plot-location predictors indicated that grapes had an average of 1.12 [95% CI 0.08, 2.16] fewer captured SLF compared to trees after accounting for plot location and

diameter. Despite rejecting the hypothesis, the minor difference in predicted captured SLF per cm between grapes and trees suggests that banding based upon the availability of preferred host species regardless of growth habit may prove effective for monitoring efforts. In fact, if monitoring efforts are not simultaneously employed as a form of mitigation, then the banding of smaller-diameter grapes would likely enable cost savings given their nearly identical capture rate per cm and their average smaller size. These results also support the use of sticky traps on viticultural crop plants if nearby tree monitoring is not available or preferable.

RISK ASSESSMENT MODELS AND PRIORITIZATION TOOLS

Modeling Effective Resource Allocation to Combat Spotted Lanternfly Infestations

Julianna Hoitt and Daniel Strömbom

Department of Biology, Lafayette College
Easton, PA 18042

hoittj@lafayette.edu

ABSTRACT

The spotted lanternfly (*Lycorma delicatula*) is an emerging global insect pest. Despite significant management efforts its spread in regions where it is invasive continues and it is clear that refined management strategies are required.

A recent study introduced a model to generalize results of empirical control efficacy studies for the invasive spotted lanternfly to include population dynamics and incomplete delivery. In particular, they introduced a population growth formula that provides the minimum proportion of a population that must be treated with a given control to induce population decline. Unfortunately, in its current form it cannot be used to address the more relevant question of how to best deploy a given control to maximize population decline.

Here we generalize this model and formula and use it to address this question in a number of settings. For the case when the effect of control deployed is proportional to effort expended we show that exhaustive sequential deployment of stage-specific controls in order of efficacy is the optimal strategy. When the effect of controls exhibits diminishing returns with effort we derive a formula for when to switch controls that provides an effective strategy in situations when management resources are variable and can be cut at any time, and use numerical optimization methods to obtain optimal strategies in the case when there is a known fixed budget. We show that both of these strategies are superior to random deployment of controls. We also characterize the efficacy of random deployment of controls and show that the results of employing such a strategy can be disastrous.

The overall conclusion of our work is that adopting an effective strategy for deployment of stage-specific controls is essential for effective management. Unfortunately, we cannot find any paper or report in the spotted lanternfly literature on this topic, nor any information on which, if any, such strategies are being used in practice. Given that the resources available to combat the lanternfly is limited we should strive to make sure that they are used effectively, and the work introduced here, as well as other optimization approaches that are regularly employed in other areas, can contribute to this.

RISK MITIGATION AND PRACTICAL MANAGEMENT

Spotted Lanternfly Adaptive Management Strategies and Lessons Learned by Three Land Managers

Bill Oldland, Heather Smith, Craig Larcenaire, and Rick Turcotte

USDA Forest Service, Eastern Region, State, Private and Tribal Forestry
Morgantown, WV

willam.k.oldland@usda.gov

ABSTRACT

Spotted lanternfly (SLF), *Lycorma delicatula* (White) (Hemiptera: Fulgoridae), is a planthopper native to China, India, Vietnam and recently detected in South Korea, Japan, and the United States (was first discovered in 2014 on a property in southeastern Pennsylvania.

The objective of following SLF populations at three different sites owned by three different agencies was to monitor impact on ecosystem and visitation, assess treatment and monitoring tools, and provide information for future sites on dealing with SLF.

The three sites chosen were: Cherry Valley National Wildlife Refuge (CV) is 4,350 acres and located in Monroe County, Pennsylvania, near Stroudsburg, First State National Historic Park Brandywine Valley Unit exceeds 1,350 acres and located in New Castle County in Wilmington, DE., and Fair Hill Natural Resource Management Area (FH) is 5,656 acres and located in Cecil County, in Elkton, MD.

Cherry Valley National Wildlife Refuge (USFWS) first reported six SLF adults in 2019. USDA Forest Service staff and USFWS staff began mapping *Ailanthus altissima* in 2020. During this time two SLF egg masses were found on birch within the CVB proclamation boundary. Also, in 2020 a USDA FS grant with Pennsylvania Department of Agriculture began. There is a 10-acre vineyard next to the refuge and the owner and staff were nervous about SLF expanding its range. In 2021 *Ailanthus* surveys continued as well as suppression. Five large *Ailanthus* were removed, but the stumps were not treated. Spot treatments of Bifenthrin on clusters of SLF was used to attempt to reduce SLF and slow its spread to neighbors. The vineyard was also using spot treatments, egg mas scraping, sticky bands, and one circle trap. Three SLF surveys occurred in 2021. July 15th 225 nymphs and 129 adults were counted. These were not treated with Bifenthrin. On July 30th 288 nymphs and 206 adults were located and treated with Bifenthrin. Then on August 23rd, 1000, adults were counted and treated with Bifenthrin. In 2022 transect plots were established on May 19th and 159 to 255 egg masses were found. These plots were surveyed again on July 1st and 144 to 560 adults were spotted. Finally on August 17th a linear plot was established, and 51 to 150 nymphs and 150 adults were within the plot. The SLF adults were a nuisance and there were invasive plants present within this plot as well. Pennsylvania Department of Agriculture (PDA) established 83 trap trees along trails at CV. However, CV staff had *Ailanthus* removed and treated along the trails, including the trap trees. Then in 2023 12 egg masses were found off plots and there were no egg masses within the plots. In July two nymphs were

spotted on plots and 32 off plots. The PDA created 114 dinotefuran trap trees in the linear plot away from the trails. In September two adults were found on plots and two off plots. Because of these low numbers the staff at CV were hopeful that the treatments were working. Finally in 2024 no egg masses or nymphs were found on any of the plots. A survey in August found less than 100 adults on the plots.

The second site to be followed during an SLF infestation was First State National Historic Park, NPS. The first report of SLF at FS was in 2019. Public concern began to increase in 2020 so the staff installed circle traps and began to do egg mass surveys and remove them by scraping. The park began public education in 2021. Other activities in the park an *Ailanthus* survey, mapping and herbicidal treatments. The staff also selected high priority areas for SLF surveys. Additional circle traps were installed, and it appeared that SLF adult numbers dropped in late Summer. In 2022 the staff continued to the use of circle traps and surveys. Monitoring plots were installed, and it appeared that SLF was spreading through the area. The SLF was mainly located on invasive plants. The park had a few "Hot Trees" with over 400 adults per tree. The treatments of *Ailanthus* had no impact on SLF numbers. During 2023 SLF continued to disperse quickly. The staff found it beneficial to manage invasive plants at the same time as surveying for SLF. The circle traps were no longer useful. The monitoring plots had very few adults and nymphs. Finally in 2024, the staff noted that there was an increase of invasive plants where the *Ailanthus* were treated and died. The staff stopped tracking SLF.

The third site was Fair Hill State Park, MD DNR (FH). The first report of SLF was in 2019. During that year 700 *Ailanthus* were treated with Triclopyr and 200 were treated with Dinotefuran. The following year in 2020, 400 *Ailanthus* were treated with Dinotefuran. In 2021 egg mass, nymph, and adult surveys began. An equestrian event was held at FH called Maryland 5 Star and visitors were swatting adult SLF away in the infield. The staff was concerned about the wasps attracted to the honeydew of SLF near the event area. Due to time constraints the *Ailanthus* stand mortality was not surveyed. Surveys continued and expanded in 2022. An additional 200 *Ailanthus* were treated with Triclopyr. When high population areas of SLF were located Bifenthrin was used During the Maryland 5 Star event no one reported SLF being a nuisance. It was decided to put some of the *Ailanthus* bolts were placed in rearing barrels. The surveys continued in 2023, and it was noted that invasive species were dominating the understory. Finally in 2024 it was found that plots were *Ailanthus* were removed there were fewer SLF. Stands that contained *Ailanthus* continued to have high SLF counts. It was determined that 75% of the understory was dominated by Multiflora rose, stilt grass and oriental bittersweet.

At the end of following these sites for nearly six years, the mangers had several comments of what worked and what they might do different. They found treatments seemed to help in large swarm years, when staff was available to treat. It appears there may be one to three bad years and then the populations dropped off after that. When comparing CV with other refuges in the complex, where no treatments occurred, numbers seemed the same. The managers found that it was worth treating when possible as part of a good neighbor effort. As *Ailanthus* died at these sites, invasive plants increased. They concluded that while implementing SLF suppression it would be helpful to treat invasive plants at the same time. While visitors were at these sites, they tended to have more general comments more than complaints.

Spotted Lanternfly Sequestration: Determining How an Invasive Insect Uses an Invasive Tree for Chemical Defense

Brian F. Ruether[2] and Dorothea Tholl[1]

[1]Department of Biological Sciences, Virginia Tech
Blacksburg, VA 24061

[2]Mass Spectrometry Research Incubator, Virginia Tech
Blacksburg, VA 24061

bfr2015@gmail.com

ABSTRACT

Since its arrival in Pennsylvania in 2014, the spotted lanternfly has infested 16 additional states and is considered a highly polyphagous pest, causing damage to over 100 species of forest, agricultural, and ornamental plants. Despite its generalist nature, SLF most directly threatens winegrapes in terms of agricultural commodities, but also strongly prefers the invasive tree-of-heaven (ToH) (*Ailanthus altissima* Mill. Swingle), having coevolved with the tree in their shared native range. Several sources of evidence suggest SLF sequester a class of phytotoxins, the quassinoids, found within ToH for use as antipredator defense. However, little is known of the efficiency by which SLF can sequester these compounds. Here we describe the use of quantitative liquid chromatography-mass spectrometry to quantify ailanthone, the most prominent quassinoid in ToH, in ToH phloem sap, adult SLF bodies, and SLF honeydew. Preliminary results indicate that SLF are likely able to both sequester and modify/detoxify ailanthone, as concentrations in the phloem greatly exceed those in the insects and their honeydew.

OUTREACH AND EDUCATION

The Spotted Lanternfly in Gettysburg and Public Mobilization Through an Awareness Campaign

Brandon R. Fey

Department of Public Policy, Gettysburg College
CB 1041, 300 North Washington St. Gettysburg, PA 17325

Brfey05@gmail.com

ABSTRACT

As a popular tourist destination, Gettysburg attracts over a million annual visitors from an extensive geographical diversity. A considerable portion of these visitors travel from regions where the spotted lanternfly (*Lycorma delicatula*) remains unestablished and are therefore unaware of the magnitude of the threat that the invasive insect poses to native flora. The encompassing Adams County has been designated as a lanternfly quarantine zone by the Pennsylvania Department of Agriculture due to the risk the insect poses to the county's extensive fruit industry, which comprises over 60% of the total fruit production in the state. The continuous presence of uninformed visitors in a region inherently vulnerable to lanternflies presents the danger of tourists unknowingly transporting lanternflies to and from Gettysburg on their vehicles and belongings, unnecessarily contributing to the insect's proliferation.

This project was run through Gettysburg College to create an informational poster campaign tailored to Gettysburg, to inform visitors and residents about the spotted lanternfly and mobilize them to take action against it. The posters were designed to be applicable during the entire year, with information including photographs of the lanternfly during each of its developmental instars, the months during which each instar is prominent, and the relative size of each instar. Posters were created in two designs: a universal poster that applies to all locations and visitors in Gettysburg, and a Civil War-themed design inspired by the iconic history of the town. Both designs present concise information about the ecological threat posed by the lanternfly, and present 3 step instructions for assisting in the effort to combat the insect. These include ensuring careful identification per the attached photographs, reporting photos of the insect to the PA Department of Agriculture using an attached QR code and/or telephone hotline, and carefully stepping on the insect.

Posters were printed from the Ricoh Print Shop at Gettysburg College, and distributed to over 70 cooperating businesses in the town as of 2024. The posters are also displayed around the Gettysburg National Military Park for greater outreach to visitors. While the measurability of the effectiveness of a poster campaign cannot be isolated from other variables affecting the proliferation of the spotted lanternfly, researchers at Cornell University have speculated that informational campaigns have been greatly effective in combating the insect as a supplement to more direct measures. This is because despite being of a relatively similar size, South Korea experienced the complete propagation of the lanternfly across the country in 3 years, while after 10 years since its discovery in Pennsylvania in 2014, the insect has not spread to the entirety of the state.

The Gettysburg poster campaign has provided a low-cost means of engaging the public about the spotted lanternfly in hopes that visitors will be encouraged to take a proactive interest in the issue with knowledge that they can share with their home communities. It remains an ongoing effort as of 2025, as each year new designs will be created based on the previous models, to be displayed at more locations around the Gettysburg area.

OTHER

Microstructure of Sensory Structures on the Cuticle of Spotted Lanternfly

Douglas G. Pfeiffer[1] and Jon D. Eisenback[2]

[1]Department of Entomology
[2]School of Plant Environmental Science
Virginia Tech
170 Drillfield Drive, Blacksburg, VA 24061

dgpfeiff@vt.edu

ABSTRACT

Scanning electron microscopy was used to examine sensory structures on the head and thorax of nymphal and adult spotted lanternflies (SLF). The pedicel of both nymphs and adults are covered with dome-shaped groups of plaque organs, containing placoid sensilla. These have been studied in other lanternflies including SLF. The arista is expanded to a globose (in the case of the nymph) or oval (in the case of the adult) swelling, Burgoin's organ, the function of which is unknown. The front surface of the frons is a flat area containing about 20 pit organs on each side. The pits are asymmetrical, with a single trichome projecting horizontally from one side; the rim of the pit on the opposite side presents as a smooth, raised edge. Such pits widespread in Fulgoroidea. The function is unknown. On the nymphal thorax, there are similar beds of pit organs. The asymmetrical pits on one segment face in the same direction. The beds on neighboring segments face in different directions. There is possibly directionality of response. The function of these pit organs is unknown. A possibility is to detect air movement. Possible relation to SLF behavior was discussed.