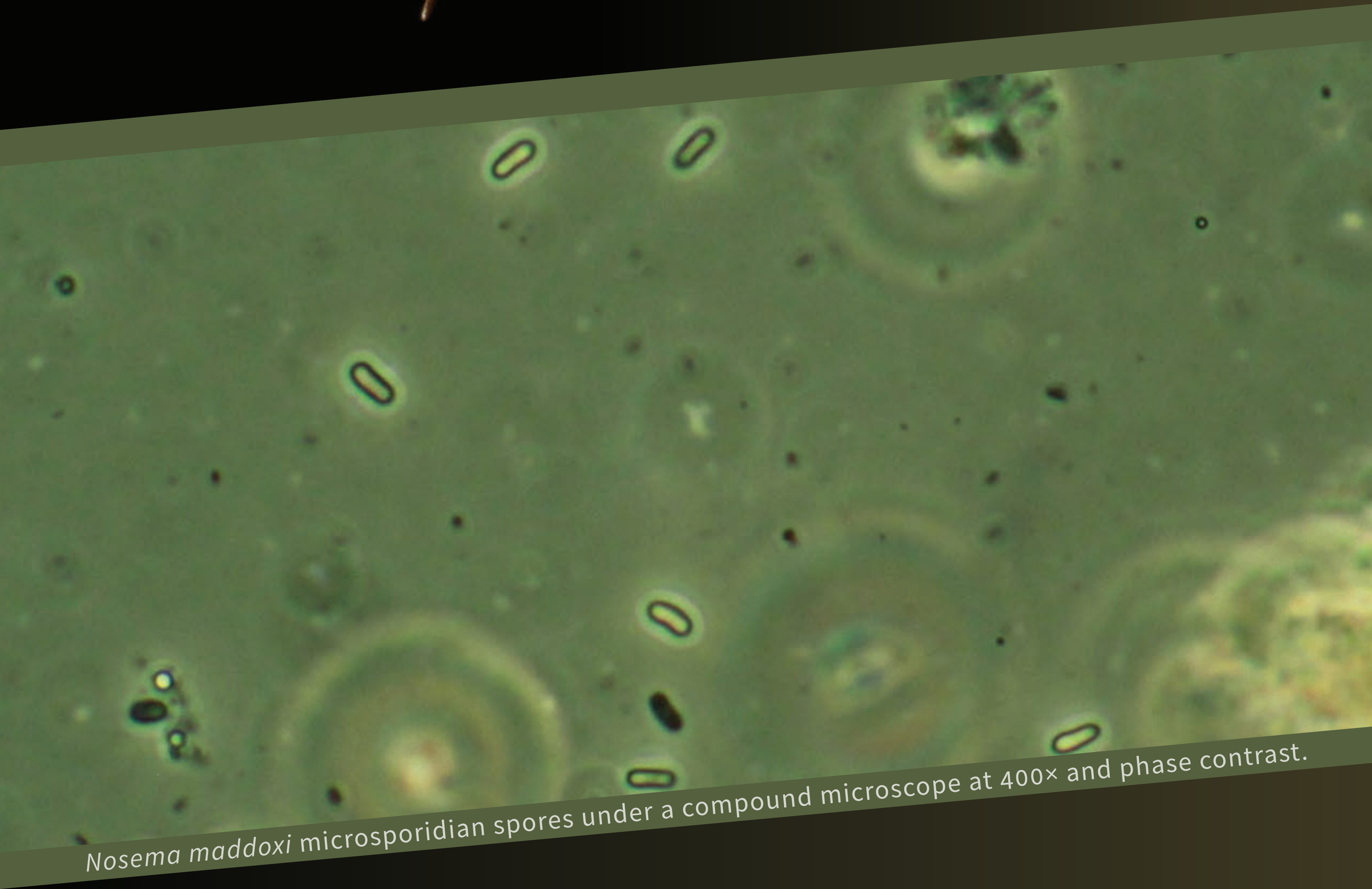
INTEGRATED PEST MANAGEMENT

Insights



Nosema maddoxi microsporidian spores under a compound microscope at 400× and phase contrast.

June 2019: Volume 16, Issue 2

Integrated Pest Management

Northeastern IPM Center

Insights

June 2019
Volume 16, Issue 2

Inside

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Biological Control of Brown Marmorated Stink Bug

By Lori Spears, USU CAPS Coordinator

A version of this article first appeared in the winter 2019 issue of the Utah Pests Quarterly *newsletter.*

Brown marmorated stink bug (BMSB, *Halyomorpha halys* (Stål)) is an economically important nuisance and agricultural pest that invaded North America from eastern Asia in the late 1990s. BMSB congregates in and on buildings during the winter, and is known to attack over 170 plant species, including fruit, vegetable, and nut crops, as well as herbaceous and woody ornamentals.

A brown marmorated stink bug is seen hiding among peaches that have severe feeding damage.

A Hardy and Mobile Pest

Unfortunately, BMSB is a challenging insect to manage. Both nymphs and adults damage crops, and adults have a tough exoskeleton that is covered with a waxy, water-repellent cuticle that can help protect them from pesticide applications.

Further, adults have a strong dispersal capacity, enabling them to easily re-invade previously treated areas. Adults can theoretically fly more than 70 miles per day, although most adults fly short distances (Wiman et al. 2014; Lee and Leskey 2015). Even nymphs, which are wingless, are relatively mobile due to their strong walking capacity (Lee et al. 2014).

> BMSB is a challenging insect to manage. Both nymphs and adults damage crops, and adults have a tough exoskeleton that is covered with a waxy, water-repellent cuticle.

Problematic Reliance on Insecticides

Growers in the Mid-Atlantic region with BMSB infestations are relying on weekly, season-long applications of broad-spectrum insecticides, as integrated-management programs are still under development.

Broad-spectrum insecticides are costly, risk development of pest resistance, may contribute to secondary pest outbreaks, and can be harmful to beneficial insects, including biological control agents.

The samurai wasp, native to eastern Asia, is a promising biocontrol agent that has made its way to the U.S. Some states where it now occurs are releasing it. Photo by Elijah Talamas, USDA ARS.

The Search for an Effective Biocontrol Agent

Natural biological control has been observed in the U.S., but not enough to manage BMSB. Generalist predators (lacewings, mantids, earwigs, lady beetles, assassin bugs, minute pirate bugs, big-eyed bugs, and spiders) feed on BMSB egg masses and nymphs (Lara et al. 2016; Morrison et al. 2016). In addition, although researchers have found at least 12 native wasp species that can parasitize egg masses of BMSB, they typically account for less than 11-percent mortality of eggs (Rice et al. 2014).

See "Biological Control" on Page 3

This article is no longer available.

Call for Submissions and Photos

Do you have IPM-related news or an IPM story to tell? We value the perspectives of growers, implementers, policymakers, and others on the front lines of pest management, and we welcome guest submissions for future newsletter editions.

Whether you'd like to write something new for us or submit something you've already had published elsewhere—given reprint permission from that publication—we want to hear from you!

Do you have high-quality photos of pests, pest damage, pest-management methods, or people demonstrating IPM practices? Your images could help us tell the story—and promote awareness—of current and emerging pest- and pest-management issues.

If we use your photos, they could appear in any of our channels or collateral, including newsletters, brochures, websites, and social media, and you'll be credited as the photographer.

Please visit neipmc.org/go/ncfs for more information.

Katydid on camera lens. Photo by Judy Gallagher, flic.kr/p/ooki1q, CC BY 2.0.

Biological Control

Continued from Cover Page

> Broad-spectrum insecticides are costly, risk development of pest resistance, may contribute to secondary pest outbreaks, and can be harmful to beneficial insects.

The samurai wasp (*Trissolcus japonicus*) co-evolved with BMSB in eastern Asia, and there, it is highly effective, with egg parasitism rates reported to be as high as 80 percent. The wasp has been identified as the most promising agent for classical biological control of BMSB in the U.S. Starting in 2007, USDA Agricultural Research Service entomologists reared samurai wasp specimens under strict quarantine conditions with the hope of mass-releases.

Surprise Arrival of BMSB's Natural Enemy

However, starting in 2014, adventive (wild) populations started to occur in many states, including Maryland, Virginia, Ohio, Michigan, Washington, and Oregon. It is speculated that the wasps arrived within stink bug egg masses on plant cargo shipped from Asia. Many of those wild populations became established, and because of this, some states are now able to release samurai wasps for control and research purposes, bypassing the lengthy procedures needed for introducing a new species.

> The samurai wasp has been identified as the most promising agent for classical biological control of BMSB.

Healthy BMSB eggs are barrel-shaped, one-sixteenth of an inch wide, and translucent, white, or light green in color. As eggs mature, dark triangular-shaped spots become visible. Eggs are typically laid on the underside of leaves in clusters of 20 to 30. If

BMSB eggs on a leaf. Photo by Jennifer Carr, University of Florida, Bugwood.org.

parasitized, however, BMSB eggs turn dark brown to black in color.

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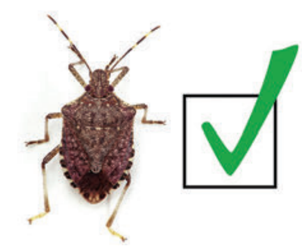


Participate in a BMSB Impact Survey

A nationwide survey currently underway aims to gather information from farmers and growers on the economic impact of the brown marmorated stink bug (BMSB) on agriculture. The ultimate goal is to better provide you with the help you need in managing this pest.

We'd like to find out when BMSB became a problem for you, where you currently get information on how to control them, how much damage you have suffered, your use of and interest in various management practices, and your feelings about biological control methods and their potential for your operation.

Survey results will be used by extension programs across the United States to fine-tune BMSB-management advice and help prioritize research and outreach activities.

The survey should take 20–25 minutes to complete. Your individual responses will be confidential and the data collected will be reported only in summaries. Your participation is voluntary and you can decide not to answer any given question if you choose.

To participate, go to neipmc.org/go/TWrG

For more information, contact Jayson Harper, interim director of the Penn State Fruit Research and Extension Center and professor of agricultural economics, at jkh4@psu.edu or 814-863-8638.

Newly Described Pathogen May Help Control Brown Marmorated Stink Bug

Nosema maddoxi microsporidian has been found to prefer the invasive pest

By Carrie E. Preston and Ann E. Hajek

This article is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, Specialty Crop Research Initiative under award number 2016-51181-25409.

Discovery of an Unwitting Ally in the Fight Against Invasive Stink Bugs

In 1978, Joseph Maddox, insect pathologist at the Illinois Natural History Survey, reported finding an insect pathogen in the green stink bug (*Chinavia hilaris*) throughout the Midwest (Maddox, 1979). It was a microsporidian species that was ultimately described in 2017 and, in deference to its discoverer, named *Nosema maddoxi* (Hajek et al., 2017).

This microsporidian was found in several stink bug species, including the brown marmorated stink bug (BMSB, *Halyomorpha halys* (Stål)), an invasive species posing a significant threat to agriculture throughout the United States.

Very little is known about this pathogen, so research has been underway to determine its effects on BMSB and whether it could be an additional tool for biological control.

Biological control—or biocontrol—is the use of a living organism to control the populations of other organisms that are considered pests. It's a potent tool in the integrated pest management arsenal, offering an alternative to pesticides by capitalizing on the control agent's natural behavior.

The Brown Marmorated Stink Bug: What Is It and Why Does It Matter?

The brown marmorated stink bug (BMSB, *Halyomorpha halys* (Stål)), is an invasive insect that was unintentionally brought over from Asia in the late 1990s. BMSB is a voracious eater that damages fruit, vegetable, and nut crops, posing significant risk of widespread agricultural and economic harm.

Brown marmorated stink bug. Photo by Wil Hershberger.

With an abundance of food sources and few natural predators in North America, BMSB has spread quickly and effortlessly, creating a critical need for the development and dissemination of effective management practices—preferably least-risk practices, especially given the pest's broad geographic footprint and its affinity for food crops.

Biological control of BMSB is one area of active research. By identifying and capitalizing on natural predatory or parasitic dynamics, scientists are exploring promising leads that may ultimately help minimize the pest's impact.

Key Facts

- *Nosema maddoxi* is a newly described microsporidian pathogen recently found in BMSB populations in the U.S.
- Infections of some microsporidia can be spread from mother to offspring via the eggs, and also from one insect to another through feeding behavior.
- Many microsporidian species cause chronic infections that impact their insect host's longevity and ability to produce eggs.
- Research is ongoing to determine what impact this pathogen could have on BMSB populations in U.S. crop systems.

What Are Microsporidia and How Do They Spread?

Fungal Pathogens and the Hosts They Depend On

Microsporidia are microscopic obligate pathogens—organisms that cannot complete their life cycle without a host—living inside a host's cells (Boucias & Pendland, 1998; Becnel & Andreadis, 2014). Many species are pathogens of fish and invertebrates, including insects (Han & Weiss, 2017).

Currently, there are 1,500 known species that infect a wide range of hosts (Becnel & Andreadis, 2014; Corradi, 2015), the majority being host-specific, meaning they will infect only certain host species (Becnel & Andreadis, 2014; Bjørnson & Oi, 2014; Hoch & Solter, 2017).

A Two-Part Life Cycle

The microsporidian life cycle consists of two phases (Han & Weiss, 2017):

- Asexual reproduction within infected host cells
- Spore production

Spores can survive outside of a host for a short period of time, but the asexual stage occurs only in the cytoplasm of a host tissue cell (Hoch & Solter, 2017).

Methods of Infection

Microsporidian infections in invertebrates—including stink bugs—occur when microsporidia cells and spores are present within the cells of a susceptible host (Onstad et al., 2006). There are two ways for microsporidia to infect new hosts.

In **horizontal transmission**, spores that have developed in an infected host are orally ingested by a potential host individual (Hoch & Solter, 2017). Once the spores are ingested, the different life stages develop within host cells in the cytoplasm.

Horizontal transmission can occur via feeding when healthy individuals feed on the feces of an infected host, or when they feed on the cadaver of an infected host that has died (Andreadis, 1987). In the lab, BMSB have been observed to feed on eggs, nymphs, eclosing adults, and on cadavers of other BMSBs (Medal et al., 2012), which could make them vulnerable to microsporidia infection. Nymphs and adults can also get infected if their environment is contaminated with spores (Hoch & Solter, 2017).

Vertical transmission occurs when a pathogen is passed from a mother to its offspring via the egg (Hoch & Solter, 2017). In the case of microsporidia, they can be inside the eggs, or on the surface of the eggs from an infected female so that the offspring become infected after hatching (Hoch & Solter, 2017).

Horizontal transmission is thought to occur more often than vertical transmission (Becnel & Andreadis, 2014; Hoch & Solter, 2017). In the case of *Nosema maddoxi*, vertical transmission has yet to be confirmed at all.

Structure of a Spore

There are several parts that make up a microsporidian spore.

The **spore wall** consists of the **endospore** and **exospore** (Keeling & Fast, 2002; Fig. 1). This protects the spores when in the environment outside the host cell.

Inside the spore are the **polaroplasts**, **nucleus**, **posterior vacuole**, **anchoring disk**, and **polar filament** (Keeling & Fast, 2002; Fig. 1). Some microsporidian species have two nuclei, but *Nosema maddoxi* has only one (Hajek et al., 2017).

The polar filament is a coiled, tube-like structure that is crucial for infecting a host, and it is one of the key features distinguishing microsporidia from other pathogens (Keeling & Fast, 2002).

To infect a host, a microsporidian must first get inside a host cell. To do so, the polar filament uncoils while everting—that is, turning inside out—and extending out of the spore to pierce a host cell (Boucias & Pendland, 1998). The spore's contents are then injected into the host cell's cytoplasm.

Microsporidia typically target host cells in the midgut, fat body, and reproductive system, but different microsporidian species can differ in this preference (Boucias & Pendland, 1998; Hoch & Solter, 2017).

What Can Microsporidia Do to Insects?
A Wide Array of Pathogens and Their Effects, Both Good and Bad

Of the 200 described microsporidian genera, 93 have insects as hosts (Becnel & Andreadis, 2014). One species is commercially available as a biocontrol agent to control pest populations of rangeland grasshoppers (Ewen & Mukerji, 1980).

But it is only by coincidence that microsporidia sometimes share human priorities, as they can also be problematic for researchers who are mass-rearing insect colonies in laboratories, either for research or for production as food and feed (Stentiford et al., 2016).

Insect colonies can collapse from microsporidian infection, and infected colonies of biocontrol agents can have reduced fitness and suffer diminished effectiveness in the field (Bjørnson & Oi, 2014).

The only method known to clean a colony from microsporidian infection is the Pasteur technique, which was created by Louis Pasteur

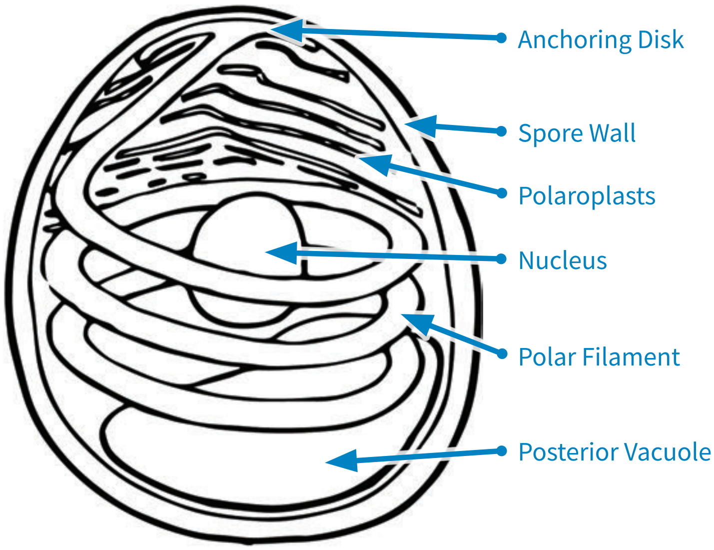


Figure 1. Microsporidian spore based on the original drawing by Naomi Fast (Keeling & Fast, 2002).

in the 1870s (Hoch & Solter, 2017). Female and male pairs are isolated from the insect colony. After eggs are produced, the adults are checked for infection. If the adults are infected, the eggs are not used to grow the colony. Otherwise, they are kept to start a new infection-free colony (Becnel & Andreadis, 2014; Bjørnson & Oi, 2014).

Prevention is the main way to ensure a healthy insect colony (Becnel & Andreadis, 2014; Hoch & Solter, 2017; Bjørnson & Oi, 2014).

Also, microsporidia have negatively affected beneficial insects, including honey bees (*Apis* sp.) and silkworms reared for sericulture (*Bombyx mori*) (Keeling & Fast, 2002).

What Does the Host Experience?

The negative impacts that microsporidia can have on an insect host (Becnel & Andreadis, 2014) include:

- Shortening life span
- Lowering fecundity—a host's fertility—by decreasing a female's ability to reproduce
- Prolonging larval development
- Decreasing egg viability, or the number of eggs in an egg cluster that successfully hatch
- Feminizing males (Becnel & Andreadis, 2014; Han & Weiss, 2017)

Chronic vs. Acute: It Depends

In most cases, microsporidia infections are chronic, tending not to swiftly prove fatal. Instead, they linger, broadening their opportunity to infect new hosts (Hoch & Solter, 2017).

However, microsporidian infections can increase within an insect population and, depending on the health of new hosts, can become acute and much more deadly (Bjørnson & Oi, 2014).

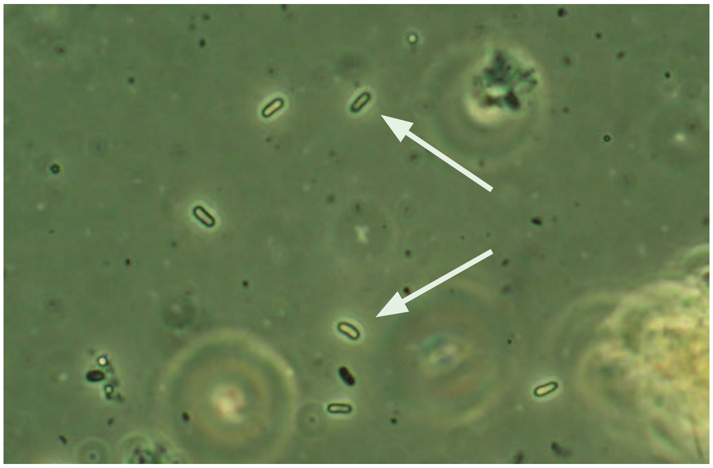
Enter *Nosema maddoxi*

Beginning in 2012, some mass-reared BMSB lab colonies in the United States were found to have collapsed. The perpetrator, it turned out, was

Nosema maddoxi, the same microsporidium in the Nosematidae family (Hajek et al., 2017) that Joseph Maddox had first found in the green stink bug over three decades earlier.

In keeping with the norm, this species is known to rely on horizontal transmission for infecting new hosts (Hajek et al., 2017). Given that BMSB adults and nymphs have been observed feeding on spores contaminating their environment as well as on eggs and cadavers, they are vulnerable to this method of infection.

Nosema maddoxi is host-specific and has been found in only four stink bug species (family Pentatomidae) in the U.S. (Hajek et al., 2017). Sharing the pathogen's purview with BMSB and the green stink bug are the brown stink bug (*Euschistus servus*) and the dusky stink bug (*Euschistus tristigmus*) (Hajek et al., 2017), North America-native species that can be pests, but that do not pose the threat to agriculture that BMSB does.



Nosema maddoxi spores under a compound microscope at 400× and phase contrast.

What's Next?

Given the tantalizing prospect of using *Nosema maddoxi* as a biocontrol agent against BMSB, research on the microsporidian's effects on the pest is underway.

Field research is being conducted to answer more questions, including: What is the distribution of *Nosema maddoxi* in BMSB populations in the United States? And what is the prevalence of infections in field-collected BMSB?

Lab studies are focusing on the pathogen's effects on BMSB survival, female fecundity, and rate of nymphal development.

While early indications are promising, there is much yet to explore and discover. Stay tuned!

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View Our Recent Webinars

The Northeastern IPM Center regularly hosts webinars on a variety of pest- and pest-management-related topics through both the *IPM Toolbox* webinar series and the StopPests in Housing program.

Webinars feature guest presenters who are experts in their field and offer up-to-date background and tips on current and emerging pest concerns. Attendees typically include pest-management professionals, homeowners, growers, or the public more broadly.

Live attendees have the opportunity to ask questions of the presenters, while webinar recordings are subsequently posted online for others to peruse at their convenience.

The IPM Toolbox

IPM Toolbox webinars are one hour in length and feature IPM experts discussing an effective IPM practice, method, or effort. They are designed to share practical IPM tools that improve environmental and social health and maintain profitability. The format is usually an interview style with questions from the audience.

Spotted Lanternfly

Earlier this year, in conjunction with the New York State IPM Program and the Department of Agriculture and Markets, the *IPM Toolbox* hosted a collection of webinars on spotted lanternfly, a recent invasive arrival inflicting agricultural damage throughout the Northeast. Each of the four webinars was directed at growers of a particular set of crops and followed a similar format.

The featured presenters were:

- **Tim Weigle**, Grape and Hops IPM Specialist, NYS IPM Program
- **Juliet Carroll**, Fruit IPM Coordinator, NYS IPM Program
- **Ethan Angell**, NYS Dept. of Agriculture and Markets
- **Brian Eshenaur**, Ornamentals IPM Specialist, NYS IPM Program
- **Dan Gilrein**, Entomology, Suffolk County Cornell Cooperative Extension

Spring Webinar Series

More recently, the *IPM Toolbox* hosted three webinars on different topics.

Varroa Mite IPM: Mite Management Is the Bee's Knees!

Presented by:

- **Kim Skyrm**, Apiary Program Coordinator/Apiarist, Massachusetts Department of Agricultural Resources
- **Jen Lund**, Apiarist, Maine Department of Agriculture, Conservation, and Forestry

How IPM Can Help Keep Children Safe from Lyme Disease at Schools and in Suburban Communities

Presented by:

- **Kathy Murray**, IPM Entomologist, Maine Department of Agriculture, Conservation, and Forestry
- **Andrew Y. Li**, Research Entomologist, USDA ARS Invasive Insects Biocontrol and Behavior Laboratory, Beltsville, MD

IPM for Industrial Hemp

Presented by **Whitney Cranshaw**, Professor and Extension Specialist, Colorado State University

Visit neipmc.org/go/ipmtoolbox for recordings of recent webinars and information about upcoming webinars when available. Recordings of prior webinars are archived at neipmc.org/go/toolbox-archive.

StopPests in Housing

In addition to conducting in-person trainings, the Northeastern IPM Center's StopPests in Housing program hosts webinars to help multifamily-housing staff use integrated pest management to understand and address threats posed by pests in housing.

These online training opportunities feature renowned specialists and address the most common and serious pests afflicting housing—bed bugs, rodents, and cockroaches—as well as exploring other challenging topics like hoarding and delusional parasitosis.

The popular webinar series often attracts 300 to 500 attendees at the live events with hundreds more watching the archived recordings. Recent highlights include:

- **Robert Corrigan**, president, RMC Pest Management Consulting, and **Matt Frye**, community IPM extension area educator, NYS IPM Program, talking about rodents and exclusion
- **Coby Schal**, Blanton J. Whitmire Distinguished Professor, North Carolina State University, discussing how to control cockroaches with baits and manage resistance
- **Richard Cooper**, senior director of technical services, Terminix, describing the essential elements of a bed bug management plan for affordable housing
- **Dini Miller**, associate professor of urban pest management, Virginia Tech, and **Stephen Kells**, associate professor of entomology, University of Minnesota, breaking down issues with pest-control contracts
- **Dawn Gouge**, extension specialist and professor of urban IPM, University of Arizona, addressing all pests as she describes what a comprehensive IPM plan for affordable housing looks like

Visit stoppests.org/go/webinars to peruse all archived StopPests in Housing webinars.

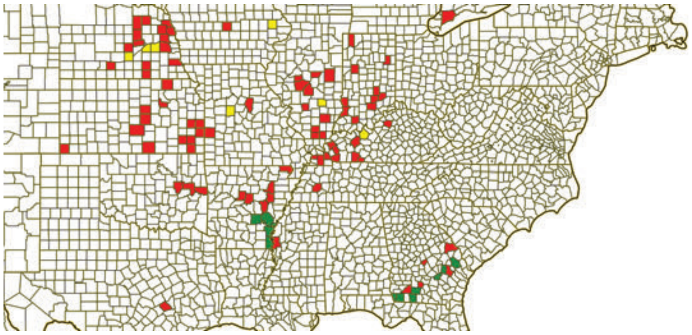
iPiPE Supports Positive Outcomes for Agricultural Producers

Data-sharing platform supports food-system security and productivity

The Integrated Pest Information Platform for Extension and Education (iPiPE) is an agricultural data-sharing program founded on the premise that our food systems are the most secure and productive when agricultural professionals have timely access to information about agriculturally important organisms.

The iPiPE platform facilitates sharing of pest and beneficial-insect observation data into a public network to track the location and spread of key crop pests and create real-time maps, alerts, and forecasts, enabling producers to limit yield loss and make fewer pesticide applications.

> iPiPE's long-term goal is summarized by its motto, "progress through sharing."



Sample of a pest map available to iPiPE users, generated by user-submitted data, displaying the spread of southern rust, a fungal disease.

iPiPE's long-term goal is to maintain a widely used, comprehensive resource that farmers and advisors use to access precise science-based information on agriculturally important organisms to enhance yield, profit, and sustainability. This is summarized nicely by iPiPE's motto, "progress through sharing."

History and Successes

iPiPE has been funded since 2015 by the USDA Agriculture and Food Research Initiative Food Security Challenge Area.

In 2018 alone, iPiPE participants shared 261,094 observations, including over 2,000 observations of pollinators. In addition, 93 extension publications associated with iPiPE became available to over 75,000 readers.

Expertise on Specific Crops and Their Pests

Crop-pest programs (CPPs) are sub-programs within iPiPE focused on one or more crops and associated pests in a specific growing region.

iPiPE by the Numbers

In 2018

261,094
observations shared by iPiPE participants, including over
2,000
observations of pollinators

93
extension publications available to over
75,000
readers

300
presentations made by crop-pest-program coordinators to almost
10,000
stakeholders

There are 28 CPPs, and their coordinators made an estimated 300 presentations to almost 10,000 stakeholders last year alone.

Dr. Mahfuz Rahman, coordinator of the West Virginia Tree Fruit CPP said about his involvement, "This project created ample opportunities to work with extension professionals involved with tree-fruit pest management in the Mid-Atlantic region. It also opened an opportunity to interact with commercial as well as backyard growers, and learn their approaches on pest management and their expectations from extension professionals."

> "This project opened an opportunity to interact with commercial as well as backyard growers, and learn their approaches on pest management and their expectations from extension professionals."
> *– Dr. Mahfuz Rahman, coordinator of iPiPE's West Virginia Tree Fruit crop-pest program*

Opportunities for Students

iPiPE also offers internships for students, who spend their summer scouting, contributing pest observations to iPiPE, and conducting research, which they present at the annual meeting.

Intern research projects have focused on, for example:

- Mitigating solar radiation damage in cranberries
- Tracking sugarcane aphid in the Lower Rio Grande Valley
- Using drone imaging to detect stem blight in blueberry crops

Describing the benefits of the iPiPE network, summer 2018 intern Loni Askew said, "Based on my experience, people can most effectively collaborate using iPiPE . . . by looking at the maps, which allow growers and extension to see where a disease has been found and track the disease as it shows up in more growers' fields. Since the website allows you to view data collected from previous years, the grower can easily view which diseases were in a field and which crop they were affecting and make better decisions for the next year."

> "Since the [iPiPE] website allows you to view data collected from previous years, the grower can easily view which diseases were in a field and which crop they were affecting and make better decisions for the next year."
> *– Loni Askew, summer 2018 iPiPE intern*

Get Involved

By joining the iPiPE network and contributing observations for the crops and regions in which you work, you are helping build a culture of information sharing and a dataset to help enhance farm profitability and sustainability and national food security, for the benefit of farmers and all who rely on them for food.

To join, visit the iPiPE participant portal (share.ipipe.org/2/login.php), follow the "Request Account" link, and follow the prompts. Or, contact support@ipipe.org for more information.

Northeastern IPM Center Supporting, Participating in Annual Invasive Species Conference

The North American Invasive Species Management Association (NAISMA) will hold its annual conference from September 30 to October 3 at the Hilton Saratoga in Saratoga Springs, NY, with the Northeastern IPM Center supporting the conference at the Prevention level and slated to both present and exhibit at the conference.

NAISMA is producing the conference jointly with the New York Invasive Species Research Institute (NYISRI) at Cornell University.

In support of its mission of connecting science to action, the conference will explore terrestrial and aquatic invasive species management, research, policy, and outreach initiatives and opportunities across North America through presentations, workshops, tours, and special symposia. A roster of keynote speakers representing a diverse array of institutions and areas of expertise will headline the event.

Deborah Grantham, Northeastern IPM Center director, and David Lane, Northeastern IPM Center evaluation specialist, will be presenting during a conference session on Integrated Pest Management.

NAISMA
NORTH AMERICAN INVASIVE SPECIES MANAGEMENT ASSOCIATION

In addition to attendees, the conference is also welcoming exhibitors, sponsors, and volunteers, all of whom will receive complimentary or discounted registrations at levels commensurate to their involvement in the event.

Discounted early registration is available through August 1, including additional discounts for students. For more information or to register, visit www.naisma.org/annual-conference.

New York State Releases Invasive Species Management Plan

Earlier this year, the New York State Department of Environmental Conservation (DEC) and Department of Agriculture and Markets released the state's finalized Invasive Species Comprehensive Management Plan (ISCMP). The final plan charts a clear path for New York's continued success in addressing invasive species impacts.

Situated centrally within the geographically compact Northeast, New York seeks to remain vigilant and proactive in addressing the threats posed by invasive species making their mark throughout the region.

"New York State's status as a hub for global commerce, its geographic setting, and patchwork of privately owned land have created significant challenges to managing invasive species," says the ISCMP's executive summary. "Intercontinental trade through the St. Lawrence Seaway and New York Harbor make New York home to some of the busiest air and sea ports on the planet and create a diverse suite of introduction pathways which consistently pose novel threats to the resources of NYS."

The ISCMP aims to encompass the full diversity of invasive-species taxa and ecosystem types throughout the state, while both building on existing programs and methods and identifying new opportunities.

Read more about invasive species in New York on the DEC's website at www.dec.ny.gov/animals/265.html. View the ISCMP as a PDF document linked from that page, or directly at neipmc.org/go/ISCMP.

Incorporating Insect Fear in Integrated Pest Management

By Ricardo Ramirez, Extension Entomologist

A version of this article first appeared in the winter 2019 issue of the Utah Pests Quarterly *newsletter.*

Predatory insects and parasitoids provide natural pest control by directly feeding on pests. An overlooked aspect of these beneficial insects that has gained attention in pest management is that they do not necessarily need to eat a pest to have an impact.

Predator Impacts on Pest Behavior

In the face of a predator, your behavior changes, whether it is an intense feeling to want to flee, freeze in place, or just crap yourself. It turns out that predators affect rodent prey even when they are not present, as their urine provides enough of a cue for rodents to scurry and hide. In agriculture, the threat of predation on insects is an emerging area being recognized as a component of biological control, given that threats, or "fear," can reduce pest damage to plants.

> Predatory insects and parasitoids do not necessarily need to eat a pest to have an impact.

Pest insects detect predators by seeing them, identifying specific odors, and sensing vibrations from movement or sound. Pest responses toward predators vary widely but can involve changes in pest behavior.

Billbugs: a Case Study in Control by Fear

In a recent article in the journal *Biological Control*, Dr. Madeleine Dupuy, former Utah State University (USU) biology graduate student, determined to what extent predatory ground beetles and wolf spiders fed on various billbug life stages in turfgrass, and how these predators impacted billbug behavior.

> When adult billbugs were in the presence of predators, they reduced their mating activity and egg-laying, and spent time playing dead.

Despite evidence that predatory ground beetles and spiders are capable of feeding on a variety of pest species, these predators posed little risk to adult billbugs, with only approximately six-percent predation. Billbug eggs were readily eaten by predatory ground beetles, but lab tests found that larval stages were less likely to be eaten when larvae were at least one centimeter deep in the soil.

Given that these predators did not consume adult billbugs or larvae within soil, we might tend to think that they are not providing effective biological control. However, Dupuy's research also found that when adult billbugs were in the presence of predators, they reduced their mating activity and egg-laying, and spent time playing dead. These behaviors diverted the pest from feeding on the turf.

> Preliminary observations show that predator odor alone can alter adult billbug behaviors.

Current USU biology graduate student Desireè Wickwar has followed up on Dupuy's research and has begun evaluating the effect of predator odor on billbug behavioral changes. Preliminary observations show that predator odor alone can alter adult billbug behaviors, and research is ongoing.

Exploring and Quantifying the Benefits of Fear

There is still a need to know which predator species has what intimidation level in the same way we evaluate the amount of prey any one predator species can consume. As research continues on this front, with evidence that just the predator cues can alter pest behavior, there may be clever ways of isolating and using predator cues or materials in pest management.

Insects' fear toward predators is a less-obvious form of biological control than actually being consumed by a predator. It is important to recognize the behaviors of pest insects in avoiding predators and how

Colorado potato beetle larvae display several defensive behaviors toward predators including wiggling, regurgitating digested plant juices, and rearing their heads upward and flailing their front legs.

they can have a negative impact on pests and assist in preventing plant damage, even to the level of direct predator consumption.

This emphasizes the point that conserving predators is even more important, given these additional ways they affect pests.

When they encounter a predator, diamondback moth larvae drop and dangle themselves from a silk thread, climbing back to leaves when danger has passed. Photo by Fitz Clarke, flic.kr/p/rjSsd7, used with permission.

Processionary weevil larvae preemptively form a circular grouping to defend against predators, such as this predatory stink bug.

Can fear behavior result in less plant damage?

Research has shown that predator-avoidance behaviors can have major implications for the insect pests' fitness, and these effects can be just as strong as the direct consumption of pests.

- **Colorado potato beetles** that were exposed to damsel bugs and other predators flail their front legs, regurgitate, walk away, and defecate. All of these behaviors detract the beetles from feeding on the plants.
- **Pea aphids** that were exposed to predators dropped from plants, exposing them to other mortality factors, and also increased the number of wing-formed offspring as compared to aphids not exposed to predators.
- **Japanese beetles** placed on leaves containing spider silk reduced their feeding as compared to beetles on untreated leaves or on leaves treated with other natural and artificial fibers.

For More Information

Aflitto, N., and J. Thaler. 2016. Fear as a biological control? How scaring farm and garden pests could lessen plant damage. New York State IPM Program. Vegetables IPM Fact Sheet No. 45068.

Dupuy, M.M., and R.A. Ramirez. 2018. Consumptive and non-consumptive effects of predatory arthropods on billbug (Coleoptera: Dryophthoridae) pests in turfgrass. Biological Control 129:136–147.

Ferrero, D.M., et al. 2011. Detection and avoidance of a carnivore odor by prey. PNAS 108: 11235–11240.

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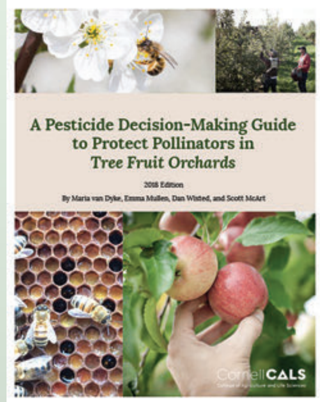

Update to Pesticide Guide that Aims to Reduce Risk to Pollinators

The Pollinator Network at Cornell and the Cornell University Department of Entomology, in consultation with the Cornell Pesticide Management Education Program, recently released the 2018 edition of the *Pesticide Decision-Making Guide to Protect Pollinators in Tree Fruit Orchards*.

Managing pests while protecting pollinators can be a balancing act. Both components are essential for a successful harvest, yet they can sometimes be in conflict with one another. Pollinators (mostly bees) are busy pollinating orchard blossoms at the same time growers need to be managing specific pests and diseases.

The guide summarizes reported pesticide effects on pollinators as of October 2018, presenting the most up-to-date information about the impacts of fungicides, insecticides, microbicides, and growth regulators on bees that pollinate tree fruits.

View the entire guide as a PDF at neipmc.org/go/mxXC.

Northeastern IPM Center's Susannah Reese, StopPests in Housing Program Featured at Bed Bug Summit

In November 2018, Susannah Reese of the Northeastern IPM Center's StopPests in Housing program was a featured speaker at the Global Bed Bug Summit.

The event, held in Denver, CO, and organized by the National Pest Management Association and BedBug Central, brought hundreds of pest-control-industry, academic, and housing professionals together to hear about research updates, successful management strategies, new products, and the challenges that remain in managing bed bugs.

The room was packed as Reese co-presented with Dr. Richard Cooper of Terminix on what's working in bed bug control in affordable housing. In short, the message of the presentation echoed the IPM approach for many other pests: there's no silver bullet and an effective IPM approach relies on education, proactive management, monitoring, inspection, and use of a variety of tools.

STOP Pests in housing
www.StopPests.org

The Northeastern IPM Center receives support from the U.S. Department of Housing and Urban Development's Office of Lead Hazard Control and Healthy Homes through the U.S. Department of Agriculture, NIFA agreement #2016-4866825905.

Susannah Reese of the Northeastern IPM Center's StopPests in Housing program was a featured speaker at the Global Bed Bug Summit.

Credits
IPM Insights: Deborah G. Grantham, Director; Mike Webb, Editor; Kevin Judd, Designer. **Northeastern IPM Center:** Nancy Cusumano, Deborah G. Grantham, Jana Hexter, Kevin Judd, David Lane, Susannah Reese, Mike Webb.

The Northeastern IPM Center is supported by the National Institute of Food and Agriculture, Crop Protection and Pest Management, Regional Coordination Program, Grant #2018-70006-28882. Printed on recycled paper. 4.5M. 6/19.

Nosema maddoxi microsporidian spores under a compound microscope at 400× and phase contrast. This newly described pathogen may help control brown marmorated stink bug.

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