You're listening to Fungi Town and this is episode 11: Tree-of-Heaven.

[Fungi Town theme music]

[0:00:13] Welcome to Fungi Town, where we scoop up seeds, test trees, and inoculate invasives. I'm your host and mayor of Fungi Town, Jen Parrilli. Today, we'll learn about invasive species, the history of biocontrol, and Kristen Wickert from West Virginia University will tell us about why she's trying to *encourage* a plant pathogen.

[0:00:37] You've probably heard the term "invasive species" before, but what makes an organism invasive and why? Ever since trade and exploration have been human endeavors, plants and animals have been moved from their native habitats and introduced to new lands to accommodate our needs.
[eating apple]
A lot of what you and I eat on a daily basis came from across the ocean somewhere. But although a lot of these plants and animals helped us survive in new lands, some of them have also done quite a bit of harm.

[0:01:07] Plants and animals get imported in several different ways, both intentionally and accidentally. But not all of them become what we call "invasive species." A lot of them make their way to foreign shores and find the conditions inhospitable. Maybe it's too cold
[wind]
for them to thrive or the native predators are too voracious.
[lion]
Some things adapt to the new environment, managing to find a niche where they're not causing any obvious problems. When a plant or animal that's not native to an area not only thrives, but starts to drive out the native wildlife, *that's* when it's considered a problem, *that's* when we call it "invasive."

[0:01:46] Some of the worst culprits for spreading invasive species are: ballast water, the pet trade, and firewood.
[ship horn]
When a ship unloads its cargo in one port, it will take on seawater in special tanks called ballasts.
[ocean]
This compensates for the weight of the offloaded cargo and fuel consumption and helps stabilize the ship. With its ballasts full, the ship then sails to another port,
[ding ding]
where it dumps that ballast water as it takes on new cargo. The problem with that is, the ballasts not only take up water, but they also take in sea life. This is probably how zebra mussels and North Pacific seastars were spread.
[pet shop]

[0:02:36] The pet trade is another notorious culprit in the spread of invasives. Animals get shipped in from other countries to be sold as pets. Then, these animals either escape or get intentionally released into habitats where they either die or multiply.
[snake hiss]
Pythons are currently causing problems in Florida, where they were probably released by neglectful owners.

[chopping wood]
[0:03:01] Firewood is primarily responsible for transporting invasive insects. The famous Emerald Ash Borer is a beautiful, shimmering beetle, but it's also a serious threat to ash trees in 30 states, wiping out tens of millions of trees. The beetle is mostly spread by the transportation of firewood. The Ash Borer likes to lay its eggs in trees, where the larvae live under the bark, munching away on the inner parts of the tree.
[crunching]
When those trees get chopped down for firewood and moved to another state, the ash borers get moved too and spread. Just one reason to buy local firewood when you head out camping, instead of bringing your own.

[ice in glass]
[0:03:43] A famous example of an invasive species is as synonymous with the South as sweet tea. It's kudzu and it's a vine that smothers trees, telephone poles, and even buildings along the sides of highways. Its scientific name is *Pueraria montana* and it can grow up to a foot a day. It was intentionally imported from Japan in the late 1800's as a novelty garden plant, but really took off when it was promoted for erosion control in the 1930's. Farmers were even paid to plant it. Now it spreads across the south at about 2,500 acres a year, smothering the native plants and even pulling down trees.

[0:04:26] A much newer example of an invasive species can be found on the Atlantic coast, especially in the coastal waters of Florida. It's called *Pterois volitans* or Lion Fish and it's been called "one of the most ecologically harmful fish in the western Atlantic." The Lion fish is originally from the South Pacific and was sold in the States as an aquarium fish. It's suspected they were introduced to our shores when people intentionally dumped them off the sides of boats when they didn't want them anymore. It's so successful in its new habitat because it's a voracious eater, consuming at least 50 varieties of local fish.
[gulp]
It's also full of venomous spines that make it deadly to local predators. The Lionfish has become such a problem that Florida now encourages fishing tournaments designed to eradicate them and local restaurants are starting to adopt them to their menus.

[0:05:22] So once we've got an invasive species, how do we control it? There are a few different ways we've attempted to rid ourselves of these unwanted invaders. One is by using chemical treatments like pesticides and herbicides.
[spray]
The issue with these is that they often have unintended consequences. They may kill off the invasives, but might also destroy the native organisms. Overapplication and runoff from these chemicals can cause problems in waterways, leading to algal blooms and other contamination. Some herbicides and pesticides may be to blame for the die-off of bees. Crop plants are sometimes genetically engineered to be resistant to invasive species. But this method has been hotly debated by folks who wish to avoid GMOs in their diets.

[0:06:12] Another way to control an invasive species is called biocontrol. This is when, instead of spraying chemicals, we bring in another organism to eat the invasives. It could be an insect that feeds on an invasive plant in its native habitat. Or, it could be an animal from India that is great at killing rats.
[squeak]
But there are problems with this method too. Once the newly arrived organism eats the problem we were trying to control, it might move on to eating the plants and animals we *do* want to have around. Or it might decide that something we have in our forests is much more tasty than the thing it was intended to control.

[0:06:50] There are a couple of famous examples of biocontrol gone wrong:

In the 1930's, Australian farmers had big a problem. Their important sugar cane crops were being decimated by beetles.
[croaking]
So they decided they would bring in some toads from Central America to eat those beetles. They didn't take into account how fast cane toads breed. One toad can lay eight to thirty thousand eggs at a time. They also had a taste for native bird eggs and they ate so many other things that they didn't leave food for the creatures already living there. And finally, making them a triple threat, they have poisonous skin, so the native predators couldn't eat them. Cane toad populations exploded and took over the northern part of Australia.

[0:07:42] Another biocontrol failure also centers around sugar cane, this time in Hawaii. In the 1880s, farmers were having a problem controlling rats in their fields. So, in 1883, the farmers imported the mongoose from India. It's true that a mongoose will eat rats, but it will also eat birds, mammals, insects, reptiles, plants, and sea turtle eggs. The farmers who imported the mongoose also didn't consider that it's nocturnal, while the rat it was brought over to control, is awake during the day and sleeps at night. The mongoose has caused an estimated $50 million in damages in Hawaii and Puerto

Rico and continues to be a serious threat to the Hawaii state bird - the nene - and the hawksbill sea turtle.

We've learned a lot from examples like these and much more study goes into biocontrol methods that are used today, but it's still not without its risks.

After the break, we'll speak to a scientist who is using biocontrol to attack an invasive tree and we'll find out why her project is successful and how it avoids the classic blunders of biocontrol.

[break music]
[0:08:58] I am extremely thankful to the guests who visit Fungi Town. Despite busy schedules, they take the time to share their expertise and enthusiasm with us. So I like to show my appreciation by sending them a hand-written thank you card. Even though we live in an age of instant connectivity, it feels pretty special to get a surprise in the mailbox, something you can hold and touch, something the sender put care into. But, sappy, mass-produced grocery store greeting cards are *not* for me. That's why I order all of my notecards from Haley at Lichen Landscapes.com. Each card features a gorgeous, hand-drawn illustration of a different lichen. The cards come in packs of four different designs and are blank inside so I can customize my message. Not only can you find a variety of card sets at Lichen Landscapes.com, but you can also order Haley's beautiful lichen prints. They're a great way to show your fungi love. So get on over to Lichen Landscapes.com and discover your favorite design! And when you enter fungi town in the notes portion of your order, a percentage of your purchase will go toward supporting the Fungi Town podcast! So what are you waiting for?

[guest ad]

[0:10:47] Before the break, we learned about invasive species and some of the problems they can cause in non-native environments. I met one researcher who's tackling one particular invasive tree species.

> My name is Kristen Wickert, and I am a PhD candidate at West Virginia University. And I study forest tree diseases in a plant pathology lab. I'm lucky that I get to look at pretty much everything in plant pathology. We work on bacteria, we work on viruses, we do all sorts of stuff. And the field of plant pathology is kind of an accumulation of botany, mycology in my case, and then just general ecology.

[0:11:30] **And Entomology too, I'm sure.**

> KW: Yes, that's a big one, too.

[0:11:35] **That sounds great. It doesn't sound like a bad job at all.**

KW: No. I do love it. It's interesting. I got a bachelor's degree in forest science, and I've always loved being outside and I maybe didn't know exactly this love in the beginning, you know, things kind of grow and evolve. And then when I went to forestry school I started to learn like, oh that's a bad invasive plant, that's an invasive plant, and it just totally changed the experience of being outside. But being in, working on a PhD in plant pathology, you pretty much learn everything. And you learn all of these really intricate relationships that go on all around you. And our forests here in West Virginia are absolutely amazing.

I work on Tree of Heaven which is probably one of the most aggressive invasive species we have in the northeast here. And where I got my alma mater and started studying tree of heaven there is a giant Tree of Heaven that is kind of this historical tree. And it just produces so much seed and increases the problem, but it's also the hub of where all this information happens against it being a good tree for gardening and horticulture.

[0:12:49] **Yeah, it's too bad you can't like, neuter the tree.**

KW: Yeah. (Laughs) I wish you could, but that would be another, there's a whole other five doctoral degrees right there.

[0:13:00] **I don't think I've ever seen a Tree-of-Heaven. Can you describe it?**

KW: Sure. Tree-of-Heaven is everywhere. I travel all over the country all the time for conferences and for my hiking activities and stuff like that. And I have seen Tree-of-Heaven predominantly in the east, but I've also seen it in the deserts of California. I've seen it in Arizona growing in sidewalk cracks. I've seen it down in Georgia. But it is most common here. But the tree is a mid-canopy tree that has some really nice looking grey bark. It kind of looks like cantaloupe skin a little bit, except it's gray. It's actually really pretty, which is a shame. But, it produces these long leaves that are actually about, you know, they can be like two feet long. They're pinnate, and they have a bunch of little leaflets on them. And then they produce these beautiful orange and red seed clusters, which can hold about 400 seeds per cluster. And then you probably have about maybe 400 of those seed clusters on one tree. So it's actually kind of a shame. It's a beautiful tree, and if you ever drive in Eastern Pennsylvania on any of the highways, especially the turnpike, it almost looks like you're in a tropical oasis because of all these Tree-of-Heaven, and their beautiful pom pom seed clusters that are orange and pink and red, and they differ on different individuals. It's actually a very pretty tree. But it's not native here, and it's invasive, also, which leads to those highways being just filled and filled with Tree-of-Heaven. But it's native to Eastern Asia, and was brought over to Philadelphia because it was so pretty. And that's kind of why you see a lot of this, of Tree-of-Heaven being a major problem in the northeast near Philly because of the introduction there.

[0:14:56] **Is the reason it's so successful here that it produces a ton of seeds, right? Like one plant could produce like 1M seeds or something. Is that why it's so successful against native plants?**

KW: That's one of the factors. This is kind of the ultimate invasive species in claiming areas that aren't its own. It has no strict habitat preferences. So it can grow in really, really bad sites, such as the, I've seen it on reclaimed strip mines. I've seen it bursting out of abandoned buildings and sidewalk cracks. Well then, if it's able to grow there in these really poor sites, it's also able to grow in these really, really rich and beneficial sites, if you want to call it that. Its ability to grow anywhere is probably the most aggressive reason of why it's so prolific. And then we also have these seeds. So I wrote a paper a little while ago. We actually had some lab techs counting seeds and weighing seeds, and we went out and you know, used statistics. But yeah, you're right. There's the possiblity that over the course of a tree's lifetime it can really easily produce millions of seeds, plural, millions of seeds. One year the tree at Penn State produced like 685,000 trees, or seeds, 685,000 seeds. So when you have one organism producing that many babies that are also 70% viable, 70% of 685,000, that's pretty significant. And there's more. There's also the fact that this tree can vegetatively reproduce. So it reproduces clonally. Especially if it's in these kind of poor sites where nothing else is growing anyway, it'll just send up root suckers off of its root base, and then you'll actually have a clonal tree. But for us it's analogous to being seven trees or something like that.

[0:16:58] **So even if you cut down that main tree, you've still got all the little suckers and stuff?**

KW: Yeah. And actually if you cut down the main tree the roots will be stressed out and respond by putting up even more trees. So that's a really big problem with like, the conservation agencies and forestry departments in these local states. They would go out and they would cut down the trees, and then they would get more trees. So they started to use herbicides, which works in this situation. But herbicides are tricky with trees. If you don't go back and apply herbicides, a few minutes after you cut down the tree it's worthless, because the tree's defense systems of closing up that opening, that big wound of being cut open, it doesn't work. So then you actually end up with more trees as well.

[0:17:45] **So it's hard to control, it's got a lot of seeds, and it can grow in a range of environments where other trees can't.**

KW: Yep. Yeah. And also, I just keep adding on, but it also produces some chemicals that have been reported to stop the germination and growth of other native seeds.

[0:18:06] **Is there a natural competitor in Asia that keeps it from being overgrown?**

KW: I think it's a lot to do with just competitive of the species in the forests in Asia themselves. So everything's kind of in its own balance over there, whereas you might have a bunch of R specialists, which are what Tree-of-Heaven are, is they rapidly reproduce, that all kind of keep it in check over there. But when you introduce that specialized, very competitive tree, that no longer has to compete with other very competitive trees in China, it kind of

dominates over here with our very slow growing species, such as our Northern Red Oak and White Oak, things like that.

[0:18:50] **So it's a very competitive species, but in China it's with a lot of other very competitive species.**

KW: Yeah, and there are of course insects and things like that that also keep it in check.

[0:19:01] **Since this is a podcast about fungi, obviously, there has to be that fungi connection. You use a fungus to try and help control this Tree-of-Heaven species, right?**

KW: Yes, ma'am. I use an *Ascomycotan* fungus, so it's not, you know, I think it's beautiful, but it's not these show stopping mushrooms that everyone sees, which are in the *Basidiomycotan*. I work with *Verticillium nonalfalfae*. So it is an asexual fungus that reproduces completely clonally. It doesn't have a sexual state, so you'll never see that big mushroom, or anything like that, or any big structure. You'll just see hyphae, and some small, very asexual spores called conidia. And this fungus, in the genus *Verticillium* is very specialized and aggressive towards Tree-of-Heaven, kind of by chances of it not being coevolved together. So *Verticillium nonalfalfae* is native here in America. It probably causes some mild disease on some herbaceous plant or something else, some other tree, but since Tree-of-Heaven has not coevolved with it, it's kind of like smallpox, like an analogy of smallpox. So when the Europeans brought smallpox over here, our Native Americans were not able to battle it because they had no immune response. That's kind of the same example, but reversed over here.

[0:20:30] **So you're looking at this fungus as a way to intentionally control the population of Tree-of-Heaven?**

KW: Yes. It's very successful. It's been studied for about, almost two decades now. And we have a bunch of different experiments that have happened in the past. And some of the things that I'm working on now, which potentially could be some of the last studies before it is released and commercialized to the general public and to land managers.

[0:21:02] **How does the fungus kill the tree?**

KW: The fungus, you remember I said it's not sexual? It's only asexual. But it still reproduces spores. And when the fungus gets into the vascular tissue of the plant, it causes a vascular wilt disease. Which means that the tree is no longer able to conduct water to its canopy to maintain its canopy's health, and the tree is actually killed off in two ways. The fungus is producing tons and tons of spores, so its asexual spores that physically clog up the vessels of the tree. Just imagine a bunch of little tiny pipes, and these little tiny pipes all get filled up with fungus. And then the tree also kind of freaks out and realizes that it has a pathogen. And it starts to make these walls inside of those pipes. They're called tyloses. And they also clog up these pipes that conduct water up to the canopy. So the tree no longer has a canopy. So that means it can't

photosynthesize, it means it can't make food, and it quickly dies because it depletes its food reserves in the roots in about a year.

[0:22:15] **What keeps it from sending up the little suckers?**

KW: It does produce the little suckers, but they die rather quickly. Since the vascular tissue goes throughout the entirety of the tree, the fungus will go down and up, so it'll go and it will kill the canopy, and it will also go down into the roots and kill any suckers that might come up.

[0:22:40] **How does the fungus get into the tree?**

KW: I put it there. So the fungus is called soil borne pathogen, which means it can reside in the soil. It actually has specialized structure for hanging out in soil. And you can have infections happen through the roots of trees in like, let's say that the root is growing and it hits a rock, it has a scratch. That's an entry point. But you know, the bark of the tree, there's still bark on roots, kind of acts as a protective layer. So what we do, is we use a hatchet or a machete and we just put a big cut into the tree. And then we have the ability in the lab to make a concentration of 10M spores per milliliter, and that kills the trees. So you can see, and we do see this, in every single site we go to where the fungus will then kill the tree, run out of its resources, and now it will start to grow as hyphae into the soil and look for a new host, which will be the Tree-of-Heaven next to it. But it won't be as quick because 10M spores directly put into your body versus something trying to find a wound on your root is very different.

[0:23:50] **But it can be effective against the neighboring trees?**

KW: Oh yes, completely. So there's two factors to that, where it can be effective. We see a much slower progression when it's going through the soil, but it is still successful. Because you know, trees are always growing. They're always hitting those rocks in the soil, or maybe there's some frost heaving that it goes through every winter, you get some cracks and wounds in the root. So there's entry ways that way. But there's also the fact that these trees, you can have kind of two facets to this, where you might have 17 trees, but they're all clones. You could have that. So if you inoculate the one, you've killed all 17 because they're all connected, right?. They're all from the same root stock. But you also have this occurrence where two trees that are separate individuals will grow relatively close to each other, and their roots will touch and fuse, and they'll share resources to kind of have a success story together. And you can see that in a bunch of different species. I think Black Locust does it, and a couple other native species. If they're same species, and their roots make contact, they'll fuse and share liquids.

[0:24:57] **And so they can share the fungus, too?**

KW: Yep. It's just like a sexually transmitted disease, pretty much. So if they just make contact like that then the fungus goes to the one root and into the other root. And we found that this actually happens a lot. We did a study, god, in like 2013 already. But in 2013 we made these really interesting... We cut down a tree with a chainsaw, and then we put on some roofing siding around that stump, and made it into like a bucket. And then we dumped a bunch of

purple dye, and I'll send you a picture of this so your viewers or your listeners can actually see that on your website. We dumped a bunch of purple dye into the tree, into this bucket. And then the tree stump sucked down that liquid and we were able to see that these trees are connected to about two to seven trees on average. Or it's 2.3 on average, so meaning it can be from zero to like seven that they're connected to. And we took a big knife and we just pulled off the bark of all these trees and they were all purple in the forest even though we only cut down one and put purple dye into one tree.

[0:26:05] **Okay, so you could see that they were all connected?**

KW: Yeah, it was actually a really fun, exciting experiment. Because there are a lot of experiments as a scientist that don't work. And this was actually one that worked, so it was cool.

[0:26:17] **Does that fungus affect any other trees?**

KW: It does, and this influences why it's taken so long for it to be regulated. But working with this disease personally for so long and actually being part of these experiments and going to these field sites, I can say that it's not that big of a deal. So, there's two ways that we looked at this. This was a big component of Dr. Matt Kasson's PhD work, where he wanted to see what hosts in our native forest, and then he also included a lot of exotics just because people have them in their yards and stuff like that. He wanted to see if there was anything that could be affected by the fungus by direct inoculation, or by natural spread. So natural spread would be, if we put it in one tree, and then it went through the soil and infected other things. And then the direct inoculation would be like taking the hatchet I described earlier and putting the 10M spores into a honey locust versus putting it into the Tree-of-Heaven just to see what would happen. And with the natural spread there were three species that were: Devil's Walking Stick, Stripe Maple, and Sumac. And the percentages of them having symptoms was 17%, 3%, and 17% respectively. And in the Sumac we were never able to actually reisolate the fungus out, so it can't be confirmed that *Verticillium* caused the disease or the symptoms. And then in direct inoculation, again we had really low numbers. For Stripe Maple it was about 15%. Paulownia, which is another invasive species was 7%, and then Birch was 3%. But a lot of these things, this is kind of an important aspect of scientific projects, you need to look at things over a long period of time. So we inoculated these trees, and Dr. Kasson went back out and he looked at them and saw that there was like, either mortality, or there was a lot of wilt that was going on. But he came back many, many times, about, I think it was 63 weeks post inoculation, and some of these trees had actually recovered. So it was more of getting an acute disease that was able to be recovered from instead of this very aggressive systemic disease which we see in Tree-of-Heaven. So, these trees that were affected, they're not necessarily desirable species. And I know that's a very kind of human agenda point of view. You know, everything has its own intrinsic value, but it's not like we were losing 17% of valuable hardwood or valuable mass

producing species for wildlife. So the percentages are low, and it's also only about five species that are affected.

[0:29:03] **Because I know that with biocontrol there can sometimes be issues. Where you introduce something to control another organism and then it does that job and causes another problem.**

KW: Yeah, and that was actually something we wanted to see, once the Tree-of-Heaven dies, will this fungus die out, or will it actually go into something else? And the thing is, that's something that you don't have to focus on as much, because our fungus was a native fungus. So it was already here, already performing some type of job. So we don't know exactly what that was. Like I said earlier, if it's causing mild wilt on some herbaceous plant, let's just say a daisy, if it's infecting daisies it will kill the Tree-of-Heaven and then it'll go back to daisies, which have coevolved together, and the daisies will just be like kind of wimpy instead of dying.

[0:30:00] **And so you're not introducing another invasive species?**

KW: Nope.

You're using one that's already here to kill the invasive species.

KW: Yep. Exactly. But it is something that's really important to think about when you're doing classical biocontrol. Which is, classical biocontrol is defined as bringing something from the same area that your invasive species has come with, or just undesirable species has come with, and that's where you have to do all those tests because if it does, again, eat everything that it's supposed to eat, well, it's still there sand it's still hungry, so what's it going to eat? But we don't have to worry about that with this species so far.

[0:30:34] **Do you have a favorite fungus?**

KW: That one, I saw it on your list and it's actually really hard, because it depends on the season. I have like a big list. I really like edible mushrooms of course, because I like cooking a lot, and it's always exciting to try new stuff. But right now my favorite for the month of August is the Jack O'Lantern fungus. Because I love going on, I go on a lot of hiking trips, and when I go overnight places, and I camp, you know, you come out in the middle of the night and there's like a little faint glow along the trail, and it's the Jack O'Lantern fungus. I just love that there's a little bit of mystery in the world yet, and just exciting things that you can't really photograph with your iPhone out there. Because I'm always, every day I take like 500 pictures. But I can't get a picture of the Jack O'Lantern fungus just because it's something. And it's just cool because there's something in nature where you have to be there to appreciate. Because I feel like that's commonly becoming more and more rare.

[funky music]

[0:31:38] It's time for de-funked, a segment where I debunk fungi myths and misconceptions. Kristen told us about the wide range of habitat that the invasive Tree-of-Heaven can grow in. Are fungi just as

adaptable, or do they only grow where there's a lot of moisture? Let's welcome back Dr. Brewer from episode 10 to answer that question.

[0:31:57] **Do all fungi need moist, dark environments to live in?**

> MB: No. They do need some water, but some can survive in pretty dry environments. The powdery mildews do really well when it's dry. That's because they have a water droplet in their spore. So when it's dry, and a lot of the other fungi aren't doing as well, the powdery mildews can thrive because they don't have any competitors. So they don't always need moisture although most fungi do much better with moisture. They do like moist, dark environments, but some do really well when there's a lot of UV. So they have special adaptations for that. They might have dark pigments in their spores.

[0:32:51] **So it's not just tropical environments or wet basements?**

> MB: Right. And there are some fungi that can even move water. So there's one that can grow on dry wood in your home and it has these special structures that can move the water long distances. So it causes a dry rot and it's the "house-eating" fungus and it has these rhizomorphs, which are these long fungal structures that'll move water from wherever it can find water all the way to where it's actually feeding on the wood. And that one's kinda scary because usually if you have a mold problem in your house or you have a fungal problem in your house, you just get rid of the moisture problem, but this one can move moisture from elsewhere.

[0:33:39] **So it's like a long straw over to where the moisture is and then sucks it up to where it's growing.**

> MB: Right.

[0:33:46] That wraps up episode 11 of Fungi Town. Thanks to Kristen Wickert for teaching us about Tree-of-Heaven and to Dr. Marin Brewer for her insight on fungi and moisture.

[Outro music]

[0:33:56] Fungi Town is written, edited, and produced by me - Jen Parrilli and hosted by Podbean. The theme song is by local Athens band Shehehe. You can find all of their awesome songs on their BandCamp page at Shehehe.bandcamp.com. Episodes of Fungi Town are released every other week. Be sure to subscribe so you don't miss the next episode, where we learn about the source of LSD. You can join the conversation and share your fungi photos with Fungi Town on Facebook, Instagram, and Twitter @fungitownpod. Fungi Town also has a brand new YouTube page and when it reaches 100

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