Genome Insider S4 Episode 3: A Shrubbier Version of Rubber - Andrew Nelson and Colleen McMahan

Menaka: Like many good ones, this story starts in a greenhouse.

Sarah: OK! So sunny, warm,

Menaka: Yeah – and this is a specific greenhouse. One I went to in Albany, California, just Northwest of Berkeley. It's a rooftop greenhouse, where researchers grow plants for their work with the US Department of Agriculture

Sarah: Oh official!

Up close, the slashes in a rubber tree's bark stand out. (Menaka Wilhelm)

Menaka: Exactly. And I want to point out one kind of tree growing in this greenhouse. It's the rubber tree, a species called Hevea brasiliensis.

Sarah: So this is the tree where we get rubber for tires, rubber gloves, and also rubber boots.

Menaka: Exactly – and there are about a dozen rubber trees here in this greenhouse. They're around 6 feet tall, with big, football-shaped leaves the size of your hand. And up and down their slim, tan trunks, are diagonal slashes.

Sarah: And that pattern? It's not part of their bark.

Menaka: Growers cut those slashes – this is the first step in making rubber. It's called tapping a rubber tree – a little like tapping a maple tree for sap, to make maple syrup. When you tap a rubber tree, liquid latex drains out of the bark.

Sarah: So you collect that liquid, then process it into rubber. So, the trees are in the greenhouse for studies,

The guayule shrub sits low to the ground with small, spiny leaves. (Menaka Wilhelm)

Menaka: Yeah – but – the rubber trees aren't our main event. They're here for comparative experiments, with the plant that's really the star of this show. Because it makes rubber, too.

Sarah: A spotlight-stealing shrub — Parthenium argentatum.

Menaka: Yeah. This shrub's common name is guayule. It's a more sustainable, climate-resilient plant, and researchers are betting that one day, this shrub could give the rubber tree a bit of a run for its money. So next door to those rubber trees? This greenhouse has another room. It's full of these guayule shrubs.

Sarah: This is a special episode of Tiny Expeditions, from the HudsonAlpha Institute for Biotechnology,

Menaka: And Genome Insider, from the Joint Genome Institute.

Sarah: I'm Dr. Sarah Sharman,

Menaka: And I'm Menaka Wilhelm. The JGI and HudsonAlpha work together on lots of projects,

Sarah: Including this one! So we've teamed up for this episode.

Menaka: It's the story of the researchers who are working to make a shrubbier version of rubber.

Sarah: Because that shrub just might grow better in our warming world.

Menaka: And it could be a useful crop in multiple ways. Researchers are hoping to harvest rubber from its stems, then convert what's leftover into other chemicals and fuels.

Sarah: So we'll meet a few of the people behind that project. There's a full team of researchers working with the JGI and HudsonAlpha on this.

Menaka: Yep. They're from the Boyce Thompson Institute at Cornell University, Bridgestone, New Mexico State University, and the US Department of Agriculture. And they're all very interested in this guayule shrub.

Sarah: So first — let's start with why we need more sources of rubber.

Menaka: To be clear, there are two different kinds of rubber in our word.

Sarah: There's synthetic rubber,

Menaka: Made from petroleum,

Sarah: And natural rubber,

Menaka: Which comes from plants.

Sarah: Synthetic rubber works well for lots of things. But for durability, natural rubber wins out. It's stronger, and more resilient against wear. A lot of stuff in our world depends on it. I heard

about this from Dave Dierig – he's a plant geneticist working on this project at Bridgestone. As in, Bridgestone tires.

Dave Dierig: So most tires, anything larger than a car tire, has a high percentage of natural rubber in it. Airplane tires are all natural rubber because synthetic rubber really can't do the same things that natural rubber does.

Sarah: As one example, natural rubber stays flexible even at low temperatures. That's why it's key for airplane tires — they see a big temperature range. But there's a pretty big problem with natural rubber.

Menaka: Almost all natural rubber comes from just one species of tree.

Sarah: Hevea brasiliensis, that species you saw in the USDA greenhouse.

Menaka: It's a tree that provides a bunch of rubber — but it's also a tree that's in trouble.

Sarah: For starters? Rubber trees are all genetically identical. They're like banana trees – they're all clones.

Dave Dierig: So we're concerned about all the risks that natural rubber plantations have right now with diseases. You know, it's a tree, it's a clonal crop.

Sarah: On a rubber tree plantation, every single tree has the same defenses against disease. If a tough fungus comes through? It can wipe out an entire plot of trees at once.

Menaka: And that's happened.

Sarah: Yeah – rubber trees are native to Brazil. But they really don't grow there anymore. A disease called South American leaf blight has pretty much squashed commercial rubber production in South America. So now, most commercial rubber grows in Southeast Asia. There, it's safe from disease, for now. But it's not safe from other issues.

Dave Dierig: Climate change is another issue that we're worried about,

Sarah: Climate change is making both droughts and floods more extreme.

Menaka: Both are bad news for rubber trees.

Sarah: And Dave pointed out one more risk.

Dave Dierig: labor shortages, because you have to go around to each tree on a daily basis and tap the tree to get the rubber out. So it's very, very labor intensive,

Menaka: So, yeah – the rubber trees are in a bit of a pickle.

Sarah: But natural rubber is hugely important for lots of industries. So Dave is looking elsewhere.

Dave Dierig: Every tire company is looking for some kind of alternate source or supplemental source of natural rubber.

Menaka: And actually, we've made rubber – at scale — from other plants before.

Sarah: Because lots of plants make rubber, actually.

Menaka: There's some rubber in sunflower leaves and lettuce. And of course – there's a shrub that makes a lot of rubber, that's also high quality.

Sarah: Enter, guayule.

Menaka: That's G-U-A-Y-U-L-E

Sarah: And pronounced why-yule-ee.

Menaka: The shrub that makes rubber!

Sarah: If we're being honest, when you see guayule, it looks a bit forgettable.

Menaka: Truly, it's a very shrubby desert plant. A lot of people describe it as tumbleweed-y. It grows about a foot or so off the ground, with little sage-green leaves.

Side by side, guayule shrubs (shown on the cart) and rubber trees (in black planter pots) look quite different, but both produce rubber.

Andrew Nelson: It's not particularly showy, even the flowers don't really look like much,

Menaka: Andrew Nelson is a plant biologist at the Boyce Thompson Institute at Cornell University. He's leading this project. For Andrew, guayule's humble appearance is not a problem.

Andrew Nelson: What's interesting about guayule is that it produces an insane amount of rubber. It stocks up a lot of rubber, in its stems.

Menaka: The stems can have 6 or 8% rubber. Not bad for a dusty desert shrub!

Sarah: And guayule has a bunch of advantages that could make it cost-effective and more sustainable in the long run.

Menaka: Unlike the rubber tree, there are different lines of guayule. So it has more potential for genetic diversity, which means more defense against disease.

Sarah: It's native to a hot, desert area — Northern Mexico to the southwestern US. That means more resilience against climate change,

Menaka: Plus — guayule grows with less water than many row crops like alfalfa or corn.

Sarah: A more sustainable crop for farmers in desert areas.

Menaka: And harvesting guayule isn't labor intensive the way tapping rubber trees is – you can cut stalks and stems from a bunch of shrubs at once, with help from machines.

Sarah: So, it's a shrub that solves a lot of the rubber tree's problems.

Andrew Nelson: In addition, when the rubber has been extracted from these plants, you can actually use what's left over as kind of a natural biofuel.

Menaka: So you could grow guayule, then process it into two renewable products – rubber, and also chemicals!

Sarah: Wow, the wonder-shrub guayule!

Menaka: Dreamy.

Sarah: And actually, people have used the guayule plant throughout history. I looked into that for a I wrote for HudsonAlpha's blog, Everyday DNA.

Menaka: Linked in the show notes!

Sarah: So let's start with the first time guayule shows up in western records. That's in the 1500's… when colonizers from Spain noticed Aztec people playing with rubber balls made from guayule!

Menaka: And guayule has actually been mass-produced before, too, right?

Sarah: Yeah - in the early 1900's, it was. Industrialists like John D. Rockefeller created a firm to turn guayule into rubber. They harvested wild guayule from Mexico, and it kind of worked. We used a lot less rubber then — but by 1910, about half of all US rubber was from that wild guayule.

Menaka: Wild guayule is quite the tongue twister. At this point it sounds like it's catching on.

Sarah: But then, between Mexico's revolutions, and over-harvesting that wild guayule? That all fizzled out.

Menaka: Ah.

Sarah: And there was actually another time where lots of people worked on making rubber from guayule – World War 2. The US got cut off from sourcing rubber from Asia after Japan seized rubber plantations. So congress funded something called the Emergency Rubber Project. During that project, researchers planted and grew over 32,000 acres of guayule.

Menaka: So the goal was to work out how to farm a domestic, natural source of rubber.

Sarah: Right. But the push for that project ended with the war. Once we could get natural rubber from Asia again, that's what we did.

Menaka: So no one has really figured out how to grow guayule .. so that it makes enough rubber .. to be a large-scale profitable crop.

Sarah: No. But understanding this plant better could change that! If these researchers can figure out how guayule makes rubber, they could boost its rubber production. And still keep all those other strengths guayule brings to the table.

Menaka: So as with many projects at the JGI and HudsonAlpha, researchers are aiming for better understanding in the form of genomics! Here's Andrew Nelson again.

Andrew Nelson: So with Bridgestone, David Dierig, at Bridgestone, Colleen McMahan at at USDA and myself, we, we spearheaded this proposal for JGI to actually sequence the genomes of these plants.

Menaka: Historically, it's been hard to sequence guayule. It's got a really big genome.

Sarah: But HudsonAlpha and the JGI have the expertise!

Andrew Nelson: And if we want to figure out like, what is actually working to turn on the rubber biosynthesis pathway in these plants and, um, you know, figure out all the molecular components, you know, we, we really need a genome.

Menaka: And actually, they're not just stopping at one genome.

Sarah: They'll sequence and analyze multiple plants.

Menaka: Right. In just a bit, we'll head back to the greenhouse where we first started out, the one that's growing guayule alongside rubber trees. It's Colleen McMahan — the third researcher Andrew Nelson just shouted out — who showed me around there. She showed me the plants

that will get sequenced, and she's got lots to say about what the guayule genome will let this team do.

First, since we made this episode in collaboration with the HudsonAlpha Institute for Biotechnology, in Huntsville, Alabama, here's a bit more about their podcast, Tiny Expeditions.

Menaka: To recap where we've been so far – right now, we rely on pretty much only one way to make natural rubber. The rubber tree, Hevea brasiliensis.

Sarah: But it's also a tree that's up against disease and climate change.

Menaka: So researchers are trying to find other rubber-producing plants. And the guayule shrub is a great candidate.

Sarah: It grows in a harsh, desert climate.

Menaka: It's easier to harvest.

Sarah: And it's got more genetic diversity than the rubber tree.

Menaka: Yeah – and I actually saw some of that diversity firsthand.

Sarah: So cool. Set the scene for us.

Menaka: Of course. So this is back at the USDA greenhouse that we started this episode with. It's a pretty big, rooftop greenhouse at the USDA building in Albany, California. Plenty of sunlight comes in. Colleen McMahan is showing me around. She's a research chemist at the USDA who is also part of this project. So we're in the greenhouse, and she wheels out a cart with three different potted guayule plants.

Chen Dong with the three versions of Guayule that this project will study. (Menaka Wilhelm)

Colleen McMahan: There are three different, guayule varieties in the initial phase of the project. And the three plants you see right here are those three plants.

Menaka: They're all little potted shrubs, about the size of a basketball, but they look different by eye. One is a dustier green, more like a sage plant. Another is a much brighter green, think, like basil. And the third is somewhere right in between those two.

Sarah: And I'd bet their differences go beyond their color.

Menaka: Right. Here's Colleen.

Colleen McMahan: They're quite different genetically as well. And so the information that we get from those plants will be huge.

Menaka: Overall, they want to understand how to get guayule to make more rubber. But it's also important to keep its other good qualities in tact. So the idea.. is to look at a handful of plants, and see the genetics behind a variety of strengths.

Sarah: OK, to get a better picture overall.

Menaka: Right. These plants each produce different amounts of rubber and have unique disease resistance.

Sarah: Nice.

Menaka: Those are the broad strokes. But I want to get just a little more specific about these plants, actually.

Sarah: Let's do it.

Menaka: OK. So these plants are actually very different in specific ways — It turns out, the greenest plant I saw is quite different from the other two, the ones that were more sagey green.

Sarah: Ok. One that's different, two that are more similar. following so far.

Menaka: Great. So let's start with that greener plant. It's a diploid plant – it's got two sets of chromosomes, and it reproduces by crossing with other plants. Chen Dong is a researcher who works with Colleen, and she told me the reason they want to look at that plant, is

Chen Dong: So we can just have a pure genome of guayule,

Menaka: So just a clear, complete genome. This is like our basic version of guayule.

Sarah: And what about the other two plants?

Menaka: Yeah – this is where our picture gets even more technical. The ones that are dustier green, that are more similar in color — they reproduce asexually. They're both tetraploid plants, which means they've got four copies of their chromosomes.

Sarah: So double the chromosomes of our first plant.

Menaka: Yes!

Chen Dong: and these are the ones that, Bridgestone uses for, breeding.

Menaka: Bridgestone is interested in diploid plants, too – but these two lines are specifically part of their breeding program. And each of these tetraploid plants are important to this study for their own reasons. The plant that's the most sagey green — it's the smallest, but it produces a bunch of rubber.

Sarah: Seems like a great plant to work with, in this quest to crank up rubber production.

Menaka: And the other tetraploid plant is interesting for a different reason. They've already figured out how to edit its genes.

Colleen McMahan takes a look at small guayule plants growing in tissue culture. This is how researchers grow plants that are genetically transformed. (Menaka Wilhelm)

Colleen McMahan: So we can genetically transform the plant. We've had success with doing that with a number of genes and in entire pathways in a couple of cases.

Sarah: So they're already able to tweak this plant.

Menaka: Right – the question is just which tweaks to make, for example, to boost the pathway that produces rubber.

Sarah: And that's where all of JGI and HudsonAlpha's genomic information comes in.

Menaka: Exactly. Beyond just getting the sequence of guayule's genome, JGI and HudsonAlpha will help this team work out which genes are there, how they're turned on and off, and what they do.

Sarah: Lots of information about how guayule makes rubber.

Menaka: So Colleen and Chen will get even more information from editing this line of plants. They'll be able to find important genes, then basically delete them with CRISPR gene editing, to see exactly how important they are.

A close-up view of a tiny guayule plant grown in tissue culture. (Menaka Wilhelm)

Chen Dong: We want to confirm the functionality of these genes, for that we'll use CRISPR to knock down these genes and see what is happening in these plants.

Sarah: So cool.

Menaka: Right! But Colleen did point out – even though these greenhouse studies will give them a ton of information, there's actually still more to the story.

Colleen McMahan: So there's a really important, genetics-by-environment component for guayule, and that's one of the areas that we're studying in this project is, what happens to the gene expression as the environment changes. And we're really excited about having the opportunity to look at that.

Menaka: So guayule growing in a controlled greenhouse will do things differently than guayule growing outside, in a field.

Sarah: Which brings us to our last researcher of this episode. He's with Bridgestone, growing guayule in the field.

Von Mark Cruz: So, I'm Mark Cruz. I'm a plant breeder at Bridgestone Americas, in Eloy, Arizona.

Sarah: Mark works with Bridgestone at its research farm in Arizona. It's two hundred and eighty-one acres of these hardy guayule shrubs. Picture green shrubs, about a foot tall, filed in organized rows in the dirt.

Menaka: A whole club of shrubs!

Sarah: That farm grows guayule for lots of projects. For this project, Mark is growing the same three lines of plants as Colleen and Chen. So he'll be able to compare these field samples with their greenhouse plants, and see what changes outdoors.

Von Mark Cruz: So knowing the gene expression patterns and how those correlate to rubber production will really help. So our goal is to determine those gene expressions at the different locations, and maybe in the future we can link it to protein expression levels too.

Sarah: Like Colleen and Chen, they'll take a look at the genes that help guayule make rubber. Mark is also interested in making guayule a hardier crop – one that more farmers can grow in more places. So he's also looking at the genes that make this shrub cold-tolerant.

Menaka: That sounds like it means even more testing.

Sarah: Exactly. Besides that farm in Eloy, they're growing guayule in two other field spots for even more comparison. So all in all, Mark and his team are growing these strains in three places, outside:

Von Mark Cruz: In Salinas, in Parlier California, and Eloy, Arizona. And we, so basically I'm responsible for the field trials, and then we send the tissues to Cornell and Boyce Thompson.

Sarah: So by Cornell, Mark means he sends his samples over to Andrew Nelson.

Menaka: Right – the plant biologist at the Boyce Thompson Institute, who told us a bit about

guayule earlier in this episode.

Sarah: Yeah. Andrew's lab will help analyze those samples. The JGI and HudsonAlpha will help too.

Menaka: Ah. We've come all the way full circle. Must be nearly time to end this episode.

Sarah: Yep, I think we've just about covered it. We've gone from trouble with the rubber tree to the guayule shrub that could help.

Menaka: And we've seen how this team will use greenhouse plants, field trials and a whole bunch of analysis to understand the genes that matter for growing guayule, and boosting its rubber content.

Sarah: To grow a reliable, sustainable version of rubber – that also supports biofuels.

Menaka: So Sarah, now that we're pretty much done, I realize I've waited this entire episode to bring something else up.

Sarah: OK?

Menaka: In terms of naming. I know we talked guayule, but like, it's a shrub, that can make rubber – so do you think…this version of rubber should be called… shrubber?

Sarah: Maybe? Seems like it's past time to run the credits.

Sarah: Tiny Expeditions is a production of the HudsonAlpha Institute for Biotechnology, a non-profit research institution located in Huntsville, Alabama.

Menaka Wilhelm: Genome Insider is a production of the Joint Genome Institute, a user facility of the US Department of Energy Office of Science located at Lawrence Berkeley National Lab in Berkeley, California.

Sarah: This episode was written and produced by Menaka Wilhelm.

Menaka: Ashleigh Papp reported the interviews with researchers Dave Dierig, Mark Cruz, Chen Dong, and Colleen McMahan.

Sarah: AJ Bouchie reported the interview with Andrew Nelson.

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Thanks for tuning in – until next time!