Genome Insider Episode 9: The Soil Blooms Green

ALISON: Hey! I'm Alison Takemura, and this is Genome Insider, a podcast of the US Department of Energy Joint Genome Institute or JGI.

TERRY: OK, yeah, I don't know if.. So we're at Harner farm. And they have a corn maze here..

ALISON: There are big, dying stalks of corn. There's even some corn still on the stalks…

TERRY: So I came here on the weekend with my son and wife. And as we were walking through the corn maze, we noticed there were a lot of soil growths between the corn rows..

ALISON: Alison again. What you just heard is me and Terry Bell, an environmental microbiologist at Penn State. Terry and I, and Mary Ann Bruns, who you haven't heard from yet, but she's a soil microbiologist at Penn State — we were all tromping around this farm on a brisk October day to see this corn maze. OK, so, not exactly the corn maze itself. But on the dirt, in the corn maze, we wanted to see these.. visible microbial communities.. called biofilms. According to Terry, this was the place to find them.

Terry and Mary Ann are studying a really thin -- just millimeters thick -- biofilm, with a thickness that's like the edge of a fingernail. And it that looks dark green because of photosynthesizing cyanobacteria.

ALISON: So, is this cyanobacteria here?

Penn State researchers Mary Ann Bruns and Terry Bell brought me, Alison, to a corn maze at Harner Farm in State College, PA to find these green biofilms. (Alison F. Takemura)

ALISON: I don't sound very confident, do I? Um, at this point in our search, I'm seeing some green on the dirt that I think could be cyanobacteria? But there's clearly some fuzzy moss, too. And, I mean, I'm just finding that the ground is an unexpectedly complicated place.

TERRY: What do you think about in here Mary Ann — like this little patch?

ALISON: Ohh..

MARY ANN: Oh yeah, uh huh.

ALISON: Wow, beautiful.

TERRY: It's kind of bluish — this one, here, too.

ALISON: Oh yeah, there's one right here.

MARY ANN: They’re all over the place.

ALISON: It’s like, really dark.

ALISON: Mary Ann and Terry suspect that these biofilms might be quietly helping farmers. And they intend to figure out how. Mary Ann and her group started studying these biofilms because they caught their eye.

MARY ANN: Every fall, we would notice that these biofilms would appear on soil surfaces of regular cornfields.

ALISON: And they’d show up on other kinds of fields: sorghum, soybean, apple orchards -- pretty much anywhere, these biofilms would appear.

MARY ANN: These coatings of dark green films are growing on many soils throughout the country, mostly in wet areas. We have biofilms that are forming all the way from Florida, all the way up to Quebec.

ALISON: So, Mary Ann and her team took these biofilms and isolated a simpler group or consortium of microbes. The consortium included cyanobacteria (which can make food for themselves by fixing carbon in the air) AND heterotrophic bacteria (which can’t make their own food). They called this simple community DG1. What does DG1 stand for?

MARY ANN: Oh, it's just very simple. It's dark green one, okay. Because my students, Shin Pang. She isolated up to 100 different mixtures.

ALISON: Because the mixtures had different isolated microbes in them, they were different colors.

The dying corn stalks allow light to fall on the field floor, encouraging photosynthesizing cyanobacteria to grow. (Alison F. Takemura)

MARY ANN: many of them had differences in pigmentation, you know, light green, yellowish green, brownish, but this dark green one: DG1 always won out in terms of its robustness and its ability to grow quickly on soil.

ALISON: Mary Ann and her team began to study DG1, wondering how it might be affecting the soil’s nutrients. And they found that DG1 is feeding the soil: a little bit of organic matter and a little bit of fixed nitrogen.

MARY ANN: Not a lot, but they are adding nitrogen without any sort of cost or expenditure by the farmer.

ALISON: Mary Ann estimates that the biofilm adds maybe 1 to 2% of the amount of nitrogen

that farmers typically add to their fields, via synthetic or natural fertilizers. The biofilm, though, also adds exopolysaccharides -- chains of sugars that the cyanobacteria weave around themselves.

MARY ANN: That would be left as a legacy of cyanobacterial growth. The more organic matter the better. And we have also demonstrated that the additional benefits of soil cohesion, soil improvement, retention of nitrogen can be beneficial for the farmer.

ALISON: The biofilm is helping the soil hold onto the nitrogen to feed crops. Which is great, because nitrogen loss is a big problem; only about half of the nitrogen applied for agriculture globally is actually used by crops in a growing season. The unused nitrogen can leach into groundwater, or get washed away in runoff. Nitrogen runoff can spur the growth of aquatic plants and algae that, as they decompose, create dead zones that suffocate other organisms living there. The biofilms, on the other hand..

MARY ANN: The biofilms may actually help retain the nitrogen in the soil.

ALISON: Using biofilms and microbes is part of a bigger movement: managing soils more sustainably.

MARY ANN: I think the emphasis on biological properties of soils has really gotten much greater in the last 10, 15 years.

ALISON: And that's why Terry's work is partly funded by the US Department of Agriculture Organic Transitions program. He's focusing on how farmers can promote microbial growth, or even add microbes to improve farm fields.

TERRY: We really can't do intensive agriculture without some sorts of additives. And so the hope is that some of these microbial products will represent much more sustainable alternatives to synthetic additives. You know, when you add synthetic nitrogen, a large portion of that is lost and not taken up by plants. And so if you have microbes that are able to provide other smaller quantities of nutrients, or provide them more on demand; that's a really great tool to have for agriculture.

ALISON: And even now, lots of farmers are using microbial products in their fields. For example, a 2014 survey in Ohio revealed that over 70% of organic farmers were using microbial products. But this practice goes way, way back.

TERRY: Late in the 1800s, there are products sold called Nitragin —

Environmental microbiologist Terry Bell (left) and soil microbiologist Mary Ann Bruns (right), both researchers at Penn State, are collaborating on a project to understand the agricultural and ecological impacts of DG1, a microbial consortium that Bruns' team isolated from a green, soil biofilm. (Alison F. Takemura)

ALISON: that's N-i-t-r-a-g-i-n —

TERRY: — and Alanite, which were nitrogen fixing products. And so at the time, we have an article from just after 1900, which is the first FDA commissioner of the US talking about how these are great things…

ALISON: But it wasn't known what was in these live microbial products, or really how effective these microbes were. And more recently, Terry's group has heard this kind of uncertainty during outreach events with farmers nearby.

TERRY: And at one we did a survey of farmers to ask if they'd use microbial products. And if they did, how did they find they worked? And so we had five different categories … None of them said that the products were not effective. And none of them said that they were really effective. It was all sort of, 'Meh, I think it was sometimes good.' Yeah, think there's a lot of desire to use them, but a hard time understanding sort of when these things are effective or not effective.

ALISON: Part of the problem is that microbes might show great promise grown in liquid cultures in the lab that don't live up to expectations outdoors.

MARY ANN: If I could imagine how it would be after.. being grown in a luxurious, you know, growth medium, obviously, it is going to be a culture shock to be applied to the soil.

ALISON: Out on the farm, lab-grown microbes could be outcompeted. AND Farmers wouldn't really be able to tell.

TERRY: The problem with microbes is the fact that without special tools, they're typically difficult or impossible to observe.

ALISON: You need to either culture or sequence microbes — and really, it's more on the sequencing side — to know who they really are.

TERRY: Yeah, exactly. We really rely on sequencing technologies to understand what's present in the soil and what those things are doing.

ALISON: That's why Terry and Mary Ann are studying this microbial consortium, DG1. You can see it to know it's there. And they can use it as a model system. They're analyzing what genes the consortium expresses in soil, and how its gene expression changes depending on what other microbes are there and how the soil has been fertilized.

JGI is partnering with Mary Ann and Terry through the JGI Community Science Program to help them sequence all of the messenger RNA in their samples: the metatranscriptome. This type of sequencing can give them clues to how the biofilm and the native soil community interact.

We spy many such patches of microbial growth in the corn maze. Here, the dark green of cyanobacteria is mixed with the lighter green of the "short plant," moss. (Alison F. Takemura)

MARY ANN: I'm very excited about the fact that JGI was interested in exploring the interactions between this consortium and the soil.

ALISON: Even though Terry's group has done their own sequencing preparation in the past, he said it's been really helpful to work with JGI.

TERRY: Working with JGI, it was so much faster, the quality is so good…

ALISON: Terry also says that the JGI staff's expertise has made things easier. For example, They would offer up technical support.

TERRY: We were trialing different types of, of extractions, we hadn't previously extracted RNA from these types of films, and we actually had quite a challenge getting quality RNA from them initially. And so we were able to, sort of, pass through our RNA quality profiles back with our project managers, got a lot of feedback on what we were trying to look for, how we might go about improving that. So, that in itself was really great to make sure that, you know, we're going to invest all of this and in looking at all of these samples, but we want to actually have great material to work with in the first place.

ALISON: And then, the JGI staff also used their gene annotation pipelines on the RNA sequencing data.

TERRY: And so, once they're done processing it, we're able to immediately look into sort of what's going on as opposed to spending months and months trying to make sure that we've annotated our data properly and everything. So, just having that experience and that quality control really made the project much, much more fun to work on. But also you just feel much more comfortable with what's going on, because they just have so much expertise in that area, and because they do this so often.

ALISON: Mary Ann and Terry are still working on understanding the interactions between DG1 and other microbial communities in the soil. But the team does have initial observations about the biofilm that they can start sharing with farmers.

MARY ANN: We have found that soil is more cohesive and actually can take up water better and retain nitrate better when the biofilms have become established even after two or three days following inoculation. So there is a benefit that can be seen, you know, quite quickly after application of the DG1 consortium.

In the fall, soil at Pennsylvania farms sports a flush of green. A biofilm microbial community has bloomed. (Alison F. Takemura)

ALISON: Sometimes, Mary Ann and Terry are even able to point out to farmers the biofilm growing in their own fields.

TERRY: One farmer we're working with has a variety of plastic tarps that they use for weed control. So they essentially use these to block out sunlight and control weeds from growing early in the season.

ALISON: Terry and the farmer noticed that the tarps that were semi-transparent were allowing enough light to pass through for these biofilms to grow. Tarps that were opaque and black didn't.

TERRY: So the farmer was actually super excited to hear about this. And he had no idea what these things were.

ALISON: But that farmer loves the idea of getting a little more atmospheric carbon and nitrogen into his soils without any additional work! Terry has actually been finding an unexpected kinship with farmers.

TERRY: I hadn't previously interacted with farmers before, or at least not in a professional capacity before starting my position at Penn State. But it's been really fun. I mean, farmers themselves are scientists, like they conduct experiments every year on their field, they will try something on, on some patch or another. I mean, that's why it's been really easy for us to actually build projects with farmers, is they're really excited to kind of just let you do something and, and see what happens.

ALISON: Mary Ann and Terry hope that they'll be able to reward that enthusiasm. They aim to share more knowledge on how microbial biofilms might be harnessed.. to create more biologically active soils that deliver nutrients more effectively to crops and reduce the loss of nutrients in runoff. And reduce the loss of those nutrients in runoff.

MARY ANN: So, what we hope to do is to be able to communicate to farmers, what ecosystem services, they're actually providing, that generally, the overall benefit should be very positive; that they shouldn't be.. concerned that there is, you know, some strange green material that's appearing in their fields.

The biofilm is a thin layer on a broken piece of the soil surface. (Alison F. Takemura)

ALISON: The green material seems to be a good thing.

If you want to see the biofilm, we have lots of footage that we collected on our farm visit. Check it out on our website.

ALISON: This episode was directed and produced by me, Alison Takemura, with editorial and technical assistance from Massie Ballon, David Gilbert, and JGI's Communications intern,

Ashleigh Papp.

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

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