

MULCH MATTERS EP. 29

Understanding Biodegradable Mulches, Microbes and Isotopes with Sean Schaeffer and Jacob Clements

[00:00:00] Nataliya Shcherbatyuk:

Hello and welcome to the *Mulch Matters* podcast where we will explore the intriguing world of mulch and its impact on agriculture and the environment, as well as update you on the latest research about soil-biodegradable mulch and recycling options for plastic mulch. I am your host, Dr. Nataliya Shcherbatyuk, and I am a communications specialist for the project, “*Improving end-of-life management of plastic mulch in strawberry system*”. In each episode, we’ll dive into the latest research, trends, news, and insights on why mulch matters and how we can improve plastic mulch end-of-life options. We’ll also branch out and discuss other plastics as well as talk to researchers, experts, and practitioners in the field who will share their insights and experiences on how to use mulch effectively in different settings.

[00:01:01] Nataliya Shcherbatyuk:

Welcome back to another episode of Mulch Matters podcast, and we will have two guests today from the University of Tennessee, Sean Schaeffer and Jacob Clements, and we will continue talking about biodegradable mulches, plastic pollution, microbes and isotopes. So, let’s welcome our guests. Hello. Hello, how are you, Sean and Jacob?

[00:01:30] Sean Schaeffer:

Doing well.

[00:01:31] Jacob Clements:

Doing great here.

[00:01:35] Nataliya Shcherbatyuk:

Fantastic. So, you know, to start up a podcast, I would really like to learn a little bit about you and your background and get the chance to audience to learn as well. So, Sean, can you be first and tell a little bit about you, your background, what brought you to this project and the work that you do?

[00:01:58] Sean Schaeffer:

Okay. My name is Sean Schaeffer. I am a professor in the Department of Biosystems Engineering and Soil Science at the University of Tennessee. My background is in soil biology and bio geochemistry. So, I do a lot of work studying how carbon and nitrogen is transformed in soil. So that means doing a lot of work on, carbon sequestration, soil health and nutrient management. I was interested in this project. I got involved. With this biodegradable, plastic work, uh, I don’t remember exactly what year. I would say about 2016 or 2017. And I was very interested in how these biodegradable plastics interact with the environment and organic carbon that’s already in the soil. And might they have some impact on soil biology and in that way impact on soil health.

[00:03:05] Nataliya Shcherbatyuk:

That's, very, very interesting. And oh, you said so many big words in your description. I'm sorry. That's, no, that's fantastic. That's great. And Jacob, what about you?

[00:03:18] Jacob Clements:

Yeah, so, my name is Jacob Clements. I'm a PhD student in Sean's lab in Biosystem Engineering and soil science at UT Knoxville. I got my bachelor's and master's in geology from the University of Oklahoma. Um, my master's was very soil science focused, um, with. A lot of focus on nitrogen, iron and phosphorous cycling under future climate scenarios. Um, so basically like what we might be experiencing in the next, uh, 25, 50 years. And I really, what inspired my research on biodegradable mulches and plastic pollution is, I mean, I've been hearing. All over the news, everything about the problems with plastic pollution, and then I reached out to Sean to work in his lab and it just, it just went from there.

Um, I mean, I was just so interested in working with him to help solve these problems and figure out how the plastics interact in soil, um, with what's already there. Specifically mineral associated organic matter is a huge one for me. That's typically what I focus on, um, because it's really stable soil carbon, and that's the kind of thing that if we're talking about soil health, um, we really want to increase.

[00:04:55] Nataliya Shcherbatyuk:

Well, that's great. And Jacob, would you mind telling, um, a little bit. About what do you think are the biggest environmental concerns associated with microplastic and nanoplastic in soil? We had a lot of conversations about, you know, plastic pollution, nano and microplastic. So, could you please give us your opinion on this question?

[00:05:23] Jacob Clements:

Yeah, for me, I think that the biggest concerns are that microplastics and nanoplastics really change how soil works as a living system. Soil is, um, really alive with microbes and its own atmosphere and its own water and everything. And so, the plastics, um, are really persistent. Um, it can disrupt soil structure and water movement.

They can affect microbes and larger soil animals that help cycle critical nutrients that we need to grow food like nitrogen. And phosphorus. And in some cases, they could even reduce plant growth or alter root function and you know, and another thing for me too is there's been some research, um, and I'm not working on this, but I know some other people are, that these particles can really carry a release, um, other chemicals.

And so that's a huge thing for me, I feel like if we're talking about soil health, we need to talk about how the plastics that are persistent are kind of. Hubs for all of these things that might be happening.

[00:06:47] Nataliya Shcherbatyuk:

That's, that's very interesting. Yeah. Sean, I have a question for you. Going back to your experience in soil biology, would you mind telling us a little bit about how do biodegradable mulch breakdown in the soil, and what role micro crops play in this process?

[00:07:09] Sean Schaeffer:

Yes. Um, it is a very interesting topic, and there are two main processes that are occurring.: One is, is that these plastic particles start out as large sheets of plastic. If they're being used as a, as a mulch on the soil surface. Uh, but they break into progressively smaller and smaller pieces, and that can be a physical process.

As they're exposed to sunlight, they degrade. As they're mixed into soil, they physically, um, break into smaller and smaller fragments. Then those fragments can actually be colonized by bacteria and fungi that literally grow on the surface. Of these particles, they can use it as an energy source because it has carbon in it, and it's that, that's what makes it biodegradable.

Um, and they can actually secrete compounds called extracellular enzymes, uh, that can chemically break down the particles that they're living on into smaller and smaller pieces.

[00:08:20] Nataliya Shcherbatyuk:

Hmm, that's, you know, when Jacob said that soil is alive. This is so true. And that's so interesting. There are so many things that we just can't see with our naked eye and that's, it's just to imagine what micro microbes are doing.

It's, wow, it's fantastic and it's so exciting what you study. And you know, I've been reading some of your research and. It shows that BDMs don't fully degrade within a year. So, Sean, can you tell a little bit about what factors, um, influence how quickly they actually can break down?

[00:08:56] Sean Schaeffer:

Yes. A lot of it has to do with the climate and the type of soil, uh, that you have. So, um, the biodegradation of these plastics is faster when it's warmer and wetter, so the microbes actually grow better. Um. Under higher temperatures, and if they have water available to them, they actually grow, um, faster as well. Uh, and that's that temperature of the soil and the amount of water in the soil is.

It is very much controlled, not just by the climate. But also, by, uh, the, physical texture of the soil, whether or not it's sandy or clay, has an enormous impact on the water holding capacity of that soil. So that's why you see, um, large differences across the country in the rates of breakdown of these materials.

[00:09:59] Nataliya Shcherbatyuk:

So, can you tell a little bit more about what type of soil or locations or states you've been working with to see this difference?

[00:10:09] Sean Schaeffer:

So, in the current project, um, we are working with soils from Washington State. Uh, Nebraska. Florida and California, and this spans an enormous range in climate. You're going from, um, subtropical, um. Florida to the Pacific Northwest. So big differences in, um, average temperature. Um, there are also big differences in rainfall, and not just how much precipitation, but when that precipitation falls. Um, in previous projects we have. Um, looked at soil from the, from Tennessee and Texas. So, we have a lot of information about soils all across the US and these soils all have different amounts of clay and silt and sand in them, so we get these textural differences as well.

[00:11:10] Nataliya Shcherbatyuk:

Hmm, that's pretty interesting. That's, it's a widely spread project, which makes it not only interesting, but also quite. Available when we talk about the results. 'cause it's not just targeted into one location, which makes it pretty strong. And um, I do have a question for both of you, and I would like Jacob to get it first.

To start with, what do you think, uh, the biggest challenges when we talk about farmers? Which are actually thinking to switch from PE polyethylene mulch to biodegradable mulch.

[00:11:50] Jacob Clements:

I, for me, know that. When I've seen the economic data, there's, there is that increased purchase cost just associated with the plastic being renewable.

Um, but you can make up for it with the lack of labor costs from having to pull up the polyethylene mulch at the end of the growing season with just tilling the BDM in. Mm-hmm. Um, and so for me, I would say that that's. It is a big challenge because farming is a very you. I mean, you really have to take care of yourself and make sure that your crop is good.

And so, you know, you're wanting to make sure that you're investing in something that's really, really good. And so, I think it needs to make sense economically and. I think it does make sense economically for BDMs, especially as we try and move towards a circular bio economy where everything can be recycled, um, or as many things, um, as can be, can be recycled but I definitely think that there should be some incentives with that. Um, and. That type of thing, potentially from the USDA in order to further incentivize farmers to pick BDMs over conventional polyethylene mulches.

[00:13:17] Nataliya Shcherbatyuk:

And Sean, what do you think?

[00:13:22] Sean Schaeffer:

Well, first I, I agree with everything that Jacob has said. Um, the only thing that I would add, uh, would be there's also a visual component. To use biodegradable mulches versus polyethylene. So, when you're using polyethylene too much, you have to remove it, uh, by hand, usually at the end of the growing season. Which means most of the large fragments and pieces of plastic are picked up and removed from, from the field at the end of the growing season.

But the biodegradable mulches, uh, are left on the field or tilled in. Uh, to the soil. And that means, um, that there may still be large visible fragments of plastic on the soil surface. Um, and I think we find that, that that is sometimes not aesthetically pleasing. Or it may give the impression to a farmer, um, that these materials are not.

Degrading, um, um, and certainly not degrading quickly enough to, to make a difference visually. And so you may have some, some plastic that accumulates on the surface and blows around and just, um, um, doesn't look as nice.. And you remove all the polyethylene by hand?

[00:14:44] Nataliya Shcherbatyuk:

Doesn't look clean.

[00:14:46] Sean Schaeffer:

Yeah, it doesn't look clean.

[00:14:47] Nataliya Shcherbatyuk:

Yeah. So, what do you think would be the most important thing that farmers should know before they start using BDMs for the first time?

[00:14:59] Sean Schaeffer:

Uh, they should know all of the things that, that both Jacob and I have mentioned, but probably the most important thing that we could tell them with our research is that yes, these materials are truly biodegradable, and they will break down, uh, eventually, even though that may not happen, um, within a year.

So, uh, you may see some accumulation and that that accumulation is not negatively impacting the function of their soil. We have research that shows that soil health is not impacted negatively by the presence. Of these particles. So even though it may not look as nice, um, it does function better in terms of promoting soil health.

[00:15:51] Nataliya Shcherbatyuk:

Interesting. Well, yeah, definitely they should understand that just because it doesn't look as clean as they would like to. The benefits are still bigger than, you know, the PE in this case and going Yeah.

[00:16:05] Jacob Clements:

I would say that as well, like in agreeing with everything that Sean said and kind of riffing off of what you said, I mean.

What they need to know is for me is, um, the only other thing I would add is that they would be contributing to a more sustainable economy. And I think that that's something that, um, especially in the eu, they're doing a good job of working towards in the us We still need to work towards a lot. Um, and this could be a really good way to do that.

And I think that would be something that, um, you could also take pride in is helping contribute to that more sustainable economy.

[00:16:50] Nataliya Shcherbatyuk:

That's great. Yeah. And Jacob, to go back to the studies that Sean been talking about in the different states, are there any results that you might be able to share specifically about where Vdms perform, especially, well, maybe some status specific soil, and where are they being quite poorly? And I'm talking about the degradation through the period of time.

[00:17:19] Jacob Clements:

Yeah, absolutely. Um, we do have some pretty great results so far, um, especially from some models where we're tying in how the mulches perform climate factors and soil factors. Um, Florida is particularly good if you're going to strawberries in Florida.

Um, these mulches break down really well because what we found is that the mulches have a real sensitivity to. Humidity, the amount of rain, increased temperature, and the amount of clay in soil. And so those are all things that we can see in Florida. Mm-hmm. And especially the climactic variables. Um, and even.

California. Um, you still get warm days, Washington, you still get wet days. Um, and so they might not degrade as fast as they would in Florida, but they still do influence the degradation there. Um, and I would just say that we're still testing it, um, it out and refining the models, but right now that's what we're seeing.

[00:18:36] Nataliya Shcherbatyuk:

Great, thank you. And now, Sean, you mentioned that bio credible materials might help increase carbon stored in soil, but can you tell us what does it actually mean for the soil health?

[00:18:55] Sean Schaeffer:

So, we've done several research projects over the years, both with, uh, this current project that, that we're all part of and with a previous, um, project.

And what we found was not so much that. The use of biodegradable plastics increased soil health metrics, whatever metrics we decided to measure, um, it was that they did not have a negative impact, compared to not using any mulch at all. Um, whereas when you use a polyethylene mulch, you can sometimes see a negative impact.

Uh, to soil health. And that's mainly due to the fact that the polyethylene mulch, um, changes microclimate underneath the mulch and at the soil surface such that, um, it often slows down microbial growth. So, we may see some potential negative impacts to soil health from using polyethylene. We don't see those negative impacts when we use biodegradable products.

[00:20:06] Nataliya Shcherbatyuk:

Interesting. Microbes are picky. So, Jacob, I wanted to confirm something with you. I think I've been reading that you actually use some advanced methods in your studies. Something like tracer studies or microbial analysis. Is that correct?

[00:20:25] Jacob Clements:

That is correct, and I'm more than happy to tell you about it.

[00:20:29] Nataliya Shcherbatyuk:

I'm more than happy to ask you more questions. Yeah. So, can you tell us how those methods actually helping you to better understand BDM breakdown?

[00:20:42] Jacob Clements:

So, it's really kind of cool, um, how they're helping us understand. BDM breakdown because we're using two isotopes of carbon because carbon is, uh, most of what these mulches are made of. Um, and they form the backbone. And so, if you can figure out where the carbon is going, then you can figure out how the mulch biodegrades before,

[00:21:07] Nataliya Shcherbatyuk:

Before we move forward with the details. Mm-hmm. Could you please just very briefly explain to our audience who don't know what the isotope is?

[00:21:17] Jacob Clements:

Yeah, so essentially an isotope is, it's the same element, but it has a different number of neutrons. And so, it's a little bit heavier and they all have different abundances in the environment. Um, so for carbon, carbon-12 is to the standard and it has, um, I think it's about 98% of all the carbon that we have in the environment. And then. There's carbon-13. Mm-hmm. Which is like carbon-12, very stable in the environment. Um, and that's about 1% of all the carbon. And then there's carbon-14, which is also naturally occurring, but it's low. Um, and you might have heard of it in like radiocarbon dating with mm-hmm. Archeological sites. Um, especially in like caves in Europe, stuff like that.

[00:22:19] Nataliya Shcherbatyuk:

So basically, just for understanding, if you use a heavy isotopes, a heavy element in your studies, you have the ability to trace them and if they move, let's say with microbes, you can actually see where they ended up. Correct?

[00:22:39] Jacob Clements:

Exactly.

[00:22:41] Nataliya Shcherbatyuk:

Okay.

[00:22:41] Jacob Clements:

Um, and so. That's basically what I'm doing here, but with these plastics. And so, um, the, I mentioned the carbon-13 and carbon-14, those are what I'm using in this experiment, the carbon-14, because there's so little of it in the environment. It's actually a really sensitive way to track where. Specific carbon atoms are going. Um, and so I can see down to, um, a few clusters of atoms where the BDM derived carbon. And so, it's really kind of cool because you can track the degradation of the plastic. In real time. Um, uh, we're at 11 weeks in this incubation and about 0.25 milligrams of plastic has actually degraded.

Um, and so that is what Sean was talking about earlier, how we know that these plastics are degrading, they're degrading a little bit slower. Um, and we know that they're impacted by climate variables. Um, and then the carbon-13, I'm using that because microbes eat it the same way that, um, they eat carbon-12.

Um, and so with that, they can uptake it and it basically. By filtering out who eats that carbon-13 versus that carbon-12, I can figure out which microbes are actually eating the plastic and assimilating that carbon through a process called DNA stable isotope probing.

[00:24:42] Nataliya Shcherbatyuk:

Interesting. So, are you adding the, the isotopes or you working with the natural bond that exists in the environment already?

[00:24:52] Jacob Clements:

I'm adding the isotopes in order to gain the precision that I need to be able to measure it.

[00:25:01] Nataliya Shcherbatyuk:

And how do you do that? How do you add those isotopes?

[00:25:04] Jacob Clements:

So, I actually made plastic in the lab. Um, through, um, a poly condensation reaction. Basically, I took a precursor to the plastic and. I polymerized it and made plastic out of it. But I used, um, those precursors, they were isotopically labeled. Um, so they had a bunch of that. They had a bunch of that carbon in there. Um, either carbon-14 or carbon-13.

And then I reacted to it, um, with a catalyst and a solvent. And then it produced plastic, um, that is somewhat similar to commercial DDMs that we see on the market today.

[00:26:01] Nataliya Shcherbatyuk:

That's fascinating and super interesting. I hope you have a lot of cool pictures.

[00:26:07] Jacob Clements:

I do. But unfortunately, since this is a podcast, I can't share them all.

[00:26:11] Nataliya Shcherbatyuk:

I know, I know. And Sean now. Based on the work you've done, and you've done a lot of work in different locations for many years, can you tell, what do you think, um, are the biggest unknowns about the long-term fate of BDMs in soil?

[00:26:33] Sean Schaeffer:

Yes. So, um. Probably the largest unknown right now is, uh, how quickly are these microplastic and nanoplastic particles transported through a soil, or even if they're transported. So, we know, um, that the degradation, the biodegradation can take several years. But over that time, these plastic particles don't stay.

In the same spot in the soil. Um, water and tillage and other kinds of soil disturbance can move those particles around and we don't have a good sense for how quickly. They can move through soil. And where they might accumulate in the soil. So, this is really important when you're thinking about, um, maybe farm fields that are next to waterways, next to a stream or a river.

Um, you might want to know if it is any. Of these plastic particles making it into, um, waterways. Is it accumulating in stream sediments? If so, where? Uh, it's not as big a problem for biodegradable fragments because we know they'll, uh, they'll eventually, they'll break down. But, um, my research also involves non-biodegradable plastics, and for that we're very interested in.

Um, the, the fate of, of those particles. 'cause we don't have good, we don't have a good understanding of how quickly they move through the environment and where they might accumulate.

[00:28:16] Nataliya Shcherbatyuk:

That it is, it is very interesting because even if you talk about it. I think even if we talk about BDMs, which are biodegradable in the soil, but they end up being in the water, they will eventually break down.

But the process, I wouldn't expect to be the same in water as it's in soil because the whole, um, you know, the scene behind that is the microbial community is the one that works on the BDMs and in water. Unless you've done some studies to maybe let us know how and what happens in water with that. BDM,

[00:28:53] Sean Schaeffer:

I don't know how quickly these particles degrade into water, but it may be faster than, than in soil just because, well, they're, they're in water and it's easy, it's easier for microbes and the plastic particles to come into contact.

[00:29:11] Nataliya Shcherbatyuk:

That's a good unknown that I hope somebody's doing the research and shortly we will know what's going on with that.

[00:29:19] Sean Schaeffer:

I agree.

[00:29:20] Nataliya Shcherbatyuk:

And yeah. And to both of you, um, if you could share one key takeaway with growers or policy makers, what would that be? Sean, I'll let you go first.

[00:29:35] Sean Schaeffer:

Um. I will try not to, um, say too much because I think Jacob has a good, uh, answer to this question. Okay. But, um, um, what we, what we need are, um, an understanding on the part of policymakers. Um, what. A biodegradable, um, plastic film is, there's not a lot of, surprisingly, not a lot of agreement on, um, how these biodegradable film biodegradable plastics can be defined because you can make a biodegradable plastic out of a non-biodegradable feedstock. you could use something like petroleum to make, um, make, um, a actually a biodegradable product. And how do you treat that? Is that different from, from a biodegradable product that's made solely from, um, organic feed stocks? Um, it's an interesting question, but, but I'll let, I'll let Jacob talk about policy.

[00:30:45] Nataliya Shcherbatyuk:

Yeah, let's go.

[00:30:48] Jacob Clements:

Yeah, I, you know, I would say that we're actually at a really kind of exciting time because, um, BDMs, since they're so new, um, and I'm actually getting, Sean and I are writing a paper on this, um, they're not really currently regulated, um, or not regulated by any major environmental regulation in the United States.

Um, and which is kinda kind of crazy to think about. Um, but you know, I think that exploring that policy connection and showing and giving policy makers, um, you know, staffers in congress, agency administrators, the metrics that they need in order to be able to define what a biodegradable mulch is in a legal context.

Then translate that into saying, okay, this is how then we can make this into laws, offer incentives, um, for farmers who use these keep, uh, for example, Oxo degradable mulches, which the EU has done a really good job of keeping those out of the market, but keeping those out of the market here in the United States to make sure that it's really just true biodegradable mules.

Um. I think that that's kind of an exciting place to be because we're literally getting ready to show people what, what we need to define mm-hmm. As a biodegradable mulch and, um, I think our research does that. And so I just think it's just, I just think it's very exciting. Um, and I also think it's the right time to fund more scientists in space because the more research that we can get, the better.

[00:32:46] Nataliya Shcherbatyuk:

Always. And what do you think, if you just imagine a little bit ahead of, you know, a few years, a few years ahead of time, what do you think the future of sustainable mulch technology look like? And that's from your perspective, Jacob.

[00:33:06] Jacob Clements:

Oh, I think it's, I think that the future for sustainable mulches is just really bright. Especially with all the different, uh, crops it's been tested with. Um, I think at this point, it's really just encouraging higher adoption through, like I mentioned earlier, through incentive programs, other methods, um, or bringing the cost down. Um, to even below polyethylene mulches. Um, I think that that will put us one step closer to more even more sustainable farming than where we're already at. And I don't know, I think that's what I think, that's what we can be seeing in the next five years.

[00:33:52] Nataliya Shcherbatyuk:

That's great. Sean, what do you think?

[00:33:55] Sean Schaeffer:

Um, yeah, I agree with what Jacob has said, and I think one of the ways, um, that we can think about increasing these adoption rates is to come. Out and develop actual standards for using these biodegradable plastic mulches in organic agriculture.

Uh, because right now there is, there isn't, um, that that standard. And so once we can develop that, we might potentially open up the market, um, more to these products.

[00:34:27] Nataliya Shcherbatyuk:

Right. Well, thank you so much. I'm, I'm still thinking about everything you said. It's so, so much great information and very, you know, thoughtful thoughts.

But thank you so much for your time and educational material was very interesting. Thank you so much.

[00:34:46] Sean Schaeffer:

Thank you for having us. Yeah, thank you.

[00:34:49] Nataliya Shcherbatyuk:

Thank you.

[00:34:50] Nataliya Shcherbatyuk:

That's it for today and until the next episode. You can find more information by following us on Instagram and LinkedIn by @mulch_matters and going to our websites www.smallfruits.wsu.edu and choose Mulch Technologies. This work is supported by Specialty Crops Research Initiative Award 2022-51181-38325 from the USDA National Institute of Food and Agriculture. Any opinions, findings, conclusions, or recommendations expressed on this podcast are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

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