Case the Place

Morel Dilemma Episode 2 Script.

[Music begins]

Izzie: Welcome to Morel Dilemma, an exploration of why some mushrooms are so highly sought, some are so heavily cultivated, and some are so very dangerous. Last week, we talked about why mushroom farmers don't grow mushrooms straight from spores like a tomato farmer grows tomatoes from a seed. Instead, mushroom farmers use bundles of hyphae that have already grown and let them sprout into mushrooms.

[Music ends]

This time, I want to talk about the process that brings us from compost to harvesting mushrooms. I wanted to interview a couple of companies from the United States and abroad that actually grow mushrooms, but they didn't call me back. So instead, I've asked my wonderful husband –

Nate: That's me.

Izzie: To pretend to be me while I pretend to be an expert. I've conducted research about this process, so even though I don't do it myself, I'm going to do my best.

[Musical tone]

Nate: So, I guess I'll start off… at the end of your last episode – which I did listen to, by the way –

Izzie: Thank you! You're the only one. [Laughs]

Nate: You mentioned spawn.

Izzie: Yes.

Nate: So, aside from a ridiculous 90's comic book character, what is "spawn"?

Izzie: It's basically a super pure clonal strain of mycelium.

Nate: ...And… how does that get made?

Izzie: When someone finds a mushroom in the wild that they want to cultivate, they take some of the mycelium out from under it and bring it to a lab. They grow it, take sections and grow the sections out, and raise mushrooms from it over and over to make sure that it's healthy, not going to change color, and give consistently sized and shaped mushrooms. Once they're sure the mycelia will give rise to the desired mushrooms, they mix the mycelial mass in a big tumbler with some dead grain. The mycelia grab onto the grains and take hold, so that you essentially wind up with mycelium seeds. Those get mixed into compost, and that mixture is called "spawn."

Nate: So the spawn is just mushroom bits and compost?

Izzie: Yes; the mushrooms can't grow without it.

Nate: I know plants like compost. Do mushrooms *need* it?

Izzie: Well, plants are photosynthetic, which means they can take the energy of the sun to turn carbon dioxide, from the air, into sugars and proteins and the like. Most of a plant's mass actually comes from the air. But like us, mushrooms don't photosynthesize. They need to get their proteins and sugars from somewhere else. Compost is how they get it.

Nate: So how is that compost made?

Izzie: Oh, you just stepped in a pile of compost. Making mushroom compost is hugely complicated! There are actually two phases. Phase one is a lot like urban compost, in which food scraps are set in a pile for microbes to digest. A lot of people think that compost is stinky, but they are thinking of covered compost, which is "anaerobic", kind of choked off. "Aerobic", or properly aired, compost doesn't smell like anything except dirt.

Nate: And aerobic compost is the kind mushrooms like?

Izzie: Yep! To make sure the huge, industrially-sized piles of compost are aerated, most mushroom farms have concrete slabs with holes in them that air can be forced through. There's also a compost turning machine that can rotate the piles and make sure nothing gets trapped on the inside for so long it gets anaerobic.

Generally, mushroom compost starts out with straw-bedded horse manure. The straw helps keep things fluffed and airy, while the manure gives the compost a ton of nitrogen. Normal soil is about 1 to 5% organic matter that plants and fungi can use, about 5% of which is nitrogen, so normal soil is about 0.25% nitrogen. But straw-bedded horse manure is almost 2% nitrogen, almost ten times as high! Plus, the manure is often supplemented with additional nitrogen fertilizer, like chicken manure (2% nitrogen) or soybean meal (7% nitrogen).

Nate: Mushrooms need more than just nitrogen, though, right?

Izzie: Of course! They need tons of carbon. The straw provides some, and that organic matter is almost half carbon, but cocoa bean hulls and corn cobs are often added to help even out the nitrogen-carbon balance. Generally, the ratio of carbon to nitrogen needs to be less than twenty to one.

Nate: So you just need corn cobs and horse poo and then you are good to go?

Izzie: Not quite. Before the mushrooms can grow, the corn cobs et cetera need to be turned into a form the mushrooms can use. That's where the microbes come in. Each species of bacteria will convert certain larger hunks of organic matter into smaller, more basic building blocks. Those building blocks will ultimately be proteins and carbohydrates that the mushrooms can use. Some microbes also change nitrogen that the mushrooms *can't* use into a form they *can* use, which is obviously important.

Have you ever felt a pile of compost?

Nate: Uh, no.

Izzie: Well if you put your hand near a large compost pile, even in the winter, it would be very warm. Just like doing jumping jacks in a closed room warms the room up, when the microbes are working fiercely to convert a lot of organic material, things heat up. In Phase I, the mushroom compost gets up to 155 degrees Fahrenheit.

Nate: That sounds gross and smelly.

Izzie: Nope! Believe it or not, the heat actually helps the pile stay un-smelly. Since hot air rises, heat comes off the piles in waves, drawing cool air up from the bottom of the pile where it's piped in.

Nate: Cool.

Izzie: After a few days of composting at this temperature, the pile of compost is a nice chocolate brown, can hold water nicely, and is 3 to 5% bacteria! They're very happy in there. By this time, the pile is also chock-full of broken down carbon and nitrogen. In fact, farmers know Phase I is done when the compost piles smell strongly of ammonia.

Nate: Which is a part of fertilizer, right?

Izzie: Right, but ammonia isn't good for mushrooms. Like, at all. More than 0.1% ammonia in the compost is toxic to mycelia.

Nate: Well that's silly! Why let the ammonia build up then?

Izzie: Well they aren't grown in the ammonia-rich compost. That's just the end of Phase I and marks the transition into Phase II of composting.

Nate: I thought that was pretty much where composting stops?

Izzie: Nope. Like you said, ammonia is awesome for plants. Most agricultural and garden compost could stop right here. But mushroom compost has a ways to go yet in Phase II.

Nate: So what is Phase II?

Izzie: It's sort of like advanced Phase I plus pasteurization. They move the piles into specialized buildings that each have separately managed HVAC systems - that's heating, ventilation, and air conditioning. Some barns may be in use to finish off compost while others are in use to grow mushrooms.

Nate: So basically they move it inside and then cook it to kill off the microbes?

Izzie: Well, the pasteurization doesn't happen until the very end of Phase II. First, the microbes are all given a chance to run totally wild and break down every molecule they can, especially the ammonia, which they turn into proteins the mushrooms can use. The barns are ventilated to make sure all the happy aerobic microbes get a turn,

and the microbes often become so abundant that they are visible to the naked eye as white spots on the compost, called "firefang".

Nate: That is a ridiculously metal name for little decaying spots in compost, but wouldn't the "firefang" compete with the mushroom for nutrients?

Izzie: Actually, mushrooms love firefang. It's a great source of that ready-made protein, as well as fats. This is especially important because fats promote the growth of fruiting bodies - so in addition to helping feed the mushrooms, the firefang actually makes it easier for mushrooms to grow.

Nate: So how long before the microbes get cooked?

Izzie: Not too long. As soon as the ammonia has been used up, after a couple of days, the piles are ready for pasteurization. The "ready" compost is put into specialized tunnels with perforated floors - air flow again - and heated up fast. Actually, the heat mostly comes from the microbes again; the compost just isn't being cooled down anymore.

Nate: Are you telling me the microbes heat themselves up so fast they die?

Izzie: Yep!

Nate: That doesn't sound very clever of them.

Izzie: Well, it doesn't happen all at once. Remember how each species of microbes converts a certain set of molecules into a form mushrooms can use?

Nate: Yes.

Izzie: Well, each species also has a temperature range it works best at. So while all our microbes might have been plugging away during Phase I, and during Phase II so far, they haven't hit their stride yet. Some of them would do *better* if the pile were a little hotter.

Nate: But "a little hotter" kills the ones that are already at their happiest?

Izzie: Exactly! See, as low-temperature microbes do their thing, they heat the pile up, sliding the temperature into the range in which middle-temperature microbes do best. By the time the pile has become too hot for the low-temperature microbes to survive any longer, the middle-temperature microbes are at peak workout. Then, by the time the middle-temp microbes are dead, they have run through most of their usable material *and* the high-temp microbes have stepped in.

Nate: What keeps the pile from heating up too fast and zapping all the microbes at once?

Izzie: The HVAC system cools the piles down somewhat, making sure that the climb in temperature doesn't happen too suddenly, and every microbe gets a chance.

Nate: So you said that during Phase I, the compost gets up to about 155 degrees. How hot does pasteurization get?

Izzie: Well, it starts out around 140 degrees in the tunnels, but over about 2 hours, the temperature rises up to about 180.

Nate: And by that time, all the microbes are dead?

Izzie: My sources are actually a little vague as to whether everything in the pile is dead at the end - many of them say that 180 Fahrenheit is the top survivable temperature for "good" microbes, which are the ones that finish the compost off completely. But theoretically, any microbes that could cause the mushrooms problems are definitely gone. Also any bugs, potential diseases, weed seeds, or fungal spores that may have landed in the compost.

Nate: So at this point, the compost is basically a hot, sterile pile of protein, sugar, and fat?

Izzie: That's the idea!

Nate: Like a donut.

Izzie: It's delicious.

Nate: Except for the protein.

Izzie: Bacon donuts.

Nate: Mmm. You could grow some serious mushrooms on one of those. But the compost is still pretty hot though, right?

Izzie: Mhm.

Nate: Again, like a fresh donut.

Izzie: Just like a fresh donut. The HVAC systems are used to slowly cool the compost down, by about 5 degrees per day.

Nate: That's really slow.

Izzie: It is really slow, but the reason is that if there are any surviving "good" microbes, this lets them eke out the last tiny little bit of material from the pile. I can't say how many microbes this is relative to our starting amount of 3-5%, but it's a really really small amount.

Nate: Okay, so Phase II is finished. We finally have our compost?

Izzie: Yep, the compost is all set.

Nate: Can we learn about the mushrooms now?

Izzie: Oh, fine.

[Music]

Voicemail Recording: Hello! You have reached the voicemail for the podcast Morel Dilemma, hosted by me, Izzie Gall. I can't talk fungi right now, but if you leave me your name, number, and a brief message, I will get back to you as soon as possible. Thank you!

Anschel Schaffer-Cohen: Hi, Izzie. This is Anschel. I've been trying to think about something to say about mushrooms. And the problem is I don't know what mushrooms are, except sort of funny looking – and not plants, apparently. So I thought about what mushrooms have meant to me, and I settled on Alice in Wonderland, which is a story that has a lot of personal resonance to me. It's sort of popped up in different parts of my life. And in a way you can see Alice in Wonderland as the story of Alice's empowerment.

At the beginning, she's just miserable. There's these animals that – she tries to make friends with them, and they just boss her around. And she eats things that unexpectedly make her grow or shrink and she's like "Alright, I'm not going to eat things" but then it turns out a fan can also make her grow – or shrink, I don't even remember. She's unhappy, and she doesn't have any control.

To me, the turning point of that is when she discovers this mushroom; she can bite into one side or the other and it makes her bigger or smaller. And for the rest of the story, she has pieces of this mushroom – she keeps one in each pocket. So I'm going to take the stance that in some sense, mushrooms are a kind of empowerment. Alice goes from being controlled by the world to controlling the world.

[Intermission music]

Izzie and Nate: [Exaggerated throat-clearing]

Izzie: And we're back. We're finally ready to mix our compost with our spawn and get to growing some mushrooms.

Nate: Cool.

Izzie: So, spawning the compost is possibly the cleanest and most carefully performed task on a mushroom farm.

Nate: But the spawn is straight from a lab, and the compost has just been pasteurized. Why do growers have to be so careful mixing these two clean things together?

Izzie: Well, the compost is full of delicious nutrients all ready for the taking by any fungus who happens along. And while the spawn has a good chance of eating it up, if any spores get in - for other mushrooms, or for water molds or blights - they could also eat it up. And if they get mixed into the center of the piles, the infection or competing fungus won't be discovered until it's too late. Plus, mushroom barns are enormous, and spores go everywhere. If one infection gets in, it could spread to the entire barn, making lots of batches go to waste and requiring the farmer to clean the barn out entirely.

Nate: So you toss the spawn and compost together in what, a mechanical turning machine?

Izzie: Yep. Then the mixture is transferred to the growing beds in mushroom barns.

Nate: And then the mycelia will send out more branches and fill the compost?

Izzie: That's right, and the more spawn is use per unit of compost, the faster the compost will be fully colonized and ready to sprout mushrooms. Plus this means that the mycelia will have faster access to the nutrients buried deep in the compost, so the mycelia will be able to put up more mushrooms earlier. I couldn't find relative rates per se, but it's a pretty intuitive rule: more spawn, faster mushrooms.

Nate: So how long before the mycelia can start popping up mushrooms?

Izzie: The compost and spawn need to be together for two or three weeks. Like with the microbes, when the mycelia are growing fiercely, they'll be heating up the place. The HVAC systems are going to be working hard during these weeks to keep the temperature almost precisely at 76 degrees. If the building gets too hot - like 80 degrees - all the mushrooms could die. The compost-spawn mix also have to be kept moist, so the mycelia don't dry out, and the air has to stay humid.

Nate: Sounds a bit like a cave.

Izzie: Pretty much. They're big caves with multiple floors.

Nate: Multiple floors?

Izzie: Each barn is laid out like an open-floor warehouse, with huge scaffolds holding several layers of spawned compost in trays. Workers can move in the aisles between the stacks, and use ladders or steps to get access to the higher trays. It looks sort of like a Costco.

Nate: It's like mushroom apartment buildings.

Izzie: Exactly!

Nate: How tall is each 'floor'?

Izzie: There's no real issue with sticking the trays practically on top of each other. Remember, it doesn't matter if there's any light reaching the bottom layers, because mushrooms don't need light to grow, but there does need to be space so the mushrooms can stay cool, get watered, and, eventually, get picked. So the trays are about a foot or two apart vertically.

Nate: So the spawn is growing in - colonizing the compost, and the air is perfect for mushrooming. After the spawn run, will we finally be seeing some mushrooms?

Izzie: Not quite yet. There's one more step keeping us from seeing our mushrooms, and it's called the casing layer.

Nate: Am I finally going to learn why you called this episode "Case the Place".

Izzie: Gah, you stole my thunder. Yes. Because when the spawn run is over, it's time to… Case the Place. It's less fun now that you already said it.

Nate: I have no regrets.

Izzie: Casing is a magical mixture of peat moss and limestone. I say "magical" because, sort of like spore activators, nobody seems to know *why* it triggers mushroom growth, but it certainly does. Besides telling the mycelia that now is the time to fruit, the casing layer keeps the moisture in the compost during the next phase, where water is especially important.

Nate: Is that phase… finally growing mushrooms?

Izzie: Yes! The mycelia, having fully colonized the compost, get the signal from the casing layer, and push up through the casing to form "pins", the name for tiny baby proto-mushrooms. Pins are the first sign of the mushroom visible on the surface of the trays!

Nate: So a bunch of pins pop out of the casing, and every pin makes a mushroom?

Izzie: Well, that actually depends on the farmer and what they're going for. There's only a certain amount of nutrients in the compost, right? So whether there are 100 pins or 200 pins, they have access to the same number of resources.

Nate: Conservation of mass and such.

Izzie: Exactly. So more pins means smaller mushrooms, relative to the mushrooms that grow with fewer pins. Some farmers will remove a certain number of pins on each tray to make sure that the mushrooms that grow will achieve a certain size.

Nate: Is there ever a reason not to *Thin the Pins*? Ooh, you should have used that [title] instead.

Izzie: Maybe some other episode I'll use that. For the pins, some mushrooms are grown smaller or larger and then sold differently. For instance, cremini mushrooms and Portabella mushrooms are both cremini mushrooms. Portabellas are just older and, usually, bigger. So a cremini farmer wanting to sell a lot of portabellas this season might trim a lot of pins.

Nate: Okay, so once they've decided how many mushrooms get to live in each tray, what crazy involved process do farmers have to do before the mushrooms grow up?

Izzie: None! It's finally time to let the mushrooms do their thing!

Nate: Finally.

Izzie: Mushrooms are harvested from 15 to 21 days after the casing layer is applied.

Nate: Do they grow a little bit each day, like plants?

Izzie: No, they pretty much just stay the same size for a week and a half, then explode in size in the last two days.

Nate: Elaborate on "explode in size".

Izzie: They double every 24 hours.

Nate: That is ridiculous.

Izzie: Yep!

Nate: How do they manage that?

Izzie: The key to a mushroom's growth is water. Water is drawn up from the compost, through the mycelia, and into the mushroom's cap. When it reaches the gills, it evaporates out of the mushroom, and more water is drawn up to replace it. This happens in plants too, where it's called "transpiration". Importantly, when the water evaporates from the cap, anything that was dissolved in the water stays behind. That's how all the nutrients in the compost finally make their way into the mushroom: The mycelia transport these nutrients all the way along their network and into the mushroom, where the nutrients slowly build up to prepare for the big expansion.

Nate: How much water does this take?

Izzie: A lot. I don't know how much. But the mushrooms have to be kept a very precise amount of wet.

Nate: What is a "precise amount of wet"?

Izzie: Legitimately nobody knows. Watering mushrooms is the most delicate part of mushroom farming. There's no easy rule about how much water mushrooms need, and the need of one batch may be different from the needs of another. Workers have to feel their way along and try neither to drown, nor dry out, the mushrooms.

Nate: Mushrooms can drown?

Izzie: Well, they don't breathe, so no, that's not precisely correct… but it's still an issue to overwater them. If there's too much water on the mushroom surface, the mushrooms can bruise or water molds can take hold and disease them. Even when workers are super careful and check or change their clothes before going into the barn - which is a thing they actually do - mold spores are everywhere and the threat of mushroom disease is all around.

Nate: Very dramatic.

Izzie: Thank you.

Nate: So how long has this whole thing taken? With composting taking a couple of weeks in each Phase, then 2 weeks for spawn to colonize compost...

Izzie: It takes about 12 weeks, or three months, to get from compost to harvest.

Nate: That's not actually very long, is it?

Izzie: In terms of agriculture? No. In 1996, US farmers averaged about five months between corn planting and harvest. It was about four months for barley, five for rice and peanuts, and seven for cotton.

Nate: So you could have two crops of mushrooms in the time it takes for one crop of cotton, if you *weren't* running different processes at the same time.

Izzie: Right.

Nate: And I bet farmers are constantly composting and rotate the compost and spawn through barns all the time.

Izzie: The farms that are big enough, yeah. And some farmers inoculate the casing layer with mycelia to make things go even faster. When mycelia are in the casing, they grow pins more evenly across the surface and, once they connect with the mycelia in the compost, that can reduce the time between casing and harvest by about a week. Which is pretty impressive!

Nate: Neat. So once the mushrooms are harvested, the trays are cleared out and a new batch of spawned compost is moved in?

Izzie: Actually, the cool thing about farming mushrooms is that each harvest lasts for a while. New mushrooms can pop up once the first batch is taken.

Nate: So there are pins forming while some mushrooms are size-exploding and getting harvested?

Izzie: Yeah. When there are lots of mushrooms around, the mycelia can rest, thinking they did a good job and all is well. They've fulfilled their part of the life cycle. So they don't send up any more mushrooms. In nature, this prevents overcrowding and makes sure that the first, oldest mushrooms have all the water and nutrients they need. Once they die, though, the mycelia are free to produce more mushrooms. After all, if the soil is still warm and wet, and nutrients are abundant, the best thing for the species is to make another fruiting body, and another, and another.

Nate: So harvest kills the old mushrooms, and the mycelia sends up new pins?

Izzie: Exactly. Each wave of mushrooms from a batch of mycelia is called a "flush" and lasts 2-4 days. After the first flush, the tray gets watered for another seven to ten days, whereupon the second flush appears as if by magic.

Nate: So the harvest times we were talking about before are pretty much irrelevant. It's not like every five months, a corn farmer harvests a bunch of corn, waits two weeks, and then harvests the same field again.

Izzie: Yeah. Plants do *not* work like this.

Nate: How many flushes do mushroom farmers use?

Izzie: Only the first three or four. The first two flushes produce most to the tray's total mushroom yield, and the third and fourth flushes kind of squeeze out another good portion of the compost's nutrients. Also, the longer a tray is out, the more chances it has to be contaminated. So it makes sense to keep each crop out for as short a time as possible.

Nate: You said the first two flushes contribute most of the mushrooms. What kind of yield are we talking about?

Izzie: The yield on these things is out of control. Depending on how the mushrooms are spaced and how big they're grown, workers can apparently pick 30 to 80 pounds of mushrooms every hour of harvest. In the US in 2001, mushroom growers got 5.75 pounds of mushrooms per square foot of growing space.

Nate: That… is a lot of mushroom.

Izzie: Yeah, and that's square foot of tray, not square foot of warehouse! To put it in perspective, in the US 2014, corn growers averaged about a quarter of a pound of corn, on the cob, per square foot.

Nate: Dang.

Izzie: And 1.75 or so pounds of rice per square foot.

Nate: That is crazy. But I guess it makes sense, since the mushrooms are directly converting compost into stuff.

Izzie: Yeah, plants make most of their mass from the air which makes them slower. Gosh, plants, catch up.

Nate: So six pounds of mushrooms per square foot. Those are all harvested by hand?

Izzie: Yep, every pound. The stalks have to be trimmed at a certain point, and the mushrooms in each flush might not age at precisely the same rate. Plus, mushrooms have to be handled a lot more gently than corn cobs, say, or they'll get bruised.

Nate: They are rather squishy.

Izzie: And we love them that way. Well, thanks very much for pretending to be me while I pretended to be someone else.

Nate: You are very welcome.

Izzie: Morel Dilemma, everyone! If people are curious where I got most of this information from, much of it came from Pennsylvania State University publication called "Basic Procedures for *Agaricus* Mushroom Growing" and it also came from the Mushroom Council's Research and Information Website.

Nate: Procedures for gregarious mushroom growing?!

Izzie: *Agaricus.* It's Latin. I am surprised that you latched onto that and not the fact that there is a Mushroom Council.

Nate: Well, I'm on the Mushroom Council.

Izzie: No, you're not. For those of you out there, the Mushroom Council is a real thing.

Nate: Do they all sit on mushrooms in a dark room?

Izzie: I hope so. And just chant the Latin names of mushrooms.

Nate: And slowly grow fruit bodies.

Izzie: Well. Slowly for most of the time, but not for the last two days of growth.

Nate: Right.

Izzie: Okay. So… Thank you for listening.

Nate: You're welcome.

Izzie: No! [Laughs] I hope someone else listens to this as well.

[Music begins]

Izzie: "Morel Dilemma" is written and produced by me, Izzie Gall. This episode's research was made possibly by NSF DBI grant 120-6197, in association with the New York Botanical Garden in Bronx, New York. Our theme song was composed and performed by John Bradley. Special thanks this episode for Anschel Schaffer-Cohen for doing the intermission. If you'd like to have your voice on the podcast, you can call the hotline at 347-41-MOREL. That's 347-416-6735. You can find other ways to contribute, and other Morel Dilemma content, at moreldilemma.org.

I would like to remind everyone that mushroom hunting is tricky business, and you should never eat a wild mushroom unless an expert has positively identified it in person and told you it is safe to eat. Remember that even so, everyone is different, and allergies to uncommon foods can be hard to predict. Species marked as edible in guidebooks could still make you sick. There are other ways of enjoying fungi. My favorite is photographs.

[Music ends]

Resources

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