Ecological Guides to the Cultivation of Edible Mushrooms

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When examining the science and art of mushroom cultivation, we can't help but notice how many mushroom cultivators have backgrounds in wild mushroom collecting and hunting. We also notice that a lot of people who do cultivate mushrooms are of eastern European decent. The eastern Europeans have a long history of wild mushroom collection. It's through their experiences of gathering wild mushrooms that they are good cultivators. For the simple reason that they've learned how to observe wild fungi in natural settings. A crop of morels was picked, by one man, during a year when the morel crop was a poor one. When asked, "Where did you get all those morels?" the collector said "Well it was really quite simple. I started finding morels in certain areas. And those were on slopes of five to twelve percent on Fayette silt loam soil under mixed deciduous tree types. After that it was all history because all I had to do was get a soil map and then I could find morels wherever I wanted to." It's observations like that, that made this man a very good wild mushroom hunter. He could take the knowledge that he has of wild mushrooms and use that to his advantage.

SCIENCE OF FUNGAL ECOLOGY

If you take all of these observations and put them into a science you could call it the science of fungal ecology. Fungal ecology is how fungi interact with substrates, the environment they grown in, their hosts, their interaction with other fungi and plants, etc. We feel that fungal ecologists have a great deal to contribute to the science and art of mushroom cultivation. We have to ask ourselves, "What is included in the area of fungal ecology?" To give you some idea , a recent book, *Fungal Ecology*, published in 1995 by Dixon Webster lists these topics as part of his book: Life strategies of fungi; the mycelium and substrates for growth; structure of fungal communities; colonization and decomposition of leaves; colonization and decay of wood; water relations; succession; fungi of the soil and rhizosphere and terrestrial macro fungi. Surprisingly enough, all of these chapters have something to do with or some application to mushroom cultivation. It also helps if the grower has a thorough understanding of the ecology of the fungus being grown, it's life history, the niche it occupies in the ecosystem and the relationship it has with other organisms including pests and other fungi. So people in the field collecting mushrooms are making observations all of the time, whether they realize it or not.

HOW DID WE ARRIVE AT THIS ECOSYSTEM?

In order to understand the development of mushroom cultivation it is interesting to note the parallel that agricultural development has had over the millennia. Although the field of plant ecology was relatively unknown to our ancestors, they were observing it all the time. For instance, how did we arrive at this type of agricultural ecosystem? Well, a long, long time ago people used to hunt and gather for a living.

As they were gathering things such as the early ancestors of corn and wheat, somebody went out in the field one day and picked a grain growing in the wild and said, "Uum, this is good we should eat it." So people began to gather this crop, often times having to travel great distances to pick this crop. Once the crop was harvested and brought back to the village, they may have begun to notice that they were dispersing the seed of this crop along the trail. Someone else had the brilliant idea to take some of the seed that was being dropped along the trail and plant it into a plot of ground. Well, from there on, everything is history. People began to save seed, crops were planted in soil that was weeded and later fertilized and we got into this interesting science of genetics. And today we have large, sometimes automated farms that produce our agricultural products. But we also have to keep in mind that agriculture is different from one region to the next. For instance, winter wheat farming in Oregon has very little in common with tobacco production in South Carolina which is certainly different from corn production in Wisconsin. So we can take a look to see how mushroom cultivation developed over the millennia. Once again, this was done by people observing things in the field: How the fungus interacted with the host it was growing on, when it fruited, etc.

SHIITAKE CULTIVATION BEGAN SOMEWHERE IN EAST ASIA

In 1994 I had the pleasure of attending the ISMS conference in Quinyuan, China, which was entitled "The Production and Products of Shiitake Cultivation." At the conference, there were many Chinese scientists who got up and proclaimed that Quinyuan was indeed the birthplace of shiitake cultivation. All the Japanese scientists in the room rolled their eyes and shook their heads. I'll let that argument be conducted by someone else; but somewhere in East Asia, shiitake cultivation began. It began rather simply. Someone noticed there was a fungus growing on a log. They ate it and it was good. They decided "We should go out and pick this." So the mushroom was picked and then someone decided that it was too much work to go into the woods to pick a mushroom when they could probably drag this log into their yard and grow the mushrooms there. So rotted wood was eventually dragged, and as the mushrooms grew and developed they were picked and eaten. Then someone observed that if they took a piece of rotted wood—and this is all conjecture, I wasn't there—but someone may have taken a piece of rotted wood and thrown it out and it landed upon a piece of fresh wood that had just fallen. The fungus grew from that rotted wood into a log. So they observed that you could increase this fungus by inoculating fresh substrate with an old one. Things developed to a point where trees were felled, gashes were made on them, fresh mushroom caps were put onto the cut for spore dispersal, the fungus grew into the log, the shiitake fruited. Then somewhere near the end of WWII, a gentleman by the name of Mori in Japan had the idea that maybe we could grow the shiitake fungus in a pure culture and put it onto a delivery system, such as the wooden peg, to put into a freshly cut log and really cultivate this mushroom so that we could have a more reliable and less hit-and-miss production. The Japanese, since then, became very good at the art of growing shiitake on natural logs. They had a long history of the fungus being native to Japan, they observed the way it grew in the wild, they mimicked those conditions and with the advent of good science they were able to develop strains and produce a mushroom crop consistently throughout the year.

We notice that often times when new mushroom crops are introduced to growers, there is a high degree of failure. Sometimes this failure is just due to people not knowing the biology of the fungus that they are growing. For instance, in the early 80's —I'd say 1984—there was a big push for shiitake cultivation in the upper Midwest. In the state of Wisconsin we had three meetings that drew over 600 people who were interested in the cultivation of this mushroom. We had the wood resources and we thought we had the climate. We had a laying yard in central Wisconsin under a canopy of white oak. We were mimicking what the Japanese were doing because the Japanese were good at this, but we thought we could do it better. We were trying to grow shiitake better than the Japanese. Well, we failed in one area—we did not take climate into consideration. The main shiitake growing region in Japan receives approximately 82-100 inches of rain a year. Being an island nation, their climate is somewhat moderated by oceans and seas that surround them. Central Wisconsin is in the middle of the continent. We are typically classified as dry and cool. For instance, logs stacked outdoors led to catastrophic failures early on in the industry for the simple reason that the weather was too severe for the fungus. During the winter of 1985 we questioned whether we were all right upstairs—living in Northern Wisconsin. We had two weekends of minus 30 degree weather with wind chills of minus 100 degrees. At that time we didn't know that Wisconsin—other than being famous for obesity and binge-drinking—is also the place where the technology was developed for freeze-drying wood! If we would have had the sense to use the training we've had by simply looking for wild mushrooms we would have realized that in Wisconsin wood does not rot in elevated piles. It rots when it's placed on the ground because that's where all the moisture is. So we learned from that major error and we started to place logs where the moisture is in our ecosystem and that is right above the soil surface. We started with elevated piles and now we're stacking them low to the ground. The simple reason is that we've learned to work with the fungus in our environment and since we've gone down to the ground surface our success rate in the logs has increased dramatically.

OFTEN TIMES WHEN NEW MUSHROOM CROPS ARE INTRODUCED THERE IS A HIGH DEGREE OF FAILURE

We've been able to learn how to work with shiitake and logs in various habitats. For instance, a planted plantation of red pine, 15-20 years of age, makes for an excellent laying yard, particularly when the grower has taken advantage of the pine needle bed and also a low stacking configuration which allows for brambles and other forest floor plants to grow and cover the logs thus providing another canopy, another layer of humidity for the log to decay. We also found that sprinkling logs due to our dry climate greatly improves things. So, it's observations such as these that have led to growers being able to cultivate a fungus, such as shiitake, successfully.

HOW TO WORK WITH SHIITAKE AND LOGS IN VARIOUS HABITATS

Now what works for us in northern Wisconsin may not be the way to grow shiitake elsewhere in the country. For instance, the state of Arkansas which has a much more forgiving climate, with approximately 40 inches of precipitation per year, warm and humid summers—the logs can be stacked in different configurations and the grower can still maintain a high degree of success.

A little further south in Ardmore, Alabama we have found that the climate is very forgiving. We visited this laying yard in 1992, and it was probably one of the nicest laying yards that I've ever been in, in terms of environmental conditions for decay. We arrived at dusk, the sun was setting and it was hot, as it always is in Alabama. We walked up to the edge of the woods and you could feel this nice breeze blowing through. When you walked into the woods the humidity wasn't as high as out on the road but it was still up there. There was a gentle breeze blowing through, and the place smelled of rot. The logs were stacked about 4 feet high in crib fashion and they were fruiting abundantly naturally. Evidently this gentleman who had these logs had a good grasp on what the shiitake fungus needed for decay and subsequent fruiting of the shiitake log. So we've learned over time that you have to be able to work with the environment that you have in order to successfully produce this crop.

ONE OF THE FACTORS TO LOOK AT IS RAINFALL

We have to look at all the environmental factors that affect colonization of the wood to be able to grow the crop in a way that will provide a good economic return. One of the factors we have to look at is rainfall and how the log orientation affects the way rain lands on the log and stays there. For instance, in our dry climate we like to expose as much of the log surface during rainfall and because the log is lying flat the water doesn't run off the log so we have better water permeation into the bedlog. In much more humid climates maybe you don't want water staying on the logs because this will lead to contamination problems. We also can look at things such as: slope aspect, surrounding vegetation, cover type, what's on the ground, where's the wood rotting in your forest. All these factors need to be observed so that you can successfully grow this crop.

MOVING LOGS INSIDE

And then once you start toying with the idea of growing bigger and moving logs inside you need to once again keep in mind the ecological needs of the fungus. Bringing logs inside has it's drawbacks. Moisture content maintenance becomes very difficult particularly when logs are stacked in such a way that you have such a gradient of moisture in the stack. From consistently moist logs on the bottom if you have poor air flow to dry logs on top. Maybe the center section of the pile is the best for spawn run and the ability of the fungi. So moving logs inside can be done but the needs of the fungus must be kept in mind.

FEW FUNGI CULTIVATED FOR CONSUMPTION

It's interesting to note how few fungi are actually cultivated for consumption. *Agaricus* is a composting fungus while for the most part the other ones are degraders of wood and other living things. We want to increase mushroom production because it's a living, and because it's also a good source of food using waste agricultural products. So what we need to do is—once again, if you're going to be growing new fungi— keep in mind the needs of that fungus.

Agaricus or the white or button mushroom has really reached the ultimate state of cultivation. Systems have been developed where everything is automated with the exception of the picking. It's a mushroom that every detail of it's life is known. So it can be grown in great quantity rather efficiently. So, can we use *Agaricus*-type

technology to grow other mushrooms? This has been tried but problems arise. Once again, we're trying to adapt a technology that was great for one mushroom but really doesn't work for shiitake. Who knows, maybe certain technologies will work in the future when we further understand the interactions between shiitake and contaminants.

INCREASE IN DOMESTIC PRODUCTION OF SHIITAKE

Statistics from USDA in 1997 show that we've broken the 6 million pounds per year shiitake mushroom production. So we've seen a steady increase in the domestic production of shiitake. One of the things we're facing as growers is educating the consumer so we can sell all these shiitake that we're producing. But we've also seen a shift from log cultivation to cultivation on particulate substrates. For the most part, shiitake is grown in the U.S. on sawdust. It points out a good thing that we could call an environmental issue: Sawdust—being a by-product of the forest product industry does have many uses. One that always comes to mind is that you can grow mushrooms on it and with that mushroom you can feed the world's population and also earn some spare change for your pocket.

CULTIVATION OF SHIITAKE ON SAWDUST

If you're not familiar with the cultivation of shiitake on sawdust I'm going to give a brief overview. Generally, the sawdust is of the hardwood type—mixed hardwood like oak and maple in the Pacific Northwest but here in the Midwest we use red oak because we have lots of it. The sawdust is blended with various additives such as wheat bran, rye, millet, etc. It's then put into a bag and sterilized and given the right conditions and time—you have a mushroom crop. The things that we have to consider when growing shiitake in a bag is that there are going to be competitors that we're going to be giving a plate to eat off of. And it's a very easy plate to eat off of because we've eliminated the competition. Through sterilization we've taken out the bacteria, all the spores of bacteria, we've taken out all of the fungi so we have a very clean substrate with which to work. Once shiitake is inoculated and colonizes the blocks it's still open to contaminants because we have one fungus in that block—shiitake—there are others that want to get in there. Because we have blocks stacked one on top of another we have great potential for contamination problems. So there are a host of problems associated with sawdust-based cultivation but I think they can be overcome. We're trying to overcome them organically and it's a real challenge.

CONCEPT OF SKINNING A BLOCK

For instance, a mushroom farm located in Madison, Wisconsin that was established in 1983 had gone through three ownership changes by 1989—no one making any money along the way. And it finally folded and the building was torn down. They had problems and contamination was certainly one of them. The concept of skinning a block, in other words, making it brown over, was not fully understood by these people. Once you have a shiitake block that has browned over, what that has done is more or less formed a bark which will prevent other fungi , or at least slow them down, from competing with shiitake for the nutrients in the sawdust. White blocks are very prone to contamination. Once a contaminant gets established in the growing room, if you don't have the means to fight it quickly and efficiently it becomes a major problem. Things like this do happen so we need to know the interaction between

shiitake, the nutrients in the block, the substrate it's growing on, and the cycles that other fungi have that want to invade that block. Which brings up fungal competition. When you have a substrate that fungi can grow on, they really want to grow there. It's not just one fungus that wants to grow there—a lot of fungi want to get into it. Take natural logs for instance, with shiitake cultivation our goal is to take that shiitake log inoculate it with a shiitake strain and produce only one mushroom crop: shiitake. Well the cards are really stacked against us. Particularly if we don't keep the needs of the fungus in mind because there are all sorts of fungi out there that want to decay this wood. There's a lot going on in wood decay and it's our job as growers to overcome that. To overcome it we need to have a basic understanding of how contaminants work.

"Black Death"

One contaminant is "Black Death." It is probably one of the grossest things that I've learned to handle in our tenure as mushroom cultivators. If anyone has seen the movie "Alien"—the slime that melts through the steel floor is mild compared to this! It's my understanding that this is a complicated process going on: bacteria, fungi, etc. are wanting to decay this particular block of sawdust. We have found that good daily water management of this block really keeps this problem in check. So we are therefore meeting the needs of the shiitake fungus by a good water management program that will not allow these competitors to get a foothold on this block.

Fungus known as the honey mushroom

One of the things that we see in our laying yard as a contaminant is the fungus known as the honey mushroom. This was known as *Armillaria*. There has been some interest in cultivating this mushroom and my question is "why?" You can pick it in the wild. It's a very tasteful mushroom however, it has a very slimy texture which doesn't agree with me, but there are people selling spawn for *Armillaria mellea*. Lets consider this fungus, what it needs and what it does in the ecosystem and then really try to address the question, "Why would we want to grow this?" Here we have a species, one of 40 world-wide. Ten species of *Armillaria* appear in North America. What do they do in the ecosystem? They do several things: it is a white-rotter and causes root or butt rot of hardwoods in the Midwest, particularly in oaks and pines. There is a species which is a pathogen of oak and that is the species *mellea* and there is another species called *gallica* which is strictly a decay fungus and does not act as a pathogen in the ecosystem. *Armillaria mellea* produces a specialized structure in the mycelium known as a rhizomorph which look like black threads. They use this rhizomorph to travel through the soil and they have this uncanny ability to find trees that are stressed. Once established in that tree they begin to rot it. The rhizomorph we have seen in our laying yard attacks shiitake bedlogs and it's a very strong competitor against shiitake so we need to manage, in our laying yard, against this fungus. Of course if we wanted to grow *Armillaria mellea* as a crop we'd just not bother managing for it. But we had to ask ourselves this question, "Do we really want to grow *Armillaria mellea* as a crop?" Yes, there's probably a market for it in Chicago and perhaps somewhere else. But it's a pathogen and when we're introducing a pathogen into the ecosystem there are consequences that are going to happen because of that.

If you take a look at a typical shiitake laying yard, for instance ours, we have an oak pine under story but the ground layer is very free of any under story plants. Why is that? That's because we're trampling it to death. All the herbaceous layer is gone. The footprints that I make going up to pick up that log and as the help goes to put that log back is leading to soil compaction which, of course, leads to problems with tree roots. Which makes *Armillaria mellea* very happy because we have a situation where we have stressed trees due to our actions where *Armillaria mellea* can take off. Now for instance, picture this, inoculate a log with *Armillaria mellea* and place it in a laying yard that has an oak canopy. You're supplying a ready-food source for *Armillaria mellea* to grow—maybe produce a fruit body or two to keep you happy—but also it will send out it's rhizomorphs to attack the nearby forest trees. So these are some of the things that we really have to keep in mind when we're trying to cultivate new fungi.

We did a fly-by-night experiment or observation last year. We know that *Armillaria mellea* is present in this woodlot because our oak trees are falling over and there was a rhizomorph so it has to be Armillaria mellea. So what we did was we took all of our oak logs in the laying yard and we elevated them above the ground surface by putting white pine posts on the ground. This kept our shiitake bedlogs up above the soil surface. We also had some logs that we didn't quite get to do this to and it's really amazing how the logs that sat on the ground this year are showing a very high rate—my best guess is about 25%— of contamination with *Armillaria mellea*. So we need to work against this problem by working with the ecosystem to get logs up to keep this from happening or, simply, just change the laying yard.

OTHER FUNGI THAT CAN POTENTIALLY BE CULTIVATED

As the interest in fungi as a food source continues to grow, we need to look at other fungi that potentially can be cultivated. Most of the new fungi are wood decay mushrooms, that is their host is wood. I ran into a guy the other day who said, "I'm going to get out of shiitake cultivation and grow morels, maitake and saucer shell." I said, "Good luck, I'm stacking the deck against you." Now why would I say that to a potential customer? Morels are being cultivated and maitake are being cultivated. Granted they are not easy mushrooms to cultivate but they can be cultivated and very reliably. Now saucer shell poses a very interesting question about if it can be cultivated. This fungus is native, well we see it in the Midwest and I don't know if you see it in the Pacific Northwest but I have a hunch that you do. This is commonly called "chicken of the woods" and the reason for that is that the young fruitbody has the texture, and I'd imagine that if you sauteed it in chicken broth it would have the taste, of chicken. It serves as a real good foil for chicken. So all of a sudden you have lots of entrepreneurs out there saying, "By God, this would be great for the vegetarian market." So let's take a look at this fungus. We know that it's a brown rotter of oak in the Midwest. We need to be careful where we're growing this. For instance, around our yard we have a lot of old-growth oak which is prime and ready to potentially be colonized and rotted by this fungus. So we need to consider the surrounding vegetation when cropping this mushroom because we are going to get a spore load that we're not going to be able to contain that's going to go out of the building and

then serve as inoculum for the surrounding trees. But more importantly there's another consideration that is very basic in the cultivation of this fungus and that is that it produces a conidia and that conidia produces very abundantly on just about any substrate you grow this on. So when you're trying to get this fungus to grow on sawdust and hold that sawdust block together it's nearly impossible to do. So there's a technological problem that will have to be overcome before we can commercially cultivate this species. Another consideration is that it's a new species of fungus we're selling to the general public. Will there be people who have allergic reactions to it? Yes, indeed there will be. It's been shown to be a gastrointestinal irritant and there are some people that will suffer stomach problems due to ingestion of this fungus.

ANOTHER WOOD DECAY FUNGUS IS MONKEY'S HEAD

Another wood decay fungus that is being cultivated that is fairly new to the US but very popular in China is the Monkey's Head, the Lion's Mane or *Hericum erinaceous*. This fungus is being produced and sold on the West coast and in the state of Florida. In the Midwest, we were producing it but we found that the public really doesn't know what it is. It doesn't have gills therefore it isn't a mushroom. So we've had to go back and assess how we can market this fungus to the general population in the Midwest. One of the things that we've observed about this fungus is that it rots wood. In the state of Wisconsin it rots hard maple in old-growth trees and it does it in the fall of the year after a good rainfall. So we need to mimic those conditions inside. Humidity is the critical part in this fungus. Yellow staining can occur due to drying in the environment, this not only causes discoloration, it also doesn't make the fungus any more appealing to the consumer and it sometimes imparts a bitter taste to this mushroom. So we know that with this one we really have to be on top of humidity to prevent this problem from happening.

ANOTHER FUNGUS IS AGROCYBE

Another fungus being cultivated commercially that is new to the mushroom scene is Agrocybe. This is being grown in Louisiana and marketed as the "Louisiana Roman Mushroom." Now where they came up with that name, I have no idea. But it is a wood-decay fungus and according to Tom Volk it was collected in the wilds for numerous years and finally someone realized it was a wood-decay fungus and what they could do with it was grow it on a supplemented sawdust base and that is being done now. It's my understanding that the product is being marketed in New York City. The mushroom business is full of rumors and that's just another one of them. Here is a fungus that does have potential, though, as another mushroom crop. It's a wood rotter; it rots a hardwood. It seems like it's fairly straight-forward in terms of cultivation. It will be interesting to see if we can grow this fungus on natural logs up north without causing all sorts of havoc to our ecosystem.

FUNGI KNOWN AS MYCORHIZAL FUNGI

As more and more people become acquainted with mushrooms, we're finding that the phone is ringing with more and more questions concerning the cultivation of a group of fungi known as the mycorhizal fungi. If you're not familiar with mycorhizal fungi, they grow in association with tree roots. At best they are very difficult to culture even on an artificial medium. They are very slow-growing. Some of them are impossible to culture without the living host being present.

The mushroom, Natsutaki, is highly sought after in the Japanese community. We've tried to culture this just for the sake of trying to see if we could get it to grow on an artificial media. It's very slow-growing and then once you grow it what do you do with it? We know that it grows in association with Jack Pine roots. And that's where we're going to leave it because we don't know what the next step is to try to cultivate this fungus. And then are we really cultivating it? Are we really going to have a reliable source week after week after week? No. It's going to be a hit-and-miss thing.

CHANTERELLE MUSHROOM

The chanterelle mushroom should be familiar to some people because you do see it in grocery stores sometimes when it is in season. The chanterelle too, is a mycorhizal fungus and we get calls from people wanting to grow this mushroom and then we have to explain to them that this really can't be done because it grows in association with tree roots and the technology really isn't there to grow this. Usually they hang up the phone very disappointed because it is a highly sought-after wild edible mushroom that I'm told tastes like apricots and smells like apricots, especially when you saute it with tiny little chunks of apricots. It's all something psychological, I'm sure. But we can use this as a case-study of ecological observations of what one really needs to do to find this mushroom in the wild. For instance, we like to hunt this mushroom in the upper peninsula of Michigan. We find it at eskers which are a glacial formation left by the last ice-age which just ended, I think, last year. We find it on sand eskers. We find it on north slopes growing in association with red pine, but really only if that red pine is between 5-15 years of age. We've seen a really distinct correlation there. And it grows best in an understory that is dominated by the mosses. So that is just an illustration of what one needs to look at to find a wild mushroom. You have to know the host and you have to know the environment that it's growing in.

ANOTHER GROUP OF MUSHROOMS IS THE GIANT PUFFBALL

There's another group of mushrooms that have potential promise for cultivation. One of these is the giant puffball. One of the things we know about the giant puffball is that it is a litter decomposer. That is, it rots leaf litter on the forest floor. It does have a very slow growing mycelium. But I'm sure that if someone took the time this one could be cultivated. Then again, I ask the question "Why?" I know someone who really rants and raves about the texture and taste of the giant puffball and I often say, "Boy, it tastes just like the butter and onions we sauteed it in." There is a possibility of production and then the marketing question becomes another issue.

THE BLEWIT DECAYS OAK LEAVES ON THE FOREST FLOOR

Another fungus that we're really looking at for cultivation right now for hobbyists is a litter decomposer known as *Clitocybe nuda*, or the blewit. The blewit is a native fungus that in our part of the country decays oak leaves on the forest floor. We know that it fruits after a cold snap. We have tissue-cultured this fungus and we've grown spawn from it and we've inoculated leaf piles with it. Now this really isn't cultivation, this is more gardening. So far, we've not even been able to garden this one successfully. Every fall when this doesn't show up, Mary Ellen says to me, "Joe, looks like you blew-it again." Anyway, some of the leaf-decay fungi have potential for cultivation. Someone in Australia is growing a similar species on a proprietary mix of leaf-litter and sawdust.

WHAT DO FUNGI DO IN THE ECOSYSTEM

I hope I was able to convey to you my points, which are: If we're going to be growing fungi we have to know what they do in the ecosystem; what they grow in association with; when they fruit; what causes them to fruit; what they have to compete against to successfully grow in an ecosystem. We need to be able to transfer that knowledge that we've learned from the field, to the lab and production facility.

QUESTIONS AND ANSWERS:

Q. *You talk about black rot. Does that usually occur where there's too much moisture?*

A. In our facility we find that the black rot problem is associated with the block surface being too dry. So we've gone to managing the block surface to keep moisture content clammy rather than sandpaper dry.

Q. *Have you had any experience with Penicillium?*

A. Our experience dates back to about a year ago, we were doing a grand experiment on skinning blocks out of the bag. We had numerous problems with it growing on the white block surface. It dawned on us that it was a problem due to not having enough moisture on the surface. We had too dry of a surface and it seemed to like that. Now you have to go the other way: too wet of a surface will cause problems with *Trichoderma*. You have to find that ideal spot in between there.

Q. *What's your water source for managing your log surface and washing? I assume you have to be pretty careful so you're not bringing in other competitors.*

A Our water comes from a deep well. It's a private well 137 feet deep drilled on the property. It's very hard water; high in calcium, iron and sulphur bacteria. If you're bringing water in from a municipal system or a well, chances are contamination from the water source are somewhat limited. It's when you start dealing with outside water sources such as farm ponds that you have to be careful what you're bringing in. One thing we do every year is have our water tested. It's required for our organic certification and that gives us the whole rundown on what's happening in our water supply. It may not be a bad idea for everyone to do that.

Q. *Is it true that mushrooms have the ability to accumulate heavy metals? And if so, is this a problem especially for those in the rice fields, in the forest and areas where there might be heavy metals?*

A I'll try to address this but I would appreciate any comments from the audience. I do know that fungi do accumulate radioactive materials as shown by the fallout at Chernobyl in the Scandinavian countries. So they do have that ability. So you really need to know what your material is and what it has in it before you start growing a mushroom crop.

Q. *What are the ecological considerations that set up the reverse of what you were talking about—the escape of shiitake into the natural environment? Shiitake, of course, is not native to North America. Have you had any experience with escaped shiitake into the surrounding woods near a laying yard or a shiitake farm? I've personally heard of very few of these.*

A Yes we have. In 1990 we had a big wind storm which dropped quite a few trees surrounding our laying yard. I cut some firewood from those trees but didn't pick up all of the pieces. Two years ago I went out looking for firewood and found some wood that had a very vigorous white rot fungus in it. We took those logs and put them in our laying yard, and by gosh, last summer those logs fruited shiitake. We've been growing shiitake in that same area for 12 years and that's the first incidence of it. So yes, it can escape.

PHOTO CONTEST PARTICIPANT

Royce & Sylira Savage, Photographer