The Importance of Mycorrhizal Fungi to the Soil:
A Special Interview with Wendy Taheri
By Dr. Joseph Mercola

DM: Dr. Joseph Mercola
WT: Dr. Wendy Taheri

DM: One of the most important strategies we can take to improve our health is to grow our own food, but that’s not easy if you don’t understand soil microbes. Hi, this is Dr. Mercola, helping you to take control of your health. Today we are joined by Dr. Wendy Taheri, who is a research microbiologist. I was introduced to her through Gabe Brown, who is a farmer in North Dakota and who is a real proponent of many of these principles.

Dr. Taheri’s formerly employed at United States Department of Agriculture-Agricultural Research Service (USDA-ARS), and she’s founded a new company, Terra Nimbus. She works with farmers and helps them enhance their yields, reduce inputs, and improve nutrient use efficiency (NUE). We’re really delighted and honored that she’s able to join us today. Welcome and thank you for joining us.

WT: Well, thank you. I’m glad to be here.

DM: I’m really looking forward to this because the mycorrhizal fungi play such an important role in helping us produce our food, and really, for nourishing us directly and indirectly. I’m wondering if you could give us some details about your background and how you first started studying in this field.

WT: Okay. I got my PhD in ecology and evolutionary biology at Indiana University. While I was there, I performed this experiment. I was doing restoration work from old coal mines to make the soil grow plants again. We were focusing on using microbes for restoration. During an experiment, I saw that the microbes I used were able to increase plant biomass by 69 percent. I said to myself, “Wow, we’ve got to get this to the farmers.” After I graduated, I took a job with the USDA to try and do that.

DM: Excellent. What was your work with the USDA? What were your responsibilities?

WT: Primarily, I was working under a senior scientist. We were trying to develop tools that allow low-cost and routine testing of mycorrhizal diversity in soils, so that we could do some more broad-scale evaluations on the impact of our farming on these organisms.

DM: I think we probably should start there, because it’s likely that a large number of people listening to this or watching this may not be familiar with mycorrhizal fungi. Why don’t you give us a primer and sort of set the perspective on their importance in soil health.

WT: Okay. Very few people have ever seen them. Most people, when they think of fungi, they think of mushrooms, right? These organisms don’t produce any large structures. You need a microscope to see them. Their spores are in the soil and their hyphae are in the soil. They actually integrate with the plant. It’s the oldest known symbiosis to science, where the hyphae filaments… So, a fungus is made up of little threads. We call them hyphae. They penetrate the roots of the plant and get inside the cells where they grow an organ called an arbuscule. That’s why we’re interested in arbuscular mycorrhizal fungi (AMF).
There are actually seven different kinds, but these are the only ones that really matter. They’re probably the most important ones because they associate with so many different plants.

**DM:** Excuse me, for interrupting. But these arbuscular mycorrhizal fungi are one of the seven types of mycorrhizal fungi? Is that correct?

**WT:** Yes. The arbuscular kind is one of the seven kinds. The other six are kind of specialize for different plant groups but the arbuscular kind associates with 90 percent of plant families.

**DM:** Terrific. Sorry, I interrupted you. You can continue.

**WT:** That’s okay. What happens is they are now part of the plant, right? Because they’re inside the plant’s cells, in its roots. And their hyphae are going out into the soil, acting like very, very fine roots, smaller than the roots, smaller than the root hair, which gives them access to a larger volume of soil, so more nutrients. They specialize in uptaking nutrients, particularly minerals, trace minerals, and things like that, but especially phosphorous, which is a limited resource. We tend to put a lot of that in our soils and use it not as wisely as we could or as conservatively as we should. This is really important because we’re going to run out eventually. Most of what we have is going to wind up in the oceans.

It’s hard to imagine just how interconnected… Most people don’t have a background in ecology. They don’t realize that the farming complex covers 30 percent of the planet. It’s agriculture. It’s the largest ecosystem on the planet right now. Our soil, our atmosphere, our water, our oceans, our streams, and our lakes are all interconnected through nutrient cycle. Right now we’re dumping a lot of our phosphorus into the ocean, which is not so good.

**DM:** Yeah. Because when they apply it as fertilizer, of course, it’s not 100 percent utilized and the runoff goes into the waterways, which spill eventually into the ocean.

**WT:** The runoff is a huge problem, yes. And then also, a lot of it is just how we manage our waste as well. We flush the toilet. We eat a lot of that food, right? A lot of that phosphorus travels through our body. [When] we flush the toilet, that’s where it ends up. It’s not being retrieved.

**DM:** Yeah. I’m a big proponent of recycling that. And personally, in my own residential area, I recycle my own urine and put it on the plants that I have. It’s a form of nitrogen and phosphorus. Because I think it’s insane. Eventually our culture is going to wake up. We cannot be throwing these valuable nutrients into the waterways. It’s just insane.

**WT:** Yes.

**DM:** It belongs back in the soil.

**WT:** It’s my opinion that everyone who eats food or breathes oxygen should be concerned with how we manage our agricultural complex because the soil and the organisms in it is the only system large enough to offset global warming. These organisms are drawing carbon through plant, through photosynthesis. The plant is taking carbon out. It’s feeding carbon in the form of sugars to mycorrhizal fungi. In fact, they get 100 percent of their carbon from the plant. And then they utilize that carbon to build soil structure, which increases the soil quality.

It’s the best way to sequester carbon, and it’s the only system big enough to offset all the oil we burned over the last century. We could actually do that. A group of scientists is working on demonstrating that how we manage our soil can affect how much carbon dioxide we can store in it. And mycorrhizal fungi use that carbon to form soil aggregates, which is how we build our soil structure. They are like keystone species in the soil; they’re very important.
When we till the soil, we have runoff into the oceans and a lot of phosphorus winds up there. But also, because we have so much carbon dioxide in the air, it’s forming carbonic acid when it mixes with water in the ocean or lakes. This means our water is becoming acidified, because all these systems are interconnected. No one has done the research to say, “Well, at what point are those tiny microbes photosynthesized in the ocean? When to stop producing oxygen?” There are very few people who realize that 50 percent of the oxygen they’re breathing this minute came from the ocean.

**DM:** Interesting.

**WT:** Balancing global warming, carbon dioxide through management of agricultural systems can solve a lot of problems for humanity.

**DM:** And the oxygen being produced in the ocean is from aquatic plants?

**WT:** Algae, mostly.

**DM:** Algae?

**WT:** Yes.

**DM:** Okay, terrific. Part of the carbon that they consume and configure into the soil, at least the mycorrhizal fungi, has a glycoprotein that was discovered about 20 years ago, glomalin, which adds to soil aggregates. I’m wondering if you can expand on that because it seems to be a really important part of the soil structure and retaining water.

**WT:** You have definitely done your homework. I’m surprised that you know about that. Glomalin is a protein that is produced by the arbuscular mycorrhizal fungi. The way soil forms aggregates… If you don’t have aggregates, you have dust and everything goes away. That’s not a good soil for farming. Aggregates are little glued-together particles that don’t fit together and compact. This is how we alleviate compaction. And the pore space is what allows drainage and air to get into our soil because plants need oxygen and many of the microbes do, too.

Also, those pore spaces are what determine, to a great extent, the water-holding capacity of our soil. The amount of carbon in the soil is how water is held in the soil. If we don’t increase our carbon to the soil, the soil’s ability to hold water declines. That means we’re more subject to problems from drought and flood, both. Because when you flood, your soil can’t absorb the water and hold it for when there’s a drought later, it all runs off the top and takes away your topsoil, which is the most active, biologically active, most nutritious, and most valuable part of your soil profile. All these things work to interact and affect what happens when we farm.

**DM:** Gabe shared stories. I’m sure you’ve heard them. In North Dakota, he gets about 16 inches of rain every year, and most of that comes in a day or two. Because of his no-till farming practices and the improved structure, he’s actually able to retain almost all that water where his neighbors, their water’s running off and depleting their topsoil.

[---10:00---]

**WT:** Yes. Just the physical act of covering your soil protects it from a lot of erosion. That’s why cover crops are so important in protecting soil. But also, we don’t normally grow our crops under diverse conditions. We grow a monocrop, right? One species covers 800 miles of corn across the nation. I actually drove one time that far and saw nothing but corn.

**DM:** Wow.
WT: This creates a problem for the microbes in the soil that are cycling these nutrients, because they can’t all associate with corn. We have to introduce diversity to have microbial diversity. There’s a long list of benefits that microbes give us – from defense from plants; to cycling of nutrients; defense against infective agents, pathogens, and things that can make our plant sick; and uptake of nutrients. There are just so many different things that are going on. There’s millions, millions, hundreds of millions of things in the soil.

You can’t manage for everything though. You certainly can’t manage for that many things. What you need to do is to manage for your keystone species because they actually boost the other beneficial organisms. The cover crops are an opportunity to introduce diversity. And above-ground diversity in our cropping systems creates the low-ground diversity. We really need that. It’s really important.

DM: Yeah, with respect to the number of microbes, I heard an interesting analogy on that. That with every teaspoon of soil, there’s more microbes than there are people on the planet.

WT: Oh yes, definitely.

DM: It puts into perspective when you view it from that way. Now, of all those, there’s another mycologist, Paul Stamets, who I’m sure you’re familiar with and who stated that 70 percent of the soil microbes are fungi and I’m wondering from your experience if you believe that’s true.

WT: I have never really looked up that information but I’m willing to take pulse – word on it.

DM: Okay, because I mean if that’s true, that’s important because, really, it’s very clear if you start to study this, that optimizing soil microbiology is really the key to improve soil health. And if 70 percent of the microbes are fungi, then we really need to be focusing a lot of attention on that. That seems a reasonable assessment. I’m wondering if you could provide some ways on how we can improve the health, quality, and growth of mycorrhizal fungi in the soil.

WT: Well, as a consumer, you can ask for organic food. You can vote with your dollar, right? I want the best-quality food I can get. I want to encourage more people to buy, and I want to encourage the people who are growing to come over to this market, and the people who are producing seeds to also produce more organic seeds, because right now, that’s a problem for farmers – getting the seed that they need.

One of the things we’ve gone, for instance, with genetically modified organisms (GMO) is, without labeling, we don’t have choices anymore. How is that even American to have to say, “We’re going to take your choice to even know when the most fundamental thing that you can do is feed your family and see to their health that way? We’re not going to allow you to even know whether or not a food is a GMO and make that choice for yourself.” We’ve taken that away from Americans and I think that is wrong.

DM: Well, it’s not “we,” because that’s unfairly criticizing people watching this video. It really is the government and the biotech industry collectively operating together who have manipulated the system.

WT: All the Americans do. But as Americans, we need to demand our right to know this and to make our own choices. I’m not speaking for them or against them, but I’m against hiding it because I don’t think that’s right.

DM: Well, again, it’s an important part of the process, and maybe we can take a little tangent here before we discuss the other component. But 85 percent of the plants that are genitally modified have resistance to the herbicide glyphosate. Glyphosate by itself… Maybe you could address how that impacts mycorrhizal health, because from my understanding, it has a significantly adverse impact.
WT: I have seen studies that go both ways. What I believe is going on is the... First of all, a lot of these studies are using seeds that are coated with pesticides, including fungicides. Certain species and certain groups are probably being affected by it, and others aren’t. In my opinion (and I have not done a study on this myself), are the most likely event. But mycorrhizal fungi are pretty sturdy, so they really stand up to a lot different things. But individual families of mycorrhizal fungi are more sensitive to some chemicals than others.

We tend to put a lot of different chemicals into our cropping systems. What I have seen myself is a decline in numbers, a decline in diversity, and a dominance by certain species in our agricultural complex, which means we’re not getting all the benefits we could out of it.

DM: Okay, you’ve mentioned earlier that one of the things we can do to increase the fungal growth in the soil is to encourage people to consume organic, which I thoroughly agree with. But wouldn’t it be important to take another step? Because just growing crops organically doesn’t mean you’re necessarily not doing no-till agriculture or using cover crops and putting armor in the soil, as Gabe Brown would say, too, which are all practices that we know increase mycorrhizal growth. Maybe we can go to the next step: certainly purchase organic but try to know your farmer, grow it yourself, or find a farmer who is integrating this practices.

WT: For organic farmers... A lot of this is farmer’s perception. That’s good. When I came out here in Georgia, I said, “Leave all the residue.” And they said, “Oh, it looks ugly. It’s bad,” you know. I went, “I’m protecting the soil.” But we have preconceived ideas of what a farm should look like and so do the farmers. For organic growers, weed control, which is often propagated by tillage, because it plants your seeds for you; all the weeds seeds would have otherwise remained on the surface where they’re susceptible to extreme weather and predation. We plant them when we till.

But we don’t have enough research yet to help them manage weeds. In fact, I’m working on that research right now. I’m working on a completely organic herbicide for weed management, so that they don’t have to till. Randy Anderson of the USDA at ARS has done a lot of research on cover crops that can be used to suppress weeds. If you go cool season-cool season, or warm season-warm season, he said, “Over the course of a few years, you’ll just deplete that seed bay completely and won’t have a weed problem anymore.” But it’s hard to get farmers to switch over from what they know works and try something new, although Gabe Brown, myself, and many others are trying to help them make that switch.

DM: It seems it really is an important effort to lead because there’s so much at stake here, as you mentioned earlier. I’m wondering what a typical home gardener might consider doing. I’ve interviewed a person. His name is Paul Gautschi. But he produced a documentary called “Back to Eden.” He essentially put on over a number of years hundreds of thousands of pounds of woodchips, and basically created this phenomenal soil that, not only did it provide an armor, but provided nutrients, and I believe increased the mycorrhizal fungi growth, and also served as the earthworm food. I’m wondering if you could comment on the use of woodchips for improving mycorrhizal fungi growth.

WT: I have not looked into woodchips and mycorrhizal fungi. They do not digest wood necessarily. They’re not composters. They do mine minerals and, particularly, phosphorus but they probably... It’s more likely they’re working in conjunction with other fungi that are composters. It’s hard to breakdown wood. That takes things that ligase and enzymes that are produced by a very specific group of fungi. And if you have a lot of wood breaking down in your soil, then those guys are going to be very active.

As things are broken down, the nutrients become available, are captured, and transferred by the mycorrhizal fungi. It’s a huge interaction between a lot of different organisms that cycle nutrients. It’s not just one guy that’s responsible for everything. I focus on the mycorrhizal fungi because if you manage for
them, you’re putting much managing for a lot of other beneficial things, including beneficial insects and other things that are important.

It’s been found that the mycorrhizal influence goes all the way to pollinators. Pollinators, if you offer them a choice of the same plants – mycorrhizal or non-mycorrhizal – even if you mix them together, they go for the mycorrhizal plants. They show a preference for them. I think that’s just because of the higher nutrient content. That’s my guess. I haven’t tested that. And I don’t know that anyone has.

DM: It’s not surprising. Look at the experience ecologically in Yellowstone where they took off the top predators, the wolf. The sequence of events have actually wound up changing the course of rivers because of all the downstream side effects that it had in changing the growth of the plants. It’s not surprising to hear that that has some type of impact.

WT: I saw that video. It was amazing.

[----20:00----]

DM: What are some of the other strategies that we can use? You’ve mentioned that you’re involved in focusing on strategies to improve mycorrhizal growth. What are some of the other ones, aside from purchasing organic?

WT: Well, there’s no-till and that’s for the farmers, of course. There is using cover crops. Those are the two main practices that are really important. I’m not a big fan of GMOs. It’s not because of the technology; it’s because it’s a bad idea to have constant exposure because that’s what breeds resistance. When the pests that you’re trying to target is constantly exposed to the same chemicals, that’s what happens. You kill the guys that are susceptible; the guys that are resistant are your new breeding population. I don’t think it’s good ecology frankly to do that. Reduced inputs.

Also, we need to reduce the amount of phosphorus we use. Too much phosphorus suppresses the plants association with mycorrhizal fungi. One of the problems I’m seeing... I had a student who is working with me who wanted to work with soybeans. I had seen some research that indicated to me that soybeans were becoming non-responsive to mycorrhizal fungi. I told him to test his plants. Well, he ran a test before he did his experiment to make sure that he had responsive plants. He went through one variety after another after another. Then he switched to wheat and then to sorghum.

The trend here is that we seem to be breeding the ability of our crop plants with these high-input breeding systems, so that we’re no longer selecting for the mycorrhizal association. This means we are breeding the ability of the plants to form the association out of them. I am, in March of this year, starting a seed certification program that will score whether or not and how mycorrhizal seeds are. Anyone can send me seeds and say, “I want to know how well these guys respond.”

If we lose that symbiosis because of the nutrient use efficiency that is created by these microbes, and their important position on the soil, and they start to die out in our soils, I don’t think we will ever become sustainable, which means our residence here as species on the planet will be numbered. As far as how many years we have left.

DM: Yes.

WT: We have to be able to grow enough food and we can’t really afford to lose this association.

DM: Some people might counter. I’m not necessarily one of them. But they would argue that you can grow plants in alternative systems or growth mediums like hydroponics. It would have seemed that mycorrhizal fungi are present in a hydroponic system. How that does work?
WT: That is true. That is true. I have recently been asked to develop some inoculants for hydroponic systems. You can do some amazing things with hydroponics, but you’re leaving the system that affects our ocean and the air we breathe to some degree. The cycles are now being changed. And where is the runoff from that hydroponic system going? Can we really afford to replace the one-third of the planets terrestrial surface with hydroponics? It’s a great strategy for places where they can’t grow much food, like the dessert, but it’s one that’s not in scope.

DM: Yeah, I don’t think it scales very well. And certainly, it’s not ecologically sound. I mean, that’s not the way food was historically grown. It’s not grown through hydroponic systems. I discourage people from using it. It’s not to say they can’t produce some descent food, maybe even if it’s [done] properly. Of course, it all depends on the nutrients they’re using, a nutrient-dense food. But without this association with mycorrhizal fungi and the other soil microbes, it’s just difficult to imagine optimally healthy and nutritious plant because it’s this really dynamic, complex symbiosis that occurs to improve the health of the soil and nutrients that it provides us.

WT: Right.

DM: It’s hard to imagine that occurring in a hydroponic system.

WT: Yeah, a hydroponic system is not using soil, so you’re not really impacting soil. You’re not improving it. Are you harming it? Well, somebody is digging up that phosphorus and those nutrients and selling them to use. Now, humans are doing the work of nature. And whenever we do that instead of looking at nature and saying, “How can I get nature to do this as part of the balance of how I’m growing my plants, instead I’m going to do it with chemicals,” which is what we’ve been doing for 50 years, nature’s job with chemicals.

Well, we inevitably have discovered we’re not as good as Mother Nature and there are side effects to what we’ve done. We have to be careful, because look at the size of our agricultural complex, a third of the terrestrial surface of the world. It is the largest ecosystem on the planet. We have to take a real serious look at the impact of that system on our water and air quality. We can't ignore it, it’s too big.

DM: Now you’ve mentioned one of the strategies is the use of cover crops. I’m wondering if there are any specific cover crops that are particularly beneficial to the growth of the arbuscular mycorrhizal fungi.

WT: I am getting ready to do some work with the people in Nebraska, Green Cover Seed. They’re a cover crop company. They have got just a lot of selection. They want me to start testing their cover crops for how much. There hasn’t been…This will be the first broad-scale testing of cover crops for how well they promote mycorrhizae and which species they promote best.

In previous research at the USDA, we did find that oats were readily colonized by a large number of different species and different groups. We only tested four plants though, so that’s not very many. But oats were really good. Clover was good, too. It was crimson clover we used on that one. But again, variety matters. I don’t remember what variety of oats we used, everleaf or something. Because we found that some oats are probably no longer mycorrhizal either just because of the way we breed them. We go out some place that’s fairly tropical, you got a long growing rain season, and then we pile in and maximize the chemicals. We select from the plants that do best under those conditions. What we really need to do…

DM: Are these typically commercial agriculture scenarios?

WT: Yes, commercial agriculture scenarios. And what we really need to do is… The only thing that’s really focused on is yield, yield, yield, yield. Because we can stack the genes now for pest control. But more importantly, what we should be doing is looking at the mycorrhizal association and breeding our
microbes and our plants together to work as a team and enhance the benefits, because the benefits are tremendous.

Let me give you a quick rundown (I can’t discuss all of them in the time we have) – increased soil fertility; increased water-holding capacity; reduced soil compaction; heavy metal tolerance; they produce a more nutritious product; they replace harmful chemicals; they can reduce or eliminate runoff when you manage for them and leaching because you can reduce your inputs; they can increase plant nutrient use efficiency; they increase essential oil production; they offer protection from both fungal and bacterial diseases; they create drought tolerance salinity resistance, earlier flowering, more flowers, more fruits, more biomass; and they sequester carbon in the soil. It’s win, win, win with these guys.

**DM:** Yeah.

**WT:** The list goes on. It’s even longer if I thought harder on that. I just wrote down those this morning. I said, “Okay, I got to let people know how important these organisms are and that we have to maintain their diversity in our soil in order to be sustainable.” What we would like to do is have a testing program and that’s what we’re doing Green Cover Seed folks, not only for cover crops but also for our crop species. And then to get some crop breeders to contact us and say, “We want to work with you to elevate the nutrient use efficiency between the plants and the mycorrhizal fungi,” because there’s an intersect there that if you bred towards that point, you would get the maximum efficiency with the lowest inputs.

**DM:** That’s terrific. Would it be safe to assume though that most seed companies that are providing seeds for typical residential gardeners would be using more like an heirloom seed, and that these would not be necessarily need to be tested because they haven’t been selectively bred for yield on a commercial scenario?

**WT:** I don’t know that it’s really safe to say that unless you specifically go after heirloom seeds. I was surprised when I was looking at some of these non-GMO websites to see that what they’re doing and that they have lists of plants that I commonly buy – squash and other things – in grocery stores that I had assumed that were non-GMO. But it’s kind of the GMO mentality is sort of seeping into everything. There’s really no way to know because you don’t have any labeling. You don’t have a choice unless you grow your own food or buy organic. That’s the only way to really know for sure if you’re getting what you want.

**DM:** Do you think it would be a wise idea for gardeners to use your service to confirm that their seeds are going to be mycorrhiza compatible?

**WT:** I would prefer to see seed companies use this service.

**DM:** Seed companies, okay.

**WT:** Because it’s an expensive process. Farming groups could bond together and say, “Let’s share the expense and get this and that, and the other tested.”

[----- 30:00 -----]

We haven’t put together our price schedule yet. It’s not going to be out until the beginning of March or the end of February. But it’s costly to do a molecular work. If you don’t do it using molecular techniques, it’s still costly because it takes a lot of man hours to look at roots, measure structures, and things like that. It’s a lot faster. As more people get the testing done, we’ll be able to reduce the prices because we’re actually sequencing DNA from the roots. We’re extracting the mycorrhizal DNA out of there and measuring how much is in there in order to quantify it, and we’ll be comparing that with the numbers of mycorrhizal structures we see.
DM: That’s terrific. It sounds like an important piece of work to make sure that we’re getting these seeds that are growing with these associations because these fungi are so crucial to producing nutrient-dense food. I applaud you for those efforts.

WT: Thank you.

DM: I had previously interviewed Dr. Elaine Ingham, who is a… I’m sure you’re familiar with her work.

WT: Oh, yes. She’s great.

DM: She was at Oregon State University, but was pushed out of there because of the studies she was doing, which weren’t supportive of the biotech industry. She has her own company now. When I discussed the issue of seeking to use strategies to encourage mycorrhizal growth in the garden, she thought they were more particularly beneficial or even composed for trees or perennials, and maybe not necessarily as much for the annual crops like a lot of vegetables that we’re growing. I’m wondering what your position is and how you might reconcile the importance of the mycorrhizal fungi in those scenarios.

WT: The mycorrhizal fungi that associate with trees are from different groups of mycorrhizal fungi. Some trees, in their really seedling stage will associate with arbuscular kind of mycorrhizal fungi. But most of those trees associate with other types of mycorrhizae, so they’re not really my direct area of study; they’re more of an indirect area of study. As far as annuals and perennials, they associate with different groups of mycorrhizal fungi.

The arbuscular kind, of course, this is primarily your vascular plants. The perennials tend to associate with the family called the Gigasporaceae. I almost never see that family in present as far as spores go in agricultural soils. I think they’re being kind of wiped out because they can’t live without a host. Here we have our plant growing and then we kill it all of the sudden when we harvest. Suddenly, the host is dead and they take a little longer to form their spores. They can’t really propagate from hyphal fragments as some species of mycorrhizal can, so they tend to die out. When I see them, I call the farmer and ask them of what his management practices are, usually and say, “Hi! I saw a Gigasporaceae.”

DM: That’s great. What about the typical residential gardener though? Because you can purchase mycorrhizal fungi inoculants. I’m wondering what’s your position on those, how useful they are, and if there are any strategies that one can incorporate to maximize their effectiveness.

WT: Yes, there are. There are a lot of things you can do with container gardening that you can’t do in the field. For instance, I have what I suspect as the largest privately-owned collection of mycorrhizal fungi. It’s probably got about a hundred strains. If I took one species of plant and test it individually with all of those 100 strains, most of them would be good but there would be a continuum of not-so-good to awesome. Okay?

DM: How do you determine awesome? By plant growth?

WT: Awesome is 200 percent increase in plant growth compared to about…

DM: Is that a common observation if you get a good association of doubling the increase of the growth?

WT: When you compare to with and without, yes.

DM: Yes, okay.

WT: Now, let’s say, I did that and then I get these awesome mycorrhizal fungi and I said, “Well, everybody should put this in their fields.” Well, in the field, you have competition. That particular species that can double or triple the growth of your plant may never successfully colonize your plant to a degree
that allows you to get to realize that growth. That’s the problem that you face when you add inoculants to your soil. They’re competing with everything out there that is adapted already to your soil conditions.

The scales of success are already tipped against them because they’re not pre-adapted. Most of the inoculants that I have seen are the same group of 12 species that are being recirculated. One of the species, for instance, is deserticola. It’s from the desert; the name tells you that. If Glomus deserticola was put in some place cool and warm into your soil, what are the odds it’s going to survive? It’s kind of like [putting] a polar bear into the desert expecting it to do well.

These species that they have selected have been selected because they’re accessible. A lot of companies have started up and keeps seeing the same species just recirculating. They’re probably buying each other’s products and stealing from each other. That’s my guess of why I always see the same groups of species. They’re not the best species, I don’t think, for your plants. It’s an infant industry and it’s growing. But in spite of that, with the container, usually any mycorrhizae are better than most or usually better than nothing.

I don’t want to slam the industry. I’m just saying that the industry still has a lot of work. I’m doing some development on inoculants myself but I think we’re three to five years away from something we know can compete in the soil for horticultural practices where people are growing in containers. It would be for high value crops, for instance, strawberries and specialty crops. Hamming the right species is really what matters. Any number of species can boost growth but having that awesome one is what you want to look for. And that work hasn’t been done yet.

**DM:** Okay. Probably, there’s no specific current commercial recommendation you’d have for inoculants.

**WT:** Not yet. The whole reason I decided to do some inoculant work and development is 1) I have the culture collection to do it and 2) nobody was doing it right, in my opinion.

**DM:** Well, good.

**WT:** So, I said, “Okay. I’m going to see what I can do here.”

**DM:** I look forward to that because it’s such a crucial component. Now, assuming you develop that at some point, and you’ve got the ideal mixture for the majority of vegetables that we’re growing or plants, I’m wondering if there are specific strategies that you can use to increase the numbers, because it’s a number’s game ultimately. And when you make compost tea, you can aerobically, massively increase the numbers by circulating water for 24 hours or so or maybe a little bit longer and just get massive amounts of bacteria. Does that same process work for the mycorrhizal fungi?

**WT:** It doesn’t. They can’t live without a host plant. The reason the inoculants are expensive is they’re hard to grow and separate from everything else, and put into inoculant and know that you haven’t carried over any disease organisms that are growing with your plant or anything like that. There’s a lot of work involved in it, and that increases the price. You really need scientists who are assisting in this kind of development.

You have to grow them in pots with plants to get them to sporulate while they’re associated with the roots. A few species are grown axenically. That means without a host plant, in a petri dish where they have modified the system enough and found out what exactly what they need to trick the AMF into growing in the absence of the plant, and being able to take up nutrients. The problem with that system, in my opinion, this is just my opinion, is that you’re no longer selecting for plant dependency.

Now, you have the opportunity to have a fungus that is not tied into the plant’s biology as effectively as it may be before as generations occur. That fungus, its demands and nutrients use is not balanced by what
the plant can give because it’s selection for breeding. Its breeding selection, whether they realize it or not. I don’t that’s really the best way to go. For what it’s worth, that’s my idea.

**DM:** Okay. These are really important species to encourage the growth in your soil. Assuming you made it clear that you’re really not going to increase those numbers by compost tea methods. But if you purchase an inoculant, what would be the best strategy to make sure that it’s growing and it’s going to reproduce? Would you take the whole plant out before you put it in with the seeds? If you have existing perennials or trees, do you dig down and put it in and cover the dirt over?

[---40:00----]

Or do you make sure that it’s cover with either mulch or cover crop? What are some of the ways that you can ensure that the likelihood of the inoculant will be successful?

**WT:** Remember again that you’re dealing with an ecological system. The best management practices for mycorrhizal fungi are, again, cover crops, above-ground diversity, and no-till. Minimize your soil disturbance because you’re breaking up your hyphae, which are not so good with for your plants, as soon you start digging around. As far as inoculants go, most of them are probably, to a large degree, one species called Rhizophagus, in the Rhizophagus genus.

Anyone who fertilizes already has a lot of Rhizophagus. In my opinion, why spend a lot of money for it? Make sure that’s not what all you’re getting because that particular species is the only group or we can just take the fungal filaments, the hyphae, and grind them up to into teeny, teeny bits. And each little tiny microscopic bit will become a propagule and be capable of colonizing a plant. But most mycorrhizal fungi can’t do that. They’re nitrogen lovers. They adapted to our growing system. So, first I would make sure that I wasn’t getting mostly Rhizophagus. That would be my first thing in shopping for an inoculant.

The second thing in maintaining them is make sure your roots are going to pass through them or that you’ve coated your roots. Some of these inoculants contain trace minerals and other things. Your increase in growth is almost entirely a result of the improved fertilization and not the microbes. You could have bought that fertilizer for a fraction of the price. Buy only microbes and do little task and see if they’re showing an improvement but it all starts with good management.

If you already have healthy soil and you continue that management or improve your management, everybody has these organisms in the soil. What you want to do is increase your diversity. Start putting diversities in your garden – companion planting and things like that. You’ll start to propagate them naturally in your soil. For container gardeners now, a lot of times you buy pottings or whatever and that’s undergone some process to make sure that it’s pretty sterile. In that case, the inoculants are more important.

**DM:** That’s good advice, especially about the species to avoid in your inoculant if you’re going to use the expense for that. I’m wondering if there are other indexes or scales that one can use to assess the quality of the soil. I’m thinking of something like the density of earthworms as an indicator, obviously beneficial for other reasons than mycorrhizal but typically earthworms thriving in healthy soils, that would also encourage the growth of mycorrhizal fungi.

**WT:** That’s an excellent question. It’s hard to test mycorrhizal fungi. I have worked with USDA to make that kind of testing available but it’s not there yet. You can’t just go out and say. “How many mycorrhizal do I have,” and get a really accurate response of how much diversity you have. There are some companies that will count how many of this and that they saw. But there’s a lot of slop in a lot of those methods.

Earthworms are very good indicator of healthy soil. But also check your garden for top predators – insect predators, spiders, and things like that. Those top predators – lizards, spiders, and things that are
eating other insects – indicate that you’ve got a good balance. Because the mycorrhizal fungi are everything with your soil, right? You’ve got a whole ecological system. You don’t want an insect pest to get out of control, and maybe you’d really rather avoid using pesticides.

When you have diversity, you have homes for a lot of different kinds of organisms, and that’s when your predators start to come in. That keeps everything in balance. It doesn’t matter that you have insects that are eating a leaf here and there. What matter is whether or not it gets out of hand. Most of the time, pathogens and things that grow on your plants are always present. Most of the time, they don’t have much impact at all because things are imbalanced. You want to make sure that your management practices are not favoring things that are eating your plants while disfavoring the things that hunt those things that eat your plants.

**DM:** Right.

**WT:** If you keep things in balance, it will work. If you have to keep adding stuff or you have an outbreak – whether it’s an insect outbreak or anything else, a disease – the first thing you do is you try to correct for it. The second thing you do is you analyze. You say, “Okay, I’ve got it under control. Now, what caused that imbalance? How can I correct my management to keep that from happening again, so I don’t have to use a pesticide or something else that I’d rather not use?”

**DM:** Terrific. Have you written any books or papers? Do you have a website that consolidates some of the information you’ve acquired?

**WT:** Well, we’ve only recently got our company started. We are going to start a YouTube channel, and talk to farmers and people like you, just like you’re talking to me. It’s all kind of new and just getting started. I am in the process of writing a book for farmers about mycorrhizal fungi and what farmers should know about them. That covers a lot of what we’ve talked about here today. That will just be a little pamphlet that they can download or pick up at some of the places where I give talks. Like I said, we’re kind of new at this and the business site, we just relocated. We took down our website and said, “Okay, we have to wait until we make up our mind with what we’re doing here.”

**DM:** All right. Let us know when you get that up and running. We’ll be glad to incorporate it to the article that we’re putting together. Do you have any other comments you’d like to make about the subject?

**WT:** I think we had a good coverage. I would, if it’s alright, like to mention that the seed testing and stuff, the research that we think that needs to be done; we’re going to start a Rocket Hub campaign and ask people to help get that done, so those kinds of test will be made available to farmers and so some of the stuff that the seed companies don’t traditionally test can get tested. We’re going to offer inoculants and stuff in exchange for those. We’re hoping the public will get involved and say, “Yeah, let’s get this research going.”

**DM:** Well, just give us a link and we’ll be glad to incorporate that into the article.

**WT:** I’ll certainly will.

**DM:** All right. Well, thank you so much for the time, the information you shared, and all the work that you’re doing in improving the health of the soil.

**WT:** Well, thank you. I appreciate being invited out to talk to you today.

[END]