Today's webinar coordinator and moderator is David Lamm. David is the leader of the National Soil Health and Sustainability team, located here at the East National Technology Support Center in Greensboro. And with that, David, I'm going to turn the webinar over to you so you can introduce the topic and our presenter.

Thank you very much, Holli, and I want to send out a big welcome to everybody. And I want to apologize for my voice. I'm battling a cold, if you can believe that in the middle of summer. And it's decided to settle in my voice box there, so if I sound a little raspy, it's just because that's just the way it is.

I'm really excited about today's webinar. It's the last one in the soil series. This'll be the 10th one. And I think we saved the best one till last. I've had an opportunity to hear Klaus speak as part of the Soil Renaissance Forum that was held earlier in the summer, about mid-July. He participated along with Dr. Honeycutt and a few other folks, and he'll explain more about that, what that is. Klaus is a farmer from Penn Yan, New York, and he farms with the lake, the organic grains, and he's just a wealth of knowledge.

And I want to give you folks a head up-- this presentation is a lot of pictures, so don't miss out. There's not gonna be a lot of written language in this one. You're gonna have to listen and take notes, because this gentleman has a lot to offer when he's talking about organic farming and building soil. And pay attention, because this is a rare opportunity.

And also, I give Klaus a big thank you, to start off with. He had a group from Cornell out to his farm this morning, he's on the webinar with us this afternoon. I don't know when he finds time to farm the 1400 acre he has there in New York. He must have it figured out. So we got Klaus. I appreciate your time, and I turn it over to you.

I wish I had it figured out some days. Talking about soil health, a lot like human health, we don't think about it except in the absence of it. And really defining it can be a problem for us. But I think the NRCS definition of soil health is a good one. We had a meeting where we discussed soil health and tried to define it for several hours, and went around in circles and then came back to the NRCS one, which I think really attests to how well thought out it was.

Right now, I'm almost afraid to quote it because I'll get it wrong, but it has to do with the ability of soils to function, to do what we want them to do. And I would go a little further on this definition of soil health and say that it is creating an environment in our fields, in our soil, that is suitable for the crop that we're trying to grow there. And just for an example on this, if we were to grow-- I'm kind of muddying the waters, but if we were to want to grow a tree fruit crop, I would think that some of our parameters and some our things that we're looking for in the soil to be healthy might be different than what they are in a row crop.

But be that as it may, a lot of the functions in soil health are going to be the same-- the ability to absorb water rapidly; the ability to hold water so that when there are periods of excessive we can store it, and then when there are periods when we're not getting water, that we can bring it back; the ability of the soil to resist diseases. Those are all key pieces of soil health.

When I became interested in it, it was right about when Cornell was starting their work. And we were noticing that yields of especially vegetable crops were dropping. And nobody could quite understand why. We had better fertilizers, we had better pesticides. But for some reason there was something pulling back the yields where they just weren't performing as well as they had before.

And a group was called together. And I really want to give Cornell credit. It wasn't just a pathologist or just somebody who studied weeds. They brought together what's known as a program work team, which represented almost all disciplines that have to do with agriculture, so that we were looking at the soil from many aspects. And it's interesting-- back when modern agricultural research started, [INAUDIBLE] did his work on minerals from the soil going into plants. And he came up with the theory of the barrel with the shortest stave limiting what the yield is.

But it's really a lot more complicated than that. And when we do a soil test, we've gotten very good at doing chemical soil tests. But we may not be identifying what is our yield limiting factor. And yield is probably the simple one. If we're really looking at health, there are other factors.

So I'm going to take you on a thought process. I want everyone to think about what happens when you abandon a field, something that's been in row crops intensively farmed. What happens the first year? And I would hazard that in most parts of the country, if it's been something that was in corn or soybeans, that the first year when we abandon it, it is covered with broad leaf weeds, things like lambsquarter, ragweed, redroot pigweed, probably some velvetleaf.

The interesting thing about these weeds, something like a pigweed or an amaranth can produce close to a million seeds. And when we come into the second year after a field that's been let go, we actually have many orders of magnitude more seeds laying on top of the same species that were there the year before. But in the second year after being abandoned, almost none of this grows. There's a different group of species.

What has happened here, is the environment in that soil has changed. And this takes me back around to a more refined definition of soil health. And that is, a healthy soil is providing an environment that the species that we're growing is best suited in. That way the species we're growing ideally should be biologically better adapted for the environment that we provided it than any of the other species.

Now if we make the connection back to human health, if we're in an environment, a person, where we have the right nutrition, we have the right temperature, we have what we need, we would expect to be healthy. And if we come into an environment where maybe it's too cold, too wet, we're not adequately fed, we would expect to get sick. I really think the analogy works very well here with soil.

When we first started farming organically, here in Penn Yan, one of the big advantages that I found in organic farming, was there were markets for almost anything we wanted to grow. I had farmed conventionally for 20 years, and sad to say, quite often, my profit was entirely in the subsidy money that I was getting, where I would plan a crop of corn knowing that it's not likely to be profitable. Prices were low, inputs were fairly high, but we were getting enough subsidy to make up the difference.

I also knew that if my corn followed, say, clover or alfalfa or some other legume crop, that it would take less inputs to produce a good yield, and that I would almost always make more money. And this created a tension for me, because the rotation crops didn't have a good market. Once we went to organic farming, we found that we had markets for almost anything that we could grow. And that made it a lot easier to create a healthy rotation, especially things-- the obvious things would be like northern corn rootworm, corn borer-- some of our weeds became easier to handle because of the way we rotated. Also, we could grow our nitrogen and not need the off-farm inputs.

But that wasn't really what we were thinking when we made our switch, that was just something we discovered. When we first made the change transition to organic, it was entirely economically motivated. We weren't making a good living on our farm, at least we didn't think we were making as much as we wanted to. We had kids coming along, and we wanted to be able to send them to college and maintain a good standard of living.

One day we saw an ad in the paper that was offering us, at that time, the astronomical price of $6 a bushel for wheat, which was roughly double the conventional price. And I went to our local experts, and they assured me that organic farming was something that probably was appropriate for a small backyard plot or a market gardener. But it was totally impractical and undoable on the scale that we were talking about it. And I guess that was all the encouragement I needed to at least try it.

But we did all the calculations of how much yield we could lose and how we were going to come out of this if the experiment failed. We definitely laid our plans for, what if we make a big mistake here? But what we also did was went to Cornell and study the Mann Library. And when we went there, we were looking for two major things. We were looking for what machinery or other things we could substitute for the herbicides we'd been using, and how we were going to be able to provide something to substitute for the fertilizer we'd been using.

And I know now that those were exactly the wrong questions. You can farm organically that way, but it's really farming conventionally with organic inputs and to sell them is very satisfactory. It's not a successful way to farm, it doesn't produce good yields, and it certainly doesn't produce good profits.

But what I found that was unexpected, when I was doing my search in the library, was a professor he's kind of the guru of weeds in Germany. He's credited with being one of the first people to do experiments with herbicides. And in his writings, there was a concept that kind of turn my thinking upside down. I'll share a quote with everyone. What he wrote was that every crop should follow its most suitable predecessor, so that the vigor of the crop alone will check the growth in weeds.

Now that was a bit of a surprise to me, but it kind of made sense. Another thing that he wrote was that cultural practices form the basis of all weed control, while the various other means should be seen as auxiliary only. Now these were interesting statements, coming from the guy who was pioneering using herbicides. And they raised more questions in my mind than they did answers.

But in finding the answers, I learned some things that made a lot of sense to me when I thought about them out in the field. One is a concept back to when we talked about abandoning the field, and you have the first year all broadleaves, or annual type weeds that make a lot of seed, and the second year, almost none of those weeds, but a different group. And if you waited a third year, we would start going into more perennials, goldenrod, some of these abandoned cropland weeds. And then if we waited a little longer, we'd start seeing brambles and woody plants, and then the beginnings of trees, and we would have a succession of species.

What Dr. [INAUDIBLE] was writing about was essentially creating an environment in our field that give us a natural succession that was providing the right environment for the crop that we were going to grow. And the concept really made sense to me from a yield standpoint, too, because if the environment in the field makes our crop be the favorite species, it would have advantages over everything else.

If you go back to our analogy to human health, if we're in an environment that's not favorable to us, we get sick. Well, if the crop's in an environment that's not favorable to it, it gets quite diseased, you start seeing insects, you definitely are going to have more weeds because the crop's not as vigorous or as competitive. And it really does help hold with that analogy.

In addition to these things there's, back to what a crop needs-- and I'm going to skip here to match the slide. At Cornell University, after we'd been farming organically for some time and had very good results-- and I'm fast forwarding here. We were pleasantly surprised with how quickly we learned how to make the system work for us. And we started with a rotation that I was somewhat familiar with already.

And that would be a winter small grain that was frost seeded to a legume, which, in our case, the most successful legume was medium red clover. The next spring that would be turned under to grow a crop of corn. That corn would be followed by either soybeans, or dry beans, or some other-- or spring small grain, something that had a lower nitrogen requirement. And that spring small grain or soybeans would be followed by a winter small grain, which would then again be underseeded to clover, and come back to corn.

Now that's an oversimplified version of the rotation, because there's all kinds of branches and options that we could add to that. But our search for, what do we do about replacing the fertility-- we had to find manure. Dairy manure will not meet the needs of a heavy corn crop unless we're putting on some really high rates. And if we're having to import the manure because we had no animals on our farm, the freight would become pretty burdensome.

So we settled on poultry manure. And we did our first couple of years just kind of by guess. And I wanted to know how much we should be using. I wanted to do some research, or see some research, that would tell us what is the optimum amount to use. And to do that I wrote a research proposal and submitted it to an organic funder who promptly turned it down. They didn't like it.

I had a friend at Cornell who said, can I use this? And he turned it into another organization, actually a conventional organization. And they funded it for five times what I had originally asked for. And we set up a randomized block where we used GPS to map out a 20 acre field. And we did a random block of many different rates using poultry litter.

And we did use our basic rotation. So the nitrogen for the corn part of the system would be also supplemented by nitrogen from the legume. And we used, for our one x-ray, actually what a conventional consultant would have recommended for a field with that soil test. And we decided to do zero, half of that. And then we doubled it. And I think we went as high as six-- well four times or whatever. It was a high multiple above what would have been used under a normal conventional system. We ran this for five years and analyzed through the rotation cycle where we got the best yield. We had used a yield monitor on a combine.

But we didn't just look at yield. We also had our weed ecologist from Cornell, Chuck Mohler, would come out and analyze the weed growth. We did soil health analysis from Niel, who's our extension specialist-- came out and studied what impacts or differences we might have seen in the soil. We tried to look at it from a multi-disciplinary approach, everything that we could learn from this.

And what we learned was quite interesting. From an NP&K standpoint, or at least for a P&K standpoint, we showed that the conventional yield response curves were the same as the organic ones, that when we put on poultry litter, we could find our top yield at just about the same place where if we were using other sources of that phosphorus and potash-- which was a really important thing to learn, because it told us we could rely on some of these pieces of research that had been pretty well done and established from the beginning.

We did learn something surprising. And that was that we were almost never short of nitrogen. We though nitrogen was going to be a big challenge. But what the research we did in that field-- and then later, Cornell University did a systems trial where there was a conversion between a regular, on a good upstate New York soil type, from conventional farming into organic. They followed essentially what were standard practices on a large number of successful organic farms.

And that research backed up the same finding, that nitrogen was almost never a yield limiting factor. Even if we only had a poor cover crop of medium red clover, we were growing more than ample nitrogen to make maximum yield in our crop. And I think that's really significant, and it should be pointing out, not just for organic farmers, but for other farmers, that where we're relying on imported manure for nitrogen, we are probably causing ourselves some problems.

In this trial on our farm, we saw that yield of weeds never tapped out, even at six times the rate where we had the top yield of corn. We were still getting an increase in the weed pressure. And the way we're measuring the weed pressure was going out and weighing the weed biomass.

And I think that was pretty significant. We've also found the time of year when we put the manure on had an impact on weed pressure, where if we put the manure on an actively growing cover crop the season before, it not only was better for the environment, but it also give us a lot less weed pressure than the crop. And from that, I wish more farmers had paid attention to that, because there are so many farmers who are applying manure hugely in excess of where they're getting maximum benefit from it. This is based on research that is pretty well documented and was done under the discipline of university trials.

Klaus, can I ask you-- I need to clarify this. So you're saying that where you put the manure on at a time and a half to the acre, you maxed out your yield. But when in excess, all you did was raise more weeds? Is that basically what you were saying?

That's exactly right. And I'm glad you brought that up to strengthen that point, because I really-- we were surprised. And we thought we could push the fertility and push our yields, but all we did was push the yields of the weeds. And it was not just the number of weeds that sprouted. And incidentally, these weeds were not in the manure. This manure was carefully heated to make sure that we weren't importing weeds.

But it had a biological effect. It increased the germination of weed seeds in the soil and also increased their growth. The time of year makes sense, when we think about it now, where it was going onto an actively growing cover crop. Whatever it was in the manure that was stimulating the weeds was being taken up by the cover crop and then returned slowly the next year to the crop, where, when we put it on the spring, it was there to feed the weeds right off the bat. So I think that's a really significant finding.

This might look like an odd picture that I just brought up for a soil health discussion. But it brings a point in what we're plowing down. And I think for a lot of us, we think soil test, and we think and NP&K and trace elements. But how often do we really think about what's in that green matter that's being returned to the soil?

And I did these calculations based on actual tests that were done on our farm. And this crop that's being plowed here was roughly three tons of dry matter. We were turning in 240 pounds of N, 30 pounds of P205, and 120 pounds of K2O.

Now that was not showing in the soil test. That was cycling through the cover crop. And I believe we are not even scratching the surface with cover crops, what they can do for us in terms of being a nutrient sink. And this is in the fall and through the winter, when we've got rain and leaching conditions, these crops are actively growing and picking up those minerals. They're adding carbon to the minerals.

And what I think is underestimated, or under appreciated, is that these cover crops also provide food for our microbes. You think about this three tons in the spring, there were an additional four ton the fall before that were turned under after a small grain crop. And I still remember the guy who was running that tractor saying, what are we going to do this mess? We can't get rid of this cover crop. It's nothing but a problem, because we're not going to be able to handle it with our machinery.

When spring came the ground was virtually bare. And if you look closely, you can see earthworm castings all over the place. This stuff was earthworm pasture. And we had, even with plowing, which I know the plow is supposed to destroy organic matter and it's supposed to destroy earthworms, but we had at least two orders of magnitude more earthworms than I've ever seen on the farm before. And because of the amount of food we were putting down.

I like to upset both conventional and organic farmers with some of the talks I do, where I ask, how many of you think the chemicals that we're using are killing the earthworms? And of course, all the organic farmers say, yeah that's what's doing it, that's what's doing it. And then I ask, well how many of you think it's the tillage that's killing all the earthworms? Another group of farmers will be yelling, yeah it's the tillage that's killing earthworms. And I say, you're both wrong. It's starvation.

Now how well are your cattle going to grow if they lived on a diet of old dead crop residue? Now there's no protein there, there's very little protein, there's very little energy, there isn't much in the way of minerals. How could we claim to be producing increases in earthworm populations if we're starving them to death? This is regardless of what kind of tillage we're doing, regardless of what kind of chemicals we're doing, if we want to have a lot of life in the soil, we have to feed it. And I think that's a really important factor all the way through.

I've had the picture of the plow here for another reason. The plow has been blamed for a lot of damage, and it's been responsible for a lot of damage to soil. I wish the resolution was a little better here, but you notice we're plowing quite shallow. And there's a little bit of green sticking up.

When I was in high school, I had a really great teacher who used to say he used to be bothered as we got bigger and bigger tractors. And the boys in the coffee shop loved to talk about how clean they were plowing and how deep they were plowing and how nice it looked when they were done. Think about where does the fence post trot off? Generally in the top four inches.

Why would we want to turn all of our organic matter down 10 inches deep and, what's worse even, flip it and create a layer so that it's all buried that deep? It's in a zone that's anaerobic, it's in a zone where there's relatively little activity. It's also being placed down so far that it's not doing us any good. When we plow it back up a year later, that would tell me that it's not gone through an aerobic breakdown. Much more likely, in those anaerobic conditions, we get biology that makes methane, makes CO_2, makes ethylene.

The products of this organic matter, if it's turned down deep, are not things that are desirable. And I really think the damage that the plow has done to the soil has really increased tremendously since we've gotten big horsepower tractors and plows that are able to grow really deep. If you go down to Lancaster and see where the Amish are plowing, I didn't see very many furrows there that were more than four or five inches deep. And the organic material is kind of mixed into that zone when they turn, and that's the way everybody did it for years.

But in recent years I see a progression, and I'd like to call this the coffee shop progression, where everybody is showing off how much black smoke they can blow, and how deep they can plow, and how cleanly they can flip it. And then the next thing, you see the plow parked and they're using a chisel plow because their yields went down or because their soil has been damaged.

And I think it's because we're making very poor use. First of all, we're not putting enough organic matter down. We're not using cover crops on anywhere near enough farms. But even when we do, we're putting them into the soil in a way that they're not giving us a lot of benefit. That's my little soapbox.

Klaus, can I ask a couple-- I had a couple questions come in here. They were wondering about-- you know, you're talking about that nutrient content. When is that going to come available as far as the crop growth of say, your fallout with corn or the proceeding, or the next?

That's a really good question. The rule of thumb with the nitrogen is that half of it'll come available during the crop year. But that's only part of the answer. Of course, that'd be 120 pounds of N. But there's also the nitrogen the root nodules left in the ground, and there's the nitrogen from the fall before.

And Cornell has done some really interesting studies on our farm, studying nitrogen fixation. And we're finding legumes are like people. They're basically lazy and only work as hard as they have to. So in these systems where there's a lot of nitrogen, the legumes really are fixing less, and we're actually recycling some of the same N over and over. And that's been done by tagging with a nitrogen isotope and actually following it through the cycle.

But what we're finding is that, up to the level where we got optimum yield, we seem to be in good shape. And the bigger problem is, if we can't time the mineralization of that nitrogen correctly-- it's a little bit like the cavalry came there after the Indians got done-- if the nitrogen becomes available late, the crop needs it upfront. And then the nitrogen is made available after the crop needed it, all it's going to do is make weeds grow. So that is one of the reasons that organic farmers rely on tillage more, is because, whether we realize it or not, is timing the mineralization of that organic material. I don't know if I answered that question completely.

No, I think that's good. And I had another question. Do you think you would achieve these kind of nutrient cycling benefits if you would just not plow that under-- let that come across or rolled it, or something like that, just knocked it down?

The question is, could we do this without plowing? Yes, we definitely could get the nutrient balance. But I'm not sure-- depending on where you are in the country-- like in the north, it's quite cool in the spring-- it would come slower. So while we would have the same amount of nitrogen, there are some environments where leaving it on top would make it mineralize more slowly and come at a later point than where we really wanted it. And I think that's why, especially in the northern areas, no till quite often is accompanied by some extra nitrogen.

But it's a, it depends answer. Actually all of this nitrogen would cycle, it just may not cycle exactly when we want it to. And that's a place where maybe we need to be looking at the species. The nitrogen in clover is tied up with a fair amount of carbon. We did some experiments where we used Austrian winter peas, which had a huge amount of nitrogen. And I know the Rodale Institute has done some research where they used hairy vetch and rolled it. And they found that, by delaying the corn planting dates slightly and then rolling these legumes that break down a little faster, they were able to time the mineralization with the needs of the crop and have no yield drop.

So again, this is a really important question, because it has to do with not just quantity but also the timing of when it comes available. Any other questions in this area?

Well no, I think you kind of summarized those good. But the key is timing, I think is what I'm hearing from you.

Yes. And that kind of makes sense, Simon, when we learn to use the sidedress nitrogen. The reason we're sidedressing is that we're timing its application with the needs of the crop, and we're also trying to avoid losses. We're trying to avoid having leaching or tie-ups that we sometimes get on cool ground, which protects water quality but protects our wallets, too, so that we're not buying extra just for what's going to be lost.

One more quick question, and I'll let you continue. How long-- you talked about this successional moving from where you were to where you are now, and then you jumped into this manure thing. How long do you think it took you before you started to reap some of the benefits of this increased soil health? The nutrient cycling is basically what you've been talking about.

Yeah, this is a really good question. It depended on crop order we used. We found that if we were trying to move into corn, we lost money for-- it took about five or six years before things worked if we started with corn as our first crop, after getting off the synthetic fertilizers.

When our first crop of soybeans-- we would actually have a full crop the first year with soybeans.

They're very efficient feeders. Then we would have a yield depression in the second year when we followed them with a grain. And then after we had the clover plowed down, we would be-- the system wouldn't be up to speed, but it was up to speed enough to grow a crop of a heavy nitrogen-using crop with no yield depression.

So in that system it took us about three years. But if we started with the wrong crop it could take five or six years and there would be a lot of red ink between when you started and when you finally got it running. So again, this has to do with order of plants order of crops. And it has to do with using our heads and using the information that's available to us. And a lot of farmers, especially when we first started, lost a lot of money trying to grow a heavy nitrogen-using crop like corn before their land was ready for it. And that creates an environment that's really not good for corn, and it makes for some pretty sick corn.

So this picture probably looks familiar to a lot of people. If we could pan over to the left, there would be a whole row of silos. This was the field that always got the manure. It was our neighbor's field. He keeps telling me, I wish you'd quit using that picture and use one of your own fields. But what's growing in this field is lambsquarter, pigweed, and velvetleaf. And in this particular case, they were about six feet tall. The corn and soybeans were four feet tall. And this was a case of making an environment where these weeds were better adapted. Even though the soybeans were doing great, the weeds were doing better.

And the reason I mention the silos is there's something about these weeds that kind of gives us some hints as to what's happening underground. These are non mycorrhizal weeds. And we're tying back to the soil test work. We saw an increase in weeds when we used more manure than where our optimum yields came on the crop. We're way past that point in this field. And incidentally, this field had been cultivated fairly well, too. These are just the weeds that were in the row.

What's interesting about these weeds is that non mycorrhizal plants really thrive where phosphorus levels are high. In fact, very high phosphorus inhibits mycorrhizae. Most of our crops have mycorrhizal root systems. And what mycorrhizae are, is a fungus that's in the soil that actually helps the plant excess water, but more importantly, phosphorus. It becomes, in effect, extension of the plant root system. And it goes out and explores a lot more of the soil than the crop root itself would. And, in the process, feeds the crop, these minerals that are hard to find.

Now the crop, on the other hand, is producing a lot more energy than what we see, what we harvest.

And some studies-- I've seen up to 50% of some plants' energy production from photosynthesis is given off in the form of root exudates, which are very high sugar, high in minerals, high in protein-- very high quality food that the plants are giving off, and feeding things like the mycorrhizae and probably millions of other species that grow around the plants' roots. If we look at what's going on here, the crop is actually farming microbes around its roots. There's a symbiosis going on here. While it's below ground, then we don't see it. We see the effects of it above ground. And this is one of the drivers of soil health, is what kind of an ecosystem do we have underground?

So back to this picture-- the crop is not getting its normal advantage here. In fact, I've seen some research that hinted that these mycorrhizal fungi, in return for the sugars they get from the plants, not only help the plant get phosphorus, but they also inhibit the growth of other plants that are non mycorrhizal ones, like the lambsquarter and the pigweed. But when we've applied so much manure and over fertilized to the point where the soil is hostile to the mycorrhizae, it gives these non mycorrhizal plants a large biological advantage over our crop.

And at that point, we can hide that by using an herbicide to kill the plants that are better adapted and allow our crop to survive. Or, in the case of an organic farmer like I was, stand there and wonder, how are we going to survive this, and how are we going to control these plants? I don't know about the rest of you, I'm sure we've all seen Palmer amaranth that kind of tall. Velvetleaf used to be the bane of my farm. When we converted organic at first, velvetleaf, by midsummer, would be so big that you could hardly pull out of the ground. In fact, you had to be pretty rugged and the ground had to be a little damp to pull out a velvetleaf by the roots, and they were commonly 12 feet tall.

I noticed something after we change our farming system. We started cover cropping every chance we had as part of our organic system. We added more diversity. We were growing small grains and not selling it, not removing the straw but leaving it out there as a soil amendment. After about five years of this, the velvetleaf started showing some yellow. And I think-- the picture on the left, you can see on the foreground that velvetleaf, those leaves aren't-- while the plant's doing fine-- those leaves aren't quite 100%.

The picture on the right was taken in a field that had been where the old barnyard was. And the first two years I farmed it organically without herbicides, I just mowed it down. The velvetleaf had taken over. But over time-- and this is using the cover crops and using a more diverse rotation-- the velvetleaf didn't get as tall anymore. And then we started noticing midsummer the leaves turned yellow, like the ones on the left but more profound. And then after a while they would turn black and they'd fall off.

In the picture on the right, that velvetleaf is just a hair over four feet tall. And it died before the summer was over. It made no viable seeds. All the leaves came off. And we found-- we actually asked one of our friends at Cornell to tell us what was going on. And he found velvetleaf and thracnose was the actual cause of death. It's very closely related tomato and thracnose. This particular race has no effect on tomatoes, but it will kill velvetleaf, Hollihocks, and mallows, I guess none of which I feel a whole lot of sympathy for.

So I thought this was great. This ought to be the answer to our organic-- we can grind this stuff up and spray the spores on the field. And in my research, I found that there had been at least one or two attempts at producing a spray made of this. The problem is, if you put it on a place, you wouldn't have repeat sales, because if the disease took hold the next year, it would still be there and it would still kill the crop. The bigger problem was-- and this was what was pointed out by our friend from Cornell who identified the disease-- was that he wanted to know why it was killing our velvetleaf. And on other farms where the velvetleaf seemed to be doing better, the velvetleaf would show signs of the disease and grow out of it, kind of like in the picture on the left, where yeah, it's got some sick leaves, but plant overall is still doing fine.

And I think he was asking the right questions. He said, why does your velvetleaf die from it? This goes back to the idea of the environment. The environment in the field, when we first converted, made velvetleaf the best adapted species, or at least one of the best adapted species. As the soil changed, the rotation was different, the inputs were different. The environment in that soil was changing in some profound ways. We couldn't always see it, but we could see the effect.

There wasn't just one disease in this velvetleaf. What we found out later was that the early yellowing was caused by a virus called Abutilon yellows, which was vectored by whiteflies. We had an interesting field day on our farm about 15 years ago, where the purpose was to show people cultivation equipment and how to use it. But everybody was clustered around these velvetleaf plants. This was in a severe drought, it was about 100 degrees outside. And they were covered with whiteflies, and yet the crop didn't have a bug on them.

And I think this showed us that, because the plant was unhealthy, the insects were moving in and attacking the unhealthy plant. And in the process of sucking juice out of those plants, they were vectoring in the virus, the Abutilon yellows. And all those factors together left that plant so compromised that when the thracnose came, it killed it. You could bend over and pull these four foot velvetleaf plants out of the ground. They didn't really have that big of roots.

And the plant in the foreground is a lambsquarter. That's another none mycorrhizal plant. And it, too, in that environment, wasn't doing so well. Somehow over several years, the environment in that soil changed back to favoring mycorrhizal plants over the non mycorrhizal plants. And I think that carries an important lesson for us, that every plant that grows in the soil changes that soil. And those changes make the soil the best environment for something else, back to our succession of species.

Every plant seems to have niches that it wants to fill. I'd be really curious to understand the biological triggers that make the plant know. Why don't spring plants sprout in the fall? Why don't fall biennials sprout in the spring? At least, most of them don't. There seem to be biological cues in these plants that either tell them to sprout now, conditions are right and you can grow, or maybe you better wait for a better chance to grow coming down the road. If we could understand those signals it would make farming a lot easier for us.

The reason I use this picture is the field on the left was just drilled organic soybeans. They were double cropped, but there was virtually no weeds there. And we had a couple of years when it got really late-- and your heaviest weed pressure tends to be the end of May. Generally by early June you have a little less emergence. When you get to late June, you really have greatly reduced emergence of those early spring weeds. And a crop like soybeans actually gets a competitive advantage then, just by the time of year.

I learned something really interesting by growing these soybeans. When you plant them late like that, it's too late to be coming back in and planting a winter grain on time. While the soybeans are still ripe, relatively early, right according to what their group is, you lose just enough time in these northern climates that it's really too late to be planning wheat. And we did an experiment there. We threw on no till spelt, wheat triticale, drove through the field-- one time I hired an airplane.

And we found there's a window-- I call it yellowleaf. About the time you see the first yellowleaf, you can do it. When we tried doing it earlier than that, it actually was killed, it was smothered. I think there was too much shade, too much competition. But what I saw happening was that if we hit that window just right, the winter grain would take off and get a really good start. If I waited too long after that, yeah the winter grain would start, but it just didn't seem to get the same kind of a take off.

My guess of what's happening is that we've had a succession there where there was a living root system from the soybeans. Again, take this as a guess, but I think it's pretty educated guess. And then when we no tilled by broadcasting the winter grain into this system, where there was a living rhizosphere, and all these functions were actively going out in the soil, they were providing the services to the plant roots of the grain crop that tillage would have provided if we had waited longer.

The good news is, by the time we combined those soybeans, we already had a four inch tall well established crop of grain in them. And it's also a whole lot cheaper to just throw that seed on top of the ground than to work the ground up and use conventional tillage to establish a grain crop in the fall.

And I'm going to digress here a little bit. Two more thoughts on tillage. I think the reason-- farmers aren't stupid. The reason the plow has so much widespread use, especially before they built the plows bigger and deeper and started doing the wrong thing with them, was that it worked, that it did result in higher yields. And I think it was the timing of the nitrogen, but also it helped destroy organic matter. Now when you burn organic matter, you're making fertility available to the next crop. And farmers observed that when you do this, it cycled the nutrients faster and your next crop grew better.

The problem came when they did it too much and they were extracting more every year than they were putting back. Remember, a lot of these systems didn't have cover crops in them, and a lot of them didn't have a lot of animals. So this continual plowing was like constantly drawing money out of the bank without putting as much as the interest back in, and you ended up depleting the organic matter.

I think we could go the opposite extreme, and I've seen that in New York. I've been asked to consultant on some fields that have been in hay for 50 years. They'd just been hayed, nobody had put any fertilizer on them, they just got mowed. And year after year, these fields got weaker. Some of the organic matters in those fields were 5% to 8%. And farmers were asking, well I've got so much organic matter, how come nothing wants to grow here? Well it's because we had pulled our phosphorus and potassium and our nitrogen down so far that the microbes were even starving to the death in this ground. We had robbed it.

That organic matter was very much like if you had a millionaire starving to death because he wouldn't take any money out of the bank and use it. I think when we're-- we need to talk about managing organic matter. I think a good goal is to always put a little more back than what we burn up, or a little more back than what we're using. But there is nothing wrong with using organic matter. We want to have a healthy, active soil life. And if we're going to have soil life, it has to be fed, it has to eat something. And that something is organic material.

The problem comes is when we're consuming more than what we're using. I also think there's quite a lot of research available, especially older research, that indicates using synthetic nitrogen can create a very similar situation to what overusing tillage can cause, that it results in a continuing decline in organic matter. And I remember talking with Dr. Rakowski about some of the long term no till trials. And these were trials, I'm pretty sure, without cover crops, where they were disappointed not to see organic matter go up. Actually, it went down. It went down slower than where tillage was used, but it still went down.

And I remember him mentioning that he was going back to the data from the moral plots, which had, early on, indicated that the use of synthetic nitrogen without enough organic material to feed that microbial bloom that comes when you put on was depleting organic matter. So it's just some observations that I've got, some speculation. But I really like these-- sorry.

Well no, I was going to ask a couple questions when you were done there. And I know you got some other things. Real quick-- related to that, do you think the timing-- you know, because we did go from plowing in the spring to plowing in the fall. And as far as nutrient cycling and all that-- comment on that.

Oh, that's important, yes. Thank you for bringing that up. Well fall plowing, talk about drawing-- you know, whenever we do tillage, it's like drawing money out of the bank. But if we're doing it in the fall and the crop won't be planted till next spring, we've had time for that nitrogen to lay there, mineralize, and be leached away, where it doesn't do us any good at all, it's just damaging the water. So when the plow is used at the wrong time of year-- and I understand some soils are high in clay and they need to be fall plowed, quote unquote, because of the structure, the physical nature of them, we're getting a big loss in organic matter with no offsetting benefit.

And I think that's a major expense. I think we need to look at any kind of tillage as an expense. It's an expense in terms of the fuel that we're using, but it's an expense, and if it's a withdrawal from the organic matter bank account that's in our soil-- which, it's OK to make a withdrawal if you're investing it in something that gives you more back-- but if we're just withdrawing it and not getting a return from it, it's destroying our capital. I don't know if I digressed too far there.

No, no, it's good.

OK I'm going to talk about one other experience we had regarding soil health. This was one where soil health testing paid off for us in a big way. It more than doubled our yields. We were growing edible dry beans. When we first converted to organic, it was almost like printing your own money. We had better yields than the conventional farmers and we were getting a sky high price for them. This was before the Chinese were dumping theirs on the market. And they grew great.

The second time we've grown-- and all the old farmers said, you need to grow them about once every seven years or five years at the soonest. So we waited our minimum amount of time and go back and plant them again. The next time they didn't grow quite as good. Figured, well maybe we did something wrong this year, or maybe it was the weather. By the third time around some of these fields, we had heavy root rot, we had very poor production, we had no resilience when the weather turned bad. They just fell apart when we had too much rain. And we just didn't know what was going on.

Professor George Abawi at Cornell was studying this problem. And these roots were just covered with nematodes. A lot of damage, lot of abrasion, and then Pythium, Rhizoctonia, Fusarium would move in and literally would destroy the root systems. George did what I consider really brilliant research in the greenhouse. He would take a variety of phaseolus vulgaris, dry beans, that was known to be very susceptible. And he would take a sample from dozens and dozens of fields and plant those samples out in the greenhouse, where he controlled the conditions, and put these susceptible beans in them and grow them out.

And he would grow them to a point where-- I don't know how many leaves they had, but it was relatively early. And he would wash the soil off and do a root reading. And he could predict-- the first thing he used this for, he could predict very accurately whether it was a good bet to plant phaseolus which, at that time, edible dry beans were a big crop in New York, and so were snap beans. They're both the same species. And he had a very good handle on whether your field was likely to be profitable, if that's what you grew, and whether you're going to have root rot, and how much.

And he scored it on one to five. But then he did something that I consider a stroke of genius. He started asking, what would happen if we had a different crop preceding the bean crop? What effect would that have on our disease level in the soil? And he tried all kinds of different crops. I saw the research once. He must have tested 50 or 60 different crops. And what you would do is get a root rot reading, and then-- plant the crop on the soil and then get a root rot reading.

And he found some species that you planted in between, even though it wasn't the beans, made the root rot reading worse. Some species were neutral, some give you a small improvement, and some gave a huge improvement. There were two species in there in particular that gave huge improvements in root rot scores. They actually, in what we know now, they were destroying the nematodes and the root rots both.

Yellow mustard was one-- I know Michigan State's done a lot of work on yellow mustard-- where just a 60 day crop, or 45-- depending on the time of year, 45 to 60 days. Short term cover crop of yellow mustard-- when that was turned into the soil it would-- there's an enzyme in yellow mustard, there's a compound in it called glucosinolate, which is, when you put mustard on your hot dog, that's what makes it sharp. But there's an enzyme in this same leaf, and this is the story that Dr. Honeycutt talked about at the Soil Renaissance press conference. That enzyme makes the glucosinolate turn into isothiocyanate, which is a gas. By turning in a crop of yellow mustard, we were fumigating our fields. It's actually a biofumigation.

Another crop you can do that with is sorghum. And a lot of farmers who are onion farmers and were really suffering from nematode problems near us that were on muck learned that they could actually afford to give up one year of cropping, plant a crop of sorghum and turn it in just for that fumigation effect, because of how it would clean up the nematode problem and the onions would grow so much better afterward. But in our case, yellow mustard was indicated.

There was one other cover crop that really improved root health ratings, and that was buckwheat. But in our case, George recommended we try to find a way to grow yellow mustard before planting dry beans. And the window that we tried was after a crop of field corn. Now in our area, we have to use every bit of season we have to get the corn right. And if we have good corn, it's really hard to get anything to grow in it that amounts to anything, because it's so competitive.

But there's a period when we're not using the land very well, and that's from about early March until we plant the dry beans, which can be as much as three months. And yellow mustard is very frost tolerant, and there are varieties that are-- the culinary varieties that have no hard seed. That means they don't lay there and become weeds in the sense that most weeds have some seeds that come right away, and some that lay there until the conditions are right, and some of those are called hard seed. Well yellow mustard has been bred to not have the hard seeds. And we started broadcasting about eight pounds per acre of yellow mustard seed in March into our corn stocks.

And the first thing we found was that the yellow mustard really likes a little more nitrogen. That is one place where it would pay to put on some chicken manure or some dairy manure, because the brassicas are heavy feeders. And that time of year, when it's cool, there's not a lot of fertility. So that's a point aside. But George also said, when you're spreading this, now, leave some strips in fields or leave half a field, because I want to see what effect you're having.

So we started growing these yellow mustard cover crops, which incidentally now, we try to cover every field of corn with yellow mustard before the next crop. And he found that if you had a root rot, whatever the root rot rating was, it improved by one. So on a scale of one to five, where five is all dead and one is zero disease, if you read two and grew a crop of yellow mustard, it would move you to one, or if you were at four, it would move you to a three. Now that's a substantial improvement in root health, just for growing a crop that we've no tilled in. And I love cross-seeding or spinning crops on. It's cheapest form of no till there is, because you don't have to buy expensive equipment.

But that was a major change for us. We started seeing our root health improve. Then we decided to try to add buckwheat, which had a completely different mode of action. You know, the yellow mustard we understand, and so sorghum would be the same way. But these are crops that produce the glucosinolate and turns into isothiocyanate and it fumigates the soil which, incidentally, when Michigan State studied it-- while it's a fumigant, it's seemed to be selective. It seemed to do a lot more damage to the pathogens than it did to the beneficials, which is-- we don't know why, but it's a lot better job of selecting to kill what you don't want and not kill everything.

But the buckwheat, we found, has an organism that grows around its root system that produces cutinase. Cutinase is an enzyme that breaks down the cell wall of fungi. And buckwheat was equally devastating to the root rot organisms that were in the soil. So we brought buckwheat in after a winter grain harvest. So for instance, after malting barley, if we had season enough, we'd grow dry beans. Malting barley also improved-- or barley, as a crop, as long as it wasn't underseeded to the legume, would improve the root rot ratings. But if it was too dry to grow dry beans, we would plant buckwheat.

So our farm, then, we had in a typical rotation cycle, we have a couple of mustard and a crop of buckwheat before we came back to dry beans. And we not only brought our yields of dry beans back up to what they had been before we started having the root rot problems, we actually went beyond there. That's one of those years you brag about for probably half your life before you have another one like. In 2008 we had some dry beans that yielded well above 4,000 pounds per acre. But we've never had anywhere near the root rot issues or the disease problem since we changed our rotation to manage that disease.

And it just shows us how having more biodiversity on a farm can make quite a difference. Before I go on to this next piece, were there any questions on this?

Well yeah, Karl just got a few more here, and then we'll kind have to wrap this up in a few minutes. There's a question related to-- coming back to the clovers that came in, did you notice a difference between varieties within the red clover, as far as-- I mean, 240 pounds of nitrogen is an awful lot of nitrogen as one being a more of a [INAUDIBLE] producer than others?

We found that any clover that was-- like our medium reds, they'll make two or three cuttings. They all seem to be pretty equal. I think it's more important to have medium red clover, or to have a clover that's well adapted to where you are than to worry about one variety or another. I really think we've badly underestimated the nitrogen fixation ability of our legumes. I know I had the old textbook that said red clover could make up to 50 pounds of N that could be credited to the crop.

And I kind of believed that for a while, and then I started doing my homework. If I grow clover, hey, even if it's not a great yield, I'm taking-- six pounds of protein contains one pound of N. And I've seldom seen clover that didn't make more like 300 or 400 pounds that we could remove in the hay. And I've seen alfalfa produce 500 or 600 pounds of N just in the form of what's being removed in the hay. I think some of these textbooks were written by people-- that these things get repeated over and over in, the way I put once, until some idiot puts it in a textbook without checking. And then it becomes fact. Sometimes you need to ask questions about some of the things that get repeated.

Yeah. And you mentioned a couple times this soil health testing. What is it you're doing?

OK, this soil health testing is an evolving process. And right now any test which NRCS is running-- and that's more of a way to imitate what a root would find in a way that more direct our synthetic fertilizer amendments. But the Cornell soil health tests are looking for other yield limiting factors. And quite often, we've done are such a great job with fertilizer and chemical soil testing, that that's seldom the yield limiting factor anymore.

So one of the soil health tests that we have had good results with is one I just described. They call it the disease suppressiveness test, which is done in a lab just by George Abawi. Another one is the water holding capacity test. There is another test that is done, and this is all part of this kind of a battery of tests, just like you test for NP&K, boron, sulfurs, ink, you test for all these different factors. Aggregate stability-- this is a test where you take a chunk of soil and you just wash it, and you're measuring how much of the soil will break up and how much will stay in stable aggregates. This is a really good indicator for soil structure. It's a good indicator for water holding capacity, even though we're measuring it directly.

And then there are tests that measure the resistance, how hard the soil is, the resistance of roots. Now, the penetrometer out in the field is OK, but it has a major weakness, because that changes with moisture. So in a lab, they're taking this soil and bringing it to a known level of hydration and then doing penetrometer readings, both for the surface and in the deeper layers. These are all measures of soil health that directly tie back to your productivity. And they are ways of identifying what is your limiting factor, not just for yield, but also for plant health. And once you've identified what those limiting factors are and measured it, then you can start working on improving it.

Interesting thing is, almost every soil health measure is improved by using cover crops, but some cover crops are better than others, just like I described in the disease suppressance.

OK Karl, we're going to have to about wrap this up. I got two more questions. And those folks are in the Cornell test, if you just Google Cornell soil health test, they've got an excellent manual online. You can download and you can read just exactly what Klaus was talking about, and it does a good job of explaining what they are and what to look for. And you can also-- it has instructions if you want to try and get some of your samples tested.

And you had mentioned earlier, your quote, I think that's the thing that's-- [INAUDIBLE] prepare with this has stuck with me, is every crop should follow its most suitable predecessor. Who was that made that quote? Because I got people here wanting to Google this guy and find that out.

Well his name was Bernard Rademacher, R-A-D-E-M-A-C-H-E-R. And probably his best paper was translated into English-- this was written in German, but it was translated into English in a journal called *Herbage*, H-E-R-B-A-G-E. And I think it might have been 1940 or '41, the paper itself was written '39.

And I remember for years, the old Kraft and Rainer agronomy book, which shows how old am. But it had all these charts that had German varieties on them. They had been lifted from Rademacher's paper in the weed section, in the American agronomy book that was used in the '50s and '60s. And I finally found the original source by looking through the bibliography. But eOrganic has this paper translated into English mounted on it. The only problem I've had with eOrganic is it's not a very user friendly site, but you should be able to get the entire paper at eOrganic.

OK. Well with that, Karl, I'm going to have to cut you off, because we've run a little bit past time. And again, I appreciate your wealth of knowledge and your energy. I don't know if you've got any closing comments. I might let you go. I know you were going to make a couple comments there about the ragweeds and the chickory, but-- go ahead, do that, then we'll have to sign off.

Each one of these plants is a specialist. Every plant that grows in the soil fits a certain environment. And it can actually-- along with the soil health tests-- understanding which conditions these weeds are favored by is a soil test itself and can be used by a manager who's really sharp. This is the idea of seeing what you're looking at. When you look at these weeds, maybe we should see something telling us that I'm here because the soil is such and such.

It's kind of a parting thought, that maybe we could be learning an awful lot from nature, just from that concept. Incidentally, this is a picture of a field of buckwheat. It's kind of pretty but it's smells like a cat box when they're blooming.

Well it sounds like we need to have you back, sir, for another hour discussion on that topic, Klaus. And with that, I'm going to have to cut it got it off. And again, I appreciate your input and your willingness to participate and encourage everybody to continue listening. We do have another organic and soil health webinar in October. I don't know exactly the date. That would be you folks out there on our mailing list, make sure you watch that, or listen and look for that. I believe it's going to be Dr. Kristine Nichols, who has just started at the Rodale Institute. We'll be talking a little more about the connection between organic farming practices and improving soil health at that time. And with that, I'm going to say thank you for participating, and look forward to visiting with you in the future.

Thanks for having me. Incidentally, that corn in the background is--