University of Minnesota Nutrient Management Podcast Episode “Soil health tests”

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(Music)

Paul McDivitt: Welcome back to University of Minnesota Extension's Nutrient Management podcast. I'm your host, Paul McDivitt, communications specialist here at U of M Extension. Today on the podcast we're talking about soil health tests. We have four members of Extension's nutrient management team, Dan Kaiser, Fabian Fernandez, Anna Cates, and Carl Rosen. Can you each give us a quick introduction?

Dan Kaiser: Well, this is Daniel Kaiser. I'm a state nutrient management specialist specializing in nutrient recommendations.

Anna Cates: I'm Anna Cates, a state soil health specialist.

Fabian F: Fabian Fernandez in the St. Paul campus. I work primarily on nitrogen management for corn cropping systems and water quality.

Carl Rosen: And I'm Carl Rosen, a nutrient management specialist. I work a lot on specialty crops, but also do work with some of the more conventional crops because they're in rotation with our specialty crops.

Paul McDivitt: Alright, so there there's been a lot of talk nowadays about soil health. What is the consensus definition of soil health?

Anna Cates: So the NRCS defines soil health as the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans. And I think the key word there is function. If you think about what you want your soil to do in terms of functions, that can help you understand what you want your soil health to be.

Anna Cates: That word health gives us kind of an analogy to the body. And when you think about your body's health, you don't start by saying, I have a slipped disc, or I have a torn ACL. You start by saying my back hurts, or my knee hurts, so I can't walk. Your function is walking in that case.

Anna Cates: So with your soil, your function might be growing your healthy crop, just staying in place, or storing water. So if your soil's blowing away, or if it's not storing water, or the crops aren't productive, then you're missing a function you really

want, and that means your health is off. So if you think about soil health, it's really attached to what you want your soil to be doing.

Fabian F: Yeah, and I think a lot of farmers, when they think of soil health, what they're really looking at is the productivity of their fields. Whether they know it directly or indirectly. That's what they are looking at is is the soil providing the medium that they need to produce high yields?

Dan Kaiser: Yeah. And I mean just kind of, that's one of the things, this question I think is pretty interesting because you see a lot of stuff floating around. Anna, that actually definition's kind of nice to hear because at least it sounds like there's at least some effort being put into having some definition with it. Because a lot of time kind of what it seems to me where I see a lot of this soil health definition functions more into like no till, or some of these organic type production systems, which I mean I don't think you really necessarily can limit it to that.

Dan Kaiser: I mean you have to look at a lot of conventional farmers right now are really looking at this more closely. And I think just getting a straight definition is really important at this because I think it'll give maybe some growers some ideas of some things they can do. Because you look at the diversity of the soils we have, there's a lot of practices out there, some good, some bad, they might work with some of the growers.

Dan Kaiser: So it just kind of depends on where you're at, and what soils you have. And that's one of the things you look at across the state. I know Carl, I mean you look at the sandy soils that you work a lot with versus some of the stuff we work with in central Minnesota. You may have different definition in terms of what you're trying to do with those particular too, just because you may not be able to do some of the same things with it.

Carl Rosen: Yeah. Exactly. The interpretations may differ. And the one thing about soil health that kind of has been a little different than the way we've thought about soils in the past is that it really brings in the biological component. And so I think that when you think about health, you think about something living. And so you think more about the microbes in the soil as as to how they might be functioning in terms of nutrients cycling, and those types of things.

Fabian F: Yeah, in thinking about that, I think that that's one of the big shifts that I'm seeing in the terms of how we look at soil fertility specifically. Even though we knew the biology of the soil's very important, kind of the view was more like the soil is this box where you just put nutrients in, and plants take them out. But in reality, there is a lot more that goes on. And I think it's important to recognize that. And beyond, Anna, you were talking about the conditions of the soil, and what benefit we get out of it. Again, the farmers I think are primarily interested in production. But there are a lot of other benefits that the soil can provide. Maybe there are some environmental benefits, or other functions that may be important, and the biology of the soil really plays a huge role.

Anna Cates: Yeah. That NRCS definition nods to this idea of the soil as an ecosystem, right, which gets it. Acknowledging the microbes there that are the foundation for the biology that builds the plants. And so it really acknowledges all those things. But the definition, even if you want to have your own definition of soil health, because there are a lot floating around, but the NRCS definition, because it says function in there, you can define your own functions. And therefore define what is for you a healthy soil, which might be different on a sand versus a Fargo heavy clay.

Dan Kaiser: Yeah. And it's one of the things to kind of with the microbial activity too. I think one of the things to think about too when we start talking about some of these that it's probably not a short term when you start looking at approach with some of this stuff. Particularly we start talking about biology. Because if you look at what's there under the soils, I mean a lot of that really is there because of what's been done over time.

Dan Kaiser: So in terms of changing some of that, may not be the easiest thing to do. It's interesting looking at it. I work a lot with specialty fertilizer amendments. And we see that now, although we did see it before, I think Carl, maybe with some stuff earlier looking at trying to affect the soil biology to increase nutrient availability. But it seems like, and now particularly with what we're seeing with nitrogen in particularly some products coming out, a bigger push from some companies just to start looking at trying to help increase or enhance the amount of nitrogen.

Dan Kaiser: But you look at the biology, it's really I think, tough to really fight what's there with trying to add something in. Because you've got something that's really been evolved from the tillage system, and from the cropping system over time that when you start thinking about it, that when you start thinking about cover crops and a few other things, working that in to be more effective at changing some of these things, and in over time, maybe trying to shift it towards changing that biology. But I don't think it's something that's going to be done in the short term. So it's kind of a longterm approach I think needs to be taken to a lot of this.

Fabian F: Yeah. And that's certainly a shift that I've been noticing with all this discussion about soil health that there are a lot of products out there that, again, the emphasis used to be kind of a product that had some nutrients in it. And now the shift has been more towards products that may not necessarily have any nutritional value per se, but that they are intended to enhance the ability of the soil, or the plant to take advantage of what is in the soil.

Carl Rosen: Or actually adding microbes to the soil. And the jury's still out on some of those products. And given the fact that each gram of soil has, what, a billion microbes bacteria, so you're looking at quite a lot of competition. So adding microbes to a soil may or may not be that beneficial. It's one of these things that needs to be-

Fabian F: It's like have a drop in the bucket when you look at the amount of biological activity already present. Right?

Carl Rosen: But there are certain practices that we can do to promote microbes. So things like cover crops, certain types of cover crops, potentially. Some might be suppressive of certain microbes, particularly pathogens. And so it's a complex system. There's no one simple silver bullet that's going to solve all problems.

Anna Cates: That's really the problem with the biological, the microbial amendments, I think is assuming that there's one microbe, or one strain of microbes that's going to do exactly what you need for your crops. The functions that we most want from microbes in the soil tend to be ubiquitous. We want them to break down residue and release nitrogen and other nutrients for the next year's crop. And millions of kinds of microbes can do that.

Anna Cates: So it's unlikely that we're going to find some microbe that's that much better at that than other microbes that if we add it, we're really going to see that big boost. Especially not right away, like you say. But in terms of how fast things can bounce back, microbes are ready to work for you. If you feed them, you give them water, you'd give them space, they're going to do their job for you. So they they do bounce back. The capacity is there, and you shouldn't have to add extra microbes.

Fabian F: Yeah. And just one more point that I think is important, we've been talking indirectly about the fact that these things are not an overnight thing. I mean, yes, you can feed the microbes, and then their functions will start. But in terms of seeing changes, improvements, that's, I think, one of the challenges that we face with this emphasis in soil health is that it's not something that you'll see overnight, and you cannot just throw more stuff at it in order to just make a change quick.

Paul McDivitt: Yeah. So there are several soil health tests available to growers now. What should they look for, and how should they go about testing their fields?

Anna Cates: I would always recommend starting with a shovel. If you're not looking at your soil regularly, and trying to understand how the structure is, and how well your roots penetrate. If you don't want to think about you know your technical soil structure definition, the roots are really good place to start. Because if the roots are penetrating 360 degrees, and having good spread, that's a sign that water can also penetrate. That's a sign that worms and beetles can penetrate. All these larger invertebrates that help with decomposition.

Anna Cates: So you can start with your roots as a sign of good structure. And if you don't have good structure there, you might want to look more specifically for compaction. So you can ask your local SWCD or NRCS office if they have a penetrometer, and get some numbers behind compaction. But you can also just

use a wire flag, or even a broken down hanger if that's what you have. And you just push it in, and see if you find a layer where there's more resistance.

Anna Cates: If you have a compacted layer like that, then you want to think about whether you can alleviate that maybe by reducing specific tillage passes, or looking at a more vertical tillage, or a strip tillage approach. Because I want to really emphasize that soil health is connected to structure. This biology needs structure to work. Just like your plants need structure in order to grow well. They can't have only too much water, or too little water. You have to have good soil structure that allows enough water to come in. So I would start with the structure and go from there.

Dan Kaiser: Well I think that you look at some of these health tests, I think to the more common one around, I think, here has been the Haney, who I've heard a lot talked about. And I think, Anna, talking about structure I think is pretty important because there's some of them, I know the Cornell, I think, does take that into account. At least looking at that, and I think that's really important to look at. Not just the some of the chemical, or the microbial cycling of nutrients in there, but to look at structure. Because that's probably the starting point.

Dan Kaiser: I think looking at the last few years we've had here in Minnesota, that's probably one of the bigger issues that probably have come to light, particularly with not being able to get into field at optimal times. Compaction I think really is a big thing that really is going to affect anything. Because a lot of our soils we look at are, we have higher organic matters. So if you look at microbial activity, you look at some of these tests, particularly the Solvita, which is a component of the Haney, which measures carbon dioxide respiration from the soil. You get high organic matter soils, you're going to tend to probably see higher respiration with that. So some of these other issues that you might be missing by not looking at some of the physical properties, I think it's really important with that.

Carl Rosen: So yeah, one of the tests that you can do, a physical property test, in addition to the penetrometer of course, is water aggregate stability, which gives us an idea of the kind of the aggregation of your soil, which is related to your organic matter, and just how you've been managing your soil. And so this particular test is a useful one that might show over time if you're seeing more water stable aggregates in there that you're promoting better soil health.

Dan Kaiser: I think one of the things you have to watch though, Carl, I brought that up before, is how much aggregate stability do you get in sand.

Carl Rosen: Yeah, it depends on your soil, and it's a relative test in my opinion. So even on the sand where you don't have a lot of water stable aggregates, if you're improving that over time by reducing your tillage or whatever, there's micro aggregates. There's some papers on that now that they're looking at. So there's things that that can be done, and it's kind of relative with each particular soil.

Fabian F: And I think that one of the challenges sometimes when you have something that you can measure, and have a number is that in a way it almost creates a stress. Because now you have people that have a soil that doesn't have very much structure, or a lot of organic matter, and you can now improve that soil perhaps as easily as some other soils where you already have a good start with, some of that good structure, good amount of carbon cycling that happens every year. And so I think it is very important to you to look at this really in terms of, okay, how can I improve these conditions over time in my specific location without comparisons across other landscapes, other soils.

Carl Rosen: Yeah. It might be difficult to have one standard for all soils. And so you're kind of looking at something incremental for your particular site.

Anna Cates: Yeah. If you're thinking about looking over time, you may have some history of standard soil tests from your farm. And looking at straight up organic matter which is often done in a standard soil test, will give you an indication of whether you're going up and down in terms of that total organic matter pool. And keep in mind that that organic matter pool, it relates to the structural things. Like Carl was saying, organic matter builds aggregates. And it also relates to your fertility.

Anna Cates: So it unites those two areas. It can give you some nitrogen release over the season, and it builds your soil structure. And if you want to dig into perhaps why your organic matter isn't changing, then you might consider something like the soil respiration test that Dan mentioned, which looks at how active microbes are over a short period of time. Or you might look at some sort of a pools within the organic matter that try to understand what carbon can a microbe eat.

Anna Cates: A lot of these biological tests are trying to essentially get into the mind and body of a microbe, and say within this soil matrix, how much is there for a microbe to eat? How capable are they of digesting the organic matter that's available? What's there? How active are they? And we're not perfect at this point at getting inside a microbe's mind, which is why all these tests are a little bit fraught, and not perfectly correlated with our outcomes in terms of plants. But you can start with that basic organic matter, and then you could dig down more into microbial activity, or to specific pools of extractable carbon within that.

Dan Kaiser: Well, looking at some of these tests too, I mean these tests really aren't cheap. I mean, I guess Anna, what would you suggest then, if you look at a grower in terms of how to sample a field, is there a certain suggestion that you see out there right now that in terms of how many samples, or where they should be sampling to try to get the best result?

Dan Kaiser: Because I assume if you look at it with these tests, I mean, you really should be trying to sample the same areas over time at least so you have a general idea. But the spatial variability out there, I mean especially with some of the variability we see in some these microbial. It's probably really more important to sample the same areas. It's just then, how many are you looking at sampling?

Anna Cates: Right, that is a real problem with this. Microbes are also, because they're living organisms, sensitive to temperature and moisture conditions. You need to be sampling at the same time of year. You need to make sure you're at approximately the same field conditions. And what I would think about is picking an area you really want to focus on.

Anna Cates: If you really want to just understand these tests, I wouldn't apply them across your 800 acre farm. I would think about a field where you really want to kind of explore these metrics to better understand this particular field. And I would sample there, maybe at just every two years to get a sense of change. And in the meantime just track your organic matter, look at your structure, monitor your crop, do the things that are cheap that really give you a lot of information about whether it's working. And don't, like Fabian says, stress about what your number is in the interim. Look for those incremental improvements over the long term.

Dan Kaiser: Yeah, that's one of the things I've wondered too. Because you look at, I've heard too, people sampling fence rows too, and just to try to get more of a native area. Although you look at some of the areas where you have a lot of wind blown wind erosion and you see a lot of blacks on those fence rows. I don't know. I mean is that native enough to... I mean, who knows?

Anna Cates: Well I think the idea is just to say if you have vegetation growing year round, you're feeding your microbial population year round, and you're going to have a really highly functioning, high organic matter soil. And so it gives you that benchmark for given your native texture you can't change, and your climate you can't change, what could you do if you had vegetation in their year round, and you never tilled it?

Carl Rosen: Yeah. One of the principles of soil health is to keep your soil covered, reduce or minimize tillage as much as possible. And so having that, I guess, the fence area that hasn't been managed as intensively, as say a row crop, would give you a comparison.

Dan Kaiser: Well I think that's, because I think Carl, what you said before I think is really important is that these things are relative. I mean they're relative to where you're at-

Carl Rosen: Initial conditions, yeah.

Dan Kaiser: ... your climate. And if you could find an area where you could look at what you deemed to be "initial", or natural or pre-whatever when the field was tilled conditions, and you immediately submit, and give you a little bit of a benchmark. But you'd probably want to be careful of where you take that sample to because it just of what can happen. You get too close to a road or something where can it chemically can change things, and with particularly gravel roads. So there might be some things to think about for that.

Fabian F: And I think in talking with farmers about some of these things, it can be demoralizing really when you think about the virgin prairie, and how much organic matter, or organic carbon we had versus what we have now. Or looking at a fence area close to the fence where maybe there is more. But really I think when you start thinking about improving the function of your soil, trying to protect what you have in there is the first step.

Fabian F: Building organic matter is not an easy thing to do. So whatever you have in there trying to protect it, like RLSA in trying to minimize tillage, trying to improve, or increase the amount of carbon cycling that happens, is really the starting point. And then yes, you can start worrying about doing things that will increase those things more. But as a starting point, I think it's just protecting what you currently have.

Anna Cates: Yeah. I think one of our colleagues sometimes says, if your soil's blowing and washing away, you don't need a Haney test. You need to start by keeping your soil on your field. And that's true. That's the baseline.

Dan Kaiser: And it's difficult too because you get to situations like potatoes or like sugar beets, especially. You look at those fields after harvest, I mean being that you got to dig the crop out of the ground, there's not a lot of cover left. But I think potatoes, sometimes you see rye going after that which I think can kind of help. So there are some things being done. But I think it's just looking at situation on what's the best for the particular-

Carl Rosen: There's certain crops where you're very limited like potatoes and sugar beets. It's going to be difficult to do a no till situation when those actually impossible to do no till. But there are things that you can do in the rotation year. And as Dan said, try to get some cover crops in there as soon as possible afterwards. Keep that soil more stabilized.

Anna Cates: Yeah. And I know the beet companies are starting to experiment with interceding cover crops under the beet cover to see if they can get a little residue leftover after that harvest that's super destructive. It'll protect it just a little more.

Paul McDivitt: So what research is available in Minnesota tying soil health tests to crop performance and yield?

Fabian F: Yeah. So there've been a number of studies. It was part of a kind of a regional study where Minnesota was part of it, but looking at using some of these soil health tests to predict how much nitrogen you need, things like that. And it's pretty difficult. I think there is a lot of variability like we were talking about, and that that creates some difficulties.

Fabian F: And the bottom line when we looked at across the Midwest, actually this study that I'm mentioning was done across the Midwest in eight different states, the

relationship with the Haney, for instance, to an economic optimum end rate that you would need to produce a corn crop was pretty low. It was less than 25, 26%, something like that. So at best you're looking at 20 some percent relationship to what you would need.

Fabian F: And so I think that that's a challenge if you use something a little bit more related to soil organic matter, like the Solvita for instance. You are able to improve a little bit, at least that's what we say in some of our studies, but still, it's not a one to one relationship that you would be like, oh yes, I know how much nitrogen to apply. And I think that that's a key distinction I think we need to make with some of the soil health test, is that, yes, they can help us improve what we are doing to improve the function of the soil. But to take that then to the next level and say, I will use these tests as a way to predict how much nitrogen I need, or how much phosphorus or potassium might need, that relationship is just not there right now.

Carl Rosen: Right. And we've done some work with the Solvita test, that's the CO2 respiration. And most of the results that we've found is that it's very similar to organic matter. There's a kind of a relationship with organic matter. We did find that yield was somewhat correlated with the Solvita test. This isn't a corn cropping system. It worked better with corn corn than it did with corn following alfalfa, or soy beans.

Carl Rosen: So I think with all these we have to remember there has to be some calibration. And we're just at the beginning of that right now. And so a lot of this takes time. Our conventional soil test, chemical soil test, took 20, 30 years to get good calibration numbers. So these types of tests are going to probably take about as long as we get more familiar with them.

Dan Kaiser: Yeah. And what I've seen with it, I mean I've looked at the Solvita as well, and what we were seeing kind of would echo some of what Carl was seeing. I think a lot of it is situations where you look at organic matter being a bigger component, like your control plots. We could look at a pretty nice, good relationship with a control plot yields with the Solvita.

Dan Kaiser: But that economic optimum end rate, it's difficult. And one of the reasons for that, I think, and then Fabian if you've got any thoughts, but I think it just understanding the dynamics of mineralization, and then inorganic nitrogen, which we have in the soil. What's more important in terms of determining what that optimum end rate is?

Dan Kaiser: Because it seems like, more often than not, you look at some of the inorganic fraction we have at the early part of the season, to me, I mean, it seems like that's more important in terms of determining what our optimum end rate is, and then mineralization, we look at that determining kind of what our yield potential is. Because mineralization, if you look at what favors that, it's also going to favor optimal plant growth and development.

Dan Kaiser: So if we increase mineralization rates, we're likely going to increase the uptake of many other nutrients in the growth of the crop, that's going to enhance crop yield. And I've seen that where you just look at almost seeing some sites where we have greater mineralization through the end of the growing season, just a higher yield potential, and really not needing much more nitrogen, or even less nitrogen at some point. But the optimum end rate was pretty similar to what we'd predicted before.

Fabian F: That's right. Yeah. We have had a very difficult time in even predicting from year to year what the EONR will be. Right? And it's directly related to that, it's the weather conditions. And a lot of these things that we do to kind of help us figure out how much nitrogen we need to apply obviously needs to be done before we do the application.

Fabian F: And at that point, when we think of the growing season, at best maybe we have have had, what, about a third of the growing season under our belt to use that information to determine what will happen. But then the next two thirds of the growing season, if it turns out to be almost ideal conditions for mineralization, which will also mean ideal conditions for corn growth and plant growth, will completely change the equation compared to a year maybe where the conditions are not so good.

Anna Cates: Yeah. And I would also add that these soil health management systems, with reduced tillage, with increased inputs from different crops and cover crops applied, the idea is to provide more organic matter to stimulate those microbes. To essentially promote more mineralization of nitrogen and other nutrients. And so, some people argue that these tests are more calibrated for systems which are promoting mineralization, are feeding their microbial populations, and trying to not only rely on that, but really boosted by feeding microbes year-round with a living root, with plenty of different kinds of residue. I don't think that has been validated with any tests, particularly in Minnesota, but it fits with what you're saying that in a system where mineralization is more important, these tests are more predictive.

Carl Rosen: And if you have have manure in your rotation as well, that's-

Anna Cates: Yeah. Another big biological-

Carl Rosen: That’s right.

Fabian F: And see, I was just thinking about that. The difficulty of predicting how much nitrogen you need when you have manure. And obviously manure would be one where it can help you quite a bit in increasing the amount of organic activity in the soil. But that's just another level of complexity in trying to determine how much would you need based on what is being released from the soil, from the manure that was applied.

Carl Rosen: Exactly.

Dan Kaiser: And one thing too, I've seen it for a number of years, I actually seen it back growing up too, my dad's been farming for a number of years, is when you change a practice, if there's some sort of benefit that longterm that you might get out of the practice, it might take a while to see it. And you may not necessarily see where it might be you may have a negative impact at certain points when you first start something.

Dan Kaiser: Just thinking no till, or some other practice that it may take a few years to see benefits of that. And that's one of the things that, when you look at this, is you've got to think long term. I mean it's something that you've got to be willing to, and some of this, I think particularly no till, I've gotten a lot of questions, particularly out of Western North Dakota where they say they can reduce their nitrogen rates with no till. But that's a different system, and that may have taken a few years to develop, as what Anna was saying, to get some of these processes going.

Dan Kaiser: So it may not necessarily be that it's something's going to happen overnight. The other thing we've been looking at, too, on some of these tests is, they've been looking at phosphorous, potassium, and some of these other nutrients, is we see a lot of correlation among a lot of these tests to some of our standard tests. And if there's correlation there, I don't see that great of a benefit to shifting towards one of these tests, particularly if it's a higher cost test where we start getting away from trying to, particularly grid sampling or zone sampling, where we can't afford to do that when we're trying to better manage particularly P&K to try to reduce overapplications in areas and try to bring soil tests down.

Dan Kaiser: So there's some things there. And if you look at, particularly, the Haney, looking at that's more of a weak acid extraction. I mean this aren't new things. I mean these are things that have been research, 20, 30, or more years ago, probably even back to when the Bray was developed, they were looking at different tests. And the reason they stuck with some of those more harsher extractions were the fact that they could correlate them easily to crop response.

Dan Kaiser: So when I look at a lot of these, I think the nitrogen, and that maybe sulfur in some of those other cycles we know, that phosphorous cycles, I mean somewhat with organic matter, but we'd also know that these tests a lot of times are just snapshots in time when you take them. So I don't think that really these soil health tests are going to be any better than any of these other ones in trying to forward predict the amount of phosphorus being available, that you just have to be careful with that.

Dan Kaiser: And I know the Cornell, they usually recommend going with whatever state recommend it is with that one. Which I think is probably a good approach. Because we've got a much stronger database behind a lot of these in terms of crop response. And yes, I mean, the weak acids are going to be similar to what a

crop row is exuding. But if you look at it in terms of weak versus strong, if they correlate together, there's really no advantage of going with one over the other.

Fabian F: And I think, we hear of some tests being used in another state maybe far away from here, from Minnesota, and people say, well if it works there, it must work in here. But we need to remember that, as we were saying earlier, a lot of these things they need to have the correlation calibration work in order to figure out, okay how much you need, how can you use these numbers to help you determine what the application would be, the nutrient application, whether it's PK, or nitrogen. And without that work, it's just a number. It lacks meaning in terms of what you do with that number, right?

Carl Rosen: Yeah, you can get a number, but what does it actually mean. And so that's where it takes the 20, 30 years of working with these tests to try to relate it to yield, or what other properties that you're interested in.

Fabian F: I think the real value really is in looking at these values over time, just simply to see if you're moving the dial, if you're improving things, but not necessarily to use those as a predictive approach to nutrient management.

Paul McDivitt: All right. That about does it for the podcast this week. We'd like to thank the Minnesota Agricultural Fertilizer Research and Education Council, AFREC, for supporting this podcast. If you haven't already, subscribe to the podcast on iTunes and Stitcher. You can also find out about new podcast episodes as well as our blog posts and videos by subscribing to Minnesota Crop News email alerts. Just Google Minnesota Crop News, and click get Minnesota crop news by email at the top of the page. And be sure to follow us on Facebook and Twitter at umnnutrientmgmt. Thanks for listening.

(Music)