Your optimal N rate: Understanding its impact on yield, water quality, and the bottom line

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Show Notes / Transcript
Advancing Nitrogen Smart, from the University of Minnesota Nutrient Management Podcast: "Your optimal N rate: Understanding its impact on yield, water quality, and the bottom line"

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(Music)

Jack Wilcox:
Welcome back to Advancing Nitrogen Smart, a special podcast series that connects the science of nitrogen in the environment to practical, efficient nitrogen fertilizer management. I'm Jack Wilcox, and I'm a communications generalist here at University of Minnesota Extension.

As always, we have Brad Carlson, Extension educator, and Dan Kaiser, Extension nutrient management specialist here with us.

In our last podcast, we talked about application timing. Today let's talk about application rate, which is the most popular topic for most producers. Brad, what should growers know about rate?

Brad Carlson:
Well, Jack, the material that we're drawing from today, as we've been pulling a lot of our podcast material out of our existing curriculums, is the rate discussion that's centered around reducing nitrate loss to water. And so one of the key principles that we've focused on throughout all of our years in Nitrogen Smart is that frequently rate is being used to mask other problems. I don't know if I want to say bad practices or maybe less than optimal practices, but frequently we'll have people bumping up their rate because they've pretty well figured they're going to lose some nitrogen because of what they did with other practices, whether the application timing was not ideal or they choose to nitrogen source that may be prone to loss compared to another. And so I think we really want to focus on rate from the standpoint of what's our ideal management, and not so much on trying to adjust that rate based on making other poor choices.

Dan Kaiser:
When it comes down to the fate of the nitrogen we apply, it's a percentage loss. It's not if you apply 100 pounds versus 200 pounds, you're looking at a percentage. I'm not just losing 10 pounds, so say I lose 10%, that's 10 pounds, 100 pounds per acre of applied. And say I apply 200 pounds, then it's 20%. So when it comes down to loss, there's a lot more risk the more we put on, especially up front, if we have conditions that are favorable for loss. If we look at the fate of the nitrogen we apply, about 40% to 70% we expect to go into the plant. If we look at average nitrogen use efficiency, though, if I look at a lot of our studies, it's closer to that 40% range.

So we're getting roughly about 40% of what we apply into the plant. And what's interesting, if you look at just our control yields or our check yields where we have no nitrogen in it, that we generally can raise anywhere from about 65% to 70% of our total corn crop just on the nitrogen that's in soil. So looking at it from the standpoint that we're chasing about the last 25% to 35% of the yield that we have with the nitrogen we apply, where does the rest of it go? About 15% to 30% we'd expect goes into soil, organic matter and immobilization. This isn't necessarily a bad thing because, as I said, we're getting some nitrogen from the soil, so it's more of a recycling mechanism that's stabilizing the nitrogen, making it less prone to loss, and then between about 10% to 30% losses. And losses really depend on your soils and your particular conditions within a particular yield.

We generally expect some denitrification loss, leaching loss. Just depends on how much rainfall and whether we get tile flow. So when it comes down to losses, and again, a lot of it, we say 10% is likely going into the atmosphere and it's not really necessarily going down into the tile drain. So really with rate, I think it's the big thing and the big consideration a lot of growers need to make is, again, looking at risk assessment. Because again, knowing what we know in terms of where some of that's going, that it becomes a bigger issue in terms of what we should be doing.
Brad Carlson:
And Dan, it seems like it should be simple. It seems like it should be a simple math equation, looking at how much fertilizer you applied and then what's in the plant and what did you lose. Some of these things are very difficult to quantify. I think as an industry we've all come to grips with the fact that only about half the nitrogen we applied ends up in the plant, but it's not all showing up in the water either. The rest of it's not showing up in the water. There's this weird black box in the soil as far as what's being pulled into the organic pools in the soil. It's very difficult, because the organic fraction of the soil is already so high, it's difficult to look at fluctuations from one year to the next, and it's very difficult to monitor what's going out in gaseous form, just basically going back as N2 gas, because the atmosphere is already all N2 gas. And so it's just a very hard thing to get a complete picture handle on.

Dan Kaiser:
Looking at from site to field to field, we know that there is real rate variation from one field to the next. Although looking at targeting the right rate, why it's important, if you start looking at

the potential for nitrate loss, is that we know that the amount of residual nitrate, it's what we typically measure in most of our studies. We don't always have tile drainage where we can measure the amount of nitrate in the tiles below every plot that we have out there. So we look at a proxy by looking at residual nitrate, or nitrate left in the soil after harvest, because that nitrate would be more subject to loss when we get losses in April, May, and June since, again, there's no crop out there that can actively take out. The more we have out there, the more we risk for loss.

One thing that we do know, if you look at across all of sites and no matter what the optimal rate was at those particular sites, is that if we can hit that within some reasonable range on a year to year basis, we know we can greatly reduce the risk for nitrate loss. We see essentially when you start getting beyond the optimal nitrogen rate within a site is where the loss potential turns to increase and can get somewhere between close to one to one in terms of a pound loss for every pound that we leave in excess in nitrate from what that crop would use. So that's a pretty extreme circumstance, but we do know that can happen. So when it comes down to it, getting at least as close as we can, and I will talk about this because again, rate variation is real, we know that it's out there, is really important in terms of trying to mitigate the risk for nitrate loss.

Brad Carlson:

Well, the other thing is, Dan, if we look at some of the data relative to residual soil nitrate, a lot of farmers will assess over 10 or 20 pounds, but typically 10 or 20 pounds isn't going to cause a real big environmental hazard. It's really when we start getting 50, 60, 100 pounds extra out there that we really start seeing a lot of problems. In addition to that, I've had a lot of producers, they've looked at some of our data or the way we look at this with residual soil nitrate, and they want to go out and look at it themselves. They're curious, "What do I have left over in the field?" That's a difficult thing to do. You really need to be out there soil sampling immediately after harvest because of the transitory nature of nitrogen. It could start to be immobilized or it could start to be lost through other pathways, and so it's possible to go out there and sample your own residual soil nitrate, but it's probably not a practice a lot of farmers are going to do.

Dan Kaiser:

Yeah, I think we could go into a tangent on that and talk for quite a while about that soil testing option. Some growers have been doing it more recently. Going from dry to wet years is really where we tend to see a lot of those issues with the residual nitrate, because growers that aren't factoring some of that in, we tend to see a lot of the nitrate go out through the title lines early in the growing season. So that's the challenge with it, I think, on the growers' side, is how accurately can we credit some of that? That's one of the things on the research side that I think if we know we're beyond a certain point, that we likely have some nitrate that can be credited from what's left over in the soil, but it's a big question mark right now. And it could be why we see some of the variation from year to year in some of our nitrogen rates.

I've been tracking this with the MRTN database, looking at over time with the start of that database tracking the yearly optimal nitrogen rates, and we haven't seen a big difference in the corn following soybean. Maybe a slight jump where about, I would say five to seven years ago, or somewhere around 2015 or so when they started making changes, that we saw a jump up in some of the guidelines, and a lot of that was just because we started adding more data into it. That's one of the things with a database, whether you like it or not. The nice thing about it is, one, it's defendable. I've got real-world data that gives me an average, at least a starting point to where we should be looking at starting with our nitrogen guidelines, and I have data to back that up. But we do know that that does change over time and it can fluctuate.

One of the biggest things that we saw in Minnesota was in the corn following corn database, where we were recommending close to about 150 or 140 pounds back when the MRTN, the maximum return to nitrogen, the recommendations were implemented. We've seen that steadily increase over time, and I think a lot of that isn't necessarily due to loss, at least due to environmental loss. It's probably more into that soil, organic matter, mineralization, and immobilization factor. As we've gotten more corn residue on the landscape, particularly in continuous corn with a lot of these newer hybrids that we get larger stocks and more residue in there, that we've seen more immobilization.
But looking at the trends, trends are trends. You'll see some ups, you'll see some downs, but in general the continuous core has gone up the last, we look at 2020 and 2021 at this time is where I've got some of that data out to. We've seen actually the yearly averages drop, and some of that could be reflective of some of these things that we're seeing for nitrate carried over. But the big thing about this is, again, we know there's real-world variation. The thing is, we have no way to effectively manage that and tell a grower, if you have 10 fields, what that optimal rate will be in all 10 of those fields. We just really don't have the ability to do that right now. The best ability we have at least is to look at the data and let the data tell us in terms of what that starting point should be.

Brad Carlson:
Well, a lot of farmers will have enough experience to know that, if you've actually explored the issue. If you're just simply applying a set rate and you've never varied the rate or looked at other circumstances where you might have lost some or had some skip applications and done some yield checks and so forth, maybe you don't even have a feel for what the actual variability is in your own fields. One of the technologies that we have been at least playing around with, I know, Dan, you spent a lot of time looking at this, but we're still not ready for prime time as a recommendation, is looking at what those yields are at zero nitrogen, as just giving us a indicator of what the field conditions are and the ability to supply nitrogen. Because that's going to ultimately affect what the total amount of supplemental needs to be from applied fertilizer.

It's something I guess if you really are curious, you could start messing around with that a little bit on your own fields, see what you can grow on zero. Obviously you're not going to put

zero on a whole field and find out, but maybe a small area and do some yield checks in that area and see what you can grow on zero. Then you know what percentage of your crop you're supplying with the applied fertilizer.

Dan Kaiser:
The main thing, if we have anybody out there that's our non-farm audience listening, is just because our rate is going up over time doesn't mean that we're getting more nitrogen loss through the tile lines. That's one of the things that's really important with that when we start looking at a lot of our data. I think certainly the nitrogen is going somewhere. I think a lot of it's either going to that other piece, that immobilization piece, or potentially denitrification. I think that's really the real big issue now, especially when we get a lot of, we're getting more soil saturated for longer periods of time in June where we get more of our denitrification occurring.

So I think that's the fear. A lot of groups see, "Okay, well, you keep increasing your recommended rates." Well, it isn't necessarily because we're getting higher yields. It's one of the things we have decoupled the recommendations from, is a yield goal based system, because it doesn't work. For about any nutrient we look at, while we do maintain some, it doesn't really work, if you look at it. And it's not just corn. I've been looking at dry edible bean, it looks about the same. We have a yield goal based system with nitrogen that doesn't seem like it's really going to hold that really matters as well. So why those came into place is, they made sense at that point in time when people were doing it with the studies that they had in place. Now that we have these large data sets that we can put together, looking at something like the maximum return to nitrogen or the MRTN is, I think, a better option, because it's more data driven versus some of what we were doing in the past.
Brad Carlson:
Well, and to reiterate one of the things you talked about, Dan, the last podcast when we were talking about timing, we were talking about doing residual cell nitrate testing post-harvest. Not that that's a big practice we recommend, but we do it in our research projects and some farmers have had some interest in that also, is really, though that kind of monitoring has shown us over the years that we are reducing nitrogen loss, nitrate loss in situations where we are most efficiently using nitrogen in the field regardless of what the application rate is. If it's the right rate, it doesn't matter if it was 100 pounds or 200 pounds. If it was the amount the crop needed, we're minimizing loss. And so those rate recommendations or the rate selection that you have as a producer, as long as that's the correct rate for that field, you will be minimizing nitrogen loss.

Dan Kaiser:
And you talked about nitrogen use efficiency, and that's one of the interesting things. When we look at nitrogen use efficiency, typically the most efficient use of nitrogen is always that first pound applied. If you look at the response curve, it's what we call a curvilinear response, essentially where it's diminishing returns, if you want to put it out that way. So what happens is, as you approach your peak or where your maximum yield is, we tend to get less yield

increase per pound then applied, and that does affect our nitrogen use efficiency. We do tend to see some differences in among our sites, and as I said, generally about 40% is what we would see for nitrogen use efficiency across the state.

The big thing, though, when it comes down to it, really is, what I see is we can get some pretty good efficiency if we can raise as much as we can with as little nitrogen, I think is what growers ... We look at it, we get the best use of efficiency, but the best nitrogen use efficiency I've seen across the state is about 50%. And that was back in 2012, I had a site where we had the most efficient use of nitrogen, near the optimal nitrogen rate, which it doesn't always necessarily work that way. Most of the time essentially we lose efficiency with every pound applied, and it gets to a point where it really starts to drop off. So that's one of the things that you'll hear a lot of things or see in the popular press, a lot of products that are really pushed out there to help you work with nitrogen use efficiency, but I have not seen any magical potions that you can apply with any of your nitrogen to greatly increase the efficiency.

It's really just a key point of trying to target the optimal nitrogen rate within your field as close as possible. And that's one of the things that I've thought a lot on, is in terms of good management, what should we consider in terms of how close we should be to that optimal nitrogen rate? And I'd be ecstatic if we get within 10 to 15 pounds. I think a lot of other researchers, if we can get within about 30 pounds, we should be happy with that. Because really looking, again, that rate variation is real. We know it's real. Just, I wish we had the technology right now that we could just say, "This is the amount you need within that range within a given field." And as Brad said, we might get there at some point.

Brad Carlson:
Yeah, I think we're not going to go too far off on a tangent here about technology, but I think artificial intelligence does potentially have the ability at some point where we can create our own data sets, producers can create their own data sets, and just allow that technology potentially to start advising you on what's working best in your own fields. And a lot of people have the ability to sort that out in their own mind, but in some cases there's a lot of things that computers can tell you that you can't figure out on your own.

Dan Kaiser:
A lot of growers will talk about their current efficiency factors. If you look at historically, I think, Brad, 1.2, the pounds of N, that's what a lot of people use in terms of their rate recommendations. Now if you look at it, 0.5, 0.6, 0.7, somewhere in there. The interesting thing, though, if you look at that, a lot of growers will talk about that. Guess what? It puts you in the range of where our MRTN is. It's kind of magic how that actually works with that. So we aren't all that far off. The main thing, though, I think is to not use old information.

And at one point too it just will not die. From a grower's standpoint, I guess it makes sense. I've got so much yield that takes up so much nitrogen. The big thing about that is, you're completely discounting essentially what that soil's supplying, and you're just completely discounting that when it comes to using something like that factor to come up with your

recommendation. And if you are going to use it, essentially your information would come pretty much into line with what we're already recommending. Really the question, though, is, do reduced rates of nitrogen help reduce nitrogen loss to water? I think we've hit that, Brad. Really looking at it, if you hit the optimal nitrogen rate, we know that has a pretty great reduction in the overall risk for potential loss.
Brad Carlson:
Well, we've got a long track record of research on that, and that's something that we keep hearing from folks on the environmental side who are advocating or looking at aggressively trying to achieve our water goals. We all want to achieve our water goals, but we do hear this occasionally. "Well, just apply a suboptimal nitrogen rate, then you'll always be very efficient." But what we've discovered is, because such a large percentage of the nitrogen that we're losing through the tile lines comes from soil organic matter, it's not impacted by fertilizer, we actually don't see a big improvement in nitrate concentrations when we do that. It just turns into a major economic penalty. And so applying suboptimal rates is not going to solve our water quality problems. That's just a fact. And then from the flip side, then from the farmer's perspective, though, is don't overfertilize. That's the other thing, because we have shown that if you're applying too much, it can be left pound for pound. As long as you're applying the right amount, we're going to pretty well minimize the amount that we're losing through the water.

Dan Kaiser:
It's one of the things that does come up. You talk to farmers and they say, "I'm raising 250 bushel now, by God, I need more nitrogen than I did 15, 20 years ago." And you look at the data we have, I plotted this, I've looked at this within our data set, and there is absolutely no relationship between yield at our optimal nitrogen rate versus that optimal nitrogen rate. I've got instances in some of my data sets where we've gotten upwards of 250 bushels per acre with less than 100 pounds of N. I know, Brad, you've seen it, you've had some studies in, was it Rice County, when you saw some of that 150 pounds N for 250 bushels?

Brad Carlson:
280, yeah. We were maximizing corn on corn where the ideal nitrogen rate was 140 pounds. In fact, this wasn't even a nitrogen study, so if we had lower rates, we couldn't have even found this out, but we had 280 bushel corn with 140 pounds of applied nitrogen, corn on corn.

Dan Kaiser:
That's one of the things I like about the maximum return to nitrogen approach, is it really factors in looking at that overall efficiency and that return per pound of N you apply, and just making sure that you're maximizing your return to your nitrogen no matter what your maximum yield potential is going to be. We certainly know there's just soils out there that are good yielding soils that are going to yield very well, no matter whether you have a suboptimal or an optimal rate, the circumstance you were talking about.

Brad Carlson:
Yeah, one of the things that we've tried, a point we've tried to bring home related to the recommended rates, the MRTN rates and the nitrogen rate calculator, is that it's not an average. It's not a situation where half the sites needed more and half the sites needed less. It actually encompasses a large percentage of the sites. And for the ones that did need more, in most cases, those situations are very knowable by the farmer. You're capable of putting a little extra on there and seeing what happens with that, knowing if it's a site that just simply needs a higher rate. And so this shouldn't just be a shot in the dark as far as, what does this field need? I think most guys should have enough track record where they can figure that out.

Dan Kaiser:
If you look at the data, even if you look at those sites where we needed more than what our MRTN recommended the range has, we've got sites that yielded 150, we've got some that yielded 250. So again, you look at that, there's no tie-in. It's all based on nitrogen loss potential in those soils. So that's really what you need to focus on. Certainly you probably could look at some of the yield maps. You've got some areas that are consistently lower yielding. Some of those, maybe they need more, maybe they need less. I don't know. That's the thing that we just don't have a good handle on right now, because the transient nature of nitrate makes it very difficult to come up with some sort of recommendation system to be more specific on some of those soils.

Maybe with AI, maybe as Brad said, we can input a bunch of factors in to help us make some of those decisions. But right now, I'm not saying it's a shot in the dark, but where we look at our MRTN is the starting point, and working away from there in terms of, at least we know that this has been demonstrated to be the optimal rate. Then we just make some adjustments based on what we know on the site. So we are looking at that. I have looked at within our rate recommendation of the database just to see if there's a way to predict. I've looked at splitting the database out by soil types. So looking at maybe our southeastern Minnesota soils, some of those less soils tend to mineralize a little bit more. Maybe they're slightly less versus our central to Western Minnesota, the high clay soils.

When I did that, it made absolutely no difference in terms of the optimal N rate. I've looked at a few other factors, it really doesn't make a whole lot of difference. Really the only thing, if I look at my control yields and my check yields without nitrogen is, we can see those soils that tend to produce, it can produce more without nitrogen, tend to be the ones that need less nitrogen. So that should make some sense. So I've been wondering if there's a way to start looking at that and whether or not, if those numbers are consistent over time in a particular field, if we could model somewhat those check yields, it might give us an idea to fine-tune or hone in better on our rate recommendations. And we're not there yet with that. But looking at the data, if you take the corn-corn and the corn-soybean data, it all fits pretty much the same model. So it really tells me, one, we know that the corn-corn, if you don't put nitrogen, you're going to get less yield from that just because of the penalty the corn residue has.

And then two is that we put these two together, that we might be able to develop a little bit better database. We could figure out a way to predict that overall yield potential without nitrogen. So to me, that looks just somewhat promising just based on the data set, because just using overall maximum yield just won't cut it when it comes to making that recommendation.

Brad Carlson:
And ultimately, I think the yield monitor data is probably going to be a big portion of where we're going to head with making more precise management decisions on these sites. Because we're just not finding factors that we can measure that are otherwise correlating to why some of these sites need less nitrogen. I go back to, here in 2024 somebody brought me a batch of soil nitrate test data when we had a lot of nitrogen deficiency showing up, and the numbers all looked bad. A lot of the stuff that we saw in season looked bad, but they were four parts per million, stuff like that. It was like what we would consider background level.

But what the guy said was, "But here's this field." He says, "This one's also four, but this one, the color looks great. This was the best looking field I've got, and it's also at background level." And so there's something going on with that soil that it was supplying nitrogen and the other ones weren't, and the soil test data was the same. Ultimately, we're probably going to have to use yield monitor data and comparing it to some of these management decisions in order to tease out where these sites are and how we're going to manage them best in the future.

Dan Kaiser:
And it may not just be soil chemical properties too. That's one of the things you look at. I don't know, how much does management 40 years ago affect things now? Compaction, now tillage. It's complicated, and that's the problem with nitrogen. It's just complicated to figure out. There's too many things that can come into play. If I look at phosphorus and potassium, the soil test is a pretty good risk assessment tool of whether I'm going to be short or not. The benefit of those two, though, is as long as you're not grossly overapplying, typically anything in excess is going to carry over from one year to the next. With nitrogen, that's not the case. And so that's one of the things. We're dealing with a biological system, and biological systems are complicated. So understanding all that and what's going into the availability can be important.

But the main thing is that if you look at it, again, reiterating this comment from before, is that if we can target that optimal nitrogen rate for every field within a given year, that should give us the greatest potential for mitigating potential risk for loss. Because again, once we get beyond the optimum nitrogen rate, anything not used by the plant that could be left in the soil after the growing season can potentially be lost. That's one of the biggest challenges and one of the things that really need to be looked at, is at least trying to get things within a better

ballpark where we're not applying in excess 40, 50 pounds of nitrogen than what that crop actually needs.

Brad Carlson:
Yeah, and Dan, to circle back where we started, as I said, we're drawing the material for this podcast out of our session on reducing nitrate loss to water. One of the concepts that we've talked a lot about is, when you apply too much nitrogen, it's pretty much left behind pound for pound in the field. And so what we've also seen with a lot of our data is that a large percentage of the nitrogen loss through tile lines is coming out in April and May and early June. And so if you've attended Nitrogen Smart, you've listened to some of our podcasts, you know a little bit about the timing of nitrate movement, so through the soil profile and how long that takes and so forth. Physically, the applied fertilizer has not had time to convert to nitrate and move down three feet into the tile line to be lost in March and April. That's not what's being lost.

And so that has to either be residual nitrogen from the previous year's crop or it's mineralized sources, and that's a topic for a different day. But particularly when we're talking about residual nitrogen from the previous year's crop, that is an area where we could stand to make a lot of improvement in water quality, is just simply not overfertilizing and leaving it behind in the field to get flushed out in the springtime. And again, if it wasn't this year's fertilizer that was applied with last year's, well, but that's still a decision that needs to be made long-term to prevent that from happening.

Dan Kaiser:
I think a talk for another podcast would be looking at some of these cover crops, because that's really what they're intended to do. If you can get them established, you get something out where it can at least draw some of the nitrate out. So looking at it in terms of that, the suboptimal rate thing, again, we talked about this before, it does come into question every once in a while. We start talking about some of the things that people are proposing out there to reduce nitrate loss, and we know that the small reductions in rates aren't really going to result in this. They shouldn't really result in a great loss of yield.

But honestly, looking at it in terms of that, we do know that there's a risk for that, and we do know that looking at reducing the amount really doesn't give us that great of a gain on that. So the risk involved really isn't there. Really the big thing is trying to be better managers and targeting the optimal rate. Getting as close as we can within a given field is really what we need to be able to do.
Brad Carlson:
Yeah, I guess that's, to wrap things up here, the main point we want to make from a water quality standpoint is that zeroing in on the correct rate is really what's important. And ultimately, applying less than what's necessary isn't going to solve our water quality problems. However, not overfertilizing is going to be a big thing. We need to make sure that we're not doing that. And we've talked about before that there's four R's, not just one. And

the one that we always dwell on is rate and how much do I apply? And really, as we've said before, if you're applying a higher rate because you're making a less than optimal decision with your timing or your fertilizer source, ultimately as an industry we can't really be in that position. We're going to have to get our rates to be what the rates need to be and our other application practices to also be ideal.

Dan Kaiser:
I think that's a big key, because you could apply the right rate and apply it, follow your re at the right rate, for the recommended rate, and lose half of that.

Brad Carlson:
Right.

Dan Kaiser:
That's the thing. You've got to consider those other R's, and we always just really hone in on rate, and I think that's where our biggest mistake has been, lots of people just looking at rate, not looking at the broader picture of some of the other practices that are out there, particularly source. Really looking at it that we know there's a big interaction between the two, but as you said before, we shouldn't be using rate to mask practices that we know we're losing nitrogen. We can't have that attitude where in the past where you'd get this wink, wink, "I'm losing more nitrogen. I know I am in the fall. What rate should I apply?" You always get that question in the past from growers, and really we need to be getting away from that, because it's just not a good attitude or not a good mindset to be in. Because if there's a better alternative out there that we still could get the same yield, but just by switching practices but reducing the risk for loss, is really what we need to be moving forward to.

Jack Wilcox:
Dan Kaiser, Extension nutrient management specialist, and Brad Carlson, Extension educator. Thank you both for all of this information.

Brad Carlson:
Thank you.

Dan Kaiser:
Thanks.

Jack Wilcox:
Have a question about something you see on your farm? Send an email to Brad or Dan at nutmgmt@umn.edu. Thank you for listening, and we look forward to seeing you next time.

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