Nitrogen Management in Organic Potato Production: Challenges and Opportunities
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I have to give you a bit of a disclaimer–I've never done organic production. But hopefully I'll be able to give you some information that will be helpful, because I'm going to try to focus not so much on the actual production, but more on some of the processes: Where does nitrogen (N) come from? Where does it go? What controls the availability of N? So hopefully, even though I don't have the organic background, I can still give you some information that you can put to use.

The goal that we've been working on is trying to match the supply and demand. Can we meet the crop N requirement, knowing that the demand by the crop is different in each field? So it's different from field to field, it's different from year to year, and we want to be able to optimize that N management so we can get the tuber yield and quality that we're looking for.

Why N? In terms of the nutrients, we tend to really focus on N for a couple of reasons. One is in terms of yield. Often N is the nutrient which is most limiting and, particularly in an organic production system, it often can be difficult to get the N supply that you need, especially with potato, which does tend to have a fairly high N demand. Clearly, without the N supply you don't get the yield and you don't get the size of tubers that you might want. The other side of it is environmental; an excess supply of N can have an environmental impact. So it's either nitrate leaching or, what we're hearing more and more about–greenhouse gasses–nitrous oxide production. That's the key greenhouse gas in terms of agricultural production.

What we've been doing is trying to look at the flow of N in the system. Where does N come from? Where does it go in terms of both the crop and in terms of other losses? What I would like to do is spend a bit of time talking about each of these today to give you a bit of an understanding of where N is going. I'm going to start here in terms of the N demand from the crop. In looking first at a whole-season basis, this is the total tuber yield of Shepody 1 cwt/acre, and this is the amount of N in the whole plant measured just before topkill. What's interesting is that there is a nice relationship between the two, and it's quite consistent. This is across 3 different years, it's with potatoes growing after the 3 previous crops–potato after barley, potato after potato, potato after red clover. In all cases we get basically the same relationship out of this site.

Now what's interesting with this is that we can actually draw a line here at about 150 lbs. So here N is limiting. If you have a higher supply you get more yield response, but you can get to the point where there is no more response. In fact, you may have more N in the plant, but it's mostly in the vines and it's not giving you yield response and actually may give you trouble in terms of either reduced gravity or difficulty actually getting the plant to die down for you in the fall. But it's not always the same.

These plots were done in the same years. You can see quite a different curve–here there is less response than over there. Why is that? Basically it had to do with water supply. There was more water stress here in these plots, so you don't have same growth, you don't have the same demand for N. So in terms of being able to supply a crop, a lot of it comes back to the demand that you have. Basically, the better your growth conditions, the more N you need. If you can plant early, if you have optimal moisture, and if you have good soil, your crop will actually require more N than the other way around.

There are two aspects. One is yield. We looked at both the total yield and the size of the 10-oz tubers as we increased our fertilizer rate, and what we're seeing quite consistently is that as you increase your N supply you will increase your yield, and eventually a plateau is reached, but the size continues to increase. In conventional production we're often going with relatively high rates, as much as anything to get the size. That was on a whole-season basis.

Let's look now at the timing of the N used by the plant. This is data from Bill Bland in Wisconsin. The blue line is the amount of N in the plant as the season progresses. This is days after emergence. There are a couple of things I want to point out. One is that you can see the very rapid increase early in the year. So the initial uptake is very rapid, and then it begins to level off. It is leveling off for two reasons. One is in terms of the actual growth of the plant. Once the tubers begin to bulk, you actually have less uptake from the soil and you have more N being transferred from the vines to the tubers. In fact, the amount of N in the vines actually decreases; it's being translocated to the tubers. The other reason is that the supply in the soil is decreased. You have a lot of N in the soil in the beginning; as the plant takes it up there is less and less, and that decreases the rate of uptake. The key to this is that quite early in the season is the period where you have the most rapid uptake or the greatest N demand by the crop. This may be one of the challenges that would be faced in organic systems, and I'll talk about that a bit more. Now that's for Russet Burbank, which is a long growing season crop. I want to contrast that with Russet Norkotah, which is a shorter-season crop. These are very different patterns. You can see that you have uptake and then it stops. You'll see again that you have the uptake in the vines, but dropping off much earlier in the season. So, again, you have an early period of rapid uptake, but that period is shorter. So again with a shorter season crop you have to have the N earlier, but it's more important to have that N early, because it actually stops taking N up later in the season.

You have to get your 150 lbs. of N in the plant to get your optimum yield. In an ideal world if you needed 150 lbs. in the plant, you would just give it 150 lbs. somehow, but life is not that simple. There are a lot of different sources of N; it comes down to variation in supply. Here's that same data, but presented in a little different way. Here is the amount of N we are applying, and here is the amount of N that is going into the plant. You can see a lot of variability. So even at the same rate there is quite dramatic differences in how much ends up in the plant. Why is that? It's differences in the soil N supply. In our conventional systems we apply fertilizer that way, but we're getting a lot of N out of the soil. In your case, where you can't apply this, knowing that soil N supply then becomes the critical factor in your management.

What I want to focus on is just a part of that. This is what I'm calling our soil N supply. So you do have a little bit of N that goes from one growing season to the next, but it tends to be small. So we're going to ignore that one. We're going to focus on these two. This is the microbial activity taking organic forms of N and breaking them down to make them plant-available, and it's coming either from the soil organic matter itself or it's coming from the crop residues. Here are some estimates of soil N supply that we've come up with. We don't apply any N in any form in the areas where we grow potatoes, and we look at how much is taken up by the whole plant at topkill. This becomes an estimate of the N supply.

There are a couple of things I want to emphasize. One is the size of these numbers. You can see that we've gotten up to 150 lbs. N/acre coming out of the soil in some cases–quite significant numbers. The other thing I want to emphasize is the variability. You can see that we have about 40 to 150 lbs–a lot of difference. There are some different reasons. One is weather.

In 1999 we had good mineralization weather. All fields were high. These higher values tend to be associated with a legume crop in rotation, so there are a number of different factors that control this. The key is to be able to get numbers that are high enough that you can get the supply you need to get your crop.

Now, in terms of the timing of the supply, what we've been doing is having plots of soil that we keep bare. We measure the nitrate over the season to see how the N accumulates to see when that occurs. We see a fairly consistent increase over time. We're seeing most of the difference in the previous crop later in the growing season, not so much early in the growing season. Again, this is a different example. Here's one where these was some more carryover, and you can see that gradual increase over time. This one was lower because of moisture stress.

The reason I was leading up to all of this was to try to put the two together–the supply and the demand. So the N demand of the crop tends to start off low. You get that period of very rapid uptake early in the season which then drops off, whereas the N supply tends to be more gradual. Without care, you can very quickly run into a deficiency situation relatively early in the growing season.

Let's talk about the N supply a bit more. If we took a snapshot at some point, it might look something like this. We actually have a large amount of N in the soil, but most of it is organic—it's not plant available. Most of your plants are taking up nitrate as well as some ammonium, but to get from here to there requires microbial activity. This is incredibly simplified. I don't want you to think that this is actually how things behave, but we're going basically from the organic form to the ammonium form to nitrate. In reality it goes back and forth and goes other places. But we're looking at microbial activity to convert organic N first to ammonium through mineralization and then, typically very rapidly, going from ammonium to nitrate through something called nitrification. It's this mineralization that you require to get that N into a plant-available form.

So if we look at different sources of N that you can use in an organic production system, there are a number of factors that control that ability to supply N. It obviously depends on how much you put on. So how much amendment? What is the amount of N in it, or the concentration? This controls the amount that you add. Then there are factors that control the availability. How available is the carbon (the carbon basically being an energy source for the microbial population)? If the carbon (C) is available, they'll use it very rapidly; you get rapid release. Of course the C:N ration will affect that. If there's not much N compared to C, you don't get much coming out of that material. Particle size is also important. If you have a very large stock of an organic residue that can't be broken down very readily, it's due to the surface area. The bacteria work on the surface of the residues, so if it's finely chopped you'll get rapid decomposition.

In terms of some of the sources, for example crop residue, you're looking at N mostly in organic form. It will increase your long-term potential for mineralization. Depending on the residue, you can get a large contribution that year, but not necessarily. For example, you would with a legume, but if you had very mature straw you would have a very limited contribution. I'm not sure to what extent you can use manure, but if you have manure or a compost that has not gone to completion you would have both organic and ammonium. Ammonium is plant available, so you have some benefit from that immediately, and then you would have an increase in the potential for mineralization from the organic N. With a mature compost it's a little different. There is no ammonium–it's basically all organic. That means that your actual contribution the year you apply it becomes very small; mostly what you're doing is increasing your potential in future years. I've noticed on the ACORN website there are a number of different organic amendments that can be used, mostly in organic form. In some cases the N is quite readily mineralizable, so you can have a significant amount being applied that year. In other cases you are basically increasing your potential for mineralization in the future.

Finally, there are a number of organic fertilizer products out there, but it becomes very specific. The source material used and the process used will really control how available that N is. You maybe can get a significant contribution that year, or maybe not. It really depends on the particular product.

Lastly, I want to talk about weeds. I've been estimating the N supply. We have plots we don't put any N on. We go out at topkill and harvest, and in a couple of cases we had fairly weedy plots. So just out of curiosity I thought I'd sample the weeds as well. Here are two examples. This is one site, and this is the second site. The green is the amount of N that is in the crop, and this is what's in the weeds. In this case it's sort of neck-and-neck as to who's going to get more N. The weeds are actually pretty competitive. What I want to emphasize is that they are very competitive. In terms of the difficulty in getting N available to begin with, the weeds then become quite a competitor. So weed control becomes very important.

Q: What process do you use to determine the amount of N available in weeds and potatoes?

A: For the potatoes, what we do is take a set area of the row and we harvest everything–we take the vines, we take the tubers, we take the stolons, and most of the roots. We wash them, we dry them, we measure the amount of N that's actually the plant tissue. For the weeds we did basically the same thing. We took a certain length of the furrow and we just harvested all of the weeds. Again, we washed them and did an analysis on them.

Q: What kind of analysis do you do?

A: We do combustion. We get the C and N both.

Q: Is the uptake pattern based really on the plant demand, or how much the plant could take based on what was left in the soil?

A: I asked the same question myself about two years ago, and I'm actually pretty convinced that this is what the plant wants because we have seen the same patterns even when the soil N supply is very high late in the season–we're seeing a very consistent pattern. It has to do with the relative sink strength, so the sink strength of the tuber is much, much more dominant than the canopy. So as soon as tuber bulking begins, the actual uptake out of the soil seems to drop off quite dramatically relative to that. So, yes, that is an excellent point and I'm sure that it's true to some extent. There's no question about it. If you run out, you run out. You can't take anything out. But I think there is an overriding pattern that is based on the relative sink strength.