NITROGEN SOURCE AS IT AFFECTS POTATO GROWTH

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This paper is one of several on nitrogen at this conference. I did some calculating which indicates that we are asking you to spend a good share of your time listening to talks on nitrogen. There is good reason for these demands on your attention. Nitrogen is involved in all life processes. Other than carbon, hydrogen, and oxygen, which are provided to a plant via the air and water, nitrogen is the most common of all the elements essential for plant growth. In potatoes, only potassium is found in amounts comparable to those for nitrogen.

Because nitrogen is absolutely essential for plant growth, and because it is required in such large amounts, nitrogen fertilization is an important, perhaps the most important, tool in any management program where a grower is attempting to increase crop yield and quality. Appropriate use of nitrogen can improve both yield and quality. Inappropriate use of nitrogen, or bad decisions involving nitrogen, can seriously reduce crop yield and quality. Total yield, percent number one tubers, and specific gravity may all be affected, and all of these affect return to the grower.

What does a grower need to know in order to use nitrogen effectively? What does he need to know to increase tonnage, quality, and specific gravity? He certainly needs the answers to three questions: how much to use, when to use it, and what form to use. A major point that I would like to make is that for each of these questions there is a simple answer, but there may also be less simple, more complex answer to each of these questions that is more realistic, more accurate, and more likely to achieve the desired results.

Let me illustrate what I mean. At one time the answer to the question regarding how much nitrogen to use was simply more. Generally, as nitrogen fertilizers first came available, crop yields increased as nitrogen use increased. There is a kind of simple logic operating here. Since nitrogen is one of the most common constituents of the potato, obviously there has to be more nitrogen available if yields are to continue to increase.

I think we are all older and wiser now. We now know that the answer is not so simple: a grower may actually provide more nitrogen than the plant can use, and situations may develop where yields are decreased because of excessive applications of nitrogen.

The second question that the good grower needs to answer is when to use nitrogen. Again, the simple answer is that the grower needs to apply nitrogen at any time he expects to grow potatoes. But the more realistic, as well as the more complex, answer is that the grower needs to assess (1) the stage of plant development, (2) the capacity of that stage to use nitrogen, and (3) how additional nitrogen will affect yield and quality. Obviously nitrogen applied too early before planting may be leached away so that after planting too little remains to sustain normal developments.

Just as obviously, I think, nitrogen applied too late in the season may interfere with normal tuber growth by continuing or promoting vine development. There may be as a result an actual decrease in tuber weight, and, perhaps even worse, a subtle yet real and economically significant decrease in total solids (specific gravity).

A discussion of all the biological mechanisms involved in nitrogen use is beyond the scope of my talk, but I do want to make the point that the answer to the question as to when to apply nitrogen may be a complex one.

The third question the grower needs to be able to answer is what form of nitrogen to use. This is the question I want to discuss in detail. Now here is a question that may have a simple answer, but if it is simple it isn't because of the lack of options. Common forms of nitrogen include urea, anhydrous ammonia, liquid or aqua ammonia, ammonium sulfate, ammonium nitrate, potassium nitrate, and calcium nitrate. This list is not comprehensive. There is a major consideration here. A grower doesn't need to do much shopping around to realize that there are some tremendous differences in costs of these different forms. Any grower considering his production costs would be compelled to look very seriously at whatever form is cheapest, particularly nowadays when one considers the cost of the money it takes to buy nitrogen.

There is good reason to consider only cost when choosing what form of nitrogen to use. Most potato fertilization studies have shown that the form of nitrogen fertilizer applied to the soil has practically no affect on potato yield and quality. Let me use some data collected by Bob Kunkel, Norris Holstad, and Brian McNeal at Washington State University to demonstrate this (Table I). In the Columbia Basin it doesn't seem to matter whether a grower uses ammonium nitrate, ammonium sulfate, or urea. Total yield, percent number ones, specific gravity, blackspot index, and chip color were all essentially the same regardless of the form of nitrogen applied. When confronted with these kinds of results, it is difficult to justify paying extra for a particular source of nitrogen.

A couple of questions might be asked here. I'm a horticulturist and a horticulturist often asks something like this: If the kind of nitrogen has no affect on potato yield and quality, is this due to a lack of preference on the part of the potato? Or does the potato actually have some preferences which, under ordinary circumstances, are not expressed?

We might also ask what happens under ordinary conditions? Under ordinary conditions it probably doesn't matter what is applied to the soil because in most agricultural soils all forms of nitrogen usually end up as either ammonium or nitrate ions before being taken up by the plant. Further, most ammonium ions are converted to nitrate ions by bacteria normally present in the soil. What's the consequence? The consequence is that as long as those bacteria are present, a potato plant is going to experience a fairly monotonous nitrogen diet.

If all these interconversions are going on, how does one go about testing whether a potato really does have some preferences for some particular form of nitrogen? Several years ago I became involved in a project funded by the Potato Commission. One objective of this project was to grow potatoes tissues under conditions where everything could be identified as to form and amount. The procedures allowing this are called tissue culture. A result is that one can study potato growth and development under completely artificial conditions. One can look at nitrogen nutrition, for example, without things being complicated by bacteria changing the form of nitrogen being provided to the tissue. Thus, using such a system we could ask how a particular form of nitrogen influenced potato growth.

Our results showed several things. First, we could grow potato tissue fairly successfully under these totally artificial conditions provided that we used the right form of nitrogen. Tissues wouldn't grow without nitrogen, which was no great surprise, but they also would not grow when only ammonium was present. They grew better in nitrate, but best growth was obtained with a combination of ammonium and nitrate. As Table II shows, unlike the field results there are substantial and striking differences in growth as a result of the form of nitrogen provided.

A combination of ammonium and nitrate nitrogen turns out to be better than a wide variety of other nitrogen sources. Using this same system we tested numerous nitrogen sources (over 20), including urea, but even urea, either alone or in combination with ammonium nitrate, was not as effective as ammonium nitrate alone (Table III).

We also looked at the effect of the ratio of ammonium to nitrate nitrogen. What we did was keep the total amount of nitrogen constant and then change the amount of ammonium relative to the amount of nitrate. In spite of there being the same amount of nitrogen in all treatments, there were substantial and again striking differences in the amount of growth (Table IV). Ammonium alone again did not support growth. Nitrate supported root growth but only a little shoot growth. Best growth occurred when both ammonium and nitrate were present in the ratio of three parts ammonium to one part nitrate. Clearly, in this artificial system, potato tissues did have a preference for the kind of nitrogen supplied.

Of course, the really important question is how these results relate to a field situation. Is there a contradiction? I personally am not sure. We don't have enough information. As I mentioned previously, in the soil generally both nitrate and ammonium are interconverted. This is routine whenever the appropriate bacteria are present. And, as long as they are present, any preferences on the part of the potato will remain insignificant and unimportant.

But what if the bacteria are not present? In that case, I can speculate that the form of nitrogen applied to the soil could conceivably become significant and important. How significant and how important is part of the next talk by Max Hammond.

Table I.

Cumulative results of studies over five years with ammonium nitrate, ammonium sulfate, and urea nitrogen fertilizers.

	SOURCES OF NITROGEN		
	NH_4NO_3	$(NH_4)_2SO_4$	Urea
Total yield (cwt/a)	540	553	530
Percent No. 1's	67	68	68
Specific gravity	1.082	1.082	1.082
Blackspot index	67	67	68
Chip color	26	26	26
Percent petiole nitrate	3.28	3.53	3.47
Percent total N	2.73	2.88	2.83

(Data from Kunkel, Holstad, and McNeal)

Table II.

Effects of inorganic nitrogen sources upon growth of potato meristems.

Treatment	mM	mg total FW	mg total DW
Control	0	2.4	0.4
Ammonium sulfate $(NH_4)_2SO_4$	15	7.2	0.9
Sodium nitrate $NaNO_3$	30	24.4	3.4
Ammonium nitrate NH_4NO_3	15	684.4	27.2

Table III.

Effects of urea and ammonium nitrate upon growth of potato meristems.

Treatment	Total fresh weight mg shoots	Total fresh weight mg roots
Control	4.4	0.0
Ammonium Nitrate	165.7	169.6
Urea	93.3	61.2
Ammonium Nitrate plus Urea	89.4	129.9

Table IV.

Effects of various ratios of ammonium and nitrate nitrogen upon growth of potato meristems.

Treatments	mg Total fresh weight shoots	mg Total fresh weight roots
100% Nitrate N	1.1	76.9
75% Nitrate N 25% Ammonium N	32.8	151.6
50% Nitrate N 50% Ammonium N	94.3	252.5
25% Nitrate N 75% Ammonium N	186.0	255.2
100% Ammonium N	0.7	9.5