NITROGEN SOURCE AND FUMIGATION INTERACTION IN POTATO PRODUCTION

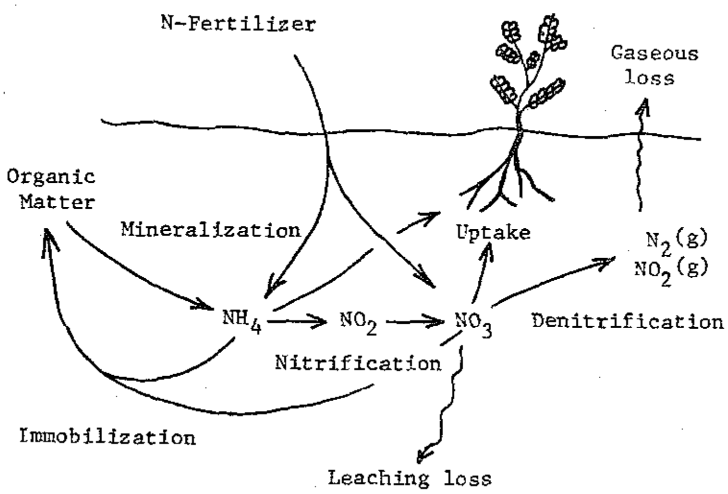
by
Max Ward Hammond
WSU - Hammond Farms

The effect of nitrogen source on potato growth and development in Washington soils has been discussed before. The findings by Kunkel (6) were that the type of nitrogen fertilizer had no effect on yield.

Under normal conditions in most of the central Washington soils, the various forms of nitrogen are rapidly converted to the nitrate form by soil microorganisms. As shown in figure 1, organic forms such as crop residues, manures and some commercial fertilizers such as urea are converted to the ammonium form by various means which are so collectively referred to as mineralization.

Figure 1.

SOIL NITROGEN TRANSFORMATIONS



The ammonium nitrogen is rapidly converted to nitrate nitrogen in a process called nitrification. As shown in figure 2, this is a very specific, two-step process carried out by two soil bacteria. Thus, under normal soil conditions where these various transformations are occurring, the potato plant receives mainly nitrate nitrogen no matter what form is applied. The question arises, what happens when nitrification is inhibited?

The practice of soil fumigation has become common and is usually essential to quality potato production in many of our soils. The soil bacteria responsible for nitrification are extremely sensitive to many soil-applied chemicals and especially soil fumigants. Their populations are rapidly reduced to low levels and are much slower than most soil microorganisms to return to normal levels. Little work has been done on nitrification inhibition by fumigation in Washington's soils. Much has been done in other areas and under normal field conditions nitrification can be inhibited for 4 to 8 weeks and sometimes even longer (5,8). The effects of fall fumigation are lengthened by soil conditions of winter since the bacteria do not grow rapidly at low soil temperatures. Work done with Vapam produced results shown in figure 3. In this research, ammonium nitrogen was applied to test plots at the rate of 100 lbs. of nitrogen per acre. In addition some plots treated with Vapam at 40 gallons or 100 gallons per acre. In the fall, the two fumigated soils showed no nitrification as measured by soil nitrate analysis. However, the ammonium in the non-fumigated soil was rapidly changed to nitrate. It appears this nitrate nitrogen was lost during winter months. In the spring there was no difference in nitrate levels between the unfertilized check and ferilized, non-fumigated treatment. The 100 gallon rate of Vapam appeared to delay nitrification well into the spring. The 40 gallon rate did not delay nitrification in the spring when soil temperatures were high enough to sustain nitrification (3).

Figure 2.

NITRIFICATION

$$NH_4^+ \xrightarrow[\text{Nitrosomonas}]{} NO_2^- \xrightarrow[\text{Nitrobacter}]{} NO_3^-$$

Aerobic

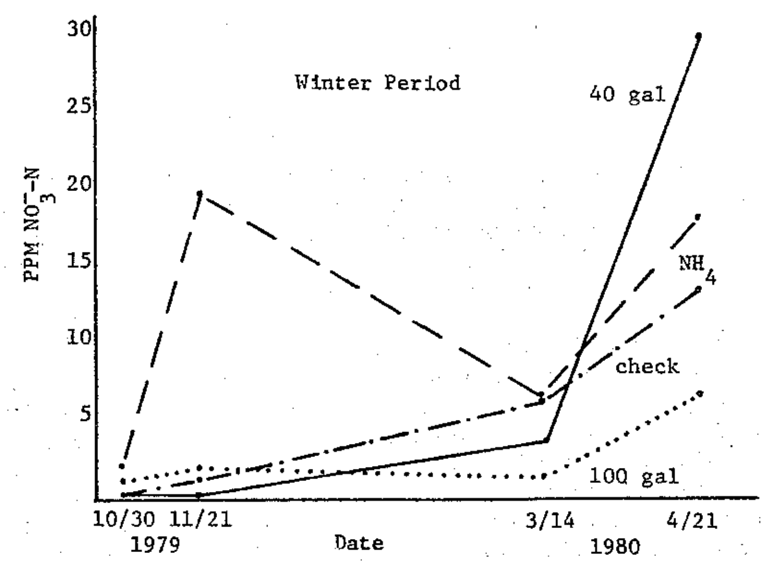
5° to 40° C.

41° to 104° F.

Fumigation Inhibits

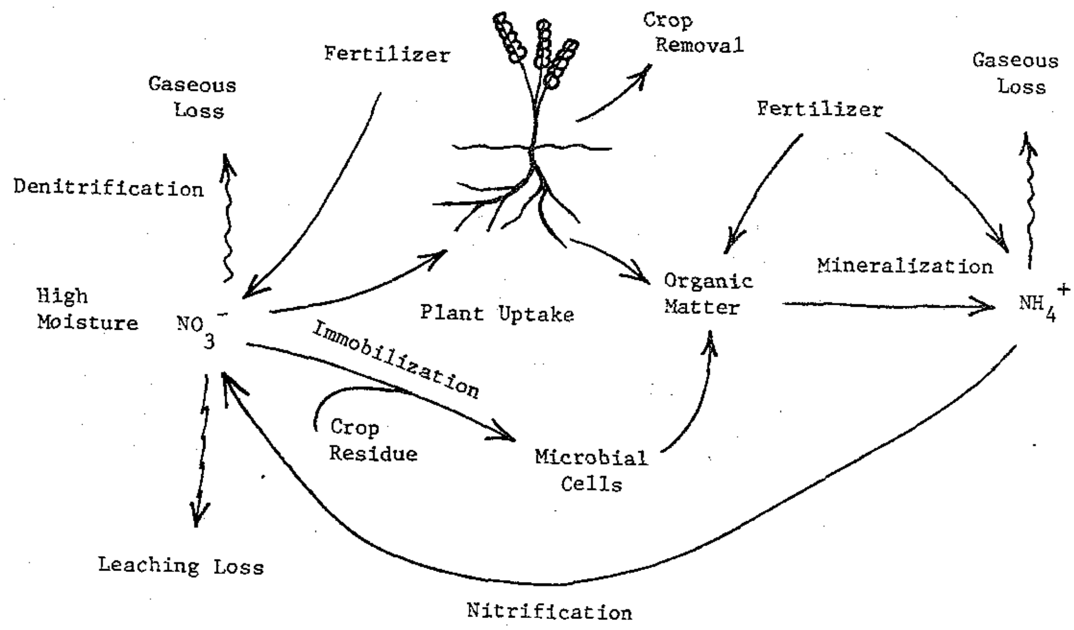
Figure 3.

NITRIFICATION INHIBITION RESULTS WITH VAPAM



Nitrification inhibition by fall fumigation can be a very effective tool in nitrogen fertilizer management. Nitrate nitrogen is highly vulnerable to loss in various ways as shown in figure 4. Plant uptake and immobilization by soil microorganisms breaking down crop residues of wide carbon-nitrogen ratios are normal and continuous processes. However, under wet soil conditions, nitrate can be rapidly leached from the soil root zone and/or lost by denitrification, the latter can account for considerable loss during low oxygen conditions brought on by high soil moisture levels. Inhibition of nitrification greatly reduces these losses.

Figure 4.



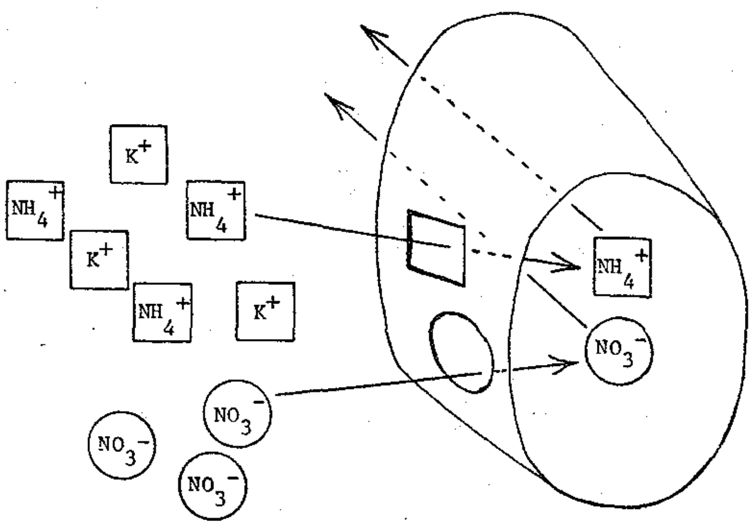
NITRATE LOSSES FROM IRRIGATED SOILS

However, nitrification inhibition during the growing season of the potato can have detrimental effects on potato growth and development. Research with other crops has shown that the resulting high levels of ammonium nitrogen uptake are detrimental to normal plant functions. Limited work with potatoes, mainly under laboratory conditions (1) some of which have now been reported in this conference (7) show the same negative effects. While more information is needed, there appear to be at least two negative effects of high ammonium uptake. Undoubtedly there is a combination of these as well as other unknown effects. The first well-known effect is that of competitive cation uptake mainly between ammonium and potassium as shown in figure 5. High ammonium levels reduce the uptake to potassium and also other plant nutrients such as calcium and magnesium (4, 9). Potassium deficiency symptoms in potatoes are increased when the main source of nitrogen is in the ammonium form (10).

A second but perhaps less understood effect is an interaction between high ammonium uptake and carbohydrate metabolism within the plant (figure 6). Carbohydrates are produced by photosynthesis and are used to synthesize plant structural materials such as cellulose, stored as starch to provide energy needed for many metabolic processes and when combined with nitrogen, the carbohydrates are converted to amino acids which are the building blocks for the various plant proteins.

Figure 5.

NH_4^+ Vs. K^+ - COMPETITIVE UPTAKE



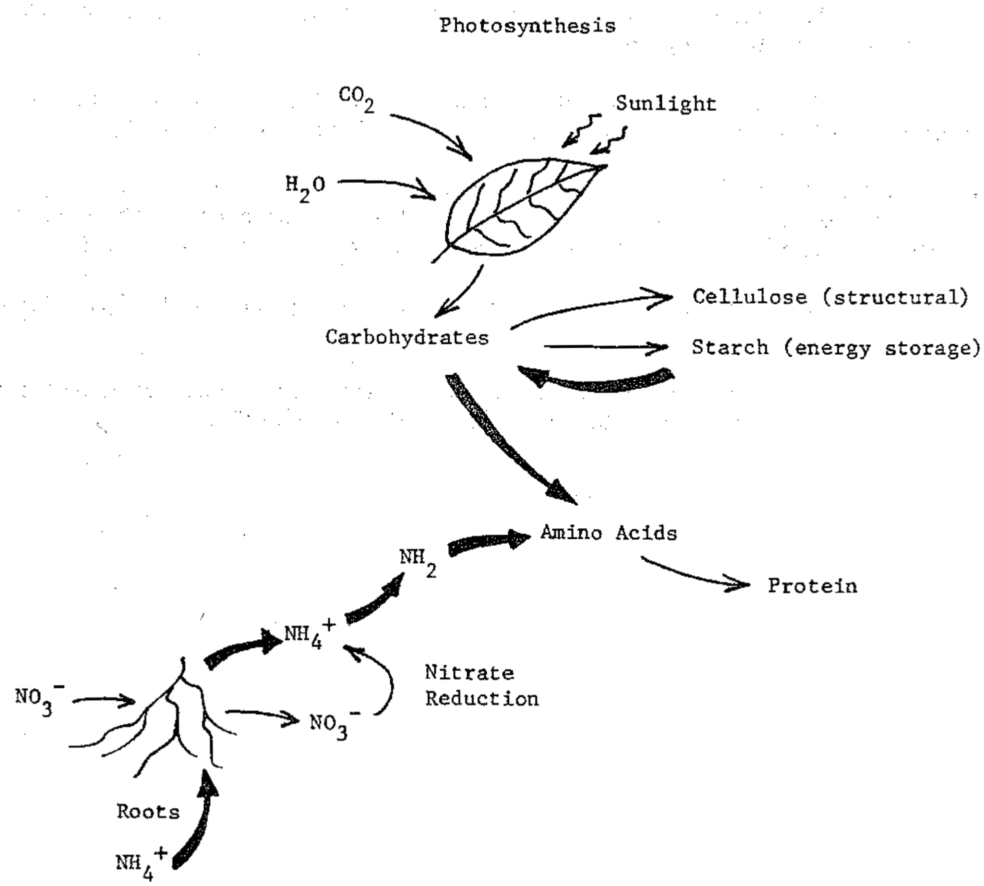
Under normal conditions, when both ammonium and nitrate are being utilized by the plant, the nitrate must be reduced to the ammonium form before being incorporated into amino acids and then other nitrogen-containing components. This step is by-passed when ammonium is utilized and when present at high levels amino acid systhesis can occur at a much higher rate. If photosynthesis is unable to provide an adequate supply of carbohydrate for this synthesis, less is used for structural synthesis and starch is pulled from storage to provide for protein synthesis. In effect, the plant becomes depleted of carbyhydrates needed for other essential processes (2, 11). This could produce weaker plants which are more susceptible to disease organisms and which have tubers with lower solids. Starch content of tubers has been sharply reduced when potassium deficient potatoes are given ammonium nitrogen (10).

In conclusion, under normal soil conditions where nitrification is not inhibited, the form of nitrogen fertilizer will have little effect on potato production. In fumigated soils where nitrification is inhibited there may be detrimental effects on potato growth and quality production.

While there are some indications that this is happening, the full extent or seriousness of the problem is not known and more work needs to be done.

Until more work is done, it is best to bear these nitrogen source-fumigation interactions in mind when making management decisions on nitrogen fertilizer.

Figure 6.



EXCESS AMMONIUM - CARBOHYDRATE INTERACTION

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