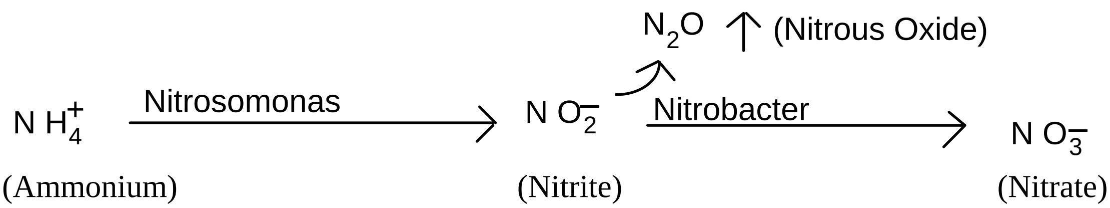
# NITRATE AND AMMONIUM NITROGEN STABILITY AND UPTAKE

WHICH FORM IS BETTER FOR CROP GROWTH?

Nitrate-nitrogen ($NO_3$) is the most abundant form of nitrogen available for plant uptake. This is due to rapid conversion of ammonium fertilizers to nitrate by the nitrification process (Figure 1) (12).

**Figure 1- Nitrification Process (12)**

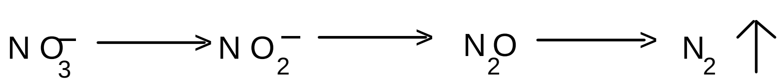



Nitrate-nitrogen is readily absorbed by root tissues via water uptake, assuring constant nitrogen supply in all but extremely dry soil conditions. Nitrate-nitrogen is the most abundant form of nitrogen in the soil and uptake is easily accomplished through water absorption. However, this does not mean nitrate is always the most beneficial and/or preferred form of nitrogen for good plant growth and development. Benefits of ammonium nitrogen are centered around chemistry in the soil as well as in plant metabolism.

Soil attraction, or adsorption, for ammonium-nitrogen ($NH_4$+) is good except for low organic matter, sandy soils. The longer soil nitrogen can remain in the ammonium ion form, the less are chances for nitrogen losses through leaching or denitrification. Unfortunately, the process of nitrification quickly converts ammonium to nitrate within two to four weeks in soils above 55˚F., and chances of enough nitrogen remaining in the root zone throughout the growing season may be slim unless nitrogen application management techniques are employed. More timely nitrogen applications made closer to crop uptake needs allow more favorable soil retention of nitrogen as well as better balance between ammonium and nitrate plant uptake.

Management techniques favoring more efficient nitrogen application include specific placement, split-nitrogen applications and/or incorporating the use of a nitrification inhibitor. Nitrification inhibitors have been shown to be effective, especially in lighter textured, well-drained soils in reducing nitrogen leaching losses, as well as in soils that tend toward water-logging, reducing nitrogen losses through denitrification (9) (Figure 2) (12).

**Figure 2 - Denitrification Process (12)**




Maintaining greater ammonium concentrations through more efficient nitrogen applications benefits plant growth as well as favoring better soil retention of nitrogen and improving phosphate availability and uptake (3). Greater concentration of ammonium ions have benefited cereal grains, corn, grain sorghum and cotton, especially during early periods of growth.

A key factor in promoting good early growth is having soil nutrients in forms that are readily available for uptake and easily metabolized for plant needs. Ammonium nitrogen fits these earlier growth needs much better than nitrate nitrogen. Looking at nitrogen conversion to protein in Figure 3, nitrate, while easily taken up by young plants, must first be converted to ammonium to be utilized in protein manufacture.

**Figure 3 - Nitrogen Metabolism Pathway (8)**

$$NO_3^- \longrightarrow NH_4^+ + \text{Organic Acid} \longrightarrow \text{Amino Acid} \longrightarrow \text{Protein}$$

Figure 3 outlines the steps involved converting nitrate to ammonium. Key factors in powering this reaction are light (producing $NADPH_2$), energy stored in carbohydrate reserves and adequate supplies of the enzyme nitrate reductase.

The key factors just mentioned can point out why too much nitrate and not enough ammonium nitrogen can be detrimental to early plant growth. Too much early nitrate uptake would force a drawdown on the small amount of carbohydrate energy reserve to power the nitrate to ammonium conversion, leaving less energy available for photosynthesis and other growth processes such as root and shoot development.

The enzyme, nitrate reductase, has to be free and in sufficient quantities to allow the reaction to continue. Excess nitrate molecules will tie-up large amounts of nitrate reductase. Young plants do not have large amounts of nitrate reductase, nor do they have the capacity to manufacture the enzyme fast enough to facilitate a nitrate dominated uptake.

Research has indicated where nitrate dominates the young plant's diet, the entire protein manufacturing metabolism shuts down due to lack of nitrate reductase enzymes (10).

Figure 4 helps illustrate the importance of balanced ammonium and nitrate plant consumption on protein leaf content in corn, with a distinct advantage apparent where the ammonium-N source (ammonium sulfate) was used with the inhibitor nitrapyrin(N-Serve) (1).

**Figure 4 - Effect of Ammonium Nitrogen on Leaf Total Nitrogen Concentration in Corn Plant Based on Field Observation**

Where nitrate is solely utilized in protein manufacture, internal plant pH increases, creating an adverse climate internally for other plant metabolic processes, notably carbohydrate manufacture and photosynthesis (10). A slowdown in carbohydrate conversion to sugar created by a nitrate dominated uptake can lead to potential occurrence and susceptibility of corn to stalk and root rot (5,10). The problem of "the lazy plant" syndrome, where photosynthate builds up in leaves and slows down photosynthesis rates can be alleviated by insuring a better balance of uptake between ammonium-N and nitrate-N forms (6). Table 35 summarizes the importance of balanced nitrogen nutrition in corn from work done at Purdue (11). Three different corn hybrid types, based on their genetic ability to respond to nitrogen, were field grown and subjected to varying proportions of ammonium-N and nitrate-N. The best yields across all three hybrid types were where ammonium-N was managed to be at least in equal proportion to nitrate-N (50/50) in plant uptake.

**Table 1 - Effect of N Source on Corn Hybrid Yields**

| | **Nitrogen** | | | | |
|---|---|---|---|---|---|
| % $NH_4^+$ | 0 | 0 | 25 | 50 | 100 |
| % $NO_3$ | 0 | 100 | 75 | 50 | 0 |
| **Hybrid Type** | **Grain Yield, Bu/A** | | | | |
| High Fertility | 123 | 151 | 175 | 187 | 175 |
| Intermediate | 118 | 147 | 155 | 167 | 159 |
| Low Fertility | 122 | 137 | 145 | 154 | 153 |

N Rate - 200 Pounds + 1 Quart N - Serve/A
Adapted From Tsai, Et Al., 1982

Disease research on wheat also cites excess nitrate uptake leads to increased incidence of Take-All root rot (2,7). Factors decreasing the magnitude of the disease were maintenance of at least three times as much ammonium-nitrogen as nitrate-nitrogen in the soil, which leads to a better balanced nitrogen uptake, more favorable soil pH surrounding the roots, and a reduction in uptake of nitrate-N by chloride. Chloride was shown to be highly effective in helping to prevent Take-All root rot in wheat, as well as showing positive responses in yield, particularly where good nitrogen management is utilized (Tables 2 and 3) (2,4).

**Table 2 - Take-all Severity Index and Gain Yield as Influenced by Soil pH and Spring N Source**

| Soil pH | Spring N source | Take-all index 11 weeks * | Grain yield Bu/A |
|---|---|---|---|
| 5.5 | $(NH_4)_2SO_4$ | 3.48 | 52 |
| 5.5 | $NH_4Cl$ | 3.16 | 69 |
| 6.6 | $(NH_4)_2SO_4$ | 3.72 | 57 |
| 6.6 | $NH_4Cl$ | 3.68 | 54 |
| LSD (p = 0.05) | | 0.16 | 7 |

* Weighted mean take-all severity class

**Table 3 - Influence of Applied N on Wheat Yield Response to KCl in South Dakota**

| Applied N[1] | 85S[3] KCl, lbs/A 0 | 85S[3] KCl, lbs/A 120 | KCl response 85S[3] | KCl response 84N[3] | KCl response 84S[3] | KCl response Average |
|---|---|---|---|---|---|---|
| lbs/A | Bu/A | | | | | |
| 0 | 58.3 | 67.9 | 9.5 | 6.1 | 6.7 | 7.5 |
| 120 | 68.2 | 74.8 | 6.6 | 2.9 | 5.5 | 5.0 |
| 240 | 67.1 | 69.6 | 2.5 | 2.0 | --- | --- |
| Soil $NO_3$ - N, lbs / A - 2' | | 53 | | 50 | 57 | |
| Yield Max. Bu / A | | 75 | | 77 | 45 | |
| N Recommended[2] | | 127 | | 135 | 51 | |

[1] Broadcast as ammonium nitrate and incorporated with a field cultivator along with the KCl immediately prior to seeding.
[2] 2.4 X Yield - Soil $NO_3N$.
[3] Plot number.

The influence of ammonium nitrogen on the soil-plant system is clearly beneficial. With soil nitrogen remaining the ammonium ion form as long as possible, nitrogen losses due to leaching and denitrification are minimized, and phosphorus is more available in the soil solution phase at the root surface. Within the plant, ammonium ions influence good early growth by enhancing protein manufacture and allowing other plant functions to occur more easily. Disease incidence is lowered through high concentrations of ammonium ions in early plant nutrition. Good management of nitrogen applications to soil-plant systems can influence the ammonium nitrogen-nitrate nitrogen balance of uptake to coincide with plant needs (10,11).

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