Nitrogen Fertilizer Management in Good Economic Times and Bad

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When the price of natural gas increases dramatically, producers of nitrogen (N) fertilizers respond by either increasing their wholesale price to fertilizer retailers or reducing the production of N fertilizers until natural gas prices drop. Consequently, farmers face higher N fertilizer costs of crop production plus the risk of fertilizer delivery delays or receiving less total fertilizer N than they would like to purchase. In some cases, fertilizer N may only be available in a form they are not familiar with or not equipped to use efficiently.

Nitrogen fertilizer availability or cost alone should not prompt farmers to reduce intended corn acres and plant additional soybean acres (particularly second year soybeans). However, when forecasts of high N fertilizer cost and (or) possible delays in availability occur, it is more critical than ever that fertilizer management be geared to achieving maximum efficiency. The purpose of this paper is to review how farmers can optimize N fertilizer use for corn.

The Nitrogen Efficiency Checklist:

- Nitrogen fertilizer rates for **pre-plant N**
  - Actual N rates for corn should not exceed **1.0 lb. of applied actual N** per expected bushel per acre in a **corn and soybean** rotation (most of Indiana's corn acreage).
  - Actual N rates should not exceed 1.2 lb. of applied N per expected bushel per acre when corn follows corn.
- Nitrogen fertilizer rates for **sidedress N**
  - Sidedress N rates normally should be 10 % lower than pre-plant N rates if the intended pre-plant rates are based on realistic yield goals, and if over 50% of the N fertilizer rate per acre is applied using sidedress application.
  - Consequently, sidedress N rates can range from 0.9 to 1.1 lb. of actual N per expected bushel per acre of corn for corn/soybean and corn/corn rotations, respectively.
- **Credit** should be given for all possible N sources going into the field including manure, municipal or industrial sludge sources (biosolids) or winter legume cover crops (see below for tips on "taking the credit").
- **Minimize the potential for stress on the crop** to the best of your ability throughout the season. Nitrogen use efficiency will be greater when corn develops under minimal crop stress conditions. You should be using or implementing the best agronomic practices at your disposal and leave nothing under your control to chance.

Your N Prescription: Run a Full Diagnostic on Your Selected N rate

1) **Evaluate your "yield goal":**
   It is common knowledge that soils vary in their productivity potential. On some soils, yields are limited by soil properties that are relatively independent of management (such as a soil's

ability to hold water). A principal factor in determining the N fertilizer rate for a given field in a given year is the identification of a realistic yield goal for that field that year. In the eastern Corn Belt, the efficiency of N fertilizer can be summarized as "use it or lose it". Fertilizer N in excess of the crop requirement typically disappears from the rooting zone between growing seasons due to nitrate leaching or denitrification. Applying N for a crop "yield goal" of 175 bu./A on a soil that has 150 bu./A productivity potential is, literally, washing N and dollars down the drain. Consider simply using the previous five-year corn yield average for a field as a realistic yield goal for that field in the following year.

2) **Take the credit and adjust the rate:**
In addition to productivity potential, Purdue University N fertilizer recommendations (Tri-State Fertilizer Recommendations, Purdue Bulletin E-2567) use an N credit system to account for other sources of N available from previous crops or applied wastes that will reduce the amount of fertilizer N needed. The amount of the credit reflects both the expected N content of the residue and how rapidly N is released by decomposition.

The following N credits are recommended for common previous crops:

30 lb./A for soybeans,
40 lb./A for grass sod or pasture,
30 lb./A for an annual legume cover crop,
and a maximum of 140 lb./A for an established forage legume (less for a poor stand).

A credit for organic materials like animal manures and biosolids can be developed from "book values", from analysis of the material, or, in the case of a material that has already been applied, from the Pre-Sidedress Nitrate Test (explained below).

3) **Reduce N rates when sidedressing:**
Purdue nitrogen recommendations are based on the assumption that the N is applied in a pre-plant application. If you sidedress N later in the season, your application will be more "efficient" because the N is applied closer to the time of crop need and less is lost prior to corn's uptake of available N. Sidedress N applications will be as effective for the corn crop as pre-plant N applications, even when total N rates are reduced by 10 % relative to a pre-plant application.

4) **Use the PSNT on organic soils or soils that have a history of manure or other "organic material" application:**
The organic matter in organic soils contains large quantities of N. During the growing season, microbes in the soil constantly release mineral N from the organic matter. This released N is then available to the growing crop. In some situations, the total amount of N released may be sufficient to meet the entire N needs of the crop.

The best way to determine the optimal N fertilizer rate on manured or organic (greater than 20 % organic matter) soils is to use the Pre-Sidedress Nitrate Test (PSNT). Nitrate concentration in the top 12 inches of the soil at sidedressing time is a reliable indicator of the amount of N that is available to corn. If the results of the PSNT indicate that no further N

fertilizer is required, then no corn yield benefit will occur by applying more N fertilizer. If the PSNT cannot be performed to adjust N rates for organic soils, N rates should be reduced 40 lb./A from the rate that would be applied to an inorganic soil.

The PSNT is also the best way to determine how much N will be available from any "organic" inputs whether the application occurred this year or in a previous year. Organic inputs such as manure or municipal biosolids will continue to add available mineral N to a soil system as long as there is any organic residue left. Note that Purdue University does not recommend using the PSNT for determining N application rates for routine sidedressing on **inorganic** soils that are not receiving any manure or other organic inputs because the test has not been found to be sufficiently reliable in optimum N rate assessments for these situations.

5) **Make sure you understand the key behavior differences among N fertilizers**: From the corn plant's perspective it really doesn't matter where the N comes from as long as there is adequate N in the soil when the plant needs it. However, there are substantial differences among common N fertilizers in how they behave in soil, and these differences need to be considered when selecting the time of application and the best product for a given tillage system. The common N fertilizers are anhydrous ammonia (82% N), urea (46% N), UAN solutions (28 to 32% N), ammonium sulfate (21% N) and ammonium nitrate (34%N).

   Nitrate is the form of N that is most easily lost from the soil via denitrification and leaching. Anhydrous ammonia, which is the slowest to convert to nitrate in the soil, has been the product of choice for many management systems. If you are accustomed to using anhydrous but find that the unavailability of anhydrous will force you to substitute a different fertilizer source for some of your applications, you should carefully check all calculations to make sure you are applying the right fertilizer rate to achieve your target total N application.

   The same rate of actual N per acre should be applied regardless of the N source. For example, let's say you intend to apply 150 lb./A of actual N. With anhydrous ammonia (82 % N) as a source, you would need to apply 183 lb./A of fertilizer product (150 divided by 0.82). With 28 % UAN solution as the source, you would need to apply 536 lb./A of fertilizer product (150 divided by 0.28).

   Furthermore, you should consider the following attributes of various N fertilizer sources:

   a) *Urea* converts to nitrate N fairly quickly (anticipate complete conversion to nitrate within 2 weeks in typical spring conditions). The nitrate is then susceptible to loss by either denitrification and leaching. Therefore, pre-plant use of urea fertilizer should be limited to applications as close to actual planting as possible to minimize the time period for N loss.
      Remember that nitrogen from urea can also volatilize from the surface of the field as the product converts through the ammonia gas phase (especially with warm temperatures). Consequently, broadcast urea should be incorporated (by tillage or rainfall) soon after application to minimize the risk of N loss. Urea should not be broadcast over residue in no-till fields or any field where residue cover exceeds 30 % and air temperatures are expected to exceed 55 F before incorporation.

b) *UAN solutions* are made up of urea and ammonium nitrate. The nitrate portion is immediately subject to denitrification and leaching and the urea portion is subject to the losses described earlier. An advantage of UAN solutions compared to urea is that a banded surface application (dribbling on the soil surface) minimizes the amount of product that comes in contact with surface residue and, thus, also minimizes the risk of volatilization. Therefore, a UAN band application is preferable to broadcast urea if you are applying to no-till, or other high residue fields. Applying the majority of the total N requirement in the form of broadcast UAN with pre-plant or pre-emergence herbicides is not recommended because of the high risk of surface volatilization.

c) *Ammonium sulfate* can be broadcast in most tillage/soil systems because surface volatilization is minimal. However, it is the most acidifying N fertilizer and requires double or more the amount of lime that would be required to neutralize the acidity resulting from the same rate of N application using another N form. Ammonium will be rapidly converted to nitrate and subject to loss, so if you have a choice (anhydrous ammonium or delaying the application), do not apply ammonium sulfate in a very early pre-plant application.

d) *Ammonium nitrate* also contains no urea so it can be surface applied where volatilization is anticipated (high residue). Like UAN solutions, a portion of the product is already nitrate and therefore immediately subject to denitrification and leaching loss. The ammonium component will be rapidly converted to nitrate and then subject to loss. Consequently, avoid applying ammonium nitrate in an early pre-plant application.

Regardless of the volatilization potential of the product, N fertilizer applied in no-till situations will be most efficient if it is placed below the residue, and in contact with the soil. Furthermore, if you are considering sidedressing some acres for the first time, select fields that are most likely to support equipment traffic. Well-drained soils will allow more rapid applicator re-entry following rainfall, reducing the risks of soil compaction and damage to tall plants that occurs when sidedressing must be delayed.

6) **Resist the impulse to "top-off" rates with a little bit extra for insurance:** University fertilizer rate recommendations are inherently conservative, seeking to minimize the risk to the farmer. In developing a recommended rate, university researchers have already accounted for the fact that some years may be better than others and that farmers do not want to be caught with insufficient available N in an unusually productive year. Nonetheless, we have reviewed enough fertility plans to know that many farmers consistently apply a little more than the recommended N rate. A year when fertilizer is unusually expensive and in short supply is a good year to put an end to a habit that is of no demonstrated agronomic value, and certainly of no economic value.

Answers to Some Frequently Asked Questions:

1. ***I'm already using the "recommended rate" but I won't be able to obtain enough fertilizer N from my dealer. How much yield will I lose per pound of N that I cut back from the recommended rate?***
   Crop response to fertilizer is generally "curvilinear". The first few pounds of N fertilizer increase yields dramatically but the last few pounds of N in the recommended rate should barely change the final yield, if at all. Therefore, if you cut back on N rate by a few pounds

per acre you will probably not see much difference in yield. Given the way that corn responds to fertilizer N and the fact that recommended rates are conservative (designed to remove N as a limit to production), cutting back N rates by 10 % from the recommended rate is unlikely to hurt yields by more than a few bushels per acre. If you can only acquire 75% of the N needed for all your corn acres, you may see significant yield reductions if you are already basing your N rates on realistic yield goals. In that case, planting second year beans on a few of your acres may be a better option.

2. ***I produced 60-bushel soybeans last year. Can I increase the "N credit" for this higher bean yield?***
   The amount of N that the soybean residue supplies to the crop is a function of the N concentration of the residue, the amount of residue and when the residue is decomposed. The 30 lb./A N credit has been found to be reliable for most stands in most growing seasons. High yielding fields will probably have more stover material compared to a very low yielding field, but the amount of vegetative biomass from 40 bushel beans versus 60 bushel soybeans is not linearly related to seed yield. In addition, later harvested soybeans may have slightly more available N credit to corn the following year than soybeans harvested in early September. Some states recommend a credit of up to 40 lb. N/A ("a pound per bushel to 40 bu"). Yield of the bean crop alone is not likely to be a reliable predictor of N availability to the following corn crop and we do not recommend taking more than 30 to 40 lb. N/A "credit".

3. ***I can get all of my needed fertilizer N, but the price is very high. To keep my budget in line I'm considering skipping some P and K applications. Should I do this?***
   You should definitely evaluate your soil test levels in terms of the recommendations published in Purdue's "Tri-State Fertilizer Recommendations" bulletin (E-2567). If your soil test levels are above the "critical" level, you will not see a yield response to additional phosphorus or potassium fertilizer. When following Purdue's build-up/ maintenance/ drawdown approach to P and K management, you can skip a year of replacing crop removal if current tests are well above "critical" levels.
   If, however, current soil tests are below the "critical" levels, skipping P and K applications will result in lower corn yields directly and lower nitrogen use efficiency because the crop is limited by the P or K availability. In the latter situation, shifting P or K fertilizer dollars into N fertilizer is pennywise but pound-foolish.

4. ***I normally sidedress anhydrous but if I can get it early should I switch to a pre-plant application just to make sure I have it?***
   Industry sources indicate that fertilizer production facilities that are temporarily idled in times of high natural gas prices can be brought back into production rapidly once natural gas prices decrease. As discussed earlier, pre-plant fertilizer N application rates will need to be higher than sidedress applications because of lower N use efficiency. If you normally sidedress, it is likely because your fields are particularly susceptible to the higher N loss risk associated with pre-plant N applications. Given the agronomic benefits of sidedressing, consider switching to an alternative N source before switching application timing.

5. ***If I can get urea in February or March, should I apply this over the ground when the temperatures are cold and surface volatilization should be minimal?***
   If you apply urea in February or March, it may very well rain before it gets warm but incorporation will not occur if that rainfall is onto frozen or snow covered ground. Surface runoff will carry away your product. Also, isolated warm weeks between February and mid-April are not uncommon and volatilization loss of unincorporated urea fertilizer can be pronounced during this time period. More importantly, the conversion of incorporated urea to nitrate N will be rapid as soon as the soil warms. On poorly drained or excessively drained soils, you may consequently lose some or all of your fertilizer N to denitrification and leaching, respectively.

6. ***If I use urea or UAN, should I use a urease inhibitor?***
   Urease inhibitors are products that interfere with the breakdown of urea and can minimize N volatilization loss of surface urea applications between the time of application and incorporation by rainfall or with tillage. Research has found urease inhibitors such as NBPT (trade name Agrotain™) will prevent significant urea loss and yield reductions related to N deficiency in situations where incorporation was delayed. The benefits of urease inhibitors are most pronounced with urea applications, but can also benefit UAN solution applications.

Keeping the Cost of N Fertilizer in Perspective

In planning a strategy for coping with high priced N fertilizers, it is important to keep the cost of N fertilizer in perspective. The tables below present a summary of how a given price of anhydrous ammonia will translate into a total N cost per acre (Table 1), an increase in N cost per acre (Table 2), a total N cost per bushel (Table 3), and an increase in N cost per bushel (Table 4) for corn grown in rotation with soybean.

Table 1: N fertilizer cost per acre, using anhydrous ammonia, for corn after soybean using the Tri-State Recommendations

		Price of anhydrous ammonia in $/ton					
Yield	N rate rec	250	300	350	400	450	500
80	50	7.62	9.15	10.67	12.20	13.72	15.24
100	80	12.20	14.63	17.07	19.51	21.95	24.39
120	110	16.77	20.12	23.48	26.83	30.18	33.54
140	130	19.82	23.78	27.74	31.71	35.67	39.63
160	160	24.39	29.27	34.15	39.02	43.90	48.78
180	190	28.96	34.76	40.55	46.34	52.13	57.93

Yield = Reasonable yield goal, N rate rec = recommended rate of actual N to be applied

Table 2: Increased N fertilizer cost per acre as anhydrous ammonia prices increase above $250/ton for corn after soybean using the Tri-State Recommendations

		Price of anhydrous ammonia in $/ton					
Yield	N rate rec	250	300	350	400	450	500
80	50		1.52	3.05	4.57	6.10	7.62
100	80		2.44	4.88	7.32	9.76	12.20
120	110		3.35	6.71	10.06	13.41	16.77
140	130		3.96	7.93	11.89	15.85	19.82
160	160		4.88	9.76	14.63	19.51	24.39
180	190		5.79	11.59	17.38	23.17	28.96

Yield = Reasonable yield goal, N rate rec = recommended rate of actual N to be applied

Table 3: N fertilizer cost, using anhydrous ammonia, per bushel of corn after soybean using the Tri-State Recommendations

		Price of anhydrous ammonia in $/ton					
Yield	N rate rec	250	300	350	400	450	500
80	50	0.10	0.11	0.13	0.15	0.17	0.19
100	80	0.12	0.15	0.17	0.20	0.22	0.24
120	110	0.14	0.17	0.20	0.22	0.25	0.28
140	130	0.14	0.17	0.20	0.23	0.25	0.28
160	160	0.15	0.18	0.21	0.24	0.27	0.30
180	190	0.16	0.19	0.23	0.26	0.29	0.32

Yield = Reasonable yield goal, N rate rec = recommended rate of actual N to be applied

Table 4: Increased cost of N fertilizer per bushel as anhydrous ammonia prices increase above $250/ton for corn after soybean using the Tri-State Recommendations

		Price of anhydrous ammonia in $/ton					
Yield	N rate rec	250	300	350	400	450	500
80	50		0.02	0.04	0.06	0.08	0.10
100	80		0.02	0.05	0.07	0.10	0.12
120	110		0.03	0.06	0.08	0.11	0.14
140	130		0.03	0.06	0.08	0.11	0.14
160	160		0.03	0.06	0.09	0.12	0.15
180	190		0.03	0.06	0.10	0.13	0.16

Yield = Reasonable yield goal, N rate rec = recommended rate of actual N to be applied

Other References for Nitrogen Fertilizer Use in Corn:

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