FS 941

# Nitrogen Best Management Practices for Corn in South Dakota

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Best management practices (BMPs) are techniques that are used to 1) maintain farm profitability and 2) minimize degradation of water, soil, and other natural resources. Nitrogen (N) fertilizer and manure BMPs are particularly important for minimizing environmental impacts from corn production. Recent nitrogen fertilizer cost increases necessitate the adoption of efficient nitrogen-management strategies.

A series of discussions were held in 2007 focusing on nitrogen management in corn production systems. This document is the result of those discussions. Practices discussed in this document include

1) soil testing as an integral component of nitrogen management;
2) estimating the residual N credit of 55 and 100 lbs. N/Acre for cropped fields and fallow situations, respectively, for estimating an N rate;
3) estimating the probability of significant residual N based on rainfall and management;
4) calculating N application rates for corn production systems.

## Nitrogen, Corn and the Environment

Corn is planted on more South Dakota row-crop acres than any other crop (USDA-NASS). Historically, corn was grown for livestock feed and as a cash crop, but it has recently become important in the production of bio-fuels. Undoubtedly, corn is an important crop for South Dakota's economy.

Of the 13 nutrients required for plant growth, N is often the most limiting. Manure and fertilizer are commonly used to supplement crop N to optimize plant growth and yield. Considering production costs and broad-scale environmental impacts, managing N to achieve optimal production while minimizing losses and environmental impact is an increasing challenge for corn producers.

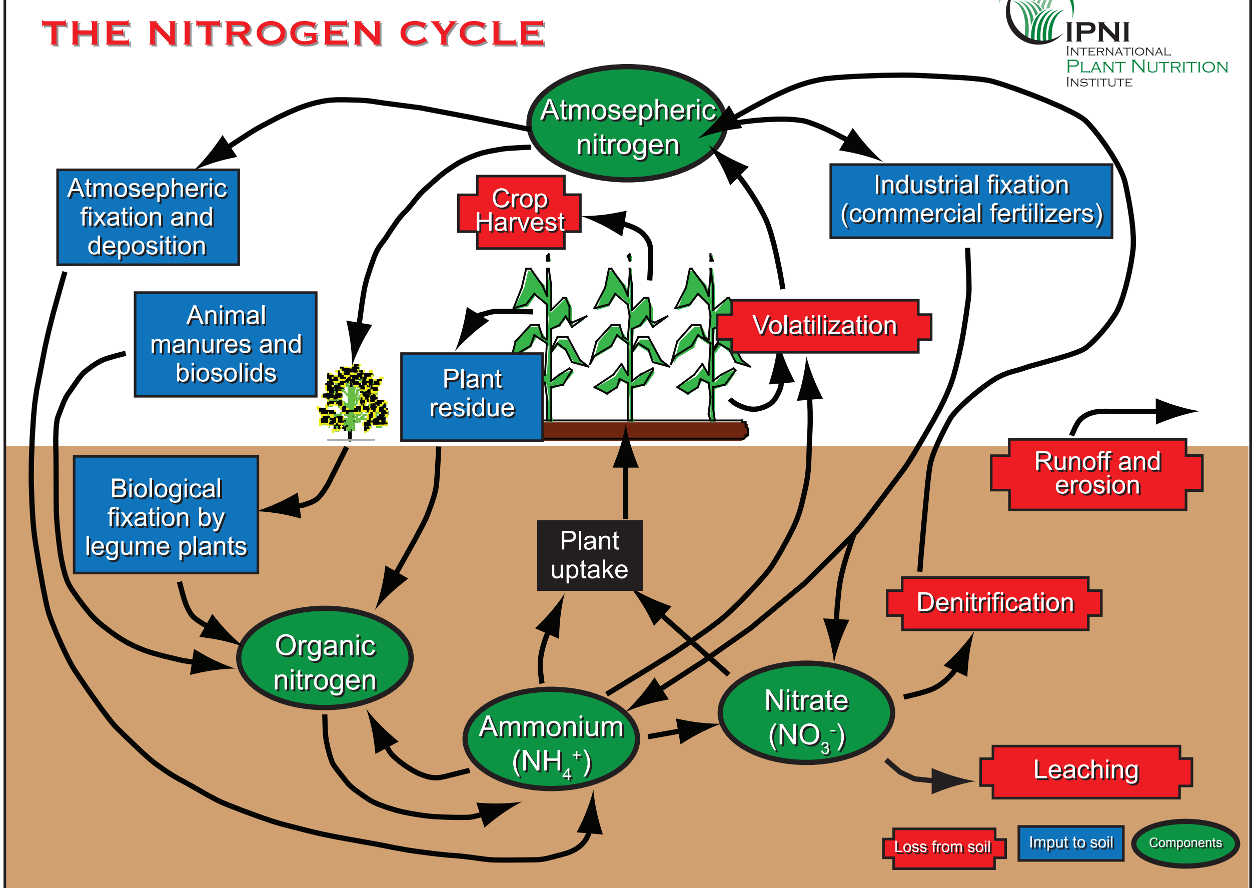
Transformations of fertilizer and manure N can lead to production of nitrous oxide, a greenhouse gas important to global warming. Nitrogen not taken up by the crop can be lost and can lead to groundwater contamination and hypoxia—zones with low dissolved $O_2$ not able to support marine life. Hypoxia has become an issue of concern in the Gulf of Mexico. The adoption of management practices designed to minimize losses and maximize crop use has the potential to both reduce the environmental impacts of corn production and improve its profitability.

## The Nitrogen Cycle

Developing an effective strategy for optimal N management requires an understanding of the N cycle (Box 1). Plants utilize N in inorganic forms (e.g., ammonium [$NH_4^+$] and nitrate [$NO_3^-$]). Most commercial fertilizers are in ammonia form, which is rapidly transformed to either organic N (immobilized) or $NO_3^-$ (available) when soil is warm and moist. Most of the nitrogen in manure is in organic form and over time becomes available to the plant as $NH_4^+$ and $NO_3^-$.

The transformation of organic N to inorganic N is largely a biological process that is partially dependent on the ratio of carbon to nitrogen (C:N) of crop residue. If the C:N ratio is high (>25:1), immobilization is likely to occur. For residues with lower C:N ratios (< 20:1), N is usually released into the soil as a result of mineralization (the microbial conversion of organic N to inorganic N). Residue from legume plants (e.g., soybean, alfalfa, clover) generally has lower C:N ratios than residue from non-legume plants. Tillage accelerates the transformation of organic N to inorganic N by increasing

**Box 1 – Important N Transformation in Agricultural Soils**




*(Courtesy International Plant Nutrition Institute)*

**Definition of Key Terms**

Volatilization – loss of N from the profile as ammonia ($NH_3$) gas

Denitrification – loss of N from the soil as $N_2$ gas

Leaching – movement and loss of $N0_3^-$ from the root zone

Immobilization – microbial conversion of inorganic N (available) to organic N (unavailable)

Fixation – conversion of $N_2$ from the atmosphere to ammonia form N

Mineralization – microbial conversion of organic N (unavailable) to inorganic N (available)

microbial activity.

Soil can be viewed as a negatively charged permeable system where $NO_3^-$ and other negatively charged molecules are repelled and can be lost with percolating water. This process is called leaching. Losses due to leaching are generally higher in sandy, more permeable soils compared to silt and clay soils that have lower percolation rates.

Plant uptake and the removal of the crop from the field is the most important loss in the N cycle. An effective N-management strategy is aimed at optimizing plant uptake, thereby minimizing other losses. Plants can utilize pools of inorganic N, but such pools are more likely to be lost compared to unavailable pools of organic N. It is important to remember that not all N from manure or commercial fertilizer can be used by the crop, as some is lost from the system.

Corn harvested for grain removes less N than corn harvested for silage. Harvesting corn for grain leaves crop residue in the field that will decay over time, releasing a portion of the residue-N back into the soil. Harvesting silage or baling residue removes most of the aboveground residue. Removing crop residue results in more N removed from the field and is likely to lead to declining levels of soil organic matter.

## Crop Nitrogen Need

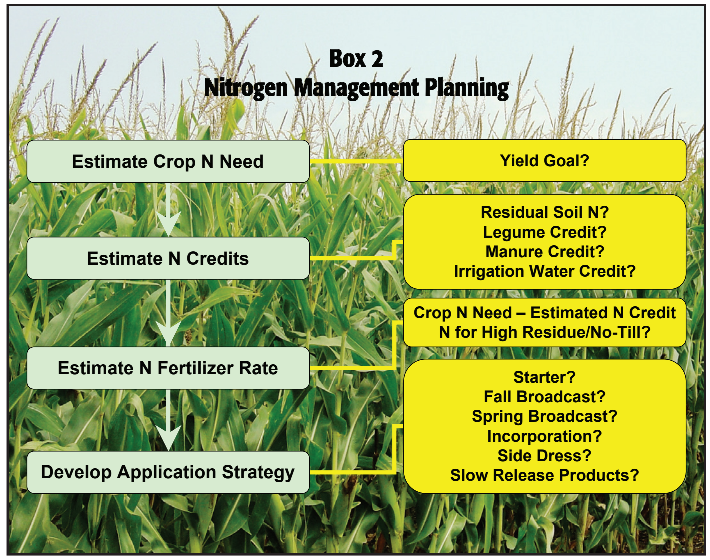
Developing a plan for managing N involves estimating crop N need, N credits, and fertilizer rate, and strategically planning how N will be applied (Box 2). Crop N need is estimated by multiplying a constant (1.2 lbs. N/bu grain or 10.4 lbs. N/ton silage) by the yield goal (Box 3, Gerwing and Gelderman, 2005).

A yield goal is best defined as the expected yield based on management and past production records. Yield goals can be estimated using the following approaches:

- o Proven Yields
- o Proven Yields + 10%
- o Proven Yields Modified for Soil Moisture
- o Modified County Averages

Estimating yield goals using the Proven Yields approach requires taking five years of yield data from the field, removing outliers, and finding the average. Note that "outliers" are abnormally high or low yields resulting from extreme conditions (e.g., extremes in rainfall, temperature, pest pressure) (Box 4). The Proven Yield + 10% approach provides an estimate of yield goal by adding 10% to the average value. The Modified Proven Yield approach considers seasonal values; to estimate the yield goal, average proven yields are modified based on soil moisture conditions. If soil moisture conditions are favorable, the value should be increased by 10 to 20%; conversely, if the soil profile is dry and continue¬d dry conditions are forecasted, the value should be decreased by 10 to 20%. However, if environmental conditions become favorable, crop yields are likely to decline due to insufficient N. If conditions become favorable early in the season, side-dress applications may be used to offset N deficiencies.

Yield goals also may be based on average yields published by the USDA-South Dakota Agricultural Statistics Service (USDA-SDASS, 2007). Yield estimates based on polls of producers in the state are likely to be incorrect in specific fields. Methods that adjust county average yields considering soil productivity index values are being used by the USDA-




### Box 3 – Fertilizer N Recommendation

**Corn for Grain**

**$N = (1.2xYG_{(grain)})$ - Credits**

**Corn for Silage**

**$N = (10.4xYG_{(silage)})$ - Credits**

Where:

- o N = Estimate of Nitrogen Need (lbs/Acre)
- o YG(grain) = Yield Goal (bu/Acre)
- o YG(silage) = Yield Goal (tons/Acre)

*(Adapted from Gerwing and Gelderman, 2005)*

### Box 4 – Estimate of Yield Goal Modified Proven Yield Approach

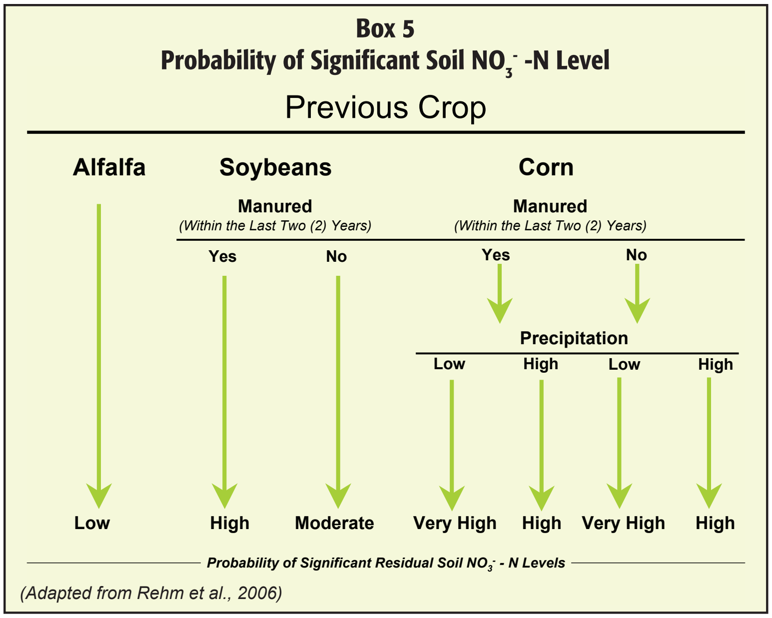
Yield Data

- o *Year 1 – 100 bu/Acre*
- o Year 2 – 150 bu/Acre
- o Year 3 – 140 bu/Acre
- o Year 4 – 160 bu/Acre
- o Year 5 – 155 bu/Acre

Removing Year 1 as an outlier results in an average of 150 bu/Acre.

Using the Modified Proven Yield approach modifies yield goals based on soil moisture conditions at planting. Add 10-20% if moisture conditions are favorable at planting. Yield goal is reduced by similar levels if moisture is limiting. In this example, adding 10% (15 bu/Acre) to the 150 bu/Acre yield goal given above results in a yield goal of 165 bu/Acre.

NRCS in South Dakota for nutrient management planning. These data are readily available to the public via both the Internet (http://www.sd.nrcs.usda.gov/technical/Nutrient_Management.html) and local USDA-NRCS offices.




**Box 5**
**Probability of Significant Soil $NO_3^-$ -N Level**

## Nitrogen Credits

Nitrogen credits are estimates of the N that is immediately available or will become available for the upcoming crop. Credits include residual soil $NO_3^-$ -N, manure–N, legume–N, and irrigation water–N. The recommended fertilizer N rate is the sum of these credits subtracted from the estimated crop N need (Box 3).

## Residual Soil Nitrogen

Residual soil $NO_3^-$-N can be measured by soil sampling (Gelderman et al., 2005). To obtain accurate results, sampling techniques should consider prior management (Clay et al., 2002). Some areas in the field may have irregular nutrient levels; if these areas are sampled, they can falsely influence soil test results (Clay et al., 2002). Wet spots or salt-affected areas may have low soil test N levels compared to the rest of the field. Other areas that can have abnormally high or low nutrient levels compared to the rest of field include old feedlots and fence lines, hay piles, turn rows, and field entry points. Unless they are to be treated differently, avoid sampling these areas, as they can lead to soil test results that do not represent the bulk of the field.

Current recommendations for N in South Dakota are based on a 0-24" sample. However, environmentally sensitive areas such as fields over a shallow aquifer may require deep sampling (0-24" and 24-48") to provide additional protection of groundwater. In deep-sampling situations, if soil test N exceeds 30 lbs. $NO_3^-$-N/Acre at the 24-48" depth, 80% of that soil test N is credited, in addition to soil test N in the sample at the 0-24" depth (Gerwing and Gelderman, 2005). If the field is over a shallow aquifer, producers operating under a Concentrated Animal Feeding Operation (CAFO) permit or a Comprehensive Nutrient Management Plan (CNMP) are required to sample to 48 inches. To find out if a field is over a shallow aquifer, or if there are questions regarding deep sampling, contact local County Extension educators, a USDA-NRCS district conservationist, or the South Dakota Department of Environment and Natural Resources.

Spring sampling is recommended. Soil samples may be taken in the fall when soil temperatures are below 50º F, but they are less reliable. If a soil test is not available, estimates of 55 and 100 lbs. $NO_3^-$-N/acre can be used in cropped and summer-fallowed systems, respectively.

Soil testing becomes more important as the potential for high soil residual $NO_3^-$-N increases (Box 5). When manure is routinely applied and/or if crop failure occurred, soil sampling for residual $NO_3^-$-N becomes critical, as making accurate recommendations is nearly impossible without a soil analysis. Always rely on a reputable laboratory for soil analysis.

## Legume Credits

Legume plants that form symbiotic relationships with rhizobium bacteria can provide a significant amount of N to the following crop. In situations where corn follows soybeans, a credit of 40 lbs. N/acre is recommended. Credits for other legume crops are given in the table provided in Box 6.

**Box 6**
**Nitrogen Credits from Previous Legume Crop**

| Crop | Population (Plants/ft$^2$) | [1,2]N Credit (lbs N/Acre) |
|---|---|---|
| Alfalfa or [3]Legume Green Manure | <1 | 0 |
| | 1-2 | 50 |
| | 3-5 | 100 |
| | >5 | 150 |
| Soybeans, Edible Beans, Peas, Lentils and Other Annual Legumes | | 40 |

[1] No-till corn into alfalfa or green manure crops, use ½ credit first year.
[2] For second year following alfalfa and green manure crops, use half credit.
[3] Includes sweet clover, red clover, and other similar legumes.

*(Adapted from Gerwing and Gelderman, 2005)*

## Manure Credits

Nitrogen recommendations need to account for the N in manure that will be available for plant use. Manure contains organic and inorganic forms of N. Inorganic N (ammonia) is immediately available, whereas organic N is made available through mineralization. Much of the inorganic N can be lost if manure is not injected or immediately incorporated via tillage or rainfall (≥ 1/2 inch) (Koelsch and Shapiro, 2006). If manure is not injected or incorporated, do not credit any of the inorganic N. Failure to do so can result in the underapplication of N and yield loss.

Using a manure analysis or representative values from the table in Box 7, the amount of available N from manure can be estimated with the worksheet in Box 8. Due to extreme variability in manure piles and lagoons, collecting representative manure samples can be difficult. Guidelines for collecting manure samples are available either from local USDA-NRCS district conservationists or online at http://www.sd.nrcs.usda.gov/news/SD_FactSheets.html (USDA-NRCS, 2002) or http://www.extension.umn.edu/distribution/cropsystems/DC6423.html (Busch et al., 2002). Representative values provided in the table in Box 7 can be used if an analysis is not available, but the values may

**Box 7**
**Estimated Nitrogen Content of Liquid and Solid Manure**

| Type of Livestock | Liquid Manure Nitrogen (N) Lbs/1000 gal | | Solid Manure Nitrogen (N) Lbs/ton | |
|---|---|---|---|---|
| | $N_{ORGANIC}$ | $N_{INORGANIC}$ | $N_{ORGANIC}$ | $N_{INORGANIC}$ |
| **Swine** | | | | |
| Farrowing | 7 | 8 | 11 | 3 |
| Nursery | 11 | 14 | 8 | 5 |
| Grow Finish | - | - | 10 | 6 |
| Grow-Finish(deep pit) | 17 | 33 | - | - |
| Grow-Finish(wet/dry feeder) | 21 | 39 | - | - |
| Grow-Finish(earthen pit) | 8 | 24 | - | - |
| Breeding-Gestation | 13 | 12 | 4 | 5 |
| Farrow-Finish | 12 | 16 | 8 | 6 |
| Farrow-Feeder | 10 | 11 | 5 | 5 |
| **Dairy** | | | | |
| Cow | 25 | 6 | 8 | 2 |
| Heifer | 26 | 6 | 8 | 2 |
| Calf | 22 | 5 | 8 | 2 |
| Veal Calf | 26 | 21 | 4 | 5 |
| Herd | 25 | 6 | 7 | 2 |
| **Beef** | | | | |
| Beef Cows | 13 | 7 | 4 | 3 |
| Feeder Calves | 19 | 8 | 6 | 3 |
| Finishing Cattle | 21 | 8 | 7 | 4 |
| **Poultry** | | | | |
| Broilers | 50 | 13 | 34 | 12 |
| Pullets | 48 | 12 | 39 | 9 |
| Layers | 20 | 37 | 22 | 12 |
| Tom Turkeys | 37 | 16 | 32 | 8 |
| Hen Turkeys | 40 | 20 | 32 | 8 |
| Ducks | 17 | 5 | 13 | 4 |

*(Adapted from Lorimor and Powers, 2004)*
These values vary drastically, depending on feeding, storage, and handling practices, and are likely not representative of the actual nutrient content of the manure. Use only for planning purposes. These values should not be used in the place of a regular manure analysis.

**Box 8**
**Estimate of Manure Nitrogen Credit**

| | | |
|---|---|---|
| A | $N_{\text{inorganic Lab Test or Estimate}}$ x [1]RF | Lbs# |
| B | $N_{\text{organic Lab Test or Estimate}}$ x [2]$Mk_x$ | Lbs# |
| C | Manure N Credit $_{(A+B)}$ | Lbs# |

# Liquid Manure Units = Lbs-N/1,000 gal
# Dry Manure Units = Lbs-N/ton

[2]If manure was applied the previous growing season, replace $Mk_1$ with $Mk_2$ to estimate N credit for $N_{organic}$.

| Poultry Manure | All Other Manure |
|---|---|
| $Mk_1$ = 0.60<br>$Mk_2$ = 0.85 | $Mk_1$ = 0.35<br>$Mk_2$ = 0.50 |

| [1]RF = Retention Factor | |
|---|---|
| Injected | 0.98 |
| Incorporate < 24 Hrs | 0.90 |
| Incorporate > 5 Days | 0.20 |

not accurately represent actual manure nutrient content. Note that using representative values may result in over- or underestimating the N content of manure, while an analysis may provide more accurate values (Gerwing et al., 2004; and USDA-NRCS, 2003).

## Irrigation Water Credit

Irrigation water can contain significant amounts of nitrogen ($NO_3^-$-N). The only way to determine this credit is to test irrigation water for $NO_3^-$-N. Collect a sample in a clean plastic bucket during an irrigation event. A subsample of the collected water should be transferred to a clean plastic container that can be submitted to a qualified laboratory for analysis. Use the analysis of this sample with the equation in Box 9 to estimate the N credit.

**Box 9**
**Estimate of Irrigation Water N Credit (IC)**
**IC = $NO_3^-$-N IW x IA x 0.23**
**Where:**
**IC = Irrigation Water N Credit (lbs/Acre)**
**$NO_3^-$-N IW = Irrigation Water $NO_3^-$-N Lab Result (PPM)**
**IA = Amount of Irrigation Applied (in/Acre)**

## Estimate N Fertilizer Rate

Using the estimates of crop N requirement and credits, an N-fertilizer recommendation can be calculated using the equation in Box 3. In no-till systems, the producer should consider increasing the N rate by 30 lbs. N/acre to account for the breakdown of residue. Rates can also be adjusted based on the relative cost of N fertilizer and the selling price of corn. An increased cost of N fertilizer relative to the selling price of the corn may warrant a small reduction in the N recommendation. An example for calculating an N recommendation is shown at the end of this publication.

## Develop an Application Strategy

How and in what form N is applied can have an impact on crop N-use efficiency. Using starter fertilizer is an excellent way to supply N to corn during early growth. Placing fertilizer in a band below and beside the seed (2x2) allows for higher starter rates than placing fertilizer with the seed (pop-up). Seed can be killed if too much fertilizer is applied with the seed; the total N + total K20 of the fertilizer should not exceed 10 lbs./acre. Reduce this rate if you are planting into dry or sandy soil, and avoid allowing urea fertilizer to come into contact with seed. Research to more accurately estimate the fertilizer rate that can be applied with the seed for specific crops is in progress.

Fall broadcast application of N fertilizer presents a significant risk of loss from leaching, runoff, denitrification, and volatilization. Fall-applied N fertilizer should only be applied when soil temperatures cool to below 50º F. As substantial amounts of N can be lost, incorporate fall-applied urea fertilizers to minimize volatilization. Soil pH can affect volatilization, as basic soils (pH > 7.4) are more conducive to ammonia volatilization compared to acidic soils. Due to leaching and denitrification occurring in the spring after snowmelt and rainstorms, significant levels of fall-applied fertilizer N can be lost.

There has been some discussion about the use of urease and nitrification inhibitors with fall-applied N fertilizers. Nitrification and urease inhibitors are designed for and have been shown to slow the reactions of fertilizer in soil that may lead to loss. However, with respect to yield response and the use of these products, research results have been inconclusive. In some situations, however, these products may be beneficial.

Applying nitrogen as close as possible to the time of plant uptake is clearly the most desirable action. Spring or split application of fertilizer provides N closer to the time when corn needs it. However, due to weather or time constraints, spring applications may not always be possible.

**Box 10**
**Nitrogen Deficiency in Corn**

Note the "V"-shaped chlorosis in younger leaves. Note that lower leaves are dead.
*(Courtesy Iowa State University)*

## In-Season Nitrogen Management (Side-Dress)

Fertilizer N is commonly applied as a side-dress between the V6 (sixth leaf) and V8 (eighth leaf) stages of corn growth. Side-dress N applications may be either a component of the management plan or, if the crop begins to show signs of N deficiency (Box 10), conducted as a rescue treatment. The in-season N recommendation can be based on 1) a pre-season N recommendation, 2) in-season soil samples analyzed for $NO_3^-$-N (preside-dress nitrate test, PSNT), 3) remote sensing, or 4) some other diagnostic tool that assesses N status. Currently, recommendations for using remote sensing-based tools are under development.

The rate of N applied as a side-dress can be based on the results of a preside-dress nitrate test. Take soil samples when plants are 6-12" tall (V3–V6), collecting 16 to 24 randomly spaced cores to a depth of 12 inches from grid cells no larger than 10 acres. Problematic areas or areas that may have been treated differently should be avoided or sampled separately (among these areas are those where manure was applied, areas with poor drainage, end rows, old farmsteads, etc.). By combining samples taken from various grid cells in the field, a single sample may be submitted for fields that are uniform in topography and fertility. If fields vary widely in soil type and topography, or if N rate will vary across the field, submit multiple samples representing those areas in the field. Side-dress N rate can be estimated from values in Box 11. These recommendations are based on research conducted in other states (Blackmer et al., 1991). The selection of the exact rate is left to the user. The user should consider factors such as yield goal, the economic and environmental costs of N fertilization, and yield response from previous years. It is anticipated that further research will refine this recommendation.

**Box 11**

**Side-Dress N Rate Recommendation**

| Soil Test $NO_3^-$-N (ppm) | Side-Dress N (lbs/Acre) |
|---|---|
| 0 – 10 | 80 – 120 |
| 11 – 15 | 50 – 90 |
| 16 – 20 | 30 – 60 |
| 21 – 25 | 0 – 40 |
| > 25 | 0 |

*(Adapted from Blackmer et al., 1991)*

Anhydrous ammonia or urea-ammonium-nitrate (UAN) liquid solutions are commonly used for side-dress applications. Nitrification occurs rapidly at this time of year (early- to mid-June), as soil conditions are normally warm and moist. Although this application involves tillage, low-disturbance applicators can be used in no-till situations. As anhydrous ammonia is applied as a gas, it is important to insure slot closure to minimize volatilization losses.

## Fertilizer and Soil Properties

The use of anhydrous ammonia and other ammonia fertilizers can lead to a reduction in soil pH over time. In some situations, the long-term use of ammonia fertilizers (including UAN, MAP, and DAP) has led to soil pHs low enough to warrant lime applications. Most soils in South Dakota do not require lime, but if pH falls below 5.6, lime should be considered (Gerwing and Gelderman, 2005). For lime recommendations, producers should consult either their County Extension educator or the SDSU Soil Testing Laboratory.

Soil properties can play a major role in developing an effective N-management strategy. Sandy or loam soils that overlie gravelly materials have a greater potential for leaching losses than heavier silt or clay soils where gravelly materials are deeper. Basic soils have a greater potential for volatilization than acidic soils. Incorporation or injection minimizes urea losses. Cultivation will bury fertilizer, thereby minimizing losses, but rainfall (1/2 inch or more) has been observed to be as effective. In no-till systems, low-disturbance fertilizer-application equipment may be an option.

Ammonia volatilization losses are greatest when early morning dew dissolves fertilizer, temperatures climb during the day, and wind carries volatilized N into the atmosphere. In these situations, a large percentage of surface-applied N can be lost.

## Foliar-Applied and Other Products

As fertilizer costs have increased dramatically, foliar-applied N and other products have increased in popularity. Current research shows little if any benefit from the use of foliar fertilizers in corn. In very isolated cases, foliar-applied N may be beneficial for severely deficient plants.  However, rates generally need to be low to avoid leaf burning.

Other products in the marketplace claim to a) increase N-use efficiency or b) allow the producer to reduce N rate by as much as 50%. Many of these products contain calcium, humic acid, and a host of other ingredients. When considering these products, it is important to remember the following:

1. Plants require a certain amount of N to reach optimal yield. This N must come from residual N in the soil, the decay of organic matter, or the application of fertilizer and/or manure.

2. Many South Dakota soils contain large amounts of Ca, humic acids, and N-fixing organisms; therefore, adding these products may have limited impact on yields.

It is advised to request unbiased research concerning products that either promise extraordinary results or are not commonly used in corn production. A compendium of published research relating to the use of non-traditional products is available via the Internet at http://extension.agron.iastate.edu/compendium/index.aspx. If a product is questionable, seek advice from a local agronomist or County Extension educator.  Questions regarding legal sales of products in the state should be directed to the South Dakota Department of Agriculture, Office of Agronomy Services (http://www.state.sd.us/doa/das/hp-fert.htm).

If a product is questionable, seek advice from a local agronomist or County Extension educator. Questions regarding legal sales of products in the state should be directed to the South Dakota Department of Agriculture, Office of Agronomy Services (http://www.state.sd.us/doa/das/hp-fert.htm).

## Record keeping

Producing a crop of corn requires a major investment of time and money. The ultimate goal is to produce a crop in a manner that will result in profit, maintain the soil resources, and have minimal impact on the environment. Record keeping is critical for assessing past practices and performance. Information that should be recorded includes but is not limited to manure and fertilizer application(s), hybrid, weather, pest pressure, and pesticide applications. Details about fertilizer/manure application time, placement, method, and form are important for the assessment of management effectiveness. While private pesticide applicators are required to keep records of restricted-use pesticide applications, keeping records of all pesticide applications is recommended. Contact your local County Extension educator or the South Dakota Department of Agriculture for details about pesticide record keeping.



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## Example – Calculating a Nitrogen Recommendation.

This example assumes a dryland, no-till system, rotating corn and soybeans every other year. Liquid dairy herd manure was applied for the past two seasons at a rate of 1,500 gal/Acre. Seasonal precipitation created favorable soil moisture conditions. Additional fertilizer N recommended for the upcoming corn crop is estimated as follows:

## Estimate Crop N Need

**Step 1. Yield Goal.** In this example, we will use the Modified Proven Yield approach shown in Box 4 (pg. 3). The five-year average yield is increased by 10%, considering adequate soil moisture, giving an estimated yield goal of 165 bu/Acre.

**Step 2. Crop N Need.** Information for Equation 2.1 is taken from that provided in Box 3 (pg. 3) and provides an estimate of N requirement for the upcoming crop of corn of 198 lbs. N/Acre.

$$\text{Equation 2.1} \quad \left[\left(\frac{165\ bu\,Corn}{Acre}\right)\times\left(\frac{1.2\ lbs.\ N}{bu\,Corn}\right)\right]=\frac{198\ lbs\ N}{Acre}$$

## Estimate N Credits

**Step 3. Residual Soil N.** Soil samples are collected from 0-6" and 6-24" depth increments, representing the whole field, and are submitted to a laboratory for analysis. Results from the lab analysis are shown in table E-1. If lab results are reported as NO3- N (ppm), convert to NO3- N (lbs/Acre) using equation 3.1. Each 6-inch depth increment (DI6) is multiplied by "2" (as each 6-inch depth increment is assumed to represent 1 acre, 6 inches deep, weighing 2 million lbs.).

$$\text{Equation 3.1} \quad NO_3 - N\,(ppm)\times 2\times DI_6=\frac{lbs\ NO_3 - N}{Acre}$$

**Table E-1. Example Soil Test Results**

| Depth (inches) | 6" Depth Increments ($DI_6$) | $NO_3^-$ N (ppm) | $NO_3^-$ N (lbs/A) |
|---|---|---|---|
| 0-6 | 1 | 9 | 18 |
| 6-24 | 3 | 4 | 24 |
| Total $NO_3^-$ N | | | 42 |

**Step 4. Legume Credit.** In this example, the previous crop was soybeans. Therefore, a legume credit of 40 lbs. N/Acre is recommended (see Box 6, pg. 4).

**Step 5. Manure Credit.** An example of a manure analysis is provided on the last page of this bulletin (pg. 12), giving an estimate of Ninorganic (6.41 lbs. N/1,000 gal) and Norganic (10.7 lbs. N/1,000 gal.). A manure analysis is recommended, but if one is not available, published estimates may be used (Box 7, pg. 5). In this example, manure was immediately incorporated. Therefore, a credit of 90% of Ninorganic is used (see Box 8, RF pg. 5). Based on these data, N credited from the Ninorganic in the manure is 9.0 lbs. N/Acre (Equation 5.1).

$$\text{Equation 5.1} \quad \left(\left(\frac{1{,}500\ gal}{Acre}\right)\times\left(\frac{6.41\ lbs N_{inorganic}}{1{,}000\ gal}\right)\times 0.90\right)\approx\frac{9.0\ lbs\ N}{Acre}$$

Nitrogen becoming available from mineralized Norganic in the manure is estimated in equation 5.2, using 0.50 as the "Manure Constant" (see Box 8, Mk2 pg. 5), as this is the second year of manure application. About 8.0 lbs. N/Acre is estimated to be available to the crop.

$$\text{Equation 5.2} \quad \left(\left(\frac{1{,}500\ gal}{Acre}\right)\times\left(\frac{10.7\ lbs\ N_{organic}}{1{,}000\ gal}\right)\times 0.50\right)\approx\frac{8.0\ lbs\ N}{Acre}$$

Summing the results from equations 5.1 and 5.2 provides an estimate of the amount of N from manure available to the crop. In this example, the total manure credit is 17 lbs. N/Acre (Equation 5.3).

$$Equation\ 5.3 \quad \left(\frac{9\,lbs\ N_{(eq.\,5.1)}}{Acre}\right)+\left(\frac{8\,lbs\ N_{(eq.\,5.2)}}{Acre}\right)=\frac{17\,lbs\ N}{Acre}$$

**Step 6. Total N Credits.** The sum of estimated residual N from a soil test, manure, and legume credits gives the total N credit (Equation 6.1). In this example, total N credits are estimated at 99 lbs. N/Acre.

$$Equation\ 6.1 \quad \left(\frac{42\,lbs\ N_{(Residual\ N)}}{Acre}\right)+\left(\frac{17\,lbs\ N_{(Manure\ N)}}{Acre}\right)+\left(\frac{40\,lbs\ N_{(Legume\ N)}}{Acre}\right)=\frac{99\,lbs\ N_{(Total\ N\ Credit)}}{Acre}$$

## Estimate N Fertilizer Rate

**Step 7. N Fertilizer Recommendation.** The amount of additional fertilizer N needed per acre is the difference between the crop N need (198 lbs. N/Acre) and total N credits (99 lbs. N/Acre). However, because this is a high-residue system (no-till), an additional 30 lbs. N/Acre is recommended. The resulting rate of additional fertilizer N is 130 lbs. N/Acre (Equation 7.1).

$$Equation\ 7.1 \quad \left(\frac{198\,lbs\ N_{(Crop\ Need)}}{Acre}-\frac{99\,lbs\ N_{(Total\ N\ Credit)}}{Acre}\right)+\left(\frac{30\,lbs\ N_{(Additional\ N\ No-Till)}}{Acre}\right)\approx\frac{130\,lbs\ N}{Acre}$$

***Additional Nitrogen Recommendation ≈ 130 lbs N/Acre***

## Develop Application Strategy

**Step 8. Application Strategy.** An optimal application strategy strives to supply N close to the time of crop need. The recommended amount of nitrogen may be applied as fertilizer or manure, split between pre-plant, starter, or in-season applications. If N fertilizer is to be placed in contact with the seed, avoid urea fertilizers and adjust rates to avoid damage to the seed (see pp. 5-6). In-season application of N should not exceed the recommended rate unless an in-season soil analysis indicates an increase is necessary (see pg. 7). Producers are cautioned to supply all the N to a crop when using manure. Excessive manure application can pose a threat to the quality of surface water by building excessive levels of phosphorus. Salts may also build to excessive levels, compromising soil productivity. Contact your County Extension educator or other consulting professional for assistance in developing an appropriate strategy.

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# Report of Analysis

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Somewhere , SD 57000

Reported: 10/26/2007

Received: 10/12/2007

| | | As Received Basis |
|---|---|---|
| 07S-00000 | LIQUID DAIRY MANURE | |
| Total Moisture, % | | 97.9 |
| Total Dry Matter, % | | 2.14 |
| Total Nitrogen, % | | 0.205 |
| Ammonium Nitrogen, % | | 0.0766 |
| Phosphorus, % | | 0.0110 |
| Potassium, % | | 0.154 |
| Density, g/ml | | 1.000 |
| **Ammonium Nitrogen, lb/1000 gal** | | **6.41** |
| **Total Nitrogen, lb/1000 gal** | | **17.1** |
| Total Phosphorus as P2O5, lb/1000 gal | | 2.10 |
| Total Potassium as K2O, lb/1000 gal | | 15.4 |

The last four values should be used to calculate application rates.

For South Dakota DENR general permit application calculations, the ammonium nitrogen value can be substituted for inorganic nitrogen.

Reviewed By: Ms. Lab Manager

**$N_{organic}$ is estimated by subtracting Ammonium Nitrogen ($N_{inorganic}$) from Total Nitrogen. Failure to estimate $N_{organic}$ can result in over estimation of manure credit and yield loss from under fertilizing. In this example $N_{organic}$ is estimated to be 10.7 lbs. N/Acre.**

$$N_{organic} = \left(\frac{17.1\,lbs\ N_{total}}{1{,}000\ gal}\right) - \left(\frac{6.41\,lbs\ N_{inorganic}}{1{,}000\ gal}\right) = \frac{10.7\,lbs\ N_{organic}}{1{,}000\ gal}$$