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EXTENSION

Best Management Practices for Nitrogen Use in MINNESOTA

BEST MANAGEMENT PRACTICES FOR NITROGEN APPLICATION

Best Management Practices for Nitrogen Use in Minnesota

John Lamb, Professor, Department of Soil, Water, and Climate; Gyles Randall, Soil Scientist and Professor, Southern Research and Outreach Center, Waseca; George Rehm, Nutrient Management Specialist (retired); Carl Rosen, Professor, Department of Soil, Water, and Climate, University of Minnesota

Introduction

Best Management Practices (BMP's) for management of nitrogen (N) were first developed for Minnesota in the late 1980's – early 1990's. These BMP's were based on University research. The objective of this series of publications is to update the BMP's with research information collected since that time. This publication will explain factors that were used to divide the state into specific regions, and the rationale for the BMP's in each region, and, finally, the process used to determine N recommendations appropriate for each region.

History

In response to the Comprehensive Groundwater Protection Act of 1989, a Nitrogen Fertilizer Management Plan was developed with the purpose of managing nitrogen (N) inputs for crop production so as to prevent degradation of Minnesota water resources while maintaining farm profitability. The central tool for achievement of this goal has been the adoption of Best Management Practices (BMP's) for fertilizer N. Fertilizer N is the primary focus of the BMP's, however, consideration of other nitrogen sources and agronomic practices is necessary for effective and practical total N management.

The focus in the majority of the publications is on N fertilization of corn. However, appropriate N management practices for small grain, sugarbeets, and edible beans are described in the appropriate publications. A separate BMP publication has been prepared for potatoes grown on irrigated soils.

BMP's for N are broadly defined as "economically sound, voluntary practices that are capable of minimizing contamination of surface- and groundwater with nitrate-nitrogen (NO_3^--N)." The BMP's recommended are based on research, particularly at the University of Minnesota and other land-grant universities, and practical considerations. This ensures that the BMP's are technically sound and likely to be easily adopted by growers.

BMP's are not universal across Minnesota. The combination of several factors lead to BMP's for each identified region of Minnesota. These factors are briefly described in the sections that follow.

Parent Material

Minnesota is a land of geologically young soils formed from many different parent materials (Figure 1). The common factor is that the soils were formed as a product of the last glacier occurrence in the Northern United States 11 to 14 thousand years ago. While to humans this is a long time period, it is considered recent in terms of geologic time. Figure 1 shows the distribution and extent of the five major parent materials (till, loess, lacustrine, outwash, till over bedrock) in Minnesota.

Till is predominant in the south central, west central and southwestern regions of the state. This material was deposited as the last glacier was melting and receding. Soils formed in this material generally have clay loam to silty clay loam textures at the surface, many different sizes of rocks throughout the root zone, and poor internal drainage. The poor drainage has a large influence on both N management practices and cultural practices.

Loess is wind blown silt-sized material that was blown in after the glacier melted. Silt deposits can range in thickness from a few inches to many feet.

The soils formed in loess generally have a silt loam texture and there are no rocks in the root zone. The majority of soils formed in loess occur in southeastern Minnesota. These loess deposits are on top of limestone or sandstone. Because of the porous state of these underlying parent materials in Minnesota, soils formed on loess are generally well drained. The loess materials in southwestern Minnesota are deposited over glacial till. The soils formed in this material in this region are generally poorly to somewhat poorly drained and N management practices are similar to those used for soils formed in glacial till.

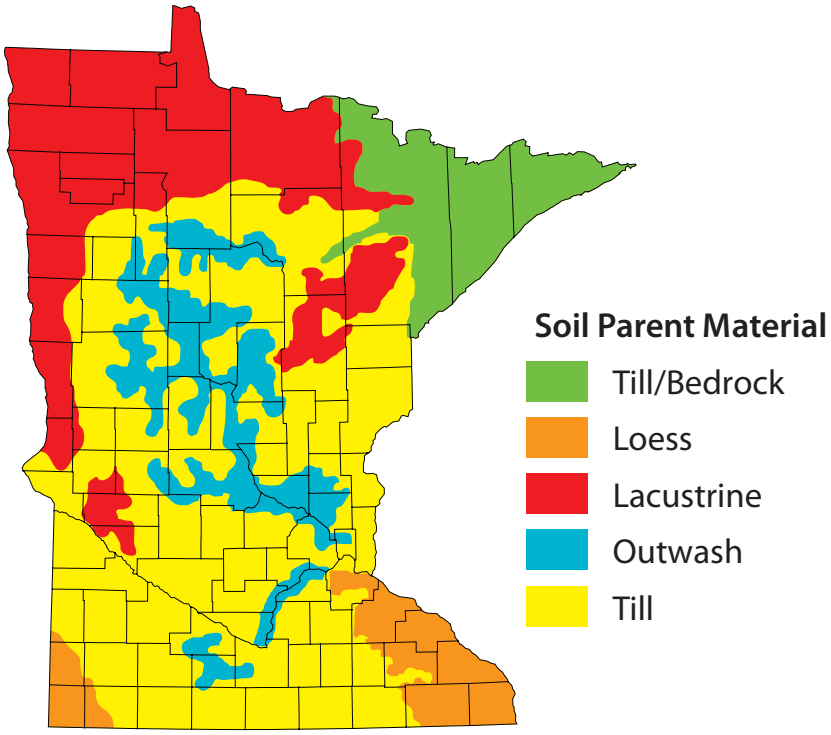


Figure 1. Parent materials of Minnesota.

Lacustrine parent materials are a result of material deposited in the bottom of a lake formed by the meltwaters of the glacier. In these lakes, the large particles such as rocks and sands were deposited immediately after the lake was formed while the smaller clay-size particles were deposited later. The soils formed under glacial Lake Agassiz in northwestern Minnesota and eastern North Dakota are good examples. There are smaller areas of soils formed in lacustrine material in other areas of Minnesota. Soils formed in lacustrine deposits have clay, clay loam, and silty clay loam textures, poor internal drainage, and no rocks.

Outwash material is the material deposited on the edges of fast running rivers of water from the melting ice of the glacier as it receded. These materials are large in size; rocks, gravel, and sand. These materials were large enough to drop out of the water flow while smaller particles continued to be transported in the current of the river. Soils formed in outwash materials are excessively well drained and have sand and sandy loam textures. Examples of areas in Minnesota with soils formed in outwash include the Anoka Sand Plain, North Central Sands, the Bonanza Valley and other parts of east central, north central, and central Minnesota.

Till/ bedrock deposits occur in northeastern Minnesota. Materials from the glacier were deposited over bedrock similar to south central Minnesota but material came from different glacial ice and there are significant areas where the soils were formed in bedrock. These soils tend to be shallow, allowing for limited root development and are not used extensively for crop production.

Climate

Since N movement in the soil is affected by the amount of soil water movement and soil temperatures, climate is an important factor in N management decisions. Precipitation is one of two factors that govern water movement in the soil. Average annual precipitation in Minnesota is the least in the northwest corner at 16 inches and greatest in the southeast corner where the average annual precipitation is 34 inches (Figure 2).

Evapotranspiration is the second factor that governs water movement through soils. Evapotranspiration is the combination of water evaporated from the soil surface and the amount of water transpired by growing plants. As air temperatures increase, evapotranspiration increases. If evapotranspiration is great, less water is available to cause loss of N by leaching or denitrification. In Minnesota, the greatest evapotranspiration occurs in the southwestern part of the state and least in the northeastern corner.

When combining these two factors (rainfall, evapotranspiration) one can calculate a leaching index or moisture index (Figure 3). This index is an indicator of average soil moisture conditions. The greater the index the more water present either in the soil or potentially percolating through the soil. There is a greater probability for N loss and greater need for careful N management as the index increases.

Chemical and biological reactions in the soil that involve N are related to temperature. Rates of various reactions increase as soil temperature increases. Normal average annual air temperatures in Minnesota ranges from 35 degrees F in the north to 46 degrees F in the south (Figure 4.). With a delay of about one day, soil temperatures fluctuate in the same way as air temperatures. Soil temperature affects N management because it has a direct impact on timing of soil sample collection and the application of N fertilizer. Lower soil temperatures are directly related to a reduced risk of the conversion of ammonium (NH_4^+), a less mobile form of N in the soil, to nitrate (NO_3^-) a very mobile form. The loss of N to denitrification, a biological process, is also related to soil temperature.

Combinations of soil parent material and climate parameters have led to the delineation of the BMP regions presented in Figure 5.

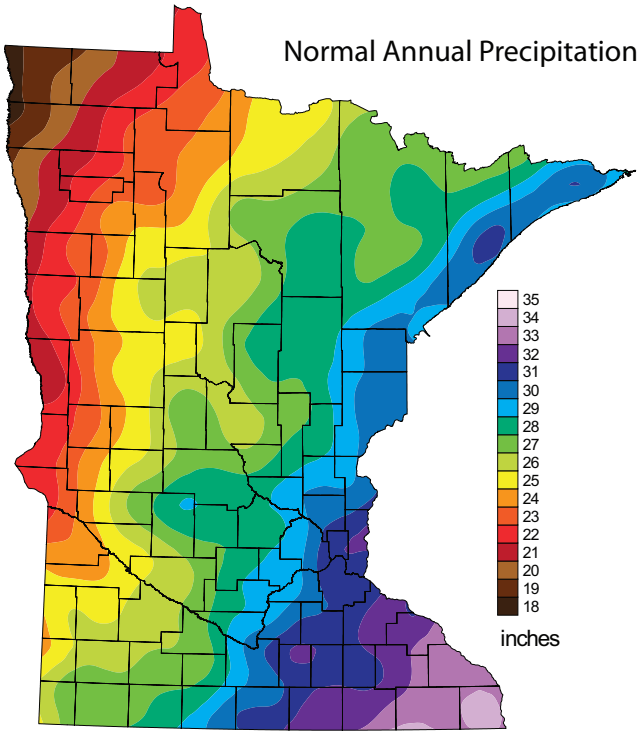


Figure 2. Normal annual precipitation in Minnesota

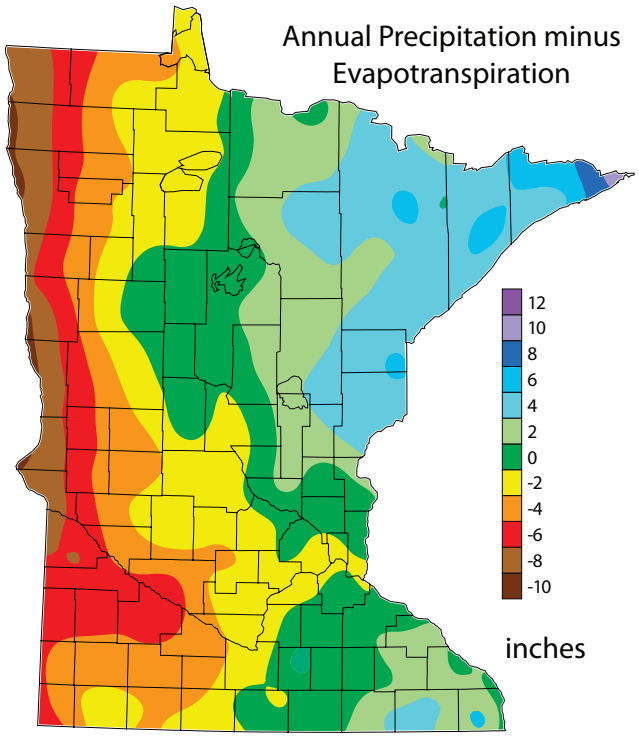


Figure 3. Annual precipitation minus estimated evaporation (leaching index) for Minnesota.

Minnesota BMP Regions

There are five BMP regions in Minnesota: Northwestern, Southwestern and West Central, South Central, Southeastern, and Irrigated and non-irrigated sands (Figure 5). The BMP's have been identified for coarse-textured soils that occur throughout the state.

The northwestern region is characterized by the least rainfall and evaporation. The parent material is predominantly lacustrine. While soils formed in lacustrine deposits are poorly drained, the reduced rainfall in this region decreases concerns for N losses from leaching and denitrification. Therefore, fall applications of nitrogen can be tolerated without a large concern about losses if soils do not have a sandy texture (sand, loamy sand, sandy loam).

The west-central and southwestern BMP region is characterized by a warmer and relatively drier climate. Glacial till and loess are predominate parent materials in this region. The loess materials are mainly found in the southwestern corner of the state. Most of the loess parent material was deposited on top of older glacial till; so soils formed in this parent material are also poorly drained. The drier climate reduces the risk of N losses; so fall N applications can be used in this region without a large concern for N loss.

The soils in the south-central region were formed in glacial till. The poor internal drainage and the increased precipitation in this region increases the chances for N losses though drainage tile or by denitrification. Fall N applications are discouraged because of these factors. The use of nitrification inhibitors should also be considered.

Southeastern region soils are formed in loess materials over a fractured limestone material. These soils have very good internal drainage. Compared to the rest of Minnesota, the precipitation is also the greatest in this region. Therefore, leaching of NO_3^--N is of great concern in this region. Spring or sidedress N application is strongly suggested.

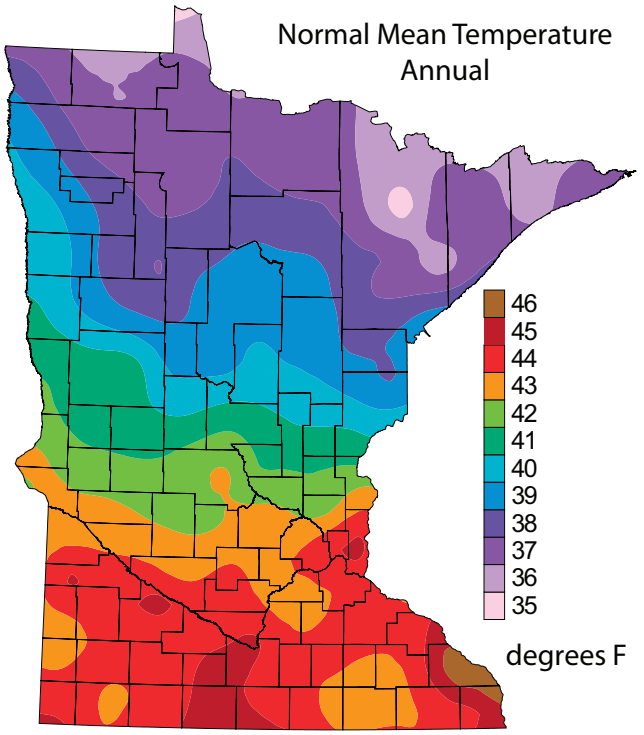


Figure 4. Normal mean annual temperatures for Minnesota.

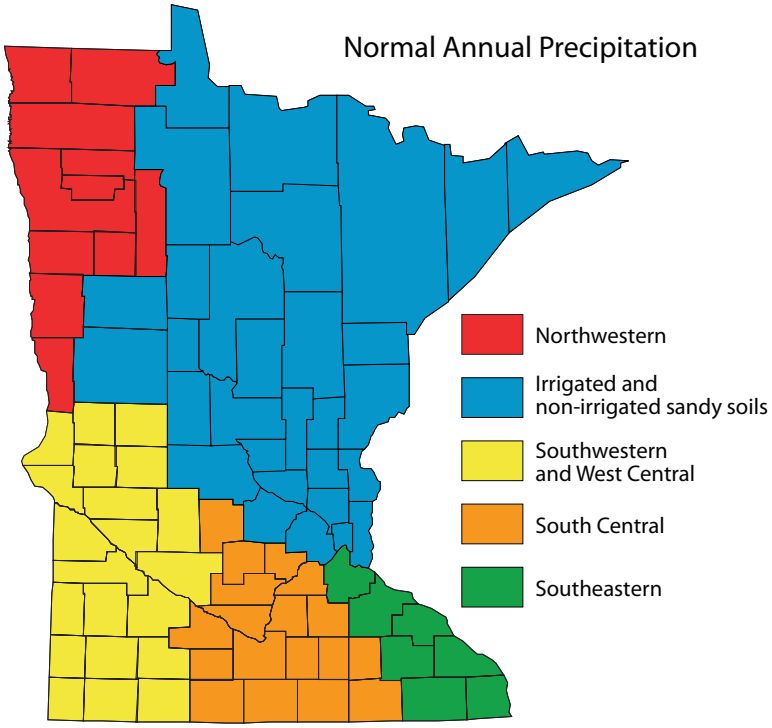


Figure 5. Minnesota NBMP regions.

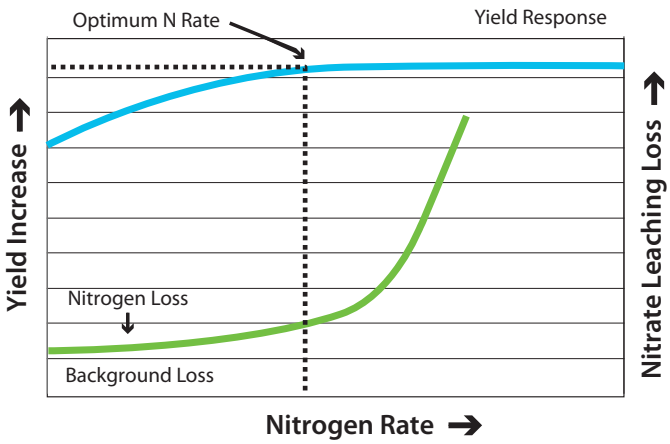


Figure 6. Importance of using optimum N rate for greatest profit and minimal nitrate-N loss.

How do we determine BMPS?

An understanding of regional differences and how they affect the N cycle is the basis of the research used to develop the BMP's. Choosing the correct rate is the number one factor in managing fertilizer N. As shown in Figure 6, N application rate is an optimization of yield increase versus N loss. Fortunately, under normal conditions, yield is optimized at the N rate where N loss is minimal. Use of the other best management practices suggested in the regional bulletins increases the probability of obtaining the most economic yield for the optimum N rate.

As mentioned earlier, the BMPs are based on University of Minnesota field research. They are the synthesis of results from research conducted from 1940 to the present day. The research has been conducted under the environmental conditions in each of the regions of Minnesota. Each field study was conducted using scientifically sound methods for making comparisons of management practices and interpreted with consideration of several other studies conducted at the same time or over years.

Summary

Best Management Practices (BMP's) for use of fertilizer N in Minnesota are diverse. There can be no "one size fits all" approach. The BMP's are different because soils and factors of soil formation are different. Recognition of these differences will result in more efficient management of fertilizer N, and maximum profit.

Related Publications

08557 (Revised, 2008) - Best Management Practices for Nitrogen Use in Southeastern Minnesota

08554 (Revised, 2008) - Best Management Practices for Nitrogen Use in South-Central Minnesota

08558 (Revised, 2008) - Best Management Practices for Nitrogen Use in Southwestern and West-Central Minnesota

08555 (Revised, 2008) - Best Management Practices for Nitrogen Use in Northwestern Minnesota

08556 (Revised, 2008) - Best Management Practices for Nitrogen Use on Coarse Textured Soils

AG-FO-5880 - Fertilizing Cropland with Dairy Manure

AG-FO-5879 - Fertilizing Cropland with Swine Manure

AG-FO-5881 - Fertilizing Cropland with Poultry Manure

AG-FO-5882 - Fertilizing Cropland with Beef Manure

AG-FO-3790 - Fertilizing Corn in Minnesota

AG-FO-3770 - Understanding Nitrogen in Soils

AG-FO-3774 - Nitrification Inhibitors and Use in Minnesota

AG-FO-2774 - Using the Soil Nitrate Test for Corn in Minnesota

AG-FO-2392 - Managing Nitrogen for Corn Production on Irrigated Sandy Soils

AG-FO-0636 - Fertilizer Urea

AG-FO-3073 - Using Anhydrous Ammonia in Minnesota

AG-FO-6074 - Fertilizer Management for Corn Planted in Ridge-till or No-till Systems

AG-FO-3553 - Manure Management in Minnesota

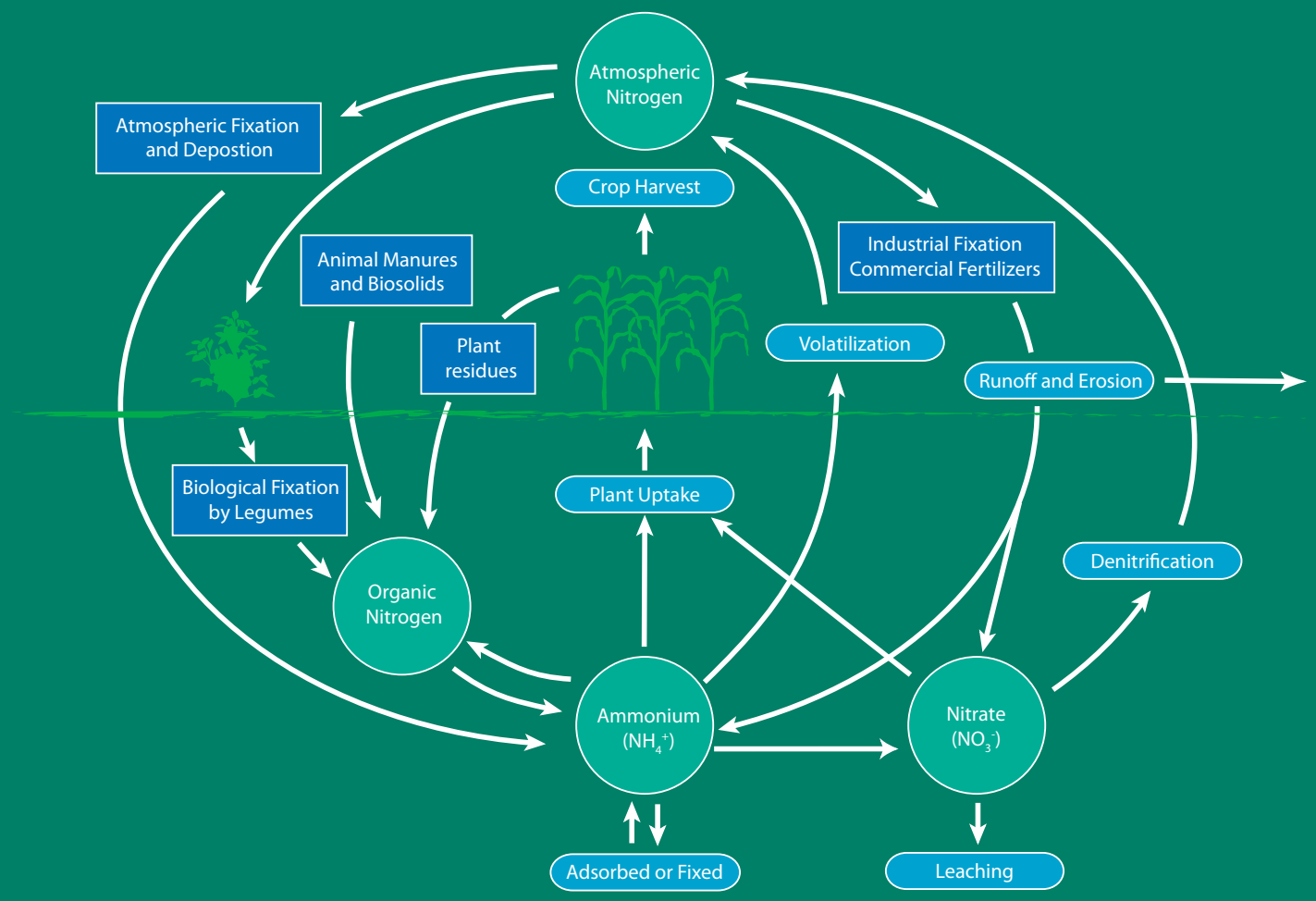
BU-07936 - Validating N Rates for Corn

Iowa State Univ. PM 2015 - Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn

FO-07715-C - Fertilizing Sugar Beet in Minnesota and North Dakota

FO-3772-C (Revised) - Fertilizing Wheat in Minnesota

FO-6572-B - Fertilizer Recommendation for Edible Beans in Minnesota



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