

Nitrogen in Mississippi Soils



Adequate nitrogen nutrition allows plants to develop a robust green color.

Nitrogen is essential for plant growth. It is the mineral plants require most. Lack of nitrogen in a plant may be seen on older leaves that are mostly pale green or yellow.

Field crops typically require more nitrogen (N) than Mississippi soils provide in a growing season. Fertilizer or manure sources of N must be added for economical crop production. But too much available N may lower yields and lessen crop quality. If soil N as nitrate (NO_3^-) supply is greater than crop demand, the excess NO_3^- may enter ground or surface water.

Nitrogen behavior is complex, but farmers must understand it so they can manage it for greatest profit and least environmental impact.

Sources of Nitrogen in the Environment

Nitrogen is in the air, water, soil, and biological materials of the earth. The air contains large quantities of N_2 gas, but it is not directly available to plants. Of the almost 37,000 tons of atmospheric N directly above each acre of land, about 5 pounds of N per acre are deposited with rain or snow each year. The small amount that falls is from lightning and burning processes, including automobile emissions. Even though the amount added by direct deposition is small, most N used by crops originated in the atmosphere and was retrieved by industrial or biological processes.

The amount of N in soils is closely associated with organic matter levels. Legumes such as soybeans and alfalfa change atmospheric N_2 to plant-available forms by way of a process involving Rhizobium bacteria and the plant roots. This “fixed” N may either return to the soil to become part of soil organic matter and serve as an N source to later crops or be removed in harvested plant materials.

Small quantities of soil N are provided by residue from plants that do not fix atmospheric N. Organic matter in Mississippi soils typically ranges from 0.5 percent to 2 percent by weight of the upper 6 inches. Organic matter is normally about 5 percent N, so total N in the topsoil ranges from 500 pounds per acre to 2,000 pounds per acre. However, only a very small portion of the total N is available to plants during a growing season. Organic matter is replenished by returning crop residues to the soil or introducing other organic sources such as manures or animal bedding.

Almost all N in commercially available fertilizers is derived by combining atmospheric N_2 with H_2 to form ammonia (NH_3), which may be used directly as fertilizer (anhydrous ammonia) or as a starting point in the manufacture of other N fertilizers.

Even though anhydrous ammonia is an efficient source of fertilizer N, it must be stored under high pressure; therefore, it requires special handling and stringent safety precautions. These requirements have made other N fertilizers more popular.

Animal manures are also important sources of N in the environment. The quantity of N in the manure depends on the animal's species, age, diet, and bedding materials. Manure begins contributing to plant nutrition and soil organic matter when added to agricultural soils, but not all the N within manure is immediately available to plants.

Forms of Nitrogen in Soils

Nitrogen is in organic and inorganic forms in soils. More than 90 percent of soil N is associated with soil organic matter. Nitrogen is in compounds identifiable as part of the original organic material such as proteins, amino acids, or amino sugars, or in very complex unidentified substances in advanced stages of decomposition. These uncharacterized substances resist further microbial degradation and account for the very slow availability of soil N.

Plants may use either ammonium (NH_4^+) or nitrate (NO_3^-), which behave quite differently in soils. Positively charged NH_4^+ is attracted to negatively charged sites on soil particles, as are other cations. It is available to plants, but it will not leach.

Negatively charged NO_3^- remains in the soil solution and moves with soil water. NO_3^- may leach out of the root zone when rainfall is excessive, or it may accumulate at the soil surface in dry weather.

Nitrogen Transformations in Soils

Nitrogen transformations depend on soil moisture conditions, soil acidity, temperature, and microbial activity. Because the Mississippi climate is characteristically warm and humid, microbial transformations occur throughout most of the year. This extended period of decomposition results in lower organic matter levels in Mississippi soils than in cooler, drier climates.

Ammonium can be adsorbed in soil particles or taken up by plants without transformation, but in most cases it is converted to NO_3^- soon after its formation or addition as fertilizer. This process, called nitrification, involves two groups of soil bacteria. First, Nitrosomas bacteria produce nitrite (NO_2^-). Nitrobacter species then convert NO_2^- to NO_3^- soon after its formation.

Two things to note: 1) NH_4^+ may exist in soils only a short time, and 2) H^+ ions are produced, which increases soil acidity or lowers the soil pH. This conversion may be slowed by commercially available nitrification inhibitors that maintain N in the NH_4^+ longer.

Mineralization is the process of converting organic N to plant-available inorganic forms. It is a gradual breaking down of large organic molecules to smaller molecules by soil microorganisms. After these microbes complete their relatively brief life cycles, they are decomposed by other microbes. Energy for this process comes from carbon (C) in the material being used, so introduction of fresh plant materials rich in decomposable C stimulates this process.

Immobilization occurs when plants and soil microorganisms incorporate inorganic N into an organic N form. Because this process depends largely on microbes, the availability of carbon and other nutrients determines the rate of immobilization. When residues with high C:N ratios are being decomposed, all readily available N within the soil system may be used by the microbes and unavailable for plant uptake.

This effect is temporary. Eventually some of the microbial population dies and decomposes, releasing N that is available to plants. The risk of immobilization is avoided by mixing plant residue into the soil well before the next cropping cycle.

Loss of Nitrogen from Soils

Even though soil N may not be available to plants through immobilization, it is still in the soil. Nitrogen can be permanently removed from soil by erosion, leaching, denitrification, or volatilization.

Organic matter, which contains most native N, is concentrated in the plow layer of soils, making it susceptible to loss by erosion. Soil conservation practices lessen erosion loss.

Leaching loss occurs when NO_3^- remains in the soil water and moves away from root uptake areas with downward water movement. This N loss is a contaminant if it reaches ground or surface waters. Nitrogen leaching is more likely when there is more rain than a crop can use.

A major mechanism of N loss in Mississippi is denitrification in waterlogged soils. As the water content of soils increases, the amount of air in soils decreases. Some soil microorganisms can use the oxygen in soil NO_3^- and NO_2^- instead of gaseous O_2 . Ultimately nitrous oxide gases (N_2 , NO , and N_2O) are produced and released to the atmosphere, resulting in a loss of N from the soil.

Conditions necessary for denitrification are waterlogged soils, carbon sources (from organic matter or plant residues) for use by the anaerobic microbes, and N as either NO_3^- or NO_2^- . The rate is greatly accelerated by higher temperatures.

The loss of volatile ammonia gas (NH_3) to the atmosphere can also occur from anhydrous, urea, or N solution fertilizer sources. Losses by volatilization are minimized

through proper management of fertilizer applications. Producers should apply anhydrous ammonia when soil conditions allow good sealing of the applicator slit after fertilization.

The first step in urea N conversion to NH_4^+ is the production of NH_3 . Volatile losses from urea are more likely with warm temperatures ($>50^\circ$), high pH soils (>7), pastures, and conservation tillage with high residues.

Ideally, you should incorporate urea into the soil or apply it before a rainfall. Since urea volatilization is increased when broadcast-applied to vegetative cover or plant residue, you must be careful when using urea as a topdressing N source. You should never place urea in contact with seed because of toxic effects of NH_3 on seedlings. The same precautions apply to N solutions since they contain urea.

Using Nitrogen Effectively

The frequent changes of N in soils limits the value of N soil testing as a predictive tool in Mississippi's warm, humid climate. While supplemental N fertilization is usually necessary for economic production of nonlegume crops, large N applications cannot substitute for poor management. Research-based economic and environmentally friendly recommendations are available for all crops produced in Mississippi.

Common Nitrogen Fertilizers			
Fertilizer	Nitrogen %	Phosphate %	Potash %
Ammonium nitrate	33.5–34	0	0
Ammonium sulfate	21	0	0
Anhydrous ammonia	82	0	0
Aqua ammonia	20	0	0
Calcium nitrate	16	0	0
Sodium nitrate	16	0	0
Urea	45–46	0	0
Urea ammonium nitrate	28–32	0	0 (solution)

Best Management Practices for Nitrogen Fertilizers

- Use realistic yield goals.
- Use the most suitable nitrogen fertilizer source, depending upon the crop, application method, and climatic conditions.
- Use proper application techniques, including variable rate technology if appropriate for the situation.
- Maintain and calibrate application equipment.
- Avoid application to surface waters.
- Time application properly for the crop.
- Control soil erosion.
- Properly control water flow.
- Use cover crops, and maintain crop residue on the soil surface.
- Credit legume crop contribution to soil nitrogen when appropriate.

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By Dr. Larry Oldham, Extension Professor, Plant & Soil Sciences.



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