APPENDIX F

Overview of the Soil Nitrogen Cycle

OVERVIEW OF THE SOIL-NITROGEN CYCLE

In the soil, nitrogen exists in the following two major classes of compounds:

- Organic nitrogen, such as proteins, amino acids, and urea, including nitrogen found within living organisms and decaying plant and animal tissues.
- Inorganic nitrogen, including ammonium (NH4+), ammonia gas (NH3), nitrite (N02), and nitrate (N03).

However, nitrogen is transformed among these various forms through a complex network of physical, chemical, and biological reactions collectively called the nitrogen cycle. Figure XX provides an overview of the nitrogen cycle. The nitrogen cycle in soil includes the following processes, in which microbes play a crucial role:

- Plant uptake
- Mineralization of organic nitrogen
- Adsorption of ammonium
- Nitrification of ammonium
- Immobilization of ammonium and nitrate
- Volatilization of ammonia
- Leaching of nitrate
- Denitrification of nitrate
- Fixation of nitrogen gas

Only inorganic nitrogen can be removed through ***plant uptake***. The greater part of nitrogen in the field, however, is usually in organic form such as proteins and amino acids (from the breakdown of plant and animal materials, microorganisms, manure, compost, or other organic matter). Under normal conditions, organic nitrogen in soil would be expected to be converted to ammonium by soil microorganisms through a process known as ***mineralization*** (also known as ammonification). Because it has a positive charge, ammonium can be "stuck" onto the negatively charged soil particles, in a process known as ***adsorption***, or it can be taken up by plants. Bacteria can also transform the ammonium in the soil to nitrate in a sequence of steps that occur in oxygenated environments called ***nitrification***. Nitrate is a negatively charged anion and therefore usually remains in the soil water rather than being adsorbed to soil particles. However, plants readily absorb nitrate through their roots and use it to produce protein. ***Immobilization*** is the term applied to the process where ammonium and nitrate are converted into organic forms of nitrogen either in the form of microbial cell mass or plant material.

Urea and ammonium forms of fertilizers applied on the soil surface may undergo a series of chemical conversions to ammonia gas. The ammonia gas can then escape to the atmosphere rather than becoming a plant nutrient. This loss, termed ***volatilization***, is reduced if the ammonia is washed into the soil by rain or irrigation or if the fertilizer is drilled into the soil to a depth of an inch or more.

Because nitrate does not adsorb strongly to soil particles, it can be carried below the root zone, perhaps to groundwater, in a process known as ***leaching*** if it is not taken up by plants. The greatest potential for nitrate leaching occurs if fertilizer is applied at a time when no crops are growing, such as during spring planting or in the fall after harvest. Leaching losses can be reduced by applying nitrogen in increments during the periods of rapid plant growth, or by applying organic nitrogen that becomes plant available slowly over time. Even with organic sources, however, leaching can occur if the nitrogen supplied exceeds the ability of the crop to use it. Factors that determine whether nitrate will reach groundwater include:

- Amount of nitrate in the soil
- Quantity and timing of rainfall or irrigation
- Soil's capacity to hold water
- Presence and density of plants
- Rates of infiltration and percolation of water through the soil
- Rate of evapotranspiration relative to precipitation and irrigation
- Soil temperature

If pockets in the soil become saturated with water so that oxygen is excluded, called an anaerobic or anoxic condition, some bacteria can meet their energy needs by reducing nitrate to dinitrogen gas or to nitrogen oxide. This biological process is called ***denitrification***. Poorly drained and heavy soils are particularly prone to denitrification, and a substantial amount of applied nitrogen may be lost to the atmosphere.

Finally, legumes can supplement soil nitrogen supplies by fixing nitrogen from the atmosphere. This is accomplished by specialized bacteria living in nodules on the plant roots that absorb atmospheric dinitrogen gas and convert it into ammonium, which plants can use. This process, called ***nitrogen fixation***, is the principal natural means by which atmospheric nitrogen is added to the soil.

THE SOIL NITROGEN CYCLE