Nitrogen loss through Denitrification

Xiaohui Fan and Yuncong Li, TREC, University of Florida, Homestead, FL

Denitrification is the natural process by which nitrate (NO$_3$-N) is reduced into gaseous nitrogen by various microorganisms known as denitrifying bacteria. Denitrification takes place under special conditions in both terrestrial and marine ecosystems. In general, it occurs when oxygen, a final electron acceptor, is depleted, and bacteria turn to nitrate in order to oxidize organic matter. Denitrification takes place in flooded soils, wetlands, groundwater, poorly ventilated niches of the ocean, and in seafloor sediments.

Denitrification proceeds through the following steps:

\[ \text{Nitrate} \rightarrow \text{nitrite} \rightarrow \text{nitric oxide} \rightarrow \text{nitrous oxide} \rightarrow \text{dinitrogen gas} \]

During the denitrification process, the nitrates become nitrite, nitrous oxide, or elemental nitrogen (N$_2$). This process takes place frequently in nature. Because denitrification causes nitrogen fertilizer loss and pollutes the atmosphere, it is an important concern for agronomy and for the environment in general. The factors controlling denitrification are supplies of nitrate, carbon, and oxygen. These factors are affected by soil moisture, soil aeration, soil temperature, soil organic carbon content, plant root systems, tillage, and the amount of N fertilizer applied in the field. Irrigation and rain are important factors affecting denitrification. Studies have shown that the denitrification rate increases 6–14 times when water filled soil pore spaces increase from 60% to 90%. Denitrification can occur at soil temperatures of 5–70°C with 25–35°C being a highly favorable temperature range. Since denitrification microorganisms need organic carbon for energy metabolism, high organic carbon contents in soils stimulate the denitrification rate. Also, the addition of organic carbon sources, such as straw, can increase denitrification. No tillage increases the denitrification rate more than tillage, because the soil water content is conserved with no tillage. Plant root systems may excrete organic carbon and thereby increase denitrification in rhizosphere soils. The rate of denitrification is highly dependent on the amount of nitrogen fertilizer applied. Thus the application to soils of large amounts of nitrogen fertilizer, or of fertilizers with high concentrations of NO$_3$-N, could result in high denitrification rates.

Studies have shown that, in some cases, up to one-fourth or more of the total nitrogen fertilizer applied can be lost due to denitrification. The exact amount of N lost by this process is hard to determine. There is no universally accepted method for measuring denitrification. Field measurement of denitrification has mainly been done using techniques such as acetylene inhibition methods and $^{15}$N gas mass techniques.

Seepage irrigation practices for vegetable production, a common practice in south Florida, create a favorable condition for denitrification. Therefore, denitrification potential in these fields should be studied in more detail.

(Xiaohui Fan and Yuncong Li, TREC, University of Florida, Homestead, FL)