Managing Nitrogen in Crop Production

Peter Scharf

Among crop nutrients, nitrogen has the most complex chemistry and behavior in soil, gives the largest yield responses, and is the most difficult to manage. Managing Nitrogen in Crop Production condenses the latest research and thinking from leading experts in nitrogen. The result will increase your understanding of nitrogen and your odds of managing it successfully.

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Acknowledgments

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Understanding nitrogen is difficult. More than any other element needed for life, nitrogen has a wide array of forms that behave very differently from each other.

Our knowledge of how nitrogen behaves is extensive, but far from perfect. This section is distilled from the knowledge of many national and world experts on nitrogen. The goal is to help you understand nitrogen’s place in our world, its place in living organisms, and its behavior in soils. This understanding is the foundation for good nitrogen management, which is the topic of the second half of this publication.

Nitrogen at the Global Scale

Nitrogen is crucial to life. All living things contain a substantial proportion of nitrogen. The special geometry of nitrogen helps give structure to the carbon-based molecules that form the “strings of life” (Fig. 1–1, 1–2).

Nitrogen is a component of DNA, the molecule that makes up the genes that pass traits from one generation to the next. For DNA to act, its information must be translated into protein molecules that are rich in nitrogen. The protein molecules do the work of life. Many nitrogen-containing molecules are so crucial that death results if just one...
of them is absent or prevented from working. Numerous herbicides act on this principle.

Most land and water environments on Earth are nitrogen-limited. This means that adding nitrogen increases the growth and mass of living things (Fig. 1–3). This is why nitrogen fertilizer is so important for agricultural production. It is also why nitrogen that escapes from agricultural systems causes problems in other environments.

Although nitrogen is relatively plentiful on Earth, much of it occurs in forms that are not available to living things. The interior—core and mantle—of the Earth contains 91% of the Earth’s nitrogen. Of the nitrogen at the surface, 1/4 is in rocks and 3/4 is in the air. Only 0.03% of the nitrogen at the surface is easily available to living things. This is why nitrogen is so important to life.

Nitrogen fixation is the process of converting nitrogen gas from the air into forms that are easily available to living things.

Nitrogen gas in the air is plentiful, but very stable and difficult to convert to biological forms. It is useless to most living things. Only a small number of living organisms are capable of fixation. People (Fritz Haber and Carl Bosch in Germany about a century ago) have figured out how to accomplish fixation through chemical reactions to make N fertilizer from nitrogen gas.

Some of the earliest known fossils are filamentous microbes that have structures resembling the nitrogen-fixing sites in modern blue-green algae. This suggests that nitrogen availability has always been limiting through the long history of life on Earth, and that nitrogen-fixing ability has always made a major contribution to building and sustaining life. This continues to be true for nitrogen fixation by humans. Vaclav Smil, in his book *Enriching the Earth*, estimated that 40% of the current human population would not be alive today if we had not developed the ability to fix nitrogen from the air to make fertilizer (Fig. 1–4). Nitrogen fertilizer use in...
Nitrogen is biologically potent across a range of environments, dramatically changing the vigor of plant growth. In a corn field research plot, corn without nitrogen is small, light, and poor at capturing sunlight; corn with nitrogen is taller, darker, captures more sunlight, and produces more grain. Photo: Rick Mascagni. Even in harsh environments like alpine (top inset) or desert, the addition of nitrogen increases plant growth, favors grasses, and may favor invasive species crowding out natives. Photo: Bill Bowman. Nitrogen also increases plant growth in seawater, leading to algal blooms, such as the one in the Gulf of Mexico near the mouth of the Mississippi River (bottom inset). Excessive algal growth leads to oxygen depletion below levels that can support animal life—this is an environmental issue that is increasing in severity and visibility globally. Photo: Nan Walker, Earth Scan Laboratory, Louisiana State University.
North America increased dramatically from 1960 to 1980 and then leveled off, but continues to rise dramatically on other continents.

Although biological nitrogen fixation is ancient, it has changed very little through its long history. **Only a small proportion of microorganisms have the genes required to fix nitrogen.** These genes have never been passed on to other higher life forms, and the key enzyme that captures and converts the nitrogen gas is nearly identical in all nitrogen-fixers. This enzyme can work only in a low-oxygen environment. This means that nitrogen-fixers need to have a way to produce a low-oxygen environment, an inconvenient and energy-demanding requirement. It’s not a very good solution to the biological need for nitrogen fixation, but it’s the only solution that has ever been found.

Because nitrogen is so important to higher life forms, **some plants have developed relationships with nitrogen-fixing bacteria that allow them access to nitrogen fixed from the air.** Among these, the most complex are the symbiotic relationships between legumes, like soybean, alfalfa, clover, and peanut, and nitrogen-fixing bacteria. A complex set of signals between the plant and the bacterium sets the process in motion, resulting in the plant forming nodules on its roots that house and feed the nitrogen-fixing bacteria. Legume–microbe partnerships can fix a tremendous amount of nitrogen from the air. Other relationships are looser, less complex, and fix less nitrogen. One
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