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WHAT HAPPENS TO FERTILIZER IN SOIL?

A lot of careful consideration goes into selecting which fertilizer should be added to a crop. After all the decisions have been made, little thought is then given to what actually happens next. A brief review of some important fertilizer reactions can help you get the most benefit from these valuable resources.

There are five major processes that happen to applied fertilizer.

- It is taken up by the crop
- It reacts with soil minerals and organic matter to become part of the soil reserve
- It can leach from the root zone with water
- It can be lost to the atmosphere as a gas
- It can move from the field through soil erosion and water runoff

Nitrogen fertilizer can be subject to all five of these processes and may be the most difficult to manage of all nutrients. Nitrogen fertilizer is most commonly added in the form of nitrate, ammonium or urea. Their behavior is quite different and they need to be managed with their specific properties in mind.

Nitrate (NO_3^-): Nitrate is very soluble in soil and moves freely with water in the soil. Excessive rainfall or irrigation can easily move nitrate below the root zone. In wet soils, bacteria may convert nitrate to nitrous oxide (N_2O), causing a loss of a valuable resource and the production of a greenhouse gas. Nitrate can also be converted to inert N_2 gas.

Ammonium (NH_4^+): As a positively charged cation, ammonium is largely held on soil cation exchange sites. In warm aerated soils, ammonium is converted to nitrate within a few days or weeks. In flooded soils, ammonium can persist for long periods of time. When left on the soil surface, ammonium is in equilibrium with ammonia gas and can be lost to the atmosphere.

Urea ($CO(NH_2)_2$): As an uncharged molecule, urea moves freely with water in the soil. In warm soils, urea is decomposed to ammonium within a week or two by an enzyme (urease) that is present in almost all soils and plants. When urea is left on the soil surface, a portion of the ammonium will be lost as ammonia gas. If urea is placed beneath the soil surface or washed into the soil by rainfall, ammonia losses are very low.

All added N fertilizer is accessed by soil microorganisms before the plant roots have a chance for uptake. Since there are between 100 million and 1 billion bacteria in a single teaspoon of soil, their numbers in an entire acre are almost unimaginable. When conditions are optimal (warm temperature and adequate carbon), microorganisms will immobilize some of the added N in their cells and it will become part of soil organic mater.

Phosphate fertilizer quickly reacts in soil to form many new compounds and remains very close to where it is applied. The most common phosphate fertilizers are diammonium phosphate (DAP; 46% P_2O_5, pH 7.5 to 8) and monoammonium phosphate (MAP; 48 to 61% P_2O_5, pH 4 to 4.5).

Phosphate fertilizers are initially soluble in water and thus readily used by plants, but they quickly react with clays and other elements in the soil to become less soluble. These newly formed compounds will slowly dissolve and release soluble P over many months or years. These chemical reactions can be influenced by modifying the fertilizer properties or by minimizing fertilizer contact with soil with banded fertilizer application.

Phosphorus movement in agricultural soils is quite limited, with diffusion occurring in the range of a few millimeters to less than an inch. In very sandy soils or where application rates greatly exceed agronomic needs, P movement through the soil can be greater.

Since P fertilizer is tightly bound to soil particles, erosion from the field in runoff water can be a pathway of loss. Conservation practices should be implemented to minimize erosion losses. Added phosphate fertilizer is incorporated into microbial biomass and soil organic matter, but in smaller amounts than N.

Potassium fertilizer is most commonly added as potassium chloride. However, all forms of K fertilizer contain the identical chemical form (K^+). Other K-containing fertilizers may contain nitrate, sulfate, thiosulfate, or phosphate, but the behavior of the K will be the same.

Potassium is simpler to manage than N or P since it is not involved in biological transformations. Most K fertilizers dissolve quickly in the soil and the K will either immediately displace another cation on the clay surface or move with water until it displaces another cation.

To get the most value from fertilizers, it is important to know what happens after they are added to the soil. Many people have little appreciation for the complex task of delivering the right nutrition to growing plants. Integrating knowledge of soil chemistry, soil microbiology and soil physics will go a long way in helping improve fertilizer management.

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Abbreviations: N = nitrogen; P = phosphorus; K = potassium.