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What is Meant by Crop Availability of Manure Nutrients?

Nutrient management guidelines in Iowa and other states use the words "manure nutrient availability" when suggesting manure application rates to supply nutrients needed by crops. People are sometimes confused about the meaning of the word "availability." In fact, manure management guidelines across the region vary in the exact use and this contributes to confusion. Interestingly, Webster's Ninth New Collegiate Dictionary includes "plant" and "nitrogen" in the definition of "available." One definition is "present or ready for immediate use", and another definition is "present in such chemical or physical form as to be usable (as by a plant) <~ nitrogen> …" So, why is there confusion?

Nutrient Availability

The main reasoning for use of the term "available" in regard to crop fertilization is that some portion of manure nutrients are often in forms that are not usable by plants immediately upon application to soil. Therefore, the implication of "crop-available" is to have the nutrient be in or converted to a form that plants can take up. Fertilizers essentially are comprised of chemical forms that plants can take up or are quickly converted upon application to soil, whereas manure often contains a mix of forms: immediately useable by plants, are quickly converted, are slowly converted, or are not converted. These forms and relative amounts vary by manure source, and for some manures conversion can occur over multiple growing seasons. Therefore, what is "crop available" can be confusing. For commonly used inorganic fertilizers, what is in the tank or truck hopper pulled into the field represents essentially 100% crop-available nutrient. For example, ammonium nitrate contains both forms of nitrogen (N) useable by plants, ammonium (NH_4^+) and nitrate (NO_3^-). For others, some conversion takes place rapidly once applied to soils. For example, anhydrous ammonia dissolves in water and immediately changes to ammonium. Urea hydrolyzes to ammonium within a few days. Mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP) are highly soluble in water and dissolve to NH_4 and orthophosphate [$H_2(PO_4)^-$ or $H(PO_4)^{2-}$, the P forms that are taken up by plant roots]. Potassium chloride (KCl, potash), dissolves in water to the potassium (K^+) and chloride (Cl^-) ions, both of which are taken up by plants.

For manure, what is in the tank or spreader hopper is a mix of organic and inorganic materials. This mix varies by manure source, animal production practice, storage, and handling. These factors greatly affect the amount and forms of N and P in manure and contributes to a greater uncertainty in manure nutrient management compared with fertilizers. These are not major issues for K, however, because almost all is in the K^+ ion form and therefore in the liquid fraction and readily available.

Contributors

- Natural Resource Conservation Service
- Agribusiness Assoc. of Iowa
- Iowa Farm Bureau Federation
- Iowa Poultry Association
- Iowa Turkey Federation
- Iowa Pork Industry Center
- Iowa Beef Center
- Iowa Pork Producers Assoc.
- Iowa Department of Natural Resources
- Iowa Cattlemen's Assoc.
- Division of Soil Conservation, Iowa Department of Agriculture and Land Stewardship
- Iowa State Dairy Association
- Iowa Commercial Nutrient Applicators Assoc.
- Coalition to Support Iowa's Farmers
- Iowa Corn Growers Assoc.
- Iowa Soybean Association
- Iowa State University, University Extension
- Iowa State University, College of Agriculture

Nitrogen

For example, N in swine manure from the liquid fraction of an anaerobic lagoon is essentially all in the ammonium form, and N in liquid swine manure from pits averages about 84% ammonium-N, but can be near 100%. This high ammonium-N content, plus the fact that manure organic N can be mineralized before or during the growing season, is why N availability with liquid swine manure is considered 100% crop available and comparable to fertilizer N. Bedded dairy or beef manure has much lower ammonium and greater (and tougher to degrade) organic materials due to bedding and feed materials. In poultry, N is excreted predominantly as the organic compound uric acid, which hydrolyzes rapidly to ammonium. The extent of uric acid conversion can cause variation in the proportion of poultry manure analyses measured as ammonium and organic N, and therefore uncertainty in the portion of organic N that should be considered immediately plant-available.

Phosphorus

Similar differences are found for P. The P in manure can be in the orthophosphate forms that plants take up and in organic or inorganic compounds that first need to dissolve or be degraded by microorganisms or enzymes to orthophosphate. Considerable P in swine manure is orthophosphate and calcium phosphate (derived both from feed and mineral supplements added to rations) that may be soluble or dissolve quickly once applied to soil. The rest is organic P that, as for organic N, ranges greatly in complexity and type of reactions in soil. Poultry and cattle manure often have higher and more variable proportions of P forms that are or change quickly to plant useable after application to soils. Testing manure for ammonium-N concentration or water-soluble N is a way of estimating immediately available manure N. Unfortunately, a similarly useful test does not exist for P.

Nutrient Supply

The difference between crop-availability and season-long supply of nutrients from manure further complicates manure nutrient management. Unfortunately, no reliable laboratory analysis method provides estimates of the amount of manure N and P that may become slowly available over a period of weeks or months. Moreover, just like with N or P fertilizer application to soil, once manure N and P are in plant usable forms losses can occur through processes such as leaching, volatilization, or denitrification for N and erosion and surface runoff for P. Also, N and P can, for short or long periods of time, be converted in soil to forms not usable by plants through processes such as immobilization to organic materials, and for P, retention by soil mineral constituents. From an agronomic perspective, loss issues are not as pertinent for P and K as long as there is little soil erosion and surface runoff. Uncertainty concerning immediate or longer-term fate of plant usable nutrients in soil is similar for manure and fertilizer, but does add to the uncertainty for manure nutrient management.

Variation in manure nutrient content, application rate, and application distribution also affect nutrient supply and contribute to uncertainty. Application rate and distribution uncertainties impact all applied nutrients, whether it is manure or fertilizer. However, due to manure characteristics, these uncertainties are more difficult to manage than with fertilizer. For meeting crop nutrient needs, the supply issues can be important for N, P, and K – although typically are of greater concern with N.

This is because manure usually is applied for corn, N is almost always needed, many Iowa soils have optimum or high P and K levels, and crop deficiency symptoms resulting from nutrient supply problems are obvious for N but seldom for P or K.

Nutrient losses and nutrient rate/distribution uncertainties usually are not included in manure "availability" estimates. Instead they are handled by management practices. But not all states are consistent in this regard and, therefore, published "crop nutrient availabilities" do vary. They even vary in Extension publications from Iowa State University. For example, in Pm-1811 (Managing Manure Nutrients for Crop Production) the use of "availability" refers to nutrients potentially available for plant uptake by the first crop after application or beyond. For N and K, the provided percent nutrient availability refers to the portion similar to that in commonly used fertilizers. For P, however, the percent availability is modified by assuming different first-year crop-availability for application to Very Low and Low-testing soils (60% available) versus Optimum testing soils (100% available) where manure is applied to maintain soil-test P. This difference is partially due to the "first-year availability" of P in manure, but also includes the greater risk of being short of needed P when soils are deficient (due to factors discussed above and others). Hence, the lower stated P availability value for low-testing soils. There is nothing wrong with this, but it is necessary to understand the assumptions that go into the estimates of availability. However, this combination of concepts adds to the confusion.

Summary

Several nutrient availability and supply issues inherent to manure contribute to more complicated and uncertain management of this nutrient resource compared with fertilizer. Manure nutrient management guidelines in Iowa typically provide suggestions for crop-availability and assume supply issues are handled in the best and most reasonable ways possible. It is important to understand the differences between manure sources in regard to nutrient availability and conversion once applied to soils, the benefits and risks involved with manure nutrient analysis and supply issues related to manure management practices (timing, placement, potential losses, etc.), and the tools available to help determine season-long nutrient supply (for example soil testing for N, P, K and crop sensing for N). In many instances consideration of supply issues is more critical than the estimate of crop-availability for successful use of manure as a nutrient source.

Written by: John Sawyer and Antonio P. Mallarino; Soil Fertility Specialists, Iowa State University

Resources

IMMAG Series, Volume 6, Is manure the same as fertilizer as crop nutrient resource? March, 2007. http://www.agronext.iastate.edu/immag/pubs/imms/vol6.pdf