



USING MANURE NUTRIENTS FOR CROP PRODUCTION

Nutrients in Animal Manure

Manure can supply nutrients required by crops and replenish nutrients removed from soil by crop harvest. Since manure contains multiple nutrients, applications should consider not only what is needed for the crop to be grown but also how the ratio of nutrients in manure could affect soil test levels. This ensures adequate nutrient supply and reduces potential for over- or under-application and subsequent buildup or depletion in the soil. Good manure nutrient management should consider short-term and long-term impacts on crop nutrient supply and soil resources.

Manure has characteristics that make nutrient management different and sometimes more complicated than fertilizer. These include a mix of organic and inorganic nutrient forms; variation in nutrient concentration and forms; variation in dry matter and resultant handling as a liquid or solid; and relatively low nutrient concentration requiring large application volumes. Since manure nutrient composition can vary significantly, sampling and laboratory analysis are always needed, while with fertilizer, nutrient concentrations are provided at a guaranteed analysis.

The manure nutrient concentration varies considerably between animal species; dietary options; animal genetics; animal performance; production management and facility type; and collection, bedding, storage, handling, and agitation for land application. Use of average or “book” nutrient values can be helpful for designing a new facility and creating manure management plans but is not very helpful in determining specific manure nutrient supply or application rates due to the wide variation in nutrient concentrations between production facilities. For example, a recent sampling across swine finishing facilities found a range in total N from 32 to 79 pounds N/1,000 gallons, P from 17 to 54 pounds P_2O_5 /1,000 gallons, and K from 23 to 48 pounds K_2O /1,000 gallons. A similar or larger range can be found with other manure types. Nutrient analyses often vary greatly as storage facilities are emptied or manure is stockpiled, and also among

multiple samples collected from loads during land application. Therefore, collecting multiple manure samples and maintaining a history of analysis results will improve use of manure nutrients.

For determining manure application rates and equating to crop fertilization requirements, it is most helpful if manure analyses give N, P_2O_5 , and K_2O based on an as-received or wet basis in pounds per ton or pounds per 1,000 gallon units. It is beyond the scope of this publication to give detailed manure sampling and laboratory analysis recommendations. Those can be found in the extension materials listed on page 6. If manure analyses are provided from the laboratory in other units, they must be converted to these units. See the ISU Extension and Outreach manure sampling publication for appropriate conversion factors. If average nutrient values or methods to estimate manure nutrient concentrations based on excretion are of interest or needed for planning purposes, those can be found in the Midwest Plan Service bulletins listed on page 6.

Manure Nutrient Availability for Crops

Nutrient management guidelines use the words “manure nutrient availability” when suggesting manure applications to supply nutrients needed by crops. However, the meaning of “availability” for manure nutrients often is not clear or its use not consistent. Available is defined as present or ready for immediate use, or present in such chemical or physical form as to be usable (as by a plant). The main reasoning for using the term “available” in describing manure nutrients is that some portions are in forms that cannot be used by plants immediately upon application to soil and have to be converted to a form that plants can take up. The term “available” is not typically applied to fertilizers because most include chemical forms that plants can take up or are quickly converted upon application to soil. According to this definition, most inorganic fertilizers contain basically 100% crop-available nutrients. For example, anhydrous ammonia dissolves in water and rapidly changes to ammonium, urea hydrolyzes to ammonium within a few days, and ammonium is further transformed

to nitrate by soil microorganisms. Monoammonium phosphate (MAP) and diammonium phosphate (DAP) are highly soluble in water and dissolve to ammonium and orthophosphate. Potassium chloride (KCl, potash) dissolves in water to potassium (K^+) and chloride (Cl^-) ions. Both orthophosphate and K ions are taken up by plants. Because all K contained in manure is in the K^+ ionic form, manure K is readily crop available in all manure sources.

For manure N and P , there is usually a mix of organic and inorganic materials that varies among manure sources, production systems, bedding, storage, and handling. This variety in forms of N and P in manure contributes to greater uncertainty in manure nutrient management compared with fertilizers. The ratio of inorganic (mainly ammonium) and organic N varies considerably with the manure source. This was shown, for example, by on-farm research that included manure sampling and analysis from swine and poultry operations. The fraction of total N as ammonium N was almost 100% for swine manure from the liquid portion of anaerobic lagoons, 65 to 100% (average 84%) for liquid swine manure from under-building pits or storage tanks, and 10 to 40% (average 20%) for solid poultry manure. The large ammonium- N concentration and organic- N fraction that is easily mineralized after application to soil explain why N in liquid swine manure is considered “highly” crop available and almost comparable to fertilizer N . Other manures have lower ammonium- N concentrations and greater (and tougher to degrade) organic materials due to bedding and feed materials. Considerable P in swine manure is orthophosphate and calcium phosphate compounds (derived both from feed and mineral supplements added to rations) that are soluble or dissolve quickly once applied to soil. The rest is organic P , which varies greatly in complexity and reaction in soil. Testing manure for ammonium- N or water-soluble N can be a way of estimating immediately available N . Unfortunately, a similarly useful test does not exist for P . Therefore, the availability estimate for manure N and P can be, and often is, less than 100% of total N and P .

Manure Nutrient Supply

There is a clear difference between crop availability of nutrients in fertilizer or manure and season-long supply of nutrients. Significant amounts of plant-usable forms of nutrients in both fertilizer and manure might be lost and become unavailable to crops after application. For example, N can be lost through processes such as leaching, volatilization, or denitrification, while P can be lost through erosion and surface runoff. Also, these nutrients can be converted for short or long periods of time into forms not usable by plants through processes such as immobilization to organic materials for N and retention by soil mineral constituents for P . Nutrient loss issues are not as pertinent for P and K as for N in Iowa soils as long as there is little soil erosion and surface runoff.

The immediate or long-term fate of plant-usable nutrients in soil can be similar for manure and fertilizer. However, variation in manure nutrient concentration, application rate, and application distribution affect nutrient supply and contribute to increased uncertainty with manure management. Application rate and distribution uncertainties affect all applied nutrient sources but are more difficult to manage with manure than with fertilizer. With careful manure sampling, pre-application nutrient analysis, study of nutrient analysis history, and calibration of application equipment, reasonable manure nutrient application rates can be achieved. Due to material characteristics, and sampling and analysis variability, field distribution and application rate variability often is greater for dry manure sources.

These supply issues can be important for N , P , and K , although typically are of greater concern with N . There are several reasons including: manure usually is applied for corn production where N supply is critical, many Iowa soils have optimum or higher P and K test levels where need for and response to P and K is much less than with N , and crop deficiency symptoms and yield loss resulting from nutrient supply problems are more obvious for N .

Manure nutrient loss, application rate, and distribution uncertainties usually are not included in crop nutrient availability estimates. Instead, they are handled by suggested management practices. Not all published guidelines are consistent in this regard and, therefore, suggested crop nutrient availabilities do vary between states and regions. In this publication, use of “availability” refers to manure nutrients potentially available for plant uptake (with no losses) by the first crop after application or beyond, and percent nutrient availability values provided correlate to those for commonly used fertilizers. The guidelines in this publication assume supply issues are handled in the best way possible as is done with fertilizers. It is important to understand that for successful manure nutrient management, in many instances supply issues are as critical, or more so, than estimates of nutrient availability.



Improving crop nutrient supply with manure can be achieved by understanding the issues related to manure nutrient analysis, application rate, application distribution, and the benefits and risks related to management practices such as application timing and placement, which influence potential losses.



nutrients. Also, manure application to meet the least restrictive or most environmentally restrictive nutrient application can result in under-supply of other nutrients.

In these cases, use of fertilizers in addition to manure application is necessary to appropriately meet all nutrient application requirements.

Additionally, use of available tools to determine initial soil nutrient levels and adjust application rates can help provide for adequate season-long nutrient supply when either manure or fertilizer is used. These tools include commonly used pre-plant soil testing for P and K, estimates of N application rate need based on response trial data (such as the Corn Nitrogen Rate Calculator), and tools to help determine need for additional N after planting corn such as the late-spring soil nitrate test and in-season crop sensing for N stress (see list of resources on page 6).

Manure Nutrient Application Recommendations

To determine manure application rates, the following information is required: needed crop nutrient fertilization rate for N, P, K, or other deficient nutrients; manure type; nutrient analysis; nutrient crop availability; and method of application. Nutrient recommendations for crops are provided in other Iowa State University Extension Extension and Outreach publications and are not repeated here (see list on page 6). Once the needed nutrient application rate is determined, the manure rate to supply crop-available nutrients is calculated based on the specific manure source being used.

An additional consideration is what portion of the needed fertilization will be supplied from manure, to meet the full crop nutrient requirement, or a partial requirement from manure and the remainder from fertilizer. This is an important consideration because manure contains multiple nutrients and a manure rate to supply the most deficient nutrient can over-supply other

Manure Nutrient Availability Values

Many of the manure N, P, and K crop availability estimates listed in Table 1 are derived from research trials conducted in Iowa. However, when local research is lacking, applicable information was taken from research conducted in other states. For manure sources not listed in the table, values based on manure with similar characteristics can provide a reasonable estimate. The ranges in nutrient availability are provided to account for variation in the proportion of organic and inorganic N and P forms, bedding type and amount, manure sampling and analysis variation, and application importance at different P and K soil test levels. See the footnote in Table 1 for further information on variability in manure nutrient availability.

Adjusting for Manure Nitrogen Volatilization

The estimates for manure N availability in Table 1 do not consider potential volatile N losses during or after application. Losses are from various volatile N compounds in manure, such as ammonia, and ammonia that is produced when urea, uric acid, or other compounds convert to ammonium. These are similar losses that can occur from some N fertilizers such as anhydrous ammonia, urea, and urea-ammonium nitrate (UAN) solutions. If manure is left on the soil surface, losses may occur until N is moved into the soil with rainfall or incorporated with tillage. Many factors affect the rate and amount of volatile loss, such as temperature, humidity, rainfall, soil moisture, soil pH, surface residue cover, and days to incorporation. Volatile losses at or after application often are difficult to predict accurately.

Table 1. First-year nutrient availability for different animal manure sources.

Manure Source	Nitrogen ¹	Phosphorus ²	Potassium ²
	Percent of Total Nutrient Applied		
Beef cattle—solid or liquid	30-50	80-100	90-100
Dairy—solid or liquid	30-50	80-100	90-100
Liquid swine—anaerobic pit	90-100	90-100	90-100
Liquid swine—anaerobic lagoon	90-100 ³	90-100 ³	90-100
Poultry—all species	50-60	90-100	90-100

¹The estimates for N availability do not account for potential volatile N losses during and after land application. Correction factors for volatile loss are given in Table 2. The ranges are provided to account for variation in the proportion of ammonium N (and for poultry manure also uric acid), bedding type and amount, and both sampling and analysis.

²The ranges in P and K availability are provided to account for variation in sampling and analysis, and for needed P and K supply with different soil test levels. A small portion of manure P may not be available immediately after application, but all P is potentially available over time. Use lower P and K availability values for soils testing in the Very Low and Low soil test interpretation categories, where large yield loss could occur if insufficient P or K is applied and a reasonable buildup is desirable. Use 100% when manure is applied to maintain soil-test P and K in the Optimum soil test category, when the probability of a yield response is small.

³Values apply for the liquid portion of swine manure in lagoons; the N and P availability will be less and difficult to estimate with settled solids.

However, losses can be significant, and, therefore, it is important to make an adjustment for volatile N losses from applied manure and for manure management planning purposes.

Values given in Table 2 provide guidance on potential volatile losses. The correction factors in Table 2 do not account for N losses during storage and handling (time from excretion to sampling for analysis) and assume a reasonable time period from sampling to land application so that the manure analysis represents the manure being applied. To estimate manure N remaining in soil after application, multiply the applied manure N rate by the appropriate correction factor.

Table 2. Correction factors to account for N volatilization losses during and after land application of animal manure.¹

Application Method	Incorporation	Volatilization Correction Factor ²
Direct injection		0.98-1.00
Broadcast-liquid/solid	Immediate incorporation	0.95-0.99
Broadcast-liquid	No incorporation	0.75-0.90
Broadcast-solid	No incorporation	0.75-0.90
Irrigation	No incorporation	0.60-0.75

¹Adapted from Midwest Plan Service MWPS-18, Third Edition. Nitrogen losses during and within four days of application.

²Multiply the manure total N rate applied times the volatilization correction factor to determine the portion of total manure N remaining.

Considerations for Time of Application

The time of application influences nutrient availability and potential manure and nutrient loss from soil. Fall applications allow more time for organic N and P portions of manure to mineralize so they are available for plant uptake the next crop season. This is more important for N in manures with high organic matter content, such as bedded systems. Iowa research has shown that fall versus springtime P and K application usually is not an agronomic issue for fertilizers or manure. The increased time for organic N mineralization with fall application also allows for nitrification of ammonium and therefore more potential nitrate loss through leaching or denitrification with excessively wet spring conditions. This is a more important issue for manure with large ammonium-N concentration, such as liquid swine manure. Coarse-textured soils, with high permeability, are the most likely to have leaching losses. Fine- and moderately fine-textured soils, prone to excess wetness, are most likely to have denitrification losses. Manure applied in the spring has less time for organic N and P mineralization before crop uptake. Delayed mineralization can be an important issue for manure with high organic matter content, especially in cold springs. With manure that contains a large portion of N as ammonium, spring application allows for better timing of nitrification to nitrate and subsequent crop use, and less chance of N loss.

The P and K contained in animal manure are estimated at 100% crop available over a long term. Residual effects of P and K not used in the year of application will be reflected in soil tests and crop use, just like fertilizer P and K applied for one year or for multiple years.

As a general rule, do not apply manure in the fall unless the soil temperature is 50° F and cooling at the four-inch soil depth. This will slow the N mineralization and nitrification processes and is an especially important consideration for manure containing a large portion of N as ammonium.

Broadcasting manure onto frozen, snow-covered, water-saturated soils increases the potential for nutrient losses with rainfall or snowmelt runoff to surface water systems. If manure must be applied in these conditions, it should be applied on relatively flat land, slopes less than 5%, and well away from streams and waterways, see Iowa Department of Natural Resources rules on setback distance.

Second- and Third-Year Availability Estimates

While manure N may become crop available over multiple years for some sources, there should not be an expectation that all of the manure N will eventually become crop available. This happens because some of the N is in difficult to degrade organic forms (recalcitrant) and will become part of the soil organic matter. For some manure sources, such as with bedded systems, not all of the manure N should be accounted for in manure plans over multiple years and the first-, second-, or third-year availability may not add up to 100%.

Animal manure that has considerable organic material can have some residual-N availability in the second or third year after application. The second-year N availability estimate for beef cattle and dairy manure is 10%, and 5% for the third year. Other manures that have similar organic N and bedding could have similar second- and third-year N availability. Manure sources that have low organic N will not have second-year crop available N. These include liquid systems like swine manure stored in under-building pits and above-ground tanks, and anaerobic lagoons. Poultry manure, since it has considerable organic material, has some, but low second-year availability (0-10%) and no third-year N availability.



Example Calculation of Manure Application Rates

Note: The N, P, and K fertilization requirements in these examples are determined from appropriate extension publications and web-based tools listed at the end of this publication.

Example 1

Manure source: liquid swine manure, finishing under-building pit.

Manure analysis: 40 pounds N/1,000 gallons, 25 pounds P_2O_5 /1,000 gallons, 35 pounds K_2O /1,000 gallons.

Intended crop: corn in a corn-soybean rotation.

Soil tests: 22 ppm Bray P_1 (Optimum), 175 ppm Ammonium Acetate K (Optimum).

Crop yield and P and K removal for determining nutrient rates needed to maintain the Optimum soil test category:

220 bushels/acre corn yield; 70 pounds P_2O_5 /acre and 48 pounds K_2O removal.

Manure rate: based on corn N fertilization requirement at 150 pounds N/acre.

Manure application: injected late fall.

Manure nutrient availability: 100% for N, P, and K.

Manure N volatilization correction factor: 0.98.

Manure rate: 150 pounds N/acre \div (40 pounds N/1,000 gallons \times 0.98)=3,827 gallons/acre.

Manure available P and K nutrients applied:

3,827 gallons/acre \times (25 pounds P_2O_5 /1,000 gallons \times 1.00)=96 pounds P_2O_5 /acre; and

3,827 gallons/acre \times (35 pounds K_2O /1,000 gallons \times 1.00)=134 pounds K_2O /acre.

Crop available P and K applied with the manure: the manure will supply more than needed P and K based on expected corn removal. The extra P and K can be used by the next soybean crop and should be accounted for, but additional amounts may be needed.

Example 2

Manure source: solid layer manure.

Manure analysis: 72 pounds N/ton, 69 pounds P_2O_5 /ton, 54 pounds K_2O /ton.

Intended crop: corn-soybean rotation.

Soil tests: 22 ppm Bray P_1 (Optimum), 130 ppm Ammonium Acetate K (Low).

Manure rate: based on P requirement for the two-year crop rotation to maintain soil-test P in the Optimum category at 120 pounds P_2O_5 /acre.

Manure application: late fall, incorporated after four days, assuming removal for 220 bushels/acre of corn and 70 bushels/acre of soybean.

Manure nutrient availability: 60% for N, 100% for P and K.

Manure N volatilization correction factor: 0.80.

Manure rate: 120 pounds P_2O_5 /acre \div (69 pounds P_2O_5 /ton \times 1.00)=.7 ton/acre.

Manure available N and K nutrients applied: 1.7 ton/acre \times (72 pounds N/ton \times 0.60 \times 0.80)=59 pounds N/acre; and 1.7 ton/acre \times (54 pounds K_2O /ton \times 1.00)=92 pounds K_2O /acre.

Corn N needed and K needed for the corn and soybean crops with a Low soil-test K category: 150 pounds N/acre and 175 pounds K_2O /acre.

Crop available N and K applied with the manure: the manure applied is not adequate to supply the N needed by corn, need additional 91 pounds fertilizer N/acre (150 pounds N/acre – 59 pounds N/acre); and is not adequate to supply the K needed by for the corn and soybean crops, need additional 83 pounds K_2O /acre (175 – 92 pounds K_2O /acre) from fertilizer.

Summary

- Carefully manage the nutrients in animal manure as you would manage fertilizer
- Have representative manure samples analyzed to determine nutrient concentration. At a minimum, samples should be analyzed for moisture (dry matter) and total N, P, and K. For additional information on N composition, samples can be analyzed for ammonium. Maintain a manure analysis history for production facilities.
- Set the manure application rate according to crop fertilization requirements and for the crop availability of manure N, P, and K.
- Adjust manure rates for estimated N volatilization.
- For manure application rates, consider the crop N, P, and K fertilization requirements and field P-Index ratings, but do not exceed the crop N fertilization need.
- Consider the nutrient needs of crop rotations rather than just individual crops, which is especially important for P and K management.
- Allocate manure to fields based on soil tests and crops to be grown.
- Fall applications of manure should not be made until the soil temperature is 50° F and cooling, especially for manure sources that have a large portion of N as ammonium.
- Do not apply manure to snow-covered, frozen, or water-saturated sloping ground to reduce risk of nutrient loss and water quality impairment.

Additional Resources

[CROP3073–Nitrogen Use in Iowa Crop Production](https://store.extension.iastate.edu/Product/14281)

store.extension.iastate.edu/Product/14281

[PM1688–A General Guide for Crop Nutrient and Limestone Recommendations in Iowa](https://store.extension.iastate.edu/Product/5232)

store.extension.iastate.edu/Product/5232

[CROP3108–Take a Good Soil Sample to Help Make Good Fertilization Decisions](https://store.extension.iastate.edu/Product/3915)

store.extension.iastate.edu/Product/3915

[PM2015–Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn](https://store.extension.iastate.edu/Product/12240)

store.extension.iastate.edu/Product/12240

[CROP3140–Use of the Late-Spring Soil Nitrate Test in Iowa Corn Production](https://store.extension.iastate.edu/Product/5259)

store.extension.iastate.edu/Product/5259

[PM2026–Sensing Nitrogen Stress in Corn](https://store.extension.iastate.edu/Product/12310)

store.extension.iastate.edu/Product/12310

[CROP3154–Use of the End-of-Season Corn Stalk Nitrate Test in Iowa Corn Production](https://store.extension.iastate.edu/Product/5089)

store.extension.iastate.edu/Product/5089

[AE3550–How to Sample Manure for Nutrient Analysis](https://store.extension.iastate.edu/Product/5059)

store.extension.iastate.edu/Product/5059

[Recommended Methods of Manure Analysis, Second Edition, 2022, University of Minnesota.](https://conservancy.umn.edu/handle/11299/227650)

conservancy.umn.edu/handle/11299/227650

[MWPS18-S1–Manure Characteristics: Section 1](https://store.extension.iastate.edu/Product/2700)

store.extension.iastate.edu/Product/2700

[MWPS18–Livestock Waste Facilities Handbook, Third Edition.](https://store.extension.iastate.edu/Product/2699)

store.extension.iastate.edu/Product/2699

[Corn Nitrogen Rate Calculator](https://cornnratecalc.org)

cornnratecalc.org

Authors

Antonio P. Mallarino and John E. Sawyer—professors of agronomy and extension soil fertility specialists, Iowa State University.

Revised, March 2023.

Expert
Reviewed

This publication was peer-reviewed by three independent reviewers using a double-blind process.