4RS OF MANURE MANAGEMENT DAIRY

The "4R"s of nutrient management in agriculture refer to using the *Right Source* of nutrients, at the *Right Rate*, at the *Right Time*, and in the *Right Place* to maximize crop uptake and production, while also minimizing field nutrient losses. Dairy manure is a valuable soil amendment that can improve soil organic matter and provide essential nutrients needed by crops. But how do 4R principles apply to crop nutrients coming from manure application, which can be more variable and less easily quantified compared to commercial fertilizer?

Right Source

Dairy manure nutrient content can vary considerably depending upon where and how it was generated. Animal age and milking status (Table 1), the amount and type of bedding material used, feed management practices, barn manure management practices, and the method used to store the manure before field application will all influence the types and amounts of nutrients available in the manure.

Animal	*Daily Production (Au/day)*	*Analysis*	*Nutrient Content: Ammonium N, Organic N, P2O5, and K20*
Lactating Cow, Liquid	*13 Gallons*	*Lb/1,000 Gal*	*14 -14 - 13 - 25*
Dry Cow, Liquid	*6 Gallons*	*Lb/1,000 Gal*	*14 - 14 - 13 - 25*
Lactating Cow, Solid	*111 Pounds*	*Lb/ton*	*2 - 8 - 4 - 8*
Dry Cow, Solid	*51 Pounds*	*Lb/ton*	*0 - 9 - 3 - 7*
Heifer	*60 Pounds*	*Lb/ton*	*2 - 8 - 3 - 7*
Calf	*80 Pounds*	*Lb/ton*	*2 - 8 - 3 - 7*
Veal	*7 Gallons*	*Lb/1,000 Gal*	*14 - 5 - 13 - 25*

Table 1. *From PA 22-23 Agronomy guide Table 1.2-10, Typical PA Average daily production & total nutrient content of manure.*

For example, manure samples submitted to the Penn State Agricultural Analytical Service Laboratory showed a fivefold range in nitrogen and phosphorus concentrations per 1,000 gallons of liquid dairy manure (Fig. 1). Additionally, phosphorus (as P2O5) content in liquid samples has been reported to range from 0.005% to 0.41%. This likely reflects stratification of nutrients that can develop within liquid storage pits, with phosphorus-rich solid material settling to the bottom and can impact phosphorus content of the slurry as the pit is emptied (Beegle & Martin, 2014). This variability in manure analysis is partially due to variability in the manure itself but may be more fully explained by variability in agitation or sampling procedures, demonstrating the importance of why regular and careful sampling is a critical component of manure management planning.

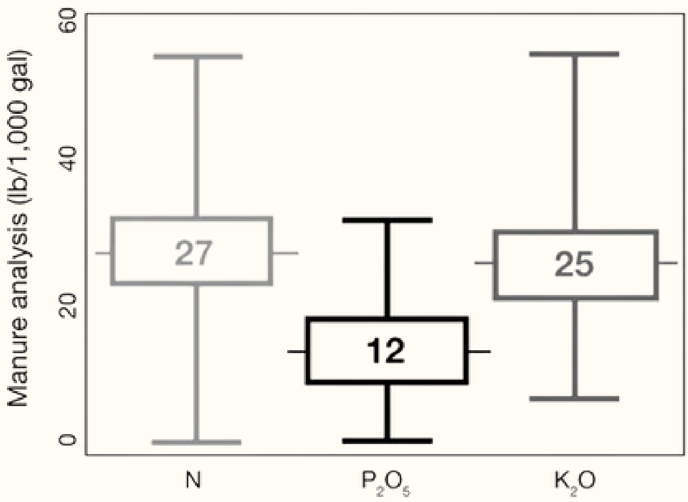


Figure 1. *Manure analysis average (in boxes) nutrient concentration and variation (vertical bars) from 311 dairy manure samples in Pennsylvania.*
Source: Penn State Extension

Right Rate

Determining the right *Rate* at which to apply dairy manure depends upon knowing what *Source* of material you will be using and how to sample it in a way that will give you a good analysis of overall nutrient content. This step is critical, and the results will be unique to the conditions of each farm. Manure should be applied to meet crop needs, and a manure analysis informs planned manure application rates. Following proper sampling procedures enables manure application at the right *Rate*.

To obtain a sample that is representative of the material you will by applying to your fields, follow these rules of thumb:

- Thoroughly agitate liquid manures.
- If possible, sample during loading or field application to reduce the difficulty of collecting the sample itself and to minimize changes in nutrient content caused by management, weather, and lacking of mixing. These samples can contribute to a running farm average for that type of manure and be used to calculate future manure application rates.
- For solid manures, ensure the sample is representative of the entire storage area by including material from multiple locations, but avoiding "abnormal" areas like edges or surface crusts.
- Use clean tools made from stainless steel or plastic to make a composite sample from many subsamples. Thoroughly mix these, and use plastic containers or bottles to sent samples to the lab.
- Follow directions from the laboratory on correct storage and shipment to preserve nutrient content in transit.

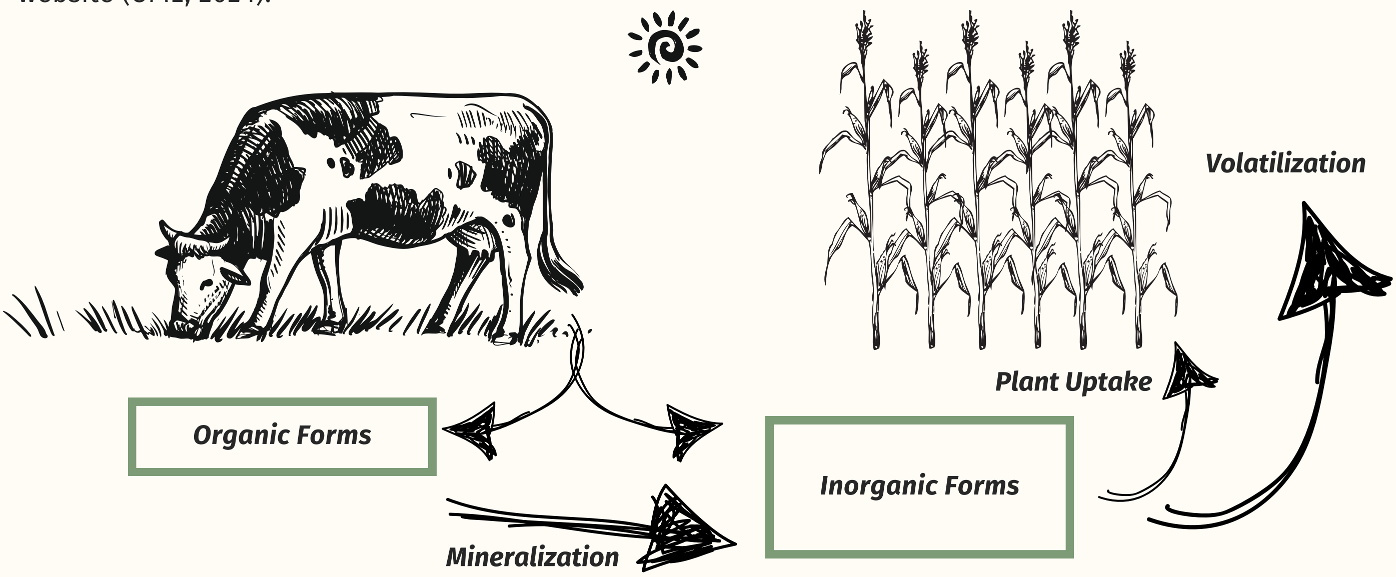
The *Rate* you apply will also depend on whether you plan to meet the nitrogen or phosphorus needs of your crop. If you choose to apply manure at the needed nitrogen rate, be aware that the amount of phosphorus applied at the same time will be higher than the crop will be able to use in one season, and so will build up in the soil over time. To avoid excessive phosphorus build-up in soils, spread manure as widely across the farm as possible, and reduce rates to match crop phosphorus rather than nitrogen needs. This will result in lower overall manure application rates that can be combined with an advanced nutrient management plan to identify areas in need of supplementary nutrients to maximize crop uptake and yield.

Once you know the nutrient content of your manure and the *Rate* you must apply it to meet crop needs, it is important to calibrate your manure spreader. The method for calibrating a spreader will depend on the type of spreader and the type of manure being applied. Detailed instructions for calibrating your manure spreader can be found at Penn State Extension's website or University of Maryland's Nutrient Management Program website.

Right Time

The best *Time* to apply manure is when it can be used by a growing crop; winter manure applications are therefore discouraged or restricted in most areas of the Bay watershed. However, the feasibility of timing manure application with crop growth may depend upon the *Source* of manure you are using, the available manure storage capacity, and access to equipment. Manure is often broadcast and incorporated in the soil immediately before a crop in planted, but manure applications to standing corn are possible with the right equipment.

The nitrogen contained in dairy manure is either readily available as ammonium-N or slowly available over the course of the growing season as organic N in the manure is broken down and released. The rate at which this organic N becomes plant-available depends upon soil temperature, soil moisture, pH, and the extent to which it has been incorporated into the soil, but averages around 35% in the year it is applied (PSU Agronomy Guide, 2023). The best recommendations for accounting for this mineralization can be found through the Penn State Extension Agronomy Guide (White et al, 2021), the Mid-Atlantic Nutrient Management Handbook (Abaye et al, 2006), or the University of Maryland's Agricultural Nutrient Management Program website (UME, 2024).



Right Place

The right *Place* to apply dairy manure depends upon available equipment and the importance of other management practices, like avoiding tillage. While surface application is quick and easy, it results in significant losses of ammonia-N from the manure - in excess of 50% - which is hard to quantify and factor into the rate required to meet plant needs. Incorporating manure the same day it is applied can keep these ammonia-N losses to 10-25%, conserving valuable nitrogen and increasing the precision of using manure as a fertilizer. However, growers who use no-till and are reluctant to disturb their soils may wish to look into the feasibility of manure injection rather than tillage for incorporation. Deciding whether to surface apply manure or incorporate it into the soil will have significant impacts on your planned application rates and potential for environmental losses of nitrogen and phosphorus (Table 2).

Application Method	Semi-solid Manure	Liquid Slurry	Lagoon Liquid
Injection	-----	95%	95%
Broadcast, immediate incorporation	75%	75%	90%
Incorporated after 2 days	65%	65%	80%
Incorporated after 4 days	40%	40%	60%
Irrigation without incorporation	-----	20%	50%
Incorpoarted after 7 days	25%	25%	45%

Table 2. *Percent of ammonia in manure that is conserved based on method and timing of application (Abaye et al., 2006).*

The right *Place* and right *Rate* for manure use are closely related because manure nutrient composition is less consistent than that of commercial fertilizers. If there are multiple sources of manure on a farm, the nutrient profile of each should be considered when deciding where to apply it. Fields that will be planted in a heavy-feeding crop like corn should receive high nitrogen manures, such as liquid lactating cow manure, whereas crops with more balanced nutritional needs should receive dry manures. To guard against untended losses of nutrients to the environment, all manures should be applied with a vegetated buffer left unfertilized next to stream channels.

Summary

Dairy manure is a valuable source of nitrogen, phosphorus, and potassium for agricultural crops, and has the benefit of also containing micronutrients and organic matter. By following the *"4Rs"* of manure management, you can maximize your plant uptake of these nutrients and minimize unintended losses to the environment. Farmers can get the full benefit of dairy manure only if they apply the right *Source* of manure at the right *Rate*, at the right *Time*, and in the right *Place*.

- *Source:* Recognize the differences in sources of dairy manure to more precisely plan nutrient application to crops.
- *Rate:* Following sampling recommendations for nutrient analysis of dairy manure to increase confidence in reported results and plant nutrient availability.
- *Time:* Apply dairy manure to a crop that has high N requirements or apply the manure at a rate that meets plant phosphorus build-up in soils.
- *Place:* Consider the pros and cons of incorporating dairy manure into the soil, and account for how your method of application will impact N volatilization when planning nutrient budgets for crops.

4R MID-ATLANTIC

References and additional information can be found on our website.

Partners

Mid-Atlantic 4R Nutrient Stewardship Association
The Nature Conservancy
Delaware Maryland 4R Alliance
Pennsylvania 4R Alliance

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