

Manure Management in Minnesota

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Livestock manure has been considered an asset to crop production since the beginning of organized agriculture. Because these manures contain several essential plant nutrients, they contribute to increased crop yields when properly applied to soils. Thus, manure represents a valuable nutrient resource for crop producers.

Livestock producers must be extremely cognizant of potential environmental risks from manure's nitrogen (N) or phosphorus (P). An emphasis must be placed on developing and implementing manure management plans as part of an operation's overall nutrient management plan so that agronomic and environmental issues are not jeopardized.

Nonetheless, manure can benefit a farm fertilization program. Besides providing valuable nutrients to the soil, including all micronutrients, manure supplies organic matter to soils. This improves soil tilth, aids in the retention of water and nutrients, lessens wind and water erosion, and promotes growth of beneficial organisms.

Manure Characteristics

Nutrient Values

The nutrient content of manure is affected by a variety of factors, many of which are unique to a specific farming operation. These factors include animal species, type of manure handling system, livestock housing and bedding system, diet, temperature, and dilution from excess water. All of these factors affect the amounts of N, P, potassium (K), and micronutrients (zinc and sulfur being of most concern in Minnesota) in the manure.

Depending on which animal species and handling system a producer has, several tables are available that approximate the amount of nutrients in the manure. There are many tables published from many different sources—all having slightly different values. Because each manure pile or pit is unique, the table values are only meant to be approximate and variations are expected. Table 1 contains recent updated values from liquid and solid manure systems. Small deviations caused by under- or overestimations can result in significant nutrient differences because several thousand pounds or gallons of manure are applied per acre.

Table 1. Estimated nutrient concentration of liquid and solid manure.

Livestock Type		Liquid			Solid		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
		----- lb./1000 gal. -----			----- lb./ton -----		
Swine							
	Farrowing	15	12	11	14	6	4
	Nursery	25	19	22	13	8	4
	Gestation	25	25	24	9	7	5
	Finishing	58	44	40	16	9	5
Dairy							
	Cows	31	15	19	10	3	6
	Heifers	32	14	28	10	3	7
Beef							
	Cows	20	16	24	7	4	7
	Finishing Cattle	29	18	26	11	7	11
Poultry							
	Broilers	63	40	29	46	53	36
	Layers	57	52	33	34	51	26
	Tom Turkeys	53	40	29	40	50	30
	Hen Turkeys	60	38	32	40	50	30

Source: *Manure Characteristics, MWPS-18 Section 1, Midwest Plan Service, 2004*

The most reliable and accurate way to determine the nutrient content of a particular farm's manure is to have a sample of the manure analyzed by a laboratory. This eliminates the numerous approximations made by using tables. Most soil testing laboratories do manure testing for a nominal charge. The best time to collect a manure sample is during the loading and/or application process. Collecting subsamples from several loads and then compositing these subsamples into a single sample is recommended. This applies to liquid, solid, or semi-solid systems. Good sampling procedures are necessary because the nutrients in manure are not distributed evenly between the urine and feces portions, as shown for beef cattle manure in Figure 1.



Figure 1. Distribution of nutrients between liquid and solid portions of beef manure.

P and K Availability

The total amount of nutrients in manure is not as important as the availability of these nutrients. Nutrients, such as N and P, that can be in organic portions of the manure, are not available until they are transformed into inorganic nutrients. The confusion as to the available versus unavailable, organic versus inorganic, and liquid versus solid fractions of manure makes rate calculation confusing. Generalized statements for P and K are straightforward: 80% of the P and 90% of the K in animal manures are available the first year. Therefore, when using a generalized table or a laboratory report, multiply the P and K values by these constants to determine the first year's amounts.

N Availability

Nitrogen availability is more complex to estimate in manure than is P or K. Nitrogen has great potential for adversely affecting the environment and increasing crop yields. Several of the transformations needed to understand manure N will be discussed in the following paragraphs with Figure 2 being a reference.

The two main forms of N of concern in manure are the organic N, which is also designated unavailable N, and ammonium N, which is the predominate component of available N. Although manure also contains nitrate N, nitrite N, and ammonia N, these forms comprise a minute fraction of the inorganic N. Nitrite N and ammonia N can cause germination problems when seeds are planted too close to concentrated zones of manure.

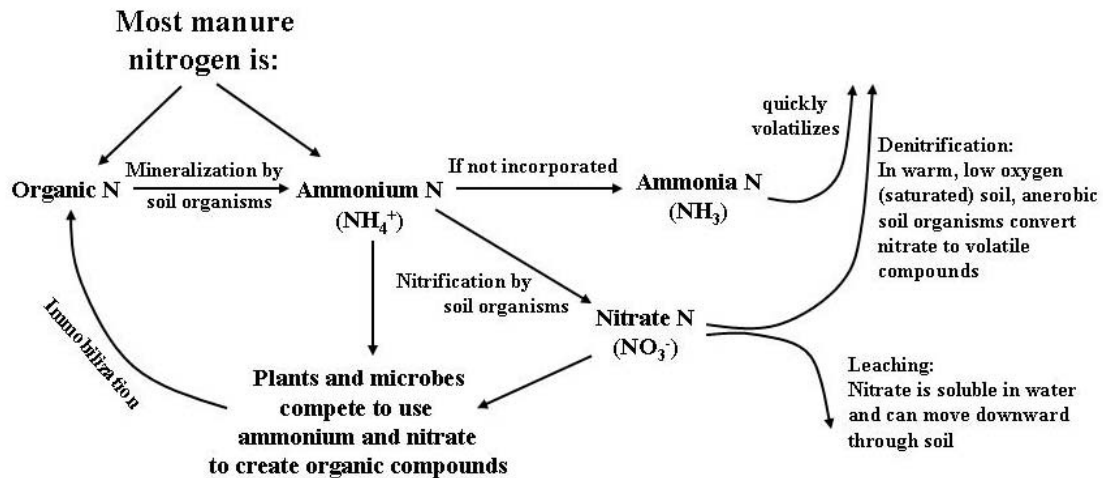


Figure 2. Nitrogen components of manure and some transformations that occur in the soil.

A. Organic N

When manure is applied to soil, the organic N begins to break down to inorganic N, which is available to plants. This process is termed mineralization. This process is affected by temperature and moisture, as well as time. Warm, moist soils will have more organic N converted to plant available N with time than the cool, dry soils. Between 25-50% of the organic N will be converted to ammonium N each year after the manure is applied. This value is affected greatly by the method of application and temperatures during the year.

The residual capacity of manure's organic N can last for several years. Second and third year contributions from the manure's organic N are significant. If 50% of the organic N will become available each year and if a specific manure sample contains 50% organic N, the second year's N credit should be 12% of the total N and the third year's N credit should be 6%.

Long-term residual effects from high rates of manure's organic N fraction can also be beneficial. Experiments at the University of Minnesota's West Central Experiment Station exemplify this. Plots were still reaching their top yields 12 years later with residual nutrients from the manure. While large amounts of manure applied in a short time frame might have agronomic value many years later, the environmental hazards associated with these applications must be a concern.

B. Ammonium N

Besides the organic N fraction of manure, the other major portion of manure N is ammonium N. When organic N is converted to available N, it is ammonium N. Ammonium N, which is available to plants, is relatively immobile in the soil and is not subject to loss. The process of nitrification eventually converts all ammonium N to nitrate

N. While nitrate N is also available to plants, it is also susceptible to denitrification on fine-textured soils and to leaching on medium- or coarse-textured soils.

One other important N loss mechanism is volatilization. When manure is exposed to the atmosphere, the ammonium N can chemically convert to ammonia N and be lost. The loss is mainly a function of time. Incorporation of manure minimizes this concern.

Application Factors

Application Methods and N Losses

Broadcasting manure onto a field is the oldest method of spreading. It is possible to broadcast during any season, however, there are some limitations to the method. From a nutrient standpoint, substantial amounts of the inorganic N are lost via volatilization. This loss occurs within several days after application. Remember, however, that none of the organic N is lost and a portion of this will become available during the growing season. However, as long as the manure is not worked into the soil, the breakdown rate is slow.

A second method, which is mainly a variation of the previously mentioned method, involves broadcasting the manure and incorporating the manure into the soil within a few days. The volatilization losses are not eliminated, but are greatly reduced. The other primary benefit is that incorporating the manure gets it thoroughly mixed into the soil and promotes conditions for the mineralization of organic N. Some broadcast methods allow some form of immediate incorporation or mixing with soil during application. One of those methods is the disk-cover system where manure is applied in a band which gets immediately covered by soil.

Other application methods are appropriate for liquid manure users. The concern of volatilization losses, as well as odor problems, created the demand for injecting manure with chisel-type knives. While volatilization losses were minimized, the potential for denitrification losses was present. The injection zones favored denitrification because of waterlogged conditions, organic material for energy, and supply of nitrate. The denitrification losses are much less than the volatilization losses that occur when the manure is left on the soil surface.

Sweep knife injection systems were developed that reduced the concentrated zones of manure beneath the soil surface. Instead of creating a vertical band of manure where a knife shank ran through the soil, a broad horizontal band was created. This method effectively eliminates volatilization potential, reduces denitrification potential, and encourages rapid breakdown in the soil because there is mixing of manure and soil.

In addition to the method of application, other factors do influence the N availability from manure applications. These include rainfall amounts and soil characteristics, such as texture and organic matter levels. Although there are numerous factors that affect manure's N availability, the manure application method is the most influential factor that

producers can control. Thus, combining methods of application, along with the generalized organic N to inorganic N ratios that are a function of livestock species, Table 2 was developed to provide N availability and loss percentages.

Time of Application

Another factor regarding N management with manure application is the time of application. Many times the logistics of the livestock operations, with their unique handling systems, etc., determine when the manure must be applied to the soil.

Fall applications of manure, either injected or broadcast, allow more time for the organic portions of the manure to break down before the plant needs the nutrients as compared to spring application. In contrast, fall applications also provide more time for potential loss of N. Fall applications of manure should be avoided on coarser-textured soils where leaching can be a threat to the environmental quality of the region. If fall application is necessary, it should be done in late fall when soil temperatures are below 50 degrees F.

Manure applied in the spring has the least amount of time for loss potential to occur. However, the rapid breakdown of organic material in the spring is more likely to temporarily tie up some of the otherwise available N in the soil, thus creating some short-term N imbalances for manure with high levels of organic N (dairy and beef, or manure with bedding). Waiting to apply all manure in the spring may also slow down other spring field operations to the point of delaying crop planting.

While winter application of manure to cropland is inevitable for a number of livestock producers, the practice is generally discouraged. First, in the winter, incorporation of the manure into the soil is not possible; therefore, most of the available, inorganic N will be lost. Second, the manure is lying on the soil surface, susceptible to movement by runoff into waterways, ditches, streams, etc. If manure must be spread in the winter, select level land and apply only conservative rates of manure to minimize nutrient concentrations susceptible for movement. In addition, avoid applying manure where tillage was done going up and down the slope and avoid applying during times of snowmelt. With good management, winter-applied manure will provide the same P and K and about a third of the available N amounts as fall- or spring-applied manure.

Table 2. Manure nitrogen availability and loss as affected by method of application and animal species.

	Surface broadcast – incorporation ¹			Injection	
	None	< 4 days	< 12 hours	Sweep	Knife
	----- % Total N -----				
Beef					
Year 1	25	45	60	60	50
Year 2	25	25	25	25	25
Lost ²	40	20	5	5	10
Dairy					
Year 1	20	40	55	55	50
Year 2	25	25	25	25	25
Lost ²	40	20	10	5	10
Swine					
Year 1	35	55	75	80	70
Year 2	15	15	15	15	15
Lost ²	50	30	10	5	15
Poultry					
Year 1	45	55	70	NA	NA
Year 2	25	25	25	NA	NA
Lost ²	30	20	5	NA	NA

¹ The categories refer to the length of time between manure application and incorporation.

² Lost refers to estimated volatilization and denitrification processes.

Third-year available N is not listed but can be computed by adding Year 1 and Year 2 and lost percentages and subtracting this sum from 100.

Time of manure application has a large bearing on the N transformations that occur in soil. However, these transformations generally have offsetting effects. Thus, time of manure application is not considered in Table 2.

Rate of Application

Manure application rates to match crop N needs can be calculated from information about N availability, and how the availability is affected by the method of application, incorporation practices, and type of manure. Crop phosphorus and potassium needs are often exceeded when manure is applied at rates which meet crop N needs. Sometimes

there are economic and environmental benefits of applying manure at rates lower than crop N needs. For example, one may choose to apply manure at a rate which meets crop phosphorus needs, and then supplement the manure N with commercial fertilizer. Regardless what nutrient the rate is based upon, once calculated, the planned application rate will need to be field tested against what the manure application equipment can actually be calibrated to apply. To calculate a manure application rate, complete the following four-step procedure as outlined in Worksheet 1:

Step 1. Establish nutrient needs of the crop.

The first step is to determine the recommendation for N, P₂O₅, and K₂O on a per-acre basis. This is best accomplished by taking a soil test and following a recommendation based on the University of Minnesota's guidelines. Many of the University's guidelines are based on soil tests and expected yields, however current N rate guidelines for corn are based on other factors such as price of N, value of crop, and soil productivity potential. Using the ratio of N price to corn value to determine N application rate is a significant change from the past. Placing a value on the N from manure is more difficult than determining the cost of N from commercial fertilizer. The value of N in manure may vary between farms and between fields on farms depending upon costs associated with storage and application, and the availability of land on which to spread manure. Because of the complexity of this issue further explanation is needed before calculating a manure application rate based on nitrogen.

The University of Minnesota's guidelines for determining corn N rates are based on the price of commercial nitrogen fertilizer, expected value of a bushel of corn, and site specific variables. In general, the N application rate needed to maximize net income decreases as fertilizer price increases and/or corn value decreases. When fertilizer prices are high or corn prices low, achieving the lower recommended N rates using manure as the N source may present some challenges. Consider the following three questions when applying manure during times of high fertilizer N prices or low corn prices:

1. With your current application equipment, can you or your commercial applicator apply the lower manure rates suggested with the higher N costs? If you are limited by your equipment, the use of a commercial applicator service or upgrading your own manure application equipment can be two possible ways of reducing rates.
2. Are there enough available crop acres to apply manure at rates lower than have been applied in the past? Applying at lower rates means more acres are needed for annual application which can result in potentially greater hauling distances and higher costs. However, when fertilizer prices are high, nearby crop producers may be willing to purchase the manure or pay for the additional hauling costs.
3. Is the N in the applied manure readily available, like that in liquid swine manure? The N in manure that is in the inorganic (ammonium) form is immediately available to plants. Manure from beef and dairy operations, or systems that use large amounts of bedding will generally have a higher proportion of N in the organic form, which must be converted

(mineralized) in the soil to inorganic N for plant uptake (see N Availability section). In some years with cold or dry soil conditions, this mineralization may not occur rapidly enough to supply enough N for early plant needs. Supplemental N may be necessary.

If you answer “No” to any of these three questions, basing the manure application rate on lower N rate guidelines for fertilizer when N prices are high may be difficult or incur some risk. An alternative approach would be to apply manure at a rate not to exceed the upper limit of the amount of N needed to maximize yield (lowest N price to corn value ratio). Table 3 contains the suggested N rates for manure application to corn. Do not exceed the high end of the recommended range because significant N losses can occur at higher rates, which can result in surface and groundwater contamination.

Table 3. Nitrogen rate guidelines for growing corn when manure is used

Previous Crop ¹	Soil/Field Productivity Potential ²	
	Highly Productive Sites	Medium Productive Sites
	----- lbs. N/acre -----	
Corn	130 - 180	130
Soybean	100 - 140	100

¹ For previous crops other than corn or soybeans use the corn following corn rate guideline and subtract any previous crop N credits.

² Soil and environmental conditions that limit crop production such as erosion, poor soil drainage, restriction to root growth, short growing season, marginal growing season rainfall among others would qualify a site as having medium productivity potential.

Getting the most economic benefit from manure should be a goal of every farm operation that uses manure. Value of the manure is calculated by the cost of commercial fertilizer that will be replaced by nutrients in manure (1st-year available N, P and K and 2nd-year available N if the intended crop requires the N) minus the costs of manure application. Generally, the use of lower application rates provide the greatest economic benefit for crop production by spreading manure according to crop nutrient requirements. It may be to your advantage to use the lower application rates to help maximize income, taking into account additional hauling time requirements and equipment limitations with uniformity of application.

Step 2. Determine nutrient content of manure.

Next, the total nutrient concentration of the manure must be determined, regardless of its form. The ideal method would be to have a manure analysis. Following good manure sampling procedures is a key to getting a representative sample and having confidence in the resulting analysis. A less desirable way to obtaining a manure nutrient concentration would be to use a table value, such as from Table 1.

Step 3. Determine nutrient availability to the crop.

Total nutrient concentration for N, P₂O₅ and K₂O will need to be adjusted to the amounts that will be available for the upcoming growing season. For N, use Table 2 to calculate the percentage of total N that will be available for the first crop year. For P₂O₅, use 80% as the availability factor, and for K₂O, use 90%.

Step 4. Calculate rate of application

In the last step, knowing what is needed and what should be available for the growing crop makes it possible to calculate application amounts necessary for each nutrient. Divide the total nutrient amount needed by the crop by the amount of available nutrient per ton or 1,000 gallons, and this will provide the number of tons or thousand gallons per acre required for each of the nutrients.

Selecting manure rate to use will depend on nutrient management and environmental stewardship goals of your operation. If you select the highest rate, which is normally based on crop N needs, over-application of P₂O₅ and K₂O will take place. This may have negative environmental consequences if continued over years, so one strategy is to reduce the frequency in which manure is annually applied on any one field. If you choose a lower manure application rate, the amount of available nutrient will need to be calculated for each of the nutrients for that rate. If there is a deficit between what the manure application supplies and what the crop needs in nutrients, supplemental fertilizer will be needed to make up the difference.

Manure Use and Crops**Corn and Small Grains**

With corn and small grains, manure management consists largely of the N management component. Fall and spring applications are the best options with injection or incorporation application methods preferred. With corn, applying all of the crop's needs with manure that has a higher proportion of organic N leads to some yield risk if climatic conditions slow the N mineralization process in the year of application. To minimize this risk, applying manure based on P needs and then supplementing the remaining N with planting-time, topdress, or sidedress applications are encouraged.

Alfalfa

Alfalfa produces its own N; thus, the added N from the manure is not used efficiently. Alfalfa will use any N from manure with some compensation in the amount of N that it symbiotically fixes from the atmosphere. From an environmental perspective, manure N used by alfalfa in this manner is better than overapplications of manure N to a non-legume crop such as corn. However, manure is often surface applied to alfalfa with little or no incorporation into the soil. This leaves manure vulnerable to being washed off the field during precipitation events, thereby causing surface water pollution.

If manure is applied to alfalfa, an obvious concern to most alfalfa growers is the influence the N will have on competing weeds and grasses in the field. Research has shown that a well-fertilized field will benefit all plant species in the field, including weed germination and proliferation. Another indirect effect of applying manure to alfalfa fields is the compaction to the soil and root crowns of alfalfa in the field. And finally, one of the most detrimental issues of manure applications is the risk of leaf/stem burn from the salts and ammonia in manure when applied to an established alfalfa field.

Despite the concerns—direct and indirect—of applying manure to alfalfa, manure can be beneficial to alfalfa with proper management. To minimize the ever-present risk of plant tissue burning, the primary option for manure applications would be as a preplant treatment. Applying manure to a field to be seeded with alfalfa based on several years worth of P and/or K would be ideal. If the manure is broadcast, ensure a good seedbed by adequately incorporating the manure into the plow zone. In this scenario, the amount of N applied will get used in the first couple of years of the stand and should not be an environmental issue.

For some producers, topdressing manure onto alfalfa is necessary. If manure must be applied to alfalfa fields, follow these guidelines. Try to select the field that has the most grass in it because the N will benefit these stands the most. The rate of liquid manure should be limited (2,000-3,000 gal./A) to curb the amount of N being applied. The manure should only be applied immediately after a cutting to reduce possible leaf burn from the manure and lessen the damage to the crop by the wheel tracks. Solid manure applications should also be limited for the same reasons as well as a concern for smothering the crowns with clumps of straw, etc.

Soybeans

As with the alfalfa, soybeans produce their own N and an increase in soil N decreases the amount produced by the plant. However, by limiting the amount of manure applied and injecting the manure or incorporating it well with the soil, producers can provide a positive effect on soybean growth and yield. While the P and K are greatly beneficial to the soybean plant, the small amount of N may benefit the plant late in the growing season.

Some manure application guidelines for soybeans are warranted. Avoid fields that have documented disease histories, as these fields may exhibit further disease incidence with manure applications. Select fields that have lower soils test for P and K, thereby increasing the value of the manure for the crop. Make sure that a good seedbed is prepared—no undisturbed zones of manure in the top two inches of soil. And, limit the amount of manure applied to the field. This would be accomplished by not applying more available N than what the soybean crop would remove on a per acre basis.

Rate of Application Worksheet:

Step 1. Nutrient needs of the crop (lbs./A)
 Use soil tests and recommendations based on
 University of Minnesota data

	N	P ₂ O ₅	K ₂ O
	_____	_____	_____

	N	P ₂ O ₅	K ₂ O
Step 2. Determine total nutrient content of the manure (lbs./ton or 1,000 gal.)	_____	_____	_____

Step 3. Determine available nutrients from manure (lbs./ton or 1,000 gal.)	<u>Table 2</u>		
Multiply the values from Step 2 by the availability factors from Table 2 and from the text	()	(80%)	(90%)
	_____	_____	_____

Step 4. Calculate the rates of application needed for each nutrient	N	P ₂ O ₅	K ₂ O
Divide the values from Step 1, amount of nutrient needed, by values from Step 3, the available nutrients per ton or thousand gallons	_____	_____	_____

Selected rate: _____ (tons or 1,000 gal./acre)

Determine amount of available nutrients being applied by multiplying the selected rate of application times the available nutrients, Step 3. This can be compared to crop needs, Step 1, to show where deficits and excesses occur.	N	P ₂ O ₅	K ₂ O
	_____	_____	_____

The amount of deficit is the amount of supplemental fertilizer that the crop will need	_____	_____	_____
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