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Manure Management in Minnesota

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INTRODUCTION

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 equally considered.

Manure can benefit an operation's soil nutrient system and overall crop production. Crop yields are increased with manure usage. Soil nutrient levels are boosted, including micronutrients. And manure provides valuable organic matter to soil that improves soil tilth, aids in the retention of water and nutrients, and promotes growth of beneficial micro-organisms.

MANURE CHARACTERISTICS

Nutrient Content

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.

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.

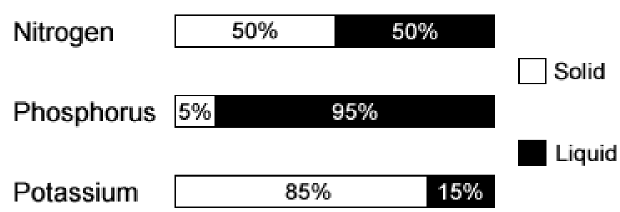

Fig. 1: Distribution of nutrients between liquid and solid portions of typical excreted manure.

Phosphorus and Potassium 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 exist in significant amounts in the organic portions of the manure, are not available until they are transformed into inorganic forms. 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.

Table 1: Estimated nutrient concentration of liquid and solid manure.							
Livestock Type		Liquid ------ lb./1000 gal. ------			Solid --------- lb./ton ---------		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
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

Nitrogen Availability

Nitrogen availability in manure is more challenging to estimate than P or K. While N has great potential for adversely affecting water quality, it has significant impact on 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 primary component of manure's 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.

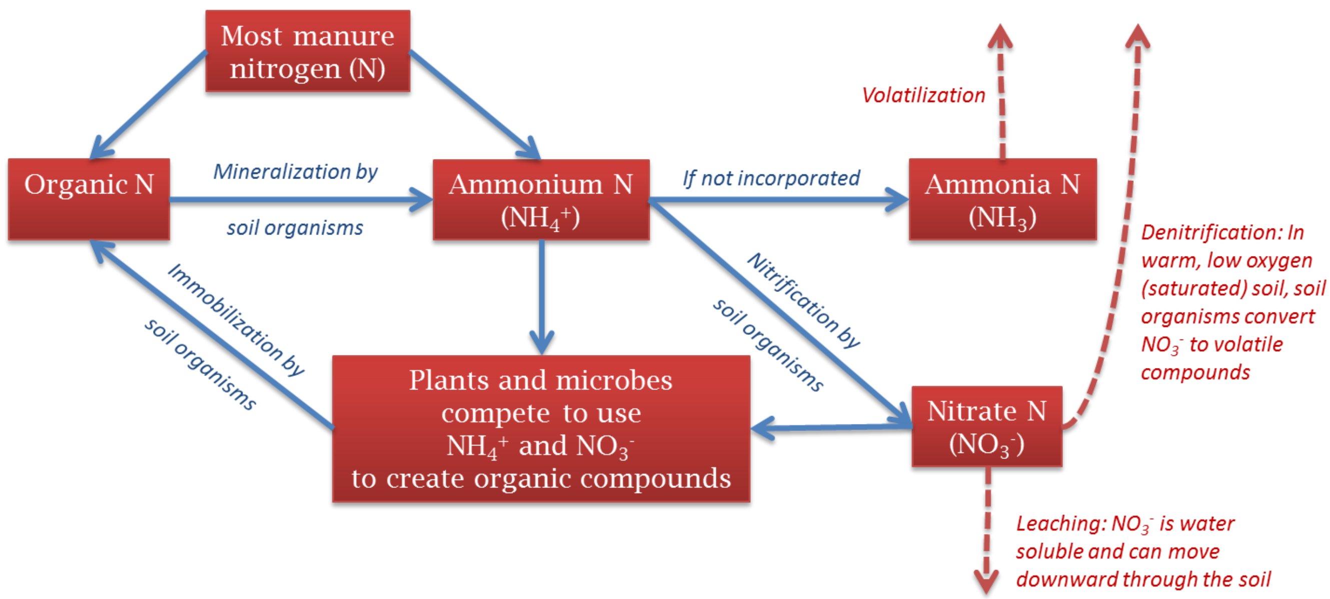

Fig. 2: Nitrogen components of manure and some transformations that occur in the soil.

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. Mineralization 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 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 effects of manure's organic N can last for several years. Second and third year contributions from the manure's organic N are significant. Assuming 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 about 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 be very significant and beneficial. A long-term study at the University of Minnesota's West Central Research and Outreach Center exemplified this. Plots were still reaching their top yields 12 years after manure applications ended from 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 addressed.

Ammonium N

Besides the organic N fraction of manure, the other major portion of manure N is ammonium-N. Organic N converts to ammonium-N in the soil, which is now available to plants. Ammonium-N is relatively immobile in the soil and is not subject to loss. This conversion process, termed 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, or injection, of manure into the soil minimizes this concern.

MANURE APPLICATION

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 this 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 organic N will become available during the growing season.

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 mineralization (conversion) of organic N. There are numerous variations of implements that apply liquid manure and have some form of immediate incorporation of the manure into the 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 saturated conditions, organic material for energy, and supply of nitrate-N. 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.

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

Animal Species and Year of Application[2]	Surface Broadcast and Incorporation Timing[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[3]	40	20	5	5	10
Dairy					
Year 1	20	40	55	55	50
Year 2	25	25	25	25	25
Lost[3]	40	20	10	5	10
Swine					
Year 1	35	55	75	80	70
Year 2	15	15	15	15	15
Lost[3]	50	30	10	5	15
Poultry					
Year 1	45	55	70	NA	NA
Year 2	25	25	25	NA	NA
Lost[3]	30	20	5	NA	NA

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

[2] 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.

[3] Lost refers to estimated volatilization and denitrification processes.

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 crop uptake 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. Early fall manure at soil temperatures above 50 degrees F can lead to significant nitrification and potential loss of nitrate-N by leaching or denitrification later in the fall or spring. 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 (process termed immobilization) 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 environmental impacts. In addition, avoid applying manure where tillage was done going up and down the slope and avoid applying manure during times of snowmelt. With good management, winter-applied manure will provide the same P and K and roughly a third of the available N amounts as fall- or spring-applied manure.

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 a factor 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 P and K 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 P needs, and then supplement the manure N with a separate application of commercial N fertilizer. It is paramount that all manure applicators calibrate their equipment such that the recommended rates can be applied with confidence.

The following four steps are used to determine rates of application. A worksheet is provided at the end of this publication.

Step 1: Establish nutrient needs of the crop.

The first step is to determine the recommended rate for N, P_2O_5, and K_2O on a per-acre basis. This is best accomplished by taking a soil test and following recommendations from the University of Minnesota. Current N rate guidelines for corn are based on factors such as price of N, value of crop, and soil productivity potential (UM Extension bulletin 3790, Fertilizing Corn in Minnesota, 2006.) Using the ratio of N price to corn value to determine N application rate is a significant change from previous University of Minnesota N recommendations. Table 3 shows the N application ranges for the various scenarios. In general, the N application rate for manure or commercial fertilizer needed to maximize net income decreases as fertilizer price increases and/or corn value decreases. When fertilizer prices are high or corn prices low, lower N rates are recommended. With manure, achieving lower rates may present some logistical challenges, most of which can be addressed with today's modern equipment.

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 corn.

Previous Crop[1]	Soil / Field Productivity Potential[2]	
	Highly Productive Soils	Medium Productive Soils
	------------- lb. N/A -------------	
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, and marginal growing season rainfall, among others, would qualify a site as having medium productivity potential.

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 obtain 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, P_2O_5 and K_2O 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 P_2O_5, use 80% as the availability factor, and for K_2O, 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 rates for each field will depend on nutrient management and environmental stewardship goals for the crop/livestock operation. If the highest rate is selected, which is normally based on crop N needs, over-application of P_2O_5 and K_2O will take place. While building soil test P and K has some benefits, this may also have negative environmental consequences if continued over years; thus one strategy is to reduce the frequency that manure is applied on any one field, so that crops in the rotation will use the excess soil-P and K. If a lower manure application rate is chosen, 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 ECONOMICS

Getting the most economic benefit from manure should be a goal of every farm operation that uses manure. In general terms, the basic economic 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_2O_5 and K_2O and 2nd-year available N if the intended crop requires N) minus the costs of manure application. Note that the economic value should not be based on all the nutrients contained in the manure—just the amount of needed fertilizer nutrients that are being replaced.

Generally, spreading manure according to crop nutrient requirements and supplementing with fertilizer where necessary provides the greatest economic benefit for crop production. Additional hauling time requirements and equipment limitations with uniformity of application at lower rates may affect economic returns and must also be accounted for in determination of rates of application.

Grid or zonal soil sampling may show some field areas significantly lower in P or K than others. If so the economic returns from manure will also be enhanced by adjusting rates of application by zone.

The University of Minnesota - Extension web-based calculator, can be used to estimate the economic value of manure from alternative manure application rates and methods: http://z.umn.edu/manurevalue

University of Minnesota Extension has developed a web-based tool that may be used to compare the economic value of manure from alternative manure application rates and methods. The value is based on crop nutrient needs for a specific field and crop rotation, fertilizer prices, manure hauling costs, manure type, and application method.

MANURE USE AND CROPS

Corn and Small Grains

With corn and small grains, manure management centers primarily on 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 prior to crop need. To minimize this risk, applying manure based on P needs and then supplementing the remaining N with planting-time, topdress, or sidedress application is 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 over-applications of manure N to corn or small grain acres. 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 heavy precipitation events, thereby causing potential surface water concerns.

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 compaction of 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-N 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 pre-plant 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 gallons per acre) 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 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 or incorporating it well into 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 restrictions 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 soil test P and K, thereby increasing the basic economic value of the manure for the crop. Make sure that a good seedbed contains no undisturbed zones of manure in the top two inches of soil as this will affect seed germination. 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.

Worksheet 1: Rate of Application Worksheet	N (lb./A)	P_2O_5 (lb./A)	K_2O (lb./A)
Step 1. Nutrient needs of the crop. *Use soil tests and recommendations based on University of Minnesota guidelines*			
Step 2. Determine total nutrient content of the manure (lb./ton or lb./1,000 gal.)			
Step 3. Determine available nutrients from manure (lb./ton or lb./1,000 gal.) *Multiply the values from Step 2 by the availability factors from Table 2 and from the text*	See Table 2	80%	90%
Step 4. Calculate the rates of application needed for each nutrient *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: ______________________________ ton/A or gal./A			
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			
The amount of deficit is the amount of supplemental fertilizer that the crop will need.			

RESOURCES FOR ADDITIONAL INFORMATION

Manure Management and Air Quality at the University of Minnesota: http://www.extension.umn.edu/manure/
University of Minnesota Nutrient Management: http://www.extension.umn.edu/nutrient-management/
Fertilizing Corn in Minnesota. UMN – Extension Publication FO-3790.
Nitrogen Availability from Liquid Swine and Dairy Manure:
Results of On-Farm Trials in Minnesota. UMN – Extension Publication 08583.

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