Estimating Manure Nutrient Availability

Department of Agronomy **MF-2562** **Nutrient Management**

Manure nutrient management planning has moved into the spotlight in recent years. While crop producers have traditionally considered crop nutrients supplied by manure, increased attention to factors influencing manure nutrient use can improve overall crop production efficiency and profitability. Increasing environmental concerns for surface water and groundwater, and accelerated concentration of livestock production also have increased the need for improved manure nutrient planning. Managing manure for efficient crop production, while minimizing potential environmental concerns, is more complex than simply disposing of the manure on agricultural lands. It entails more than focusing on the total amount of nutrients contained in manure.

A significant portion of nutrients in manure are in organic forms and not available for plant uptake until undergoing mineralization. Mineralization is the conversion of organic forms of nutrients to plant-available, inorganic forms of nutrients by soil microbes during decomposition of organic materials such as manure. Because soil microbial activity is affected by uncontrollable factors such as soil temperature and moisture, crediting the amount of crop-available nutrients provided by manure application cannot accurately be predicted. Additionally, the analysis of the specific manure used, method of application, time delay between manure application and incorporation (if incorporated), calibration of application equipment (rate and uniformity), and other specific field/crop conditions all affect the amount of manure nutrients that will become available to a crop. Unless all these factors are considered, the crop nutrients in the manure will not be used most efficiently and questions pertaining to environmental stewardship may remain.

Environmental Considerations

Manure represents a valuable source of nitrogen (N), phosphorus (P), potassium (K), and other crop nutrients that should be considered carefully when developing an overall crop nutrient management plan. With improper management, manure applications pose potential environmental risks. Manure typically contains relatively large amounts of nitrogen. Overapplication can result in high levels of residual soil nitrate-N, posing risk to groundwater supplies through leaching. Proper crediting of estimated nitrogen availability from manure is important to minimize potential problems.

Additionally, manure is an important source of phosphorus, and proper manure application management and nutrient crediting is important in protecting water quality. Non-point phosphorus runoff from agricultural fields is associated with over-enrichment (termed "eutrophication") of some surface water bodies. Eutrophication can result in excessive algal and aquatic weed growth that depletes oxygen in these waters, resulting in fish kills and the need for affected waters to be treated by public water systems. Eutrophication also has harmful effects on recreational activities.

Many states have imposed limitations on the amount of manure that may be applied to fields based on phosphorus soil test levels and expected crop removal of phosphorus. Figure 1 presents a general summary of phosphorus soil test levels that may limit crop production, soil test phosphorus ranges for manure allocation/disposal and phosphorus soil test values above which manure application is discouraged. At present, certain Kansas swine operations must operate under Kansas Department of Agriculture regulations pertaining to field phosphorus soil test values and swine manure application to agricultural lands.

Manure Analysis

Average nutrient contents for various types of manure systems (table values) are often used to estimate nutrient credits for crop production, but have serious limitations in developing specific individual manure

__Figure 1.__ Phosphorus Management Model for Kansas Crop Production and Manure Management

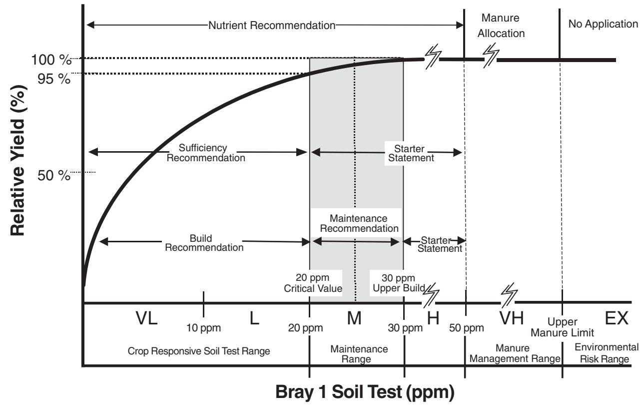
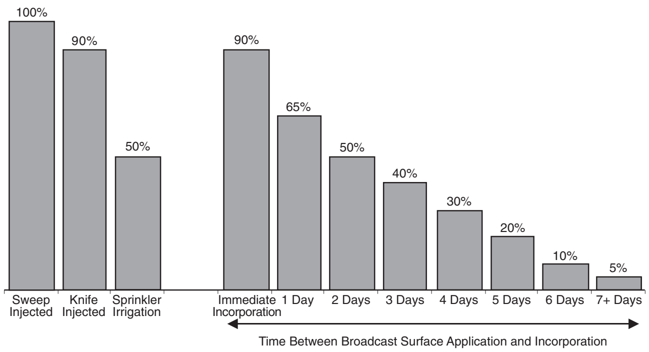


Figure 2. *Percent Of Inorganic Nitrogen Available To Crops For Various Manure Management Systems*



management plans. Determining plant-available nutrients from manure applications without analysis is difficult. Nutrient contents of specific animal manure systems are quite variable and are influenced by the type of animal involved, the ration fed, the manure storage and handling system (leaching and ammonia volatilization losses), and the moisture content of the manure. Additionally, allowances for differences in potential mineralization rates and volatilization losses cannot be reliably estimated without knowing the amounts of organic and inorganic nitrogen for a specific manure system.

Samples from individual manure systems should be submitted to a laboratory for analysis. At a minimum, manure samples should be analyzed for total nitrogen, organic nitrogen, inorganic ammonium nitrogen, total P_2O_5 equivalent and total K_2O equivalent determinations. Other nutrients and the salt/sodium hazard of the manure can also be requested but generally are not essential. For solid manure samples, most laboratories report pounds of nutrient per ton of manure on an as-received moisture basis. For liquid manure, results are generally reported as the pounds of nutrient per 1,000 gallons of manure or pounds of nutrient per acre-inch of lagoon water.

If only the total nitrogen in the manure is known (organic and inorganic nitrogen not determined by laboratory), Table 1 can be used to estimate the fraction of the total nitrogen in various manure systems expected to be present as organic and inorganic ammonium nitrogen. For example, if a producer is using solid dairy manure containing 12 pounds total nitrogen / ton (organic and ammonium nitrogen content not determined), estimate that 45 percent of the total nitrogen is ammonium nitrogen (5.4 pounds per ton) and 55 percent of the total nitrogen would be organic nitrogen (6.6 pounds per ton). An estimate of the relative quantities of organic and inorganic nitrogen is needed to estimate the effects of application management on potential crop nutrient credits. Though not as desirable as having a complete manure analysis with organic and inorganic nitrogen components broken out, knowing the total nitrogen content of the manure when calculating nitrogen credits is far better than not having an analysis at all and relying on average table values.

Average nutrient contents for various types of manure can be used if an analysis is not available – but the accuracy of the nutrients credited will be severely limited. Table 2 presents some average manure nutrient credit values for various manure systems. Keep in mind, however, that these average values are based on many different systems – and consequently result in much larger margins of error than if the actual analysis of the manure is known.

Nitrogen Credits

In general during the growing season after application, about 25 percent of the organic nitrogen in solid manure, 30 percent of the organic nitrogen in liquid manure and 20 percent of the organic nitrogen in compost will undergo mineralization in warm season cropping systems. Mineralization rates likely will be somewhat greater in southern climates and slightly lower in northern regions since soil microbial activity is dependant on soil temperature. Less organic nitrogen from manure/compost will become available to cool season crops (wheat for example), since soils are cooler and microbial activity slower during the primary period of crop nutrient uptake. About one-half or less of the amount of organic nitrogen mineralized during the first growing season after manure application will be mineralized during the second growing season. Even less nitrogen will be mineralized during the third growing season (Table 3).

Table 1. *Typical Ratio of Ammonium-Nitrogen and Organic-Nitrogen in Manure Systems*[1]

	Solid Manure Systems		**Liquid Manure Systems**	
	NH_4^+-N	Organic N	NH_4^+-N	Organic N
	% of Total Manure N		*% of Total Manure* N	
Dairy	45	55	50	50
Beef	35	65	50	50
Swine	60	40	70	30
Turkey	65	35	--	--

Table 3. Estimated Percentage Of Organic Nitrogen Available To Crops After Manure Application

	Year 1	Year 2	Year 3
	- - - - -	% N mineralized	- - - - -
Liquid Manure	30	12	6
Solid Manure	25	12	6
Compost	20	6	3

All of the inorganic ammonium nitrogen in manure is potentially available to growing crops and is dependant on overall application management. Nearly all of the inorganic nitrogen in manure is present as ammonium-N. Very little nitrate-N is normally detected. The amount of inorganic ammonium-N ultimately available to the growing crop is greatly affected by several aspects of application management. Application method (broadcast, knife injected, sweep injected, etc.) and time of delay between broadcast application and incorporation have large effects on potential nitrogen loss of inorganic nitrogen from manure. Little or no nitrogen loss occurs with subsurface applications or immediately incorporated surface broadcast manure, while nearly all of the inorganic-N is lost for unincorporated surface manure applications.

Surface applications of manure are subject to severe losses of ammonia-N via volatilization under warm conditions. Even if manure applications are incorporated on the day of application, significant volatilization losses (10 to 20 percent) are likely to occur, while a delay of only 24 hours will likely result in a loss of more than one-third the ammonium-N present (Figure 2). If incorporation is delayed one week or longer, essentially all of the ammonium nitrogen present may be lost through volatilization. Application of manure under cool conditions will result in a slower rate of volatilization loss, but the total loss will eventually be similar regardless of environmental conditions.

Injection of liquid manure below the soil surface is highly recommended as a way to minimize odor potential and increase nitrogen efficiency (eliminate volatilization losses). However, some research has indicated significant losses (10 to 30 percent) of inorganic nitrogen if knife

Continued on page 8

Table 2. *Representative Analysis Of Several Manure Systems – Animal Types*[1]

	Bedding Or Litter	% Dry Matter	Total N	NH_4^+-N	Total P_2O_5	Total K_2O
		Solid Manure Analysis (as received /wet sample analysis)				
			- - - - - -	*Lbs / ton*	- - - - -	
Dairy	No	18	9	4	4	10
Dairy	Yes	21	9	5	4	10
Beef	No	15	11	4	7	10
Beef	Yes	50	21	8	18	26
Swine	No	18	10	6	9	8
Swine	Yes	18	8	5	7	7
Poultry	No	45	33	26	48	34
Poultry	Yes	75	56	36	45	34
Turkey	No	22	27	17	20	17
Turkey	Yes	29	20	13	16	13

	Bedding Or Litter	% Dry Matter	Total N	NH_4^+-N	Total P_2O_5	Total K_2O
		Liquid Manure Analysis (as received sample analysis)				
			- - - - - -	*Lbs / ton*	- - - -	
Swine	Pit	4	36	26	27	22
Swine	Lagoon	~1	4	3	2	4
Beef	Pit	11	40	24	27	34
Beef	Lagoon	~1	4	2	9	5
Dairy	Pit	8	24	12	18	29
Dairy	Lagoon	~1	4	2.5	4	5

[1] Table 1 and 2 values adapted from "Livestock Manure Management," M. Vitosh, H. Person and E. Purkhiser, Michigan State University Extension Bulletin, "Utilization of Animal Manure as Fertilizert," A. Sutton, D. Nelson, and D. Jones, Purdue University and "Vermont Manure Nutrient Managert," B. Jokela, J. Rankin and S. Hawkins, University of Vermont, in "Computer Programs to Assist with Manure Nutrient Management," SSSA Symposium, Oct. 30-31, 1995.

Example Solid Manure Nutrient Credit Worksheet

This worksheet is used to calculate the amount of crop available nutrients to credit warm season crops in the year of manure application. For solid manure, most laboratories report the amount of nutrients on an as-received moisture basis (pounds nutrient per ton), while the nutrient contents for liquid manure systems are normally reported on a thousand gallon or acre-inch basis (pounds nutrient per 1,000 gallons or acre-inch). Once the amount of manure nutrients available for the crop is estimated and the amount of nutrients required for the crop production system is determined then the amount of manure to uniformly apply can be calculated.

Solid Manure Example

Solid Beef Manure Analysis		**Management Information**
Total N – 10 lbs/ton		P Soil Test - Low
Organic N – 6 lbs/ton	Ammonium N – 4 lbs/ton	Broadcast Manure Application
Total P_2O_5 – 8 lbs/ton	Total K_2O – 12 lbs/ton	Incorporated Day after Application

1. Estimate 65% of ammonium available to crop – 35% volatilization loss (from Figure 2).
   4 Lbs ammonium N / ton × 65% = 2.6 lbs available ammonium N / ton

2. Credit 25% of organic N available in year of application (from solid manure worksheet)
   6 Lbs organic N / ton × 25% = 1.5 lbs available organic N / ton

3. Total organic N credit and ammonium N credit for total N credit
   2.6 lbs ammonium N + 1.5 lbs organic N = 4.1 Lbs total available N / ton

4. Credit 50% of total P_2O_5 available (very low, low, medium P soil test – from worksheet)
   8 lbs P_2O_5 / ton × 50% = 4.0 lbs available P_2O_5 / Ton

5. Credit 85% of total K_2O available (from worksheet)
   12 lbs K_2O / ton × 80% = 10.2 lbs available K_2O / ton

Table 4. *Solid Manure Nutrient Crediting Worksheet*

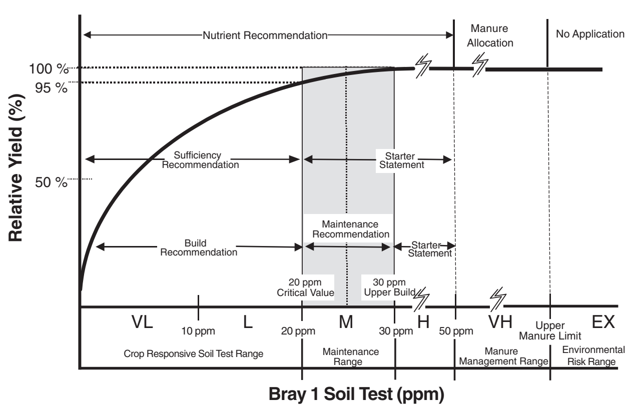
Example 1. *(from preceding page)*

	Manure Lab Results	×		Nutrient Availability Factor	=	Plant Available Nutrients
	(lbs/ton)				*(lbs/ton)*	
Organic N	6		25%	Available In Year Of Application	1.5	Organic N
NH_4^+-N	4		65%	NH_4^+-N Availability Factor From Fig. 2	2.6	NH_4^+-N
Total N	10				4.1	Sum Of NH_4^+-N & Organic N
Total P_2O_5	8		50%	50% for Very Low to Low P Soil Tests 100% for Medium to Very High P Soil Tests	4.0	Available P_2O_5
Total K_2O	12		85%	Potassium Efficiency Factor	10.2	Available K_2O

Your Farm

	Manure Lab Results	×		Nutrient Availability Factor	=	Plant Available Nutrients
	(lbs/ ton)				*(lbs/ton)*	
Organic N	_____		25%	Available In Year Of Application	____	Organic N
NH_4^+-N	_____		_____	NH_4^+-N Availability Factor From Fig. 2	____	NH_4^+-N
Total N	_____				____	Sum Of NH_4^+-N & Organic N
Total P_2O_5	_____		_____	50% for Very Low to Low P Soil Tests 100% for Medium to Very High P Soil Tests	____	Available P_2O_5
Total K_2O	_____		85%	Potassium Efficiency Factor	____	Available K_2O

Figure 1. *Phosphorus Management Model for Kansas Crop Production and Manure Management*



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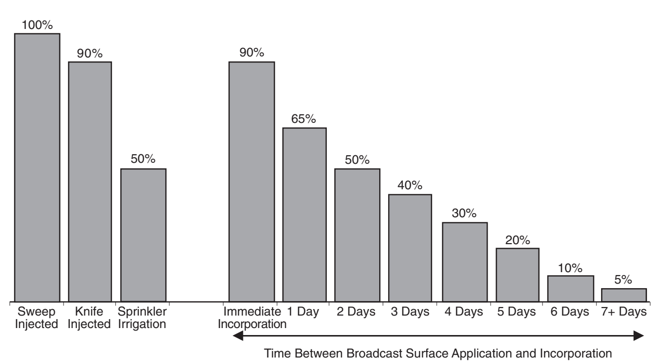

Liquid Manure Nutrient Credit Worksheet

This worksheet is used to calculate the amount of crop available nutrients to credit warm season crops in the year of manure application. For liquid manure, most laboratories report the amount of nutrients on a thousand gallon or acre-inch basis (pounds nutrient per 1,000 gallons or acre-inch) while solid manure is normally reported on an as-received moisture basis (pounds nutrient per ton). Once the amount of manure nutrients available for the crop is estimated and the amount of nutrients required for the crop production system is determined then the amount of manure to uniformly apply can be calculated.

Liquid Manure Example

Liquid Swine Manure Analysis		**Management Information**
Total N – 4 lbs/1,000 gal		P Soil Test - High
Organic N – 2 lbs/1,000 gal	Ammonium N – 2 lbs/1,000 gal	Knife Injected Manure Application
Total P_2O_5 – 3 lbs/1,000 gal	Total K_2O – 3.4 lbs/1,000 gal	Maintenance P Application Desired

1. Estimate 90% of ammonium available to crop – 10% loss (from Figure 2).
   2 lbs ammonium N / 1,000 gal x 90% = 1.8 lbs available NH_4-N / 1,000 gal

2. Credit 30% of organic N available in year of application (from liquid manure worksheet)
   2 lbs organic N / 1,000 gal x 30% = 0.6 lbs available organic N / 1,000 gal

3. Total organic N credit and ammonium N credit for total N credit
   1.8 lbs ammonium N + 0.6 Lbs organic N = 2.4 Lbs total available N/1,000 gal

4. Credit 100% of total P_2O_5 available (high, very high soil P test – from worksheet)
   3 lbs P_2O_5 / 1,000 gal x 100% = 3.0 lbs available P_2O_5 / 1000 gal

5. Credit 85% of total K_2O available (from worksheet)
   3.4 lbs K_2O / 1,000 gal x 85% = 2.9 lbs available K_2O / 1000 gal

Table 5. *Liquid Manure Nutrient Crediting Worksheet*

Example 2. *(from preceding page)*

	Manure Lab Results *(lbs/1,000 gallons)*	×	Nutrient Availability Factor	=	Plant Available Nutrients *(lbs/1,000 gallons)*	
Organic N	2.0	30%	Available In Year Of Application		0.6	Organic N
NH_4^+-N	2.0	90%	NH_4^+-N Availability Factor From Fig. 2		1.8	NH_4^+-N
Total N	4.0				2.4	Sum Of NH_4^+-N & Organic N
Total P_2O_5	3.0	100%	50% for Very Low to Low P Soil Tests 100% for Medium to Very High P Soil Tests		3.0	Available P_2O_5
Total K_2O	3.4	85%	Potassium Efficiency Factor		2.9	Available K_2O

Your Farm

	Manure Lab Results *(lbs/1,000 gallons)*	×	Nutrient Availability Factor	=	Plant Available Nutrients *(lbs/1,000 gallons)*	
Organic N	_____	30%	Available In Year Of Application		_____	Organic N
NH_4^+-N	_____	_____	NH_4^+-N Availability Factor From Fig. 2		_____	NH_4^+-N
Total N	_____				_____	Sum Of NH_4^+-N & Organic N
Total P_2O_5	_____	_____	50% for Very Low to Low P Soil Tests 100% for Medium to Very High P Soil Tests		_____	Available P_2O_5
Total K_2O	_____	85%	Potassium Efficiency Factor		_____	Available K_2O

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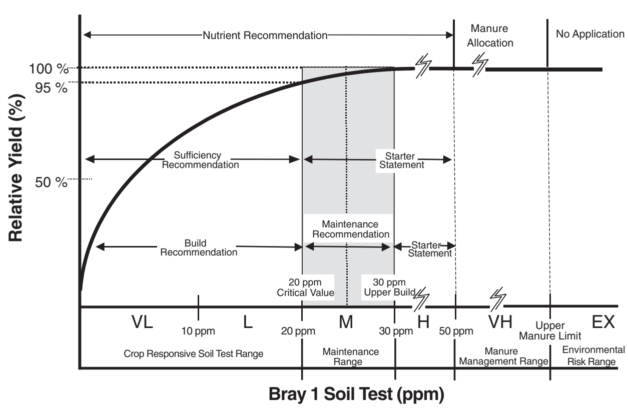

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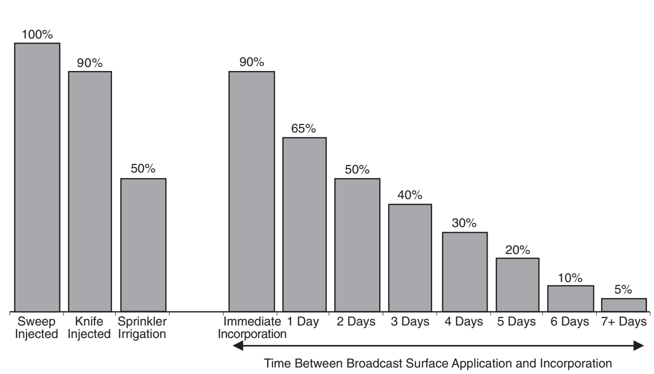

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injection is used. Denitrification is thought to be at least partially responsible since the injection zone becomes waterlogged and contains high levels of organic material – conditions favoring microbial denitrification. Sweep injectors dilute the liquid manure with more soil and minimize denitrification losses while eliminating the potential for nitrogen volatilization losses (Figure 2).

Phosphorus Credits

Both organic and inorganic phosphorus forms are present in manure. Phosphorus is not subject to volatilization loss like inorganic manure nitrogen, but small amounts of organic and inorganic phosphorus can be moved by surface runoff from manure in storage and from unincorporated surface manure applications. For phosphorus nutrient crediting purposes, 50 percent of the total P_2O_5 present in the manure should be credited for fields having phosphorus soil test values in the very low and low ranges (situations where crop responses to applied phosphorus applications are expected). For fields with soil test values in the high to very high ranges, 100 percent of the P_2O_5 present in the manure should be credited (Bray P-1 or Mehlich III of > 20 ppm or Olsen phosphorus of > 12 to 13 ppm).

Starter fertilizer applications often result in crop response regardless of soil test values or complementary broadcast applications; however, manure applications are not a substitute for starter phosphorus or potassium fertilizer applications.

Potassium Credits

Potassium is not present in organic forms in manure; all is present in an inorganic, plant-available form. Consequently, potassium availability from manure is not related to mineralization rates or soil microbial activity. The total K_2O present in manure should theoretically be potentially available for crop uptake in the year of application. However, research frequently supports crediting only about 80 to 90 percent of the total K_2O from manure in the year of application. This may be a result of the inherent difficulty of uniformly applying manure in many systems.

Summary

Wise and proper use of manure can improve overall crop production efficiency and profitability for many fields in Kansas. At the same time, proper application minimizes potential for phosphorus movement to Kansas surface waters or leaching of nitrogen to groundwater. Since a significant portion of crop nutrients found in manure are present in an organic form and are unavailable for plant uptake until converted to inorganic nutrient forms by soil microbes, the amount of nutrients ultimately used by plants in the year of application is difficult to predict.

Soil temperature and moisture affect the activity of soil microbes and are nearly impossible to predict with a high degree of accuracy. However, development of manure nutrient management plans that take these and other factors into account can improve overall manure management, crop production efficiency, and profitability. Careful attention to the composition of manure from specific animal systems, method of manure application and timing of manure incorporation have potentially large effects on the amounts of nutrients available during the growing season.

The information presented in this publication was adapted from work conducted in Kansas and other states. Information from all these sources varies to some degree, but was interpreted to best represent conditions and situations representative of Kansas and Kansas producers.

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