MANURE MANAGEMENT

Livestock wastes have been considered valuable to crop production since the early years of organized agriculture. Livestock manure can serve as a supply of all the essential plant nutrients plus providing valuable organic matter. When used properly this means manure cannot only supply much of the nutrient needs of a crop, but also through the addition of organic matter it can improve soil tilth, aid in the retention of water and nutrients and promote the growth of beneficial organisms. On the negative side, improper application of livestock manure has been associated with water contamination. Therefore, recognizing livestock manure as a valuable resource and making applications in an economically and environmentally sound manner is essential.

Manure Nutrient Management.

Manure nutrient management planning has moved into the spotlight in recent years. While crop producers have taken into account crop nutrients supplied by manure in the past, increased attention to management factors influencing manure nutrient use by crops can improve overall crop production efficiency and profitability. Also, increasing environmental concerns for surface and ground waters and accelerated concentration of livestock production has also 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 and entails more than simply focusing on the total amount of nutrients contained in manure.

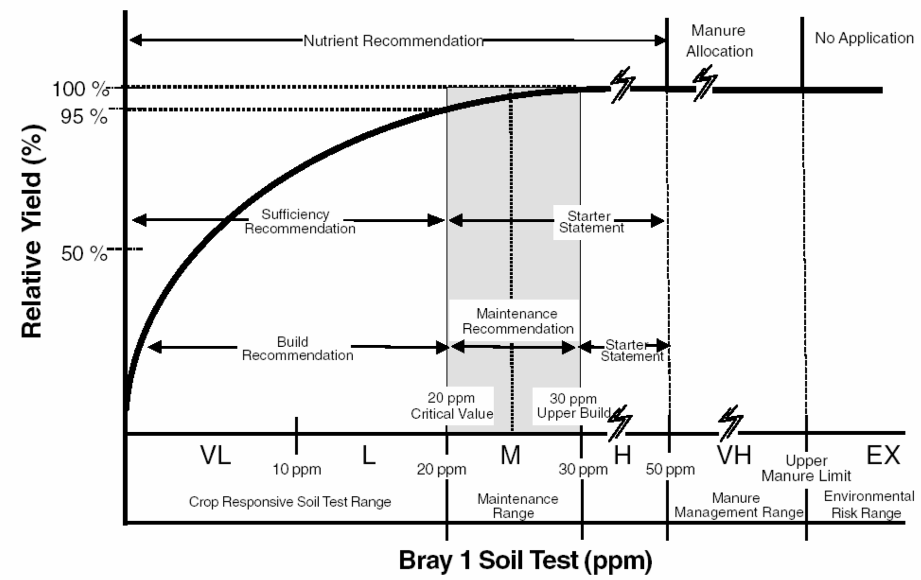
A significant portion of nutrients in manure are in organic forms and not available for plant uptake until undergoing mineralization. Mineralization is the conversion of plant unavailable, organic forms of nutrients to plant available, inorganic forms of nutrients by soil microbes during decomposition 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 be predicted with absolute accuracy. 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, most efficient utilization of crop nutrients in the manure will not be realized 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 carefully considered when developing an overall crop nutrient management plan. With improper management, however, manure applications pose the potential for environmental risks. Manure typically contains relatively large amounts of nitrogen. Consequently, over application of manure may result in high levels of residual soil nitrate-N posing risk to groundwater supplies through leaching. Proper crediting of estimated N availability from manure is important to minimize potential problems.

Additionally, non-point P 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 which 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 deleterious affects on recreational activities. Manure is an important source of P and proper manure application management and nutrient crediting is important in protecting water quality.

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



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

Manure Sampling

The first step in sampling manure is to obtain a clean container that is suitable for mailing. The amount of manure which should be collected depends on the tests being run; however, a routine analysis of liquid manure usually requires a one-pint volume. Solid or dry manure samples (less than 50% moisture) can usually be handled in small freezer type plastic bags

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Obtaining a representative sample with dry manure can be difficult due to its variability. Solid manure is often variable in moisture content, bedding material and livestock waste content. The best procedure is to take subsamples from a number of locations in proportion to the variable conditions you observe. These subsamples can then be mixed to form a composite sample representative of the manure to be spread.

Lagoons usually have distinct liquid and sludge layers. The liquid layer is usually quite uniform and contains 2% or less solids. The sludge layer is generally relatively thin but contains the majority of the nutrients. If a lagoon is to be agitated prior to pumping, the sample should include a proportionate quantity of bottom sludge or be sampled periodically during application. For first year livestock producers using table values is a reasonable approach until samples taken during application can establish historical values.

Liquid or slurry manure are those contained in steel or concrete pits and normally contain 5 to 20% solids. Liquid manure is a non-uniform mixture due to sedimentation and stratification. Like lagoon manure, in order to obtain an accurate sample probing the pit with a specially designed tube that will collect a proportionate quantity of manure from each level is necessary. The other alternative is to thoroughly agitate the pit prior to sampling or to sample loads during pumping. Be certain to sample loads at all stages of the pumping process as loads will vary in solids and nutrient content even with agitation.

Once samples are collected they should be shipped or taken to the testing laboratory as soon as possible. If shipped, sample bottles should be placed in a box large enough for packing material to be placed around the bottle and the lid should be taped to prevent leakage. Preferably samples should be mailed to avoid being in the postal system over a weekend.

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 the development of specific individual manure management plans. Determining plant available nutrients from manure applications without the analysis of the manure 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 unless the amounts of organic N and inorganic N for a specific manure system are known.

As a result, it is strongly recommended that samples from individual manure systems be submitted to a laboratory for analysis. At a minimum, manure samples should be submitted to laboratories for total N, organic N, inorganic ammonium N, 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 are generally 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 N in the manure is known (organic and inorganic N not determined by laboratory), Table 1 can be used to estimate the fraction of the total N in various manure systems expected to be present as organic and inorganic ammonium nitrogen. For example, if a producer is utilizing solid dairy manure containing 12 Lbs total N / ton (organic and ammonium N content not determined), we

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

	Bedding Or Litter	Solid Manure Analysis (as received /wet sample analysis)				
		% Dry Matter	Total N	NH_4^+-N	Total P_2O_5	Total K_2O
				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	Liquid Manure Analysis (as received sample analysis)				
		% Dry Matter	Total N	NH_4^+-N	Total P_2O_5	Total K_2O
				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

would estimate that 45% of the total N would be ammonium N (5.4 Lbs/ton) and 55% of the total N would be organic nitrogen (6.6 Lbs/ton). An estimate of the relative quantities of organic and inorganic N 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 N components broken out, knowing the total N content of the manure when calculating N credits is far better than not having an analysis at all and relying on average table values.

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	--	--

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.

Application Methods

Broadcasting manure on the soil surface has long been the most common method of application. Broadcasting has the advantage of lower equipment costs and power requirement compared to soil injection. However, incorporation of surface applied manure is essential to reduce volatilization, odor problems and manure runoff.

The rate of nitrogen loss due to ammonia volatilization is rapid with dry, warm and windy conditions. In general, incorporation within 12 hours will result in minimal volatilization loss of nitrogen (Figure 2). Incorporation as soon as possible, but within 2 days, is recommended.

Broadcast manure that is not incorporated can potentially lose all of the ammonium nitrogen.

Injection below the soil surface is a best management practice to reduce problems with manure odor and ammonia volatilization. Injection below the soil surface also can reduce the potential for surface runoff into surface water. Disadvantages of injection include higher power requirements, disruption of crop residue, and potential crop seedling injury from salts and ammonia in the concentrated bands of manure.

Injection equipment can be equipped with knives or sweeps. Knives place manure in a concentrated, vertical band about 6-8 inches below the soil surface with 30-60 inch spacing between knives. Sweep injectors spread manure in less concentrated, horizontal patterns under the soil surface and can result in better crop utilization of manure than with knives. Advantages of sweeps over knife injectors include:

- Faster breakdown of the manure and lower potential for denitrification. Knives produce a zone of concentrated manure where microbial breakdown of organic N is slowed and the environment also favors the activity of microbes that denitrify nitrate-nitrogen.

- Less potential for crop root damage from salts and ammonia in the injection zone.

Liquid manure can also be applied with irrigation systems. Application through center pivots is more uniform than with flood irrigation. Most sprinkler irrigation systems can handle liquid wastes containing up to 4% solids, which is typically higher than effluent from lagoons or holding ponds. For heavier solids using a big gun or flood irrigation would be more appropriate. Big gun sprinklers can handle wastes up to a consistency of thick milk. Flood irrigation requires good design and management to avoid runoff and to obtain uniform distribution.

Precautions include flushing irrigation pipes with fresh water to avoid corrosion from solids remaining in the pipe and being aware of potential for crop damage form the accumulation of excessive manure when the pipe is detached. Crop precautions include avoiding the application of semi-solid manure to a growing crop. To avoid crop injury, apply at minimal rates unless fresh water is also applied. For alfalfa, apply as soon as possible after hay cutting. For corn, do not apply with the plant is very young or during silking. Manure solids can coat crop leaves, reducing photosynthesis and causing salt burn of foliage. You may need to rinse-spray the crop with clean water about every hour if irrigating during the heat of the day.

Seasonal Application Timing

The timing of manure application can be extremely important from an environmental and economical standpoint. Fall application increases the time for dilution of manure salts and for microbial breakdown of organically combined nutrients, making them available for spring planted crops. On the negative side, fall application also increases the potential for nitrogen loss due to leaching if applied to land where there are no active crop roots to absorb nitrogen. Where no crop is actively growing, fall applications of manure should be limited to soils with a low leaching potential and late enough in the fall so that cool soil temperatures will limit the nitrification of ammonium-nitrogen.

Winter application to frozen soils can lead to significant losses of ammonium and nitrate sources of nitrogen. Nitrogen from surface applied manure cannot infiltrate into frozen soil and is subject to runoff and subsequent contamination of surface waters. If there is significant snow or ice cover, nitrogen runoff is virtually assured when melting occurs.

Winter applications of manure should be restricted to fields where runoff potential is low. Factors which reduce the potential for runoff include: a) unfrozen soil, b) flat or gently rolling field (<6%), c) heavy crop residues, d) contour farming, e) terraces, f) grass filter strips and g) application of minimal rates of manure.

Spring applications of manure reduces the length of time there is opportunity for runoff or leaching losses of nitrogen. At the same time, spring is also the time of year with the highest probability of precipitation runoff events. Also, spring application with heavy equipment can result in compaction problems and/or delay fieldwork.

Summer application of manure to fields with heavy crop residues reduces the possibility of manure movement off fields and is preferred over spring applications.

Summer application of manure to forage crops such as alfalfa, alfalfa/grass mixtures or pure grass stands provide an in-season alternative for manure application. Studies have demonstrated that manure can be successfully topdressed to established alfalfa provided care is taken to limit injury to the stand.

The first key is to rate the suitability of alfalfa fields for topdressed manure based on the age and quality of the stand. Preference should be given to alfalfa fields that contain the most grass, usually the older stands, as they will show the greatest benefit and the least potential damage.

Second, manure applications should be timed immediately after hay removal to reduce the risk of salt burn and potential palatability problems.

Third, limit applications of liquid manure to 3,000 to 5,000 gallons per acre in a single application to limit salt burn.

And finally, limit crown damage and soil compaction by making applications to soils that are not excessively wet. From an environmental standpoint alfalfa or forage grasses are very effective at removing nitrogen from the soil profile.

Field Site Considerations

Filter strips of close-growing vegetation on field borders or adjacent to bodies of water can reduce sediment and nutrients in runoff waters. Sediment is deposited and runoff infiltrates or passes through the buffer strip with a substantially reduced nutrient load. This is especially important with phosphorus, since it is strongly adsorbed to soil colloids. Buffer strips are less effective at removing nitrate or small amounts of soluble phosphorus.

Manure Nutrient Credits

Nitrogen. As a general guideline, about 25% of the organic N in solid manure, 30% of the organic N in liquid manure and 20% of the organic N in compost will undergo mineralization in warm season cropping systems during the growing season after application. Mineralization rates will likely be somewhat greater in southern climates and slightly lower in northern regions since soil microbial activity is dependant on soil temperature. Less organic N 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. Approximately one-half, or less, of the amount of organic N mineralized during the first growing season after manure application will be mineralized during the second growing season. Even less nutrient N will be mineralized during the third growing season (Table 3).

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 N in manure is potentially available to growing crops, and is dependant on overall application management. Nearly all of the inorganic N 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 N loss of inorganic N from manure. Little or no N loss occurs with subsurface applications or immediately incorporated surface broadcast manure applications, while nearly all of the inorganic-N in manure is lost, and subsequently unavailable for crop uptake, 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 (10-20%) 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 in the manure (Figure 2). If incorporation is delayed one week or longer, essentially all of the ammonium N 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 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 (10-30%) of inorganic N if knife 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 N volatilization losses. (Figure 2).

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

Potassium. Potassium is not present in organic forms in manure. All of the potassium 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 80-90% 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.

Calculating Manure NPK Credits

The worksheets in Tables 4 and 5 are 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 (Lb nutrient / ton), while the nutrient contents for liquid manure systems are normally reported on a thousand gallon or acre-inch basis (Lb nutrient / 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 - the amount of manure to uniformly apply can be calculated.

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 of manure to agricultural lands will minimize the potential for P movement to Kansas surface waters or leaching of N 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 utilized 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 all have potentially large effects on the amounts of crop 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.

Liquid Manure Nutrient Crediting Worksheet

The worksheet presented 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-is moisture basis (Lbs nutrient / ton), while the amount of nutrients for liquid manure systems are normally reported on a thousand gallon or acre-inch basis (Lbs nutrient / 1,000 gallons or acre-inch). The amount of manure to uniformly apply to achieve the crop nutrient determined.

	Manure Test Results From Laboratory	X	Nutrient Availability Factor	=	Plant Available Nutrients
	(Lb per 1,000 gal)				(Lb per 1,000 gal)
Organic N	________	X	**25% Availabile In Year Of Application**	=	**Organic N**
Ammonium N	________	X	________ **Availability Factor From Fig. 1**	=	**Ammonium N**
Total N	________	X	**Sum Of Organic & Ammonium N**	=	**Ammonium + Organic N**
Total P_2O_5	________	X	________ **50% for V. Low - Low P Soil Tests** **100% for Medium - V. High Soil Tests**	=	**Available P_2O_5**
Total K_2O	________	X	**85% Potassium Efficiency Factor**	=	**Available K_2O**

Fig. 1. Percent Of Inorganic N Available To Crops For Various Manure Management Systems

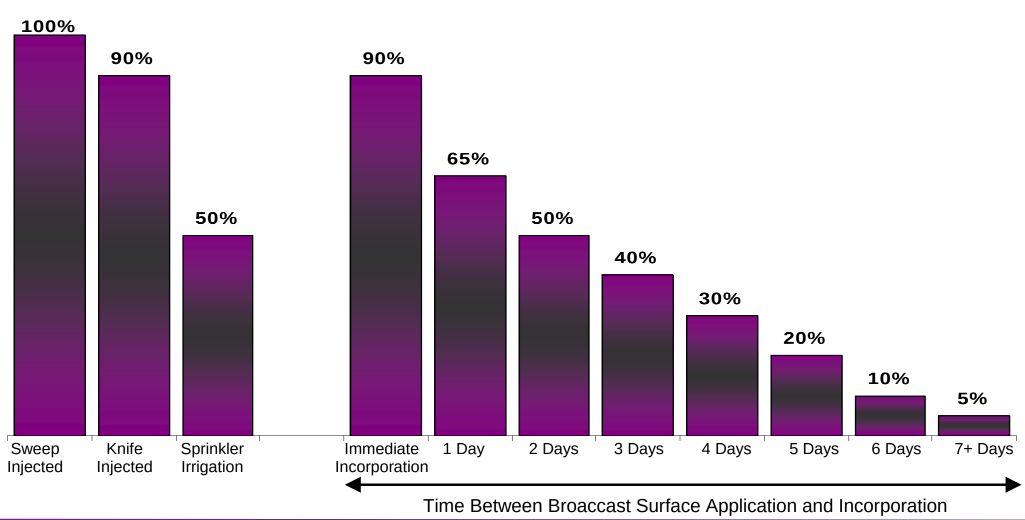
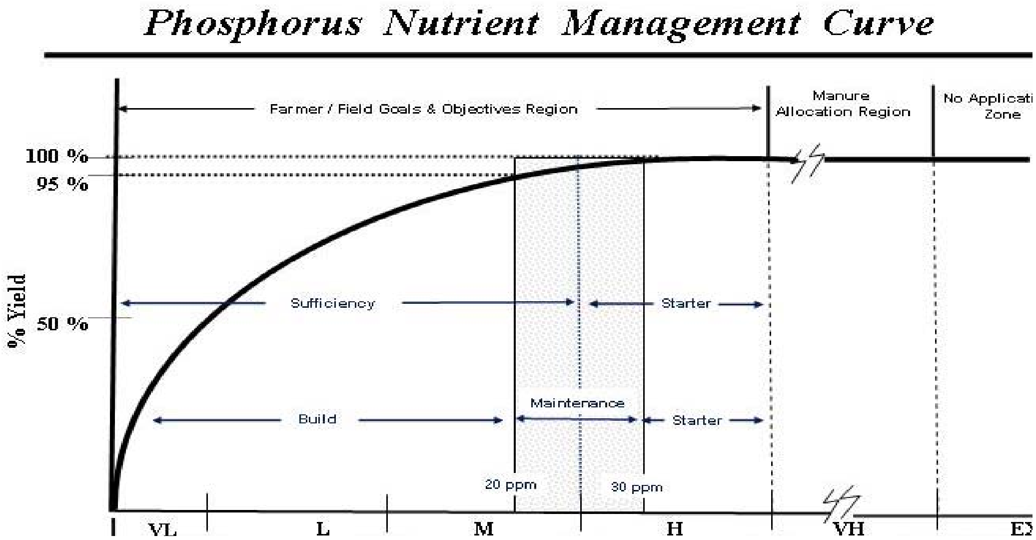


Figure 2. General Summary For Crop Production and Manure Management



Example

Liquid Swine Manure Analysis

Total N – 4 Lbs/1000 gal
Organic N – 2 Lbs/1000 gal
Total P_2O_5 – 3 Lbs/1000 gal
Total K_2O – 3.4 Lbs/1000 gal

Pertinent Management Information

P Soil Test - High
Ammonium N – 2 Lbs/1000 gal
Knife Injected Manure Application
Maintenance P Application Desired

1. Estimate 80% of ammonium available to crop – 20% denitrification loss (from Figure 1).
   2 Lbs ammonium N / Ton x 0.8 = 1.6 Lbs available NH_4-N / 1000 gal

2. Credit 30% of organic N available in year of application (from liquid manure worksheet)
   2 Lbs organic N / Ton x 0.3 = 0.6 Lbs available organic N / 1000 gal

3. Add organic N and ammonium N for total N credit
   0.8 Lbs ammonium N + 1.6 Lbs organic N = 4.1 Lbs available Total N/1000 gal

4. Credit 100% of total P_2O_5 available (high, very high soil P test – from Fig. 2)
   3 Lbs P_2O_5 / Ton x 1.0 = 3.0 Lbs available P_2O_5 / 1000 gal

5. Credit 85% of total K_2O available (from worksheet)
   3.4 Lbs K_2O / Ton x .85 = 2.9 Lbs K_2O / 1000 gal Available

Solid Manure Nutrient Crediting Worksheet

The Table 1 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-is moisture basis (Lbs nutrient / ton), while the amount of nutrients for liquid manure systems are normally reported on a thousand gallon or acre-inch basis (Lbs nutrient / 1,000 gallons or acre-inch). The amount of manure to uniformly apply to achieve the crop nutrient determined.

	Manure Test Results From Laboratory (Lb per ton)	X	Nutrient Availability Factor	=	Plant Available Nutrients (Lb per ton)
Organic N	________	X	25% Availabile In Year Of Application	=	☐ Organic N
Ammonium N	________	X	______ Availability Factor From Fig. 1	=	☐ Ammonium N
Total N	________	X	Sum Of Organic & Ammonium N	=	☐ Ammonium + Organic N
Total P_2O_5	________	X	______ 50% for V. Low - Low P Soil Tests 100% for Medium - V. High Soil Tests	=	☐ Available P_2O_5
Total K_2O	________	X	85% Potassium Efficiency Factor	=	☐ Available K_2O

Fig. 1. Percent Of Inorganic N Available To Crops For Various Manure Management Systems

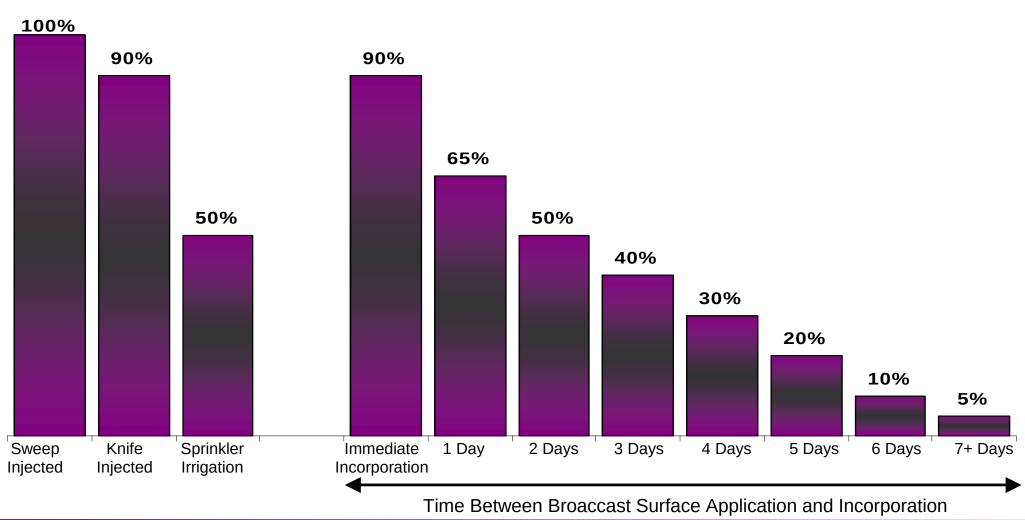
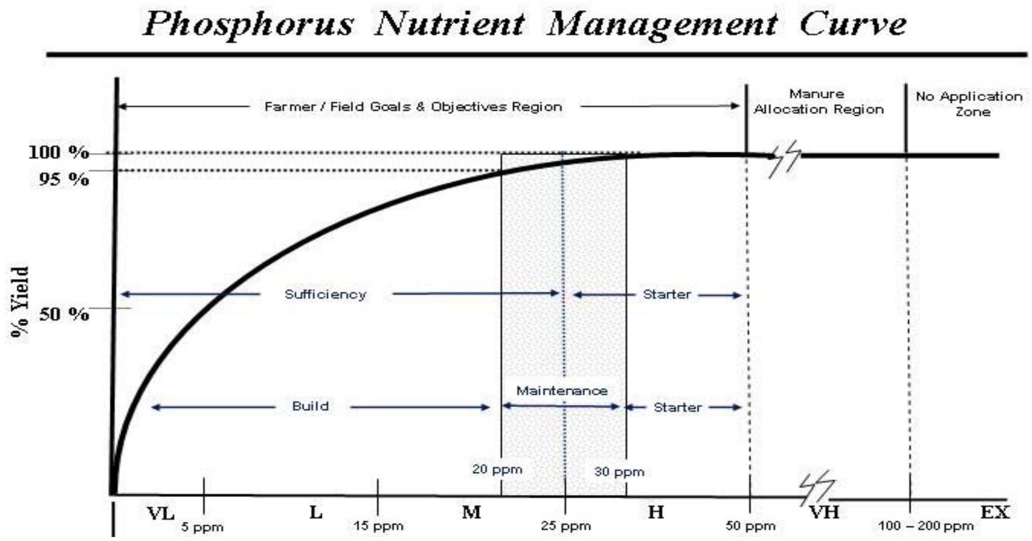


Figure 2. General Summary For Crop Production and Manure Management



Example

Solid Beef Manure Analysis

Total N – 10 Lbs/ton
Organic N – 6 Lbs/Ton
Ammonium N – 4 Lbs/Ton
Total P_2O_5 – 8 Lbs/Ton
Total K_2O – 12 Lbs/Ton

Pertinent Management Information

P Soil Test - Low
Broadcast Manure Application
Incorporated one day after application

1. Estimate 65% of ammonium available to crop – 35% volatilization loss (from Figure 1).
   4 Lbs ammonium N / Ton x .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 x .25 = 1.5 Lbs available organic N / Ton
3. Add organic N and ammonium N for total N credit
   2.6 Lbs ammonium N + 1.5 Lbs organic N = 4.1 Lbs available Total N/Ton
4. Credit 50% of total P_2O_5 available (very low, low, medium P soil test – from Fig. 2)
   8 Lbs P_2O_5 / Ton x .50 = 4.0 Lbs available P_2O_5 / Ton
5. Credit 85% of total K_2O available (from worksheet)
   12 Lbs K_2O / Ton x .85 = 10.2 Lbs available K_2O / Ton