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Fertilizing Cropland with Swine Manure

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Manure management should be a top priority on hog farms as we approach the 21st century. Mismanagement of manure can have a substantial negative impact on our water, soil and air resources. When used appropriately, manure has nutritive, and thus economic value. Manure also improves biological activity, soil tilth, and soil chemical properties.

According to 1990 Minnesota Agricultural Statistic Service data, the swine industry in Minnesota generates approximately 11 million tons of manure annually. Hogs and pigs in Minnesota excrete almost 73,000 tons of nitrogen (N) per year that can serve as a nutrient source for crops. This manure also contains 55,000 tons of P_2O_5 (phosphorus fertilizer equivalent) and 58,000 tons of K_2O (potassium fertilizer equivalent). Although some losses of these nutrients are inevitable in handling and storage, manure can replace the need for commercial fertilizer on thousands of Minnesota's cropland acres.

Manure Inventory Assessment

A comprehensive manure management plan is essential for all hog operations. Knowing the amount of manure produced as well as its nutrient content will help a hog farmer plan for the number of acres that will be manured.

The **best method to determine nutrient supply from manure is to analytically test it** for nutrient content and multiply this by the storage volume. This method does not require numerous assumptions--yet it does require that representative manure samples be collected and storage volume calculations be made. Collecting a representative sample of liquid hog manure is difficult because of the constant settling of the solid portion of the manure. Because much of the phosphorus and the organic N is in this layer, the manure must be agitated enough to suspend the solids that can be resuspended. However, the sediment layer will never totally be removed by agitation.

An alternative method to determine nutrient quantities is to calculate storage capacities and multiply by the average nutrient content, based on the species and storage and handling methods (Table 1). While Table 1 might be a good reference to begin developing application rates, these tabled values will vary significantly among storage facilities and livestock operations. Research results for manure analyses in Minnesota range from 25-300% of the average values.

Table 1. Nutrient analysis of swine manure. Livestock waste facilities handbook, Midwest Plan Service, March 1985.

Form	Dry Matter	Total N	P_2O_5	K_2O
Solid:	%	------- lbs/ton		--------
No bedding	18	10	9	8
With bedding	18	8	7	7
Liquid:		----lbs/1000 gal		----
Anaerobic storage	4	36	27	22

A third alternative is relatively easy to calculate: Calculate the average amount of manure produced per animal, multiply by the number of hogs/pigs/sows and assume standard storage and handling losses. Table 2 can be used to calculate the initial amount of manure produced by the hogs/pigs/sows. Table 3 lists some average N losses that affect nutrient content from several storage and handling systems. This method may be a good one for planning cropland needs with proposed increases in livestock numbers.

Table 2. Daily swine manure production. Livestock waste facilities handbook, Midwest Plan Service, March 1985.

Animal Size	Manure Produced[1/]		N	P_2O_5	K_2O
lbs	lbs	gal	----------	lbs	---------
25	2.3	0.3	0.02	0.01	0.01
65	4.2	0.5	0.03	0.02	0.02
150	9.8	1.1	0.07	0.05	0.05
200	13.0	1.5	0.09	0.07	0.07
gestating sow	8.9	1.1	0.06	0.05	0.05
sow and litter	33.0	4.0	0.23	0.17	0.18
boar	11.0	1.4	0.08	0.06	0.06

[1/] linear interpolations of manure production between weight categories is acceptable.

Table 3. Storage losses of nitrogen.
Livestock waste facilities handbook, Midwest Plan Service, March 1985.

System	N Lost
	--%--
Solid:	
Daily Scrape and Haul	15-35
Manure Pack	20-40
Open lot	40-60
Liquid:	
Beneath barn pit	15-30
Above-ground storage	10-30
Earthen storage	20-40

Determining Application Rates

Next, manure application rates must be calculated. This requires knowing the nutrient content of the manure, nutrients required by the crop, and availability of applied manure to the crops.

The majority (70-90%) of the phosphorus and potassium applied in manure will be available to the crop the first year after applications. The availability of N varies considerably. This variation is primarily a function of the method of application. Table 4 provides an estimate of the amount of the total N that will be available in the application year and in the year after application.

Table 4. Nitrogen availability and loss as affected by method of application.

	Broadcast-Incorp.[1]			Injection	
	None	<12 hrs	<4 day	Sweep	Knife
	--------------------% Total N --------------------				
Av. Yr. 1	30	65	45	65	50
Av. Yr. 2-3	30	25	30	30	35
Lost	40	10	25	5	15

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

Often there is a sense of futility in trying to use manure analysis, application loss coefficients, and crop nutrient requirements to determine manure application rates. Here is a five-step process to get started:

1) Determine nutrient needs of each field's crop based on soil tests, previous crops, yield expectations, etc.

2) Make an initial manure rate selection. Use crop needs and a tabled nutrient composition of the manure, or a previous year's test.

3) While applying the manure at the predetermined rate, collect a representative manure sample--either when loading the spreader in the yard or unloading the spreader in the field. Send it to a laboratory for analysis.

4) After receiving the laboratory analysis (presumably the manure will have been applied), calculate the actual amount of nutrients applied based on data and the application rate.

5) In a record keeping system, record any possible overapplications or underapplications. If fewer nutrients were applied than planned and a fall application was made, starter or sidedressed programs can supply the deficiency. If spring manure applications were made and less N was applied than planned, a sidedressed application of N can be made. Overapplications should be credited for the next year.

Field Spreading Priority

Each livestock producer should determine the amount of manure generated on their farm and the nutrient requirements of the crops where the manure is to be applied. If the manure produced on a farm cannot supply all of the farm's crop nutrient needs, it is economically and agronomically best to base the manure application rates on the phosphorus requirements. This strategy will use lower rates of manure and necessitate supplemental N fertilizer, which can be easily applied using starter N, weed-and-feed N, or sidedress-applied N.

If there is an excess of manure produced in relation to the crop's needs, manure rates should be based on the crop's N requirements. At no time should rates in excess of agronomic needs be used--this is both illegal (state rules, chapter 7020) and environmentally unsound. Rates will have to be based on P requirements if there is a potential phosphorus/surface water problem because of soil erosion, a very high soil test for phosphorus, and/or there is close proximity to water. Additional strategies such as applying manure onto legumes (see Special Use), hauling the manure off-farm, composting the manure and/or acquiring more cropland must also be considered in situations where excess manure is produced.

A field priority system should be developed to maximize the nutrient value of the manure. Priority should be given, in order, to those fields that: 1) require the greatest amount of N to grow the crop, 2) have the lowest phosphorus and potassium soil tests, and 3) will benefit most from adding the organic material to the soil.

Making a multi-year plan

Thus far we have discussed annual manure management plans. For most planning processes, a three- to five-year forecast is often desirable. This may also be true with manure. In developing a multi-year plan, cropland nutrient needs often change due to crop rotations. The supply of nutrients should not change from year to year unless animal numbers change.

For each year in a rotation, the crop's needs must be determined and appropriate application rates determined. In an operation where cropland needs always exceed the manure's nutrient supply, each field's application rate will change yearly. If there is a near balance in nutrient supply and needs, strategies that can correct for those "excess" and "deficient" years are needed. The primary strategies would be to apply/allow for multiple year needs.

Also, due to manure's residual properties, second and third year credits need to be accounted for in determining crop needs. Approximately 35-50% of the N in the organic fraction is available each year. Thus, second and third year N credits should be given for manure (Table 4). After applying swine manure, approximately 20% of the total N is available to the crop in the second year; approximately 5-10% is available in the third year.

Calibrating Application Equipment

Correct application of manure to cropland is critical to maximize the value of manure to crop producers. For manure to replace commercial fertilizer and not create environmental problems, farmers must be confident about the application rate. All calculations involving calibration of manure must be done using manure on an "as is" basis. All analysis should be interpreted on an "as is" basis and the application rate should be as well. Do not worry about the moisture content or change to a dry matter basis.

Three conditions must be addressed to achieve this confidence in rates. First, the **analysis of the manure loaded into the application equipment must be known** and should not change. For liquid systems, good agitation in the storage facility and in the transport tank are important. Loading procedures that do not separate the solids and the semi-solids can assure this for solid manure systems. Second, the **rate of manure being applied to the field must be known** and kept constant. Calibration must be conducted for all manure applications. And finally, the **application or spread pattern of the manure must be uniform throughout the field** so that all plants will have equal access to the nutrients. Having a predetermined travel plan for applying manure to a field and noting where loads stop and start will help ensure uniform applications.

Liquid systems

Calibration of liquid manure equipment requires that the manure be measured in gallons/acre (GPA). Getting a weight of the tank before and after spreading the manure and dividing by the density of the liquid manure (8.3 lb/gal) is the best way to determine the volume. Combining this with the width of the spread pattern and the distance the tank takes to empty will provide the information to determine the application rate. *For example, Operator A takes a loaded manure tank across a scale and it reads 29000 lb The operator applies manure to a field with four injector knives (2.5 ft centers); it takes 1200 ft to empty the tank. Driving the emptied tank across the scale gives a reading of 8500 lb. The rate is:*

[(29000 lb - 8500 lb)÷8.3 lb/gal]÷{[1200 ft x (2.5 ft/injector x 4 injectors)]÷43560 ft^2/acre} = 8965 GPA

Or, fill the tank to its predetermined volume to avoid needing a scale. However, the listed capacity is often different from what is hauled to the field with a "full" tank. Counting the number of loads needed on a given size field and assuming a set volume per load will allow calculation of a rate per acre, although this does not ensure uniform application within a field. *This example has Operator B filling a 3200 gal tank 90% full for each load, then spreading 29 loads on a 23-acre field. The solution is:*

[(3200 gal/load x 0.90) x 29 loads]÷23 acres = 3630 GPA

Solid systems

Calibration of solid manure equipment is similar to liquid manure equipment. The weight of manure applied can be determined by any one of several ways. Weigh your manure spreader before and after going to the field and determine the weight of manure spread. Then determine the width the manure is being spread and the distance it took to unload the manure. Using the ratio of weight per portion of an acre, a per-acre application rate can be calculated. It is best not to unload the entire spreader because the spread pattern at the end of a load is not representative. *Example: Operator C weighs a loaded spreader; it is 9800 lb. After spreading a 12-ft width of manure a distance of 300 ft, the spreader is reweighed and it now measures 6200 lb. The rate calculation is:*

$$[(9800 \text{ lb} - 6200 \text{ lb}) \div 2000 \text{ lb/ton}] \div [(12 \text{ ft} \times 300 \text{ ft}) \div 43560 \text{ ft}^2\text{/acre}] = 21.8 \text{ tons/acre}$$

A practical method is using a scale to determine a weight per load, then counting the number of loads it takes to spread manure on a given field. Calculate the total tons per field and divide by the number of acres in the field to determine rate of application. *For example, Operator D has previously calculated a spreader holds 8.5 tons of manure when fully loaded and uniformly applied 16 loads in a 13-acre field. The solution for rate is:*

$$(16 \text{ loads} \times 8.5 \text{ tons/load}) \div 13 \text{ acres} = 10.5 \text{ tons/acre}$$

Another method is to lay a tarp or piece of heavy-duty plastic in a field. After the spreader has passed over, collect and weigh the manure from the tarp or plastic. Then determine the area of the plastic, and convert the weight measurement to a per-acre basis. This method generally has a large amount of variability unless several samples are collected and weighed. *In an example, Operator E places five 4 ft by 4 ft plastic sheets in their field and spreads manure across these sheets. The combined weight of the sheets is 38.5 lbs. The solution for the rate is:*

$$(38.5 \text{ lb} \div 2000 \text{ lb/ton}) \div \{[5 \times (4 \text{ ft} \times 4 \text{ ft})] \div 43560 \text{ ft}^2\text{/acre}\} = 10.5 \text{ tons/acre}$$

After determining the manure application rate, it is often necessary to adjust the rate to better match the recommended rate that you need. The most common method to change application rate is by changing the speed you drive across the field. Solid manure equipment may also have an adjustment that changes the chain speed in the box, thereby changing the manure rate. Liquid manure equipment may have valve opening adjustments to alter the rate. A concern with liquid manure systems is the difference in flow from the start to the end of the tank. Pressurized tanks, flow pumps, and new distributor designs are solving some of these problems in variable flows.

Special Concerns and Issues

Solid versus liquid manure

Nutrients voided by swine are the same whether the manure is to be handled as a liquid or a solid. It is the handling systems that create losses of nutrients or changes in the manure composition resulting in different nutrient analyses between solid and liquid manure.

The available plant nutrients in manure are often found in different fractions. Nitrogen, for example, is fairly evenly split between the feces portion, which contains the majority of organic N, and the urine, which contains most of the inorganic N. Therefore, it is essential to preserve and adequately mix these fractions before field application.

Phosphorus is found mainly in the feces component. Phosphorus is not lost by any chemical or biological process and the majority of this nutrient is available in the year of application. With a liquid storage system, the bulk of the phosphorus is in the settled solids at the bottom of the pit unless you agitate before spreading. Potassium is almost the opposite of phosphorus; almost all of it is in the urine.

Spring/winter/fall application times

Time of manure application can be extremely important if site-specific conditions create an environmental hazard. Fall applications allow for maximum time for the manure to break down before the crop uses the nutrients. While this is generally beneficial, it can also lead to environmental hazards if N loss from the soil is a concern. Fall applications of N are generally not recommended on coarse-textured soils.

With spring applications, there is less opportunity for N losses from a field. However, spring applications result in less time for organic decomposition of the manure, including the release of some nutrients. Spring application also generally delays fieldwork and planting, and could increase soil compaction.

Many producers use winter applications. While there will be significant losses of available N, the organic N fraction will still contribute to the plant-available N pool. The potential for nutrient runoff is an environmental concern for winter applications on frozen, sloping soils. If manure is applied to frozen soils and there is runoff from snow melt or rain, nutrients in the manure will be lost with the runoff. This situation is not recommended.

Methods of application

Broadcasting is a way to apply solid or liquid swine manure. Sometimes this is followed by incorporation with a tillage operation. Other times, like with winter applications, the manure is left on the soil surface. Nitrogen loss is a concern with broadcast manure. The amount of loss depends mainly on the time between application and incorporation. Manure that is broadcast but never incorporated can lose about half of its total N. Incorporation within 12 hours is ideal for maximum N efficiency (See Table 4). Local ordinances and neighbors should be considered in determining where and when manure is broadcast due to odors.

With liquid manure systems, several more application options are available to crop producers. Injection methods place liquid manure below the soil surface, thus eliminating the majority of volatilization losses. Traditionally, injection knives placed the manure in a concentrated, vertical band about 6-8 inches below the soil surface with 30- to 60-inch spacings between knives. New injection systems such as sweep and disc injectors are being marketed that spread the manure in horizontal patterns under the soil surface. These systems allow for faster breakdown of the manure and places the manure in a more favorable position for early season plant uptake.

Another option for liquid manure handlers is to apply the manure with an irrigation system. Because this is an efficient method to apply large amounts of manure, excessive rates are often applied. Although application is often uniform, volatilization is still a major concern.

Special uses

Many pork producers grow soybeans and often consider spreading manure on these acres. Although soybeans do not necessarily benefit from the N in the manure, they can benefit from all other nutrients in the manure. The recommended rate should, therefore, be based on P or K requirements of the crop. The soil may also benefit from the organic material addition (soil tilth). When manure is applied to soybeans, the added N reduces the amount of N symbiotically fixed by the nodules. This has neither a consistent positive or negative effect on the soybean yields.

A recent trend with some hog/corn producers in Minnesota is to switch to ridge-till systems. Manure can be worked into this system in two ways. First, the manure can be injected in the ridge valleys as a sidedress application. This is a good method to prevent nutrient loss, yet the nutrients are not in the root-filled ridge and the soil disturbance counteracts some of the ridge-till philosophy. Manure can also be spread into the ridge valleys as a preplant or sidedress application; then incorporated into the ridge with subsequent cultivations. Take care not to broadcast manure onto the young plants because burning will take place. Nutrient movement into the ridges is limited in the year of application, but with several years of ridging, the nutrients will be well mixed into the ridge.

Conclusion

With the increased demand for pork, more manure will be generated. Recycling manure into the soil through a predetermined manure management plan is efficient and practical. This will optimize the nutrient value of the manure while minimizing potential environmental hazards. Manure is a valuable resource on a farm and should be treated as an asset.

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