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The Agronomics of Manure Use for Crop Production

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Interest in the farm use of animal manures has been renewed in recent years, primarily because of regulatory concerns related to water quality. The purpose of this publication is to review the use of manure in providing beneficial nutrients to crops from an agronomic viewpoint. Proper agronomic use of animal manures is often compatible with other best management practices (BMPs) likely to be required as part of water quality regulations.

The Agronomic Value of Manure

Animal manure is the digestive by-product of feed ingested by an animal. As such, the chemical content of manure is similar to the chemical content of feeds consumed by animals. During digestion of feedstuff by animals, energy as well as some nutrients, vitamins, and minerals are retained by the animal for its own metabolic functions. However, much of the nutrient content of the feed passes through the animal in fecal and urine elimination. For example, about 75% of the nitrogen (N), 80% of the phosphorus (P), and 85% of the potassium (K) content of feedstuff consumed by cattle passes through their bodies in urine and feces. In addition to nutrient content, fecal material also contains sizeable amounts of indigestible or partially digested organic residues originating from the feedstuff consumed. Because of this, animal manure provides the following agronomic values when applied to soil:

1. It provides nutrients for use by plants.
2. It increases the organic matter content of soil, thereby improving soil structure (aggregation), porosity (bulk density), and water-holding capacity.

Efficacy of Animal Manure to Provide Plant Nutrients

How well animal manure performs agronomically is greatly affected by the chemical form in which nutrients occur, how much manure is applied, how it is applied, and when it is applied. These factors are discussed as follows.

Nitrogen

- About half the N in most animal manure is present in the soluble form as urea, with the remaining half as insoluble organic compounds.
- In poultry manure, about half the organic N becomes available within a year following application. Together with the soluble N, this can represent 65% to 75% of the total N available to the following crop. There are also indications that 60% to 65% of the total N in swine manure is available, following application and incorporation.
- The soluble urea N content of manure reacts just like fertilizer urea when spread onto fields and has the same potential for losses.
- The insoluble organic N in manure is available only slowly over a long period of time.

The information summarized in Table 1 shows the effect of either a delayed soil incorporation of manure or of at least 0.3 in. of rainfall occurring after application on N availability for summer crops, and the effect of a winter cover crop on subsequent N availability of manure spread *and incorporated* in spring or fall or winter. Other reports indicate only 60% to 70% of the total N in broiler litter is initially available immediately after spring application and that 40% to 50% is still available following a time lag of five to six days between application and incorporation.

Despite such differences in reported losses, the point to remember is that (a) if the intent is to incorporate manure, the longer the delay between application and incorporation the greater the losses will be, or (b) if the intent is to topdress and not incorporate, count on sizeable losses unless a rain of about 0.3 in. occurs within two to three days after application.

While the information summarized in Table 1 provides an estimation of soluble plus released N availability to the next crop grown following manure application, it does not show the residual N value which accumulates in the soil from the insoluble organic fractions of manure and becomes available

Table 1. *Availability of Nitrogen In Manure.*[1]

Method of Manure Use	% of N Available to Following Crop — Poultry Manure	Other Manure
Manure applied in spring for summer annual crops		
Incorporated within 1 day	75	50
Incorporated within 2 days	50	40
Incorporated within 3-4 days	45	35
Incorporated within 5-6 days	30	30
Incorporated after 6 days	15	20
Manure applied and incorporated in fall or winter		
No cover crop planted	15	20
Cover crop planted, harvested, and fed, or used for green manure	50	40
For small grains	50	40

[1]*Data from D.B. Beegle, Penn State University*

over long periods of time as these fractions slowly decay. An estimate of this residual N value from manure application is summarized in Table 2. Figures shown are percentages of total N in *each annual manure application*. Note that the fraction of residual N increased with the frequency of application.

Table 2. *Percentage of Slowly Available N Which Becomes Available Annually*[1]

Field History of Manure Use	Poultry Manure	Other Manure
Manure rarely or never used	0	0
Manure frequently used (4 to 8 out of 10 years)	7	15
Manure used every year	12	25

[1]*Data from D.B. Beegle, Penn State University*

Phosphorus

The agronomic value of P in animal manures can be summarized as follows:

- P is present mostly in organic forms in manure.
- P in manure is only available to crops slowly over a long period of time as the manure decays in soil.
- Organic P is less likely to be "fixed" in soil than inorganic P (the P in nearly all commercial fertilizers is in inorganic form).
- P in manure is as effective as fertilizer P in building and maintaining soil test levels of P.
- Because of the slow availability of manure P, manure should not be considered as a "starter" fertilizer where high concentrations of available P are needed in a short period of time. Wisconsin data suggests that about 60% of the total P becomes available during the first year following application.

Potassium

The K content of manure is mostly in the soluble fraction and consequently is readily available to crops. The K in manure will react in soil (with the cation exchange capacity) just as fertilizer K does.

Amounts of Animal Manure to Apply

In order to determine the amount to apply, the nutrient content of manure must be known. While "rule-of-thumb" or "book" values for available nutrient content of manures can be used, they can vary from the "real" content of the manure source in question by ± 100%, since actual nutrient content is so greatly affected by source of manure, variability in rations consumed by animals, and the handling and storage process. For determination of actual nutrient content, the University of Kentucky College of Agriculture's Division of Regulatory Services offers a manure testing service through its Soil Testing Laboratory. Use of this service can be obtained through county Extension offices.

After getting results from a manure test, or estimating nutrient content from tabular values such as those shown in University of Kentucky publication AGR-1, the rate calculation is based on content of the plant nutrient which is of most concern or has highest priority. This usually is based on content of either N or P. A rate is then calculated which will not apply an excess of the priority nutrient over what is needed for the intended crop. Refer to University of Kentucky publication AGR-1 for nutrient rate recommendations for crops.

Crop rotation of the field onto which manure is to be applied also should be considered. If the field is currently being used for N-responsive crops (tobacco, corn, small grains, grain sorghum, forage grasses), the rate of calculation should be based on the N rate requirement of the crop. If the field is currently being used for legumes (soybeans, forage legumes), the rate calculation should be based on the P requirement of the crop.

Caution should be used in applying manure to tobacco since manures contain chloride, which, if excessively applied, can cause curing and quality problems. No more than 4 T/A of poultry manure should be used for a tobacco crop, since poultry manure contains about 12 lbs chloride per ton, and a rate of 4 T/A would apply 48 lbs/A of chloride — about the maximum rate of chloride that can safely be used. This rate would supply 175-200 lbs/A of available N if immediately incorporated after application. For other animal manures, no more than 10 T/A should be used on tobacco.

Another important consideration in rate of manure applied is the *uniformity with which it is applied*. Where application is non-uniform, the rate of manure applied can vary greatly within the same field. Manure application methods (mechanical spreaders and irrigation systems) should be calibrated accurately to provide the correct application rate. Failure to uniformly apply manure greatly diminishes the agronomic performance expected from calculating the rate needed.

Placement of Animal Manures

The greatest concerns about placement of animal manures are maximizing the agronomic effectiveness of its soluble (or available) N content, minimizing its loss by surface erosion, and minimizing its potential for stunting plant growth ("organic matter toxicity"). Maximum agronomic N value is attained by incorporating into soil (see the preceding section on N), which lowers the potential for volatilization losses of ammonia (NH_3) during the hydrolysis of urea (conversion of urea N to ammonium N). If applied to the surface of a field and not incorporated, or if about 0.3 in. rain does not fall within one to two days, substantial loss of N in manure is likely.

If liquid manure is injected into the soil in concentrated subsurface bands, there is likelihood, particularly under poor soil drainage conditions, for anaerobic decomposition with subsequent production of organic compounds toxic enough to stunt root growth of plants or even kill roots. On soils likely to have restricted movement of air and water within the rooting zone of the soil, this risk can be minimized by surface broadcasting the manure and disking it in.

Another possible concern related to high rates of manure application, particularly over several consecutive years or areas in a field where manure has been stockpiled, is a "salt" build-up. In this situation, high concentrations of ammonium and soluble salts of potassium, sodium, calcium, and magnesium can accumulate, resulting in germination damage to seeds, reduced soil water availability, and dispersion of soil clay (destruction of soil structure). Soil pH of such fields or areas within a field is likely to be 7 or higher.

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