Manure Management Facts

Calculating Manure Application Rates

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Using Manure As A Fertilizer

Manure is both a natural by-product of livestock production and an excellent source of nutrients for crop production. Manure contains nitrogen (N), phosphorus (P), potassium (K) and micro-nutrients needed for crop production and can be a substitute for synthetic fertilizers. Unlike synthetic fertilizers, manure also contains organic matter which helps to improve soil tilth, structure, aeration and water holding capacity.

Not all of the nutrients in manure are immediately available to the crop. The availability of manure nutrients depends upon the nutrient composition of the manure, method of manure application and weather conditions at the time of application. Nutrient availability must be estimated when determining the manure application rate. The following are six basic steps to calculating a manure application rate in order to use manure as a fertilizer.

1. Test the Soil

Soil sampling and analysis is the only way to directly determine the plant-available nutrient status of a field and to receive field-specific fertilizer recommendations. There are a number of soil sampling strategies and analytical packages available. Manitoba Agriculture, Food and Rural Initiatives (MAFRI) recommends that the soil be tested for:

0 to 6 inch (0 to 15 cm) depth:

- nitrate-nitrogen (NO_3-N)
- sodium-bicarbonate extractable (Olsen) phosphorus (P)
- potassium (K)
- sulphate-S (SO_4-S)
- pH and
- electrical conductivity (EC)

0 to 24 inch (15 to 60 cm) depth:

- NO_3-N
- SO_4-S and
- EC

At a bare minimum, to calculate a manure application rate, soils should be sampled at the 0 to 24 inch (0 to 60 cm) depth for NO_3-N and 0 to 6 inch (0 to 15 cm) depth for Olsen -P.

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Fertilizer recommendations and crop nutrient removals

The soil test report should provide fertilizer recommendations. When necessary, the *Manitoba Soil Fertility Guide* can also provide nutrient recommendations based on soil test values. In some situations, estimates of crop nutrient removals may be more appropriate for determining target manure application rates.

2. Test the Manure

Testing manure for each livestock operation and each application event is the best way to estimate the nutrient content of manure. A manure analysis should be based on a well-mixed, representative sample. Manure is very heterogeneous and obtaining a representative sample can be very difficult. Often, more than one sample is required.

It is ideal to know the nutrient content of the manure before application so that application rates can be predetermined to meet crop nutrient requirements. However, receiving manure test results prior to application can be challenging, particularly for liquid manure. This is because the manure storage structure is not typically agitated until just before and during pump-out. An alternative is to have a database of historical manure test results for a given operation to use until recent test results can confirm the nutrient content of the manure. Rapid field test kits for liquid manure exist for estimating the readily available portion of N; however, the result of a field test should be verified by comparing it to a laboratory analysis of the same manure sample.

A basic manure analysis package should include total nitrogen, ammonium-nitrogen (NH_4-N), total P, total K and dry matter content. In some instances, sulphur and micronutrient analyses may also be desired. Nutrient analyses for various types of manure are provided in Table 1.

3. Establish a Realistic Target Yield

Manure application rate calculations are based on fertilizer recommendations or crop nutrient removal estimates for realistic crop yield targets. The target yields should be appropriate for the region, productive capacity of the soil and the producer's management practices. Historical yield records for the operation are the best indicators of realistic future yields. Crop insurance data can also be used to give guidance on yield potentials for the region. Agriculture Capability ratings, which are based on natural soil and landscape characteristics, can be used to identify the severity and kind of limitations to crop production for a given field. If the target yield chosen is not realized, soil nutrient levels should be monitored and future target yields should be adjusted accordingly.

4. Calculate the Manure Application Rate

Soil test results will determine whether an N-based or P-based application rate should be used.

TABLE 1: NITROGEN, PHOSPHORUS AND MOISTURE CONTENTS OF VARIOUS MANURES[1]

Manure Type		Total Nitrogen	Ammonium Nitrogen	Organic Nitrogen	Total Phosphorus	Dry Matter
		---------- lb/1000 gal ----------				%
Liquid Pig[2] n=70	Ave	36	22	14	12	4.3
	Max	68	52	37	32	8.0
	Min	6.0	4.4	1.6	1.0	2.0
Liquid Dairy n=208	Ave	31	15	16	8.2	7.1
	Max	76	72	56	85	15
	Min	7.0	0.7	0.5	1.0	1.0
Liquid Chicken n=65	Ave	79	58	21	25	8.3
	Max	115	99	92	51	14
	Min	30	1.1	1.3	6.0	2.6
Manure Type		**Total Nitrogen**	**Ammonium Nitrogen**	**Organic Nitrogen**	**Total Phosphorus**	**Dry Matter**
		---------- lb/ton ----------				%
Solid Dairy n=75	Ave	11	2.6	8.2	3.0	20
	Max	16	6.4	15	17	38
	Min	6.6	0.0	1.6	1.0	15
Solid Beef n=147	Ave	11	1.2	9.6	2.3	28
	Max	40	8.5	40	13	67
	Min	2.8	0.0	1.4	0.6	15
Solid Chicken n=54	Ave	45	14	30	20	48
	Max	94	34	82	56	84
	Min	6.0	4.1	0.3	1.2	16

[1] MARC 2008. Manure Application Rate Calculator software for Manitoba, Manitoba Agriculture, Food and Rural Initiatives

[2] For pig manure data by operation type with and without phytase use, see the Farm Practices Guidelines for Pig Producers in Manitoba, Manitoba Agriculture, Food and Rural Initiatives, April 2007.

Nitrogen based application rates

Manure application rates are based on the soil analyses and fertilizer recommendations, manure analyses, timing and method of application and weather conditions. Traditionally, manure application rates have been based on N. For all crops except legumes, the rate of manure application has been based on the amount of fertilizer N required to achieve a target yield. Since legumes can fix their own N and do not require additional fertilizer, manure application rates for legumes have been based on the potential N removal of the crop (Table 4).

The N requirements of a crop can be provided by manure N. However, not all of the N in the manure will be available to the crop in the first year after application. Therefore, the available N in the manure must be estimated.

The manure test report provides results for total N and ammonium N. Organic N is calculated from the manure test report as the difference between total N and ammonium N.

Organic N = Total N – Ammonium N

Nitrogen availability is estimated for both the inorganic (ammonium) and organic forms. All of the ammonium is available to the crop, however, it is also highly susceptible to volatilization losses as ammonia gas. The actual amount of ammonium N available is the amount remaining after volatilization:

Available Ammonium N = Total Ammonium N x (100% – % Volatilization Loss)

Volatilization loss estimates are provided in Table 2. Two factors are considered when estimating volatilization loss: weather conditions at the time of application and method of application. Generally, volatilization losses are expected to be greater under warmer and dryer conditions (e.g. summer) and lower under cooler and wetter conditions (e.g. early spring or late fall). Volatilization losses also increase with prolonged exposure of manure on the soil surface. Therefore, injection of liquid manure, or rapid incorporation following broadcast application, should minimize loss of ammonia to the atmosphere.

Organic N must be mineralized before it can be used by the crop. The proportion of organic N in manure that is estimated to be available to the following crop is 25%:

Available Organic N = 25% Organic N

For solid manure that contains considerable amounts of straw or other bedding materials, less than 25% of the organic N may be available in the first year following a single application. As soil microorganisms consume the carbon (C) from the bedding materials, they tie up N from the manure and/or soil that would otherwise be available to the crop. Solid manure, that contains a lot of bedding, returns a significant amount of carbon to the soil. Application of this type of manure may result in temporary immobilization of N, reducing plant-availability. Repeated applications of solid manure, however, may result in a build-up of soil N that becomes available to crops grown in subsequent years.

The estimated total available N is determined by adding the available organic and inorganic fractions:

Total Available N = (Ammonium N – Volatilization loss) + 25% Organic N

Total Available N = Ammonium N x (100% – % Volatilization loss) + 0.25 Organic N

Manure application rates must not result in residual soil nitrate-N levels exceeding the regulatory limits (Table 3).

TABLE 2: VOLATILIZATION LOSSES (%)[1]

Method of Application	Weather Conditions				
	Average	Cool Wet	Cool Dry	Warm Wet	Warm Dry
Injected	0	0	0	0	0
Incorporated 1 day	25	10	15	25	50
Incorporated 2 day	30	13	19	31	57
Incorporated 3 day	35	15	22	38	65
Incorporated 4 day	40	17	26	44	72
Incorporated 5 day	45	20	30	50	80
Not Incorporated	66	40	50	75	100
Irrigated	Above +10%	Above +10%	Above +10%	Above +10%	Above +10%
Standing/Cover Crop/Stubble	35	25	25	40	50

[1] MARC 2008. Manure Application Rate Calculator software for Manitoba, Manitoba Agriculture, Food and Rural Initiatives.

TABLE 3. MAXIMUM RESIDUAL[1] SOIL NITRATE-N FOR SOILS RECEIVING MANURE

Agriculture Capability Rating	Maximum Residual Nitrate-N[2,3] (lb/ac)
Class 1, 2 and 3 (except 3M and 3MW)	140
Class 3M, 3MW and 4	90
Class 5	30
Class 6, 7 and unimproved organic soils	No manure application

[1] Refers to nutrient remaining in soil after the production of a crop.
[2] Under the Livestock Manure and Mortalities Management Regulation (MR42/98).
[3] Limits apply to the top 2 feet of soil.

Phosphorus based application rates

Manure nutrients are typically not in balance with the nutrient requirements of the crop. Manure application rates are most often based on N. Although P is usually found in manure in smaller quantities than N, crops require significantly less P than N to reach optimum yields. Therefore, it is common for more P to be applied than the crop can remove when application rates are based on N. This results in a build-up of soil test P.

This nutrient imbalance is magnified when manure is applied using a practice that does not conserve N for crop use and, instead, exposes the N to greater loss from the field. For example, broadcast application of manure without incorporation leads to increased loss of N through volatilization. To compensate for this fact, the manure application rate must be increased to ensure that the N demand of the crop is satisfied. A higher manure application rate leads to a higher application of manure P and a more rapid rise in soil P. The same situation also arises with annual applications of manure having a low available N content (common with solid manure).

As soil test P levels increase, soluble P also increases. Soluble P is more mobile in soil and can threaten surface water quality if it moves from the field to a watercourse. Controlling the build-up of soil test P will reduce the formation of soluble P. This can be achieved by reducing the P in manure or by basing manure application rates on P.

As soil test P builds, the requirement for additional fertilizer P decreases, often to only starter P rates. The fertilizer recommendation for P can be found on the soil test report. Fertilizer P is expressed as P_2O_5:

$P \times 2.3 = P_2O_5$

When manure is applied based on P, the target application rate should be based on the crop-specific removal rate for P, expressed as P_2O_5 (Table 4). In order to slow the build up of soil test P, at moderate to high soil test P levels (60 to 119 ppm Olsen P), the manure P_2O_5 application rate should not exceed two times the crop P_2O_5 removal rate:

At 60 to 119 ppm Olsen P:

Manure P_2O_5 Application Rate ≤ 2 x Crop Removal P_2O_5

When soil test P values are high to very high (120 to 179 ppm Olsen P), manure P_2O_5 application rates should not exceed the total amount of P_2O_5 that the crop can remove. This will prevent further build-up of soil test P.

At 120 to 179 ppm Olsen P:

Manure P_2O_5 Application Rate ≤ 1 x Crop Removal P_2O_5

Manure should not be applied to soils that already have excessive levels of soil test P (>180 ppm Olsen P). These soils should be cropped to bring down soil test P levels before additional manure is applied.

Multi-year P_2O_5 Application Rate

It is often not technically feasible or economically practical to apply manure to meet annual crop P requirements or crop P removals. In this situation, it may be necessary to apply manure at a rate that is equivalent to multiple years of crop P_2O_5 removal (e.g. total P removed by crops that will be grown over several years). After a multi-year application, manure is not re-applied until subsequent crops have removed all of the P applied. In this system, other nutrient requirements, such as N, are met using synthetic fertilizer or other sources.

Appendix A provides an example manure application rate calculation for liquid manure. Appendix B provides an example manure application rate calculation for solid manure.

The Manure Application Rate Software (MARC), developed by Manitoba Agriculture Food and Rural Initiatives, is available for calculating manure application rates.

TABLE 4: ESTIMATED CROP REMOVAL RATES FOR N AND P_2O_5 [1]

Crop	Example Target Yield[3]	Average Nutrient Removal Rate per Unit Yield[2]		Nutrient Removal for Target Crop Yield[4] (lb/ac)	
		N	P_2O_5	N	P_2O_5
Alfalfa	5 tons/acre	58.0 lb/ton	13.8 lb/ton	290	69
Barley - Grain	80 bu/acre	0.97 lb/bu	0.42 lb/bu	78	34
Barley - Silage	4.5 tons/acre	34.4 lb/ton	11.8 lb/ton	155	53
Canola	35 bu/acre	1.93 lb/bu	1.04 lb/bu	68	36
Corn - Grain	100 bu/acre	0.97 lb/bu	0.44 lb/bu	97	44
Corn - Silage	5 dry tons/acre	31.2 lb/ton	12.7 lb/ton	156	64
Dry Edible Beans	18 cwt/acre	4.17 lb/cwt	1.39 lb/cwt	75	25
Flax	24 bu/acre	2.13 lb/bu	0.65 lb/bu	51	16
Grass Hay	3 tons/acre	34.2 lb/ton	10.0 lb/ton	103	30
Oats	100 bu/acre	0.62 lb/bu	0.26 lb/bu	62	26
Peas	50 bu/acre	2.34 lb/bu	0.69 lb/bu	117	35
Potatoes	400 cwt/acre	0.32 lb/cwt	0.09 lb/cwt	128	36
Rye	55 bu/acre	1.06 lb/bu	0.45 lb/bu	58	25
Soybeans	35 bu/acre	3.87 lb/bu	0.84 lb/bu	135	29
Sunflowers[5]	22 cwt/acre	2.80 lb/cwt	1.10 lb/cwt	62	24
Wheat - Spring	40 bu/acre	1.5 lb/bu	0.59 lb/bu	60	24
Wheat - Winter	75 bu/acre	1.04 lb/bu	0.51 lb/bu	78	38

[1] Adapted from Nutrient Uptake and Removal by Field Crops, Western Canada, 2001. Compiled by the Canadian Fertilizer Institute.

[2] The nutrient content of crops and crop residue vary based on environmental conditions, field history and nutrient supply of the soil. Mean values are suitable for general use but for more accurate farm specific values, producers should consider using tissue test analysis.

[3] Example target yields for Manitoba. Site specific yields will depend on the agricultural capability of the land, climate and the producer's management practices.

[4] Phosphorus (expressed as the fertilizer equivalent P_2O_5) removed in the harvested portion of the crop based on achievement of the example yield given in the table. Phosphorus (P) x 2.28 = P_2O_5.

[5] Adapted from "Nutrients Removed in Harvested Portion of Crop" compiled by the International Plant Nutrition Institute.

5. Calibrate Field Equipment to Deliver Target Rate

Calibration refers to the combination of settings needed to deliver manure at a particular rate. The calculation of a target manure application rate is of little value if the equipment is not properly calibrated to deliver the required application rate. Details on how to calibrate manure application equipment can be found in the *Tri-Provincial Manure Application and Use Guidelines* (Manitoba Version, 2004) and the *Commercial and Off-farm Manure Applicators Course Manual* (Assiniboine Community College, 2008).

6. Keep Records

Maintaining detailed records on an ongoing basis is an essential part of proper manure nutrient management. Every livestock operation should keep track of soil and manure test results, manure application rates, application methods, application dates, crop rotations and yields, and any other relevant information for each field that receives manure.

The key steps to proper manure management are:

1. Test the soil
2. Test the manure
3. Establish a realistic target yield
4. Calculate the manure application rate
5. Calibrate field equipment
6. Keep detailed records

For More Information

- Your local Manitoba Agriculture, Food and Rural Initiatives Growing Opportunities (GO) Centre or Office.
- Manitoba Agriculture, Food and Rural Initiatives website: **manitoba.ca/agriculture**

APPENDIX A: LIQUID MANURE APPLICATION RATE CALCULATION WORKSHEET (IMPERIAL UNITS)

Line #				
1	Field ID	Crop:		
2	Target Yield			bu/ac
				tons/ac
Step 1 - Nitrogen Recommendation based on Soil Test Result				
3	N			lb/ac
Step 2 - P_2O_5 Recommendation based on Soil Test Result or Crop Removal Values				
4	P_2O_5			lb/ac
Step 3 - Manure Test Data				
5	Total Nitrogen			lb/1000 gal
6	Ammonium Nitrogen			lb/1000 gal
7	Organic Nitrogen (line 5 - line 6)			lb/1000 gal
8	Phosphorus (P)			lb/1000 gal
9	P_2O_5 (line 8 x 2.3)			lb/1000 gal
Step 4 - Amount of manure nutrient available to crop				
10	Method of application			
11	Anticipated weather conditions during spreading			
12	Expected volatilization loss			%
13	Available ammonium N (line 6 x [100 - line 12]%)			lb/1000 gal
14	Available organic N (line 7 x 25%)			lb/1000 gal
Step 5 – Accounting for season of application				
15	Total available N (Spring and Summer Applications) (line 13 + line 14)			lb/1000 gal
16	Total available N (Fall Applications only) (line 15 x 83%)			lb/1000 gal
17	Total P_2O_5 (line 9)			lb/1000 gal

Step 6 - Application rate based on N recommendation			
18	N based application rate (line 3 ÷ line 15 x 1000 for Spring/Summer) OR (line 3 ÷ line 16 x 1000 for Fall)		gal/ac
19	Amount of P_2O_5 applied (line 17 x line 18 ÷ 1000)		lb/ac
20	P_2O_5 balance (line 19 – line 4) A positive result indicates an over-application of P_2O_5. A negative result indicates an under-application of P_2O_5 and additional P fertilizer may be required.		lb/ac
Step 7 – Application rate based on P_2O_5 recommendation or removal			
21	2X P_2O_5 removal rate (2 x line 4 ÷ line 17 x 1000)		gal/ac
22	1X P_2O_5 removal rate (line 4 ÷ line 17 x 1000)		gal/ac
23	Amount of available N applied (line 21 or 22 x line 15 ÷ 1000 for Spring/Summer) OR (line 21 or 22 x line 16 ÷ 1000 for Fall)		lb/ac
24	N balance (line 23 - line 3) A positive result indicates an over-application of N. A negative result indicates an under-application of N and additional N fertilizer may be required.		lb/ac
Step 8 - Select a rate			
If soil test P < 60 ppm, select a N rate of application (line 18) If soil test P is 60 ppm – 119 ppm, select a 2X P_2O_5 removal rate of application (line 21) If soil test P is 120 ppm – 179 ppm, select a 1X P_2O_5 removal (line 22)			gal/ac

APPENDIX B. SOLID MANURE APPLICATION RATE CALCULATION WORKSHEET (IMPERIAL UNITS)

Line #				
1	Field ID	Crop:		
2	Target Yield			bu/ac
				tons/ac
Step 1 – Nitrogen Recommendation based on Soil Test Result				
3	N			lb/ac
Step 2 – P_2O_5 Recommendation based on Soil Test Result or Crop Removal Values				
4	P_2O_5			lb/ac
Step 3 – Manure Test Data				
5	Total Nitrogen			lb/ton
6	Ammonium Nitrogen			lb/ton
7	Organic Nitrogen (line 5 - line 6)			lb/ton
8	Phosphorus (P)			lb/ton
9	P_2O_5 (line 8 x 2.3)			lb/ton
Step 4 – Amount of manure nutrient available to crop				
10	Method of application			
11	Anticipated weather conditions during spreading			
12	Expected volatilization loss			%
13	Available ammonium N (line 6 x [100 - line 12]%)			lb/ton
14	Available organic N (line 7 x 25%)			lb/ton
Step 5 – Accounting for season of application				
15	Total available N (Spring and Summer Applications) (line 13 + line 14)			lb/ton
16	Total available N (Fall Applications only) (line 15 x 83%)			lb/ton
17	Total P_2O_5 (line 9)			lb/ton

Step 6 – Application rate based on N recommendation			
18	N based application rate (line 3 ÷ line 15 for Spring and Summer) OR (line 3 ÷ line 16 for Fall Applications)		ton/ac
19	Amount of P_2O_5 applied (line 17 x line 18)		lb/ac
20	P_2O_5 balance (line 19 – line 4) A positive result indicates an over-application of P_2O_5. A negative result indicates an under-application of P_2O_5 and additional P fertilizer may be required.		lb/ac
Step 7 – Application rate based on P_2O_5 recommendation or removal			
21	2X P_2O_5 removal rate (2 x line 4 ÷ line 17)		ton/ac
22	1X P_2O_5 removal rate (line 4 ÷ line 17)		ton/ac
23	Amount of available N applied (line 21 or 22 x line 15 for Spring and Summer) OR (line 21 or 22 x line 16 for Fall Applications)		lb/ac
24	N balance (line 23 - line 3) A positive result indicates an over-application of N. A negative result indicates an under-application of N and additional N fertilizer may be required.		lb/ac
Step 8 – Select a rate			
If soil test P < 60 ppm, select a N rate of application (line 18) If soil test P is 60 ppm – 119 ppm, select a 2X P_2O_5 removal rate of application (line 21) If soil test P is 120 ppm – 179 ppm, select a 1X P_2O_5 removal (line 22)			ton/ac