Managing Manure within Tillage Systems and Crop Rotations

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Introduction

Manure is a valuable source of nutrients for crop production. Most crop rotations can be designed to benefit from manure as the nutrient source. The use of manure, however, also introduces some unique challenges that must be taken into consideration when planning the crop rotation and fertilization system. These challenges include tillage options, crop selection, timing of manure application operations and when the nutrients will become available to the crop.

In addition to taking advantage of the nutrient value of manure, flexibility in the crop rotation system allows producers to address adverse situations such as elevated nutrient levels. Manure management planning should take advantage of any opportunities within a crop rotation system to maximize crop nutrient removal and minimize the risk of nutrient loss to the environment.

Tillage Systems and Manure Application Options

Annual Tillage – Tilled land provides the best opportunity to inject or incorporate manure. Injection and incorporation of manure is possible within most conventional and minimum-tillage cropping systems. Injection or immediate incorporation of manure reduces atmospheric losses of nitrogen through volatilization and losses of manure to surface water via runoff. However, in some landscapes, incorporation of manure may increase the risk of soil erosion due to wind, water or tillage.

Rotational Tillage – Some lands are only tilled occasionally throughout the crop rotation. Perennial forage crops are examples of these systems. Manure can be injected or incorporated most effectively when the field is tilled in the establishment year of the perennial forage crop. In-season and split applications of surface-applied manure are more feasible in future years because perennial forages generally have low crop tolerance to soil disturbance once the crop is established. Recent developments in application equipment, such as low disturbance injectors and the aerator, offer producers more opportunities for subsurface placement of manure.

Zero-tillage – Annual crops in a zero-till system are also good recipients for manure, although there are fewer options for how to apply the manure. Incorporation of surface-applied manure is not possible in zero-till systems and even low-disturbance manure injection technology results in tillage-like disturbance of the soil. Surface application of manure to zero-till land elevates the risk of nutrient loss from volatilization and surface runoff. Therefore, other manure management practices, such as timing of application, must be relied upon to maximize the fertility value of the manure and minimize environmental risk.

Table 1. Suitability of manure application methods for each tillage system.

Application Method	Annual Tillage	Rotational Tillage	Zero-tillage
Deep injection of liquid manure	Well suited	Suitable only in the year when the soil is tilled	Unsuitable due to level of soil disturbance
Low-disturbance injection of liquid manure	Suitable, however, pooling and volatilization may be elevated without incorporation	May be suitable on established crops depending on the level of disturbance that can be tolerated	May be suitable depending on the level of disturbance that can be tolerated
Surface application using the dribble bar	Suitable, however, volatilization losses will be elevated without incorporation	Suitable, however, volatilization losses will be elevated when incorporation is not possible	Suitable, however, volatilization losses will be elevated because incorporation is not possible
Surface application using a low-level splash-plate	Suitable, however, volatilization losses will be considerably elevated without incorporation	Suitable, however, volatilization losses will be considerably elevated when incorporation is not possible	Suitable, however, volatilization losses will be considerably elevated because incorporation is not possible
Surface application using a high-level splash-plate	Suitable, however, volatilization losses will be greatly elevated without incorporation	Suitable, however, volatilization losses will be greatly elevated when incorporation is not possible	Suitable, however, volatilization losses will be greatly elevated because incorporation is not possible
Irrigation	Unsuitable due to extremely high odour production, N losses due to volatilization, decreased N:P ratio of manure and soil P loading risk		
Surface application of solid manure	Suitable with incorporation	Suitable, however, incorporation only possible when the soil is tilled	Suitable, however, incorporation not possible

Crop Nutrient Utilization and Removal

Nitrogen and phosphorus uptake and removal vary by crop (Tables 2 and 3). Nutrient uptake is the total quantity of nutrient taken up by the plant and stored in the roots, leaves and seeds. Nutrient removal refers to only the quantity of nutrient that is in the harvested portion of the plant and is exported from the field.

Table 2. Estimated rates of nitrogen uptake and removal for various crops.[1]

Crop	Uptake per Unit of Crop [2]	Removal per Unit of Crop [3]	Example Manitoba Target Yields [4]	N removed from a field (lb/ac) [3]
Alfalfa	N/A	58.0 lb/ton	5 tons/ac	290
Barley - Grain	1.39 lb/bu	0.97 lb/bu	80 bu/ac	78
Barley - Silage	N/A	34.4 lb/ton	4.5 tons/ac	155
Canola	3.19 lb/bu	1.93 lb/bu	35 bu/ac	68
Corn - Grain	1.53 lb/bu	0.97 lb/bu	100 bu/ac	97
Corn - Silage	N/A	31.2 lb/ton	5 dry tons/ac	156
Dry edible beans	N/A	4.17 lb/cwt	18 cwt/ac	75
Fababeans	8.4 lb/cwt	5.02 lb/cwt	34 cwt/ac	171
Flax	2.88 lb/bu	2.13 lb/bu	24 bu/ac	51
Grass hay	N/A	34.2 lb/ton	3 tons/ac	103
Lentils	5.08 lb/cwt	3.39 lb/cwt	18 cwt/ac	61
Oats	1.07 lb/bu	0.62 lb/bu	100 bu/ac	62
Peas	3.06 lb/bu	2.34 lb/bu	50 bu/ac	117
Potatoes	0.57 lb/cwt	0.32 lb/cwt	400 cwt/ac	128
Rye	1.67 lb/bu	1.06 lb/bu	55 bu/ac	58
Soybeans	5.2 lb/bu	3.87 lb/bu	35 bu/ac	135
Sunflowers [5]	N/A	2.80 lb/cwt	22 cwt/ac	62
Wheat - Spring	2.11 lb/bu	1.5 lb/bu	40 bu/ac	60
Wheat - Winter	1.35 lb/bu	1.04 lb/bu	75 bu/ac	78

[1] Nutrient uptakes and removals for all crops except sunflowers were adapted from Nutrient Uptake and Removal by Field Crops, 2001. Compiled by the Canadian Fertilizer Institute. http://www.cfi.ca/files/publications/archive/d161_NU_W_01.pdf

[2] Total nutrient taken up by the crop

[3] Nutrient removed in the harvested portion of the crop.

4 Example target yields for Manitoba. Actual yields for any parcel of land should be used to calculate field specific nutrient removal values. Actual yields depend on the agricultural capability of the land, climate and the producer's management practices.

5 Nutrient uptake and removal for sunflowers were adapted from "Nutrients Removed in Harvested Portion of Crop" complied by the International Plant Nutrition Institute. http://www.ipni.net/ppiweb/ppibase.nsf/$webindex/article=FC18933385256A00006BF1AD5F8663ED

Table 3. Rates of phosphorus (as P_2O_5) uptake and removal for various crops.[1]

Crop	Uptake per Unit of Crop [2]	Removal per Unit of Crop [3]	Example Manitoba Target Yields [4]	P_2O_5 removed from a field (lb/ac) [3]
Alfalfa	N/A	13.8 lb/ton	5 tons/ac	69
Barley - Grain	0.56 lb/bu	0.42 lb/bu	80 bu/ac	34
Barley - Silage	N/A	11.8 lb/ton	4.5 tons/ac	53
Canola	1.47 lb/bu	1.04 lb/bu	35 bu/ac	36
Corn - Grain	0.63 lb/bu	0.44 lb/bu	100 bu/ac	44
Corn - Silage	N/A	12.7 lb/ton	5 dry tons/ac	64
Dry edible beans	N/A	1.39 lb/cwt	18 cwt/ac	25
Fababeans	2.90 lb/cwt	1.79 lb/cwt	34 cwt/ac	61
Flax	0.83 lb/bu	0.65 lb/bu	24 bu/ac	16
Grass hay	N/A	10.0 lb/ton	3 tons/ac	30
Lentils	1.37 lb/cwt	1.03 lb/bu	18 cwt/ac	19
Oats	0.41 lb/bu	0.26 lb/bu	100 bu/ac	26
Peas	0.84 lb/bu	0.69 lb/bu	50 bu/ac	35
Potatoes	0.17 lb/cwt	0.09 lb/cwt	400 cwt/ac	36
Rye	0.84 lb/bu	0.45 lb/bu	55 bu/ac	25
Soybeans	0.90 lb/bu	0.84 lb/bu	35 bu/ac	29
Sunflowers [5]	N/A	1.10 lb/cwt	22 cwt/ac	24
Wheat - Spring	0.8 lb/bu	0.59 lb/bu	40 bu/ac	24
Wheat - Winter	0.61 lb/bu	0.51 lb/bu	75 bu/ac	38

[1] Nutrient uptakes and removals for all crops except sunflowers were adapted from Nutrient Uptake and Removal by Field Crops, 2001. Compiled by the Canadian Fertilizer Institute. http://www.cfi.ca/files/publications/archive/d161_NU_W_01.pdf

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Forage and Legume Crops and Manure Application

Highly productive legume and forage crops use much more N than cereal crops and oilseeds (Table 2). Although legumes can meet their N requirements by fixing atmospheric N they are also capable of withdrawing N from soil, manure or commercial fertilizer. As such, some legumes – such as alfalfa - are good recipients for manure because they are high nutrient users. Other legumes which are poor fixers of nitrogen – such as dry beans (e.g. navy, pinto, kidney) – may also benefit from manure application. However, manure should not be applied directly to growing crops that are being produced for human consumption.

There are some potential disadvantages of fertilizing legumes with manure. They include:

- elevated levels of available N early in the season may inhibit nodulation and reduce N-fixing capacity
- elevated N levels early in the growing season may adversely impact growth, yield and quality of soybeans

Some high yielding forage and legume crops also use more P than annual cereal crops and oilseeds (Table 3). If soils have elevated P levels and reduction is desired, crops with high P removal rates can be added to the rotation and fertilization practices adjusted accordingly. Manure application may have to be rotated with only commercial N fertilizer to adequately reduce soil P build-up.

Fertilization of native or tame perennial forage stands can affect the relative dominance of different forage species. Over time, species that respond well to applied nutrients tend to become dominant after manure application, while those that thrive under low fertility conditions tend to become less dominant. Although forage yield may increase with manure application, the potential shift in plant species on pasture should be considered when planning where to apply manure.

Mechanically harvested forage land – Mechanically harvesting forage crops removes most of the aboveground biomass. Consequently, nutrient removal is high on mechanically harvested forage fields, making them appealing crop choices on fields where nutrient levels are elevated.

Grazed forage land and pastures – Pastures generally respond well to manure application because their soil N fertility is often depleted after years of grazing with little or no N supplementation. However, in contrast to mechanically harvested forage lands, crop P removal from pastures is low as the P consumed is re-deposited on the field by the grazing livestock. Soil P build-up on pasture lands should be monitored where manure is regularly applied. It may become necessary to rotate manure application with commercial N fertilizer to reduce soil P build-up or to harvest the forage mechanically on grazed fields with rising P levels.

Consideration should be given to providing a period of time between manure application and subsequent grazing so that the stand can make use of the applied nutrients. This practice will ensure a stronger re-growth of the pasture grasses and minimize the risk of nutrient loss to the environment. Delaying grazing following broadcast application of manure is also recommended as a preventive measure against transmission of potentially harmful pathogens that may be present in livestock manure.

Matching Manure Application Rates to Crop Nutrient Needs

Soil sampling is the first step in establishing an appropriate manure application rate. It is the only way to directly determine the plant-available nutrient status of a field and to receive a field-specific fertilizer recommendation. The nutrient content of the manure can be determined from book values or, preferably, manure nutrient analyses. Manure application rates are then calculated based on fertilizer recommendations or crop nutrient removal estimates for realistic crop yield targets. Calibration of manure application equipment is necessary to ensure that the target manure rate is being achieved. These principles reduce the likelihood of over-application of manure.

Over-application of manure increases the risk of nutrient losses to the environment. There are also agronomic issues associated with over-application of manure. These include:

- cereal crops, flax, soybeans - high N rates may cause lodging and/or delayed maturity;
- green feed crops - excessive application of N may result in high nitrate content that poses a health risk to livestock; tissue testing should be done to identify toxicity

Crop N Needs and the Timing of Manure N Release

Manure contains organic and ammonium N. The ammonium in the manure is immediately available to the crop and behaves similarly to ammonium fertilizer. The organic N in the manure must be converted to inorganic N before it is available to the crop. If most of the N in the manure is in the organic form, the manure behaves like a slow-release fertilizer. The timing of manure N availability should coincide with the N needs of the crop.

Delayed or prolonged N availability from manures with most of the N in the organic form (which becomes available later in the growing season) may be **detrimental** to certain crops such as:

- cereals and canola because these crops take up most of their N early in the season and any delay in N availability is detrimental to early season growth and yield
- canola if the prolonged release of organic N in manure favours protein production over oil and increases green seed content
- malting barley if the prolonged release of N increases protein content above acceptable levels for malting

Prolonged N availability from manure may be **beneficial** to certain crops such as:

- long season crops such as corn, dry beans and sunflowers if the prolonged release of N better matches the N uptake pattern of these crops
- cereal crops that take up late season N and apportion it into protein such as wheat

Adapting the Rotation to Retrieve Leached Nitrates

Over-application of manure or unexpectedly poor crop performance can lead to excess soil nitrates that leach below typical crop rooting depths. Including deep-rooting crops (Table 4) in the rotation can reduce nitrate-N accumulations deeper in the soil profile. The greater water demand from these crops (Table 4) can reduce the amount of water at risk of leaching and may draw water and nitrate up to where the crop can utilize it.

Table 4. Depth of root penetration and annual water use for various crops.

Crop	Annual Water Use (in.)	Root Penetration (ft)
alfalfa	20	14
sainfoin	16	11
Russian wild ryegrass	13	7
tall wheatgrass	12	7
sweetclover	11	7
sunflower	not available	6
barley & wheat	7	4

Examples of Crop Rotations Fertilized with Manure

The following are some typical crop rotation scenarios in which manure may be used as a fertility source. In some scenarios, manure is not applied annually to the same field. Periodic application of manure (i.e. rotation of manured fields) can be used to manage elevated soil nutrient levels.

The star (*) denotes the optimal point in the rotation for manure application. A star immediately following the crop indicates a fall manure application whereas a star immediately preceding the crop indicates a spring manure application.

Traditional small grain rotation

Year 1		Year 2		Year 3		Year 4
spring seeded cereal	→	spring seeded oilseed	→	spring seeded cereal	→	spring seeded oilseed
spring wheat *		canola *		barley		flax *

- In this rotation, manure is applied: in the fall following the wheat crop (to fertilize the canola crop); in the fall following the canola crop (to fertilize the barley crop); and in the fall following the flax crop (to fertilize the next wheat crop).
- Manure is not recommended following the barley crop due to the low N demand of flax.

Traditional rotation plus winter cereal

Year 1		Year 2		Year 3		Year 4
spring seeded cereal	→	spring seeded oilseed	→	fall seeded cereal	→	spring seeded oilseed
spring wheat *		canola *		winter wheat		flax *

- In this rotation, manure is applied: in the fall following the wheat crop (to fertilize the canola crop); in the fall following the canola crop (to fertilize the winter wheat crop); and in the fall following the flax crop (to fertilize the next wheat crop).
- Injection or incorporation of manure in the fall prior to seeding winter wheat may damage standing stubble, reducing its snow-trapping potential and jeopardizing survival of the crop over the winter.
- Manure application in the spring of a winter wheat crop year may cause some damage to the stand through leaf tissue burning or wheel traffic, however, anecdotal evidence indicates that this practice can be employed safely in Manitoba.

Traditional rotation plus annual legume

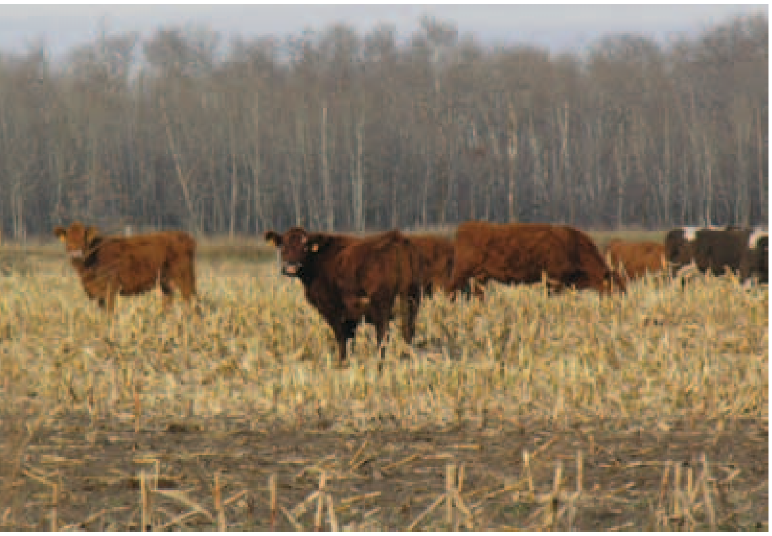
Year 1		Year 2		Year 3		Year 4
spring seeded cereal	→	spring seeded cereal	→	spring seeded legume	→	spring seeded oilseed
spring wheat *		corn		soybean *		canola *

- In this rotation, manure is applied: in the fall following the wheat crop (to fertilize the corn crop); in the fall following the soybean crop (to fertilize the canola crop); and in the fall following the canola crop (to fertilize the spring wheat crop).
- Manure application prior to the soybean crop should be avoided because nodulation may be inhibited - devaluing the inoculant and the manure. As well, supplying all of the crop N requirements at the beginning of the growing season with a single manure application may result in delayed maturity and reduced yield and quality due to excessive vegetative growth.

Livestock rotation including silage and forage

Year 1		Year 2		Year 3		Years 4, 5 and 6
spring seeded cereal	→	fall seeded cereal	→	spring seeded silage	→	perennial forage
barley *		winter wheat *		silage corn		* alfalfa

- In this rotation, manure is applied: in the fall following the barley crop (to fertilize the winter wheat); in the fall following the winter wheat crop (to fertilize the corn); and in the spring prior to establishing the alfalfa crop.
- Features of this rotation include early spring growth (winter wheat), high nutrient demand (corn), deep rooting crop, soil quality improvement and erosion protection (alfalfa).



- Manure can be applied to established alfalfa but it must be carefully timed, either early in spring or shortly after a cut, in order to avoid damage from compaction and burning at an advanced growth stage.
- Potassium accumulation in forage can increase on heavily and/or repeatedly manured fields. If this forage is to be fed to dry dairy cows, there can be herd health concerns. Potassium levels in forage should be monitored.

Summary

Manure is an alternative to commercial fertilizer that can be integrated into most cropping systems. However, tillage operations and crop rotations will affect how manure is included in a farm's fertilization program. In particular, whether or not the manure can be injected or incorporated is determined by the operation's tillage practices. Options are very limited for zero-tillage, as compared to conventional and rotational tillage systems, in order to avoid soil disturbance.

Crops vary considerably in their uptake and removal rates for both N and P. Producers may elect to include certain crops in the rotation in order to better use manure nutrients and manage soil nutrient levels. Productive forage crops have relatively high nutrient removals, making them attractive choices for lands with elevated soil nutrients. However, it is only through mechanical harvesting that high nutrient removal rates are achieved, as nutrients are largely redeposited by the livestock on manured fields that are grazed.

Matching manure application rates to crop requirements or removals is essential for sustainable manure management. Over-application of manure N has significant agronomic consequences such as lodging and delayed maturity. In addition to the rate of application, taking into account the timing of manure N availability can be critical to achieving yield and quality goals.

Over-application of manure N also increases the risk of nitrate leaching. Including crops in the rotation that have a high water demand and can retrieve deep-leached nitrates can reduce the risk of nitrate contamination of ground water.

Tillage systems and crop nutrient needs determine how manure can be incorporated into any crop rotation. With proper planning, most operations can benefit from using manure and reduce their reliance on commercial fertilizer.

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**