Applying Manure on Perennial Forage



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Introduction

This manual's objective is to provide livestock and perennial forage crop producers with the information and tools to make decisions about applying manure on perennial forage crops. It also contains information on the regulations for applying manure on forage crops, and resources for more in-depth information or assistance.

As of January 1, 2003, there were approximately 6.1 million head of cattle and calves on Alberta farms, as well as 2.14 million pigs. Tame forage acreage (hay and pasture) was approximately 10 million acres (4.05 million ha) and native range an additional 15 million acres (6.10 million ha). Thus, forage land accounts for a substantial part of the area available for application of livestock manure. Under some circumstances, manure spreading on perennial forages may be the best option available.

Nutrient management is the process of balancing nutrients in fertilizers, manure and soil with the requirements of the crops. For the livestock producer who needs to recycle the nutrients in manure, this requires determining the total amount of manure available, the composition of the manure, the plant availability of manure nutrients and the requirements of the crop that will receive the manure. A manure application rate that will meet the crop's needs without leading to over-application and the required land area to use the quantity of manure available can then be calculated. From a forage producer's perspective, the goal is to apply the appropriate amount of manure to supply the crop's nutrient requirements. The forage producer starts with a crop nutrient requirement, uses manure nutrient content and availability, and calculates an application rate. Based on the amount of forage land, the end result is the total amount of manure required.

By explaining the 'whys and hows' of these various steps, this manual will help livestock producers who have manure to recycle and forage land available for manure application, and forage producers who want to apply manure from a nearby livestock operation.

Pros and Cons of Applying Manure on Perennial Forage

Advantages

Manure can be a valuable source of nutrients for forage crops. It is a “complete” fertilizer, containing varying amounts of all the major plant nutrients – nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) – as well as essential micronutrients such as calcium (Ca), magnesium (Mg), copper (Cu), manganese (Mn), iron (Fe) and zinc (Zn).

Manure applications may also improve soil physical properties such as water infiltration rate, aggregate size and stability, pore size and crust strength. These improvements in turn translate into better soil quality, particularly for degraded soils, and improved productivity.

Manure broadcast on perennial forages has a lower potential for nutrient losses through runoff or erosion and less likelihood of contamination of adjacent water bodies compared to broadcast application without incorporation on cultivated cropland.

Perennial forage land may provide options for manure application throughout the growing season rather than just at the beginning or end of the season, as with cultivated crops. For example, manure may be spread immediately following a hay harvest or on pasture after livestock are moved to a new paddock. With this greater flexibility in application timing, it may be possible to have shorter manure storage periods and therefore smaller manure storage facilities (at less cost).

Perennial forages can use more nutrients than annual crops because perennial forages grow for a longer portion of the year. As well, the extensive root system of forages and the deep root system of alfalfa in particular can scavenge nutrients from the soil profile more efficiently than annual crops. This characteristic of forages may also reduce the likelihood of nutrients leaching out of the root zone and eventually finding their way into the groundwater. The relatively high water use of perennial crops may also decrease deep percolation of water and thus decrease the probability of groundwater contamination. While alfalfa is generally considered to be a crop with low N requirement due to its N-fixing capability, it will use large quantities of soil mineral-N if available.

Disadvantages and Risks

The disadvantages and risks associated with manure application on perennial forage are primarily due to method, timing and rate of application. Broadcast application of liquid manure without incorporation can result in volatilization losses of N as high as

30%, compared with less than 2% for injected and 5% for broadcast and incorporated, which is only feasible with annual crops.

Broadcasting manure without incorporation also leaves nutrients and pathogens, which may be present in the manure, more susceptible to removal in runoff. This may result in contamination of surface water and potential health and/or environmental impacts.

Broadcasting manure on actively grazed pastures may result in livestock refusal to graze fouled forage. This is more of an issue with liquid manure than solid. Crop smothering can occur if high rates (in excess of 50 to 60 tons/acre (110 to 132 tonnes/ha)) of solid manure are applied or if application is not uniform and large clumps are deposited. Uniform application can be especially difficult when long-stemmed bedding is used in large quantities.

Whether the N source is manure or commercial inorganic fertilizer, application of more N than the crop can use for growth and convert to organic forms will cause accumulation of high levels of nitrate (NO_3) in the crop and the potential for nitrate poisoning. Therefore, care must be taken that N application rates do not exceed crop requirements. If in doubt, test the forages for nitrate levels.

Potassium concentrations in grasses that receive manure applications may also be an issue. Very high K concentrations in a ration can cause reduced absorption of calcium (Ca) and magnesium (Mg), which in turn can cause metabolic disorders in cattle including milk fever and calving problems. Urine output is greatly increased and therefore the risk of kidney failure is increased when cattle are on a ration very high in K. Potassium content of grasses appears to generally increase as a result of manure application. However, the K concentration alone may not be the only factor in such animal health issues. Low Mg:Ca ratios and Mg:(K+Ca) ratios can cause grass tetany. There are species differences in these ratios even when K concentrations are similar. Forage testing can indicate potential problems.

Species composition of mixed forage stands (native and tame) is altered by increasing fertility levels. Because species that are more responsive to higher fertility tend to become dominant, forage production may increase due to the change in species mix but biodiversity is lost.

Weed infestations originating from seeds in manure are another possible drawback to applying manure on forage. These infestations are generally more difficult to deal with in forage crops than in annuals. Weeds in hay can decrease its quality and value especially in horse-hay or dairy-quality alfalfa. If weeds are a concern, then consider composting manure. Proper composting will kill most weed seeds.

Manure as a Source of Nutrients

Manure Composition

The nutrient concentrations of animal manures vary greatly, creating challenges to using them effectively. Concentrations and ratios among N, P and K vary with type and age of animal, diet, bedding, manure moisture content, and other factors.

Table 1. Nutrient content of typical agricultural livestock manures for various species

Livestock species and type		Moisture % range (average)	Total N % range	Total N*		Available N**		Crop N***		Total P	
				lb/ ton	kg/ tonne	lb/ ton	kg/ tonne	lb/ ton	kg/ tonne	lb/ ton	kg/ tonne
Beef	Feeders Finishers Feeder calves Cows w/calves Cows/bulls	30 - 70 (50)	0.65 - 1.25	20.0	10.0	5.1	2.6	6.5	3.2	4.8	2.4
	Paved feedlot	50 - 75 (65)	0.45 - 0.80	14.0	7.0	5.4	2.7	5.0	2.5	1.7	0.9
Dairy	Free stall	85 - 95 (90)	0.35 - 0.60	8.0	4.0	3.6	1.8	3.3	1.7	1.7	0.9
	Tie stall Loose housing Replacements Calves	70 - 85 (80)	0.45 - 0.65	10.0	5.0	4.2	2.1	3.8	1.9	1.7	0.9
Swine	Liquid	90 - 99 (96)	0.20 - 0.55	7.0	3.5	3.2	1.6	3.1	1.6	2.2	1.1
	Solid	40 - 70 (50)	0.60 - 0.90	16.0	8.0	6.4	3.2	6.2	3.1	3.0	1.5
Poultry	Layers (solid) Belt cage	30 - 60 (40)	2.50 - 3.50	60.0	30.1	40.0	20.1	37.7	18.9	30.8	15.4
	Layers (solid) Deep pit	30 - 60 (40)	2.00 - 3.00	48.0	24.1	32.0	16.0	30.1	15.1	24.6	12.3
	Layers (liquid)	85 - 95 (90)	0.50 - 1.00	12.0	6.0	8.0	4.0	7.5	3.8	5.0	2.5
	Broilers Pullets	30 - 50 (35)	3.50 - 4.00	68.0	34.1	38.9	19.5	36.8	18.4	19.0	9.5
	Breeders	30 - 50 (35)	1.60 - 2.10	60.0	30.1	34.3	17.2	32.4	16.3	19.0	9.5
Turkey	Breeders	30 - 50 (35)	1.50 - 2.00	35.0	17.5	20.0	10.0	18.0	9.5	11.8	5.9
Horses	Feedlot	30 - 60 (50)	1.00 - 2.00	30.0	15.0	15.0	7.5	14.3	7.1	4.6	2.3

* *Total N: The total of both inorganic and organic forms of nitrogen in the manure.*
** *Available N: Inorganic nitrogen (available to plants).*
*** *Crop N: (Inorganic nitrogen + that portion of organic nitrogen that is expected to be converted to inorganic forms during the year of application) - expected nitrogen losses during the year of application.*

Source: Agricultural Operation Practices Act, *2001*

Manure Testing

Book values, giving averages and ranges of nutrient content for different types of animal manures (Table 1), are a good place to start in calculating manure application rates. However, variation in manure nutrient content can easily lead to under- or over-application of nutrients, neither of which is desirable. More precise nutrient management can be achieved by analyzing manure samples to determine actual nutrient concentrations.

By sampling and testing manure annually as it is being applied, producers can build a database of the typical nutrient concentrations from their operation. This is the best source of information from which to calculate manure application rates. It will also indicate changes in manure nutrient concentrations resulting from changes in management (e.g. feed, bedding, etc.). Manure may be sampled prior to or during spreading, and there are pros and cons to either way. Sampling procedures vary with the manure system and time of sampling.

Timing of Sampling

Sampling before hauling

Pros:

Timeliness	Test results can be used to determine this year's manure application rates. This is strongly recommended when the first manure analyses are being done for an operation.

Cons:

Accuracy	Obtaining a representative sample prior to hauling and applying manure is difficult due to the non-uniform nature of a bedding pack, stockpile, storage lagoon or compost windrow. Tests will not be representative if manure is not thoroughly mixed.
Safety	Sampling manure storage structures, especially pits or tanks, can be dangerous due to risk of falling into the manure or being overcome by hydrogen sulphide (H_2S) and ammonia (NH_3). For more information, see *Ammonia Emissions and Safety* (Alberta Agriculture, Food and Rural Development, Agdex 086-2) and *Hydrogen Sulphide Emissions and Safety* (Alberta Agriculture, Food and Rural Development, Agdex 086-8).

Difficulty	Accessing manure in storage facilities or from deep within a manure pack or stockpile can be difficult and time consuming.
Timing	For liquid systems, agitation of lagoons is done when the lagoon is to be emptied. The turnaround time for sample shipping, analysis and return of results may make it impossible to use the current year results for calculating manure application rates. Quick-test kits can give ball-park numbers, which may be better than book values.

Sampling during application

Pros

Accuracy	Tests should be more representative because the process of agitating and mixing during loading results in a more consistent product. Sub-samples can be taken from several loads.
Speed	Sampling during application generally requires very little time.
Safety	Sampling manure from application equipment reduces risk of falling into manure or being overcome by gases.

Cons

Timing	The results obtained from samples collected during hauling cannot be used to plan the current year's application rates. However, they can be used to determine whether adequate amounts of plant nutrients were applied and can provide an estimate for next year's manure nutrient content.

Sampling Procedures

Solid manure

Sampling from piles, packs or loose-housing areas
To get an estimate of the variability, more than one composite sample should be collected and sent for analysis. Manure should be taken from several depths and locations throughout the pile or pack using a fork or spade. Due to the difficulty of obtaining samples from the middle of a large solid manure pile, it may be necessary to access the centre of the pile using a front-end loader. A sample can then be obtained from the loader bucket.

Sampling during spreading
Single samples can be taken from each of several spreader loads during loading. Spreader loads should be sampled at the beginning, middle and end of the application process with the total number needed depending on the amount of manure to be spread. As samples are collected, they should be stored in a cool location until sampling is complete.

Obtaining a representative sample
Whether samples are obtained before or during spreading, they must be adequately mixed and then sub-sampled to obtain a final sample that is as representative as possible of the entire mass to be spread. The following method is recommended:

- **Step 1.** Combine all samples on a plastic sheet or cement pad and mix thoroughly. Break up large clumps with a fork or spade.
- **Step 2.** Divide the well-mixed manure into four portions.
- **Step 3.** Discard two of the four portions.
- **Step 4.** Combine the remaining two portions and mix.
- **Step 5.** Repeat steps 2, 3 and 4 until the remaining sample is small enough to send for analysis, that is, about 1 lb (0.5 kg).

Poultry manure

Collect eight to ten samples from the entire barn down to the depth to which the litter will be removed. Thoroughly mix the samples in a large pail, and make a 1lb (0.5 kg) composite sub-sample.

Liquid manure

Sampling from pits or lagoons
Sampling pits or lagoons is not recommended due to the hazards of manure gases such as ammonia and hydrogen sulphide, and the danger of falling into the manure.

Never enter an enclosed area that contains manure without wearing proper respiratory equipment.

For more information, see *Respiratory Protection for Producers* (Alberta Agriculture, Food and Rural Development, Agdex 086-8).

If it is necessary to sample directly from a lagoon or a pit, agitation prior to sampling is desirable because the solids tend to settle out of liquid manure over time. A can attached to a long pole may be used to dip into the pit or lagoon, taking samples from near the top, middle and bottom of the structure at several locations. Alternatively, an 8 to 10 ft (2.4 to 3.0 m) length of ¾ inch (18 mm) PVC pipe can be pushed into the manure. The pipe's top opening can be sealed by a hand over the opening, and the pipe withdrawn and emptied into a bucket. The samples should be mixed and then sub-sampled to obtain a representative sample (usually about 1 L).

Sampling during application
If a manure tanker is being used, single samples can be taken from each of several loads, and then mixed and sub-sampled to obtain a representative sample (usually about 1 L). If using a drag hose system, several samples can be taken at intervals from the tap near the pump or from the injectors when they are lifted out of the ground. Manure samples can be collected during manure irrigation by placing catch cans randomly in the field. The collected samples must be mixed and sub-sampled.

Handling and shipping samples

It is best to consult the manure testing lab on lab-specific requirements for sample size, packaging and shipping, turn-around times, analytical options and costs. Some labs provide containers, labels and submission forms for manure samples. Generally, zip-lock bags are suitable for solid manure and 1 L plastic bottles with airtight closure for liquid manures.

Leakage, nutrient loss by volatilization, moisture loss and nutrient transformations must be prevented as much as possible. Therefore, the following are recommended:

- Liquid manure containers should be no more than three-quarters full to provide air space in the container for manure gases and to allow for expansion if the contents are frozen.

- Samples should be kept cool, either by refrigeration or by placing on ice until they are transported to the lab.
- Samples should be transported within a day. If this is not possible, they should be frozen until shipped.
- Samples should spend no more than two days in transit. Shipping should be scheduled to ensure that samples are not held over weekends or holidays.

Required Analyses

The following analyses are required to provide the information necessary to assess availability of major plant nutrients and potential soil impacts:

- moisture content or dry matter content
- total N
- NH_4-N (ammonium)
- total P
- total K
- salinity (measured by electrical conductivity)

Nutrient Availability from Manure

The greatest challenge to supplying crop nutrient requirements from manure sources is balancing supply and demand because the ratio of N:P in manure is very different from that required by crops. Typically, N:P ratios range from 5:1 to 7:1 for liquid dairy manure, 2.5:1 to 3:1 for hog manure, 1.5:1 to 2.2:1 for poultry manure and 3:1 for beef manure. Crops require N:P in the range of 8:1 to 10:1.

Nitrogen (N)

Raw manure

Nitrogen supplied from manure can produce an equivalent crop response to that from inorganic N sources such as commercial fertilizers. Nitrogen is present in manure in organic and inorganic fractions. Total N and the proportions in the inorganic (available) and organic (mostly unavailable) forms vary with livestock species and manure form (Table 1). Inorganic or mineral N consists primarily of ammonium, which is subject to loss to the atmosphere through volatilization. Small amounts of inorganic N are present as nitrate, which does not volatilize, but may be lost through leaching.

A portion of the organic N in manure will be mineralized (converted from organic to inorganic forms primarily through microbial action) and become plant-available during the year of application. The inorganic N plus mineralized N minus a factor for expected N loss constitute what is termed 'crop N', which is the number used to calculate application rates. As seen in Table 1, crop N in the year of application can range from about 3 to nearly 40 lb/ton (1.5 to 20 kg/tonne), depending on livestock species and manure form. The rate of mineralization depends on the total N concentration and the carbon to nitrogen (C:N) ratio of the manure, temperature, moisture, soil aeration and other factors. Nitrogen mineralization is rapid under warm, moist, well aerated conditions when the C:N ratio is about 9:1 or less.

Nitrogen can be lost by volatilization to the air, leaching out of the crop root zone, and runoff. The magnitude of these losses depends on many factors including manure form, application method, temperature during and after application, rainfall (or irrigation) timing and amount, soil texture, soil moisture, and field topography. Broadcast liquid manures are highly susceptible to volatilization losses, but the losses are mostly eliminated if injection is used. Losses are greater when manure is applied during hot, dry conditions compared to cool, moist conditions.

Leaching losses are more likely to occur for coarse-textured than fine-textured soils, while runoff losses tend to have the opposite relationship to soil texture, due to the difference in infiltration rate. Rainfall soon after manure is broadcasted can reduce volatilization losses but, depending on intensity and duration, may increase runoff losses.

Compost

Like raw manure, compost can be used to supply the N requirements of crops. However, most of the inorganic N in raw manure is either volatilized or converted to stable organic nitrogen compounds by microbial action during composting. Therefore, N loss at the time of application is low, but the N available during the year of application (crop N) is also low. Crop N as a proportion of total N in compost is less than half that of liquid dairy manure and less than one-third that of ammonium-nitrate fertilizer. Therefore, the application rate of compost has to be high if the crop's N requirements are to be supplied only by the compost. The N:P and N:K ratios of compost are lower than those of raw manure, so applying compost at a rate that supplies all the crop's N requirement is likely to result in a greater accumulation of excess P and K compared with applying raw manure. A better alternative is to use compost as a P source and to add commercial fertilizer N as required to meet the crop's N requirements.

Detailed information on composting methods and regulations and compost use can be found in the *Manure Composting Manual* (Alberta Agriculture, Food and Rural Development, 2005).

Phosphorus (P)

Phosphorus in manure is mostly inorganic and converts quickly to a plant-available form, so that between 50 and 100% of the P in manure will be available in the year of application. The range is due to differences in soil texture, organic matter content and microbial populations as well as differences in manure source (cattle versus swine or poultry). In severely P-deficient soils, large amounts of P can become unavailable through adsorption and other mechanisms.

Phosphorus is not subject to volatilization losses. It moves slowly through the soil profile so leaching is of little concern unless large amounts of P are applied over a long period of time. Losses through erosion or runoff can be large and can contribute to poor surface water quality.

Plants tend to take up only the P that they require. Therefore, a manure application rate that is high enough to meet crop N needs in the year of application may supply P needs for several years. Soil testing is required to monitor available P from year to year.

Potassium (K)

Potassium in manure is mostly in inorganic forms and therefore virtually all K is available at the time of application. Manure application to supply the crop's N requirements will result in over-application of K. Plants are luxury consumers of K – that is, if it is available, they will take up more K than they require for normal growth and physiological development. High K concentrations in forage can cause health problems for cattle consuming the forage. Forage testing will indicate potential problems, and low-K forage from other sources can be mixed in the ration to reduce the overall K concentration.

Other Nutrients

Sulphur, Calcium, Magnesium, and many other micronutrients including boron, copper, manganese and zinc are also present in manure in varying concentrations, depending largely on the feed source and animal species. Poultry manures tend to be high in micronutrients because feeds are heavily supplemented with these constituents and animal nutrient retention is low.

The effect of manure application on crop chemical composition appears to be inconsistent. While some studies have found higher micronutrient concentrations following manure application, others have shown little effect. Generally, livestock rations in Alberta require some micronutrient supplementation. Forage testing will indicate what level of supplementation is required with feed produced from manured land.

Manure Application

Nutrient Management Planning

Nutrient management is the process of balancing nutrients in commercial fertilizers, manure and soil with the requirements of crops. A good manure management plan is one that is environmentally sound, maximizes crop yield and quality, minimizes nutrient loss during collection, storage and application, and maximizes nutrient use by crops.

Key components of a nutrient management plan are:

1. Manure testing (or using book values).
2. Soil testing to determine nutrient levels and other soil characteristics such as acidity/alkalinity (measured by pH) and salinity (measured by electrical conductivity).
3. Determining crop nutrient requirements based on realistic yield goals and considering all nutrient sources including legumes, commercial fertilizer, past manure applications and previous crops grown.
4. Calculating an appropriate rate of manure application.
5. Calibrating the spreader or injector to apply the calculated rate of manure.
6. Applying manure at the best time and in the best way possible to maximize nutrient use and minimize losses.
7. Keeping accurate and detailed field records.

Manure Application Planning

Site Selection

A number of factors influence the suitability of a forage stand for manure application.

Pasture versus hayland

Hayland may be more responsive to increased fertility since hay stands are likely to be in better health than pastures. However, manure application timing on hayland is restricted to early spring, immediately following a harvest, or fall. Timing may be more flexible on pastures, but grazing animals may have to be temporarily removed from manured pastures. Growth prior to application may be fouled by manure so time is needed to allow new plant growth. Also, animals that graze on freshly manured forage may risk picking up parasites or pathogens.

Nutrient removal by haying is much greater than by grazing. Up to 90% of ingested nutrients are returned to the land by grazing animals. Soil nitrate levels tend to increase under intensive grazing. Therefore, manure application rates and/or frequency will have to be less on pasture than on hayland.

Whether applying manure on hayland or pasture, a realistic yield potential based on the health of the stand, climatic and soil zones, and irrigation or dryland conditions is required to determine the crop's nutrient requirements and therefore the manure application rate. If available, a producer's own yield history and experience are the best source of this information. Alternatively, Agriculture Financial Services Corporation (AFSC) can provide yield averages for various forages within square township areas.

Crop species

The choice of crop species will vary according to the objectives of the nutrient management plan. If the objective is to apply as much manure as possible on the least land area, then alfalfa may be the crop of choice. Although legumes have the ability to fix atmospheric N, they will readily use soil N if it is available. For example, one study showed that alfalfa irrigated with swine lagoon water removed over three times as much N per acre as corn, which is normally considered to have a high N requirement. The deep-rooting characteristics of alfalfa also enable it to scavenge nutrients from deeper in the soil profile than can grasses. In general, alfalfa is likely to have a higher yield potential than grasses and, coupled with the higher N concentration in the crop, should result in greater N removal by alfalfa. Alfalfa also tends to consume more P than grasses (Table 2).

If increasing crop productivity is the primary objective, grasses tend to be more responsive to N fertilization than legumes.

Table 2. Typical nutrient removal by forage crops in Western Canada

Crop	Yield (tons/ac)	Nutrient removal (lb/ac)			
		N	P_2O_5	K_2O	S
Alfalfa	5.0	261 - 319	62 - 76	270 - 330	27 - 33
Clover	4.0	194 - 237	50 - 61	181 - 222	10 - 12
Grass	3.0	92 - 113	27 - 33	117 - 143	11 - 14

Source: Canadian Fertilizer Institute, 2001.

Native range versus seeded pastures or hayland

Seeded pastures show greater yield response to manure application than native range, but forage yields of native range can be significantly increased by manure application. There is some indication that native range will conserve slightly more of the N contained in liquid manure due to a reduction in volatilization losses of ammonia.

Environmental considerations

Alberta's *Agricultural Operation Practices Act* (AOPA) sets out regulations relating to the protection of common bodies of water[1] from contamination by runoff from manure application sites. Some of the minimum setback distances within which manure **must not be applied** are:

- Within 33 ft (10 m) of a common body of water if subsurface injection is used.
- Within 100 ft (30 m) of a water well.
- Within 500 ft (150 m) of an occupied building if not incorporated within 48 hours.

Table 3. Minimum setback distances for manure application on forage crops

Average slope	Required setback distance
Less than 4%	100 ft (30 m)
4 to 6%	200 ft (60 m)
6 to 12%	300 ft (90 m)
More than 12%	No application allowed

Minimum setbacks from a common body of water also vary with the average slope of the land where the manure is being applied (Table 3).

Manure application rates are limited by legislation according to soil salinity. Raw manure or compost must not be applied to soil if the salinity is greater than four deciSiemens per metre (dS/m) as measured by the electrical conductivity in the 0 to 6 inch (0 to 15 cm) depth of soil, or if the amount of manure applied will increase soil salinity in the 0 to 6 inch depth by more than one dS/m (AOPA Standards and Administration Regulation, Section 25).

Raw manure or compost must not be applied if the amount of manure applied will increase soil NO_3-N levels in the 0 to 24 inch (0 to 60 cm) depth to a level that equals or exceeds the specified limits as indicated in the AOPA regulations (Table 4).

Table 4. Nitrate-nitrogen limits in soil

Soil zone	Sandy textured soil (<45% sand and water table shallower than 4 m)	Sandy textured soil (<45% sand and water table deeper than 4 m)	Medium and fine textured soils
Brown	75 lb/ac (80 kg/ha)	100 lb/ac (110 kg/ha)	125 lb/ac (140 kg/ha)
Dark brown	100 lb/ac (110 kg/ha)	125 lb/ac (140 kg/ha)	150 lb/ac (170 kg/ha)
Black	125 lb/ac (140 kg/ha)	150 lb/ac (170 kg/ha)	200 lb/ac (225 kg/ha)
Luvisolic	100 lb/ac (110 kg/ha)	125 lb/ac (140 kg/ha)	150 lb/ac (170 kg/ha)
Irrigated	160 lb/ac (180 kg/ha)	200 lb/ac (225 kg/ha)	240 lb/ac (270 kg/ha)

[1] A common body of water is the bed and shore of an irrigation canal, drainage canal, reservoir, river, stream, creek, lake, marsh, slough or other exposed body of water, and a waterworks system. For complete details, see AOPA 2004.

Neighbour impact

One of the problems associated with manure application is odour. Relations with neighbours can be strained when manure is spread in a location where they are affected by the odours. As noted in the section on minimum setbacks, manure that is surface-applied and not incorporated must not be applied within 500 ft (150 m) of an occupied building.

Some additional practices to consider that may lessen odour impact are:

- Spread when winds are blowing away from dwellings or populated areas.
- Spread when temperatures are cooler to lessen volatilization of odour-producing compounds.
- Inject manure if possible.
- Reduce the angle of the deflector on broadcasting equipment to reduce the spreading arc.
- Communicate with neighbours to avoid spreading when they may have special outdoor activities planned.

Application Timing

Early spring application shortly after snowmelt has several advantages. Nutrients are available to the crop as it begins to grow, helping the crop achieve its yield potential. Nutrient uptake is maximized, and the potential for loss by leaching or runoff with spring snowmelt is minimized.

Manure can be applied mid-season, after a first cutting of hay is removed or after a first rotation of grazing. While timing may be more flexible on pastures, grazing animals may have to be removed for a period of time to allow new growth on the pasture after the manure application. As noted, manure applications may foul existing foliage, and livestock may pick up parasites or pathogens if they graze freshly manured forage.

Crop nutrient uptake and nutrient use are lower if manure is applied in the fall versus spring. Surface application in the fall increases the risk of nutrient loss by runoff. Poor ground cover increases this risk, while good ground cover reduces it. Fall application may allow a producer to use available labour, equipment and manure storage more efficiently.

Application Rate

To calculate the appropriate rate of manure application, three pieces of information are required:

1. **Soil nutrient status**
   This is determined by a soil test. Ideally, areas of a field that are dissimilar due to topography, soil texture, erosion, crop cover, or prior history of manure or fertilizer application should be sampled separately, and application rates calculated for each area. Practically, this may not be possible, and samples are usually taken at random throughout the field to provide an average of the field's nutrient status. For fields smaller than 80 acres (33 ha), at least 15 to 20 samples are needed to provide a representative sample of the field.

   Some key points to remember are:

   - A soil probe is the best tool to use for sampling to a depth of 24 inches (60 cm). Most fertilizer dealers will lend probes or can do custom sampling.
   - Take separate samples from the 0 to 6 inch (0 to 15 cm), 6 to 12 inch (15 to 30 cm) and 12 to 24 inch (30 to 60 cm) depths.
   - Thoroughly mix the samples from the same depth interval, creating one large sample for each of the three depth intervals. Remove a sub-sample of about 1 lb (0.5 kg) from each large sample.
   - Spread the sub-samples thinly on paper or a shallow container and air dry them as soon as possible. Take care to avoid contamination and to maintain correct identification of sub-samples.
   - Recommended analyses include NO_3-N, P, K, SO_4-S, pH and electrical conductivity.

   Recommendations from the soil testing lab for nutrient additions generally give ranges depending on the producer's yield goals and expectations.

2. **Available manure nutrients**
   An estimate of the nutrients available from manure to the crop in the current year is obtained from manure nutrient analysis or book values, as discussed previously.

3. **Crop nutrient requirements**
   These requirements need to be based on realistic yield goals for the producer's climatic and soil zones.

Nitrogen-based Applications

The formula used to determine the manure application rate for solid manure is:

Recommended N fertilizer rate (lb/ac) ÷ Crop N content of manure (lb/ton) = Application rate (tons/ac).

For example, if the recommended fertilizer N rate is 98 lb/ac and the estimated crop N from manure is 6.5 lb/ton, then the manure application rate is 98 ÷ 6.5 = 15.1 tons/ac. For liquid manure, the crop N is expressed in lb/1000 gal, and the application rate is in 1000 gal/ac, rather than tons/ac.

Table 5 shows how a producer can use expected crop yields, typical N concentration in the crop, soil test N levels and manure crop N values (from manure analysis or book values) to calculate the manure application rate to supply crop N requirements. This table shows the effect of crop type and soil N levels on manure application rates.

Table 5. Sample calculations for N-based manure application rates

Crop	(A) Expected yield (tons/ac)	(B) N removed by crop (lb/ton) (Table 2)	(C) N required by crop (lb/ac) (A x B) = C	(D) Soil nitrate N content (lb/ac) (soil test)	(E) Crop N from manure (lb/ac) (Table 1)	(F) Application rate (tons/ac) (C-D) ÷ E = F
Alfalfa	5.0	56	280	50	6.5	35.4
Bromegrass	3.0	36	102	10	6.5	15.1

If manure has been applied to the field within the past ten years, mineralization from prior applications must be included in the available N pool. A declining rate of mineralization over five years has been suggested with the rate in the first year after application being 10% of the residual N, and the rate for years two to five starts at 6% and declines 1% per year. Table 6 shows how carry-over N is calculated.

Table 6. Calculation of residual N from prior year's manure application

Years after application	(A) Total N applied or remaining (lb/ac)	(B) Crop N available	(C) Residual manure N A - B = C
0	708	230 (35.4 x 6.5)	478
1	478	48 (A x 10%)	430
2	430	26 (A x 6%)	404
3	404	20 (A x 5%)	384

The assumption is that the total N content of the manure was 1%. Manure was applied at 35.4 tons/ac (Table 6) resulting in a total N application of 708 lb/ac. Initial year crop N is 6.5 lb/ton (Table 1). The residual N at the end of one year becomes the total N pool for the next year. Ten percent of that will be mineralized and will be available to the crop. Calculation of residual N continues for five years following manure application, after which mineralization becomes inconsequential. If manure is applied annually, the required rate will become lower in succeeding years due to the residual effect from prior applications.

Phosphorus-based Applications

Continued annual applications of manure to meet the N requirements of a crop will lead to accumulation of excessive amounts of P over time. Therefore, a more sustainable approach to manure application is to apply it based on the P requirement of the crop.

The same procedure is used as for N except P values are used instead. For example, the alfalfa crop used in the N-based example would remove 15 lb P_2O_5 equivalent per ton of crop (Table 2). The P to be added would be 15 lb/ton × 5 tons/ac = 75 lb/ac. If the P available from the manure is 11 lb/ton, then the application rate would be 75 ÷ 11 = 6.8 tons/ac. Because crops tend not to take up more P than they require, it may be practical to apply manure to fields rotationally, applying a rate to meet P requirements for two or three years at one time or applying manure at an N-based rate and then not returning to that field for two to four years to allow use of the available P.

For grass crops, additional fertilizer N should to be applied to meet the crop's N requirement if manure is applied at a P-based rate. If crop N from manure in the year of application were 6.5 lb/ton, then 6.8 tons/ac would supply 44 lb N/ac. In the grass example used for N-based application, the total to be applied was 98 lb/ac. Therefore, the additional fertilizer N required would be 54 lb/ac. If manure were applied in consecutive years, residual N would need to be taken into account, as discussed previously in the N-based section.

Economic Benefit of Manure Application

Nutrients from manure can replace commercial fertilizer inputs so there is an economic value to manure application. A fertilizer equivalent value for manure can be calculated based on current prices for nutrients from inorganic fertilizer sources and the nutrient concentrations in the manure.

We will use arbitrary costs to show how a value can be derived. Assuming N at $0.40/lb of actual N, P at $0.38/lb of P_2O_5 and K at $0.22/lb of K_2O, and the crop N, P and K concentrations of the manure at 6.5, 11 and 15 lb/ton, respectively, in the year of application, then the value of the manure would be (6.5 × $0.40) + (11 × $0.38) + (15 × $0.22) = $10.08/ton. For an application rate of 15 tons/ac, the manure would have a fertilizer value of $151.20/ac. However, the value of the P and K would be realized over a period of years since the amount applied would exceed annual crop uptake. On the other hand, there would be residual N, which would have a value in succeeding years. Beef manure with a total N content of 1% applied at 15 tons/ac could be expected to supply about 20 lb N/ac in the year following application (10% of 200 lb/ac residual N) for an additional benefit of $8.00/ac.

A net value for manure application would be the gross value as calculated above minus loading, transportation and application costs. Custom rates for corral cleaning or emptying lagoons are generally based on hourly charges, and many variables affect the quantity of material that can be handled per hour. For beef manure from corrals or bedding packs, ball-park numbers for loading, hauling and spreading within one mile of the source are about $4.00 - $5.00/ton at the time of writing. In the example calculated above, the net value would then be $10.08 - $4.00 (or $5.00) = $6.08 (or $5.08)/ton and at the 15 tons/ac rate, $76.20 to $91.20/ac.

There is also a value to the micronutrients in manure and to the improved soil water-holding capacity and tilth that manure provides. These values are highly dependent upon soil conditions prior to manure application (e.g. are the micronutrients really needed?) and are extremely difficult to generalize and assign a dollar value.

The value of injecting liquid manure is quickly evident. For example, if the N content of the manure is 7 lb/1000 gal (liquid hog manure, Table 1), available N is about 3.5 lb/1000 gal and crop N is suggested at 3.1 lb/1000 gal to allow for losses (primarily volatilization). However, research indicates the losses from broadcast liquid manure can range up to 30% of available N while injection can reduce this to about 2%. The difference is nearly 1 lb/1000 gal. If the target is to apply 100 lb crop N/ac, using the average value of 3.1 lb/1000 gal, a producer would apply (100 lb/ac ÷ 3.1 lb/1000 gal) = 32,300 gal/ac. The available N applied would be 3.5 lb/1000 gal × 32,300 gal/ac = 113 lb/ac. If the manure was broadcast, up to 30% or about 34 lb/ac could be lost, and the actual crop N would be only about 80 lb/ac. If injected, the loss might be as little as 2 lb/ac and the crop N could be 110 lb/ac. The N conserved by injecting (30 lb/ac) would be worth $12.00/ac using the assumed value of $0.40/lb for N. *Although solid manure cannot be injected at present, research is underway in Saskatchewan to develop solid manure injection equipment.*

Forage Testing

Forage testing is always advisable to ensure proper ration balancing for livestock. It may be even more important when manure is applied to forages because nutrients will be applied in amounts and proportions different from crop requirements. This is particularly true for K. As discussed previously, very high K levels in forage or low Mg:(Ca + K) ratios can cause health or reproductive problems in cattle. If very high rates of N are applied, high nitrate concentrations in forage are also possible.

The most important factor in forage sampling is to obtain a representative sample. For large round bales, approximately 5% of bales should be sampled with a coring tool, sampling from the round surface of the bale into the centre. Haylage can be sampled as it is put into the pit or silo. Each field and/or forage type should be sampled separately, and the feeds that have been sampled need to be identified and stored so that they can be matched to the appropriate analysis when fed. Detailed instructions for forage sampling can be obtained where you pick up sample bags.

Forage testing can also indicate nutrient imbalances in the crop that may be limiting crop productivity and can be corrected in future years through nutrient management plans.

Beneficial Management Practices

- Be aware of and comply with all AOPA regulations.
- Apply manure to meet crop nutrient requirements. Phosphorus-based rates are better because excess P will accumulate in soil if manure is applied based on N requirements of crops. Alternatively, apply at an N-based rate, but then do not re-apply to the same field until soil tests indicate available P levels are low enough to warrant another application.
- Test soils and manure annually, and keep records of manure analyses and application rates on each field.
- Inject liquid manures to conserve N and reduce odour impacts.
- Apply manure in the spring or between hay harvests, but avoid traffic on fields when moisture conditions are likely to lead to soil compaction.
- If fall application is necessary, delay application until the soil temperature is less than 10°C to reduce mineralization and the potential for leaching losses.
- When broadcasting liquid manure, keep the deflector angle low to reduce the spreading arc and airflow through the manure in order to reduce odour emissions.
- Choose fields that are a low risk for runoff (e.g. low slope, good plant cover) or that do not have a nearby common body of water.
- Delay re-introduction of livestock into manured fields to allow forage regrowth and pathogen death in order to reduce the potential for disease transference in the herd.

Appendix

Nutrient Management Plan Worksheets

Worksheet 1. Determine total manure produced

Livestock type	Animal numbers	Manure produced (tons/head/year)*	Total manure produced (tons/year) A**
Beef (feedlot)	5000	2.4	12,000
Hot (feeder)	2000	2.8	5,600
Poultry	-	-	-
Dairy	-	-	-

** From Table 5 in AOPA – Standards and Administration Regulation (AR267/2001), Part 2 General Administration Matters.*
*** Values to be used in other worksheets.*

Worksheet 2. Determine available nutrients from manure

Livestock species	A* Total manure produced (tons)	B** Crop N (lb/ton)	A x B Total crop N (lb)	C** Crop P_2O_5 (lb/ton)	A x C Total crop P_2O_5 (lb)	D** Crop K_2O (lb)	A x D Total crop K_2O (lb)
Beef	12,000	5.1	61,200	11.0	132,000	16.0	192,000
Hogs	5,600	3.0	16,800	5.0	28,000	4.0	22,4000
Poultry	-	-	-	-	-	-	-
Dairy	-	-	-	-	-	-	-

** Calculated on Worksheet 1.*
*** Average values – actual farm values may vary widely. Use results from manure testing.*

Worksheet 3. Determine manure application rates based on crop's P requirements*

Field ID	(A) Area (ac)	(B) Recommended P_2O_5 rate ** (lb/ac)	(C) Crop from P_2O_5 manure (lb/ton)	D = B ÷ C Manure application rate (tons/ac)	E = A x D Total manure applied (tons)	(F) Manure remaining, starting from 12,000 tons ***
Field #1	160	30	11	2.73	437	11,563
Field #2	200	30	11	2.73	546	11,017
Field #3						
Field #4						

** Example: beef feedlot as a manure source*
*** Obtained from soil tests results*
**** Quality from Worksheet 1*

The process of allocating manure to fields continues until all manure is used or all available land is used, in which case additional land must be found for manure application. The acreage needed would be F ÷ D, where F is the excess manure and D is the application rate as calculated above.

Manure Application Record Sheet (example)

Date	Field ID	Soil nutrient levels (soil test) (lb/ac)			Manure applied (tons/ac)	Nutrients applied (lb/ac)		
		N	P_2O_5	K_2O		N	P_2O_5	K_2O
May 1, 2005	Field #1	18	64	420	2.73	14	30	44

Additional Information Sources

Alberta Agriculture, Food and Rural Development

Call the Ag-Info Centre at 1-866-882-7677.

Visit Ropin' the Web (http://www.agric.gov.ab.ca) - Information on the *Agricultural Operation Practices Act* can be accessed from this website by searching for AOPA.

Natural Resources Conservation Board (NRCB)

Call your nearest NRCB office:

Calgary	(403) 662-3990	Edmonton	(780) 422-1977
Fairview	(780) 835-7111	Lethbridge	(403) 381-5166
Morinville	(780) 939-1212	Red Deer	(403) 340-5241

Visit the NRCB's website (http://www.nrcb.gov.ab.ca/web/about/contacts.cfm).

Useful Conversion Factors

tonne (metric)/hectare x 0.446 = ton/acre

ton/acre x 2.24 = tonne/hectare

tonne x 1.102 = ton

ton x 0.9072 = tonne

kilogram (kg) x 2.205 = pound (lb)

pound x 0.454 = kilogram (kg)

hectare x 2.472 = acre (ac)

kilogram/hectare x 0.891 = pound/acre

pound/acre x 1.12 = kilogram/hectare

acre x 0.405 = hectare

P x 2.3 = P_2O_5

P_2O_5 x 0.43 = P

K x 1.2 = K_2O

K_2O x 0.83 = K

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