



Soil Facts

Dairy Manure as a Fertilizer Source

Dairy manure and wastewater are excellent sources of nutrients for most agronomic, horticultural, and silvicultural crops. Proper management of these manures as nutrient sources is critical to promoting optimum plant growth and yield while protecting the environment. Optimum management of this resource includes

- *Handling and treating waste properly*
- *Testing soil and manure regularly*
- *Setting realistic yield goals*
- *Applying manure in a uniform and timely fashion*
- *Practicing soil conservation and environmental sustainability.*

Nutrient Content of Dairy Manures

Tables 1 and 2 show average nutrient values for four dairy manure types. Table 1 also shows the range in concentrations that make up the average. Note the variability! Because nutrient values vary considerably over time, it is important to have a manure sample analyzed for nutrient content before applying

the manure to the land. Because of the nature of manure slurry systems, it may not always be possible to have a sample analyzed before land application. However, analysis results received after the slurry application will indicate whether there is a need for supplemental fertilizer. Samples can be sent to the North Carolina Department of Agriculture (NCDA), Agronomic Division, Plant and

Table 1. Nutrient Composition of Dairy Manure

Manure Type	Total Nitrogen N	Ammonium NH₄-N	Phosphorus P₂O₅	Potassium K₂O
Lot-scraped manure (lb/ton) range	10 (3 to 20)	3 (2 to 15)	6 (0.6 to 13)	9 (2 to 20)
Liquid manure slurry (lb/1,000 gal) range	22 (8 to 50)	9 (4 to 13)	14 (0.2 to 38)	21 (0.7 to 50)
Anaerobic lagoon sludge* (lb/1,000 gail) range	15 (3 to 42)	6 (1 to 12)	22 (2 to 64)	8 (2 to 20)
Anaerobic lagoon liquid (lb/acre-inch) range	137 (17 to 268)	88 (22 to 130)	77 (10 to 233)	195 (13 to 571)

Source: Biological & Agricultural Engineering Department, North Carolina State University, 1980 to 1990.

*No manure solids removed before lagoon input

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Table 2. Average Secondary and Micronutrient Content of Dairy Manure

Manure	Ca	Mg	Se	Na	Fe	Mn	B	Zn	Cu	Cl
Lot-scraped manure (lb/ton)	5	2.2	1.7	1.3	0.9	0.1	0.01	0.1	0.02	3.3
Liquid manure (lb/1,000 gal)	10	4.8	3.1	3.2	1.8	0.2	0.02	0.2	0.05	6.1
Lagoon sludge* (lb/1,000 gal)	12	4.5	3.6	1.4	1.5	0.3	NR	0.4	0.4	2.3
Lagoon liquid (lb/acre-inch)	69	35	25	48	12	1.3	0.15	2.0	0.3	67

Note: Ca = Calcium, Mg = Magnesium, Se = Selenium, Na = Sodium, Fe = Iron, Mn = Manganese, B= Boron, Zn = Zinc, Cu = Copper, Cl = Chloride

NR = Not reported.

Source: Biological & Agricultural Engineering Department, North Carolina State University.

*No manure solids removed before lagoon input.

Waste Analysis Lab, P.O. Box 27647, Blue Ridge Road Center, Raleigh, NC 27611; phone: (919) 733-2655. The current charge is \$4 per sample. Many private laboratories can also perform manure analyses.

Because the accuracy of the analysis depends on a representative sample, take several subsamples from different locations in the manure pile or the lagoon and mix them together in a plastic bucket. After mixing the subsamples in the bucket, place approximately 3/4 of a pint of the manure material in a nonmetallic, flexible container, leaving some air space for gas expansion. If possible, refrigerate or ice the sample, and deliver it to the lab promptly.

Samples of liquid manure slurries are more difficult to obtain because the manure basin must be thoroughly agitated before a representative sample can be taken. For liquid manure slurry systems take samples as the slurry material is being pumped out of the lagoon. The agitation caused by the removal of the slurry will provide a representative sample. Record the analysis results to develop a representative farm average as a guide for future slurry applications.

Land Application

Nutrient Availability

Only a portion of the nutrients in dairy manure are available immediately after application for use by the crop. Some of the nutrients are part of the manure's organic structure and require microbial decomposition to release them. In general, only about 50 percent of the organically bound nitrogen (N) and 70 to 80 percent of the other nutrients become available to a crop during the year of application. With solid and slurry manures, the remaining organically bound nitrogen can be released in subsequent years and should be accounted for in fields where manure is applied annually.

Ammonium and urea are readily available forms of nitrogen that are present in many manures. Both of these forms, however, can change into ammonia, which evaporates readily. When surface-applied manure is not incorporated for one month or longer, as much as 75 percent of the ammonia can be lost to the atmosphere. Incorporating the manure within 48 hours reduces losses to about 25 percent; with direct soil injection all but 5 percent of the ammonia is retained.

Coefficients are used to estimate nutrient availabilities and to account for different manure types and methods of land application. These "availability coefficients" are multiplied by the total nutrient concentration for each element as reported in the manure analysis report or, if no sample was taken or no analysis is available, they are multiplied by the average manure values listed in Table 1. The sum of these values is the nutrient concentrations available to plants. Availability coefficients are listed in Table 3. If manure samples are sent to the NCDA Agronomic Division, analysis results will report both total nutrient concentrations and plant-available nutrients using these same availability coefficients.

Application Rate

Land application rates should be based on the nutrient requirements of the crop being grown. Manure can be applied at a rate to supply any of the recommended nutrients. Be careful, however, that the application rate chosen to meet one specific nutrient requirement does not result in either excessive or inadequate application of other nutrients that can negatively impact water quality or the crop's health. If

Table 3. Dairy Manure First-Year Availability Coefficients

Manure Type	Injection	Disking in within 48 hours	Surface Spread	Irrigation
All manure types	0.8	0.8	0.7	0.7
N availability coefficients				
Lot-scraped manure	—	0.6	0.4	—
Liquid manure slurry	0.7	0.6	0.4	0.4
Anaerobic lagoon liquid	0.8	0.7	0.5	0.5
Anaerobic lagoon sludge	0.7	0.6	0.4	0.4

Table 4. Suggested Nitrogen Fertilization Rates Based on Realistic Yield Expectations

Crop	Suggested Nitrogen Application Rates
Wheat (grain)	1.7 to 2.4 lb N/bu
Barley (grain)	1.4 to 1.6 lb N/bu
Oats (grain)	1.0 to 1.3 lb N/bu
Rye (grain)	1.7 to 2.4 lb N/bu
Triticale (grain)	1.4 to 1.6 lb N/bu
Corn (grain)	1.0 to 1.25 lb N/bu
Corn (silage)	10.0 to 12.0 lb N/ton
Sorghum (grain)	2.0 to 2.5 lb N/cwt
Cotton	0.06 to 0.12 lb N/lb lint
Sorghum-sudangrass (hay ^{1,2})	45.0 to 55.0 lb N/dry ton
Bermudagrass (hay ^{1,2})	40.0 to 50.0 lb N/dry ton
Tall fescue (hay ^{1,2})	40.0 to 50.0 lb N/dry ton
Orchardgrass (hay ^{1,2})	40.0 to 50.0 lb N/dry ton
Annual ryegrass (hay ^{1,2})	25.0 to 30.0 lb N/dry ton
Small grain (hay ^{1,2})	50.0 to 60.0 lb N/dry ton
Millet (hay ^{1,2})	45.0 to 55.0 lb N/dry ton
Pine and hardwood trees ³	40.0 to 60.0 lb N/acre/year

¹Annual maintenance guidelines.

²Reduce nitrogen rate by 25 percent when grazed only.

³On trees less than 5 feet tall, nitrogen will stimulate undergrowth competition.

manure is applied to supply any nutrient other than nitrogen, apply the amount suggested by soil-test recommendations or crop removal rates (See Extension Service publication AG-439-16, *Nutrient Removal by Crops in North Carolina*.)

Because manure usually does not contain the optimum nutrient balance required for each field, be sure to check the soil recommendations for each nutrient and, if necessary, supplement with commercial fertilizer as needed. If

annual applications continue to over apply nutrients, environmental impacts can occur. Alternative management strategies should be implemented before this occurs.

In most cases, dairy producers use manure to supply the nitrogen requirements of their crops. Nitrogen recommendations for various crops are listed in Table 4. Adjust the application rate to match the yield capability of each field. Applying more nitrogen than is required for the crop usually does not increase yield and can potentially contribute to nitrate contamination of groundwater and to elevated nitrate concentrations in forages. Nitrogen recommendations given on North Carolina soil test reports are not based on the soil sample submitted or the yield capabilities of an individual field or farm. Soils test report recommendations reflect a wide range of yield conditions across the state. To customize your nitrogen application rates use the values in Table 4. A worksheet with an example is included at the end of this fact sheet to help you determine the amount of dairy manure needed for different crops and fields.

Besides monitoring nutrients, maintain an adequate soil pH. Optimum soil pH promotes good yields, nutrient availability, and manure decomposition. When dairy manure is applied at agronomic rates, high salinity (excess salt) has not been a problem, given the amounts of rainfall normally received in North Carolina.

The most recently applied manure is not the only source of nutrients; in most fields, some nutrients are available from previous manure applications or previous legume crops. With the exception of nitrogen, updated soil tests are the best means of determining nutrient reserves from these sources. Table 5 can be used to estimate the available nitrogen carryover from legumes. Nitrogen carryover from manure is

more difficult to estimate. If manure has been applied to a field for several years in succession, reduce the nitrogen rate below the suggested guidelines in Table 4. Table 6 provides an estimate of the potential nitrogen from residual carryover after 5 and 10 years of continuous manure applications. To use these numbers effectively, you need an estimate of the average nitrogen content of the manure and the application rate over the period. An example is included in the following worksheet to show how this number can be used to adjust application rates.

Plant tissue analysis is another excellent tool that you can use to fine tune manure application rates. The NCDA Agronomic Division also provides this service.

Timing and Uniformity of Manure Applications

To minimize nitrogen losses, apply manure as close as possible to planting time or to the stage of crop development requiring maximum nitrogen uptake. Good timing increases the amount of nitrogen used by the crop and thus reduces the amount of nitrate that may leach into groundwater. Contamination of surface water and groundwater is greater when manure is applied in the fall or early winter for spring crops in the absence of a cover crop.

Whether dairy manure is applied with a manure spreader or by irrigation, it is important that it be applied uniformly. Nonuniform application leads to nutrient excesses and deficiencies, reduced yields, and uneven crop growth.

Calibrating Manure Application Equipment

Spreaders can apply manure at varying rates and patterns, depending on forward travel speed, power takeoff (PTO) speed, gear box settings, gate openings, spread

Table 5. Estimated Residual Nitrogen Provided by a Good Stand of Legumes Grown in Rotation

Legume	Residual Nitrogen Available (lb/acre)
Alfalfa ¹	80 to 100
Harry vetch ¹	80 to 100
Crimson clover ¹	60 to 75
Austrian winter pea ¹	50 to 60
Soybeans ²	15 to 30
Peanuts ²	20 to 40

¹Killed before planting current spring crop.

²Legume planted in previous year. More nitrogen will be available if the fall-planted crop immediately follows the legume. On sandy soils and in years with normally high precipitation, less nitrogen will be available to spring-planted crops.

Table 6. Estimates of Residual Manure Nitrogen that Is Available after 5 and 10 Years of Continuous Application

Manure Type	Years of Application	Total Nitrogen Carryover (%)
Solid	5	15
	10	20
Slurry	5	10
	10	15

widths, and overlaps. Spreader calibration is the process of determining the combination of settings and travel speed needed to apply manure at the desired rate and uniformity.

Spreader Capacity

The capacity of liquid spreaders is normally rated by the manufacturer in gallons. Multiply the capacity in gallons by 0.0042 to find the capacity in tons. Solid and semi-solid spreaders are rated by the manufacturer either in bushels or cubic feet. (Multiply bushels by 1.25 to get cubic feet.) Most

spreaders have two rating capacities: (1) struck, or level full, and (2) heaped. Because manures and litters have different densities, perform an on-farm test. Fill a 5-gallon bucket level full with material to be spread. Do not pack the material into the bucket but ensure that it settles as it would in a loaded spreader. Weigh the bucket full and then empty. Multiply the weight of the contents by 1.5 to find the weight in pounds per cubic feet. Multiply this value by the capacity of the spreader in cubic feet and divide the result by 2,000 to find the weight in tons of the material in a spreader load.

Spreader Load (tons) =

$$\frac{\text{Manure Weight (pounds)} \times 1.5 \times \text{Spreader Capacity (cubic feet)}}{2,000}$$

Calibration Method 1

This method is most useful for liquid spreaders but can be used for all types. Spread at least one full load of manure, preferably in a square or rectangular field pattern for ease of measuring, with normal overlaps. Measure the length and width of the area covered, recognizing that the outer fringe areas of the coverage will receive much lighter applications than the overlapped areas. Multiply the length by the width and divide by 43,560 to determine the coverage area in acres. Divide the number of tons of manure in the spreader by the acres covered to determine the application rate in tons per acre. (Refer to the box at the right.)

Repeat the procedure at different speeds and spreader settings until the desired application rate is achieved.

Calibration Method 2

This method is often used for solid and semisolid spreaders. Use a tarpaulin or plastic sheet of about 100 square feet (approximately 9 feet by 12 feet or 10 feet by 10 feet). To determine its exact surface area multiply the tarp's length by its width. After measuring, weigh the tarp using a set of spring-tension or platform scales, and then spread and pin it on the field surface. Operate the spreader at its normal settings, speed, and overlap. With a rear discharge spreader, make three passes: the first directly over the center of the sheet and the other two on opposite sides of the center at the normal spreader overlap spacing. Reweigh the sheet, including the collected manure. Subtract the weight of the empty sheet from the total weight to find the weight of the collected manure. Multiply the weight of the collected manure in pounds by 21.8 and divide the result by the collection area of the sheet in square feet to find the application rate in tons per acre. (Refer to the box at the right.)

CALIBRATION METHOD 1

$$\text{Application Rate (tons/acre)} = \frac{\text{Amount of Manure in Spreader (tons)}}{[\text{Length Covered (feet)} \times \text{Width Covered (Feet)}] / 43,560}$$

CALIBRATION METHOD 2

$$\text{Application Rate (tons/acre)} = \frac{\text{Amount of Manure Collected (pounds)} \times 21.8}{\text{Collection Area (square feet)}}$$

Repeat the procedure using different settings or speeds to obtain the desired application rate.

Spreader Pattern Uniformity

To determine the uniformity of spread and the amount of overlap needed, evenly place (2 to 4 feet apart) a line of small pans or trays across the spreader path. The pans should be a minimum of 12 inches by 12 inches or 15 inches in diameter, no more than 24 inches square, and 2 inches to 4 inches deep. Make one spreading pass directly over the center pan. Weigh the contents caught in each pan or pour the contents into equal-sized glass cylinders or clear plastic tubes and compare the amount in each. Find the effective spread width by locating the point on either side of the path center where the manure contents caught in the containers is half of the amount collected in the center. The distance between these points is the effective spread width. Overlap the outer fringes of the coverage area beyond these points on the next path to ensure a uniform application rate over the entire field. Flat-top, pyramid, or oval patterns are most desirable and give the most uniform rate of application. Make adjustments for unsatisfactory M, W, steeple, or lopsided patterns.

Acres Requirements for New or Expanding Facilities

When planning a new or expanded dairy operation, producers need to determine if there is adequate land to properly apply the manure. If an existing operation is expanding, it would be useful to use the average manure nutrient analysis from the farm if records have been maintained. When using farm records, allow for 4.1 tons per head per year for calves, 12 tons for heifers, and 17 tons for milk cows. When records do not exist, state average figures can be used. Table 7 has been developed using average manure nutrient values from Table 1, availability coefficients from Table 3, and the nitrogen suggestions from Table 4.

Value of Manure

To compare the economic worth of manure to that of commercial fertilizers, convert total manure nutrient concentrations to plant-available nutrients by using the coefficients in Table 3. For example, using the average total nutrient concentrations of lot scraped manure from Table 1 (10 pounds of nitrogen per ton, 6 pounds of phosphate per ton, 9 pounds of

Table 7. Minimum Amount of Land Needed to Apply Dairy Manure as a Nitrogen Fertilizer Based on the Nitrogen Rate Required by the Crop for Two Methods of Application

Manure Handling and Production Units (lb N/acre/year)	Method of Application							
	Soil Incorporated ¹				Surface Broadcast ²			
	100	200	300	400	100	200	300	400
	(acres/animal unit capacity)							
Lot-scraped manure								
Calf	0.23	0.12	0.077	0.058	0.18	0.089	0.059	0.044
Heifer	0.68	0.34	0.23	0.17	0.52	0.26	0.17	0.13
Milk cow	0.96	0.48	0.32	0.24	0.73	0.37	0.24	0.18
Liquid manure slurry								
Calf	0.25	0.13	0.085	0.064	0.19	0.093	0.062	0.046
Heifer	0.75	0.38	0.25	0.19	0.55	0.27	0.18	0.14
Milk cow	1.1	0.53	0.35	0.26	0.76	0.38	0.25	0.19
Anaerobic lagoon liquid								
Calf	0.076	0.038	0.025	0.019	0.057	0.029	0.019	0.014
Heifer	0.22	0.11	0.074	0.055	0.17	0.084	0.056	0.042
Milk cow	0.31	0.16	0.10	0.078	0.24	0.12	0.078	0.059
Anaerobic lagoon sludge								
Calf	0.041	0.021	0.014	0.010	0.030	0.015	0.010	0.0075
Heifer	0.12	0.061	0.040	0.030	0.088	0.044	0.029	0.022
Milk cow	0.17	0.085	0.057	0.042	0.12	0.062	0.041	0.031

¹Incorporated within two days. ²Not incorporated for one month or longer; lagoon liquid irrigated.

potash per ton) and the availability coefficients for soil incorporation within 48 hours (0.6 for nitrogen and 0.8 for phosphorus and potassium), there are 6 pounds of plant-available nitrogen, 4.8 pounds of plant-available phosphate and 7.2 pounds of plant-available potash per ton of manure. At a value of \$0.25, \$0.22, and \$0.15 per pound for commercial nitrogen, phosphate, and potash, respectively, one ton of lot-scraped manure would be worth \$3.64:

$$(6 \times \$0.25) + (4.8 \times \$0.22) + (7.2 \times \$0.15) = \$3.64$$

This sum does not include the value of the secondary or micronutrients that are present in manures, nor does it include the cost of labor, transportation, or spreading costs to apply the manure. In addition, it

assumes that a soil test calls for applications of phosphorus and potassium, when in fact many soils may already have adequate supplies. Nutrients not needed should not be considered in assessing the financial value of the manure.

Land Application Worksheet

Bill Jones is a dairy producer using a manure basin to store his manure before applying it to land. He plans to plant corn for silage in a field that had 10 years of continuous manure applications, and he anticipates a yield of about 18 tons of silage per acre. Because he applies this manure as a slurry, which requires agitation, he decides to use the average nutrient values in Table 1 to determine the application rate. He

does not plan to use any preplant or starter fertilizer. His fields have grass borders to help reduce erosion and the potential for nutrient and pesticide runoff. He plans to incorporate the manure within 24 hours after application. In the past 10 years he has applied an average of about 10,000 gallons of manure per acre. How much liquid manure slurry will he need to apply per acre to meet the nitrogen needs of his silage crop? Will he need to supplement his slurry application with commercial fertilizers to meet the soil test recommendations of 50 pounds of phosphate and 80 pounds of potash per acre, or will he have a surplus of these nutrients? The answers to these questions are given in the worksheet that follows. Use the same worksheet to determine the manure rates to apply on your farm.

Worksheet: Determining the Nutrient Needs of Your Crop

	Example	Your Farm
1. Crop to be grown	corn silage	_____
2. Total nutrients required		
a. nitrogen		
(a ₁) yield goal (tons) ¹	18	_____
(a ₂) lb N/unit production (Table 4) (lb/ton)	12	_____
(a ₃) N needed (lb/acre) (2a ₁ x 2a ₂) = (18 x 12)	216	_____
b. P ₂ O ₅ (soil test) (lb/acre)	50	_____
c. K ₂ O (soil test) (lb/acre)	80	_____
3. Pounds of starter or preplant fertilizer used		
a. N (lb/acre)	0	_____
b. P ₂ O ₅ (lb/acre)	0	_____
c. K ₂ O (lb/acre)	0	_____
4. Residual N credit from legumes (Table 5) (lb/acre)	0	_____
5. Net nutrient needs of crops		
Nitrogen: total need (item 2a ₃) minus additional N from starter (item 3a minus N from legume (item 4)		
a. N: 216 - 0 - 0 (lb/acre)	216	_____
Phosphate and potash: total need (item 2b, 2c) minus additional nutrients from preplant fertilizer (3b, 3c)		
b. P ₂ O ₅ : 50 - 0 (lb/acre)	50	_____
c. K ₂ O: 80 - 0 (lb/acre)	80	_____
RATE OF MANURE TO APPLY		
6. Nutrient totals in manure (from Table 1 as waste samples). If analysis report already gives available nutrients, skip this item.		
a. Total N (lb/1,000 gallons) ²	22	_____
b. P ₂ O ₅ (lb/1,000 gallons) ²	14	_____
c. K ₂ O (lb/1,000 gallons) ²	21	_____
7. Nutrients available to crop (6a, 6b, 6c) times availability coefficients (Table 3) or as reported on manure analysis if present.		
a. Available N: 22 x 0.6 (lb/1,000 gallons) ²	13.2	_____
b. Available P ₂ O ₅ : 14 x 0.8 (lb/1,000 gallons) ²	11.2	_____
c. Available K ₂ O: 21 x 0.8 (lb/1,000 gallons) ²	16.8	_____

Worksheet: Determining the Nutrient Needs of Your Crop (continued)

	Example	Your Farm
<p>8. Residual N available to crop. Average application rate in past years times average N concentration (Table 1 or from manure analysis reports) times percent residual N (Table 6) times availability coefficient (Table 3). If units are lb/1,000 gallons divide answer by 1,000.</p> <p>From example:</p> <p>Average rate applied = 10,000 gal/acre Average N concentration = 22 lb/1,000 gal (10,000 X 22 X 0.15 X 0.6)/1,000 =</p>		
	19.8	_____
<p>9. Application rate to supply primary nutrient:</p> <p>a. Priority nutrient</p>		
	nitrogen	_____
<p>b. Amount of priority nutrient needed: (lb/acre from 5a)</p>		
	196.2	_____
<p>c. Rate of manure needed to supply priority nutrient: (9b / 7a) multiply by 1,000 if units are lb/1,000 gal (196.6 / 13.2) x 1,000 (gal/acre) =</p>		
	14,864	_____
<p>10. Pounds per acre of all nutrients supplied at the application rate required to meet the needs for the priority nutrient. For each nutrient multiply the available nutrients (7a, 7b, 7c) times the manure rate (9c). Divide by 1,000 if units are lb/1,000 gal.</p>		
a. N supplied: 13.2 x 14,864 / 1,000 (lb/acre)	196.2	_____
b. P ₂ O ₅ supplied: 11.2 x 14,864 / 1,000 (lb/acre)	166.5	_____
c. K ₂ O supplied: 16.8 x 14,864 / 1,000 (lb/acre)	249.7	_____
<p>11. Nutrient Balance: net nutrient need (-) or excess (+) after application of manure at calculated rate. Amount of nutrient applied by manure (10a, 10b, 10c) minus net amount needed by crop (9b, 5b, 5c).</p>		
a. N balance: 196.2 - 196.2	0	_____
b. P ₂ O ₅ balance: 166.5 - 50	+116.5	_____
c. K ₂ O balance: 249.7 - 80	+169.7	_____

Note: Calculation format modified from Pennsylvania Department of Environmental Resources, *Field Application of Manure*, October 1986.

¹Substitute appropriate yield units. ²Substitute appropriate manure units.

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