CHAPTER 5

LAND APPLICATION OF DAIRY MANURE

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Land application of dairy manure to crop and forest land is an effective way of recycling the nutrients back to the land. There are four key steps to utilizing manure in an environmentally and economically sound manner:

- know the available nutrient content of the manure
- know the nutrient needs of the crop, and apply the manure at the correct rate and time to provide the nutrients
- use application and conservation practices that minimize movement of the nutrients from the field
- adjust the use of supplemental fertilizer to compensate for the nutrients applied in the manure

NUTRIENT CONTENT

Applications of dairy manure as a crop nutrient source may provide a portion, or all of the plant nutrient requirement, dependent on the rate of application and the relative content of the nutrients. Application rate decisions are usually based on either the nitrogen or the phosphorus content of the manure and environmental concerns are typically based on the amount of nitrogen, phosphorus, zinc, copper, or arsenic added to the soil. Average nutrient contents of different types of dairy manure are listed in Chapter 3. Knowing the nutrient content of dairy manure is critical to using it as a crop nutrient source. Not knowing the nutrient content of the manure to be applied can result in large errors in application rate -- either too much or too little.

NITROGEN-BASED APPLICATION RATES

Dairy manure additions are often based on the nitrogen requirement of the crop and the available nitrogen content of the dairy manure. Crops that require and remove a lot of nitrogen are favored for receiving dairy manure because more manure can be applied to less land. This approach reduces the hauling costs of implementing a manure management plan, however this approach increases the chance of causing phosphorus pollution of surface waters. Soil analysis should be used to ensure that soil pH and nutrient conditions are at optimum levels even when manure is applied based on nitrogen.

Nitrogen fertilizer recommendations for commonly grown crops are listed in Table 5.a.1. These rates are suggested as the most profitable rate over a period of years with good management. Ranges in nitrogen rate recommendations reflect differences in yield and management potential. For instance, nitrogen recommendations for dryland corn are 100 lb N/acre for 80 bu/acre or less, 120 lb N/acre for expected yields of 80 to 130 bu/acre, and 150 lb N/acre for productive soils where yields in excess of 130 bu/acre are often obtained. Recommended nitrogen fertilization rates for well managed irrigated corn are 180 to 220 lb N/acre for yields of 150 to 200 bu/acre. Similarly for bermudagrass, 240 lb N/acre should be sufficient to produce 4 to 5 tons hay/acre and 400 lb N/acre should produce 6 to 7 tons hay/acre with normal rainfall. Recommended nitrogen rates are reduced 20 lb N/acre for crops grown after a legume (typically soybeans or peanuts).

Table 5.a.1. Nitrogen fertilizer recommendations for commonly grown crops in South Carolina.

Crop	Nitrogen, pound/acre
Corn, dryland	100 - 150
Corn, irrigated	about 200
Corn, silage	180
Cotton	80 - 100
Soybean	150 *
Wheat	80 - 100
Bermuda grass hay	240 - 400
Bermuda grass pasture	about 150
Fescue pasture	about 100
Annual rye for grazing	about 120

* Recently conducted research by Camberato, Albrecht, and Adams has shown little excess nitrogen in the soil profile when soybeans are fertilized with up to 150 pounds nitrogen per acre.

Nitrogen Application Timing

The release of nitrogen from manure should coincide with crop nitrogen accumulation. If the crop is not actively accumulating nitrogen then nitrate-nitrogen in the soil will be subject to loss via leaching. Manure can be applied to actively growing annual crops or on fallow land no greater than 30 days before planting a crop. Manure can be applied to pasture and hay fields during the growing season and no greater than 30 days before the breaking of dormancy.

Annual crops such as corn, cotton, and wheat have high nitrogen requirements for short time periods. For example, corn accumulates 67% of its nitrogen from the knee high stage to tasseling. Adequate nitrogen must be available during this time period if optimum yields are to be obtained. Pasture and hay crops have more moderate nitrogen requirements over longer periods of time and are not very sensitive to short-term deficits in nitrogen availability. Periods of nitrogen accumulation and nitrogen application windows for crops commonly grown in South Carolina are presented in Table 5.a.2.

Dairy manure may be applied to the soil as a solid or as a liquid dependent on the waste handling system being used. Nitrogen availability from dairy manure is greatest and most predictable when incorporated into the soil due to less ammonia loss to the air and better moisture for organic-nitrogen mineralization. Most of the plant-available nitrogen is released in 3 to 4 weeks when temperature and moisture are favorable for nitrogen mineralization. Solid manure applications to annual crops, therefore, are typically made preplant and incorporated into the soil.

Liquid manure applications can be made to established annual crops before or after planting. Topdress applications can be made, but determining when and how much nitrogen will become available is difficult. The impact on yield of delayed nitrogen availability and over- or under-estimation of nitrogen availability is not as great a concern with grass fields as with annual crops.

Table 5.a.2. Dairy manure application windows for crops commonly grown in South Carolina. Months with cross-hatch or darkened indicate approximate times that dairy manure applications providing nitrogen can be made to that particular crop. Darkened months indicate times of peak nitrogen accumulation. Adapted from similar by Dr. Virgil Quisenberry.

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Corn		▨	▨	▨■	■	■	▨					
Cotton				▨	■	■	▨					
Soybean				▨	■	■	■	■	▨			
Wheat		▨■	■	■	■	▨				▨	▨	
Bermudagrass				■	■	■	■	■				
Fescue		■	■	■	■				■	■	■	
Rye	▨	■	■	■	■	■			■	■	■	▨
Bermudagrass/Rye	▨	■	■	■	■	■	■	■	■	■	■	▨

PHOSPHORUS AND POTASSIUM BASED MANURE APPLICATIONS

Nitrogen-based applications typically over-apply all other essential plant nutrients, especially phosphorus. Although most manure management plans base application rates on plant-available nitrogen, applying dairy manure based on its P_2O_5 or K_2O content may be more economical or necessary to protect surface waters from phosphorus pollution. The availability of P_2O_5 and K_2O in manures is similar to that of fertilizer sources, so basing application rates on the manure's content of P_2O_5 and K_2O should be adequate. Recommended rates of P_2O_5 or K_2O are based on soil analysis, soil type, and crop to be grown and are provided with a routine soil test. These recommendations can also be obtained from your County Agent or Clemson University Extension Circular 476. On soils testing high in P_2O_5 and K_2O, when these nutrients are not recommended by soil test, consider using the manure on other fields requiring P_2O_5 and K_2O. Manure nutrients are much more valuable when applied to low fertility fields. See section, Determining the Value of Manure Nutrients, for further explanation.

CONTROLLING PHOSPHORUS MOVEMENT FROM THE FIELD

The Natural Resources Conservation Service Phosphorus Index (NRCS-PI) is an evaluation system for determining the potential for phosphorus movement from the field to surface waters. Phosphorus movement from the land into surface waters, such as lakes and streams, is considered pollution. Phosphorus movement occurs by erosion and runoff. Erosion is the movement of soil or particles of manure from the field. Runoff is water movement over the surface of a field containing little sediment. In South Carolina, erosion and runoff occur primarily from heavy rainfall or excessive irrigation. Phosphorus in erosion and runoff can be bound to the soil, contained in soil organic matter and manure particles, or dissolved in the water.

Many factors affect the amount of phosphorus that moves from the field to the water. These factors include:

- slope of the land
- soil type
- distance to the water
- rainfall and irrigation intensity and duration
- method of manure application
- soil phosphorus level
- presence of conservation practices-filter strips, contour planting, riparian zones

Manure application on sloped land is subject to greater loss via runoff and erosion than applications made on flat land. The greater the distance between the application area and the surface water the lower the chance of phosphorus movement into the water. Hence, the rationale for application setbacks from ditches, streams, ponds, and lakes (See Section 200.100 B&C) for the numerous setbacks affecting the application of dairy manure). On tilled soils, incorporated manure results in less phosphorus runoff and erosion then when the manure is left on the soil surface. High soil phosphorus is another factor that increases the potential for phosphorus pollution of surface waters. The higher the level of phosphorus at the soil surface the greater the concentration of phosphorus in the runoff water and erosion sediments. When soil test phosphorus is high at the soil surface, application of manure to other fields should be considered. An alternative practice in some instances may be deep plowing to mix the high phosphorus surface soil with low phosphorus subsurface soil. Installation of conservation practices that reduce runoff and erosion are also beneficial to reducing phosphorus pollution of surface waters.

In most soils with moderate phosphorus application rates, phosphorus remains in the soil where it is placed with little downward movement. Phosphorus added to the soil is bound by clay particles so that only a portion remains available to the crop. This process reduces the amount of dissolved phosphorus in runoff water, but does not affect the loss of phosphorus in erosion sediments. Soils have finite capacities to absorb phosphorus. When the capacity is exceeded, added phosphorus remains dissolved in the soil water and can be leached downward. Leaching of phosphorus can occur on coarse sandy soils with high application rates of phosphorus and on high organic matter soils commonly occurring in Carolina Bays. In these soils, phosphorus leaching into the water table and lateral movement of ground water can move phosphorus to the stream or lake. However, in soils with clay subsoils the leaching of phosphorus through the soil profile is slow since these soil layers have a substantially greater capacity to absorb phosphorus than surface soils. The potential for phosphorus leaching and subsequent lateral movement to surface waters is a component of the NRCS-PI to determine the suitability of the field for manure application and the nutrient determining the application rate (either nitrogen or phosphorus). Lateral flow of soil water containing phosphorus can occur in the absence of tile drains, but is accelerated by artificial drainage.

If the risk for phosphorus movement to surface waters is low, manure application rates remain nitrogen-based. However, at medium and high phosphorus index values manure application rates are based on twice crop removal of phosphorus and crop removal of phosphorus, respectively. When risk of phosphorus movement from the field to surface waters is very high, no manure application is allowed. Switching from nitrogen-based waste management plans to phosphorus-based waste management plans greatly increases the land needed to utilize the manure from a dairy.

CROP NUTRIENT ACCUMULATION

Dairy manure applications are greatly reduced when based on crop removal of phosphorus, rather than recommended nitrogen fertilizer rates. Phosphorus removal for crops commonly grown in South Carolina are listed in Table 5.a.3. Row crops remove about 30 lb P_2O_5/acre at typical yield levels and hay crops remove more than 50 lb P_2O_5/acre.

Crop accumulation of nutrients from the soil and removal from the field determines the efficiency of crop nutrient utilization (Table 5.a.3). Nutrient utilization is routinely less than 100% due to inefficiencies in nutrient uptake by the crop, soil reactions that render the nutrient unavailable, and loss of the nutrient from the soil by leaching, erosion, or volatilization. Only a portion of the nutrients in the crop will come from that year’s application of animal manure or fertilizer. The remainder of nutrient accumulation will have come from nutrients already present in the soil.

Nutrients in the crop parts that remain in the field, such as corn or wheat stover, will be recycled to the soil and available to the next crop. Nitrogen has been the plant nutrient most studied. Accumulation efficiency by annual crops from fertilizer is typically around 60% of the nitrogen added and removal efficiency is about 50%. Hay field typically accumulate a greater percentage of nitrogen from fertilizer, about 75%. Nitrogen efficiency from manures is usually less than that from fertilizer.

ZINC AND COPPER REGULATIONS AFFECTING LAND APPLICATION

South Carolina regulates animal waste applications by the concentration of zinc (Zn), copper (Cu), and arsenic (As) in the manure or by the amount of Zn, Cu, and As that can be applied on a cumulative basis (See Section 200.100 B and Chapter 3). Good record-keeping of the amounts of manure applied to a field and the concentration of Zn, Cu, and As in the manure is necessary to meet the conditions of the regulations.

Zinc and Cu are present in dairy manure in varying amounts (see Table 3.3) and are essential crop nutrients. However, long-term use of dairy manure based on providing the total N requirement of the crop provides more Zn and Cu than the crop requires, and these nutrients can accumulate to high levels in the soil. Crop toxicities may occur in certain situations, particularly zinc toxicity in peanuts. Crop removal of Zn and Cu from the field is quite small, around 0.03 pounds of Cu per acre per year and about 0.11 pounds of Zn per acre per year (see Table 5.a.3) and no leaching of these nutrients occurs. Therefore, once applied to the soil they remain there. The toxicity of high soil Zn and Cu is reduced by increasing soil pH, however, increased soil pH will not completely eliminate Zn and Cu toxicity in some instances. If soil pH is increased too much, deficiencies of other micronutrients may be induced by the high pH.

Arsenic is not an essential plant nutrient. Crop production problems are unlikely to occur from As applications typically applied in dairy manure.

APPLY THE CORRECT AMOUNT OF DAIRY MANURE UNIFORMLY

Applying the proper amount of animal waste to the field in uniform fashion is the next step in effectively utilizing animal waste. Spreaders must be calibrated to apply the proper rate and be adjusted for uniform application.

Use of dairy manure on nitrogen sensitive crops like cotton and tobacco is difficult because of the uncertainty of nitrogen availability, calibrating delivery equipment, and making uniform applications. Herbicide application timing, insecticide effectiveness, growth regulator applications, and defoliation decisions are all affected by the amount of cotton growth which is highly dependent on nitrogen. Variability in height and growth within the row complicates this management. Too little nitrogen on tobacco reduces yield, and too much can delay harvest and reduce quality. Harvesting and curing of non-uniform tobacco may also be a problem. If dairy manure is applied at the correct rate one season there should be no problems growing cotton or tobacco the next year.

Table 5.a.3. Nutrient accumulation and removal by crops commonly grown in South Carolina. ***(Most values from the ipni.net Crop Nutrient Removal Calculator.)***

Crop	Yield level	Plant part	N	P_2O_5	K_2O	Cu	Zn
			---- pounds of nutrient per acre ------				
Corn	100 bu/acre	grain	67	35	25	0.02	0.10
		stover	45	16	110	------	------
		total	112	51	135	------	------
Cotton	1,000 lb lint/acre	lint, seed	64	28	38		
		stalks	57	17	55	------	------
		total	121	45	93	------	------
Oats	80 bu/acre	grain	62	22	15	------	------
Peanuts	3,000 lb nuts/acre	nuts	105	17	26	0.04	0.10
		vines	50	10	36	------	------
		total	155	27	62	------	------
Soybean	30 bu/acre	grain	98	22	36	0.03	0.10
		stover	33	7	30	------	------
		total	131	29	66	------	------
Tobacco	2,000 pounds/acre	leaves	72	18	114	0.04	0.13
		stalks	27	7	68	------	------
		total	99	25	182	------	------
Wheat	50 bu/acre	grain	58	24	14	0.02	0.13
		stover	35	8	60	------	------
		total	93	32	74	------	------
Hay and Silage Crops							
Bermudagrass	6 tons/acre	hay	276	72	300	------	0.12
Bahiagrass	3 tons/acre	hay	129	36	105	------	------
Fescue	3 tons/acre	hay	111	36	162	------	------
Annual ryegrass	3 tons/acre	hay	129	36	129	------	------
Corn (67% moist.)	20 tons/acre	silage	194	62	146	------	------
Sorghum	5 tons/acre	silage	74	28	141	------	------

REDUCE FERTILIZER APPLICATIONS ACCORDINGLY

When dairy manure is used as the primary nitrogen source for crops, supplemental phosphorus, potassium, and micronutrient applications are usually not needed. Eliminating unnecessary fertilizer applications is a benefit both economically and environmentally. For nutrients other than nitrogen, traditional manure, soil testing, and plant tissue analysis methods are adequate for determining if further additions of these nutrients are required.

DETERMINING THE VALUE OF MANURE NUTRIENTS

Major Nutrients

The value of manure nutrients is dependent on soil fertility level, crop nutrient needs, manure nutrient content, and the cost of purchased nutrients and manure application.

Manure has the greatest nutrient value when applied to low-fertility fields and the least value when used on the same field year after year. When soil fertility status is low, high nutrient application rates of phosphorus and potassium are recommended in addition to the standard nitrogen application. In this situation the crop will benefit from the addition of phosphorus and potassium and the application of these nutrients in the manure is valuable. However, most manures when applied based on the crop's nitrogen requirement provide more phosphorus and potassium than is required and these nutrients accumulate in the soil. When soil fertility status becomes high, supplemental nutrients are not required, and the application of phosphorus and potassium is not recommended. In this situation the phosphorus and potassium in the manure does not have any value. If manure is continually applied to the same field, then the main benefit derived is the nitrogen content of the manure. No benefit is derived from the continual application of excess phosphorus and potassium and the potential for phosphorus runoff polluting lakes, rivers, and streams is greatly increased. Applying manure to low-fertility fields first and having enough land to use manure every second or third growing season are good ways to maximize the nutrient value of the manure and minimize the potential for polluting.

This point is illustrated in Table 5.a.5. A producer applies 24 tons of scraped paved lot dairy manure per acre to three fields varying in soil fertility level to provide 180 lb N/acre in anticipation of growing corn silage. The manure also applies 150 lb P_2O_5/acre, 210 lb K_2O/acre, and 40 lb S/acre. One field has a low phosphorus and potassium level and 100 lb/acre P_2O_5 and K_2O are recommended, therefore, a significant amount of the potassium and phosphorus in the manure has value. In this low soil fertility situation, the nutrient content of the 24 tons manure per acre is worth \$90.00 per acre or \$3.75 per ton. An extra 50 lb P_2O_5/acre and 110 lb K_2O/acre was applied. However, when soil test phosphorus and potassium is medium, less P_2O_5 and K_2O is recommended and the dairy manure is worth less, \$69.00 per acre or \$2.88 per ton. At medium soil fertility levels an extra 100 lb P_2O_5/acre was applied. At high soil test phosphorus and potassium, no P_2O_5 or K_2O is recommended, and the nutrients in the dairy manure are worth only \$48.00 per acre or \$2.00 per ton. One-hundred fifty lb P_2O_5/acre valued at \$36.00 and 210 lb K_2O/acre valued at \$37.80, was wastefully applied to the high fertility soil.

Excess crop nutrients are not necessarily lost from the soil and without value for the next growing season. In most soils some of the excess phosphorus added in one year will be available to future crops over several years. If phosphorus applications in future years are reduced or eliminated by the initial manure application, then some of the excess phosphorus provided in the initial year has value. Excess potassium will also be available to some extent in future years in clayey Piedmont soils and Coastal Plain soils with clayey subsoils within 15 inches of the soil surface. In coarse sandy soils with deep subsoils, however, much of the potassium may be lost between the first and second cropping season and that value will be lost. Even though some of the value of manure nutrients is captured after the first year, fertilizing one year for several years is generally not recommended because some of the phosphorus and potassium will be wasted and the phosphorus may pollute surface waters.

The key to getting the most value from manure nutrients after the initial growing season is not to apply any more phosphorus and potassium when soil test in subsequent years indicates those nutrients are adequate.

Table 5.a.5. Nutrient value of a typical scraped paved lot dairy manure containing 7.5 pounds available nitrogen, 6.2 pounds of phosphorus (as P_2O_5), 8.7 pounds of potassium (as K_2O), and 1.7 pounds of sulfur per ton (see Table 3.2). The manure was applied to the field at a rate of 24 tons per acre based on available nitrogen to supply 180 pounds of nitrogen per acre in anticipation of growing corn silage. **The value of the manure nutrients changes dependent on the soil fertility status of the field.**

Fertility status	**Nutrient**	**Recommended application**	**Amount applied with manure**	**Value**	**Excess nutrients applied**
		pounds per acre		$ per application	lb/acre
LOW	N	180	180	180 x 24¢ = $43.20	0
	P_2O_5	100	150	100 x 24¢ = $24.00	50
	K_2O	100	210	100 x 18¢ = $18.00	110
	S	20	40	20 x 24¢ = $4.80	20
MEDIUM	N	180	180	180 x 24¢ = $43.20	0
	P_2O_5	50	150	50 x 24¢ = $12.00	100
	K_2O	50	210	50 x 18¢ = $9.00	160
	S	20	40	20 x 24¢ = $4.80	20
HIGH	N	180	180	180 x 24¢ = $43.20	0
	P_2O_5	0	150	0 x 24¢ = 0	150
	K_20	0	210	0 x 18¢ = 0	210

Table 5.a.5. Nutrient value of a typical scraped paved lot dairy manure containing 7.5 pounds available nitrogen, 6.2 pounds of phosphorus (as P_2O_5), 8.7 pounds of potassium (as K_2O), and 1.7 pounds of sulfur per ton (see Table 3.2). The manure was applied to the field at a rate of 24 tons per acre based on available nitrogen to supply 180 pounds of nitrogen per acre in anticipation of growing corn silage. **The value of the manure nutrients changes dependent on the soil fertility status of the field.**					
	S	20	40	20 x 24¢ = $4.80	20

Micronutrients

The example above did not consider the value of micronutrients (zinc, copper, manganese, etc.) because soil testing and plant analysis has shown that micronutrient levels in most fields are adequate most of the time. However, when soil testing or plant analysis identifies micronutrient deficiencies and recommend micronutrient additions, the value of the micronutrient application in the manure should also be considered. Calculate the value of the micronutrient by multiplying the recommended application rate by the fertilizer cost of the nutrient. Micronutrients are typically much more expensive than nitrogen, phosphorus, and potassium, so when needed their value is significant to the overall benefit of the manure.

Liming Value or Cost

Liming soils in South Carolina is a very important aspect of crop production. Generally, most South Carolina soils will be limed with a ton of dolomitic limestone every two to three years to maintain soil pH in the range of 5.8 to 6.5 (for most crops). The use of acid forming nitrogen fertilizers is the main reason that soil pH decreases. The estimate of one ton of lime per acre every three years is for nitrogen application rates of around 120 pounds of nitrogen per acre per year. The nitrogen forms in manure lower pH in a similar manner as commercial fertilizer nitrogen. Higher manure application rates than needed will cause the soil pH to drop faster and lime will be required more frequently and in greater amounts.

Stockpiling Manure Solids Lowers Value

Uncovered stockpiling results in decreases in the nitrogen and potassium content of the manure. Also, the manure becomes more difficult to spread uniformly. Leaching and runoff of nitrogen and phosphorus from the stockpiled manure may pollute ground and surface water. Weed seeds, particularly pigweed, may be deposited in stockpiled manure and flourish in that environment. Application of stockpiled manure to crop land may introduce weed seeds into the field. Covered stockpiles are not a problem. If manure is covered while stockpiled, the spreading characteristics of the original material will be preserved. The cover will eliminate any pollutant runoff from occurring. The proper siting of covered stockpiles on high ground should prevent, movement of the water table into the pile and the potential for groundwater pollution.

References

International Plant Nutrition Institute (IPNI) Crop Nutrient Removal Calculator. (2013, November 21). Retrieved from https://www.ipni.net/app/calculator/home September 6, 2016.

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