RECYCLING LIQUID DAIRY CATTLE WASTE TO SUSTAIN ANNUAL TRIPLE CROP PRODUCTION OF FORAGES

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Introduction

Our current society demands that dairy farmers accept manure management as a part of their business and assume responsibility for utilizing or disposing of it without polluting the environment regardless of the cost. Most managers of dairy farms have production of milk as their primary objective and consider manure as a nuisance by-product they would like to avoid. Although dairy cattle manure has value as plant nutrients for crop production, reuse as bedding material and other specialty products, these uses may not provide a positive cost benefit ratio.

Providing feed usually amounts to 50% or more of the cost of producing milk. It is necessary to include forages in diets of dairy cows to maintain normal rumen function and feed nutrients from forage crops are usually the most economical. In most of the coastal plain areas of the Southeastern United States, the soils are low in natural fertility and the rainfall patterns and amounts are erratic, which oftentimes subjects crops to drought stress. Because of such conditions, the production of forage crops in these areas may be less dependable, lower in quality, and cost more per unit of dry matter compared to that for other areas. However, the prevailing temperatures in this region are such that selected forage crops can be grown very successfully throughout the year provided the needed supplementary plant nutrients and water are applied. Thus, it seems that many dairy farms in the coastal plain areas of the Southeast could be uniquely well suited for removing manure by water flush and recycling it on-farm to cows through forage crops.

Manure Removal By Flush Cleaning. Labor saving water flush systems are easily automated for low cost, rapid and complete removal of manure from animal confinement areas. The primary disadvantages of these flush systems are the generation of very large volumes of "dirty" water and ice formation in colder climates. Because of environmental restrictions, this very dilute liquid manure should not be applied to saturated, wet, or frozen cropland. Storing this dilute liquid manure to allow for timely application to croplands usually requires investment in large volume storage structures, recycling of flush water, and loss of plant nutrients (especially nitrogen) during storage. In the milder areas of the southeastern United States, liquid manure usually could be applied onto actively growing crops throughout the year soon after it was collected. Doing this would minimize loss of nitrogen to the atmosphere and allow relatively small and much less expensive storage facilities.

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Nutrients in Manure. Since the early history of man, it has been recognized that animal manure provides nutrients for growing plants. Klausner (4) reported that about 70 to 80% of nitrogen, 60 to 85% of phosphorus, and 80 to 90% of potassium fed to animals is excreted in manure. This varies according to species and nutrition provided, but the high proportions in manure make the recycling of plant nutrients from crop to animals, then back to crops again, appear economically attractive. Calculations for the value of manure usually have included only nitrogen, phosphorus, and potassium. Other important macro nutrients such as calcium, magnesium and sodium, and micro nutrients such as sulfur, zinc and manganese, are relatively high in dairy manure. Other advantages the soil gains from application of manure include increased organic matter and greater water holding and exchange capacity. A USDA research report (6) showed the annual manure production from a 1,400 pound dairy cow would contain nitrogen, phosphorous, potassium, calcium, magnesium, sodium, manganese, zinc, and copper amounting to 172, 29, 137, 101, 31, 21, 0.57, 0.42, and 0.10 pounds, respectively. These data show the diversity and proportions of nutrients, but the amounts excreted by the better fed and more productive cows of today should be higher. Most attempts to calculate a dollar value for manure is difficult because of the fluctuating costs of the above elements and whether they are needed to supplement the soils onto which the manure is applied. Most of the high sand content soils in the coastal plain areas should benefit from these other manure elements in addition to the N, P, and K which are usually purchased as chemical fertilizers. Sulfur is no longer an integral component in the newer forms of commercial fertilizers and, if needed in the soil, must be purchased as an additional ingredient. Because of this, sulfur content of the manure may increase its fertilizer value.

Separating Manure. A companion development to the widespread adoption of water flush removal of manure from animal facilities has been the use of manure solids separators. Removal of the larger solids reduces plugging of liquid handling pumps, piping, sprinkler nozzles and avoids rapid accumulation of solids in storage lagoons. Producing solids that can be recycled for bedding, mulching or other specialty uses is another reason for separating. Moore (5) reported that retention of plant nutrients in the separated liquid varied according to the specific nutrient and ranged from 70 to 88% of that in the unseparated manure slurry.

Objective. Scientists of the Animal Science Department and the Crops Systems Research Unit, USDA, ARS, at the Coastal Plain Experiment Station have cooperated in research on the production of forage crops using liquid manure from a water flush cleaned dairy as the only fertilizer source of plant nutrients. The primary goal has been to develop a system which provided crops to receive applications of manure throughout the year and thereby produce palatable forage crops having high nutritive value. The remainder of the paper will present some results from this work.

Materials And Methods

Source of Manure. A facility covering about 1-1/4 acres where about 90 cows are milked, fed and continuously confined with free stalls for resting is flush cleaned twice daily at milking with clean water. After each cleaning, the manure slurry is pumped over an inclined, fixed, separator screen (Agpro, Inc., Paris, TX). Separated solids move by gravity off the screen into a collection bin and the liquid containing fine manure particles is diverted to a holding lagoon or tank. Daily volume of separated liquid manure, excluding any rainfall, usually ranges from 24 to 37 thousand gallons. Concentration of nitrogen usually averages 30 to 35 pounds per acre inch of separated liquid manure.

Irrigation Equipment. The bottom of a rectangular lagoon for holding separated liquid manure slopes with the long axis and particulates in the liquid manure tend to migrate and settle at the deep end. The manure is pumped onto cropland through a center pivot equipped with a standard sprinkler package. Intake is through a water jet cleaned rotary screen (1/4" holes) suspended under a pontoon supporting a 35 rpm prop type agitator (48" diameter) at the deep end of the lagoon. Operation of the agitator during irrigation of manure brings settled particulates into suspension by moving about 11,300 gallons of liquid per minute. A meter to measure flow rate and volume pumped, plus a sampler, is attached on the delivery pipe from the pump. The pumping system applies about 300 gallons per minute and is connected to a fresh water lagoon for system flushing and applying supplementary water. The system is valved to a cable tow gun sprinkler to distribute excess liquid manure not used experimentally. The center pivot system evolved from one having a small holding tank and underground distribution lines with fixed risers for portable gun sprinklers which required twice daily applications. Operation of this system was a dirty, labor intensive task which resulted in non-uniform coverage. It was replaced by a center pivot equipped with large gun sprinklers which also failed to provide uniform coverage needed for research. During evolution through these irrigation systems, many different crops and combinations of crops were grown using different application rates of liquid manure as the only fertilizer. Through these trial and error efforts, a dependable minimum tillage system of using bermudagrass, rye and corn for year round production of forage crops was developed using liquid manure as the only source of fertilization.

Cropping System. The cropping system begins with an established sod of Tifton 44 bermüdagrass, maintained with irrigated liquid manure and supplemental water during late summer and early fall to prevent stress from lack of water or plant nutrients. Accumulated growth may be grazed or harvested at 4 week intervals for hay or silage. Tifton 44 is used because its extensive development of underground rhizomes provides a special capacity to survive overplanting. Vigorous early growth, resistance to pests, ability to grow at lower temperatures than other small grains, and early spring maturity help rye fit the system especially well. It is interplanted with 2 bushels of seed per acre into the Tifton 44 bermudagrass sod in mid to late October. Irrigation with liquid manure immediately after planting, plus follow up applications of manure or water to prevent nutrient or water stress on either crop, allows them to grow compatibly until the bermudagrass is made dormant by winter temperatures.

Grazing of the rye-bermudagrass usually can begin within 3 to 4 weeks following seeding of the rye and continue until about the first week of February. Because of the very high moisture content of rye forage during winter and the danger of extensive freeze damage to a large volume of accumulated growth, grazing is the preferred harvesting method. Cattle are removed in February and the rye is allowed to grow to boot or early head maturity, then harvested as wilted silage about the middle of March. Producing this silage crop discourages late tillering of the rye, and through shading, helps keep the bermudagrass dormant. Immediately after rye is harvested, a tall growing, mid-season corn is minimum till seeded in rows 36" apart with kernel spacing of 6-1/2" for an expected harvest population of about 24,000 plants per acre. Using a row spacing of 30" or growing a full-season corn excessively delays recovery of the bermudagrass following ensiling of the corn. Liquid manure is applied to settle soil to seed and assure adequate moisture for germination. Should residual rye or emerging bermudagrass appear to be a problem, they may be retarded by spraying the sod with Gramoxone within 2 or 3 days following seeding of the corn. Usually, this is not required because the corn grows more vigorously during the cool spring and dominates the bermudagrass by shading. Manure or water is applied as needed to prevent moisture or nutrient stress of the corn until it is harvested for silage in late June or early July. The low quality retarded bermudagrass and corn plant stubbles remaining after corn harvest should be shredded with a rotary mower to prepare for production of high quality hay. If large amounts of residual bermudagrass are present, this low quality material should be cut, dried, and baled to feed animals not under production stress. If broadleaf weeds become a problem, 2-4D is used to control them. Liquid manure or water are applied as needed to maintain the T-44 bermudagrass in vigorous growth for production of high quality hay or silage until about mid-October when a repetition of the cycle begins with the interplanting of rye into the bermudagrass.

Crop Production. *The experiment reported here was the third year of* growing three forage crops in succession on the same land for comparisons of production from four application rates of fertilization with liquid manure. Each treatment was applied to one quadrant of the 23 acre pivot area. The soil was a Tifton loamy sand (fine-loamy, siliceous, thermic, plinthic, paleudult). Usually, manure treatments were applied weekly except during periods of harvest, excessive rainfall, or equipment malfunction. Amounts applied deviated from the planned rate ratio of 1.0:1.5:2.0:2.5 and over the year averaged a ratio of 1.0:1.3:1.9:2.5. Supplemental irrigation with fresh water was differentially applied to treatment areas when tensiometer readings indicated it was needed to avoid water stress. In accordance with the previously described cropping system, the one year production period began after the 7-27-87 harvest of retarded growth bermudagrass remaining after silage corn harvesting on 7-22-87. Bermudagrass hay was harvested on 9-4-87 and 10-16-87 and yield determined from 8 random sample areas per treatment quadrant. Rye was interseeded into the bermudagrass on 10-27-87 and grazed until 2-15-88 when cows were removed. The subsequent growth was harvested for silage on 3-17-88. Replicated areas protected from animals were harvested on 1-14-88, 2-9-88, and 3-14-88 to estimate rye yields. Corn was minimum-till planted into the rye-bermudagrass sod on 3-21-88 and Counter® was added to control soil insects and crows. The production year ended with the corn silage harvest on 7-19-88. Yields were estimated from 18 randomly selected, 10' long row plots within each treatment quadrant. Estimated treatment totals for liquid manure applied during the crop year were 11.1, 14.1, 21.3, and 28.5 inches, which amounted to about 340, 440, 660, and 880 pounds of nitrogen per acre, plus correlated amounts of other previously discussed plant nutrients found in liquid cattle manure.

Results And Discussion

Yield Differences. Forage crop dry matter production is summarized in Table 1. Crop performance and yields were similar to that obtained from this system of cropping during the two most recent prior years. Even though the highest manure application rate was about 2.5 times that of the lowest rate, total crop dry matter yields were not significantly modified by application rates. Rye was the only crop to show an effect of application rate on yield, but this effect was not linear and disappeared when individual crop yields were pooled to obtain total yield for this year. This failure of crops to increase yields as manure application rates were increased agrees with earlier work of Johnson, et al. (3) and Butler, et al. (2). In a 4 year experiment, Burns et al. (1) showed a doubling of the application of lagooned swine waste (avg of 528 and 1080 lb nitrogen equivalent/acre annually) failed to significantly increase forage production. The mixed forage crop of fescue (winter) and bermudagrass (summer) averaged 4.95 tons/acre for the low application compared to 5.57 for the high application. By comparison, our average forage dry matter annual yields ranged from 11.73 to 12.58 tons/acre, from manure nitrogen applications ranging from a low of 340 to 880 lb/acre.

Nutrients in Soil. Applying manure frequently in small amounts may have increased nutrient use efficiency more for lower application rates compared to that for the higher applications. Since forage yields were similar, it is logical that some of the less leachable elements from the manure may have accumulated in the soil. Results of soil analyses in Table 2 do not show any consistent accumulation trends. This cropping system of always having an actively growing root mass in the soil may be functioning to absorb higher than normal amounts of nutrient elements when their concentration in the soil is excessive. The value of manure for increasing soil pH without applying lime is shown by the near neutral soil pH following several years of manure application.

Luxurious Consumption of Nutrients. Total annual dry matter yields failed to be increased by increasing the applications of liquid manure (Table 1). However, data on protein and nitrogen in forage dry matter (Tables 3, 4, and 5) show that uptake of nitrogen increased as application of manure increased. It appears that the corn crop removed prior to the production of the bermudagrass harvested on 9-4-87 was very effective in uptake of nitrogen, even though applications of manure were similar to those for this crop year being discussed (1987-1988). This is evident from the similar crude protein percentage (16.0 to 16.5) in dry matter (harvested on 9-4-87) from the different manure treatments (Table 3). However, by the second cutting of hay (10-16-87), the higher applications of manure could be associated with higher protein in the hay. This relationship of higher protein and nitrogen, as manure application increased, became even more pronounced with the rye forage dry matter (Table 4) and continued to be evident in the corn dry matter (Table 5).

Even though forage dry matter production was relatively low from the rye, this crop was highly effective in uptake of nitrogen. This makes it especially useful because amount of daily production of manure on dairy farms is relatively uniform and needs to be recycled as it is produced during winter. The total uptake of nitrogen by rye was similar to that of corn, even though the corn crop produced much more dry matter per acre. Based on the protein and nitrogen content of the corn dry matter, it seems the two lower applications of manure (340 and 440 lb/acre) did not supply enough nitrogen to produce corn dry matter with "normal protein content" of 8.1% (National Research Council Table of Feed Composition). Summarized data in Table 6 indicate that the proposed cropping system is very suitable for recycling animal manure through production of forage crops. The nitrogen in liquid manure is primarily ammonia and some volatliizes to the air during and after application. Manure treated soils also have increased denitrification and subsequent loss of nitrogen to air. Because of these factors and the large recovery of nitrogen in crop dry matter, it appears the proposed cropping system for recycling manure could be an environmentally sound system for disposal and utilization of animal manures.

Manure Residues. Particulates in the manure accumulated on leaves of the crops but this did not cause any detectable increase in leaf or stem disease. This is consistent with prior experience using this same cropping system. There was no evidence that manure residues decreased palatability of the crops when either grazed or used as stored forages. Desirable fermentations were obtained when crops produced with irrigated liquid manure were ensiled.

TABLE 1. Mean yields of forage dry matter from crops fertilized with liquid manure.

Total Estimated Application Manure (lb N/acre/yr)	Crop, Tons DM/Acre			
	T-44 Bermuda	Abruzzi Rye	Corn Silage	Total
340	1.82	1.90[a]	7.97 (175)[c]	11.69
440	2.30	2.26[a,b]	7.54 (163)	12.10
660	2.06	2.78[b]	7.70 (161)	12.54
880	2.03	2.48[a,b]	8.00 (169)	12.51

[a,b] Means within a crop not followed by the same letter are different (P<.05).

[c] Means in ( ) are bushels of grain/acre in silage.

TABLE 2. Means of soil test analyses of three composite samples per manure application treatment.

Date and Treatment[1]	pH	P[2]	Soil Elements, lb/acre[3] K[2]	Ca	Mg
02-05-87 (1)	6.9	327	167	1561	218
12-09-87 (1)	6.7	243	193	1267	212
05-13-88 (1)	6.7	226	160	1209	208
02-05-87 (2)	7.0	317	192	1803	265
12-09-87 (2)	7.0	387	269	2182	334
05-13-88 (2)	6.9	274	206	1753	314
02-05-87 (3)	7.0	271	173	1611	209
12-09-87 (3)	7.0	246	235	1556	274
05-13-88 (3)	6.9	255	186	1593	278
02-05-87 (4)	6.9	221	175	1502	202
12-09-87 (4)	7.0	320	277	2248	333
05-13-87 (4)	7.0	289	239	2052	298

[1] Estimated amounts of manure nitrogen applied annually is coded as (1), (2), (3), and (4); and is 340, 440, 660, and 880 lb/acre, respectively.
[2] Means for P and K are shown as P_2O_5 and K_2O.
[3] The top 15 cm of soil were sampled.

Table 3. Mean yield of dry matter (DM), crude protein (CP), and nitrogen (N) from Tifton-44 bermudagrass.

Total Estimated Manure Application (lb N/acre/yr)	Harvest Date	DM Yield (lb/acre)	Protein Yield %	(lb/acre)	N Yield (lb/acre)
340	09-04-87	1424	16.1	229	36.3
	10-16-87	2209	16.6	367	58.7
	Total	3633		596	95.3
440	09-04-87	1824	16.4	299	47.8
	10-16-87	2768	16.7	462	73.9
	Total	4592		761	121.7
660	09-04-87	1948	16.0	312	49.9
	10-16-87	2168	18.3	397	63.5
	Total	4116		709	112.4
880	09-04-87	1551	16.5	256	41.0
	10-16-87	2509	18.4	462	73.9
	Total	4060		718	114.9

Table 4. Mean yield of dry matter (DM), crude protein (CP), and nitrogen (N) from abruzzi rye.

Total Estimated Manure Application (lb N/acre/yr)	Harvest Date	DM Yield (lb/acre)	Protein Yield %	Protein Yield (lb/acre)	N Yield (lb/acre)
340	01-14-88	1226	20.5	251	40.2
	02-09-88	650	26.0	169	27.0
	03-14-88	1939	18.7	362	58.0
	Total	3815		782	125.2
440	01-14-88	1395	24.2	338	53.3
	02-09-88	767	27.8	213	34.1
	03-14-88	2365	17.5	414	66.2
	Total	4527		965	153.6
660	01-14-88	1422	26.6	378	60.5
	02-09-88	988	29.8	294	47.0
	03-14-88	3156	22.6	713	114.1
	Total	5566		1385	221.6
880	01-14-88	1655	28.1	465	74.4
	02-09-88	785	31.4	246	39.4
	03-14-88	2514	26.1	656	105.0
	Total	4954		1,367	218.8

Table 5. Mean yield of dry matter (DM), crude protein (CP), and nitrogen from corn.

Total Estimated Manure Application (lb N/acre/yr)	Harvest Date	DM Yield (lb/acre)	Protein Yield %	Protein Yield (lb/acre)	N Yield (lb/acre)
340	07-19-88	15,940	6.15	981	157.0
440	07-19-88	15,080	7.31	1,102	176.3
660	07-19-88	15,328	7.76	1,190	190.4
880	07-19-88	16,000	8.16	13,06	209.4

Table 6. Total combined annual yield of forage dry matter (DM), crude protein (CP) and nitrogen (N) from Tifton 44 bermudagrass, abruzzi rye and corn.

Total Estimated Manure Application (lb N/acre/yr)	DM Yield (lb/acre)	Protein Yield (lb/acre)	N Yield (lb/acre)
340	23,388	2,359	377
440	24,199	2,828	453
660	25,010	3,284	525
880	25,014	3,391	543

Conclusions

1. Irrigation of screened liquid dairy manure onto a minimum tilled annual crop sequence of Tifton 44 bermudagrass, then rye followed by silage corn seems to be a very satisfactory system of recycling manure to cows through production of forage crops in areas similar to the coastal plain of Georgia.

2. Crops used in the triple cropping system tolerate large variations in application rates of liquid manure without showing any toxic symptoms or significant modifications of yields.

3. The cropping system maintains a stable sod, even during corn production, and minimizes erosion potential.

4. Providing plant nutrients and water to prevent nutrient or water stress while rye or corn becomes fully established following seeding is very critical for success of the triple cropping system.

5. Maximum manure application rates the cropping system will tolerate without polluting the environment have not been established, but our current research includes this objective.

6. Application rates which maximize manure nutrients use efficiency for the cropping system have not been established, but our current research addresses the need.

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