NUTRIENT BALANCE FOR TRIPLE-CROP FORAGE PRODUCTION SYSTEMS FERTILIZED WITH DAIRY MANURE OR COMMERCIAL FERTILIZER

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Abstract. Three forage crops per year were grown on the same land to investigate production and environmental effects of manure fertilization. Crop sequences were corn silage-bermudagrass hay-rye/clover haylage or corn silage-corn silage-rye/clover haylage. Both systems received each of two fertilizer sources; liquid dairy manure (600 kg of N/ha/year), and commercial fertilizer (recommended rates based on soil test). The cropping sequence including two crops of corn silage has produced 26% greater forage dry matter than the system of one crop of corn silage, and manure fertilization has produced 29% greater forage dry matter yields than commercial fertilizer application.

For the first full cycle of crops, nitrogen recovery in crops for the corn-bermuda-rye/clover system was 60.7% for manure and 54.4% for fertilizer while for the corn-corn-rye/clover system it was 55.3% for manure and 48.3% for fertilizer. There was a trend for increasing nitrate in the soil water at 0.8 meter depth under both cropping systems during early fall. This effect tended to be greatest for the system including bermudagrass and for commercial fertilizer application.

For the manured treatments, an average of 33% of the phosphorus applied was removed in forage while for the fertilized treatments 205% of the amount applied was removed in forage. Phosphorus removal was similar for both cropping systems, but tended to be greater (on a kg/ha basis) for manure fertilization.

This is a study-in-progress, but at the current time it appears that crop production (digestible dry matter yield) and nitrogen (recovery and movement) parameters may be somewhat superior for manure compared to commercial fertilization. The long term effects of applying more phosphorus than is removed may limit the sustainability of manure application at this and similar rates.

INTRODUCTION

Dairy farms in the Southern Region of the United States have total sales in excess of $2.9 billion with over $440 million of net farm income (USDA, 1992, 1993). Thus, dairying represents a significant, value-added component of the southern agricultural economy. However, the region's estimated 1.7 million dairy cattle (USDA, 1993) excrete over 30 billion kg of feces and urine per year. The management of this, and other, animal manures are significant problems. The three major constraints on dairy production in the Southern United States are heat stress, production of superior forage, and manure utilization. From the forage standpoint, Southeastern feed costs per unit of milk exceed the combined feed plus labor costs of milk in any other region of the United States (Lakshminarayan et al.,1994).

Dairy, livestock and poultry production has concentrated into units with greater animal numbers and, regardless of unit size, in localities with specialized infrastructure (Pagano and Abdalla, 1994). This production, often on farms limited in acreage or suitability for extensive manure distribution, is potentially non-sustainable. Utilization of manure on a frequent, year-round basis should reduce manure storage with its associated costs and potentials for nutrient loss, odor and overflow; maximize capture of nutrients in crops on a given land area; and reduce labor demands associated with seasonal manure application. The goals of the research on which progress is reported in this paper include development of a system that is capable of utilizing manure from intensive operations, offers predictable nutrient utilization and movement, is economically as well as environmentally sound, and produces crops of high feeding value.

METHODS

The research sites include a center pivot-irrigated field (configured to include 5.7 ha, divided into quadrants along topographic lines) and twelve 10 m x 10 m plots serviced by a traveling irrigation simulator. Both sites are connected to the same dairy manure and fresh water sources. One pivot quadrant and three plots each receive one of the four nutrient source x cropping system treatments. The nutrient treatments are either liquid manure to supply 600 kg nitrogen/ha/yr (in applications approximately every 14 days, year round) or inorganic fertilizer application (with split chemigation of nitrogen) based on soil test, plus fresh water irrigation.

One cropping system is a mixture of Abruzzi rye and crimson clover overseeded in fall on a Tifton 44 bermudagrass sod (for spring haylage), minimum tillage silage corn seeded after rye/clover harvest, and bermudagrass hay harvest in summer. The other cropping system includes conventional minimum tillage with rye and clover established in fall (for haylage), a first crop of temperate corn in spring and a second crop of tropical corn in summer (both for silage).

Each pivot quadrant contains a network of 18 ground water sampling wells (nine wells set at 3 m and nine set at 6 m, sampled quarterly). The perimeter of each pivot quadrant includes a berm to collect, and a flume with a sampler to estimate the volume of, and sample, runoff leaving similar contributing land areas of each treatment. Each plot contains four suction lysimeters (two at 0.8 m and two at 1.6 m) for sampling soil water (at biweekly intervals). Soils are sampled at each crop transition and manure is sampled for each quadrant and plot at each application. Three areas of each pivot quadrant are used as forage sampling plots and two areas of each small plot are sampled for forage yield and composition.

RESULTS AND DISCUSSION

Forage production and digestibility for the first full cycle of crops on the pivot field are shown in Table 1. The cropping sequence including two crops of corn silage produced 26% greater forage dry matter than the system of one crop of corn silage, bermudagrass hay, and rye-clover haylage. Previous work (Johnson et al., 1995), although not in side-by-side comparisons, suggested that a system including double cropped corn should produce at least 15% more forage than the system based on a Tifton 44 bermudagrass sod at this level of fertilization. Yield differences would likely have been greater under different weather conditions. The rye and clover were planted 2 weeks later for the double crop corn system, and their growth appeared to be restricted by the extremely wet winter of 1997-98.

Manure fertilization produced 29% greater forage dry matter yields than commercial fertilizer application. Chase et al. (1991) found significant increases in corn yield for both injected and surface-applied liquid manure compared with commercial fertilization. Many short term studies have found that manure is not as effective in supplying plant nutrients as commercial fertilizers. This is likely a reflection of the slower release of manure nitrogen and/or microbial or other changes in the soil which must occur before optimum manure utilization occurs. For example, Sweeten et al. (1995) and Moore and Gamroth (1995) reported lower forage production and nitrogen recovery during the first year of liquid dairy manure fertilization than during subsequent years. The pivot field in the present study had received dairy manure as the primary supplemental fertilizer for 6 years prior to the start of the experiment. This may explain the excellent results obtained with manure fertilization. Much of the yield difference between nutrient sources was due to a

Table 1. Yield And *In Vitro* Digestibility Of Forages From Two Systems In Response To Manure or Fertilizer

System Nutrient Source	Corn Silage	Bermuda Hay	Rye/Clover Haylage	Total	IVDMD
Corn-Bermuda-Rye		(kg/ha)			%
Manure	10,142	7,371	2,120	17,570	64.1
Fertilizer	5,444	7,407	1,426	12,908	62.9
Corn-Corn-Rye					
Manure	22,502		1,078	23,579	66.6
Fertilizer	19,017		96	19,112	65.5

lower yield of corn silage for commercial fertilizer application on the corn-bermuda-rye system. This appeared to be due to early rapid growth of bermudagrass in response to the initial application of fertilizer intended for corn production coupled with warmer than normal March temperatures (average maximum daily temperature 7.7C above long term norm). There may also be some level of nutrient application in the early season that allows corn to thrive in a bermuda sod, as low nutrient application in previous studies also favored bermudagrass over corn.

The average *in vitro* dry matter digestibility (IVDMD) (weighted for yield of each harvest) was 2.5 percentage points higher for the corn silage-corn silage-rye/clover haylage system than for the corn silage-bermuda hay-rye/clover haylage system; and 1.1 percentage points higher for manure than for commercial fertilizer. Corn silage generally has a higher digestibility than bermuda hay. The differences in digestibility between cropping systems would likely have been greater if rye/clover yields had been more nearly equal. Westerman et al. (1982) reported that IVDMD of manure irrigated bermudagrass forage was higher than that from control plots, and increasing manure rates tended to increase digestibility (significantly during 4 yrs). As a result of digestibility and yield differences in the present experiment, digestible dry matter production per hectare per year was 31% greater for the corn-corn-rye/clover system than for the corn-bermudagrass-rye/clover system, and 32% greater for manure compared to commercial fertilizer.

Nitrogen and phosphorus application, recovery in crops, and amounts remaining are shown in Table 2. In addition to crop content, nitrogen lost to denitrification and via runoff has not yet been calculated. Nitrogen recovery in crops for the corn-bermuda-rye/clover system was 60.7% for manure and 54.4% for fertilizer while for the corn-rye/clover system it was 55.3% for manure and 48.3% for fertilizer. For the manured treatments 80% of the non-recovered nitrogen was accounted to the rye/clover phase while for the commercial fertilized treatments the rye/clover phase accounted for only 24% of the non-recovered nitrogen (applied minus harvested nitrogen during the rye/clover period divided by applied minus harvested nitrogen for the year; note, commercial fertilizer for rye/clover was based on recommendations for cereal-legume mixtures, which accounted for part of the differences in application rate between nutrient sources). Excess rainfall during the fall and winter, including cloudy weather, may have affected these results. Some of the excess nitrogen applied during the rye/clover phase may also be available to the subsequent corn crop. Davis et al., (1995), at this location, reported nitrogen recoveries by a triple crop system fertilized with manure to be 12 to 17 percentage points higher than those found in the current study. Other than *el niño*, no explanation for this difference is readily apparent.

Phosphorus data (Table 2) was similar for the two cropping systems, but drastically different for the two nutrient sources. Since the soils in all quadrants initially had high phosphorus levels, only a maintenance amount of phosphorus was applied to the commercial fertilized areas. For the manured treatments, an average of 33% of the phosphorus applied was removed in forage while for the fertilized treatments more phosphorus was removed in forage than was applied (205%). On a mass basis, more phosphorus tended to be taken up under the manure treatments than under the commercial fertilizer treatments. Most of this trend was due to yield differences, but bermudagrass and the rye/clover had slightly higher phosphorus concentration in response to manure (0.07%), while corn had slightly higher concentrations of phosphorus in response to commercial fertilizer (0.04%).

Table 2. Nitrogen And Phosphorus Utilization For Two Forage Systems In Response To Manure or Fertilizer

System	Nitrogen				Phosphorus		
Nutrient Source	Applied	Harvested	Balance		Applied	Harvested	Balance
Corn-Bermuda-Rye				(kg/ha)			
Manure	515.4	312.7	202.7		205.8	69.8	136.0
Fertilizer	447.5	243.5	204.0		25.4	48.7	-23.3
Corn-Corn-Rye							
Manure	524.5	290.1	234.4		200.7	63.0	137.7
Fertilizer	432.5	208.6	223.9		25.4	55.8	-30.4

In a previous study at this location (Newton et al., 1995), phosphorus uptake by a triple crop system fertilized with manure was about 20 kg/ha greater (excluding the first year during which phosphorus uptakes were over 100 kg/ha) than during the current study. There was a modest increase (14 mg/kg) in soil phosphorus (Mehlich 1) concentration in the 10 to 15 cm soil depth samples between January 1997 and July 1998 with manure application, while commercial fertilizer resulted in decreases within all soil depth samples to 30 cm. As was the case for nitrogen, the greatest difference between applied and harvested phosphorus for the manure treatment occurred during the fall-winter period.

Nitrate (NO_3-N) concentrations in the wells have remained essentially unchanged. The concentration of NO_3-N in samples from the suction lysimeters remained relatively constant, generally in the 2 to 15 mg/L range, until September 1998. After a 12+ cm rainfall following 5 weeks with only traces of rain, NO_3-N concentrations exceeded 40 mg/L in most of the 0.8 m depth lysimeters. This spike tended to be greatest for the corn-bermuda-rye system fertilized with commercial fertilizer (mean near 60 mg/L) and least for the corn-corn-rye system with commercial fertilizer (mean near 35 mg/L) (both systems fertilized with manure had means near 40 mg/L). This occurrence may indicate that too little irrigation water was applied during the drought.

CONCLUSIONS

While sound conclusions cannot be made from work in progress, some items appear to warrant more attention or possibly additional study. Systems which apply manure uniformly through the year should give careful consideration to nitrogen utilization during the fall-winter period. Methods to reduce phosphorus concentration in manure or increase its uptake in plants is likely to be critical in developing sustainable manure fertilization systems. Avoiding moisture stress may be a critical factor in reducing NO_3-N leaching. Manure fertilization can produce high quality forages in amounts at least as great as commercial fertilization.

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