THE EFFECTS OF COMPOST, MANURE, AND UREA ON YIELD AND FORAGE QUALITY WHEN TOPDRESSED ON A PERENNIAL FORAGE MIX OF IRRIGATED, COOL SEASON GRASSES

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ABSTRACT

Significant quantities of animal manures are generated by livestock and equine facilities along the Front Range in Colorado. Topdressing raw manure on perennial forage is not recommended due to high potential losses of N into the atmosphere and surface water. Composted manure contains significantly less ammonium-N than raw manure. In a 2 year study conducted to determine the effects of topdressing composted manure, raw manure and urea on the yield and forage quality of irrigated perennial grass forage, composted horse manure and raw manure at 10 T/ac and 20 T/ac and raw manure 10 T/ac manure with wood shavings were topdressed once on established grass forage. Urea at 185 lb N/ac was topdressed each spring for 2 years. Forage yield and quality were measured in the first and second hay cuttings. No yield differences among any of the fertility treatments were apparent during the first year after application. In the second year and first cutting, annually applied urea resulted in significantly higher yield than the organic treatments, but neutral detergent fiber (NDF) and acid detergent fiber (ADF) levels indicated higher forage quality from both compost and manure at 20 T/ac. In the second cutting yield was also higher where urea was annually applied. Without considering crude protein, which is not available at this time for 2007, and considering both years and both harvests, forage quality based on NDF and ADF shows compost at 20 T/ac applied once in 2006 resulted in the highest forage quality, followed by compost at 10 T/ac, manure at 20 T/ac, and urea applied annually at 185 lbs N in the next group, followed by manure at 10 T/ac both with and without wood shavings. This study shows potential for maintaining forage quality and yields on irrigated grass forage with topdressed composted horse manure.

INTRODUCTION

Manure from large dairies and feedlots is plentiful along the Front Range of the Rocky Mountains in Colorado. Significant quantities of manure are produced in small spaces, necessitating movement off-farm for proper utilization. Equine facilities, both large and small, also abound here. Due to urbanization along the Front Range and an increase in the number of small equine facilities, horse manure utilization can be problematic due to insufficient agricultural land and lack of knowledge about how to use it.

While the use of synthetic fertilizers is well understood and convenient, several problems are associated with its use. One ton of urea cost $82 in 1970, $184 in 1990, and $453 in 2007 (http://www.ers.usda.gov/Data/FertilizerUse/). Rising fertilizer prices may result in an increased interest in managing soil fertility with manure and composted manure. Nitrogen losses from fertilizer and manure have been recognized as potential contaminants of surface and ground water. Nitrogen volatilization from synthetic nitrogen fertilizers can be high in alkaline soils, especially when fertilizer cannot be incorporated or is applied during warm weather. These losses are both an economic problem and a growing environmental concern. Manure and synthetic nitrogen fertilizer applications are now linked to nitrogen deposition in Rocky Mountain National Park and subsequent ecosystem impacts (Colorado Department of Public Health and the Environment, 2007).

Increasing the use of manure and composted manure to maintain soil fertility on agricultural crops seems like a practical course of action as prices of commercially produced nitrogen fertilizers increase, the manure supply is plentiful and environmental problems with its use emerge. Composting manure reduces its volume, produces a finer textured material which spreads well and contains very little ammonium nitrogen. Most of the nitrogen in compost is in organic forms which are slowly mineralized in the soil when moisture is adequate, soil microorganisms are present and soil is warm.

Published information on agronomic rates of compost application on crop land is limited, which is a deterrent to the use of compost. The objective of this research is to provide information about using compost to maintain soil fertility on irrigated perennial grass forage where soil amendments cannot be incorporated into the soil. Information from this study can be applied to organic forage production, which is a growing concern for organic dairies which are mandated to provide grazing for their dairy cows. An increase in published information about plant response to composted manure can encourage the appropriate use of the large quantities of manure that are generated in this region by livestock and equine facilities.

MATERIALS AND METHODS

This study began in spring 2004 when meadow brome (*Bromus bilbersteinii*), smooth brome (*Bromus inermis*), and orchardgrass (*Dactylis glomerata*) in a ratio of approximately 1:1:1 were drill seeded on plots located at Colorado State University's Agricultural Research, Development and Education Center (ARDEC), located near Ft. Collins, CO.

Compost Preparation

The compost used in this study, made from equine manure from CSU's Equine Teaching and Research Center and plant material, such as cut alfalfa, wheat straw and fallen leaves, was made on-site during the fall and winter of 2005-2006.

Crop Establishment

Prior to planting, 160 pounds nitrogen (N) per acre were applied as urea (46-0-0) and incorporated. No additional phosphorus (P) was applied. These rates were based on soil test results from soil sampled the previous fall and recommendations developed at Colorado State University for grasses and alfalfa (Davis et. al, 1996). The new planting was irrigated during the 2004 growing season and cut once to suppress annual weeds. Hay was also cut during the growing season in 2005 but no data was taken.

Experimental Design

The experimental design was a randomized complete block design with six treatments replicated four times. Each plot measured 20 feet wide and 40 feet long.

Irrigation

Irrigation was sprinkler applied using a Zimmatic Lateral Move System (http://www.lindsaymanufacturing.com/zim_agsysystem_latmov.asp) weekly throughout both growing seasons.

Climatic Factors Affecting Crop Growth at ARDEC

While there is no official weather station at ARDEC, precipitation reported through the Community Collaborative Rain, Hail and Snow Network (http://www.cocorahs.org/) was less than 8 inches during the 2005-2006 water year which is October 1 through September 30. During the 2006-2007 water year 13.14 inches of precipitation were measured at ARDEC. The 2007 growing season experienced close to normal precipitation at ARDEC, while precipitation during the 2006 growing season was only slightly over half the average annual precipitation.

Fertility Treatments

Six fertility treatments were applied (Table 1) in the spring of 2006. Composted horse manure and raw manure were both applied at 10 T/ac and 20 T/ac (C1, C2, M1, and M2, respectively). Raw horse manure at 10 T/ac (M1) was applied alone and with the addition of 40% by volume of softwood shavings (M1 + WS) which are locally used for equine stall bedding, and often end up mixed with horse manure that is land-applied. The control treatment, urea (46-0-0) was spring applied in 2006 at the agronomic rate (Davis et. al, 1996), based on soil test results from fall 2005, yield estimates, and crop.

Table 1. Soil Fertility Treatments.

Soil Treatment	Application rate	% N	N/ac (pounds)	Carbon /ac
Compost 1 (C1)	10 T/ac***	0.67	~62	~680 pounds
Compost 2 (C2)	20 T/ac***	0.67	~124	~1360 pounds
Manure 1 (M1)	10 T/ac***	0.95	~190	~2 tons**
Manure 2 (M2)	20 T/ac***	0.95	~380	~4 tons**
Manure 1 + Wood Shavings (M1 + WS)	10 T/ac + WS 40% by volume	0.95	~190	~ 3 tons** (M1=2, WS=1)
Urea spring 06 * (U)	402 lbs/ac	46.0	185	0
Urea spring 07 * (U)	402 lbs/ac	46.0	185	0

*Urea applied annually at agronomic rate, based on crop grown, yield expectations, fall soil test, and CSU fact sheet 0.537, Fertilizing Alfalfa and Grasses. All other treatments applied once in spring of 2006.
**Assume 19 lbs N/Ton "as is" manure, 50% moisture, manure C:N 20:1
***Applied "as is;" all %N on dry basis.

Organic treatment rates were not based on agronomic recommendations for compost and manure, as mineralization rates are not locally available for topdressed organic amendments. Measuring N mineralization is another phase of this field study, not reported here. Rates were determined based on what is practical to apply with a manure spreader. Ten tons per acre of manure is a locally common application rate. This rate plus double this rate were chosen for both manure and compost and manure with wood shavings.

Organic treatments (C1, C2, M1, M2 and M1 + WS) were applied once in the spring of 2006. Fall 2006 soil tests indicated that to meet the nitrogen needs for the 2007 growing season that 185 lbs. N/ac as urea should again be applied (Table 1).

Crop Management

Forage was cut and baled for hay twice during each of the growing seasons. The first cutting was made between jointing and anthesis stages, which fell both years in early June. The second cutting was made in August in 2006 and September in 2007.

Yield Measurement

Prior to cutting samples for yield, three foot wide alleys were cut between the plots using a Carter flail harvester (http://www.cartermfgco.com/product2.htm). To obtain yield data, the center three foot strip, minus the alley width at each end of the swath, was cut from each plot, resulting in a sample area of 3 feet by 37 feet. Cut forage was blown into a large plastic trash container mounted on a weigh pad on the back of the harvester. Weights were recorded manually from an electronic readout in front of the tractor operator. Grab samples were taken from the forage as it was harvested, bagged and weight recorded. Bags were oven dried for several days until dry, then weighed again. Wet and dry weights were used to calculate moisture content and dry matter content which was converted to tons per acre.

Forage Quality

The dried grab samples for moisture determination from each harvest were saved and ground through a 1-mm sieve using a Retsch SM 2000 Heavy-Duty Cutting Mill. To date, neutral detergent fiber (NDF), acid detergent fiber (ADF), and percent total nitrogen have been measured. NDF and ADF were measured using an Ankom fiber digester (Ankom, 1998). The % N was analyzed using a LECO (St. Joseph, MI) Total CHN 1000 Elemental Analyzer which quantitatively determines the amount of nitrogen in all forms (ammonium, nitrate, protein and heterocyclic nitrogen) in plant material using an induction furnace and a thermal conductivity detector. Samples are ignited in an induction furnace at approximately 900°C in a helium and oxygen environment in a quartz combustion tube. An aliquot of the combustion gases is passed through a copper catalyst to remove oxygen and convert nitrous oxides to N_2, scrubbed of moisture and carbon dioxide, and nitrogen content is determined by thermal conductivity. Crude protein is calculated from the nitrogen content (CP=%N x 6.25).

Statistical Analysis

Statistical analyses were performed on the data using SAS 9.1 using the proc glm model and the LSD for mean separation. P values are reported in each data table where statistically significant differences occur.

RESULTS AND DISCUSSION

Forage Yields

The soil amendments applied in this study are diverse (Table 1), ranging from about 62 pounds of N from compost at 10 T/ac (C1) to 380 pounds of N applied in the 20 T/ac raw manure treatment (M2). The 185 pounds N/ac from urea (U) applied spring 2006 and 2007 totaled 370 pounds over the 2 year study, about the same as M2 applied once in spring 2006.

In addition to the range in levels of actual N applied, carbon application also covered a wide range. Compost and raw manure both contain carbon. The compost used in this study had a C:N ratio of 11 to 1, while raw horse manure contains more carbon, with a C:N of about 20:1. The wood shavings added to 10 T/ac manure (M1 + WS) added about 1 T/ac carbon in addition to what was in the manure. This treatment was included to study the effect of surface applied stable waste, which can contain large amounts of bedding. Softwood shavings, produced by local mills from logging and slash removal in the nearby mountains, are commonly used for equine bedding in this region. Adding carbon to soil is known to temporarily immobilize nitrogen, resulting in decreased plant growth. While the low rate of manure (M1) resulted in significantly lower yield than the annually applied urea (U), the yield from the treatment M1 + WS was not significantly lower than the manure treatment applied at the same rate but without the added wood shavings (M1), indicating that the expected immobilization of N did not occur or has not yet occurred. Visual inspection of these plots indicated that the wood shavings could have acted like surface mulch that prevented some water loss

In 2006, there were no significant differences in yield (Table 2) among any of the fertility treatments, in spite of the range in amounts of N and C applied (Table 1). While this study was irrigated, 2006 precipitation was about half of average. The lack of differences in any of the treatment yields might be due to less than adequate water during this growing season.

Table 2. Forage Yields

Soil Treatment	Forage Yields (Tons/ac)					
	2006			2007		
	June	August	Total	June	Sept.	Total
C1	1.2	1.2	2.4	0.3 b	2.0 b	2.3
C2	0.7	0.9	1.6	0.3 b	2.2 b	2.5
M1	0.6	0.5	1.1	0.3 b	1.9 b	2.2
M2	0.7	0.6	1.3	0.3 b	1.8 b	2.1
M1 +WS	1.4	0.8	2.2	0.3 b	1.8 b	2.1
Urea	1.9	0.9	2.8	0.4 a	2.7 a	3.1
Avg. yield	1.1	0.8	1.9	0.3	2.1	2.4
p-value	NS	NS	NS	0.0014	0.0100	.0050

Statistics: SAS 9.1, proc glm, mean separation test LSD.

In 2007, yields showed significant differences on both harvest dates. Yields in the plots fertilized both springs with urea were significantly higher than yields in any of the other plots. There were no significant differences among the yields of any of the organic treatments (C1, C2, M1, M2, M1+WS).

Forage Quality

In addition to yield, forage quality is important in evaluating fertility treatments on forage. NDF and ADF (Table 3) are important forage parameters for ruminants. NDF measures the hemicellulose, cellulose and lignin fiber fractions found in forage and is partially digestible.

A high NDF value decreases feed intake and can limit the effectiveness of forage in supporting high milk production (Stokes and Prostko, 1998). Lower NDF values indicate better forage quality. ADF measures the cellulose and lignin content in plants and is also partially digestible. Increasing ADF levels decrease fiber digestion and are negatively correlated with forage quality. Lower values for ADF also indicate better forage quality. While high levels of crude protein (CP) in forages may be desirable for dairy cattle, this forage quality parameter is best evaluated along with NDF and ADF. CP levels in forage for both June and August 2006 showed no differences due to treatment. The average CP for each cutting was 12.4%.

In both years of this study, significant differences occurred in NDF and ADF levels among treatments at both harvests (Table 3). In 2006, considering both harvests and NDF and ADF together, forage quality was ranked from highest to lowest. The first group included only the higher rate of compost (C2), followed by the lower rate of compost (C1), the higher rate of manure (M2), and urea (U) in the second group, followed by manure at the lower rate both with and without wood shavings (M1, M1+WS). In 2006 there were no significant differences in CP from any of the fertility treatments to consider in making forage quality determinations.

Table 3. Forage Quality: NDF and ADF.

Soil Treatment	2006				2007			
	June		August		June		September	
	% NDF	% ADF	% NDF	% ADF	% NDF	% ADF	% NDF	% ADF
C1	57.8 ab	32.3 abc	59.4 c	31.5 b	59.1 bcd	29.6 bc	58.6 ab	33.0 b
C2	56.3 c	30.9 c	59.3 c	30.5 b	58.3 d	28.8 d	58.4 ab	33.6 b
M1	58.0 a	33.2 a	61.4 ab	31.6 b	59.4 abc	30.1 ab	57.8 bc	32.7 b
M2	56.3 c	32.3 abc	61.2 ab	32.2 b	58.4 cd	29.1 cd	58.6 ab	35.0 a
M1 + WS	57.0abc	32.8 ab	62.0 a	35.5 a	60.0 ab	30.4 a	57.4 c	32.4 b
Urea	57.8 ab	31.6 abc	60.1 bc	31.7 b	60.3 a	29.4 bcd	59.2 a	33.3 b
p-value	0.073	0.022	0.0002	0.008	0.0004	<.0001	0.0019	0.0017

SAS 9.1, proc glm, LSD; NDF: neutral detergent fiber; ADF: acid detergent fiber

In 2007, without considering CP which is not yet available, and again considering both harvests and NDF and ADF together, forage quality was ranked from highest to lowest. The first group included only compost at the higher level (C2), followed by the lower rate of compost (C1), both rates of manure (M1, M2), and urea(U) in the second group, followed by the lower rates of manure both with and without wood shavings.

Future analysis of CP for 2007 and nitrate-nitrogen for both years will provide additional information about forage response to manure and compost and synthetic nitrogen fertilizer. Since both high yields and good forage quality are important to animal producers, the potential impact on both should be considered when making decisions about whether to use an organic or commercially produced fertilizer to surface apply to irrigated grass pasture. This study shows potential for maintaining forage quality and yields on irrigated grass forage with topdressed composted horse manure.

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