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On-Farm Demonstration of the Use of Compost Amendments for Mitigation of Greenhouse Gas Production

Final Report

Sponsored by

CANADIAN CATTLEMEN'S ASSOCIATION
GREENHOUSE GAS MITIGATION PROGRAM FOR CANADIAN AGRICULTURE

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Abstract

With manure composting growing into an economical and practical method for managing cattle manure, improving the process by retaining more of the valuable nutrients, and reducing odour and greenhouse gas emissions are also becoming important considerations for cattle producers. The aim of this project was to show through an on-farm demonstration that composting of beef cattle manure using natural amendments can reduce the production of nitrous oxide (N_2O) and methane (CH_4), while retaining valuable nutrients. The demonstration project was funded by the Greenhouse Gas Mitigation Program for Canadian Agriculture (GHGMP). The federal program was designed to promote awareness of agricultural practices that reduce atmospheric levels of greenhouse gas or increase carbon storage in soils. The Canadian Cattlemen's Association (CCA) administered the delivery of the beef sector component of the program. Windrow composting was conducted at the Olds College Compost Technology Centre using manure and bedding material from the College feedlot. Zeolite, obtained from Bear River Zeolite Inc.(Idaho USA), and perlite from Cornerstone Industrial Minerals (Oregon USA) were added to the beef manure in 5:1, 10:1, and 20:1 ratios (manure:amendment). Carbon dioxide, CH_4 and N_2O emissions during composting were measured using a flux chamber situated on the top of the compost pile. The finished composts were applied to field crops (barley silage and mixed grass pasture) in both spring and fall applications and were showcased against synthetic fertilizer. Harvest results indicated that both compost and commercial fertilizer application improved pasture biomass ($P<0.05$) over the unamended controls. Economic analysis indicated that there are significant advantages to composting with amendments, zeolite and perlite, particularly at lower inclusion rates. The recommendation from this study is the inclusion of zeolite or perlite in composting at a rate of 5%, based on results from economic analysis, compost nutrient analysis, windrow temperature results, and crop yield. It was recognized that public and producer awareness is essential for the adoption of sustainable management practices and mitigation of potential climate change. Olds College students were exposed to the project through classroom teachings as well as through project participation. A field day was hosted to provide an avenue for increased public and producer awareness.

Background

In the fall of 2002, the Canadian government ratified the Kyoto Accord calling for a national reduction in greenhouse gas (GHG) production to below 1993 levels. Despite an absence of guidelines or plans for implementation of an effective strategy to reach these gas reductions it is almost certain that compliance with this Accord will affect all industry sectors including agri-business. An estimated 3% of Canadian GHG's come from livestock production. Methane (CH_4) and nitrous oxide (N_20), which are 21 and 310 times more potent than carbon dioxide (CO_2) on a 90-year time horizon are GHG's produced by bacterial decomposition of organic waste. Composting is an effective and economically feasible method of reducing the weight and volume of livestock manure while retaining nutrients, with the final product serving as a valuable fertilizer and soil amendment. Careful management of the composting process to maintain aerobic conditions is the primary method of minimizing GHG emissions. The emission of GHG's during composting of cattle manure reduces the agronomic value of the finished compost and increases the greenhouse effect. Research indicates that GHG emissions produced from manure composting are highly dependant on the management method (Hao et al, 2001; Hao et.al., 2004; Fukumoto et.al., 2003). Hao and Chang (2000) reported no change in atmospheric concentrations of N_2O during composting. A recent study at the University of Alberta comparing GHG emissions from stockpiling versus composting cattle manure found composting produced 43% less emissions than stockpiling (Singh et al., 2005). Although CO_2 emissions were large during aerobic decomposition, N_2O emissions were low and only observed during late stages of composting. Methane emissions were virtually negligible during the composting process. Other studies have confirmed the potential of composting to reduce GHG emissions (Hellman et al, 1997). Zeman et al (2002) conducted a comprehensive review of the impact of various composting regimes on overall GHG emissions.

Aluminum silicates have the capacity to sequester reactive ions, providing the potential to reduce CH_4 and N_2O production during the composting of livestock manure. Zeolite is known to be effective at adsorbing ammonia and as a result it affects the nitrogen dynamics in compost. Lau et al (2003) found the addition o biocatalyst (zeolite and yeast) could reduce N_2O emissions to a certain degree, but not throughout the entire active phase of composting. Zeolite and perlite also have the capability to enhance plant growth. Perlite provides aeration and improved moisture retention. Zeolite acts as a slow release fertilizer, releasing nutrients as they are required by the crop. The high affinity of zeolite for ammonium ions (NH_4^+) and its slow release capabilities make zeolite of special interest in minimizing environmental pollution during animal waste management. Adsorption properties of zeolite have enabled them to be used as NH_4^+ adsorbents during composting (Bernal et al, 1993) and in poultry facilities (Koelliker et al, 1978). Reduced ammonia volatilization preserves the nitrogen, resulting in compost with a higher nutrient value. There have been several studies on the use of zeolite in composting for the prevention of ammonia volatilization (Witter and Lopez Real, 1988, Lefcourt and Meisinger, 2001, Kithome et al, 1999). The ability to desorb NH_4^+ ions allows zeolitic composts to be used as slow release fertilizers, providing significant crop benefits when applied to the soil (Kithome et al, 1998). Excess nitrogen can be absorbed by zeolite and released when nitrogen-poor conditions exist in the soil.

Composted manure has several advantages over raw manure including reduced weed seed and pathogen content, reduced volume, uniform particle size, and no odor when spreading. Compost has the potential to improve soil structure, texture, water holding capacity, cation exchange capacity, nutrient and organic matter content, and biological diversity. Compost application has advantages over application of synthetic fertilizer as well. Since composting recycles nutrients, it is not fossil fuel intensive and its use will reduce GHG emissions from fertilizer production. There is no danger of over-applying compost because nutrients are released slowly. Over application of synthetic fertilizer can lead to water pollution. Compost has the potential to improve physical and biological properties of soil whereas synthetic fertilizer only impacts the chemical characteristics of soil. The main disadvantage is that although compost offers a wide range of nutrients, the nutrients are in low concentrations and large quantities are needed to meet soil requirements.

This study was intended to investigate and demonstrate the impacts of natural amendments on CO_2, CH_4, and N_2O production, nutrient retention during manure composting and crop response following compost application. The demonstration project was funded by the Greenhouse Gas Mitigation Program for Canadian Agriculture (GHGMP). The federal program was designed to promote awareness of agricultural practices that reduce atmospheric levels of GHG or increase carbon storage in soils. The Canadian Cattlemen's Association (CCA) administered the delivery of the beef sector component of the program. With manure composting growing into an economical and practical method for managing cattle manure, improving the process by retaining more of the valuable nutrients, and reducing odor and GHG emissions are also becoming important considerations for cattle producers. The aim was to demonstrate how these objectives are achieved when composting beef cattle manure with zeolite and perlite. The ultimate goal was to produce high quality compost that can be used as a bio-based soil amendment. Through demonstration, local producers were able to see first-hand the economic benefits of adopting such a process for their operations including the production and use of a bio-based soil amendment on their own land or marketing the composted manure as a commercial product.

Project Details

Compost production

The composting demonstration trial was conducted at Olds College School of Innovation's Compost Technology Centre. Windrows were constructed on a $10{,}000 m^2$ clay-based pad. Cattle manure and bedding material from the Olds College feedlot was used to form seven composting windrows. The windrows were approximately two meters tall, four meters wide, and 50 meters long. One windrow received no amendment and was designated as the control. Zeolite and perlite, were added to the manure using a front end loader as it was windrowed. Perlite was obtained from Cornerstone Industrial Minerals in Lakeview, Oregon, USA and zeolite was obtained from Bear River Zeolite Inc. in Idaho, USA. Three windrows contained zeolite and three contained perlite, in percentages calculated to match a manure:amendment ratio of 5:1, 10:1, and 20:1 (w/w).

Table 1: Treatment list

Windrow ID	Amendment type	Ratio Manure: Amendment	Amendment % of total
T1	None	N/A	N/A
T2	Zeolite	5:1	17
T3	Zeolite	10:1	9
T4	Zeolite	20:1	5
T5	Perlite	5:1	17
T6	Perlite	10:1	9
T7	Perlite	20:1	5

A Scarab compost windrow turner was used to work the products into the manure (Figure 1). Windrows were monitored using a temperature probe to ensure that temperatures reached 55°C, needed for the destruction of pathogens and weed seeds, and the windrows were turned five times within the first fifteen days, according to CCME guidelines (CCME, 2005).

Figure 1: Windrowing and turning the amended manure

GHG sampling and analysis

Gas sampling was conducted using the techniques identified by the United States Environmental Protection Agency (Kinbush, 1986). An emission isolation flux chamber is an enclosure with one open end that is placed on the compost pile surface to quantify gas emissions. The chamber has an inlet to introduce “sweep air”, an outlet to allow chamber air to exit and a sampling port for sampling chamber gas. Surface flux is the rate of exchange of gases between the compost surface and the atmosphere. An emission isolation flux chamber is used to measure surface flux by placing the chamber on the surface of the pile and passing very pure sweep air through the chamber at a known rate. Gases diffusing from the compost surface enter the flux chamber and mix with the sweep air until an equilibrium is reached. Once at equilibrium, the concentration of target gases (greenhouse gases) in the chamber is measured. Sweep air is being forced into the chamber with a vent at the top which enables the internal chamber pressure to equalize with ambient air pressure, avoiding pressurization of the can. Essentially no reduction in surface flux rate should be observed due to pressure buildup.

In this demonstration, the flow was calibrated on all cylinders for 5L/min using a flow gauge. A blank sample was run using the flux chamber situated flat on a stainless steel surface. One equipment blank was taken at the start of daily measurements and one at the conclusion of sampling for each flux chamber. Equipment was set up as soon as possible following the turning of the windrow. Samples were taken at three locations along the length of each windrow (one at each end and one in the middle) at Day 0, Day 10 and Day 30 from the start of composting. The air-pressure regulator was connected to the “Sweep In” port of the flux chamber (at bottom of can) using ¼-in. flexible tubing with a nylon cable tie. The rim of the flux chamber was worked into the windrow surface 2-3 cm to minimize ambient air intrusion. Purge gas (UHP nitrogen) was permitted to flow through the flux chamber for 30 minutes prior to taking the sample. To obtain a sample, a double ended needle was inserted through the sampling port on the top of the flux chamber and a vacuutainer was inverted over the needle (Figure 2). Samples were analyzed by gas chromatography (GC-TCD) at Alberta Research Council Analytical Chemistry Laboratory, Vegreville, AB for GHG concentrations. Flux rate for each gas was calculated in units of $g/m^2/min$, given the concentration of the gas, the molecular weight of the gas, the sweep rate and the basal area of the flux chamber (ERD SOP, 1999).

Figure 2: Withdrawing gas sample for analysis

The equipment blank sample concentrations were compared to the concentrations of the same gases detected in the samples. Soil flux measurements from individual analyses with a gas concentration less than five times the maximum concentration of that gas detected in any equipment blank sample were treated as non-detections (US EPA, 1989). A comparison of equipment blank concentrations and results of the seven treatments indicated that in all cases the gas concentration was less than five times the maximum concentration in the blank, and therefore all readings were taken as non-detections. Levels of CO_2 and CH_4 were extremely low in blank samples and in test samples. N_2O was non-detectable in any of the samples tested. An important consideration is that in the EPA design, air within the chamber is stirred by the sweep air, which is emitted from port attached to the side of the chamber near the bottom. This method likely requires sweep rates of 5L/min to achieve gas equilibrium in 30-60 minutes. Because of this higher sweep air rate, emission concentrations will be lower than in modified, more expensive chamber systems, making the detection of treatment differences more difficult. It is possible that treatment differences were so small in this demonstration that they were undetectable with the chamber system used.

The protocol was revised in order to reduce the dilution effect of sweep gas and also to permit gas sampling prior to as well as following the act of windrow turning. The vented static chamber technique (Hao et. al., 2001) was used to sample the windrows at 55 days following initiation of composting. The same chamber was used as in the flux chamber technique, but samples were taken regularly over a 30 minute period rather than once at the end of a 30 minute sweep-out phase. Samples were taken at the windrow surface at 0, 5, 10, 20, 30 and 60 minutes after the chamber was put on the windrow surface. Samples were obtained using a double-ended needle and vacuutainer and analyzed as before. Mass flux rate was calculated according to the following formula (Singh et al, 2005) with the assumptions that emissions are uniform over the entire length of the pile and with time:

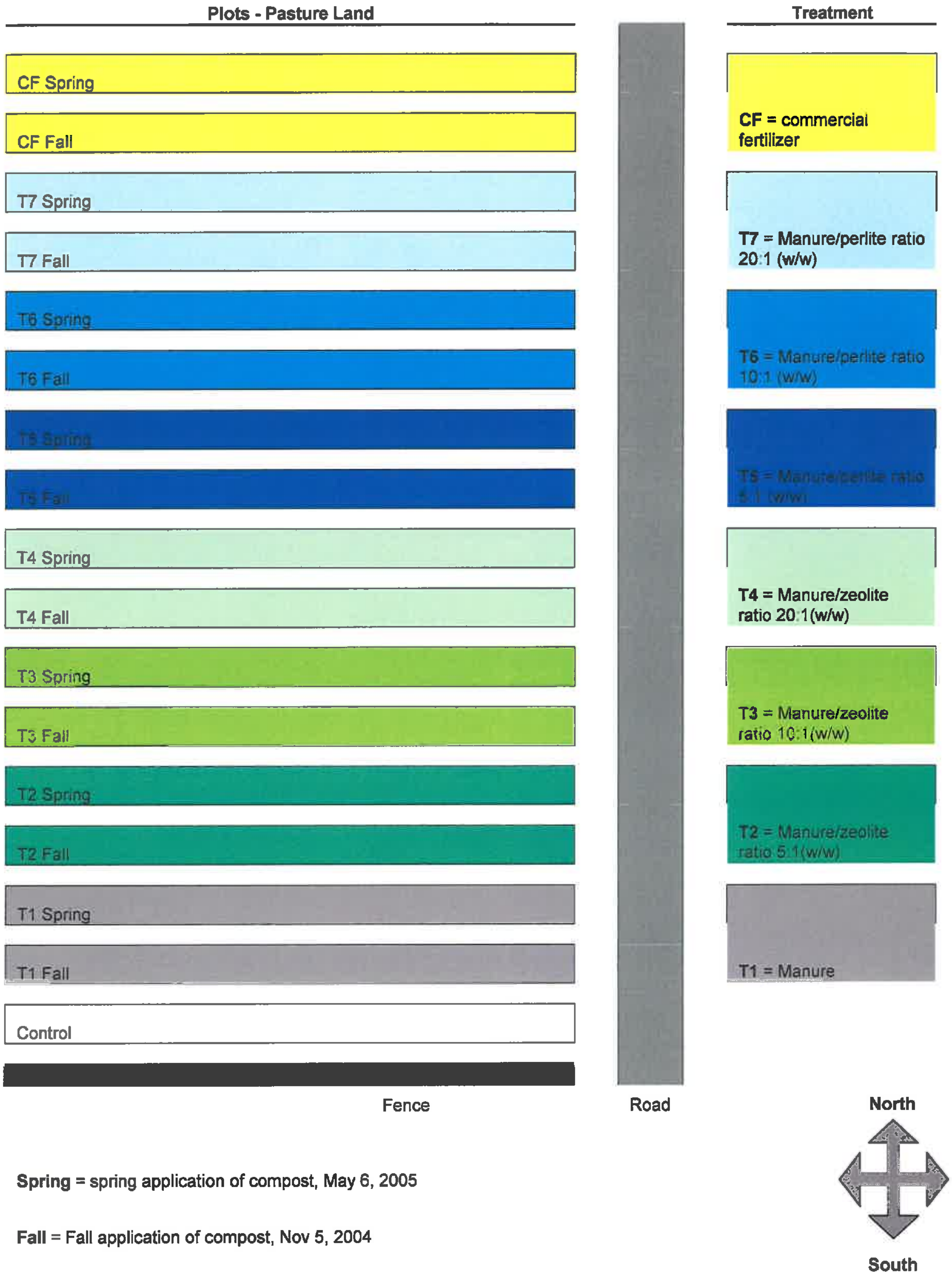
$$m = [C/10^6][MV_s/v_m]$$

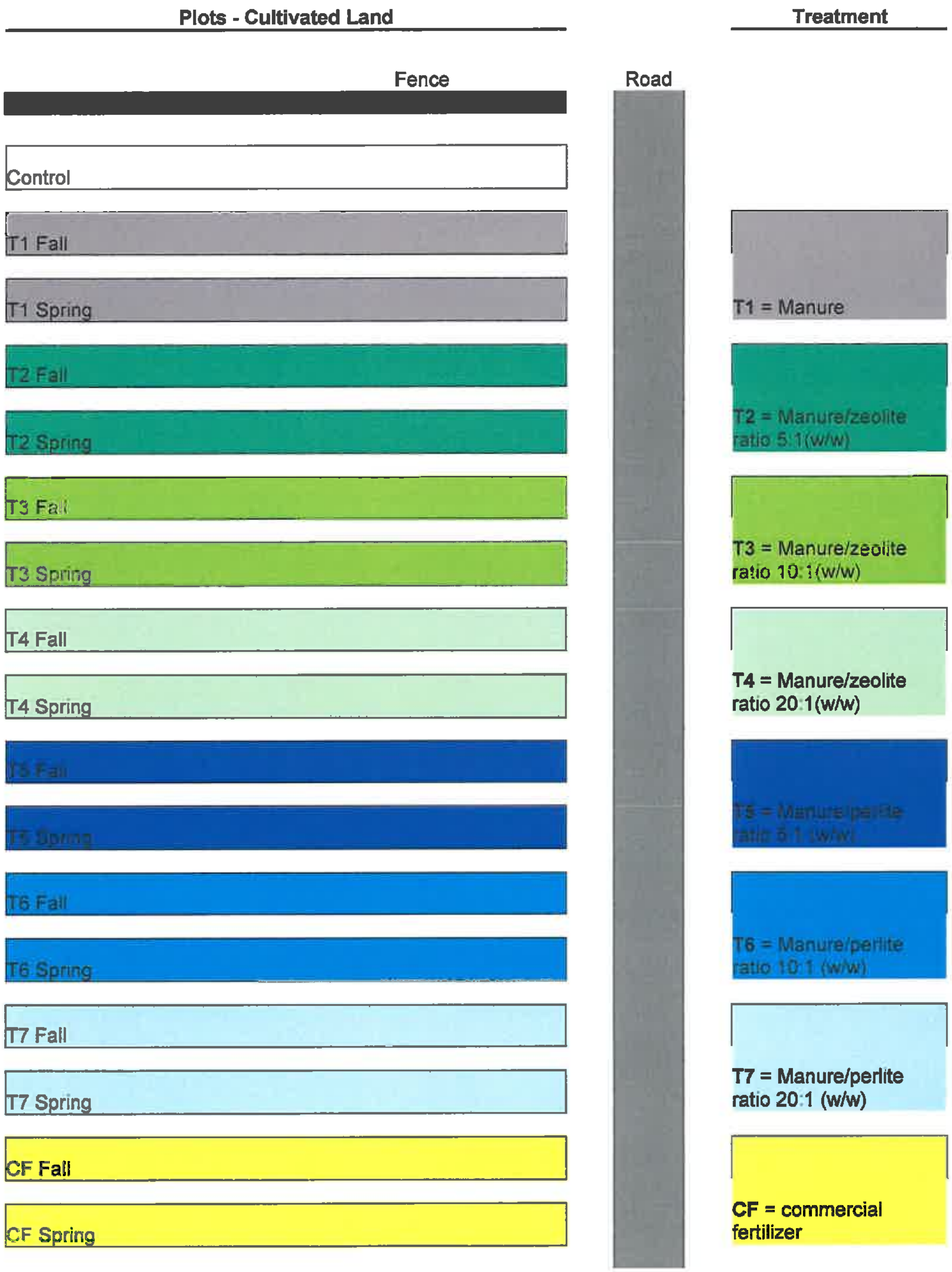
where:
m= mass flux rate (g s^{-1})
C= concentration change (uL L^{-1} s^{-1})
M= molar mass of GHG (g mol^{-1})
V_s = volume of static chamber (L)
v_m= 22.4 (L mol^{-1})

Field demonstration of compost

Once the active phase of composting was complete, the compost was left to cure. Samples were analyzed for moisture content, electrical conductivity and nutrient content (N, P, P_2O_5, K, K_2O, Na) at Norwest Labs prior to field application. The finished compost was applied as a bio-based soil amendment for field crops and showcased against synthetic fertilizer at the Olds College research plots. Each treatment was divided into four equal parts. The compost was broadcast applied using a John Deere manure spreader to mixed grass pasture plots (orchardgrass, fescue, Kentucky bluegrass brome) with split application in the fall and spring. This application was not incorporated. The other half of the compost was applied to barley (2-row feed barley) with the same split application timing, but the compost was incorporated. Plot size was 5m by 50m with a 3m by 50m alleyway between each plot.

Figure 3: Field plot layout

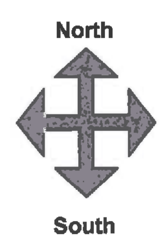




Spring = spring application of compost, May 6, 2005

Fall = Fall application of compost, Nov 5, 2004

Plot size = 5mx50m **Alley size** = 3mx50m



Application rates were determined for each treatment based on normalization of nitrogen concentration with a target of applying 60lb N / ac. In this calculation, the nitrogen availability in the compost was assumed to be 33% in the first year. This translated to an application rate of 4-5 t compost / ha for this trial. The fall applications of compost were made in November, 2004 and spring applications and seeding of barley were conducted in May, 2005. Seeding was conducted at a rate of 100lbs/ac using a disc drill. Project leaders included a comparison between compost and commercial fertilizer applications to showcase the performance of compost versus synthetic fertilizer in field crop applications. Urea was applied as the commercial fertilizer at a rate of 60lb / ac (60kg/ha) for the comparison. Where possible, results were analyzed using Microsoft Excel with significance assessed at P<0.05.

Project Findings

Windrow temperature

Temperatures were maintained within the thermophilic (40-65°C) range throughout the active phase of composting. This is essential to ensure pathogen and weed seed destruction is achieved. Addition of zeolite at a rate of 17% resulted in lower composting temperatures whereas the 5% amendment stimulated composting temperatures. Temperature is an indicator of microbial activity in the windrow. Addition of perlite at any rate did not have any significant impact on windrow temperature. Elevated temperatures at the Day 1 measurement indicate that the manure was already actively decomposing at the time that it was windrowed.

Figure 4: Windrow temperature (°C)

Compost analysis

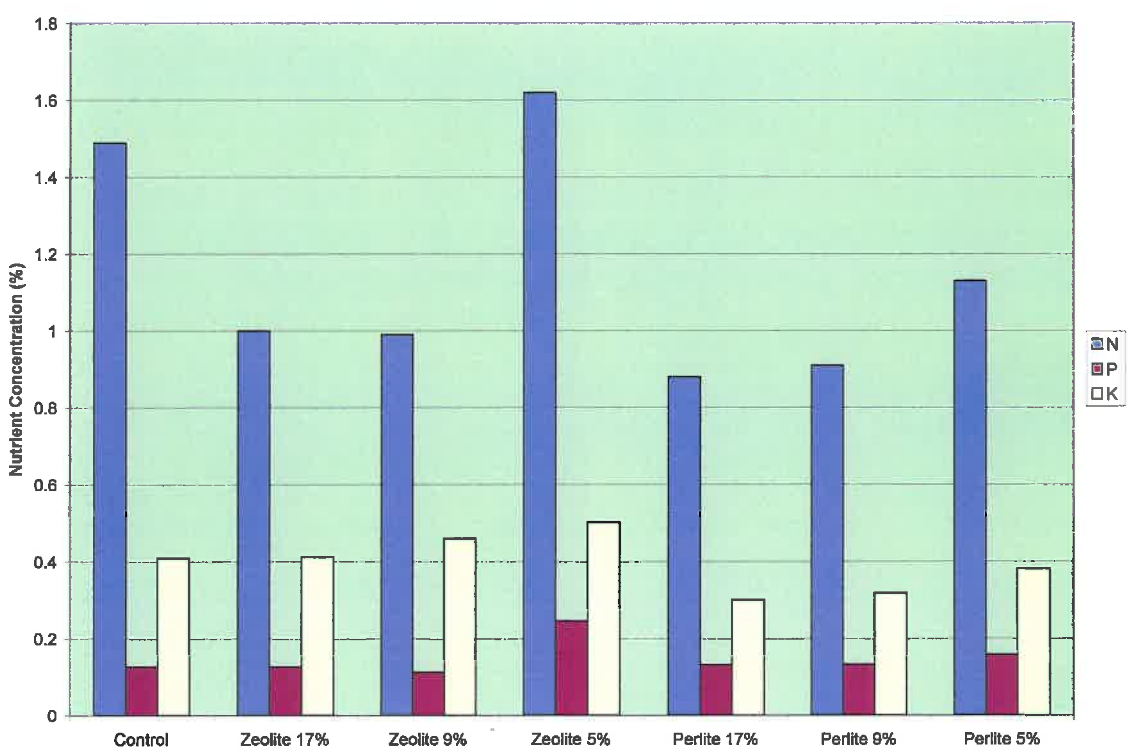
The addition of a compost amendment was successful in reducing the electrical conductivity (measure of salinity) of the finished compost from 23dS/cm to <16dS/cm. This reduction provides a more favorable environment for plant growth. Elevated levels of soluble salts in soil (>4 dS/m) inhibit the germination and growth of most plants, reducing seed germination, plant growth, and overall plant survival.

Table 2: Characteristics of composts

Windrow	Moisture Content (%)	Electrical Conductivity (dS/m)	Bulk Density (kg/m^3)
Control	62.2	23.3	276.7
Zeolite 17%	53.7	13.7	348.4
Zeolite 9%	51.7	15.7	369.6
Zeolite 5%	38.7	30.4	395.4
Perlite 17%	52.6	15.6	371.7
Perlite 9%	53.1	15.9	366.7
Perlite 5%	45.9	17.4	369.2

Nutrient analysis of the unamended compost revealed nitrogen, phosphorus and potassium contents of 1.49%, 0.335%, and 1.09%, respectively, on a dry basis. The concentration of nitrogen in the six treated composts were lower than the control, as a result of the dilution effect of adding large volumes of nitrogen poor amendment, with the exception of one. Amendment with zeolite at a 5% rate produced compost with a nitrogen content of 1.62%.

Figure 5: Compost nutrient analysis



The theoretical nitrogen concentration of the windrows was calculated with the assumption that average nitrogen concentration of the manure was 2%. After correction for the inorganic fraction of the compost mostly the fraction of perlite or zeolite, it is clear that the amendments are actively retaining nitrogen in the windrows (Table 3). Amendment with zeolite at a rate of 5% retained an additional 16% of available nitrogen over the unamended control. The 5% amendment with perlite retained an additional 12% of nitrogen over the unamended control. The results indicate that a 5% amendment rate is optimal for nutrient retention.

Volume reduction of manure in the unamended control was 42%. The addition of substantial quantities of non-biodegradable amendments (perlite and zeolite) resulted in volume reductions of only 22-33%, as would be expected.

Table 3: Nitrogen retention in the compost

Windrow	Theoretical N (%)	Actual N (%)	N Retention (%)	Volume reduction (%)
Control	3.72	1.49	40	42
Zeolite 17%	2.06	1.00	49	24
Zeolite 9%	2.79	0.99	36	33
Zeolite 5%	2.91	1.62	56	33
Perlite 17%	2.14	0.88	41	32
Perlite 9%	2.16	0.91	42	22
Perlite 5%	2.16	1.13	52	29

GHG sampling and analysis

Collection of gas samples into vacuutainers had an unavoidable minor affect on measured gas concentrations. As samples could not be measured directly, this method was unavoidable. On analysis it was determined that the vacuutainers were void of CO_2, CH_4, and N_2O. However, they did contain some residual air. Since the vacuutainers are filled with a larger volume of sampled gas the diluting effect of residual air was considered to be minor.

Any small impact would be consistent across treatments and should in no way impact the overall results or influence treatment differences. Analysis of the gas samples indicated that there was very little, if any ammonia produced from the windrows. Analysis also indicated that evolution of CH_4 was very low. There was a nearly undetectable increase in CH_4 concentration over the 60 minute measurement periods for each windrow. With respect to the turning of the windrow, detectable concentrations of CO_2 and CH_4 were slightly higher after turning, due to release of trapped gases in the windrow pore spaces. Release of the gases, in particular CO_2, continued at a high rate for a period of 0 to 20 minutes following a turning event, at which point evolution of the gas returned to its normal state of production.

Table 4a: CH_4 content in gas sample taken before and after windrow turning

CH4 Concentration (% of sample) Before Turning of Windrow							
Time (min)	T1	T2	T3	T4	T5	T6	T7
0	0.05	0.05	0.06	0.04	0.05	0.04	0.06
5	0.05	0.06	0.05	0.05	0.04	0.06	0.06
10	0.05	0.04	0.04	0.04	0.05	0.07	0.03
20	0.02	0.05	0.06	0.05	0.04	0.07	0.03
30	0.07	0.05	0.05	0.06	0.06	0.04	0.04
60	0.07	0.06	0.06	0.04	0.04	0.04	0.05
CH4 Concentration (% of sample) After Turning of Windrow							
Time (min)	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
0	0.09	0.09	0.08	0.09	0.09	0.09	0.10
5	0.07	0.10	0.08	0.09	0.10	0.10	0.10
10	0.07	0.08	0.08	0.10	0.09	0.10	0.11
20	0.08	0.09	0.08	0.09	0.10	0.33	0.11
30	0.08	0.10	0.09	0.09	0.10	0.11	0.09
60	0.08	0.05	0.08	0.09	0.09	0.08	0.10

Table 4b: CO_2 content in gas sample taken before and after windrow turning

CO2 Concentration (% of sample) Before Turning of Windrow							
Time (min)	T1	T2	T3	T4	T5	T6	T7
0	0.10	0.13	0.09	0.10	0.10	0.09	0.09
5	0.13	0.10	0.10	0.14	0.11	0.09	0.10
10	0.14	0.10	0.09	0.16	0.11	0.10	0.10
20	0.11	0.10	0.10	0.11	0.10	0.10	0.08
30	0.14	0.11	0.09	0.18	0.11	0.09	0.08
60	0.18	0.11	0.10	0.18	0.12	0.11	0.10
CO2 Concentration (% of sample) After Turning of Windrow							
Time (min)	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
0	0.15	0.13	0.11	0.12	0.12	0.14	0.15
5	1.39	0.54	0.44	0.35	0.16	0.32	0.43
10	1.61	0.34	0.27	0.35	0.27	0.34	0.36
20	1.35	0.28	0.20	0.36	0.19	0.29	0.27
30	0.94	0.21	0.20	0.25	0.17	0.33	0.15
60	0.33	0.16	0.11	0.13	0.14	0.12	0.15

N_2O was undetectable for all samples taken prior to and following windrow turning. This is important given the potency of N_2O as a GHG. These findings indicate that aerobic windrow composting is an environmentally sustainable manure management technique with reduced GHG effect. GHG production was not different ($P<0.05$) among windrows receiving amendment or between amended windrows and the control. It is possible that the limits of detection in this study were small enough to prohibit the identification of treatment differences. It is also possible that the trial was too short in duration to observe the production of N_2O. Factors that must be considered when interpreting and comparing the results of this demonstration to evidence from other related trials, include the age of the manure used, the method of composting used, and the unavoidable delay between sampling and sample analysis that was encountered in this study.

Field demonstration of compost

Pasture plots: Pasture harvest was conducted by hand clipping the biomass within a $0.25m^2$ frame at three locations across each plot (east end, middle, west end). Average dry yield for pasture crops in the Olds area is 7110kg/ha for orchardgrass (Alberta Government). Yield data will vary from year-to-year depending on growing conditions and pasture quality. Results were averaged over the three locations sampled.

The standard deviation of the results is largely due to variations over the length of the plot. Compost and commercial fertilizer application improved pasture biomass ($P<0.05$) over the unamended control. Biomass results from commercial fertilizer application was not greater than that of compost ($P>0.05$). Biomass yield was similar for spring and fall application of compost and commercial fertilizer. It was expected that the biomass yield would be greater for the fall application with compost and greater for the spring application with commercial fertilizer. This is due to the time and microbial activity required for nutrient release associated with compost application and because of leaching of unused nutrients with application of commercial fertilizer. There was no trend in the results suggesting improvement with fall application with compost but there did appear to be a slight improvement with spring application of the fertilizer.

Figure 6a: Pasture harvest yield- fall application of treatments

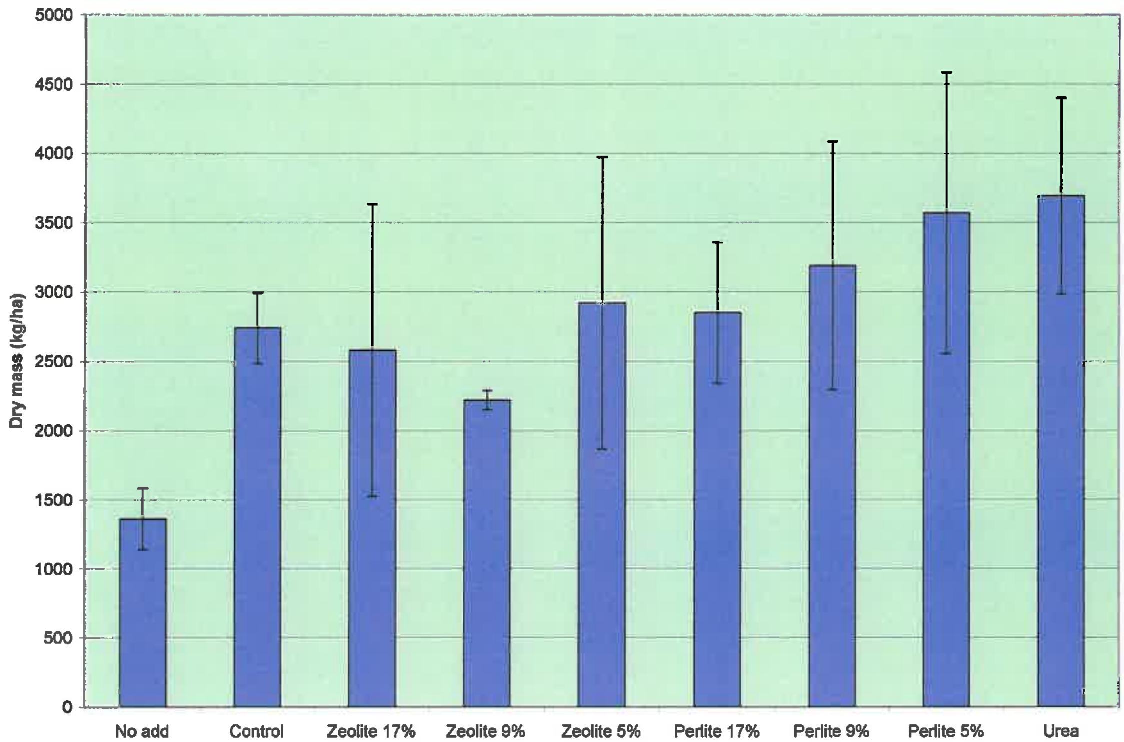
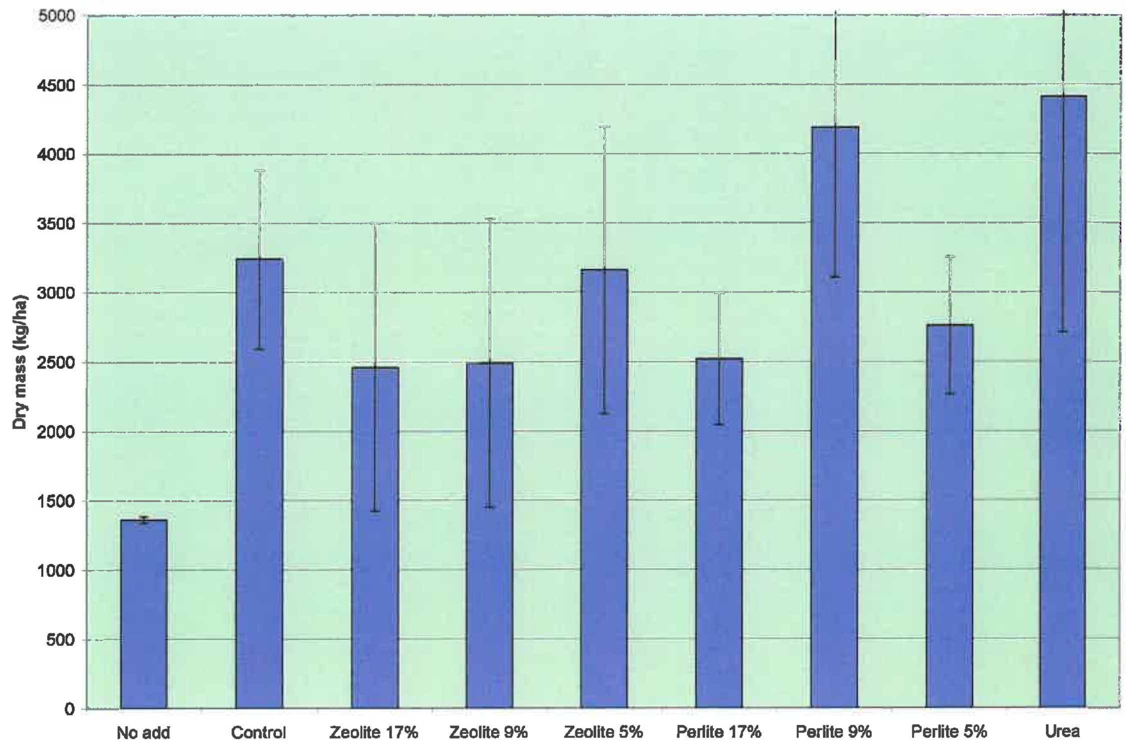


Figure 6b: Pasture harvest yield- spring application of treatments



Precipitation received in the 2005 growing season exceeded that of the normal yearly average. Between March and August, 2005 the total precipitation received was 380mm, compared to a normal of 349mm (Environment Canada). The total precipitation for June alone was 188 mm, more than doubling the normal value received.

Barley plots: A hand harvest and stem count was conducted in July 2005 on the barley plots to determine if there were any early differences between treatments. There was good germination in all plots. The plot receiving no amendment was the shortest at 41cm and the amended plots were similar in height, ranging from 47-57cm. Preliminary results indicated that plant biomass (particularly root mass) is larger in compost amended plots compared to the control. Plants were in the tillering stage characterized by the formation of side shoots. On average, 5 or 6 tillers were noted for each treatment.

A hail storm on October 7, 2005 resulted in an estimated 60% crop damage on the barley plots. Plots were sprayed with Round-Up on October 12 to ensure readiness for direct combining. Harvest was conducted using the Bayer custom plot combine on October 18.

Figure 7: Combining the barley plots

A single pass of 50m length was combined and seed yield and moisture content was determined. Typical barley yield for this area and soil type was estimated at 75 bushels per acre (Hamilton, personal communication). Higher than average yields were expected this year as a result of increased rainfall. Results were as follows:

Table 5: Moisture content and seed yield in barley plots

Plot	Moisture Content (%)	Seed Mass (kg)	Yield (bush/ac)	Corrected Yield (bush/ac)
No add	13.30	19.61	45.04	75.07
Control-spring	13.80	21.32	48.97	81.62
Control-fall	13.70	20.85	47.89	79.82
Zeolite 17%-spring	14.20	19.23	44.17	73.61
Zeolite 17%-fall	13.80	18.97	43.57	72.62
Zeolite 9%-spring	15.10	22.38	51.40	85.67
Zeolite 9%-fall	14.00	22.23	51.06	85.10
Zeolite 5%-spring	14.60	20.50	47.09	78.48
Zeolite 5%-fall	14.40	21.84	50.16	83.61
Perlite 17%-spring	15.30	23.06	52.97	88.28
Perlite 17%-fall	14.60	23.66	54.34	90.57
Perlite 9%-spring	15.50	24.23	55.65	92.76
Perlite 9%-fall	15.40	25.63	58.87	98.11
Perlite 5%-spring	14.70	23.53	54.05	90.08
Perlite 5%-fall	14.40	21.63	49.68	82.80
Urea-spring	15.00	22.27	51.15	85.25
Urea-fall	14.40	23.50	53.98	89.96

*Yield corrected for estimated 60% crop loss due to hail.

This project was designed as a demonstration trial rather than a research project. As a result, only one plot was used per treatment and statistical analysis of the results is not possible. However, some generalizations may be made based on the findings. Seed yield was improved with the addition of all composts and urea. The only exception to this was the compost containing 17% zeolite. Application of perlite amended compost had very favorable results in terms of seed mass and seed yield. It is important to remember that the black chernozemic soil in Olds is of very high quality for crop production and that compost application will likely have more dramatic impacts in poor quality soils by improving soil structure, texture, water-holding capacity, and providing organic matter.

Demonstration and Awareness

Olds College students benefited from the opportunity to participate in the demonstration project sponsored by the GHGMP. In the future, these students will become the agricultural specialists that will disseminate greenhouse gas mitigation technologies to agricultural producers. One student participated in the GHG testing and three other student researchers participated in the field demonstration.

The Olds College School of Innovation frequently conducts tours and information sessions for industry partners, agriculture producers, stakeholders, students, and international groups. From a recent survey conducted by the Olds College School of Innovation within a 50 km radius of the Town of Olds, 156 intensive livestock operations were identified producing 280,000m^3 of manure annually (Abiola, 2005). This figure illustrates the potential local opportunity for adoption of beneficial manure management strategies.

A Field Day hosted by Olds College School of Innovation on August 3, 2005 gave producers a first hand look at how manure composting and direct seeding techniques can be used to improve both cereal and forage crop production systems, while reducing GHG's. Invitations were mailed out to local producers, industry, and government representatives. Newspaper ads were placed in The Olds Albertan, The Olds Gazette, The Western Producer, and the Alberta Express to advertise the event. Ads were run on Q91 radio and the Olds radio station for two weeks prior to the event to reach additional interested parties. The Field Day was attended by 45 researchers, industry consultants, government representatives, and producers.

Figure 8: Dr. Abiola explaining the composting trial to Field Day attendants

"It's known that composting deals very well with the issues of pathogens, weed seeds and other challenges associated with livestock manure management." said Pat Walker, the coordinator for the Canadian Cattlemen's Association's activities of the federal Greenhouse Gas Mitigation Program for Canadian Agriculture. "There has been conflicting research, however, about the levels of greenhouse gas emissions related to composting. The work done here at Olds suggests that greenhouse gas emissions are negligible if composting is done properly. That's the key to maximizing all the other benefits of composting as well...do it properly."

Figure 9: Pat Walker of the CCA addressing the Field Day attendants

Field day participants saw three demonstrations on direct seeding. Increased production of forages and reducing tillage operations also helps reduce GHG emissions. The techniques, which eliminate or reduce tillage in crop production, play a dual role in capturing and storing carbon in the soil. Don Wentz, an agronomist in Lethbridge with Alberta Reduced Tillage Linkages which coordinates Alberta's soil and nutrient component of the Greenhouse Gas Mitigation Program, explained, "An old perennial forage stand was removed by use of herbicide rather than cultivation. Cultivation breaks down organic matter releasing carbon dioxide to the atmosphere and tends to result in lumpy organic clods that break down slowly and result in a poor seed bed. The site was direct seeded with barley. A larger seed is preferred when direct seeding into sod because the vigour of larger seeds gives more reliable establishment. As well, the use of herbicide rather than tillage results in a better seed to soil contact, resulting in better germination and a more even stand."

A direct seeded wheat site was toured with both a higher and lower than normal seeding rate. By increasing seeding rates it is hoped that we reduce weed pressure and reduce tillering which results in a more even stand and should result in higher yields. The third site was a perennial cereal rye stand planted for forage. Perennial cereal rye offers the opportunity to grow cereal forage in your rotation without having to plant each year but also not having the difficulty of removing a perennial grass or legume.

Classroom discussions centered on manure management alternatives and livestock nutrition. Olds College researchers showed how anaerobic digestion is used as a manure management strategy to generate "green" energy, how net feed efficiency in cattle can be measured and interpreted and how supplementation of cattle rations with oilseeds may reduce GHG emissions and enhance cattle performance.

A press release was issued following the Field Day to highlight the project and its findings. An article was published in Alberta Beef Magazine about the project as a result. Public and producer awareness is essential for the adoption of sustainable management practices and mitigation of potential climate change. Demonstrations such as this one are designed to provide the avenue for increased awareness.

Economics

Start up costs for composting facilities include the capital required for purchase of equipment, property, permitting costs, and building construction. All of these costs can be quite substantial depending on the size of the operation. In the case of a composting operation at an intensive livestock operation, some of these costs will already have been incurred (land, equipment). The self-propelled windrow turner can be a piece of equipment that uses a large portion of the start-up cost. Whether the operation is large or small, there needs to be a mode of aeration for the composting piles or windrows. Although windrow turners are the most effective for aeration, a front end loader, skid steer or perforated pipes and a blower may also be used. Temperature and oxygen monitoring equipment are recommended for larger composting operations. Again, the cost of this equipment will depend on the level of sophistication.

Operational costs in composting facilities include worker salary, equipment maintenance costs and utilities. The operational cost of a facility does not increase proportionately with the volume of waste treated. As a matter of fact, the larger volumes will result in lower operational cost to the facility per unit of compost produced. For example, the personnel required to monitor two windrows will be the same as for four windrows. Similarly, equipment maintenance will be very similar with twice the manure volume handled. Fuel costs will increase with an increase in volume. In a study by Tompkins et al (1997) on the economics of composting feedlot manure and operational cost comparison was conducted for raw manure management versus composting manure. The economy of scale used was 25000 cubic yards per year. All manure was assumed to be applied within 1.6km (1 mile) of the feedlot so no differential transportation costs were considered. Pen loading and cleaning was conducted using a truck mounted spreader in the case of the raw manure and an end-dump truck in the case of the composted manure (12 cubic yards per load). Transport to either the field or the composting site was assumed to be 1.6km maximum. The calculation for raw manure did not include spreading time and the calculation for composted manure included all maintenance. Data for this study was provided by P. and B. Morrison.

Table 6: Operation cost comparison for composted vs raw manure

Operation	**Raw Manure Management ($/cubic meter)**	**Composting Manure Management ($/cubic meter)**
Pen cleaning/loading	0.85	0.85
Transportation	1.11	1.11
Compost Production	0	2.29
Total	*1.96*	*4.25*

Adapted from Tompkins et al, 1997.

The distinct operating cost to composting under this model was demonstrated at $2.29 greater than the alternative. It was concluded that there must be economic incentives associated with composting before it would provide an acceptable alternative management strategy. One of the options explored was the hauling distance. If the manure could not be used within 1.6km of the feedlot, the costs associated with land application would increase incrementally. The composting process typically results in a volume reduction of 50% with feedlot manure. If the material is composted prior to hauling, this translates to movement of one-half the total volume or one half the total number of loads, reducing the transport costs by 50%. Therefore, the economic incentive to composting can be related to haul distance. Tompkins et al (1997) found that it became more economical to compost prior to hauling when the round trip distance is greater than 4km (2.5 miles).

In the composting demonstration conducted at Olds College, production costs for 700m^3 of compost were determined. Pen cleaning and manure hauling costs for the project were $1200, corresponding to a price of $1.71/m^3. Compost production for this smaller volume and under the monitoring regime required for research was $13.59/m^3. The current bulk price for zeolite was $115/t and for perlite was $30/t. Transport costs to move the compost to the field was estimated at $75/hr with approximately 25m^3 per load and 2 loads per hour (Hamilton, personal comm.).

Table 7: Production cost per m^3 compost

Windrow	Control	Zeolite 17%	Zeolite 9%	Zeolite 5%	Perlite 17%	Perlite 9%	Perlite 5%
Manure hauling	$ 1.71	$ 1.71	$ 1.71	$ 1.71	$ 1.71	$ 1.71	$ 1.71
Transportation	$ 1.50	$ 1.50	$ 1.50	$ 1.50	$ 1.50	$ 1.50	$ 1.50
Compost production (research)	*$ 13.59*	*$ 13.59*	*$ 13.59*	*$ 13.59*	*$ 13.59*	*$ 13.59*	*$ 13.59*
Compost production (feedlot)	$ 2.44	$ 2.44	$ 2.44	$ 2.44	$ 2.44	$ 2.44	$ 2.44
Amendment	$ -	$ 6.29	$ 3.97	$ 2.21	$ 1.62	$ 0.93	$ 0.43
Total	**$ 5.65**	**$ 11.94**	**$ 9.62**	**$ 7.86**	**$ 7.27**	**$ 6.58**	**$ 6.08**
Compost production (research) was calculated from this trial but smaller windrows and increased monitoring as part of the research							
project increased the costs over what would normally be experienced at a feedlot composting operation.							
For economic analysis, compost production (feedlot) was taken from Tompkins et al (1997) and adjusted for 4% inflation each year.							

Because of the additional cost of the composting amendments, adoption of the above protocols will depend a great deal on economics. Potential sources of revenue associated with composting include fertilizer offsets, income from increased crop yield and the possibility in the future of carbon credits. Composted manure mixed with perlite or zeolite is a high value product, which could be sold commercially or used to improve poor quality soil areas, providing both economic and environmental benefits. Confined feeding operations may utilize the composted product on their own land base or sell to neighbors and the horticultural industry as a valuable fertilizer. The use of composted manure will result in reduced usage of commercial granular fertilizers and the GHG emissions associated with the production of these fertilizers. Because composting has the potential to reduce GHG emissions relative to other options such as stockpiling manure, there is an opportunity for producers to sell carbon credits to large emitters if a carbon trading market develops. Carbon credits are currently selling for $34 - $40/tonne in European markets.

Urea was purchased from Parkland Fertilizer at a price of $390/t. It was not possible through this project to weigh the biomass produced from the barley trial so seed yield was used to calculate the potential for increased revenue with application of either compost or urea. Seed revenue was estimated at $2/bushel (Hamilton, personal comm).

Table 8: Economic analysis

Costs vs Revenues	Control	Zeolite 17%	Zeolite 9%	Zeolite 5%	Perlite 17%	Perlite 9%	Perlite 5%	Urea
Costs								
Compost application (t/ac)	1.81	2.12	2.31	0.47	2.92	2.00	1.12	0.00
Bulk density (kg/m3)	276.70	348.40	369.60	395.40	371.70	366.70	369.20	N/A
Compost cost ($/ t)	20.42	34.27	26.03	19.88	19.56	17.94	16.47	0.00
Compost cost ($/ac)	$ 36.96	$ 72.65	$ 60.13	$ 9.34	$ 57.11	$ 35.89	$ 18.44	$ -
Urea cost/ac	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 25.27
Revenues								
Seed yield increase (bush/ac)	5.65	0	10.31	5.98	14.36	20.37	11.37	12.54
Revenue/ac from yield increase	$ 11.30	$ -	$ 20.62	$ 11.96	$ 28.72	$ 40.74	$ 22.74	$ 25.08
Balance	**$ 25.66**	**$ 72.65**	**$ 39.51**	**$ (2.62)**	**$ 28.39**	**$ (4.85)**	**$ (4.30)**	**$ 0.19**

Values in brackets indicate a positive return.

The economic analysis indicated that applying composted manure without amendments is more costly that applying urea (Table 8). The cost of urea was almost exactly offset by the increase in seed yield that accompanied its use. There are other, difficult to measure benefits associated with composting and application of compost that should be mentioned here. Indirect benefits of manure composting include odor control, reduced pollution and weed seed and pathogen elimination. Compost itself can often have natural disease suppressive effects, reducing the need for and associated costs with pesticides. The addition of compost can improve the water holding capacity of soils, improving drought resistance. Although drought was not a problem in the year of this study, it has had serious effects on crop yield in the past. All of these benefits are difficult to assign a monetary value to but have significant value to agricultural producers in Western Canada.

This analysis also indicated that there are significant economic advantages to composting with amendments, zeolite and perlite, particularly at the 5% inclusion rates. When zeolite was used as the amendment, the input costs were substantially higher. The compost cost ($/ac) for the zeolite amended compost at the 5% rate was lower than would be expected because of a higher rate of nitrogen retention. Because the nitrogen concentration was higher, there was less compost required to achieve the 60lb/ac N requirement. Coupled with the increase in crop yield and the offset from the fertilizer, the economics were positive. The input costs associated with perlite addition were lower than that for zeolite and the increased revenue associated with the improved seed yield increase were very high. These factors led to a positive economic return when compost was amended with perlite at the 9% or the 5% rate.

Conclusions

Greenhouse gas measurement findings indicated that aerobic windrow composting was an environmentally sustainable manure management technique with minimal greenhouse gas emissions. Of the two most significant greenhouse gases produced in manure management, methane was extremely low and nitrous oxide was undetected. Because of this, it was not possible to detect treatment differences with the addition of the amendments.

Addition of zeolite at a rate of 17% resulted in lower composting temperatures whereas the 5% amendment stimulated composting temperatures. Temperature is an indicator of microbial activity in the windrow. Nutrient analysis of the unamended compost revealed a nitrogen, phosphorus and potassium content of 1.49%, 0.335%, and 1.09% respectively, on a dry basis. The nutrient content of the six treated composts were not different from the control with the exception of one. Amendment with zeolite at a 5% rate improved nitrogen retention and produced compost with a nitrogen content of 1.62%. The addition of compost amendments was successful in reducing the electrical conductivity (measure of salinity) of the finished compost from 23dS/cm to <16dS/cm. This is useful in providing a more favorable environment for growing plants.

Wet spring conditions in 2005 and fall crop damage due to hail impacted crop production. The pasture harvest results indicated that both compost and commercial fertilizer application improved pasture biomass ($P<0.05$) over the unamended control. Biomass results from commercial fertilizer application was not greater than that of compost ($P>0.05$). The timing of the application (spring versus fall) did not impact the biomass yield significantly. The barley seed yield was improved with the addition of all composts and urea. The only exception to this was the compost containing 17% zeolite. Application of perlite amended compost had very favorable results in terms of seed mass and seed yield.

It was recognized that public and producer awareness is essential for the adoption of sustainable management practices and mitigation of potential climate change. Olds College students were exposed to the project through classroom teachings as well as through project participation. A Field Day was hosted by Olds College to provide an avenue for increased public and producer awareness.

This analysis also indicated that there are significant economic advantages to composting with amendments, zeolite and perlite, particularly at the 5% inclusion rates. Increased crop yields, improved nutrient retention, fertilizer cost savings and increased seed yield were some of the benefits associated with amended composts. These factors led to a positive economic return when compost was amended with zeolite at the 5% rate or perlite at the 9% and 5% rate. Economic analysis revealed how compost production costs are offset as the hauling distance to the field site increases, because of the reduction in manure volume. Additional benefits of composting that do not have a monetary value but are of paramount importance include odor control, reduced pollution and weed seed and pathogen elimination

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