Dairy Compost Utilization Program

Marketing Composted Manure to Public Entities

Texas Cooperative Extension
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INTRODUCTION

Approximately 75 dairies with an estimated 38,000 cows operate in the Bosque River watershed. Previous studies have demonstrated that excessive applications of manure to land areas in the immediate proximity of the dairies have contributed to water quality problems in the basin (McFarland and Hauck 1999). In a joint effort to address water quality concerns, TCEQ and TSSWCB developed the TMDL Implementation Plan and within that plan, interest and support developed for the production of composted dairy manure as a means for encouraging transport of dairy animal manure out of the watershed. Both agencies worked to create programs supporting a sustainable composting industry. These programs included incentive payments to support the transport of manure from dairies to compost facilities, incentive payments for public entities to purchase dairy compost to gain experience with its use and an educational effort to expand knowledge and market development regarding use of dairy manure compost.

It was the latter that sparked development of the Dairy Compost Utilization Program. This program, funded by the TCEQ through a Section 319(h) Clean Water Act Grant from the US EPA, was administered by the Texas Water Resources Institute (TWRI) and conducted by Texas Cooperative Extension (TCE) and Texas Agricultural Experiment Station (TAES). Ron Alexander and Associates (RAA) were contracted through the project to conduct marketing activities. The Dairy Compost Utilization Program tasked TWRI and TCE with:

1) Providing assistance to composters in production practices and achieving product consistency;
2) Assessing compost quality and working to improve the material produced;
3) Expanding public knowledge of composted dairy manure through educational programs, publications and demonstrations;
4) Expanding local governmental purchasing and use of dairy manure compost; and
5) Assisting TCEQ in creating a sustainable dairy manure composting program.

The Dairy Compost Utilization Project officially began in July 2002. In the past three years, significant changes and impacts have occurred as a result of the project.

Provide assistance to composters in production practices and achieve product consistency.

Dairy compost producer knowledge of sound production practices, record keeping and testing has vastly increased. Only a few facilities existed before the Dairy Manure Export Support (DMES) Program began and therefore, several of the compost facilities that went into business following the DMES Program were managed by former nursery producers, dairy farmers and commercial transportation operators. Thus, at project onset, many of the compost producers had little knowledge concerning compost production. Through workshops, site visits and personal communication, compost facility operators gained considerable knowledge on compost production.

Assess compost quality and work to improve the material produced.

With the training of the compost producers, the quality and consistency of composted material have improved substantially through the life of the project. Five of the six dairy compost producers in the watershed have joined the Seal of Testing Assurance Program and have established standard protocols for material sampling and assessment. Through the project, the compost producers learned the value of a regularly scheduled testing regime.

Expand public knowledge of composted dairy manure through educational programs, publications and demonstrations.

TCE agents and specialists gained considerable knowledge on the use and application of dairy manure compost. This information was conveyed to the public through demonstrations, fact sheets, news articles, presentations, and other communications. In addition, this information will continue to be utilized by compost producers, agency personnel and end users as valuable guidance in proper use and management of this resource.

Expand local governmental purchase and use of dairy manure compost.

Use of dairy manure compost also has increased in several markets. Prior to the project, use of composted dairy manure primarily was limited to only TxDOT, a few agricultural applications and organic farmers. The City of Waco was the only city that participated in the purchase and use of the compost for an annual public compost sale.

Through Project efforts, however, the compost producers have each found expanded and niche markets for distribution of their compost. Namely, the small nursery operators and landscape farms have begun purchasing and selling the compost material for bulk distribution or as a bagged product. Also, several school districts have utilized the material as a topdress for athletic fields. The Leon Bosque Resource Conservation and Development worked to promote the application of a compost/sand blend (50/50) to athletic fields in the surrounding area. Despite efforts to market the compost to local cities, very few of the municipalities purchased the material on their own accord. Partnerships with the project were formed and demonstrations occurred on city property, yet continued use of the material by cities has not occurred. Limited budgets and lack of adequate experience with compost use in the small cities within the Bosque and Leon River Watersheds were perhaps primary reasons for the lack of adoption of compost use.

Assist TCEQ in creating a sustainable dairy manure composting program.

While market development has not occurred to the extent desired within the timeline of the project, the market effectively is still very young and indications are that it will continue to grow with time. Unfortunately, time and related constraints of the project did not allow for stronger market development. Namely, the composted material was atypical compost, which caused some of the project's efforts to focus on determining the nature and cause of the atypical characteristcs, improving quality and identifying a best fit market for this type of material. Secondly, lack of participation by compost producers hindered market development. Next, the amount of true 'on the ground' marketing was limited because Texas Cooperative Extension is not in the position to be a marketing agency as its role is to provide unbiased information to the public. Finally, time was also an issue. Research shows that a typical successful market development project requires at least 2.5 years of a pure market push excluding background market assessment prior to development. In the Dairy Compost Utilization Project, however, the first 2 years were devoted to assessment of compost production, its consistency and quality and the proper use of the material. Nevertheless, substantial progress made through these project efforts and the marketing aspect during the last year established the potential for the dairy compost program to achieve success.

RESULTS BY TOPIC

Given that the end goal of the Dairy Manure Compost Utilization Project was to develop a sustainable compost market through the expanded use of compost by the public and private sectors, it was imperative for initial efforts to strategically assess compost material, production methods and potential markets, identify priority product improvements and market development goals, develop necessary strategies to obtain these goals and adapt the strategies as the project progressed and more knowledge was made available.

First, the Dairy Compost Utilization Project assessed the composition and characteristics of the compost material and current and potential compost markets. Subsequently, efforts were made to 1) educate compost producers on proper production techniques, 2) improve manure feedstock and compost quality, 3) evaluate appropriate uses of dairy manure compost so sound recommendations could be made through public outreach, and 4) demonstrate the use of compost and educate the public on dairy manure compost availability and use.

Compost Market Assessment

At project inception, the potential dairy compost market was evaluated in specified geographical areas. TCE conducted a telephone survey of municipalities and other public entities within a 17 county area grouped by population. Results were tabulated and summarized in the "Dairy Compost Use and Production Survey Results" Report (**Appendix E**).

Of the 102 public entities identified within watershed, TCEQ identified 40 entities total to be surveyed and TCE received responses from 70% of the contacted entities. Of the positive responses received by TCE, 63% use some type of organic material in their management practices. Consequently, 38% do not currently use any organic materials in their land and plant management programs.

Of the 63% that do use organics, approximately half produce their own product and of those, a majority produce a mulch product rather than a compost product. Generally, entities that produce their own product do so to conserve landfill space and money. Input costs for this production are low as entities receive materials from their citizens in the form of green waste from lawn and yard trimmings. Therefore, it is more economical for entities to produce a mulch type product rather than a compost type product. For the remaining half who use compost, but do not produce their own, TCE discovered that these entities purchase or receive their organic material from a variety of sources. A majority of the entities who produce compost or a mulch product give or sell the product to their citizens or another entity (i.e. TxDOT). Only 3 of the contacted entities stated they used a compost or mulch product in their land management needs such as city parks, football fields and local schools.

The 32% who do not currently use or produce compost provided several reasons behind their disinterest. The majority lacked the funds, personnel and public demand to warrant the production or the purchase of compost. Furthermore, given funding, entities admitted that compost was not their most significant priority.

Given the findings, TCE determined that significant interest in purchase and use of dairy compost did not exist among the surveyed public entities. In addition, project personnel discovered many barriers facing the dairy compost market. There were already well developed organic markets in the large metropolitan areas and the dairy compost would have to compete with free organic sources typically provided by cities that produce them. Concerns about compost quality also existed as the market was new and poorly understood. Compost producers lacked experience and knowledge to produce quality compost. The public was generally misinformed about composted dairy manure and its proper use. Finally, most public entities had limited budgets to utilize compost.

Project personnel were subsequently tasked to address these barriers (**Table 1**).

To address compost quality concerns and to improve the knowledge of compost producers, dairy compost production and marketing consultants assisted compost producers within the watershed to ensure production techniques were consistent with those necessary to produce a quality product, and project personnel worked with compost producers to test their composted material and establish a regular testing regime.

To address limited compost use knowledge, TCE worked with TAES to establish field verification studies and demonstration plots in the project area to determine and ensure environmentally sound application and use techniques. As a result, more efficient and sustainable uses of compost by public entities were demonstrated and appropriate literature was developed.

To address cost issues, TCE worked to promote the Composted Manure Incentive Program administered by TCEQ. Through participation in the incentive program, use of compost became more economical for public entities. In addition, TCE faced the challenge of highlighting the economic benefits of compost that do not necessarily have a set value. For example, application of dairy compost can improve soil tilth, water holding capacity, cation exchange capacity and porosity in addition to providing plant nutrients. An inorganic fertilizer, however, can only provide plant nutrients. Yet, economic comparisons with inorganic fertilizers are typically based on nutrient costs alone. Therefore, TCE worked to showcase the non-nutrient benefits of compost in its use demonstrations and publications. Specifically, the Economics of Compost Use fact sheet educates the public on the benefits of compost in addition to nutrient costs.

Table 1. Identified dairy compost market barriers, strategies developed to address the barriers and resulting activities to implemented strategies.

Challenge or Barrier	Strategy	Activities or Results
Manure feedstock quality	Educate dairy producers on development of manure pack and manure collection procedures	Educated dairy producers (DOPA) to improve manure collection techniques
	Educate compost producers on accepting high quality manure	Composters sought manure from dairies that provided better quality material. Composters learned it was acceptable to refuse manure due to poor quality
Compost production techniques	Direct assistance to compost producers	Improved compost consistency and quality
	Assessment of compost facilities and provide recommendations for improvements	Improvements in compost facilities and production practices (better temperature and processing records).
	Compost production workshop	Provided workshop to compost producers on proper production techniques
Compost material assessment	Train producers on proper sampling techniques	Provided a compost sampling publication and provided one-on-one assistance in sample collection. Assisted compost producers in joining the STA program – six of the seven are STA members
Compost not meeting standards	Improve organic matter content and reduce pH	Conducted the 'Modification of Low Quality Dairy Manure Study'
Unachievable standards	Educate TxDOT Regional Engineers on typical characteristics of dairy compost (low organic matter and high pH)	RAA had numerous discussions with TxDOT encouraging the use of dairy manure compost as its use showed no detrimental effects to roadsides
Excessive transportation costs	Add carbon source to reduce bulk density	Worked with DOT to allow use of woodchips to decrease density
	Reduce amount of inorganic material collected thru manure collection process	Educated dairy producers (DOPA) to improve manure collection techniques
Lack of marketing by compost producer	Provide direct assistance to composters in making sales calls;	RAA directly assisted compost producers in making sales calls
	Compost Marketing Workshop	Provided sales and marketing training workshop to compost producers
Lack of customer service by compost producer	Provide sales literature or use literature for composters to provide to customers	Provided project literature to compost producers as well as offered product specific literature for their own
Lack of application equipment (large and small scale applications)	Encourage composters to create a 'bundled' price – compost purchase and application	Compiled list of application services in the area and shared list with compost producers to set up a joint effort
	Given no small scale application equipment existed, project purchased a turftiger to apply compost to athletic fields or parks	Used Turftiger for demonstrations conducted at schools/parks. Allowed compost producers to use applicator if necessary for small applications
Misconception of composted dairy manure	Provide unbiased information about compost characteristics, specifically dairy compost	News releases, public demonstrations, fact sheets
Limited compost use knowledge especially with atypical dairy compost	Implement verification studies in the surrounding area focusing on compost use in various venues;	Field days showcasing verification studies; fact sheets outlining data collected; presentations to citizens, agencies and professional colleagues
	Organics Training Workshop	Provided training on a variety of compost use techniques, rates and application methods to County Extension Faculty, thereby reaching general public
Budget constraints of potential compost users	Utilize the Composted Manure Incentive Program to promote the use of compost on a trial basis and economically	Several school districts took advantage of incentive payment to apply compost to athletic fields. Upper Leon Soil and Water Conservation District Compost Rebate Program allowed several distributors/wholesalers access to the material
	Showcase the additional economic benefits of compost (benefits in addition to nutrients)	Developed Economic of Compost Use fact sheet and demonstrated non-nutrient benefits in compost use demonstrations

Compost Education, Demonstration and Marketing Activities

TCE and RAA worked to expand public markets in addition to TxDOT through education and demonstration activities. Given the variety of organic materials available, it was important to promote the use, incentives and benefits of dairy manure compost.

To kick-off awareness of the Dairy Compost Utilization Program, TWRI developed an informative project brochure. Over 1,500 printed copies were broadly distributed to all project participants (County Extension Offices, dairy manure compost facilities, SWCDs, TSSWCB, BRA, TCEQ, TIAER, TxDOT, and COGs) to further promote the Program.

In follow up to the brochure, RAA and TCE then trained the trainer. In an effort to take advantage of the local Extension network, RAA and TCE provided education to County Extension Faculty on the use of compost. Finally, to address the general public, state-funded entities and the private sector, RAA and TCE implemented a three-fold approach. First, personnel attended trade shows and speaking events. Second, personnel conducted and provided information at compost use demonstrations in conjunction with County Extension educational events. And third, news and magazine articles as well as project fact sheets were developed and distributed.

Training the Trainers: To ensure a knowledgeable staff and a consistent message, a two-day organics training workshop was one of the first events conducted through the Program. County Extension Faculty, District Extension Administrators, Researchers and RAA participated in the training. Participants received educational materials for their own use and distribution at the county level. Presentations at the workshop addressed the use and benefits of dairy compost so that county personnel would be better informed during future outreach and education efforts. The two-day workshop concluded with a demonstration of a top-dress application of compost and a tour of a local compost facility. Through this workshop, local knowledge of dairy compost substantially improved laying the groundwork for a successful project.

Trade Shows and Speaking Events: The Dairy Compost Utilization Program was promoted to public entities at the following trade shows. Information presented at trade shows focused on proper use of compost and the Composted Manure Incentive Payment available to public entities through TCEQ.

- Texas Public Works Association annual meeting in San Antonio
- Texas Nursery and Landscape Association Trade Show in Dallas
- Dairy Compost Seminar hosted by TIBH in Fort Worth (cities present included Carrollton, Farmers Branch, Arlington, Fort Worth and Coppell)
- Texas Section of the American Society of Landscape Architects Conference in Dallas.
- City of Waco hosted a one day discussion to utilize compost as their landfill cover and to establish vegetation around landfill areas
- North Central Texas COG Compost Workshop – Using compost on public right-of-ways and Successful community compost events

- North Central Texas COG Compost Roundtable Discussion at Tierra Verde Golf Club
- Central Texas COG compost workshops in Temple and Cameron (cities present included Cameron, Rockdale, Temple, Killeen, Belton)
- Austin Organic Growers Association in January 2005

Demonstrations: At least ten compost use demonstrations were conducted throughout the project. Many of these demonstrations occurred on public land and the public entity was directly involved in the decision to utilize dairy manure compost as well as the purchase and application of the material. Two types of compost use demonstrations occurred through this project: 1) demonstrations initiated by a city or a partnering agency and 2) demonstrations initiated and conducted in cooperation with County Extension faculty.

TCE actively participated in the compost use demonstrations promoted by cities and partnering agencies by providing fact sheets, information on compost incentive payments and technical expertise on the use and characteristics of composted dairy manure. Photos from some of the demonstrations listed below are posted on the project Web site at http://compost.tamu.edu/photo_gallery.php.

- Compost Use Demonstration at Mary Head Carter Park in Carrollton
- Stormwater BMPs demonstration conducted at Sawyer Ranch development West of Austin
- North Central Texas Council of Government Compost Use Demonstration on Road Right-of-Ways (cities present included Arlington, Mansfield, Plano, Haltom City, North Richland Hills)
- Compost application demonstration at Plano in fall of 2003
- Topdress application demonstration at City of Carrollton
- Use of compost to establish landscapes at the annual Turf/Ornamental Field Day in 2003, 2004, 2005

County Extension Agents worked with various entities in their individual counties to demonstrate and promote the use of dairy manure compost to the public during 2004 and 2005. These county-level marketing and education efforts were conducted both inside and adjacent to the Bosque River Watershed and included County and City Courthouse lawns and landscape areas, city owned gardens, athletic field complexes, public school grounds and greenhouse or nursery operations. **Figure 1** lists demonstration sites by county and type. In many of these demonstrations, photographic data and some visual assessments were collected and posted on the project Website at http://compost.tamu.edu/research.php. Reports for individual demonstrations where data and/or information were collected are included in **Appendix F**.

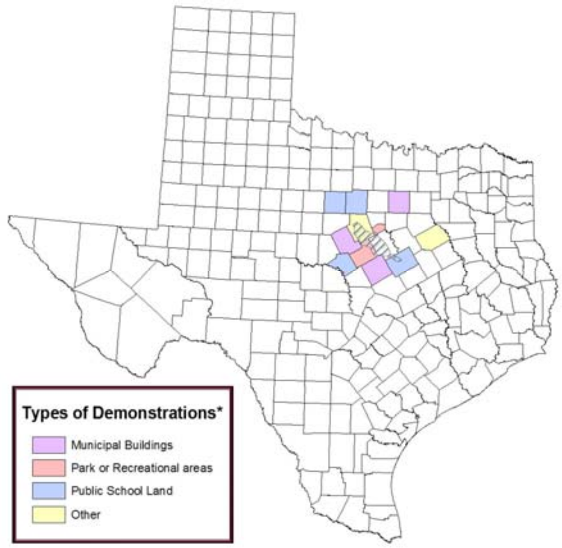

Figure 1. Type and location of compost use demonstrations conducted at the county-level.

News Articles and Fact Sheets: Various communication outlets were utilized during the Dairy Compost Utilization Project. RAA distributed articles and literature to professional organizations while TCE distributed similar material to newspapers, local government offices, such as the NRCS, as well as through all appropriate County Extension Offices.

Project related literature was included in the fall 2003 newsletter of the Texas Chapter of American Society of Landscape Architects. The article provided information on the benefits and various uses of compost and addressed the type of compost a Landscape Architect should specify for various uses (**Appendix G**). RAA also provided a 6 article series to the Texas Nursery and Landscape Association monthly magazine (**Appendix H**). This series provided information on (1) compost and its benefits; (2) the STA Program; (3) the DMES Program; (4) compost use in landscaping; (5) compost use by professional growers; and (6) selling compost through landscape suppliers.

TCE utilized numerous local outlets to promote the Dairy Compost Utilization Project. News releases focused on the general use of compost, its availability and the incentive payments available to both public and private entities. Three news releases were produced on the incentive payments throughout the project. Key articles are provided in **Appendix I**.

Many newspapers prefer to develop their own articles, but need leads provided in brief summaries or "story tips" (see example in **Appendix J**). These information pieces developed through the Dairy Compost Utilization Project also were provided to the TCE Agricultural Communications Department, which lists such tips on AgNMore, a daily listserv distributed to approximately 250 daily newspapers in Texas

Five compost demonstrations and uses evaluated as case studies were publicized in a news release format. This format allowed project personnel to send these highlighted compost uses to key newspapers publicizing a local compost use, the overall Dairy Compost Utilization Program and its beneficial incentive payments. Each selected case study showcases a different compost use and typically showcases a different compost user. The following 5 case studies were selected and are included in **Appendix K**.

- Breckenridge ISD demonstrates Dairy Manure Compost on Football Field
- City of Waco sells Dairy Manure Compost to Citizens
- Lovell Lawn and Landscape raises Live Oaks in Dairy Compost
- Santo ISD Utilizes Dairy Manure Compost in Sports Field Management
- Citizens and Compost Beautify Tarrant County Courthouse

Finally, in addition to utilizing media outlets, TCE also developed five fact sheets and education materials throughout the project. Initially, a series of fact sheets was developed to address basic compost uses in horticulture and turf, compost as an erosion control treatment, compost sampling techniques and incentive programs; these publications filled significant voids in the literature. All fact sheets were distributed at trade shows, workshops, various speaking events and compost use demonstrations, and were sent to all agency and county offices for local distribution. Copies of these project fact sheets are presented in **Appendix L** and available on the project website.

New fact sheets were developed and existing fact sheets revised, as necessary (**Appendix M**). These educational materials will support dairy compost producers in their future marketing efforts. However, on numerous occasions, RAA offered to assist compost producers in developing sales literature, product labels or compost use guidance. Unfortunately, no compost producers accepted RAA's offer of assistance and therefore, no compost producer specific marketing tools were developed.

<u>Additional Marketing Efforts:</u> A specific effort dedicated to fact sheet distribution and to compost marketing was a joint Texas sales call effort of TCE and RAA. TCE provided RAA with a list of municipalities within the project region and RAA staff phoned individual contacts on the list to communicate the following: 1) the Dairy Compost Utilization Project; 2) the benefits of compost use within their own land management plans; 3) the incentive payments currently available; and 4) the economic and environmental benefits of compost use. RAA determined interest levels in the use of compost such as specific needs or upcoming projects and denoted these entities as potential leads. Finally, the sales calls also allowed TCE to distribute educational material to the municipalities. A full report of contacts, literature received and potential sales (highlighted in yellow) is included in **Appendix N**.

As a result of these sales calls, over 600 fact sheets were distributed to public entities to promote potential sales. Of the 120 contacted entities, 37 were identified as leads. These leads on potential compost use or projects were communicated directly to the compost producers and the composters were urged to contact the individuals to finalize the compost sale. As a result, it is estimated that over 8,000 CY of composted dairy manure were sold to public entities in follow up to the sales call effort. (TCE did not have direct access to compost sales data. Therefore estimates are based on data provided by TCEQ of compost sales through 2004)

Extensive efforts were also conducted to sustain the TxDOT market as it had become the primary market for dairy compost producers. However, with the introduction of the new standards, most of the producers were not able to successfully bid as many projects and their sales consequently suffered. To assist the compost producers, RAA and TCE worked with TxDOT engineers/inspectors as well as some of the contractors to educate them on typical dairy compost characteristics and its use on roadsides. Specifically, the high pH and low organic matter content of the dairy compost did not negatively affect the performance of the compost in controlling erosion and/or establishing vegetation.

Finally, the individual sales assistance provided by RAA introduced a variety of markets to the compost producers. The following are examples of sales completed as a result of this assistance.

- Cities of Dallas (Parks), Mansfield (Parks), Farmers Branch, Hurst, N. Richland Hills, Waco, Carrollton (erosion control and vegetation establishment)
- City of Carrollton also developed compost use specifications for their city parks
- Dallas Community College
- Elmont Independent School District
- Valley Mills Independent School District
- One compost facility sold 10,000 CY for a sports complex development in Cleburne

<u>Upper Leon Soil and Water Conservation District Compost Rebate Program:</u> In addition to the above efforts to promote the use of compost to public entities, TCE saw major advantages in the use of composted dairy manure on private agricultural lands. First, the dairy compost facilities are located in an area dominated by agricultural production. Second, the high cost of transportation limited distance the compost could economically be transported and therefore, establishment of a local market would be ideal. Third, with costs for inorganic fertilizers increasing dramatically the potential for compost as an economical nutrient source was significant.

However, even with all of these incentives, four issues limited widespread compost use by agriculture.

Economics

First, use of dairy compost or any organic amendment may not be economical when compared to inorganic fertilizers within the first year. Rather, to adequately compare the economics and benefits, cost and effects must be considered over at least a 3-year period. Unfortunately, most agricultural producers cannot and do not base decisions on a 3-year economic outlook. The difficulty of quantifying the additional benefits of compost also was a factor. While compost does provide physical, chemical and biological benefits to the soil and plants, these benefits do not have a set value and therefore, typical economic comparisons between compost and inorganic fertilizer were based on nutrient costs alone.

Behavioral Change

Second, the use of dairy compost in agricultural applications, particularly on a large scale, was a behavior change for most individuals. Factors such as the environment, weather, and cropping and production scheme all must be considered with any amendments in agricultural production. Given application is often not included with purchase of compost and a nutrient management plan is recommended, even more planning is required to apply compost on agricultural land. Thus, producers must allow more time and effort to utilize composted dairy manure in their production scheme.

Raw manure was easily accessible and inexpensive

Third, given the large number of dairies in the area and the youth of the composting program, agricultural producers, who did apply organic amendments, generally utilized raw manure supplied by local dairies due to lower cost.

Lack of application equipment

Finally, compost applications on agricultural land require specialized equipment and little or no equipment was available in the area. Further, inorganic fertilizer, could be purchased and applied with a single order. Despite encouragement by project personnel, very few compost producers provided application services with the purchase of the composted dairy manure.

To address the issue of economics, TCE, in collaboration with the Texas State Soil and Water Conservation Board (TSSWCB) and the local Soil and Water Conservation Districts (SWCD), established a private producer incentive payment. It was anticipated that by reducing the cost of compost, agricultural producers would be more likely to utilize the material on a trial basis. This would then lead to behavior change and more compost use, creating incentives for development of compost application services. The program utilized the local SWCDs as compost purchasers for the general public. Specifically, the three SWCDs involved in the program included the Upper Leon, Cross Timbers and the Hamilton-Coryell Districts. By utilizing the SWCD, a compost producer was able to sell composted dairy manure to private producers at a reduced price. The Upper Leon SWCD was responsible for the program, which became known as the ULSWCD Compost Rebate Program.

Requirements for the program followed the Composted Manure Incentive Payment program. Additional requirements included: 1) limiting the amount of compost purchased by a single buyer through the program to 4,000 CY, 2) applications of the compost had be made outside of the Bosque River Watershed to support implementation of the TMDL manure export target, and 3) agricultural producers had to obtain a TSSWCB Certified Water Quality Management Plan before applying the compost. Unfortunately, little to no activity occurred through the program during its first year. While much interest was expressed, the complexity of the program and time limitations hindered program advancement. Therefore, program requirements were revisited in August, 2005 and the ULSWCD Compost Rebate Program was revised to include compost distributors, baggers, etc. and agricultural applications only required a TSSWCB Certified Nutrient Management Plan.

The ULSWCD shared all transactions with TCE through April 30, 2006. A summary and a complete list of purchases are provided in **Figure 2 and Table 3**, respectively.

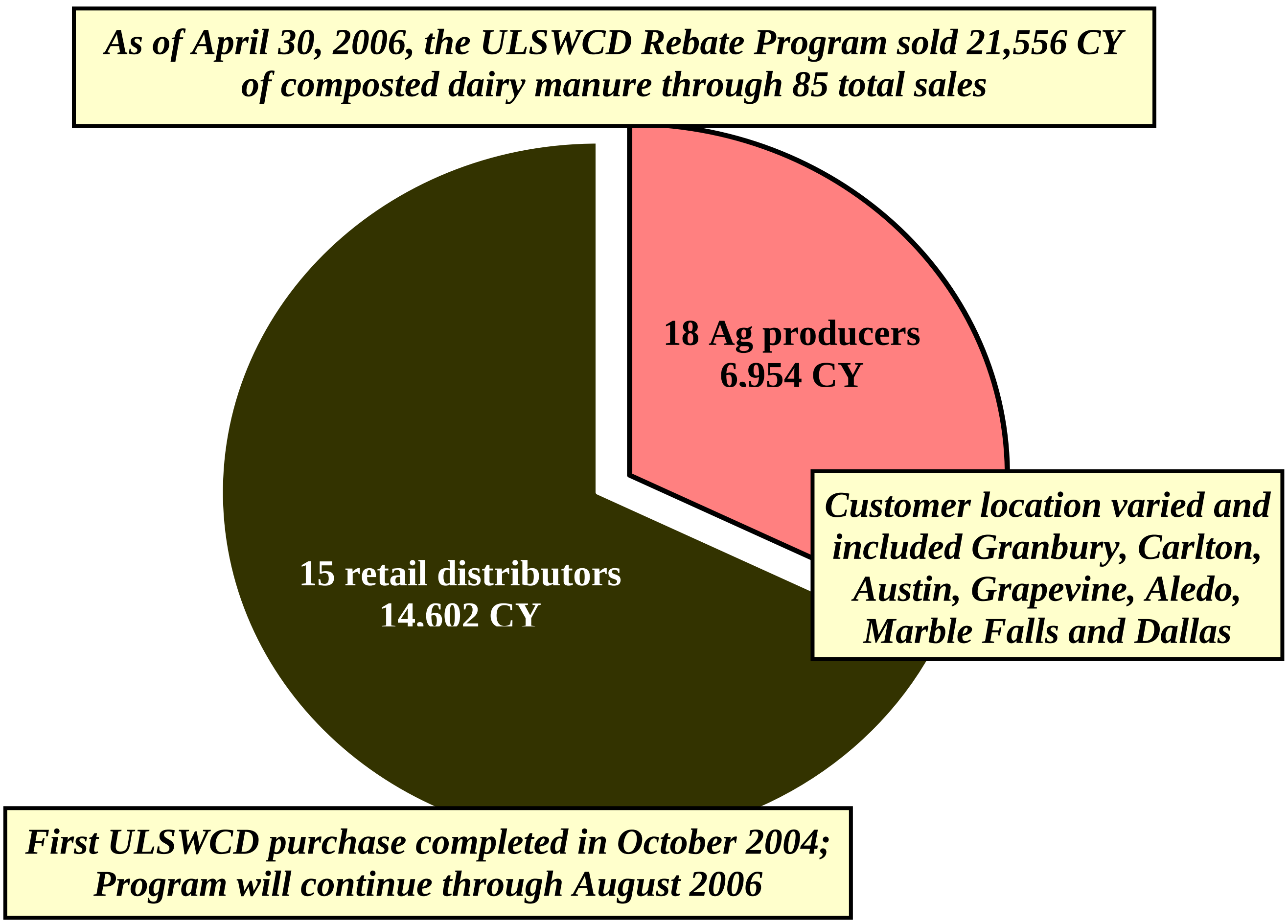

Figure 2. Summary of ULSWCD Compost Rebate Program purchases.

Table 2. Total purchases completed through the ULSWCD Compost Rebate Program.

Customer	CY	Customer Type	Compost Use	Location
Accent Rock & Landscape Material	35	Distributor	Retail	Granbury
Adolf Gebert	100	Producer	Land application	Carlton
Backbone Valley Nursery	130	Distributor	Wholesale/Landscape	Marble Falls
Circle J Backhoe	1267	Producer	Land application	Stephenville
Clark Gardens	65	Distributor	Retail	Weatherford
Clear Fork Materials	2027	Distributor	Bagged distribution	Aledo
Dunbrokus Ranch	280	Producer	Winter Pasture	Carlton
Ed Pare	350	Distributor	Retail	De Leon
Eddie Kimmel	250	Distributor	Retail	Comanche
Geo Growers Inc	4000	Distributor	Retail	Austin
Gerald Burns	100	Distributor	Retail	Comanche
Greg Mitchell	100	Producer	Land application	Comanche
Growers Select	195	Producer	Land application (Ryan, OK)	Mission
Joe Paul McCullough	2460	Producer	Land application	Comanche
John Moore	80	Producer	Land application	NA
Jr. Jones	50	Producer	Land application	Gustine
Jr. Stephens	400	Producer	Land application	Gustine
Karan Kirk	126.8	Producer	Land application	Gorman
Larry Adams	350	Producer	Land application	NA
Lilly Day Gardens	50	Distributor	Retail	Burnett
Lindsey Landscaping	50	Distributor	Retail	China Springs
Mark McCullough	200	Producer	Land application	Gustine
Natural Gardener	2300	Distributor	Bulk Distribution	Austin
Nicholson Farms	235	Producer	Land application	Gustine
Pat Bays Construction	50	Producer	Land application	Dublin
Ronnie Lamb	50	Producer	Land application	Gustine
Scotts Company	4000	Distributor	Bagged distribution	Cresson
Sid Waynick	550	Producer	Land application	Carbon
Soil Building Systems	776	Distributor	Retail	Dallas
Steve Turknett	324	Producer	Hay & Pecans	Grapevine
Todd Denman	200	Producer	Land application	Carlton
Tomlinson Ball Field	220	Distributor	Sportsfield application	Granbury
Wolfe Landscape	185	Distributor	Bagged distribution & topsoil	Waco

The Dairy Compost Utilization Web site was a major marketing and educational tool developed and utilized in the project. All fact sheets, practice verification studies information and results, compost demonstrations information and results, PowerPoint presentations and useful publications or links from other projects were posted on the Project Web site for public access. Many of these documents were posted in Adobe Portable Document Format so they could be easily downloaded, simplifying and expanding availability.

In May of 2004, user statistic software was added to the project Web site to track usage. The number of unique users per month steadily increased throughout the project. **Figure 3** graphically displays the increase in number of unique visitors from May 2004 through December 2005. Another advantage of the user statistic software was the ability to determine which Web pages were most utilized and downloaded. **Figures 4** and **5** display the unique hits per page-type for 2004 and 2005, respectively. Data for 2006, although not presented here as it is still in progress, is similar to the 2005 data. The photo gallery remains the most visited page. In second in number of visits for 2006 are the fact sheets with the practice verification studies in a close third.

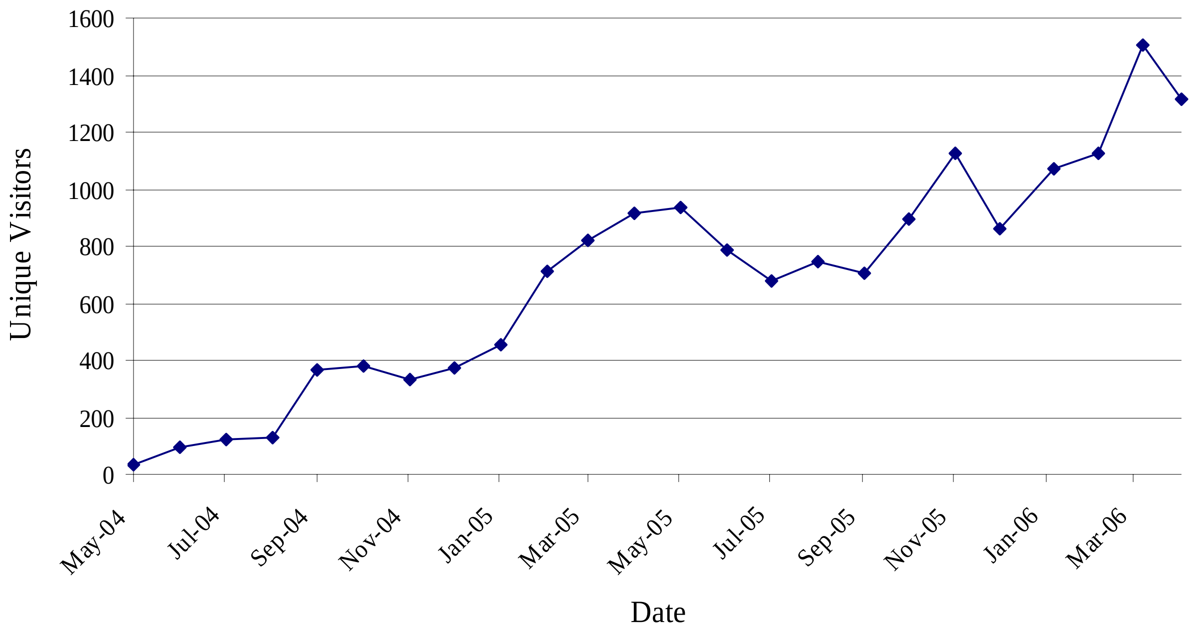

Figure 3. Number of unique visitors to project Web site from May 2004 to April 2006.

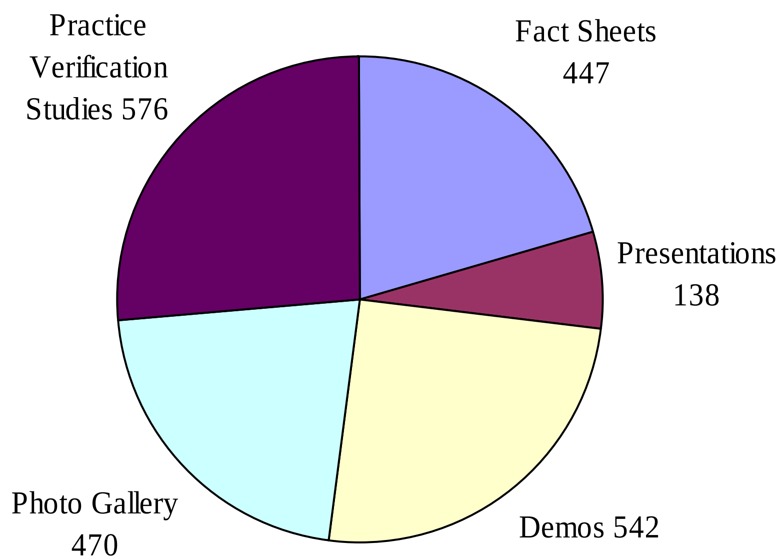

Figure 4. Type and number of sites accessed in 2004 on the Project Web site.

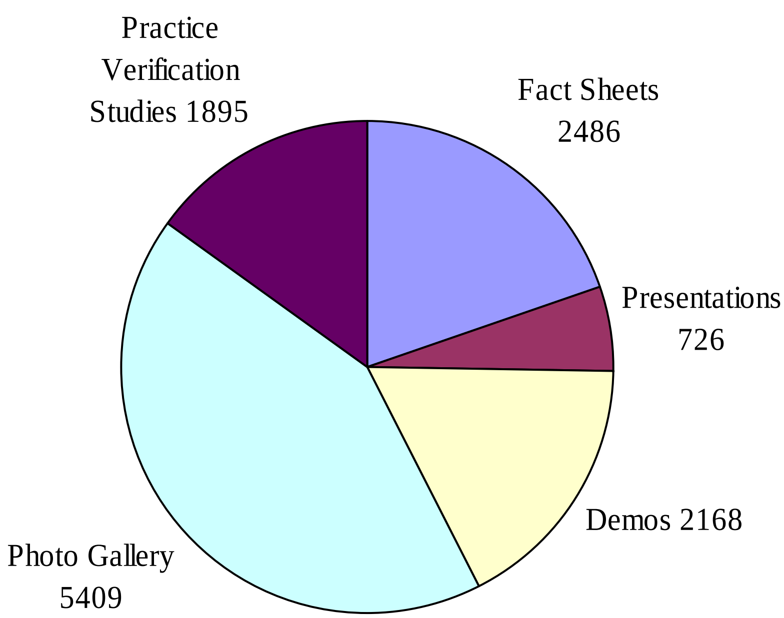

Figure 5. Type and number of sites accessed in 2005 on the Project Web site.

Compost Producer Education and Assistance

Each compost facility in the project area was evaluated and reviewed in an on-site visit conducted soon after initiation of the project. Following the evaluation, composters were provided an assessment of their facility, production practices and market plans. This first step also introduced the compost producers to the project, which opened lines of communication for all involved.

Another benefit of the compost facility visits was RAA and TCE became familiar with the specific areas where compost producers needed the most assistance. As a result, RAA and TCE hosted two workshops.

The first workshop conducted in the spring of 2003 addressed compost production. Specifically, compost producers were taught the value of a high quality manure feedstock and project personnel encouraged the compost producers to work with dairy producers to improve the quality of raw manure delivered to the compost facilities. Secondly, the workshop addressed sound record keeping skills, equipment needs, product sampling techniques, compost quality characteristics and various end use or application options.

The second workshop conducted in the fall of 2003 addressed compost sales and marketing. Compost producers received a Marketing Training Manual, which provided the basics of marketing an organic product and the potential markets in their area. In addition, compost producers were encouraged to jointly work together creating a stronger market for dairy compost.

Throughout the project, numerous contacts between TCE and the composters and between RAA and the composters occurred. Compost producers inquired about various issues including proper procedures to produce compost, information associated with acquiring and obtaining TCEQ permits requirements and the process surrounding the private and public rebate programs. TCE and RAA also served as the source of information about TxDOT specifications and participating in the TxDOT program. In addition, composters received assistance in developing their markets. RAA and TCE worked with the composters by participating in sales calls and providing the composters with sale leads. For example, two of the compost producers were able to secure a bid with TxDOT for a 27,000 CY job as a result of RAA’s marketing assistance.

One of the most important long-term accomplishments of the Dairy Compost Utilization Project was facilitating participation of the composter producers in the Seal of Testing Assurance (STA) Program. TCE and RAA assisted composters in meeting the requirements of the STA Program and developed and distributed a fact sheet on STA sampling procedures (more information on Project Fact Sheets is provided in the Compost Education, Demonstration and Marketing Activities Section). Prior to the Project, none of the dairy compost producers were STA certified or even had a sound compost sampling protocol established. As a result, they did not have a clear understanding of product quality or appropriate markets or end uses for their products. Participation in the STA program provided composters with a better understanding and confidence in product characteristics, which enhanced their marketing and use strategies by enabling them to identify the most appropriate customer base. In addition, participation in the

STA Program also enabled composters to continue to pursue the TxDOT market as TxDOT adopted STA as its standard in 2003.

While the STA program ensures testing uniformity, the analytical costs are relatively expensive and quite often beyond a compost producer’s means. In contrast, service laboratories, such as the TCE-SWFTL (Soil, Water, Forage Testing Laboratory located at Texas A&M University), are structured to process large numbers of samples and offer more “analytical packages” than specific analyses for individual samples. Test results are used to make research based recommendations relating to crop fertilization needs, forage and hay quality, suitability of water for irrigation, etc. Because of the high throughput, analytical costs are less expensive than those charged by labs adhering to strict (TMECC) procedures. The reduced analysis costs of a service type laboratory provide a means by which compost producers can assess their material on a more frequent and lower cost basis.

However, the question of how each laboratory’s results compared did exist. And the organic matter improvement study provided the opportunity to evaluate the two laboratories and their analytical procedures. Within the organic matter improvement study, compost samples were analyzed through both a service laboratory (SWFTL) and a STA Certified Laboratory (Soil Control Laboratory). Both laboratories provided standard analyses on samples and sample results were statistically compared between the two laboratories. With the exception of organic matter, there were significant differences (at the 95% level) in the nutrient levels (N, P, Ca and Na), pH and soluble salts determined by the two laboratories. For organic matter, there were no significant differences between labs even though two distinct procedures were used to estimate organic carbon levels in the samples.

The results of this comparison indicate composters could effectively use data provided by SWFTL as management decision aids and in assessing the quality and potential applications of their products in less time. Service laboratories such as the TCE-SWFTL can provide good assessments of compost quality at a fraction of the cost. Through the Dairy Compost Utilization Project, these types of services were introduced to the compost producers and as a result, composters adopted a more frequent testing program and were able to assess and judiciously modify various production techniques and product amendments.

Near the end of the project, TCE and RAA conducted a final assessment of the compost facilities to document improvements in production practices, marketing and compost quality. A complete report of each facility’s initial and final assessment was provided to the individual composters (**Appendix A**).

Compost Quality Assessment

During initial compost facility site visits, TCE discovered that the dairy manure compost being produced was atypical for a compost product. This appeared to be due to a lack of consistency in production practices and problems with manure feedstock. The compost was denser, had high inorganic content and was very heterogeneous in nature. Therefore, project personnel visited dairy facilities within the watershed to evaluate manure collection practices. Todd Williams, an associate of RAA, visited Gustine Compost and associated contracted dairy facilities. Both groups determined that the primary source of inorganic contamination was related to dairy manure collection procedures, whether the manure was collected by mechanical scraping or through vacuuming. In an effort to reduce soil contamination during manure collection, TCE reinforced their education efforts (the Dairy Outreach Program Area and the Dairy Waste Management Handbook) to promote the development and maintenance of a manure pack. As a result, composters reported that the quality of manure received from dairies improved throughout this project.

These initial site visits also revealed that compost producers lacked experience in production practices and knowledge in methods for producing a consistent product. In addition, they had little or no knowledge of proper compost sampling procedures, means for obtaining a sample analysis, or the value of tracking material characteristics. Prior interest in product testing had been limited by the availability of a thorough sample analysis (i.e. the Solvita Maturity test was the only available test at project initiation). Although, the introduction of the STA Program provided compost producers with a means to obtain a complete sample analysis, the analysis costs exceeded their budgets. So, although compost producers and TCE were receiving inquiries as to the value, characteristics and proper use of dairy compost, this information was unknown. Therefore, knowledge of compost quality (sampling and analysis of compost) was required to determine a starting point and gauge the impacts of the project.

While TxDOT was shifting to TMECC as their standard methodology, the unique nature of this dairy compost precluded the assumption that standard methodology would provide adequate results. Specifically, temperatures utilized in the Loss on Ignition (LOI) method can cause clay minerals (like those in central Texas) to lose structural water, which will increase the total sample weight loss leading to an overestimation of organic matter content (Schumacher 2002). To possibly avoid over estimating organic matter content, the sample can be pre-treated (as noted in the TMECC methodology) using HCl. However, the use of HCI may dissolve part of the organic matter leading to an underestimation of the organic matter content and the potential need to use a correction factor. Interestingly, ASTM method D 2974 allows for ashing the sample at 750°C for peats and other organic soils, such as organic clays, silts, and mucks (ASTM, 2000) presumably based on the assumption that no carbonates and little to no mineral matter are present in the sample that could influence the resultant organic matter content. However, the dairy manure compost samples contained substantial mineral matter and thus, an assessment and modification of the LOI procedure was required.

The TCE Soil, Water and Forage Testing Laboratory (SWFTL) ran multiple analyses (**Table 2**) on dairy compost collected at various facilities to determine what modifications were needed to properly and correctly analyze the atypical dairy manure compost. Per observations by SWFTL, the LOI method as written in the TMECC methodology failed to provide complete oxidation of the sample and thus over estimated organic matter content. The repeated modified analysis presented in **Table 2** varied in both temperature and time. Consistent results were finally obtained on 4/1/03 and 4/9/03 when samples were oxidized at 650° (Pitt et. al. 2003).

Table 3. Results of multiple analyses conducted on dairy compost samples at project initiation.

Lab #	Organic Carbon Modified Methodology				Loss on Ignition (%)
	2/25/03	**3/4/03**	**4/1/03**	**4/9/03**	**4/8/03**
37385	9.38	16.2	9.91	10.04	24.26
37386	8.27	14.3	7.79	7.88	18.68
37387	7.98	13.8	10.77	10.74	23.95
37388	6.50	10.2	8.29	8.33	19.08
37389	6.71	11.6	6.84	6.83	16.08
37390	3.97	6.8	4.85	4.83	12.40

At this early point in the project, the applied research study QAPP was under development and so separate funding sources were used to support analysis costs. This enabled the project to continue to move forward by providing critical information regarding dairy compost product quality and characteristics.

Cost to compost producers also led TCE to not utilize an STA laboratory in the beginning of the project. While project funds would have sufficiently funded STA analysis, the overall project goal was to create a sustainable program for dairy and compost producers. In evaluating and improving compost methodology at the SWFTL, the Laboratory was able to provide information to compost producers about the quality of their material on a more frequent basis and within their operational means. Further, because of the large quantities of composted dairy manure available, a targeted end use of the material at project initiation was for agronomic purposes (i.e. horticultural or agricultural applications). Agronomic laboratories, such as SWFTL, typically provide recommendations of application rates utilizing crop response data and specified yield goals. Thus, SWFTL was an ideal candidate to provide compost sample analysis at project onset. By expeditiously investigating and discovering major issues regarding compost quality, TCE was able to move forward with project activities and provide assistance to producers to address problems related to proper manure collection practices, agronomic application rates, proper production and monitoring practices and proper selection of feedstock and/or ratios of blends.

In contrast to a service laboratory, an environmental laboratory, such as Soil Control Laboratories, typically provides information about compost standards, the range in which a sample falls for meeting desired specifications and possible techniques to amend the production process or the sample, if necessary, to meet standards. In addition, an environmental laboratory will provide a general use recommendation; however, the recommendation is not typically based on crop response data or specified yield goals. As project efforts moved forward and compost standards such as the STA Program progressed and grew more prevalent within several of the potential markets, the use of an environmental laboratory became necessary and beneficial to assess compost quality.

Thus, upon approval of the amended and revised QAPP in 2005, TCE conducted two additional compost sampling trips to assess compost quality through an STA Certified Laboratory, namely Soil Control Laboratory. TCE along with TCEQ personnel at some locations collected samples from Producers Compost, O'Neals Compost, Dairy Cow Compost and Organic Residual Reclamation in August, 2005 and from Bosque River Compost and Organic Residual Reclamation in September, 2005.

Results of compost assessment were shared with TCEQ both as "blind" samples (**Appendix B**) and as identified samples. Each compost facility received an official STA report of their sample along with a brief summary of the material description provided when the sample was collected. Further, as requested, the composters also received a complete set of results. Each sample was left unidentified in the full report to protect the privacy of each facility.

It should be noted that none of the samples met current TxDOT specifications. Samples failed due to the high pH, low percent organic matter, or both. Failure to meet TxDOT specifications was a common concern for compost producers in the region typically because of inherent problems in feedstock quality. Elevated inorganic material levels (primarily sand) decrease the organic matter content, increase bulk density, and contribute to an elevated pH. To produce quality material that meets the TxDOT specification, dairy composters have two feasible alternatives: 1) improve the quality of the manure feedstock or 2) add a carbon source to the compost.

Improve quality of manure feedstock.

Simultaneous collection of bedding material along with manure is the key issue in improving manure feedstock quality. At project onset, most dairy producers utilized sand as their bedding material due to availability and cost. Through the project, compost producers began encouraging dairy producers to utilize organic materials as bedding. While manure from dairies that bed on an organic material is preferred and even paid for in some cases, many dairy producers still utilize sand. However, project information and pressure from compost producers has motivated more dairies to begin use of organic bedding materials, such as cotton burrs, which will be highly beneficial as the composting program moves forward.

Another strategy for improving the dairy manure feedstock is to utilize only separated dairy manure. Unfortunately, only a small percentage of dairy producers have manure separation systems. Therefore, while this is a very reliable and confirmed method to increase organic matter content and decrease pH, it is not a feasible option for every compost producer in the watershed.

Through the project, TCE and RAA worked with compost producers to educate them in the selection of only high quality feedstock. Compost producers were encouraged to be in close communication with the dairies to 1) further educate the dairy producer on what type of material the composter required and 2) create a business relationship for future interactions, even offering payment for higher quality material.

Add a carbon source to the compost.

An alternative strategy for improving compost quality is to add a supplemental organic carbon material to the manure prior to composting or to the finished compost. By adding a carbon source, organic matter content may be increased (depending on rate of addition) and the final product typically becomes less dense. Lowering density reduces transportation costs per unit volume. Throughout the project, transportation costs were a major barrier to market development especially when competing for markets in larger urban centers situated more than 60 miles away. This second alternative led to the Compost Quality Improvement study conducted to assist compost producers in determining which carbon materials and rates of addition would enhance organic matter content in the compost to meet required standards. This study, conducted in 2004 and 2005, is discussed in detail in the next section.

Granted, meeting TxDOT standards was a primary focus in compost quality assessment due to the large market share available for compost producers. However, it was not the only objective of compost testing. The initial testing was a critical component in the project to develop and convey a basic understanding of the issues facing compost producers. It created the basis for change and improvement in production practices. The continued testing and assistance in improving production techniques to develop a consistent product led to introduction and sustained life of markets outside of TxDOT.

Over time participation in the TxDOT market depended more on availability of material and proximity to the job site, which led to fewer direct sales of dairy compost to the TxDOT. Therefore, dairy compost producers were encouraged to identify niche markets that each could fulfill on an individual basis. Specifically, some of the compost producers were able to provide a higher quality material for topdress applications on golf courses or sportsfields; yet, some of the compost material continued to contain greater levels of inorganic material, which were more appropriate for agricultural applications or compost manufactured topsoil. Overall, the transportation costs and the high inorganic material in the compost led project personnel and compost producers to identify a set of potential markets during the Dairy Compost Utilization Program. These markets were communicated to compost producers and each was encouraged to market their composted material as appropriate. The following is a list, although not a complete list, of markets identified, pursued or captured throughout the project.

Topsoil and topsoil blends

The high levels of soil inherently mixed with the dairy manure compost lend the material to be an ideal topsoil source for landscaping services and nurseries. Through the Upper Leon Soil and Water Conservation District Rebate Program, numerous gardening centers and bulk suppliers purchased dairy manure compost to distribute to consumers for this purpose. The dairy compost was sold in bulk and bagged as a stand-alone product or mixed with additional organic material.

Topdress applications of golfcourses or sportsfields

A common disadvantage of traditional dairy compost produced from lot dairy manure is the contamination of rocks or small pebbles found in the finished product. While these pebbles are typically considered inconsequential for most uses, they can create problems for superintendents of sportsfields and/or golfcourses. These landscapes are mowed frequently and often with a reel type mower. Even the smallest pebbles can damage the blades of the mowers. Some specially processed compost, however, can be appropriate for such topdress applications. Specifically, one compost producer grinds the composted dairy manure to a fine powder. Another compost producer utilizes only separated manure as the feedstock, which leads to a fibrous, nitrogen-rich, material that is ideal for topdress applications.

Sportsfield Construction

As noted in the Project fact sheet, “Using Organic Matter to Improve Sportfields”, the key to successful sportsfields is to establish a healthy soil when constructing the field. Through the Dairy Compost Utilization Project, the compost was marketed to the City of Hamilton in the construction of their City Recreational Facility. The city took advantage of the rebate offered by the Leon Bosque RC&D to purchase the dairy compost.

Rangeland revegetation

Increased troop numbers and reduced training land area caused increased erosion and sediment loss on the Fort Hood Military Training Base. The use of compost on these denuded lands provided much needed nutrients and topsoil to reestablish vegetation, thereby preventing erosion and sediment loss in runoff events. Through efforts associated with the Dairy Compost Utilization Program, various rates and timings of dairy compost applications were evaluated. Improvements in vegetation and soil health were demonstrated and therefore the use of dairy compost on Fort Hood became a viable market. In other revegetation activities, dairy compost can be applied to establish native grasses following brush control activities. For example, the Central Texas Cattleman’s Association through the Leon River Restoration Project, worked with individual landowners to clear undesirable vegetation from the Leon River Watershed and improve habitat for endangered species. Both types of revegetation activities can benefit from applications of dairy manure compost.

Nursery Potting Mixes

Through a demonstration with the Lovell Lawn and Landscape Company, the use of dairy manure compost as potting soil mix proved to be beneficial in reducing water use and plant health over the traditional non-dairy compost mix. As a result, Lovell Lawn and Landscape continued to utilize the dairy manure compost as a potting mix and as bedding material for landscape projects. Dairy compost producers were encouraged to market their material as a potting mix to local nursery producers.

Compost Manufactured Topsoil

A specified product by the TxDOT is compost manufactured topsoil, which is typically blended at the job site. However, with the amount of soil material mixed with the dairy compost, it was possible for dairy compost producers to market their product as pre-blended manufactured topsoil for the TxDOT jobs.

Agricultural applications

Through verification studies performed at the Research and Extension Center in Stephenville, the use of dairy compost was demonstrated to yield similarly or better than inorganic fertilizers when applied to irrigated corn silage and coastal Bermudagrass. Given these data, the location of the dairy compost facilities (an area dominated by agricultural production), the high cost of transportation (distance the compost could economically be transported was limited), it seemed ideal to promote and establish a strong market for agricultural applications of compost. And although the market did not flourish as personnel anticipated, the number of applications did increase over the project period and with this increase, it is anticipated more agricultural producers in the area will adopt the practice of dairy compost application in their management systems.

Most importantly, at project completion, dairy compost producers had learned the value of establishing a sound compost testing program as a quality control and marketing tool. The ideal strategy for compost producers to maintain high quality compost production involves 1) participating in the STA program and testing material through an STA Laboratory on the appropriate schedule and 2) intermittently utilizing a service laboratory, such as SWFTL to monitor compost quality on a more frequent basis. **A sound and successful market is based on a consistent product and knowledgeable sales people.** By utilizing both types of laboratories, composters are able to affirm the quality of the material being produced at their facility as well as provide information to consumers about the use of their product.

Compost Quality Improvement Study

Given the dairy manure compost produced in this region typically failed to meet the organic matter content standard of 25 percent and the pH standard of 8.5, a Compost Quality Improvement Study was proposed in 2004 to evaluate the addition of carbon sources to finished compost.

While the addition of carbon materials can improve compost quality, it also adds production cost. However, importance of the TxDOT market and the need to meet TxDOT specifications was a major concern for dairy composters.

As a first step, RAA completed the Organic Matter Improvement Survey, where potential sources of organic carbon were identified. Results were communicated to the composters who were encouraged to contact the entities with carbon sources to set up their own system. A full report and tabular results of the Organic Matter Improvement Survey can be found in **Appendix C**.

Three carbon sources, woodchips, sawdust and peanut hulls, identified as abundant and available in the area by the survey were obtained and tested for utilization in the organic matter mixing study. Several sources of dairy manure compost were then sampled and tested to determine their status in meeting the TxDOT specification. All compost samples and organic carbon samples were sent to an STA approved facility, the Soil Control Laboratory, in Watsonville, CA and to a service laboratory, the Soil, Water and Forage Testing Laboratory, in College Station, TX. All 4 compost sources initially failed the TxDOT specification based on percent organic matter and 3 of the 4 sources failed based on high pH. The 4 sources of compost material utilized in the mixing study included Gustine Compost, Producers Compost, O'Neals Compost and Dairy Cow Compost. Each carbon source was mixed with the composted dairy manure at 2 ratios, 10% and 30%, and then tested at 0, 30, and 60 days after mixing.

All data from the organic matter mixing study was entered in excel format, statically analyzed and interpreted (**Appendix D**). In this study, significant differences existed in organic matter contents, pH, total N and C:N ratios between the four compost sources tested, thereby, high degrees of variation existed within the data. Adding 10% and 30% (v/v basis) of three high carbon materials (peanut hulls, sawdust and wood chips) resulted in significantly higher organic matter levels when analyzed between the four compost sources but *only the higher (30%) rates of the amendments increased organic matter contents across compost sources.* While the physical mixing of high carbon amendments with low quality dairy manure composts can increase organic matter content and alter C:N ratios, it will have limited effects on pH, soluble salts and nutrients. With the exception of the 30% rate of peanut hulls (which significantly lowered pH and increased total N between compost sources), carbon sources had no significant impacts on the parameters tested between or across compost sources. When considered across all compost sources and high carbon amendments, adding 10 and 30% of the amendments to the composts increased the mean organic levels from approximately 9.8% to 11.3% and 14.6%, respectively. *On average, the blended materials met the modified (>10%) but not the base (25-65%) TxDOT specification for organic matter content.*

Blending larger rates of high carbon amendments may be required to meet the TxDOT specification for organic matter content. However, if adding higher rates of the amendments are cost prohibitive, a better application of low quality composts may be their use in the preparation of CMTs or ECCs. Other studies have shown blending high carbon constituents with dairy manure prior to composting (Michel, et al, 2005) is also a viable option for improving compost quality.

By comparing the STA certified laboratory results obtained in the Compost Quality Improvement Study with the service laboratory results, the study also determined the value of the two types of laboratories for the dairy manure composting industry. Data comparisons in the study demonstrated that values for selected nutrients (total N, P, Ca and Na), pH and soluble salts differed significantly between the two laboratories, yet there were no differences in organic matter levels. Thus, service laboratories can be effectively used to provide compost facility operators with more frequent, low cost preliminary assessments of compost quality for use as management decision aids, particularly when modifying organic matter content. Because STA-TMECC results are often required and necessary to market compost products and provide compost users with information that equitably compares product qualities, determines use rates, etc., compost producers and retailers can rely on STA Laboratory results as a scheduled test to monitor production and product consistency.

Practice Verification Studies

One of the most important and lasting accomplishments of the Dairy Compost Utilization Project was the development and completion of several practice verification studies utilizing dairy manure compost. Prior to the project, little or no scientific data existed regarding the effective use of dairy manure compost. This project supported efforts to evaluate the use of compost in horticultural, agricultural and roadside or construction applications. The 7 studies completed during the project included:

1. **Establishment of a Newly Constructed Landscape with Dairy Compost.** Construction of new homes and businesses is a continuous process in rapidly growing urban areas such as the Dallas metroplex. Large sections of land are quickly converted to residential homes, business offices, or strip malls. Post-construction landscaping is usually approached from only the plant-selection viewpoint. Little thought or effort is devoted to soil preparation prior to planting the landscape and unfortunately, the soil has usually been severely disturbed and compacted by vehicles and soil-moving machinery. Although ornamental plants and turfgrass planted in this disturbed soil may perform well in the short term due to abundant watering and fertilization, they frequently decline over time when heat and drought stress become prevalent. The effects of mixing low to high rates of compost with the soil prior to establishing the landscape were evaluated in the newly constructed landscape study at Dallas.
2. **Compost as a Bed Amendment under Shaded Conditions.** Many urban compost applications occur in already established planting beds. These beds typically coexist with mature trees and shrubs. Therefore, compost is applied directly in the bed under shady conditions and typically as a thick mat leading to abnormally high nutrient applications. Application of dairy compost under these conditions was evaluated in the shade study at Dallas.
3. **Establishment of Turfgrass on Compost Amended Soils.** Turfgrass establishment is a primary component of landscape development following the construction of a new home or business. Sports and recreation fields typically require even more intense management to sustain performance. Therefore, studies to evaluate the response of turfgrasses to dairy compost were conducted in conjunction with the newly constructed landscape study.
4. **Use of Compost on Coastal Bermudagrass.** Improved Bermudagrasses are a dominant agricultural crop throughout the region. These studies evaluated rates, timing and economics of compost use for forage Bermudagrass production.
5. **Compost use on Irrigated Corn Silage**. While produced on a limited number of acres in the region, corn silage requires significant amounts of plant nutrients. These studies evaluated rates of compost for optimum production of corn silage under irrigated conditions.
6. **Establishment of Jose Tall Wheatgrass with the use of Compost.** A wide variety of animal production systems in the project area utilize forages and range as their basis for animal nutrition. These include dairies, beef cattle, goats, sheep and wildlife. However, little or no information existed on the use of dairy manure compost in various forage systems.
7. **Evaluation of Soil and Water Quality following Compost Applications for Erosion Control.** Dairy compost is commonly used to help revegetate roadsides and construction areas and is applied as a supplement to erosion control mixtures. While these efforts

have largely been successful, questions exist regarding nutrient loads and runoff potential from these applications. To provide a scientific basis for decision making in the use of compost in these applications, studies were conducted at the Riverside Campus near Bryan-College Station.

All studies were conducted between 2003 and 2005. Study progress, data and photographs were posted on the Web site as the projects progressed. All presentations, posters, etc. related to these studies were posted on the Web site. Final reports for each study are included in **Appendix O**.

Additional Projects

Supplemental projects that supported the efforts of the Dairy Compost Utilization Project also occurred during the project period. Some of these were supported by additional TCEQ funds, while others received funding from various sources, both state and federal. Results and information collected in these studies supported and enhanced the Dairy Compost Utilization Project. Several key examples are presented below.

Increased troop numbers and reduced training land area have caused increased erosion and sediment loss on Fort Hood. Many of the training landscapes have minimal vegetation and are almost void of quality top soil. Many areas will require multiple applications of compost and many years of management to completely reclaim the land. To evaluate the best practices for land reclamation, TWRI and personnel at the Blacklands Research and Extension Center in cooperation with NRCS have been utilizing dairy compost and other best management practices such as ripping and gully plugging to establish vegetation and reduce soil erosion and sedimentation. These activities, when used in combination, minimize soil loss and stabilize the landscapes for future activities.

TCEQ supported some of the compost application efforts on Fort Hood through supplemental project funds provided in 2004. A contract amendment to the Dairy Compost Utilization Project provided for the purchase, transportation and application of dairy compost along abandoned tank trails at Fort Hood. Six different dairy manure compost producers supplied material for these applications and vegetation was established along the tank trail. Comparison between types of material was not conducted as the study site conditions precluded development of a statistical plot layout. Regardless, site evaluations indicated that application of dairy compost was beneficial. The tank trails and compost were stable even during heavy rainfall immediately following application and all application areas established vegetation. Unfortunately, a common problem with any Fort Hood application, the cattle quickly found the fresh vegetation and compromised data collection on compost performance. Photo documentation was collected and a full report is included in **Appendix P**.

TWRI also met with Central Texas Cattleman’s Association and the Rangeland Ecology and Management Department to discuss and expand the use of dairy manure compost in their project, the Leon River Restoration Project. This project, supported by federal, state and local funds, worked with individual landowners to clear undesirable vegetation from the Leon River Watershed and improve habitat for endangered species. Dairy manure compost was utilized on several of the project sites to establish native grasses and reduce erosion once the undesirable vegetation was cleared.

Texas Agricultural Experiment Station personnel in the Soil and Crop Sciences and Biological and Agricultural Engineering Departments received multiple sources of funds to evaluate the use of compost and manure to producer turfgrass sod. One hypothesis of this project is that excess phosphorus in the Bosque River Watershed could be exported in the form of sod produced with manure or compost. Researchers evaluated nutrient runoff and leaching from both compost and manure when used as a base for sod production. In addition, the researchers worked with local sod producers to include this practice in their production schemes. **Appendix Q** includes a summary of the research evaluating compost use to sod production.

TWRI has cooperated with the Brazos River Authority in their efforts to administer the North Bosque Watershed Coordination Project and develop a Watershed Protection Plan for the Bosque River. Communication with the Leon-Bosque RC&D was also established to effectively market dairy compost for topdress application to sports fields. Another effort which involved local dairy cooperators and TIAER, worked to demonstrate the removal and/or reduction of phosphorus from dairy effluent resulting in less phosphorus applied to waste application fields.

Each effort, although individually implemented and sometimes geographically focused, is working to improve the water quality in the North Bosque River Watershed.

ISSUES OR PROBLEMS

Complexity in required project processes and in development of project documents caused considerable delays in the Dairy Compost Utilization Project. In addition, compost markets did not develop as fully as anticipated due to a number of factors.

The State of Texas required bids for selection of a Compost Marketing Firm. The bid and approval process delayed the early planning and development of a strong marketing effort. The lack of background information regarding market potential and development also slowed and limited the Project's marketing efforts. As stated in the introduction, successful market development takes several years and typically feeds off self generated momentum. Unfortunately, due to delays in the bid process and contract approval with RAA, the marketing firm was not hired until 6 months into the project allowing for only 2 years of marketing efforts. The project needed more *on the ground*, market development efforts. For instance, obtaining additional trade show promotional booths, staffing an on-site salesperson (that the composters could have potentially hired after the project was over), or providing more *day-to-day* assistance. TWRI or TCE could not provide direct marketing such as an on-site salesperson because of their public structure; both are state agencies established to provide the public with unbiased information while not advocating one specific product over another. TCE and TWRI did provide education to the public about the use of compost and its benefits, but was not able to directly sell dairy compost.

By splitting the budget up by task for each individual involved, the project grew from a few manageable accounts to 38 separate accounts. In addition, the split budget further complicated project reporting and management. Much of the time utilized to manage the project was consumed by budget and administrative efforts.

Significant confusion affected timely development of the QAPP. Fortunately, these requirements were clarified at a discussion meeting between TCE and TCEQ, which allowed TCE to move forward with drafting necessary project documents. However, once drafts were submitted, the review and comment period was extensive, time consuming and numerous discussions and drafts were shared between TCE and TCEQ. Consequently, budget expenditures were less than expected which concerned TCEQ and thus, a budget meeting was scheduled to project future spending activities. The lack of a QAPP also delayed collection of field data. Background information and research data were imperative for project personnel to educate potential compost users and to develop marketing or educational materials.

TCE and RAA were continually contacted by composters regarding the compost quality needed to meet TxDOT specifications. In addition, TCE and RAA were heavily involved in assisting composters in both sales and product development activities related to TXDOT. Although not a responsibility of the project, it was very important to the composters, and TCE and RAA were the only individuals providing assistance in this area. Many of these issues arose with the introduction of a new TxDOT standard. The dairy manure composters were able to actively participate in the TxDOT market when the jobs were bid on the old specification. However, dairy compost sales began to plummet as jobs under the new specification were announced. Due to the inherent nature of the soil and the manure collection practices, compost producers within the watershed likely will not be able to meet the specification without a significant addition of a carbon material such as wood wastes or yard clippings. While such amendments may improve quality, they will also add to the costs of producing the material, further limiting marketability. Compost facility location and transportation costs already pose a challenge to the compost producers when competing with other compost sources such as municipal composters. TCE and RAA, at the request of the composters within the Watershed, met with State Representative Sid Miller to discuss the ability of compost produced from dairy manure within the Bosque Watershed to meet TxDOT specifications. The meeting was a result of unsuccessful communications between the composters and TxDOT personnel. RAA attended as part of the contractual duties to assist the compost producers in their markets, while TCE attended to provide technical input regarding compost sample analysis. As a result of the meeting, RAA worked with TCEQ and TxDOT to develop suggested language for a temporary revised specification. While more sales were generated for the dairy composters through the revised specification, the market was only available for a short time as the modified specification ended when the compost incentive payment ended.

Numerous marketing challenges were faced by project personnel and the dairy compost producers. As previously noted, to produce a higher organic matter content and lower density material, supplemental carbon should be added during production. Unfortunately, such additions increase production costs. Given the location of these facilities, transportation costs also will continue to be a barrier especially when competing for a market in the larger urban centers situated more than 60 miles away. The variety of markets available to the compost producers is limited. It ultimately may be up to individual composters to identify niche markets to succeed.

Finally, the project goal was to provide compost producers with the tools necessary to effectively market their product and in doing so, establish markets which would be sustainable without government assistance. However, participation and active support of the marketing aspect of the project by compost producers was limited. This hindered the ability of the project to provide the type and level of service possible and necessary to build markets for their products.

CONCLUSION

Multiple programs will be required to protect water quality in the Bosque River. Through the Dairy Compost Utilization Project, several agency partnerships were developed and a variety of projects working to reduce point and nonpoint source pollution continue in the Watershed today. While production and use of dairy manure compost is a viable part of a solution, it is not the only means towards water quality improvements. Efforts need to continue to enhance the dairy manure composting program so that it can be most effective. Finally, the Dairy Compost Utilization Project successfully established a greatly expanded Extension educational program dealing with compost that will continue within the watershed and will spread to other parts of the State.

Compost producers continue to rely on the TxDOT market and would prefer to keep the program alive (note: some compost producers wanted the variance to continue while others would like to see it eliminated). Also, it has been requested and is recommended that TxDOT engineers receive training about the characteristics of dairy manure compost compared to other composted materials.

Given the source of dairy manure in the area, most of the compost producers will continue to struggle with low organic matter content and high pH in their compost. Based on the results of the organic matter improvement study, composters can amend their material by obtaining bulking agents or supplemental carbon. Ideally, the composters could identify a supplement that they would be paid to manage and create a back haul program with the carbon supplier. However, even with a steady source of carbon material, the composted dairy manure may still fail to meet TxDOT specifications related to organic matter content and pH. Therefore, compost producers must reduce their sole dependency on TXDOT sales and take marketing activities more seriously.

While DFW is the largest and closest urban center, composters must expand their marketing efforts to other population bases in addition to DFW as this area already has several sources of organic material. With the limited geographical area and the unique nature of the material, compost producers must work to identify their own unique marketing strategy as individual as the product they produce. Creative marketing and niche market development will be the keys to success for sustaining the dairy compost market. Several facilities have already worked to establish their own specialty markets. Some have developed nursery mixes, others are bagging their material to transport and sell to urban markets, and at least one is offering application services and applying material to agricultural lands. Utilizing the new knowledge and information generated through the Dairy Compost Utilization Project, compost producers can move forward to establish a sound and sustainable compost market in the Bosque River Watershed.

The Composted Manure Incentive Program Model provided several benefits in developing and establishing a dairy compost industry. However, with each benefit or factor in the development of this market, a lesson was learned.

The partnership with TSSWCB and its incentive program to foster transportation of dairy manure from dairy operations to compost facilities successfully initiated the composting industry in the watershed. Without this cooperation and the DMES program, the composting industry would have struggled to begin.

One of the first lessons came early in the Programs. The initial lack of supervision during the first phases of the hauling incentive program and during the opening of some of the compost facilities created problems for the young composting industry. For example, compost producers were not judiciously accepting only high quality manure (i.e. fresh manure), which led to the stockpiling of poor-quality and old manure at several of the facilities. Both agencies worked expeditiously to rectify the problems and amend the programs to avoid such events in the future. Unfortunately, some of the damage was not reconcilable. The stockpiled lower quality material at the compost facilities continued to cause problems for the composting industry and the market throughout the Dairy Compost Utilization Program.

In review, the second lesson learned was the need for more upfront education. Stockpiling of old material potentially could have been avoided if dairy producers, trucking industry and compost producers were effectively educated on the benefits of selecting high quality fresh manure to produce quality compost. Education for compost facility operators on proper production techniques prior to either DMES or CMIP also could have facilitated more effective market development. If the initial composted dairy manure had been of higher quality and the compost producers more knowledgeable about their product, the market development process would have faced fewer hurdles.

The third lesson surfaced when addressing market potential. More background research regarding the composted product and its market was needed. The composted product that could be produced from all types of dairy manure available in the Bosque River Watershed should have been evaluated first. The DMES program was fully operational and efforts to develop the TxDOT and other public markets were already underway when the Dairy Compost Utilization Program first began; yet, it was this program that was tasked to assess dairy manure compost quality. A market can not be effectively evaluated or established until product characteristics and quality are known. By fully understanding their product, compost producers and RAA could have better focused their efforts in market development by identifying its best potential uses, competition and niche.

In summary, more upfront efforts (prior to the Program) were needed, including education for all involved, assessment of current and potential product quality and an effective evaluation of market potential. The project also would have benefitted from more active involvement in the marketing process by the compost producers. Finally, give the unique and complex nature of this program, more time was needed to fully achieve the market desired.

Given the circumstances present at the initiation of the Program and the time allotted, the Dairy Compost Utilization Program achieved its goals. Namely, *compost producers gained valuable knowledge* regarding compost production; *dairy manure compost quality improved*; the *base knowledge of compost use increased* substantially and this information was effectively conveyed to the public; *purchases of composted dairy manure expanded*; and finally, *the development of a sustainable market* was substantially enhanced.

In looking ahead, the dairy compost market is still very young and has potential to grow and reach a sustainable level. However, given the geographic location and type of composted material produced, the market is unfortunately limited and will only bear a certain amount of production. Thus, the *development of niche markets by compost producers will be necessary for their long-term success*.

Ultimately, the compost industry is benefiting the region by providing an additional means to effectively manage livestock manure. However, manure composting is just one of the efforts that are helping achieve this goal. *Multiple programs are necessary and must complement one another to support a sustainable dairy industry and protect water quality in the North Bosque River Watershed.*

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Appendix A

Compost Facility Assessment Report

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Producers Compost

Enclosed is the trip report summarizing our recent site visit to your composting facility. The trip report updates our report of two years ago, focusing on process issues, as they relate to compost production and quality, as well as market development issues. Please review our comments and call me so we may discuss them further.

ORIGINAL REPORT – 5/8/03

The facility started receiving manure in January of 2001 and the site is surrounded by the owner's property. The facility consists of a graded soil pad extending over a reported 44-acre area. Although, upon further review, it appeared that there was actually more land in actual use. Little activity was occurring on the site when we visited, as we were told that the operation reportedly had incurred a substantial financial loss. This situation caused Producers to release their two full time operators, leaving Jef as the lone operator on site trying to manage both the production and marketing of the compost. The facility had not been receiving manure for several months. When in operation, the process consisted of 186 windrows, which were turned every 4 days, over a 25-28 day period, using a 20-foot track driven Scarab windrow turner. Temperatures were reportedly monitored at 4 points per pile, every other day during this period, in order to maintain the temperatures above 131°F. However, no records/monitoring data was provided to us during the site tour. Two front-end loaders (FEL's) were also available on site, as was a water truck. Screening is done using a rented McCloskey Brothers ½" trommel screen, when needed. No screen was on site at the time of the visit. Many larger windrows (surge piles), created by the FEL's, were also located on site. Jef identified moisture as the main operational challenge. Odors and vectors were not a problem, but the weather was cold (30°F's) and no operational activities were occurring. Jef estimated that between 180,000 and 200,000 cubic yards of composted/stockpiled manure was on site. (This was not independently verified due to time constraints of the visit). He estimated that it cost them $3.50-$4.00/CY to produce compost, and another $1/CY to screen it.

Jef estimated that approximately 80,000 cubic yards (CY) of compost were sold and moved off of this site in 2002 at a price of $9/CY. They will sell product for $9.00-$9.50/CY, depending on the size of the order (project). Their largest market, so far, has been TX DOT projects. They try to produce a product possessing 20-30% moisture content and bulk density of 1450 lb/CY. They typically ship in 30CY truckloads, and they appear to have several truckers lined up to ship their product. Producers have produced no product literature (promotional, instructional) thus far, but have run some radio ads locally to promote the product to farmers. They also had a deal set up with a fertilizer company to sell compost to farms for a price of $15/CY, applied. They have made no real effort to market to non-agriculture markets. Jef stated that they 'need to hire a compost salesperson'.

BIGGEST CHALLENGE – The facility did not appear to be very active. The windrow turner tracks were rusting, and no screening, windrow turning or product movement was occurring at the time of the visit. Jef stated that he did not expect the operation to be funded further, until income from product sales is realized. It was obvious that Producers needed to start actively marketing their product, or hire someone else to do so.

UPDATE – 4/7/05

Producers have been selling a great deal of compost to TX DOT; although things had been slowed recently because of rains. They have been selling EC compost and GUC, but CMT has been their biggest seller to TX DOT. CMT for 'blending on site' to be precise. They are blending bulking agent (e.g., wood, pushdown feed and cotton burr bedding) into their compost in order to increase its organic matter content to 25% and lower its pH. They do much of the compost hauling themselves, but also contract out some hauling. They can usually haul 32 yd3 of compost per load, and a typical price is $15-20 yd3, delivered. Producers is concerned that TX DOT will no longer give priority to manure compost. They are also concerned about changes to the manure and TX DOT hauling grants. They feel that both are still necessary. They stated that they probably have 100 K yd3 of compost products on order from TX DOT, and a total of 250-275K yd3 on-site. They are working hard on developing backhauls for bulking agents and compost in order to be more competitive. They also stated that the manure they are receiving appears to be a lot cleaner than in the past.

Bosque River Compost

Enclosed is the trip report summarizing our recent site visit to your composting facility. The trip report updates our report of two years ago, focusing on process issues, as they relate to compost production and quality, as well as market development issues. Please review our comments and call me so we may discuss them further.

ORIGINAL REPORT – 5/8/03

This 5-acre site began receiving manure in March 2002. Dwayne and one other operator run the site. They have a clay-surfaced composting pad that is well graded to a holding pond for runoff collection. Approximately 5-7 windrows are on site at any given time. Each windrow is approximately 20 feet wide at the base, 12 feet tall, and 100 yards long. Two of the seven windrows appeared to be several months old, with no recent turning. Equipment includes a Trojan 15Z loader, equipped with a 10 CY bucket that is used for pile building, turning, screening and product load out activities. A skid steer loader is used to grade the site in between windrows. A rented ½" McCloskey trommel screen was on site at a cost of $2,000 per week. Mr. Wolf estimated that approximately 10% screening 'overs' are generated from the clumps and the rocks found in the manure they receive. Pile turning is done daily to assist in drying the material and pile temperatures are reportedly measured daily after temperatures rise above 131°F. However, we did not witness any temperature monitoring while we were 'on site'. No odors were detectable on site, except those coming from the poultry operation on the adjacent property. Dwayne claims that he achieves a 50% volume reduction during composting and that he sells compost for $8/CY. It was estimated that about 17,000 CY of manure was currently being composted on site.

He primarily sells screened compost, but has started to produce some topsoil/compost blends. He would like to see compost prices sales prices at $10-12/CY. Dwayne indicated that he has sold about 3,600-4,000 CY of compost to TX DOT and another 2,000CY for other uses (sold

6,000CY in 02'). He usually ships 30CY truckloads (25 tons) of compost for a delivered price of $12-$14/CY. They appear to have several truckers lined up to ship their product. Aside from placing ads in some local newspapers, Wolf has not applied much effort towards compost marketing. They have interest in promoting their compost product to their nursery customers.

BIGGEST CHALLENGE – Moisture reduction from the wet incoming manure is the biggest processing concern. Dwayne has had discussions with the dairies he hauls from regarding them drying their manure through better on-site operational practices prior to the material being delivered. Low organic matter content in their finished product is also a major concern. Wolf also needs to actively market their product to improve sales volumes.

UPDATE – 4/7/05

Bosque River Compost had primarily been selling to Scotts/Hyponex, but recently lost this customer to a composter outside of the watershed ($0.50/yd3 cheaper). He is trying to cut a deal with another large compost bagger. He does not sell much to public entities, but has sold some to TX DOT contractors. They don't sell any product into the DFW Metroplex. Marketing is still their biggest issue.

The Bosque River site is now 15 acres in size and is very well kept. He is receiving cotton burrs with the manure he is getting, and the overall quality of the manure has improved. They are having the dairies pile wet manure onto their bedding when they stockpile it. This makes it dryer when they receive it. Bosque River has had a few dairies pay them to accept manure. Bosque River stated that the public sales rebate program hasn't helped them that much. They think that rebates should be directed at the composters, and not the dairies or end users. They also stated that they don't understand how all of the existing rebate programs even work. They believe that the programs need to be less complicated, and the user related programs should be made more available to private companies who want to use the product.

Dairy Cow Compost

Enclosed is the trip report summarizing our recent site visit to your composting facility. The trip report focuses on process issues, as they relate to compost production and quality, as well as market development issues. Please review our comments and feel free to call me if you have any questions or comments.

Operations – This composting site was permitted in September, 2004 and operates on 13 acres (9A currently in process). The site is the old Erath Earth site. When Dairy Cow Compost took the site over, it possessed large volumes of old manure. Dairy Cow Compost primarily receives manure from the EXCEL Dairy and they use wood and pushdown feed as a bulking agent. The facility operates with one full time person, and their primary equipment is a large FEL and a large deck screen. They process their product by blending the new manure with bulking agent, then windrow composting it for approximately 6 months. Depending on the product, they then may blend in some old manure. They have an arrangement with a wood grinder (Grind & Green) which provides them with green waste (for bulking agent) and helps them sell/haul finished compost. They are considering a site expansion to add 20 acres. They own 3 trucks and haul their manure themselves.

Marketing – They screen their product through a 5/8 inch deck screen and have to blend in green waste in order to produce an acceptable TX DOT compost. The old old manure on the site is sold as topsoil. 90% of the product they sell goes to TX DOT. Their biggest TX DOT products are: #1 GUC, #2 CMT and #3 EC compost. Dairy Cow Compost has primarily received TX DOT projects in the DFW. They stated that they get 40 yd3 of compost on a load, but sell it as 36 yd3 (overloading). They are also selling a little product to area landscapers ($15 yd3) and homeowners ($18 yd3). He stated that they need a salesman to further expand their marketing efforts. The hope to develop landscape yards for product in DFW, Austin and San Antonio with Grind & Green's help. These landscape yards would help in product distribution. Dairy Cow Compost are also interested in bagging in the future. They are in the USCC's STA Program.

BIGGEST CHALLENGE – 1) Meeting the 25% organic matter spec for TXDOT – try have to blend materials to do so, 2) getting rid of the old manure pile, and 3) getting the compost dryer so they can ship more per truck..

Organic Residual Reclamation

Enclosed is the trip report summarizing our recent site visit to your composting facility. The trip report updates our report of two years ago, focusing on process issues, as they relate to compost production and quality, as well as market development issues. Please review our comments and call me so we may discuss them further.

ORIGINAL REPORT – 5/8/03

This 15-acre site has been in operation for two years. As manure is received, it is placed directly into tall windrows using front end loaders (FEL's), then is turned 5 times over a 2-week period. Piles are monitored for temperatures, but no data was available for review during the site visit. Two FEL's, with 5 CY capacity buckets, were on site, as was a rented trommel screen. A truck scale was operating at the scale house across the street from the compost site. There was significant loading activity on site during our site visit, with up to 6 trucks on site at any one time being loaded with screened compost (for offsite delivery). Windrows were being moved and re-stacked and screening was taking place with a rented McCloskey 621 trommel screen. Two operators, a full time marketer and a scale house operator are involved in the operation, as well as part-time supervision by Israh Cortez. Significant stockpiling of manure was noticed, with well over 10,000 CY of undisturbed and piled manure on site in a surge pile. Minimal odors were noticed on site.

Their finished compost reportedly weighs between 1,100 and 1,400 lbs/CY, and their typical moisture content, at time of shipping, is 30%. They produce both a ½" and 1" screened compost, as well as some blended topsoil and erosion control mix. Reportedly, 16,000 CY per month of compost alone was marketed from this facility in 2002. Their largest market is TX DOT projects, but are expanding their sales efforts to/through wholesale/resale resale operations. They also sell a little compost into agriculture, and hope to expand that market. They contract ship all of their product, and showed great interest in receiving compost usage information/research.

BIGGEST CHALLENGE – None noted.

UPDATE – 4/9/05

ORR now operates on a new site (old site was Erath Earth #2). They stated that their compost is typically 45-50% moisture and weighs 750 to 1,150 lbs/yd3. They now use a Viper deck screen which screens their compost down to a ¼". Their principal markets are landscapers, topsoil blenders, nurseries and a materials company selling and blending products for the athletic field and golf markets. They also sell 25-30% of their product to TX DOT (their coarser material). They have also been very successful in selling to municipal entities throughout the region. They are not in favor of the manure hauling rebate program.

Gustine Compost

Enclosed is the trip report summarizing our recent site visit to your composting facility. The trip report updates our report of two years ago, focusing on process issues, as they relate to compost production and quality, as well as market development issues. Please review our comments and call me so we may discuss them further.

ORIGINAL REPORT – 5/8/03

This is a 10-acre site that was created from graded soil. It has been receiving manure since March 2002. A very large surge pile of manure (45,000 CY in size?) was located on site, as was approximately 10 windrows of compost. No front-end loader (FEL) was on site due to maintenance problems (L150C Volvo, with a 6 CY bucket). This FEL was being repaired. Randy indicated that a second W26 Case loader, with a 4 CY capacity bucket, was 'on order'. A windrow turner was on site, but not being used. It was reported that a ½" trommel screen is leased when needed for screening. Randy stated that 41,000 CY of manure had been received at the site since it began operation last year, however this number seems low based on the size of the manure surge pile and compost windrows. In addition, fresh manure was being delivered to the site with over 1,000 CY of manure dumped on the ground waiting to be placed into windrows. Randy indicated that he hoped to be able to turn the windrows with a FEL every 5 days when he gets his new FEL, and the old FEL is returned. Randy indicated that they used to take wet manure, but that they now only receive "drier" manure from the dairies. His manure also appeared to contain less rock than manure found at many of the other composting sites. No odors were detectable on site.

He is producing only a ½" screened compost product thus far, and estimated that he sold 2,000 CY in 2002. He is charging $8.50/CY (FOB) for the product, but has had to reduce his price to compete for a TX DOT project in the DFW area (shipping costs). They have also shipped product to a TX DOT project in Killeen. They hope to produce erosion control compost in the future. Randy's partner stated that he used some of the compost on growing corn silage, with good results, and would like to sell compost to area farmers. Their marketing activities have been limited up to now.

BIGGEST CHALLENGE – Moving the remaining stockpile of manure and begin to consistently operate and monitor the compost process. They also need to start actively marketing their product.

UPDATE – 4/7/05

Gustine is involved in both the manure hauling and TX DOT transport rebate programs. He is interested in seeing the TX DOT organic matter and pH derivation continue and he still receives manure under the manure hauling rebate program. Their primary customer is TX DOT, and they are selling to projects allowing 10% organic matter in the compost. They primarily sell compost to TXDOT contractors as CMT. Randy stated that some TX DOT contractors have complained that they were getting 'shorted' on their loads from some of the composters. If he needs addition compost, he purchases it from ORR, who are also renting him their trammel screen. They are selling to no other public customers. However, Gustine are trying to sell compost to farmers under the farm use rebate program.

Gustine stated that he still has an old old pile of manure on his site. That is the material sold as CMT. He is also blending some lab animal bedding into his product to improve the organic matter content. Gustine now turns their compost piles with a SCAT compost turner.

Erath Earth

Enclosed is the trip report summarizing our recent site visit to your composting facility. The trip report updates our report of two years ago, focusing on process issues, as they relate to compost production and quality, as well as market development issues. Please review our comments and call me so we may discuss them further.

ORIGINAL REPORT – 5/8/03

This facility is a long and narrow 6-acre site that has been used to process manure for 6 years. The site is steeply sloped down its length to a holding pond. Equipment includes a CAT 938G front-end loader (FEL) and a home-made ¾" punch plate trommel screen. The facility is operated by Mr. Cortez and his two sons, on a part time basis. Last year he received approximately 10,000 CY of manure at the site. Mr. Cortez stated that he currently has about 6,000 CY of compost on site. Half of this is in windrows and the other half is in an old surge pile. He cannot receive a general permit at this site because he does not have the 150' buffer space between his operation and one abutting property owner. He does not use a windrow turner, as there are too many rocks in the manure to turn it with a conventional turner. Piles are turned, then stacked as tall as the FEL will allow. He stated that they are using the static pile composting method, but the piles of material as high may be to high for efficient composting. After 60 days he rolls the large piles and considers the material complete. It is uncertain whether temperatures are monitored and documented during active composting. No monitoring data was available for our review during the site visit.

Mr. Cortez stated that he sells compost for $12 per CY and has well established outlets in local nurseries and lawn care shops in Austin. He tests his product through Texas Plant and Soil Lab (Chandler, TX) and is unable to sell any compost to TX DOT because he cannot show that the product meets PFRP. He also produces a compost tea that was used at the Governor's mansion, as well as some nursery media (by blending compost with ground wood and decomposed granite). Their main market for the compost is 'south' of the region, into Waco and Austin. Their product is sold by two large wholesale yards, which sell the product to landscapers. They do not currently sell into agriculture, but believes that it may have potential (coastal Bermuda grass). They appear to have trucking set up, and can, on occasion, haul their product using 'backhauls'.

BIGGEST CHALLENGE — Mr. Cortez indicates that the manure he receives is already heating readily from the stockpiles on the dairy sites and that the lack of energy is sometimes a problem in achieving high temperatures on his site. This did not seem to be a problem at other sites. Markets appear to be well established.

UPDATE – 4/7/05

Erath Earth is not a part of the manure hauling or TX DOT transportation rebate programs. He pays to have manure hauled into his facility. However, he still believes that if these programs end, the regional composts will suffer. They have been proactive in selling compost for horticultural applications. They are selling locally, as well as in Austin and San Antonio. Erath Earth sells compost and compost blends to greenhouses growers (vegetable transplants) and sales to organic farmers have also grown. Sabino is involved with organic agricultural organizations in the area. They also bag their potting mix in 20 and 40 quart bags for resale through garden centers. They also are selling the mix in 2 yd3 bulk bags (at $65/yd3) on a pallet.

O'Neal's Compost

Enclosed is the trip report summarizing our recent site visit to your composting facility. The trip report updates our report of two years ago, focusing on process issues, as they relate to compost production and quality, as well as market development issues. Please review our comments and call me so we may discuss them further.

ORIGINAL REPORT – 5/8/03

This 30-acre site is graded soil and has been processing manure for 2 years. Equipment includes a track loader, 3 front-end loaders (FEL's), a tractor driven rototiller and a ½"vibratory deck screen. Two full time employees and an office clerk are at the site. Approximately 45,000 CY of old manure was piled on site in a surge pile, as well as in several active windrows composting. Material is stacked in high windrows with a FEL and O'Neal stated that piles are turned every 3 days for about 30 days, while temperatures are monitored. O'Neal claimed that pile temperatures in the 130^{o}F -170^{o} F range are common, however, no records were provided for our review.

O'Neal also has a manure spreader for applying compost onto farmland. They charge $40/acre to spread 3-4 tons of compost. He sells compost for $5-7 per CY and $9/CY for erosion control mix (FOB). Primary markets have been DOT projects. O'Neal stated that the compost weighs 1,200-1,700 lb/CY depending on its moisture content, and claims that he has sold in excess of 50,000 CY of product over the past 6 months. Trucking is done through a family owned trucking business.

BIGGEST CHALLENGE – No process challenges were obvious. However, diversifying markets outside of the DOT would be helpful for longer-term success.

UPDATE – 4/7/05

O'Neals stated that they have a lot of farmers within the watershed interested in using their compost, but need the rebate to make the product economically attractive. They have been out of the manure hauling program for 2 years, but are still receiving manure (with some farmers paying him $20/load to offset some of the hauling costs). Their biggest customer is TX DOT. GUC is the primarily product they sell to TX DOT, with 90% receiving the hauling rebate. They primarily sell to TX DOT at $8yd3, plus freight ($2.50/loaded mile for hauling, going up to $3.00/loaded mile). They can usually haul 36yd3 of compost per load. O'Neals is selling more product to farmers ($10yd3 + freight) for Coastal Bermuda and Sudan grass. With a finer screen he believes that they could sell more to Pecan growers (remove stones). They are also selling more compost to municipal entities and a little to homeowners ($20/yd3).

Appendix B

Dairy Compost Quality Assessment Results

TxDOT specification listed by parameter.

Parameter	TxDOT Specification
pH	between 5.5 and 8.5
EC (Soluble Salts)	less than 5.0
Organic matter	between 25 and 65
Arsenic	less than 75
Cadmium	less than 85
Copper	less than 4,300
Lead	less than 840
Mercury	less than 57
Molybdenum	less than 75
Nickel	less than 420
Selenium	less than 100
Zinc	less than 7,500
Fecal Coliform	less than 1000
Respiration	less than 8
Biological Avail. Carbon	less than 8
Emergence	greater than 80
Relative Seedling Vigor	greater than 80
0.38” to 0.64”	less than 30

STA Sample 1 through 6 results. Parameters specified in the TxDOT specification are shaded in gray.

	Units	STA Sample 1		STA Sample 2		STA Sample 3		STA Sample 4		STA Sample 5		STA Sample 6	
		Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis
Total N	%	0.51	0.72	0.67	0.91	0.49	0.70	0.67	0.90	0.52	0.69	0.69	0.86
Ammonia	mg/kg	17	25	138	189	93	133	22	30	36	49	100	123
Nitrate	mg/kg	370	519	270	369	296	423	305	408	348	468	471	580
Organic Nitrogen	%	0.48	0.67	0.63	0.86	0.45	0.65	0.64	0.86	0.48	0.64	0.64	0.79
Phosphorus as P2O5	%	0.60	0.84	0.64	0.88	0.33	0.48	0.59	0.79	0.60	0.80	0.85	1.00
Phosphorus	mg/kg	2647	3712	2824	3860	1467	2099	2587	3460	2619	3521	3734	4599
Potassium as K2O	%	0.93	1.30	0.88	1.20	0.59	0.84	1.30	1.80	0.86	1.20	1.10	1.40
Potassium	mg/kg	7711	10813	7327	10017	4876	6980	11074	14814	7133	9589	9397	11574
Calcium	%	5.10	7.20	8.8	12.0	3.1	4.4	9.50	13.00	5.30	7.10	12.00	15.00
Magnesium	%	0.42	0.59	0.37	0.50	0.24	0.34	0.51	0.68	0.42	0.57	0.59	0.72
Sulfate (SO4)	mg/kg	1430	2006	1403	1919	1783	2553	1607	2150	1466	1971	1568	1931
Copper	mg/kg	23	33	20	27	20	28	23	31	22	30	33	41
Zinc	mg/kg	82	116	54	73	44	64	74	98	81	109	148	182
Iron	mg/kg	3805	5335	3460	4729	3093	4428	5288	7074	3999	5376	5633	6938
Manganese	mg/kg	150	211	107	146	72	103	145	194	154	207	177	218
Boron	mg/kg	16	22	9	13	1	2	17	22	11	15	19	24
Sodium	%	0.17	0.24	0.23	0.32	0.10	0.14	0.2	0.26	0.18	0.24	0.15	0.18
Chloride	%	0.097	0.14	0.24	0.32	0.16	0.22	0.15	0.2	0.11	0.15	0.059	0.073
pH	units	9.09	NA	8.64	NA	8.81	NA	8.55	NA	8.36	NA	9.08	NA
EC (Soluble Salts)	mmhos/cm	2.282	3.2	4.36	5.96	3.297	4.72	2.542	3.4	2.358	3.17	4.076	5.02
Bulk Density	lb/cu ft	65	46	63	46	68	48	60	45	68	51	65	53
Carbonates as CaCO3	lb/ton	220	308	414	566	192	274	352	471	200	269	746	919
Organic matter	%	12.9	18.1	14.4	19.7	13	18.6	14.8	19.8	12.2	16.4	12.1	14.9
Organic Carbon	%	6.1	8.6	8.5	11.6	5.6	8.1	8.6	11.5	6.2	8.3	9	11
Ash	%	58.4	81.9	58.8	80.3	56.9	81.4	60	80.2	62.2	83.6	69.1	85.1
C:N Ratio	ratio	12	12	13	13	11	11	13	13	12	12	13	13
Moisture	%	28.7	0	26.8	0	30.1	0	25.2	0	25.6	0	18.8	0
Arsenic	mg/kg dw	2		2		1		4		3		3	
Cadmium	mg/kg dw	less than 1		less than 1		less than 1		less than 1		less than 1		less than 1	
Chromium	mg/kg dw	6		5		4		6		5		9	
Copper	mg/kg dw	33		27		28		31		30		41	
Lead	mg/kg dw	3		1		5		2		6		2	
Mercury	mg/kg dw	less than 1		less than 1		less than 1		less than 1		less than 1		less than 1	
Molybdenum	mg/kg dw	1		less than 1		less than 1		2		1		1	
Nickel	mg/kg dw	5		4		3		5		4		5	
Selenium	mg/kg dw	less than 1		less than 1		less than 1		less than 1		less than 1		less than 1	
Zinc	mg/kg dw	116		73		64		98		109		182	
Cobalt	mg/kg dw	2		2		2		2		2		3	
Total Solids	%	71.3		73.2		69.9		74.8		74.4		81.2	
Fecal Coliform	mpn/g dw	48		less than 2		less than 2		70		4		less than 2	
Salmonella	mpn/4 g dw	less than 3		less than 3		less than 3		less than 3		less than 3		less than 3	

Respiration	mg CO2-C/g OM/day	1.6	1.5	1.2	1.7	2.3	2.1
Biological Avail. Carbon	mg CO2-C/g OM/day	8.3	5.5	7.5	4.7	4.2	4.5
Emergence	%	100	80	100	100	70	100
Relative Seedling Vigor	%	53	75	100	100	57	100
Description of plants	NA	fungus	stunted	healthy	healthy	fungus	stunted
0.38” to 0.64”	% by weight	3.7	0.0	0.0	0	7.7	0.9
	% by volume	3.4	0.0	0.0	0	9.9	0.8
	Bulk Density (g/cc)	0.95	0.00	0.00	0	0.67	1.1
0.25” to 0.38”	% by weight	9.5	0.0	0.0	6.8	12.6	9.3
	% by volume	10.7	0.0	0.0	8.6	14.8	9.1
	Bulk Density (g/cc)	0.77	0.00	0.00	0.67	0.73	0.96
0.16” to 0.25”	% by weight	15.6	4.7	0.0	9.1	13.3	9.6
	% by volume	16.9	7.1	0.0	10	14.8	11.1
	Bulk Density (g/cc)	0.8	0.68	0.00	0.77	0.77	0.81
0.08” to 0.16”	% by weight	20.7	13.6	11.7	18	18.9	17.8
	% by volume	23	17.9	19.6	19.5	20.2	19.8
	Bulk Density (g/cc)	0.78	0.78	0.59	0.78	0.8	0.84
<0.08”	% by weight	50.5	81.7	88.3	66.1	47.5	62.4
	% by volume	46.1	75.0	80.4	61.9	40.4	59.3
	Bulk Density (g/cc)	0.95	1.12	1.08	0.9	1	0.98

STA Sample 7 through 13 results. Parameters specified in the TxDOT specification are shaded in gray.

	Units	STA Sample 7		STA Sample 8		STA Sample 9		STA Sample 10		STA Sample 11		STA Sample 12		STA Sample 13	
		Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis	Wet Wt Basis	Dry Wt Basis
Total N	%	0.59	0.69	0.54	0.75	0.91	1.20	0.97	1.20	0.88	1.10	0.87	2.00	0.66	0.88
Ammonia	mg/kg	91	105	339	470	171	224	543	665	617	785	196	441	284	377
Nitrate	mg/kg	208	241	72	100	202	264	32	39	16	20	18	39	265	352
Organic Nitrogen	%	0.56	0.65	0.50	0.69	0.88	1.10	0.91	1.10	0.82	1.00	0.85	1.90	0.61	0.81
Phosphorus as P2O5	%	0.75	0.87	0.66	0.91	0.63	0.83	0.66	0.81	0.66	0.84	0.36	0.81	0.73	1.00
Phosphorus	mg/kg	3306	3827	2885	3998	2791	3641	2896	3548	2910	3704	1590	3573	3219	4268
Potassium as K2O	%	1.10	1.30	1.10	1.50	1.60	2.00	1.70	2.10	1.70	2.20	0.53	1.20	0.90	1.20
Potassium	mg/kg	8982	10398	9042	12531	12890	16815	14017	17173	14347	18560	4441	9981	7442	9866
Calcium	%	7.90	9.20	6.10	8.50	12.00	16.00	10.00	12.00	9.00	11.00	2.9	6.4	6.8	9.1
Magnesium	%	0.55	0.64	0.47	0.65	0.54	0.71	0.58	0.71	0.64	0.81	0.24	0.54	0.35	0.46
Sulfate (SO4)	mg/kg	1305	1510	1512	2096	1840	2400	1087	1331	1143	1455	291	651	2505	3321
Copper	mg/kg	24	27	20	28	25	32	27	33	27	34	28	63	21	28
Zinc	mg/kg	117	136	78	108	74	96	79	96	80	102	52	116	54	72
Iron	mg/kg	5091	5893	4067	5637	4493	5862	5280	6469	6182	1869	2317	5209	5108	6772
Manganese	mg/kg	149	173	142	197	151	197	162	199	170	217	74	165	110	146
Boron	mg/kg	14	16	13	18	17	22	19	23	19	24	8	17	14	18
Sodium	%	0.16	0.18	0.22	0.31	0.24	0.31	0.25	0.31	0.25	0.32	0.11	0.25	0.22	0.29
Chloride	%	0.087	0.1	0.15	0.21	0.2	0.26	0.2	0.24	0.19	0.24	0.11	0.24	0.27	0.36
pH	units	8.81	NA	8.4	N/A	8.85	NA	8.67	NA	8.83	NA	8.56	NA	8.63	NA
EC (Soluble Salts)	mmhos/cm	3.922	4.54	8.053	11.16	3.074	4.01	3.983	4.88	4.329	5.51	1.824	4.1	5.687	7.54
Bulk Density	lb/cu ft	71	61	62	44	56	43	53	43	53	42	38	17	63	48
Carbonates as CaCO3	lb/ton	794	919	1210	1677	378	493	405	496	111	142	86	194	336	445
Organic matter	%	10.8	12.5	12.5	17.3	16.8	21.9	15.5	18.9	17.5	22.3	21.2	47.7	13.1	17.3
Organic Carbon	%	7.2	8.4	6.5	9.1	12.8	16.7	13.8	17	12.1	15.4	14	31.4	8	10.6
Ash	%	75.6	87.5	59.7	82.7	59.8	78.1	66.2	81.1	61	77.7	23.3	52.3	62.4	82.7
C:N Ratio	ratio	12	12	12	12	14	14	14	14	14	14	16	16	12	12
Moisture	%	13.6	0	27.8	0	23.3	0	18.4	0	21.4	0	55.5	0	24.6	0
Arsenic	mg/kg dw	3		2		3		3		3		3		2	
Cadmium	mg/kg dw	less than 1		less than 1		less than 1		less than 1		less than 1		less than 1		less than 1	
Chromium	mg/kg dw	7		6		6		6		8		6		6	
Copper	mg/kg dw	27		28		32		33		34		63		28	
Lead	mg/kg dw	2		3		4		3		4		4		4	
Mercury	mg/kg dw	less than 1		less than 1		less than 1		less than 1		less than 1		less than 1		less than 1	
Molybdenum	mg/kg dw	less than 1		1		2		2		2		2		1	
Nickel	mg/kg dw	5		4		5		5		6		5		4	
Selenium	mg/kg dw	less than 1		2		less than 1		less than 1		less than 1		less than 1		less than 1	
Zinc	mg/kg dw	136		108		96		96		102		116		72	
Cobalt	mg/kg dw	3		2		2		2		3		3		2	
Total Solids	%	86.4		72.2		76.7		81.6		78.6		44.5		75.4	
Fecal Coliform	mpn/g dw	less than 2		less than 2		less than 2		less than 2		2		110		less than 2	
Salmonella	mpn/4 g dw	less than 3		less than 3		less than 3		less than 3		less than 3		less than 3		less than 3	

Respiration	mg CO2-C/g OM/day	1.4	2	2.3	6.4	5.8	5.9	1.6
Biological Avail. Carbon	mg CO2-C/g OM/day	5.8	5.4	4.9	9	7.5	10	5.7
Emergence	%	100	100	100	100	100	100	100
Relative Seedling Vigor	%	100	100	100	100	100	100	70
Description of plants	NA	stunted	healthy	stunted	healthy	healthy	healthy	stunted
0.38” to 0.64”	% by weight	0	14.1	15.7	9.4	3.6	0.0	0.0
	% by volume	0	14	13.9	7.8	2.5	0.0	0.0
	Bulk Density (g/cc)	0	0.86	0.85	0.79	0.91	0.00	0.00
0.25” to 0.38”	% by weight	8.7	13.2	9.8	11.9	8.9	0.0	0.0
	% by volume	12.3	14	10.9	11.9	9.1	0.0	0.0
	Bulk Density (g/cc)	0.71	0.81	0.68	0.66	0.63	0.00	0.00
0.16” to 0.25”	% by weight	10.1	17.8	11.3	11.2	14.3	4.2	0.0
	% by volume	11	19.1	12.2	11.5	14.2	6.5	0.0
	Bulk Density (g/cc)	0.92	0.8	0.7	0.64	0.65	0.25	0.00
0.08” to 0.16”	% by weight	16.6	22	17.1	17.9	19.6	19.1	2.0
	% by volume	19.4	23.3	19.6	19.3	19.6	21.7	2.0
	Bulk Density (g/cc)	0.85	0.81	0.66	0.61	0.64	0.35	0.95
<0.08”	% by weight	64.6	33	46.2	49.6	53.6	76.7	98.0
	% by volume	57.3	29.8	43.5	49.4	54.5	71.7	98.0
	Bulk Density (g/cc)	1.13	0.95	0.8	0.66	0.63	0.42	0.96

Appendix C

Organic Matter Improvement Survey Report

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Organic Matter Identification and Quantification Survey

- **Introduction**

The dairy farmers located in the Bosque River Watershed (Erath County) are working with area composters, under the direction from TCEQ, to transform their manure into compost. This effort is ensuing in an effort to alleviate surface water impairments associated with excessive levels of nitrogen and phosphorus entering the watershed. These compounds, after composting, are much less available to leaching and run off, as more complex and less soluble forms are created. Further, a goal of the composting initiative is to raise the value of the manure, allowing it to be transported out of the impacted watershed. The majority of the manure being obtained for composting, however, is low in organic matter and high in pH, calcium and sodium. The finished composts possess similar characteristics, and have a high bulk density. These characteristics make the products less desirable for TxDOT usage and more expensive to ship.

It has been determined that the addition of organic matter, especially carbon rich sources, to the dairy manure compost can modify product characteristics, thereby improving its potential marketability. This should also assist composters in producing a finished compost product that will meet TxDOT compost specifications. Meeting TxDOT compost specifications would be an obvious benefit for the compost producers in the impacted watersheds as TxDOT is currently the largest user (specifier) of compost in Texas. Unfortunately, few large sources of organic matter (or carbon rich bulking agents) have been identified locally or regionally, and those that have been identified, have been somewhat costly.

As part of its contract through Texas A&M University, R. Alexander Associates, Inc. (RAA) was tasked to conduct a survey of potential public and private sources of organic matter. The impacted compost producers have expressed concern about paying for sources of organic matter (carbon), and remaining competitive with other composters in the State. Therefore, sources of recycled materials from both the public and private sectors were sought out, as an alternative to just purchasing products like commercially available sawdust and wood chips. It was hoped that an adequate supply of 'waste' carbon could be identified which may address two existing challenges: one for the 'generator' of the carbon waste and one for the composters. Specifically, it was hoped that compost producers could find materials available for a minimal fee (cost of transportation) or even better, receive a fee for management of the 'waste' carbon.

2.0 Methods

The surveying efforts encompassed an area approximately 50 miles in diameter, with Stephenville being the central point and a radius extending an approximate distance of 25 miles in all directions. It was estimated that anything located within this circle would pose minimal transportation challenges from both expense and logistical perspectives. Potential sources of high carbon organic matter or carbon rich by-products were sought out, quantified and evaluated for economic feasibility.

Various organic by-products sought included, but were not limited to:

- Yard waste, wood waste
- Tree trimmings, wood chips
- Sawdust
- Agricultural by-products (cotton burrs, rice hulls, spoiled hay, peanut hulls)
- Paper, cardboard

RAA utilized a variety of sources to create a contact list of possible generators and/or suppliers of this carbonaceous material. These included:

- municipalities who purchased wood chippers through solid waste grant programs
- city and county recycling officials
- other municipal officials
- county agricultural agents
- city chamber of commerce business lists
- referrals from those listed above, and other sources

The survey was conducted through telephone contact, but also included E-mail contact when requested by the prospect. The project duration was approximately 4 weeks, and took place primarily during the month of August 2004. The findings of the survey are listed in this report, and in the attached spreadsheet files.

Since several composters are already purchasing a variety of bulking agents to add to their compost, we did not concentrate on identifying additional sources of material that would have to be purchased. Up to now, Erath composters have purchased sawdust, wood chips and shavings, cotton burrs and peanut hulls in an effort to increase their organic matter content and reduce their pH. These materials possess a cost ranging from $2.00 cubic yard (just the cost of delivery) to $31.00 to $55.00 cubic yard delivered. Other materials such as push down feed and spoiled hay have also been obtained, when available, typically for the cost of transportation.

2.1 Projects Tasks

Task 1: Develop contact list to utilize during organic matter material survey.
Concentrate on municipalities, major employers and manufacturers producing such by-products and supplement the list with contacts from regional cities and counties (as well as their contractors).

Task 2: Conduct survey to identify organic matter material available within the Bosque River Watershed.
Data will be uniformly collected using a standard survey form in order to obtain valuable qualitative and quantitative data. Data collection will also identify the most easily accessible organic by-product sources, volumes, their general characteristics, seasonality of generation, price/tip fee to be paid, etc. Survey will be completed through the telephone, and samples of viable by-products will be obtained for verification.

Task 3: Target specific suppliers or organic matter materials.
Criteria include specific entities, which 1) are willing to pay a tip fee for the management of these materials, thereby generating additional revenues for the composters, or 2) can provide already sized reduced material (chipped, shredded, ground), thereby offsetting any related processing costs.

3.0 Survey Findings

The prospects were all initially contacted by telephone, in relatively random order. The initial key limiting factor determining prospect viability was their distance from Stephenville. They were asked a series of questions in an attempt to; determine if they generated any organic matter rich materials, define the type of materials they generated, determine the available quantity, determine the value, if any, that they assigned to the material, and other related questions. A copy of the survey questionnaire is included in this report as **Exhibit 1**.

A mix of both public and private entities was contacted based on the list of potential generators defined above. A total of 72 prospects were defined and contacted during the survey. This consisted of 43 municipal contacts (city, county, state and federal) and 29 private industry contacts. There are two types of available sources of materials available. There are ‘stockpiled’ supplies, that are available immediately, and there are ‘ongoing’ sources available throughout the year. The stockpiled sources are the result of periods of normal by-product collection and product stockpiling that resulted primarily from the generators inability to distribute the material, and also acute stockpiling situations that resulted from heavy spring storm clean up projects in the area. Most of these materials are yard debris, such as brush and tree trimmings. The ongoing production is, as the name implies, produced on a predictable basis throughout the year. This should be a consistent source of material for the composters once they develop a business arrangement with the generator.

3.1 Material Specifications

The vast majority material identified was in the form of shredded brush, generated by municipalities. Almost no supplier could give very specific specifications other than “the material had been run through a grinder”. A size range of 2- to 5-inch was given by the City of Cleburne and 4- to 6-inch by SMS Woodstone and the City of Burleson. No other producers were able to give specific size or chemical specifications.

All of the municipal producers indicated that their material had a small level of contamination that ranged from a low of 1 percent and up to 5 percent. Most reported their materials having the lesser percentage of contamination. This contamination was claimed to be primarily film plastic, resulting from the trash bags used to collect the leaves and smaller brush, but there is also likely to be an assorted collection of some larger man-made debris contained in most of the stockpiles.

3.2 Quantity

Most of the contacts could only estimate the quantity of material that currently is or will be available. They were asked to take their best, conservative guess during the survey. Some of the estimates were given in a weight (tons) estimate and others were provided in volume (cubic yards). A ratio of 2 cubic yards equals 1 ton was used to standardize results in calculating the data totals listed below. This is a conservative figure, even for yard debris which is ground and aged to some degree. Therefore, even greater volumes are likely available.

Some key supply prospects are listed below in **Figure 1** with their estimated quantities. These contacts were all passed along to the composters, TX A&M and TCEQ. In some cases, the composters were provided the contacts as soon as they were identified. This occurred when a need for urgent action was expressed by the generator of the material. The complete survey spreadsheet, with all contact information, is included in this report as **Exhibit 2**.

Stockpiled Supply – Immediate Availability	
City of Irving	5,000 cubic yards
City of Fort Worth	40,000 cubic yards
City of Cleburne	10,000 cubic yards
City of Arlington landfill	80,000 cubic yards
TOTAL	**135,000 cubic yards**

Ongoing Annual Supply	
City of Waco	12,000 cubic yards
City of Burleson	30,000 cubic yards
City of Arlington landfill	10,000 cubic yards
City of Dallas	60,000 cubic yards
City of Fort Worth	10,000 cubic yards
TXU Electric Company	75,000 cubic yards
Assorted other suppliers	21,000 cubic yards
TOTAL	**218,000 cubic yards**

Figure 1. Estimates of stockpiled and ongoing supplies of organic carbon materials near the Bosque River Watershed.

3.3 Financial Considerations

The vast majority of the municipal generators, as well as the TXU Electric Company, were more than willing to just have their material taken off their hands at no charge. It is a nuisance and a problem for them and for the most part would like to arrange a permanent and ongoing removal of it from their property. There were a few suppliers, however, who were either hinting at or asking to be paid something for the material. Some of the generators were obviously looking to offset the cost of grinding. Others may just be posturing or negotiating and will, in reality, also be satisfied to have the material removed from their sites at no charge. It will ultimately be up to the composters to negotiate the best possible arrangement. Perhaps one or more of the composters should even consider soliciting one of the larger generators for a yard debris management contract. In this scenario, they would set up a grinder at the generators location, then ship the ground product down to their Erath county location.

The City of Arlington landfill, as an example, has a supply in both categories above. They are asking $2/cubic yard for this material. This seems unusual since they appear to have a significant excess which they would like to have removed. They also claim to be selling it. Several of the producers claimed to be using part of their production locally as mulch or, in one case, as a road stabilization base. Most of the municipal producers also had established public give-away programs for their residents. None of these self-use programs, however, seemed to be absorbing the total production of a facility in any but the smallest municipal producers.

3.4 Potential Challenges

Like any business arrangement, there will always be potential challenges or barriers to implementing a new program. A list of some of these potential challenges is listed below.

3.4.1 Contamination

All of the municipal generators indicated that there was a level of contamination in their product. This consists primarily of film plastic from bags used by residents to collect and store the material. A few also indicated that some larger piece of debris (e.g. furniture pieces, auto debris, etc.) might occasionally be included in the material. If the composters were to accept this material, we assume that a waste management license may also be required.

Additionally, the risk for chemical contamination has also been addressed by some of the compost producers. Particular herbicides present in yard-wastes have been proven to persist in composted material and could pose a threat to producers who sell their material for landscape or greenhouse type uses. While this threat does not affect all uses of compost, it is difficult to test carbon material for presence of herbicide. Therefore, some compost producers are not willing to any source of ‘waste’ carbon.

3.4.2 Sizing

The composters should be able to receive all of the carbon rich materials after it has been shredded. There will, however, be some inconsistency in the sizes, as different generators will use different size screens on their shredding equipment. As would be expected, some of the generators actually contract out the shredding service to private contractors.

It may ultimately be advantageous for some of the composters to accept un-shredded waste to offset the cost of shredding incurred by the generators, and perhaps offer a new service to the industry. The composters would likely need to grind the materials at a site closer to where it is generated or concentrated in order to reduce ultimate transportation costs. This type of scenario would also allow the composters to have a better control of the size of the materials they obtain. This opportunity can only be determined on a case by case basis after the composters make contact with the individual generators, determine material availability and investigate the financial implications of accepting the material as shredded versus un-shredded.

3.4.3 Bidding laws

There was once a situation, with the City of Irving, where they were not permitted under City law to give material away to a private entity. They were permitted, however, to make such arrangements with either another municipality or with a state agency. These same rules exist if a City is interested in having a private firm manage their by-products for a fee. Therefore, if a composter wanted to obtain a source of material, especially with a larger community, they would likely have to go through a bidding process.

3.4.5 Truck loading

The largest, and perhaps best source of wood waste that was identified was the TXU Electric Company. They operate 20-30 small sites throughout the area in question and produce a regular supply of very clean waste wood. They typically make arrangements with private landowners to stockpile the material, but could not guarantee that there would necessarily be any equipment at these private sites to load the trucks if the composters wanted to obtain it. This situation, like all of the potential generators, will need to be specifically reviewed and addressed. The essential key is the willingness on the part of TXU to cooperate and provide the material.

3.4.6 Dumpsters

There were a couple of the private industry wood waste generators who expressed an interest in cooperating, but indicated the need for either a dumpster or a container of some kind be left at their site to collect the wood scraps and/or sawdust. This is certainly a possibility, but would also require the composters to possess a truck that can haul a roll off container.

4.0 Conclusions and Recommendations

It is the opinion of RAA that a fairly significant supply of very usable, carbon rich waste material exists within a reasonable distance of Erath County. With this said, of course, transportation costs should not be just dismissed. Regional generators should be able to assist with fulfilling both an immediate and longer term requirements of the composters. The composters would, however, need to complete the due diligence in order to assure that:

- quality of the ‘waste’ or by-product meets their requirements,
- specific site challenges or licensing issues can be addressed and solved,
- a mutually agreeable financial arrangement can be made, and
- the transportation logistics are mutually agreeable and cost effective.

A specific, recommended plan of action for the composters is as follows:

1. Review the attached spreadsheet and determine which generators produce the type and volume of material they require.
2. Consider transportation options and costs to determine if the location of the material is within a manageable distance.
3. Contact every supplier on the list who appears to have available material and arrange to visit the site and evaluate the material firsthand. We believe that this is critical, as opposed to just requesting a sample in the mail. It will give the best sense of product quality, site truck loading needs, material contamination, etc.
4. Concentrate on those perspective generators identified above as ‘immediate’ first. They may make other arrangements if the composters do not act in a timely fashion.
5. Review some of the specific challenges listed above and be prepared to address them. Some of the larger generators have presented these and they must be solved in a mutually agreeable way.
6. Make sure the composting site is prepared to accept large quantities of material in a convenient and efficient manner, so as not to hinder either the truck unloading or the composting operation activities. Consider licensing and permitting requirements. This can be easily accomplished by contacting the TCEQ.
7. Keep looking for additional sources. The composters may well find additional sources of material after they get established with the sources identified in this report.

Exhibit 1

ORGANIC BY-PRODUCTS QUESTIONNAIRE

Date:__________

1. **Company** ____

2. **Location** ____

3. **Contact/Title** ____

4. **Type(s) of Product Produced** ________________________________

5. **Type of By-Products Generated (carbon/nitrogen based)** ____________

____

- **Amount of By-Product Produced (tpd/ypd)** _______________________

____

7. **By-product characteristics (particle size, pH, bulk density, OM content, WHC, moisture content, NPK). Send samples and chemical analysis.**

____

____

____

8. **Tip fee paid? Price paid for? (per ton or yard, picked-up, bulk vs. bagged, sliding scale)**____

____

9. **Current distribution strategy (Major markets? Who uses? Product Literature? Advertise? Etc.**____________________________________

____

10. **Other comments** ____

Exhibit 2

ORGANIC BY PRODUCT SURVEY RESULTS

Company	City	Residual	Volume	Price/Tip Fee	Current Status	Comments
City of Hewitt	Hewitt	brush chips	160 yds/yr	0	give away and compost for own use	contact him to discuss need, he is open to concept, no other city generators
City of Waco	Waco	yd debris	6000 tons/yr	0	give away and compost for own use	christianh@ci.waco.tx.us, do NOT contact hi until he has OK, Waco has lawsuit going against some dairy farmers-OK to call
City of Teague	Teague	brush chips	400 yds/yr	0	give away and compost for own use	contact him to discuss need, he is open to concept, no other city generators
City of Groesbeck	Groesbeck	brush chips	200 yds/yr	0	give away and compost for own use	contact her to discuss need, he is open to concept, city and prison also have corrugated
City of Thorton	Thorton	brush chips	??	0	just starting, will give away	this is first season with chipper, will raise issue with Council for their review
Limestone Cnty Coop. Ext.	Groesbeck	hay	n/a			very little produced, most bought
City of Marlin	Marlin	brush chips	500 yds/yr	0	none, just piling up	contact him to discuss need, he is open to concept
City of West	West	brush chips	n/a	n/a		
City of Mart	Mart	brush chips	150+ yrds/yr	0	burning most of it	contact her to arrange pick up, no other city generators
City of Lorena	Lorena	brush chips	will call back			
City of Media	Media	brush chips	not sure	0	give away and compost for own use	contact him to arrange pick up, no other city generators — would like to swap compost for chips
City of Morgan	Morgan	brush chips	none			produce a small amount which they use
City of Robinson	Robinson	brush chips	none		use and give away	nothing available
Texas Forestry Assoc.			unknown		sent e-mail with volume and timing needs	he is interested in trying to help
Cradick Lumber	Dallas		none			generate tiny quantities which they just trash
Ken Jordon Shutter Mfg.	Dallas	wood, sawdust	500 yds/yr	0	disposal	will give away to manure generators if they can provide him with a dumpster or place to keep it

Dean Foods	Dallas	none	none			
Alrtria Foods	Dallas	none	none			
Jon Lin Corp.	Marlin	onion skins	40,000#/day?			
West Pallet Co.	West	sawdust	not sure			would need to have a container placed there, creating lots of sawdust every day
TST College	West	chips	none		they use all for mulch	
Schrieber Foods	Stephenville	cardboard	6000+ #/wk	?	baling and disposing?	He will look into the possibility of giving it to our people, they will be expanding and have more in future
Fibergrate Composite Structures	Stephenville	cardboard	? Tons/yr	?	baling and recycling?	He will look into the possibility of giving it to our people, but he thinks that they receive $$ for it now
Lone Star Corrugated	Irving	cardboard	none		baling and recycling	getting paid for cardboard
Erath County Coop. Ext.	Stephenville	hay	none			very erratic, undependable supply, IF at all
Thelin Recycling	Ft. Worth		none			mortal ENEMY of Erath dairy guys
City of Benbrook	Benbrook		none			small residential community with no sources that she is aware of
City of Arlington	Arlington		none			
Arlington Landfill	Arlington	ground brush	80,000 yds now, 10,000/yr	$2/yd asking price	claims to be selling	has large stockpile now, and annual supply, he wants to sell it
City of Burleson	Burleson	brush & compost	about 30,000 yds/yr			city makes and gives away yd trimming compost but has surplus, contractor grinds and removes
SMS Woodstone	Burleson		LOTS			
SMS Woodstone	Burleson	brush	LOTS	0	mostly give away to variety of users	wood grinding company @$.30-$1.70/yd to grind, grind about 3.75MM yds/yr
City of Cleburne	Cleburne	brush	10,000 yds now	0	resident giveaway	double grinds for resident giveaway now, has large stockpile of larger material on site and available
City of Cross Plains	Cross Plains		none			
Potter Game Tables	Cross Plains	sawdust & scraps	15 yds,yr+	0	disposal	has both sawdust and undefined quantity of natural wood scraps from furniture business

City of Dallas	Dallas		maybe at landfill			
City of Duncanville	Duncanville	brush+	avg. 80 yds/wk	0	resident giveaway and living earth tech.	also 2 cabinet makers in town with large waste wood supply, send him an e-mail and he will coordinate
City of Euless	Euless		none			
Dallas City landfill	Rick White	brush & chips	70,000 tons/yr	pay $0.93/yd to grind	use for road stabilization	would probably only offer unground waste, contains about 5% inerts
Trinity Waste	Randy Shiflet	6 landfills	None, EXCEPT contaminated			lots of waste BUT NO source separation in Texas, ALL waste is co-mingled MSW
Council of Governments	Mary Neutz		none			thinks we are on right track and has no easier, faster way to go about carbon search
City of Ft. Worth	Ft. Worth	yd waste & brush	20,000 tons++	0	some giveaway, ed.shumpert@fortworthgov.org	has 20,000 tons, ground and available NOW from a storm clean up, has 100 tons/wk year around
Abitibi Paper	Ft. Worth					handles all paper recycling for Ft. Worth
Supreme Corp.	Cleburne	cardboard?	Call 8/16			
Dr. Pepper	Dublin					
TX Institute of Applied Env. Res.	Stephenville	see EPA	none		beran@tiaer.tarleton.edu	
Trinity River Authority			No Waste or Info.			
TXU Electric Delivery Company	various	chips	300++/day	0	giving away, disposal	has been contacted by Paul Fagan from Organic Reclamation (STA member) and trying to work with him, have 20-30 private locations that they store chips at, NO loading ability unless private sites can do
City of Granbury	Granbury					
City of Grand Prairie	Grand Prairie					
City of Irving	Irving		left message			
City of N. Richland Hills	N. Richland Hills		left message			

City of Stephenville	Stephenville	yd waste & brush	2 tls/wk	0	used to giveaway to composter who went out of business	pay to have it ground about 1/yr, pretty clean, open to connecting with manure folks
City of Waxachie	Waxachie					
City of Weatherford	Weatherford	brush	350 yds/yr	0	local giveaway	would be interested in Erath project
Hamilton County Recycling	Hamilton		left message			
Central Texas Corrugated		corrugated	left message			
EPA Region 6	Dallas		left message			

Appendix D

Modification of Low Quality Dairy Manure Compost with Organic Amendments

Modification of Low Quality Dairy Manure Compost with Organic Amendments

Cecilia Gerngross, Randy Bow, Ron Alexander, Mark McFarland and James Supak

Summary

Marketing compost to governmental entities for use on public landscapes, sports fields, playground facilities and road construction provides an option for exporting dairy manure out of the impaired North Bosque River watershed. Composts produced with dairy manure from that area tend to contain high levels of inorganic components (50 to 75%, mainly quartz sand and limestone fragments) and often fail to meet the pH and organic matter standards set by TX DOT and other users. Addition of high carbon amendments to finished composts is being employed as a means to adjust these parameters to meet the TxDOT standards. Four "low quality" compost products were amended with three high carbon by-products (peanut hulls, sawdust and wood chips) by physically mixing the amendments (10% and 30% v/v basis) with the composts. Significant differences *between* the four compost sources were noted for several parameters including organic matter, total N, C:N ratios and pH. Sampling dates (0 DAI and 30 DAI) also resulted in significant differences in organic matter; pH; total P, Ca, and Na; and the bioassay for cucumber seedling vigor, indicating variability *within* the compost products. Adding 10% and 30% high carbon amendments resulted in significantly higher organic matter levels when analyzed *between* compost sources but only the higher (30%) rates significantly increased organic matter contents *across* sources. With the exception of the 30% rate of peanut hulls which produced a significant decrease in pH and a significant increase in total N between compost sources, the organic amendments had no consistent effects on pH, N, P, Ca, Na, soluble salts or cucumber seedling vigor between or across compost sources. Results suggest that the physical mixing of high carbon amendments with low quality dairy manure compost can be used to increase organic matter content and alter C:N ratios but will have limited effects on pH, soluble salts, nutrients or cucumber seedling vigor.

TMECC have been adopted as the industry standards for compost testing but due to strict QA/QC requirements, analytical costs tend to be relatively high. Service laboratories that do not use TMECC or are not STA certified often offer "analytical packages" for lower costs. A comparison of compost test results provided by Soil Control Laboratory (an STA certified laboratory) and the Texas Cooperative Extension Soil, Water Forage Testing Laboratory (a service laboratory) showed that values for selected nutrients (total N, P, Ca, and Na), pH and soluble salts varied significantly between the two laboratories but there were no differences in organic matter levels. Numerically, the mean values obtained by SWFTL were higher for N (7.6%), P (14.8%), Na (59.3%, due in large part to a subsequently identified contamination problem), pH (1%), and soluble salts (12.6%) and were lower for Ca (5.6%) and organic matter (5.9%). Composters and retailers are required to use TMECC results in marketing their products but service laboratories can be effectively used to provide preliminary assessments of manure and compost quality for use as management decision aids at a fraction of the cost.

Introduction

Composting is an effective means of increasing the utility and value of dairy manure by reducing its weight and volume; minimizing odor, pathogens and weed seeds and transforming the manure into a biologically stable product. This process enables the final product to easily be exported for sale and use to commercial markets far removed from the dairy and composting operations. Compost can be used in agricultural and horticultural applications as a source of plant nutrients and to improve physical properties of soils. It is also used in roadbed and other construction activities alone or in mixtures with other materials for erosion control and modification of disturbed sites to promote establishment of permanent vegetation.

Approximately 75 dairies with an estimated 38,000 cows operate in the Bosque River watershed (Stephenville Special Project Office, TCEQ Region 4). Studies by the Texas Institute for Applied Environmental Research (TIAER) demonstrated that excessive applications of manure to land areas in the immediate proximity of the dairies has contributed to water quality problems in the basin (McFarland and Hauck 1998 and 1999). As early as 1998, interest and support developed for the production of composted dairy manure as a means for encouraging transport of dairy animal wastes out of the watershed. Monetary incentives were provided to encourage manure transport to composting facilities which fostered the establishment of several composting operations in the watershed; Other incentives were initiated to expand government and public markets for composted dairy manure from this area (TCEQ and TSSWCB 2002).

Although numerous public and private entities have taken advantage of the incentive programs, the Texas Department of Transportation (TX DOT) has become, by far, the largest user of dairy manure compost for two primary reasons. First, TX DOT requires large volumes of compost and amended compost products for use in road and highway construction and maintenance. Much of the manure from this watershed contains high levels of levels of sand and frequently fragments of limestone rock. These inorganic contaminants often result in compost products that are unacceptable for top dress applications (i.e. turfgrasses in lawns and sports facilities) but are well suited for use in erosion control along roads and highways. Secondly, TX DOT qualified for incentive payments, which made the use of dairy manure compost a viable and economic alternative for TX DOT.

The dairy compost produced in the Bosque River watershed can also be used to produce compost manufactured topsoil (CMT) and various erosion control compost (ECC) products that comply with TX DOT specification but the general use compost (GUC) typically fails to meet the organic matter (25 to 65%) and pH (5.5 to 8.5) base standards set by TX DOT in 2003. Therefore to capture more of the DOT market, dairy compost producers lobbied for a variance in the specification. In 2004, TXDOT temporarily modified its standard by reducing the organic matter requirement to a minimum of 10% and pH to a maximum of 9.5 for compost generated from livestock and dairy manure. This variance opened the DOT market once again for the compost producers although GUC products from this area frequently fail to meet even the modified standards.

Unfortunately, the variance allowed by the TX DOT was only temporary and more permanent solutions to the low organic matter and high pH material would need to be determined. Proposed solutions include 1) utilization of various techniques to separate organic fractions from the sand and rock contained in the manure, 2) use of organic bedding materials e.g. cotton burs, in lieu of sand, 3) mixing high carbon containing materials e.g. wood chips, with manure prior to composting (Michel, et al, 2005), and 4) mixing high carbon materials with the finished, low quality compost prior to its final screening. The latter is regarded as a potential method for improving the quality of existing compost to meet minimal TX DOT specifications for GUC. A large volume of stockpiled compost currently exists at several of the facilities. While this stockpiled material varies in age, production techniques and stability, it does have one common bond – it is low in organic matter and high in pH. To support the export of the older stockpiled material, compost producers needed to improve its quality.

Sources of various organic by-products in Central Texas were identified by Ron Alexander and Associates in 2004 and include yard waste, tree trimmings, wood chips, sawdust and agricultural by-products (Organic Matter Improvement Survey Report). Composters had previously adopted a mix ratio (v/v basis) of 20 to 25% of a high carbon material with low quality compost to improve organic matter content and reduce pH, but information was lacking on the effectiveness of such treatments in adequately modifying these parameters in existing dairy manure compost to consistently meet TX DOT standards.

The primary objective of this trial was to evaluate the effectiveness of blending available carbon rich by-products with low quality dairy manure composts in modifying organic matter levels, pH and other parameters including particle size, soluble salts, respirometry, cucumber bioassays (germination and vigor) and nutrients. A secondary objective was to compare laboratory methodologies used to analyze composted dairy manures from the North Bosque watershed.

Methods and Materials

Compost Materials

Much of the compost that failed to meet TX DOT specifications has been stored in windrows or large stockpiles at compost yards in the Bosque River watershed for a year or longer. Approximately 2-cubic yards (cy) of dairy manure compost over 1-year old were obtained from stockpiles at two separate compost facilities and designated Composter A and Composter B. Additionally, 2 to 3 cy of compost that were over 3-years old were obtained from from two other facilities designated as Composter C and Composter D, respectively. All compost materials were screened prior to being loaded and transported to the Texas A&M Research and Extension Center at Stephenville, TX. Once at the Station, the materials were covered and kept separated with plastic sheets and stored outdoors until use. Samples of all compost materials were collected on 4/8/2005 and submitted to the Soil Control Lab, 42 Hangar Way, Watsonville, CA and the Soil, Water and Forage Testing Laboratory, Texas Cooperative Extension, College Station, TX for analysis.

Organic Amendments

Wood chips, sawdust and agricultural crop residues (including peanut hulls), were identified as organic by-products that were available in Central Texas in sufficient volume for commercial use in blending with dairy manures and composted materials. For this study, sawdust, consisting of finely ground poplar, ash, oak and pine wood, was obtained from a local cabinet shop and stored until use in 30-gal plastic containers. Finely ground peanut hulls were obtained from a peanut processing facility at Gorman, TX and stored in large plastic woven bags until use. Shredded wood chips (consisting of trimmings from hackberry, mesquite, cedar, oak and other tree species) were obtained from a local tree service. The wood chips were mechanically shredded to further reduce their size (to approximately 2-3 inch lengths) using a small chipper/shredder and were stored outdoors until use. Samples of the organic amendments were collected on 4/8/2005 and submitted to the Soil Control Lab for analysis.

Blending of Composts and Organic By-Products

Blending ratios of 10% and 30% organic by-products to compost (v/v basis) were used in this study. Theoretically, because of the high content of inorganic material (50-75%), much higher levels of organic amendments might be required to appreciably change compost composition. Inputs from the composters and others, however, indicated that addition of organic by-products in excess of 20 to 25% may not be economically practical.

Treatments used in the trial included 4 sources of dairy manure compost amended with 3-organic by-products (woodchips, sawdust and peanut hulls) that were applied at 2-rates (10% and 30% v/v basis). Each of the 72 treatments was replicated 3-times. Since the approved protocol for this study did not include non-amended compost treatments, a companion test was initiated that included only the 4-compost materials replicated 3-times. This essentially set up a split plot design with compost sources as the main plots and the amended compost treatments as the sub-plots.

Individual treatments were prepared as follows: The average weight of 0.67 ft^3 of each compost product and organic by-product was determined by filling and weighing the respective material in 5-gal buckets. Buckets were filled with the appropriate material, tamped once on a concrete floor, leveled with a straight edge and weighed. Additionally, the weight of each organic amendment needed to prepare the 10% and 30% blends was calculated.

The 5.0 gal (0.67 ft^3) container of compost and the appropriate, pre-weighed, amount of organic amendment were dumped into a small cement mixer and thoroughly mixed (for 3-4 minutes) mechanically and by hand to ensure homogeneity. Two samples were obtained for laboratory analysis using the TMECC sampling procedure (collecting 5-subsamples with a trowel to form a composite sample that was subdivided and the appropriate amounts transferred to labeled quart size plastic “zip-lock” bags). The remaining compost-organic amendment blend was transferred from the mixer to the original 5-gal container, leveled with a straight edge, weighed and randomly positioned in a large, open shop area. The plastic bags containing the samples were packed into 5-gal buckets, cooled to 4ºC in a cold storage unit and shipped overnight to the appropriate laboratories.

Prior to initiation of the trials, a few treatments were prepared to test the procedures described above and to monitor the samples for changes (settlement, temperature changes, moisture accumulation). Further, temperatures of treatments were randomly monitored for approximately 10-days following initiation of the trials and confirmed that minimal biological activity (indicative of further or renewed composting) resulted from the blending of the composts with the organic amendments.

Treatments were re-sampled approximately 30 and 60-days after initiation (DAI) of the study.

Each 5-gal container was again dumped in the cement mixer, stirred for 2-3 minutes, sampled and processed as described above with the exception that the containers were not re-weighed.

Chemical and Physical Properties

Changes in chemical properties of the composts and amended composts were monitored by submitting samples to Soil Control Lab (SCL), 42 Hangar Way, Watsonville, CA 95076 for analysis according to standard protocols specified by the US Composting Council's Test Methods for Examination of Composting and Compost (TMECC, 2002), Table 1. Determinations included moisture content, C:N ratios; organic matter content; soluble salts; pH; total N, P, Ca, and Na; particle size; respiration and cucumber bioassays (germination and vigor) for the 0 and 30 day sampling periods. The total P, Ca and Na determinations and the respiration and cucumber bioassays were excluded for the samples collected 60 DAI.

Duplicate samples from the 0 and 30 day sampling periods were also submitted to the Soil, Water and Forage Testing Laboratory (SWFTL), Texas A&M University, College Station, TX. The SWFTL is primarily a service laboratory which is not STA certified and therefore, does not solely utilize TMECC procedures in its compost testing protocols. For example, the SWFTL employs a modified dry combustion procedure (LOI) to estimate total organic carbon when testing materials that contain carbonates (Pitt, et al, 2003). Determinations made by the SWFTL include total organic carbon (LOI), soluble salts, pH, N, P, K, Ca, Mg, Na, Zn, Fe, Cu, and Mn, Table 1.

Wet and air dry bulk densities were estimated from the volumes and weights of the composts and amended composts determined during preparation of the individual treatments. Moisture determinations for each sample were made by the testing laboratories.

Data Analysis

Resulting data were analyzed to ascertain treatment differences across and between compost sources using standard SAS procedures for AOV and means separations. Since the experimental design used was not a factorial due to the inclusion of control treatments, data were analyzed with both a split-plot application of a repeated measure design and a general linear model (GLM) application of a repeated measure design. The Dunnett and Tukey tests were used to test for differences of least square means at the 95% confidence level. The same models were used to compare (across compost sources only) the test results obtained by the SCL and SWFTL. Statistical analyses were conducted by Dr. Keith Schumann, formerly a graduate student in the Department of Agricultural Economics, Texas A&M University and currently with Welch Consulting, Bryan, TX.

Table 1. Methodology utilized by Soil Control Laboratory (SCL) and by the Soil, Water and Forage Testing Laboratory (SWFTL).

Parameter	SCL Method (TMECC Method)	SWFTL SOP
Chemical Properties		
Electrical Conductivity	04.10-A	0072R0
PH	04.11-A	0071R0
Organic Properties		
Organic Matter	05.07-A	0060R0
Fecal Coliform	07.01-B	--
Metals		
Magnesium	04.12-B/04.14-A	0074R0
Sodium	04.12-B/04.14-A	0074R0
Manganese	04.12-B/04.14-A	0074R0
Copper	04.12-B/04.14-A	0074R0
Calcium	04.12-B/04.14-A	0074R0
Zinc	04.12-B/04.14-A	0074R0
Iron	04.12-B/04.14-A	0074R0
Arsenic	04.12-B/04.14-A	--
Chromium	04.12-B/04.14-A	--
Cadmium	04.12-B/04.14-A	--
Lead	04.12-B/04.14-A	--
Mercury	04.12-B/04.14-A	--
Molybdenum	04.12-B/04.14-A	--
Nickel	04.12-B/04.14-A	--
Selenium	04.12-B/04.14-A	--
Nutrients		
Total Nitrogen	04.02-D	0073R0 / 0075R0
Total Phosphorus	04.12-B/04.14-A	0074R0
Total Potassium	04.12-B/04.14-A	0074R0
Physical Properties		
Particle Size	02.02-B	--
Maturity	05.05-A	--
Stability	05.08-B	--
Moisture	03.09-A	--

Results and Discussion

The chemical, physical and biological properties of dairy manure composts and organic amendments used in these trails as determined by SCL using STA-TMECC procedures are summarized in Table 2 and the chemical properties, as determined by SWFTL are presented in Table 3. The mean chemical, physical and biological properties of the compost and amended compost treatments used in the study as determined by the SCL are presented in Table 4 and those determined by the SWFTL are shown in Table 5. Only the STA-TMECC results provided by the SCL were statistically tested to ascertain treatment differences and those results are summarized in Tables 6 and 7.

Variations within and among compost sources and lots are common and proper sampling is essential to ensure representative samples are obtained for laboratory testing. TMECC procedures were used in sampling each compost product but even then, variability within each source remained a factor as evidenced by significant sampling day effects on several test parameters (i.e. organic matter, total P), Tables 6 and 7.

Compost Sources

Dairy manures constitute the basic feedstocks for commercial composts produced in the Upper Bosque watershed. These feedstocks vary in composition/qualities due to management practices and adulterations at the dairies and composting facilities. Manure composition and quality is influenced by the feed rations, bedding materials, other additives (i.e. push-down feed), waste management (solid-water separation, storage) systems and other practices used by the multiple dairies from which feedstocks are obtained. Thus, the resulting feedstock can vary from primarily organic solids that were separated from potential contaminants to those that contain manure with varying amounts of extraneous matter such as bedding materials, sand, rock fragments, etc. Collection (frequency, loading methods) and transport of manures to the compost facilities and the composting, storage and handling processes used by the individual compost producers also affect the quality of the final product. High levels of inorganic materials (primarily sand and limestone rock) reduce organic matter levels. Storage of raw manure and finished compost, windrow construction, frequency and uniformity of mixing, temperature and moisture control are all factors in producing products that will meet customer specifications.

Variability of Compost Sources

Significant differences in pH, total N and C:N ratios occurred between the four compost sources used in this study, Tables 6 and 7. Organic matter content of Compost C and Compost D were similar but significantly lower than those of Compost A and Compost B. Compost B contained significantly higher levels of Ca and Na than the other products, Table 7. All other parameters (except cucumber seedling vigor) did not differ significantly between the four compost sources.

Table 2. Chemical, biological and physical properties of four dairy manure composts and three organic by-products determined by the Soil Control Laboratory. (Note: need to add bulk densities)

Sample ID	C:N ratio	OM content	Soluble Salts	pH	Total N	Total P	Total Ca	Total Na	Size <5/8"	Size <3/8"	Respiration	Cucumber Bioassay	
		% dw	umhos/cm		% dw	-------------mg/kg dw-------------			---------%--------		mg CO2-C/gOM/d	% germ	% vigor
Composter A	14.00	10.47	1495	9.77	0.58	2207.5	31078.5	1924.5	100	100	1.735	100	95
Composter B	15.00	13.67	1665	9.285	0.835	4048.5	119201.5	1725.5	100	98.5	0.695	50	90
Composter C	12.50	7.53	2190	8.185	0.425	1330.5	43823	1117.5	100	98.5	0.71	100	90
Composter D	13.00	8.765	1630	9.13	0.505	2671	61646	760.5	100	100	0.765	80	50
Source A (Sawdust)	643.50	99.68	1180	3.975	0.082	49.5	347	85.5					
Source B (Peanut Hulls)	56.00	95.915	5120	5.62	0.9	414	1967.5	377.5					
Source C (Wood Chips)	143.50	95.46	2270	6.705	0.36	274.5	6029	73					

Table 3. *Chemical properties of four dairy manure composts determined by the Soil, Water and Forage Testing Laboratory.*

Rep	Sample ID	LOI	Soluble Salts	pH	N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Mois
		%	umhos/cm	units	----------%----------						----------ppm----------				%
1	Composter A	10.4	1532	9.3	0.4760	0.2032	0.5040	3.01	0.2798	0.2723	83.9	5300	23.08	160.7	25.4
2	Composter A	11.3	1743	9.2	0.5100	0.2005	0.5328	3.24	0.2879	0.2843	84.3	5461	24.59	164.0	24.7
1	Composter B	17.1	2245	8.8	0.8560	0.4531	0.9838	12.24	0.6666	0.3425	211.7	8704	46.14	280.8	27.8
2	Composter B	16.2	1982	8.7	0.8240	0.4417	0.9091	12.16	0.6299	0.3198	202.4	8028	43.76	270.5	27.2
1	Composter C	7.6	1982	8.1	0.4040	0.1302	0.5141	4.62	0.3478	0.2223	59.3	6712	13.57	166.5	23.4
2	Composter C	8.1	1709	8.1	0.4210	0.1378	0.5694	4.67	0.3762	0.2334	62.1	7264	13.62	180.4	24.1
1	Composter D	8.1	1720	8.9	0.4850	0.2858	0.8229	6.51	0.4324	0.2473	86.6	9655	19.64	217.4	23.4
2	Composter D	8.7	1487	8.4	0.4720	0.2838	0.8092	6.55	0.4289	0.2123	85.5	8926	19.21	222.4	23.7

Table 4. Mean chemical, biological and physical properties of the compost and amended compost treatments determined by Soil Control Laboratory 0, 30 and 60 days after initiation (DAI) of the study.

Sample ID	Sample Interval	Added Carbon		C:N ratio	OM	Soluble Salts	pH	Total N	Total P	Total Ca	Total Na	Size		Respiration	Cucumber Bioassay		Moist	Bulk Dens.
	DAT	Source	Level		% dw	umhos/cm (1:5 w/w)	units (1:5 w/w)	%	mg/kg	mg/kg	mg/kg	<5/8"	<3/8"	Mg CO2-C/gOM/d	% germ	% vigor	%	g/cm^3
Composter A	0	--	0	13.6	10.02	1215	9.3	0.480	1957	35001	1790	100	100	1.64	100	99	22.4	1.095
Composter A	0	A	10	16.6	12.59	1109	9.2	0.480	1951	36156	1822	100	100	2.45	100	95	23.1	0.994
Composter A	0	A	30	22.0	17.10	924	9.1	0.400	1983	35882	2046	100	98	1.66	100	99	22.7	1.030
Composter A	0	B	10	16.0	12.26	1175	9.1	0.470	1780	34999	1583	100	100	1.81	100	95	23.5	0.993
Composter A	0	B	30	19.0	16.03	1274	8.8	0.533	1976	39131	2280	100	100	2.11	96	99	23.9	0.991
Composter A	0	C	10	15.0	12.42	1228	9.1	0.463	1845	36780	1668	100	97	1.02	97	95	24.6	1.016
Composter A	0	C	30	26.6	22.68	1276	9.1	0.450	1697	31034	1828	98	96	1.51	100	100	25.6	0.941
Composter A	30	--	0	11.6	9.48	1158	9.4	0.353	2021	33514	1649	100	99	2.53	100	99	21.4	
Composter A	30	A	10	14.3	12.46	1184	9.4	0.493	1759	41474	1443	100	100	2.27	100	95	21.6	
Composter A	30	A	30	20.0	17.35	918	9.2	0.447	1784	35354	1492	100	100	2.02	100	100	20.7	
Composter A	30	B	10	14.0	11.93	1293	9.3	0.477	1875	30249	1504	100	99	2.06	100	98	21.0	
Composter A	30	B	30	17.3	15.29	1054	9.3	0.507	1858	41305	1489	100	99	2.00	N/A	85	21.6	
Composter A	30	C	10	14.3	11.46	1284	9.2	0.453	1813	31918	1511	89	97	2.11	100	99	21.7	
Composter A	30	C	30	14.3	13.65	1106	9.1	0.550	1719	31156	1212	99	97	2.27	100	87	23.3	
Composter A	60	--	0	11.3	8.51	2034	9.0	0.453				100	100					
Composter A	60	A	10	13.0	10.39	1734	9.0	0.363				100	100					
Composter A	60	A	30	15.6	15.09	1312	8.6	0.417				100	99					
Composter A	60	B	10	12.0	10.93	1884	9.2	0.477				100	99					
Composter A	60	B	30	14.6	14.18	1624	9.3	0.473				100	100					
Composter A	60	C	10	14.0	11.59	1762	9.2	0.470				100	99					
Composter A	60	C	30	19.0	14.99	1660	9.1	0.447				99	97					
Composter B	0	--	0	14.6	14.48	1416	9.1	0.807	4740	12586	1939	100	97	0.28	100	100	25.2	1.112
Composter B	0	A	10	17.0	17.19	1252	9.0	0.803	3656	11966	1773	100	95	0.89	98	97	26.5	0.983
Composter B	0	A	30	20.0	19.36	1129	8.8	0.727	3591	15620	2187	100	99	0.89	100	98	23.6	0.873
Composter B	0	B	10	16.6	15.58	1393	8.9	0.813	3325	13461	1796	100	95	1.75	97	98	23.9	1.003
Composter B	0	B	30	19.0	19.11	1257	8.7	0.703	3326	12691	1662	100	98	2.22	100	99	24.8	0.899
Composter B	0	C	10	17.6	18.06	1459	9.0	0.687	2298	11933	1491	100	95	0.93	100	96	27.7	0.990
Composter B	0	C	30	26.0	27.76	1276	8.9	0.693	3338	11182	2062	100	93	1.32	97	98	28.6	0.956

Table 4 (cont'd). Analysis from Soil Control Laboratory

Sample ID	Sample Interval	Added Carbon		C:N ratio	OM	Soluble Salts	pH	Total N	Total P	Total Ca	Total Na	Size		Respiration	Cucumber Bioassay		Moist	Bulk Dens.
	DAT	Source	Level		% dw	umhos/cm (1:5 w/w)	units (1:5 w/w)	%	mg/kg	mg/kg	mg/kg	<5/8"	<3/8"	mg CO2-C/gOM/d	g/cm^3	% vigor	%	g/cm^3
Composter	30	--	0	15.3	14.36	1526	8.7	0.703	3261	13607	1318	100	97	1.31	100	100	21.3	
Composter	30	A	10	9.67	16.83	1182	8.9	0.867	3669	13220	1791	100	95	1.44	100	72	24.5	
Composter	30	A	30	19.3	19.13	988	8.9	0.677	3231	13323	1382	100	95	1.32	100	100	22.9	
Composter	30	B	10	15.6	15.12	1271	8.9	0.853	3384	12856	1640	99	94	0.76	100	95	22.2	
Composter	30	B	30	18.0	23.17	1241	8.9	0.863	3238	13796	1234	100	94	1.08	100	61	22.0	
Composter	30	C	10	16.3	16.04	1430	8.8	0.790	3346	11654	1465	98	92	1.35	100	77	24.6	
Composter	30	C	30	18.3	15.69	1308	8.8	0.813	3249	10493	1713	97	88	1.69	100	100	22.6	
Composter	60	--	0	14.3	14.42	2212	8.8	0.737				100	93					
Composter	60	A	10	15.6	15.85	1823	8.9	0.727				100	95					
Composter	60	A	30	16.6	17.47	1544	8.8	0.813				100	94					
Composter	60	B	10	15.0	15.73	1834	8.6	0.890				100	92					
Composter	60	B	30	16.3	18.14	1928	8.6	0.920				100	94					
Composter	60	C	10	14.0	14.87	2033	8.7	0.907				100	90					
Composter	60	C	30	16.3	19.80	1546	9.1	0.813				99	90					
Composter	0	--	0	14.0	7.93	1858	8.0	0.400	1346	51196	1528	100	99	0.16	88	99	22.1	1.295
Composter	0	A	10	14.0	9.89	1541	7.7	0.423	1266	41363	1448	100	99	4.51	94	97	21.5	1.155
Composter	0	A	30	20.3	13.67	1354	7.6	0.423	1204	45593	1325	100	98	6.78	100	99	19.8	1.001
Composter	0	B	10	16.0	10.19	1564	7.8	0.470	1359	48659	1464	100	99	1.48	106	99	20.1	1.164
Composter	0	B	30	17.3	13.22	1514	7.5	0.400	1181	44209	1593	100	98	1.78	112	98	20.8	1.036
Composter	0	C	10	15.0	9.65	1565	7.7	0.433	1181	48424	1375	98	96	0.58	118	100	21.5	1.169
Composter	0	C	30	25.6	14.52	1625	7.8	0.430	1150	46629	1283	99	97	1.23	124	100	22.2	1.018
Composter	30	--	0	17.6	7.90	1716	7.8	0.287	1409	54343	1112	100	99	1.81	88	95	20.0	
Composter	30	A	10	20.3	9.15	1413	8.2	0.303	1555	58769	1335	100	98	3.84	94	99	19.7	
Composter	30	A	30	27.3	11.61	917	8.6	0.287	1425	68595	1368	100	100	3.81	100	100	19.2	
Composter	30	B	10	19.0	9.91	1694	7.9	0.377	1097	49822	1176	100	97	1.19	106	96	20.8	
Composter	30	B	30	22.0	12.03	1507	8.0	0.267	1145	51457	949	100	97	1.24	112	88	19.5	
Composter	30	C	10	22.3	8.79	1620	7.8	0.250	1232	70710	1257	98	96	1.76	118	91	20.8	
Composter	30	C	30	18.6	15.24	1552	8.1	0.457	1187	41192	1027	99	93	2.31	124	94	21.5	

Table 4 (cont'd). Analysis from Soil Control Laboratory

Sample ID	Sample Interval	Added Carbon		C:N ratio	OM	Soluble Salts	pH	Total N	Total P	Total Ca	Total Na	Size		Respiration	Cucumber Bioassay		Moist	Bulk Dens.
	DAT	Source	Level		% dw	umhos/cm (1:5 w/w)	units (1:5 w/w)	%	mg/kg	mg/kg	mg/kg	<5/8"	<3/8"	mg CO2-C/gOM/d	% germ	% vigor	%	g/cm^3
Composter C	60	--	0	11.0	8.12	2460	8.0	0.46				100	97					
Composter C	60	A	10	13.0	7.69	2027	7.9	0.46				100	96					
Composter C	60	A	30	16.3	10.24	1219	8.8	0.46				100	97					
Composter C	60	B	10	13.0	9.01	2243	7.9	0.50				100	97					
Composter C	60	B	30	14.3	12.61	1953	7.8	0.50				100	96					
Composter C	60	C	10	12.0	8.19	2016	7.8	0.47				99	94					
Composter C	60	C	30	14.6	9.04	1687	8.0	0.41				99	93					
Composter D	0	--	0	12.6	8.34	1294	9.0	0.43	2415	56892	1114	70	97	0.47	N/A	94	21.9	1.276
Composter D	0	A	10	16.0	11.05	1319	8.8	0.43	2214	63192	799	99	96	2.47	N/A	97	21.5	1.164
Composter D	0	A	30	21.6	15.97	935	8.7	0.41	1962	66148	746	100	98	1.62	97	94	19.9	1.025
Composter D	0	B	10	14.3	10.63	1239	8.8	0.43	1925	77547	1034	100	97	1.35	97	96	20.6	1.139
Composter D	0	B	30	18.0	13.19	1208	8.7	0.42	2021	60969	831	100	99	1.81	N/A	90	20.4	1.001
Composter D	0	C	10	14.6	9.29	1264	9.0	0.42	1963	61350	877	99	96	1.56	99	100	21.1	1.091
Composter D	0	C	30	15.3	12.71	1202	8.9	0.44	2478	61237	610	99	96	2.36	100	100	21.4	0.981
Composter D	30	--	0	12.6	7.56	1292	9.0	0.50	2744	67840	1116	100	97	1.48	N/A	50	20.9	
Composter D	30	A	10	15.6	9.51	1119	9.0	0.44	2534	68356	869	100	99	1.95	100	70	19.1	
Composter D	30	A	30	21.0	13.56	857	8.9	0.48	2718	83677	1085	100	97	1.38	100	38	18.7	
Composter D	30	B	10	14.0	9.60	1383	9.0	0.48	2759	64946	1001	100	98	0.73	100	63	18.0	
Composter D	30	B	30	16.6	13.09	1161	9.0	0.42	2377	61005	997	100	97	1.83	100	47	17.8	
Composter D	30	C	10	16.6	8.84	1379	8.8	0.40	2745	63789	1060	100	98	1.39	100	53	19.4	
Composter D	30	C	30	20.0	13.15	1338	8.9	0.41	3296	76217	1151	98	92	1.63	N/A	50	17.6	
Composter D	60	--	0	11.6	7.81	1903	8.7	0.43				100	97					
Composter D	60	A	10	13.6	8.76	1312	8.9	0.44				100	95					
Composter D	60	A	30	17.6	10.76	1044	8.4	0.42				96	90					
Composter D	60	B	10	13.6	8.83	1907	8.7	0.43				99	92					
Composter D	60	B	30	16.6	12.22	1778	8.6	0.46				99	98					
Composter D	60	C	10	13.0	9.14	1669	8.7	0.41				100	96					
Composter D	60	C	30	14.0	11.26	1884	8.7	0.44				100	95					

Table 5. Mean chemical properties of compost and amended compost treatments determined by the Soil, Water and Forage Testing Laboratory 0 and 30 days after initiation (DAI) of the study.

Sample ID	Sampling	Added Carbon		LOI	Soluble	pH	N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Mois
	DAT	Source	Level	%	umhos/cm	units	%	%	%	%	%	%	ppm	ppm	ppm	ppm	%
Composter A	0	--	0	10.1	1466	9.53	0.489	0.214	0.577	2.955	0.291	0.304	77.8	6282	1.30	176	22.6
Composter A	0	A	10	11.7	1347	9.47	0.560	0.192	0.523	2.797	0.275	0.318	70.3	5996	1.31	166	23.0
Composter A	0	A	30	15.6	1297	9.37	0.455	0.182	0.493	2.583	0.261	0.294	66.1	5343	1.32	156	42.6
Composter A	0	B	10	11.4	1486	9.53	0.495	0.195	0.534	2.788	0.288	0.321	70.4	5318	1.33	166	23.1
Composter A	0	B	30	14.4	1449	9.57	0.505	0.194	0.551	2.793	0.295	0.327	70.9	5125	1.33	169	23.1
Composter A	0	C	10	10.0	1365	9.63	0.479	0.193	0.513	2.829	0.280	0.297	39.4	5463	14.21	162	23.6
Composter A	0	C	30	10.5	1361	9.63	0.493	0.198	0.535	2.906	0.289	0.315	39.2	5652	13.22	168	24.8
Composter A	30	--	0	10.1	1441	9.53	0.493	0.203	0.530	2.952	0.291	0.337	84.5	5854	21.71	174	22.7
Composter A	30	A	10	12.4	1165	9.37	0.508	0.203	0.538	3.016	0.293	0.330	83.6	5909	21.89	173	21.5
Composter A	30	A	30	16.5	1449	9.07	0.478	0.188	0.492	2.736	0.271	0.328	77.5	5428	20.65	161	20.8
Composter A	30	B	10	11.7	1373	9.43	0.515	0.202	0.535	2.929	0.294	0.347	83.3	6092	21.50	173	22.1
Composter A	30	B	30	13.4	1404	9.17	0.524	0.198	0.537	2.854	0.297	0.329	81.1	5507	21.26	166	21.6
Composter A	30	C	10	10.2	1345	9.43	0.504	0.201	0.523	2.962	0.292	0.349	83.2	5744	22.07	172	22.8
Composter A	30	C	30	10.6	1313	9.40	0.516	0.203	0.519	2.991	0.292	0.338	83.0	5707	22.47	170	23.8
Composter B	0	--	0	16.4	1989	9.03	0.854	0.451	1.062	13.556	0.690	0.415	161.3	9488	36.20	290	24.2
Composter B	0	A	10	18.6	1814	9.10	0.815	0.430	1.018	12.411	0.659	0.404	152.7	8978	34.06	280	25.9
Composter B	0	A	30	23.6	1608	9.10	0.753	0.402	0.922	11.486	0.608	0.347	143.0	8208	32.50	263	24.6
Composter B	0	B	10	17.5	1248	9.17	0.784	0.419	0.954	11.925	0.631	0.325	149.0	8574	29.87	269	23.9
Composter B	0	B	30	21.5	1826	9.03	0.821	0.414	0.996	12.021	0.643	0.320	146.6	8148	29.35	262	24.4
Composter B	0	C	10	16.4	1894	9.13	0.834	0.433	1.006	13.012	0.661	0.314	159.3	8850	30.94	281	26.4
Composter B	0	C	30	16.9	1766	9.17	0.816	0.437	1.019	13.188	0.671	0.319	158.0	9010	31.81	281	26.4
Composter B	30	--	0	16.7	2237	8.77	0.851	0.459	1.022	13.156	0.695	0.413	204.3	9444	45.59	299	26.0
Composter B	30	A	10	18.2	1532	9.07	0.820	0.438	0.974	12.759	0.661	0.387	193.9	9436	44.90	287	23.8
Composter B	30	A	30	22.2	1683	8.80	0.766	0.423	0.939	12.641	0.646	0.372	194.6	8913	42.50	277	23.3
Composter B	30	B	10	18.5	1596	8.93	0.835	0.454	0.973	12.985	0.680	0.374	203.9	9095	43.77	294	22.8
Composter B	30	B	30	20.9	1536	8.87	0.841	0.440	1.007	12.933	0.683	0.391	196.7	8952	42.56	295	23.5
Composter B	30	C	10	16.2	1837	8.80	0.815	0.455	0.994	13.222	0.688	0.386	206.0	9428	44.11	297	23.9
Composter B	30	C	30	17.4	1499	9.07	0.812	0.450	1.001	13.428	0.687	0.376	203.5	9619	43.58	298	24.2

Table 5 (cont'd). Analysis from Soil, Water and Forage Testing Laboratory

Sample ID	Sampling	Added Carbon		LOI	Soluble	pH	N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Mois
	DAT	Source	Level	%	umhos/cm	units	%	%	%	%	%	%	ppm	ppm	ppm	ppm	%
Composter C	0	--	0	8.0	1919	8.23	0.433	0.138	0.557	4.556	0.367	0.240	16.5	7055	3.24	176	21.9
Composter C	0	A	10	9.5	1858	8.10	0.372	0.130	0.547	4.299	0.370	0.236	14.0	6864	2.76	171	21.8
Composter C	0	A	30	13.4	1611	8.33	0.389	0.130	0.553	4.189	0.357	0.285	13.5	6706	2.96	173	19.8
Composter C	0	B	10	9.4	1556	8.97	0.391	0.136	0.595	4.595	0.376	0.269	15.1	7194	3.02	181	21.3
Composter C	0	B	30	11.6	1412	8.87	0.380	0.128	0.551	4.058	0.350	0.254	13.4	6615	2.76	163	23.0
Composter C	0	C	10	7.9	1802	8.27	0.406	0.137	0.594	4.768	0.403	0.263	15.6	7331	2.74	188	21.6
Composter C	0	C	30	8.5	1531	8.63	0.396	0.141	0.581	4.795	0.388	0.260	16.6	7351	2.76	189	21.2
Composter C	30	--	0	8.0	1969	8.20	0.338	0.144	0.552	4.558	0.380	0.303	64.4	7932	14.91	194	21.4
Composter C	30	A	10	8.1	1381	8.40	0.386	0.140	0.561	4.594	0.385	0.294	63.0	7839	14.93	188	20.3
Composter C	30	A	30	11.4	902	8.60	0.408	0.143	0.566	4.607	0.383	0.292	62.6	7898	14.56	191	19.8
Composter C	30	B	10	9.1	2085	7.87	0.439	0.148	0.588	4.757	0.401	0.290	65.2	7867	14.14	193	19.6
Composter C	30	B	30	11.3	1357	8.13	0.436	0.138	0.569	4.502	0.385	0.288	62.3	7570	13.61	183	20.2
Composter C	30	C	10	8.0	1881	7.97	0.408	0.139	0.565	4.504	0.392	0.267	62.9	7973	12.90	192	20.0
Composter C	30	C	30	7.1	1195	8.27	0.415	0.145	0.570	4.925	0.397	0.289	64.9	7844	13.49	192	20.1
Composter D	0	--	0	8.6	1541	9.10	0.449	0.285	0.850	6.620	0.436	0.256	39.2	8914	6.55	218	21.4
Composter D	0	A	10	11.2	1442	9.10	0.471	0.277	0.823	6.207	0.425	0.273	36.8	8627	6.66	214	21.1
Composter D	0	A	30	15.1	1240	8.93	0.480	0.261	0.765	5.807	0.403	0.233	33.0	8447	4.89	203	20.4
Composter D	0	B	10	10.9	1451	9.20	0.363	0.275	0.814	6.107	0.428	0.248	36.2	8528	5.91	212	16.5
Composter D	0	B	30	13.5	1472	8.93	0.538	0.271	0.817	5.897	0.422	0.259	34.1	8419	5.37	207	20.4
Composter D	0	C	10	9.0	1331	9.13	0.515	0.279	0.828	6.503	0.431	0.272	37.6	8868	7.60	222	23.9
Composter D	0	C	30	9.4	1401	9.20	0.519	0.279	0.825	6.332	0.426	0.243	37.6	8681	5.44	211	21.0
Composter D	30	--	0	8.2	1347	8.90	0.486	0.296	0.838	6.489	0.457	0.297	87.5	9825	18.02	228	19.8
Composter D	30	A	10	10.6	1382	8.83	0.478	0.293	0.815	6.400	0.451	0.292	86.6	9646	18.10	225	19.8
Composter D	30	A	30	13.8	813	8.93	0.464	0.281	0.774	6.339	0.435	0.271	82.7	9445	16.99	221	19.1
Composter D	30	B	10	9.7	1566	8.77	0.393	0.295	0.839	6.316	0.455	0.272	87.0	9619	17.20	221	19.5
Composter D	30	B	30	12.8	1056	8.77	0.508	0.287	0.832	6.285	0.458	0.258	84.3	9548	16.87	222	18.7
Composter D	30	C	10	8.9	1019	8.47	0.482	0.302	0.834	6.772	0.464	0.292	89.0	10049	17.95	233	19.6
Composter D	30	C	30	9.3	1271	8.73	0.481	0.291	0.804	6.306	0.444	0.271	83.4	9742	16.54	226	19.3

Table 6. Influence of Compost sources, incorporation of high carbon byproducts (v/v basis) and sampling dates (0, 30, and 60 DAI) on organic matter, total N, pH, and soluble salts. Differences were determined by Dunnett's means separation test between and across compost sources.

Comparisons	Organic Matter (%)	Total N (%)	pH	Soluble Salts (umhos/cm)
Between Compost Sources				
Compost Sources				
Composter A vs. Composter C	*	*	*	n.s.
Composter B vs. Composter C	*	*	*	n.s.
Composter D vs. Composter C	n.s.	*	*	n.s.
Carbon Sources Volumes				
Source A 10 vs. Control	*	n.s.	n.s.	n.s.
Source A 30 vs. Control	*	n.s.	n.s.	n.s.
Source B 10 vs. Control	*	n.s.	n.s.	n.s.
Source B 30 vs. Control	*	*	*	n.s.
Source C 10 vs. Control	*	n.s.	n.s.	n.s.
Source C 30 vs. Control	*	n.s.	n.s.	n.s.
Sampling Dates				
2 vs. 1	*	n.s.	*	n.s.
3 vs. 1	*	n.s.	n.s.	*
Across Compost Sources				
Carbon Sources Volumes				
Source A 10 vs. Control	n.s.	n.s.	n.s.	n.s.
Source A 30 vs. Control	*	n.s.	n.s.	n.s.
Source B 10 vs. Control	n.s.	n.s.	n.s.	n.s.
Source B 30 vs. Control	*	n.s.	n.s.	n.s.
Source C 10 vs. Control	n.s.	n.s.	n.s.	n.s.
Source C 30 vs. Control	*	n.s.	n.s.	n.s.
Sampling Dates				
2 vs. 1	*	n.s.	*	n.s.
3 vs. 1	*	n.s.	n.s.	*

n.s- not significantly different at 95% confidence level
*- significantly different at 95% confidence level

Table 7. Influence of compost sources, incorporation of high carbon byproducts (v/v basis) and sampling dates (0 and 30 DAI) on C:N Ratios, nutrients (N,P, K, Ca, Na), respiration, and cucumber seedling vigor. Differences determined by Dunnett's mean separation tests between and across compost sources.

Comparisons	C:N Ratio	Total P (%)	Total Ca (%)	Total Na (%)	Cucumber Bioassay (%/vigor)
Between Compost Sources					
<u>Compost Sources</u>					
Composter A vs. Composter C	*	n.s.	n.s.	n.s.	n.s.
Composter B vs. Composter C	*	n.s.	*	*	n.s.
Composter D vs. Composter C	*	n.s.	n.s.	n.s.	*
<u>Carbon Sources Volumes</u>					
Source A 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source A 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Source B 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source B 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Source C 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source C 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
<u>Sampling Dates</u>					
2 vs. 1	n.s.	*	*	*	*
Across Compost Sources					
<u>Carbon Sources Volumes</u>					
Source A 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source A 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Source B 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source B 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Source C 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source C 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
<u>Sampling Dates</u>					
2 vs. 1	n.s.	*	*	*	*

n.s- not significantly different at 95% confidence level
*- significantly different at 95% confidence level

Organic Matter and pH

Dairy manure composts from the Bosque River Watershed frequently fail to meet the TXDOT specifications for organic matter content and pH. Consequently, these parameters are of primary concern to the composters in this area. In efforts to improve product quality to meet standards, composters frequently blend available high carbon by-products such as cotton burs, peanuts hulls, sawdust and wood chips with existing compost materials. Blend ratios of 80:20 to 75:25 compost:organic amendment are commonly used to modify low quality composts to meet minimum TX DOT standards for GUC. Use of higher levels of carbon, e.g. 50:50 blend of compost:organic amendment, could result in better end products but are considered by the composters to be uneconomical due to limited availability and costs (purchase price, transportation, handling) of acceptable carbon sources.

Organic matter: The mean organic matter content of the four composts used in this study was 9.8%. Addition of the 10% (v/v) rate of peanut hulls, sawdust and woodchips raised mean organic matter levels to 11.4%, 11.2% and 11.2%, respectively whereas the 30% rates increased the levels to 14.7%, 14.3% and 14.7%, respectively.

Statistically, when comparisons were made *across* compost sources, there were no significant differences in organic matter levels due to the 10% (v/v) applications of peanut hulls, sawdust or wood chips. Significant differences did occur, however, when applications rates were increased to 30% for all treatments, Table 6. Additionally, significant differences were also noted in organic matter levels between the 0 and 30 DAI and 0 and 60 DAI but not between the 30 and 60 DAI sampling periods. The latter findings may indicate that the repeated mixing of the treatments contributed to improved sample homogeneity

When comparisons were made *between* compost facilities, compost sources and organic amendments contributed to significant differences in organic matter levels, Table 6. The composters listed in order of mean increasing organic matter levels are: Composter C ≥ Composter D > Composter A > Composter B with the levels being significantly different except between Composter C and Composter D. All organic amendments applied at the 10 and 30% rates resulted in significantly higher mean organic matter levels over those in the controls, with no discernible differences between the sources (peanut hulls, sawdust and woodchips). As with the *across* compost source comparisons, significant differences in organic matter levels occurred between the 0 and 30 and 0 and 60 DAI sampling dates.

None of the compost or amended compost treatments met the base TX DOT standards for organic matter (25 to 65%) and only compost B consistently met the modified TX DOT standard for organic matter (≥10%) before treatments were applied, Tables 2 and 3. Compost A met the minimal organic matter standard following the addition of 10 and 30% rates of the 3-high carbon amendments. In contrast, the 30% rates of the three amendments were required to meet the standard with composts C and D. Either through testing, experience or both, composters are typically able to modify low quality dairy manure compost with varying amounts organic amendments to meet customer requirements.

pH: High pH readings are a common concern for most facilities that produce dairy manure compost in the Bosque River watershed. The four compost materials used in this study differed significantly in pH (Table 6) but all met the modified TX DOT standard for pH (≤9.5). The compost from the Composter C facility was the only product that met the agency's base (≤8.5) pH standard. Blending high carbon materials with low quality composts had little effect on pH. When analyzed between compost sources, only the 30% peanut hull treatment resulted in a significant reduction in pH whereas when tested across compost sources, the addition of high carbon sources at either the 10 or 30% levels (v/v) had no significant effects on pH, Table 6.

When the compost materials used in this study were initially collected, the odor of NH_3 (ammonia) was noted but by the time the study was implemented, NH_3 odors were generally not detectable. High pH may result from the presence of ammonia nitrogen (NH_3) in compost due to non-uniform and incomplete composting of the dairy manure feed stock. As composting methods improve (via smaller and more manageable windrows, more frequent and more thorough turning/mixing of manure/compost, screening, etc.) high pH due to excess NH_3 is less likely to occur.

Nutrients, Soluble Salts

Composts are generally recognized as products that are high in organic matter and contain multiple plant nutrients, some of which are complexed with organic constituents and released for plant use over time. Although composts may be beneficial as soil amendments, in the marketplace, they generally must compete with commercial fertilizers as a source of plant nutrients. Of the plant nutrients, nitrogen and phosphorus tend to be the most important for agricultural and horticultural applications. The compost sources used in this study contained approximately 6 to 12 lbs. of N and 5 to 15 lbs. of P_2O_5 per wet ton, respectively. Typically, nitrogen is the most costly and limiting nutrient that is required in greatest quantities by plants. Phosphorus is also essential for plant growth but is generally required in lesser amounts. Both N and P may be become problematic if applications substantially exceed plant needs and soil retention capacities. Nutrients in commercial fertilizers are frequently blended in ratios to meet specific plant needs and applications rates are set accordingly. Because nutrient ratios in composts are "fixed," application rates often must be adjusted to meet plant needs of the most abundant nutrient (i.e. P) and other nutrients (i.e. N) supplemented with commercial fertilizers.

The four compost products used in this study differed significantly in total N but not in total P, Tables 6 and 7. Blending organic amendments with the compost products did not significantly change total N levels with the exception of the 30% peanut hulls treatment, Table 6. Total P levels were not affected by the addition of the high carbon amendments, Table 7.

The compost B product was significantly higher in Ca and Na than the products from the other facilities. Blending organic amendments with the four compost sources had no affect on Ca or Na levels (Table 7) or on soluble salts (Table 6). The Na levels and soluble salt reading, Tables 4 and 5, indicate the compost products tested did not pose a salinity hazard to soils or plants.

Carbon: Nitrogen (C:N) Ratios, Respirometry and Cucumber Bioassays

TMECC guidelines (TMECC, 2000) consider three characteristics is assigning a maturity index for compost: C:N ratio, stability (based on microbial activity determined by respirometry) and phytotoxicity (cucumber bioassays for germination and vigor). Composts with C:N ratios less than or equal to 25:1 are categorized as mature and those with higher C:N ratios are considered immature. Respirometry measures the CO_2 evolution from compost samples and is used to estimate the relative stability (biological activity) of composts. Compost with CO_2 evolution rates of less than or equal to 2-4 mg CO_2/g OM are rated as mature. Cucumber germination percentages of 80-90 % and vigor ratings of 85-95% indicate no phytotoxic effects from the growth media and indicate that composts are mature whereas lower ratings indicate immaturity.

C:N Ratios: Organic carbon determinations were confounded by the limestone rock ($CaCO_3$) fragments contained in the inorganic fraction of all compost sources. To obtain accurate estimates of organic carbon, the SCL and SWFTL used procedures to differentiate between the organic and inorganic carbon (C) contained in the compost samples. SCL used separate tests to determine the level of inorganic C (contained in the $CaCO_3$) in each sample and subtracted that amount from the total C to establish the organic C. The SWFTL utilized a modified Loss on Ignition (LOI) procedure that prevents the loss of inorganic carbon yet achieves full recovery of organic carbon (Pitt, et. al., 2003).

C:N ratios of the compost products used in this study ranged from 13 to 15, Table 2 and differed significantly between compost sources, Table 7. Blending the three organic amendments at the 10 and 30% rates tended to numerically increase the C:N ratios in all compost sources. However, only the 30% levels of peanut hulls, sawdust and wood chips resulted in significantly higher C:N ratios (Table 7) which ranged from 15 to 19, Table 4.

Respirometry: Carbon dioxide evolution rates were less than 2 mg CO_2/gm OM for all compost sources, Table 2. Mixing the organic amendments with the composts had no appreciable effect on respiration with the exception of compost C amended with 10% and 30% (v/v) peanut hulls, Table 4. It is possible the higher respiration rates (3.8 to 6.8 mg CO_2/ g OM) and the somewhat higher C:N ratios were related to the maturity of compost material selected for preparing these 6-samples, thus reflecting the variability which exits in these compost sources.

Cucumber Bioassays: The germination percentages for cucumber seed planted in the 4-compost sources ranged from 80 to 100 (with one exception) and the vigor ratings (again with one exception) from 80 to 100%, Table 2. Of the 2-sets of cucumber seed planted in two samples of Compost B, one failed to produce any seedlings (0% germination) whereas all the seed germinated in the other sample. Also, one of the two sets of seedlings planted in Compost D was not rated for germination due to excessive mold growth on the media and poor condition of the seedlings (which received a 0% vigor rating); seedlings in the companion sample exhibited 80% germination and 100% vigor.

The mold problem persisted even after high carbon materials were blended with the 4-compost sources. Of the samples collected 0 DAI and 30 DAI, 21% and 25%, respectively, were not rated for germination because of excessive mold growth. Two-thirds (66.67%) of the moldy samples occurred in the treatment samples (control, 10% and 30% organic amendments) prepared with compost D, suggesting that seedling disease organism survived the composting process in this lot of dairy manure.

Due to the missing germination ratings, only the cucumber seedling vigor data were statistically analyzed. When compared between compost sources, the treatments prepared with Compost D had significantly lower vigor rating, Table 7. Cucumber seedling vigor ratings were also significantly different for the 0 and 30 DAI sampling dates when tested between and across compost sources.

The combined C:N ratios, respirometery and cucumber bioassay ratings indicate that the 4-compost sources can be classified as mature but that classification is confounded by the variability that seems to exist in one or more of the compost products.

Laboratory Comparison

Due to differences in dairy manure feedstocks, manure storage and handling procedures, composting methods and other factors, the chemical, physical and biological properties of dairy manure composts are highly variable. Standardized testing procedures are needed to provide composters and users with a means for assessing compost quality to determine if the end product meets specific needs. Test results may establish the need for further processing (i.e. adding organic amendments; producing alternate products such as CMT), suitability for specific applications (i.e. top-dressing sports fields), rates at which the products should be used for one or more applications (i.e. soil amendment; crop fertilization) and as a basis for pricing products.

The U.S. Composting Council has endorsed the TMECC through its STA program. Laboratories seeking STA certification must invest in equipment and personnel training to meet QA/QC testing standards set by the Council. The STA program ensures testing uniformity but analytical costs are relatively expensive due to QA/QC requirements, equipment and personnel expenses, the often small and variable volume of samples generated by the compost industry, and the variability in types of analyses requested per sample. In contrast, service laboratories, such as the TCE-SWFTL, are structured to process large numbers of soil, plant, water, manure/compost and other samples and to offer more “analytical packages” than specific analyses for individual samples. Test results are used to make research based recommendations relating to crop fertilization needs, forage and hay quality, suitability of water for irrigation, etc. Because of the high throughput, analytical costs are less expensive than those charged by labs adhering to strict (TMECC) procedures.

The analytical tests performed by the SCL and SWFTL are listed in Table 1, and the results of the analyses conducted on the 84 treatments samples are shown in Tables 4 and 5, respectively. With the exception of organic matter, there were significant differences (at the 95% level) in the nutrient levels (N, P, Ca and Na), pH and soluble salts determined by the two laboratories, Table 8. For organic matter, there were no significant differences between labs even though two distinct procedures were used to estimate organic carbon levels in the samples. Higher order interactions were detected between organic matter levels and carbon sources, labs X carbon sources and sampling dates (according to GLM model but not Split Plot-Mixed design model; data not shown in Table 8). Higher order lab X carbon interaction was also noted for soluble salts and lab X day interactions for pH and Na.

Numerically, the mean SWFTL readings were higher for N (7.6%), P (14.8%), Na (59.3%), pH (1%), soluble salts (12.6%) and were lower for Ca (5.6%) and organic matter (5.9%) than the mean readings obtained by the SCL, Figure 1. SWFTL managers were aware of, and were in the process of correcting, contamination problems which resulted in abnormally high Na readings. The other variations may reflect differences in precision, accuracy and bias of the methods used.

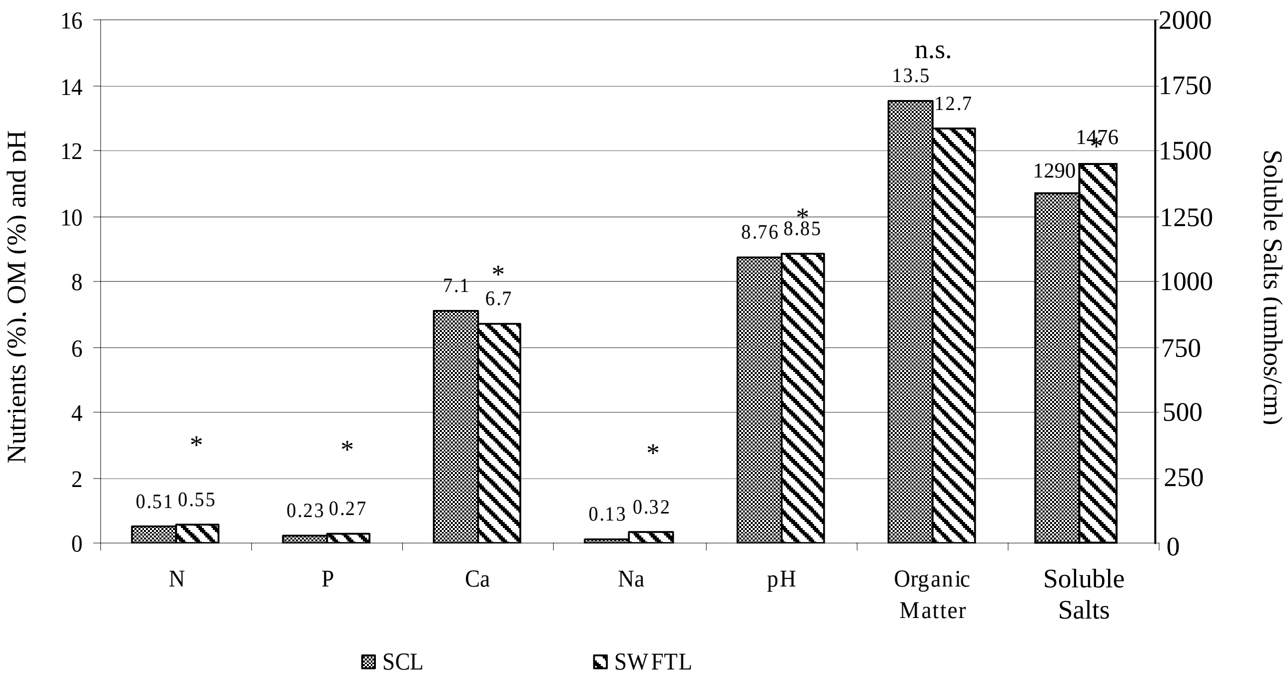
Although composters and retailers are often required to use TMECC results provided by STA certified laboratories in marketing compost products to certain entities, service laboratories such as the TCE-SWFTL can provide good assessments of compost quality at a fraction of the cost. The results of this comparison indicates composters could effectively use data provided by SWFTL as management decision aids (i.e. amending manures or composts with high carbon materials) and in assessing the quality and potential applications of their products (i.e. GUC, CMT).

Table 8. Comparison of compost test results obtained by the Soil Control Lab and the Soil, Water and Forage Testing Laboratory determined by Analysis of Variance using split plot application of a repeated measure design

Comparison	Total N	Total P	Total Ca	Total Na	pH	Soluble Salts	Organic Matter
	---Across compost sources---						
Laboratories	*	*	*	*	*	*	n.s.
Carbon sources/volumes	n.s.	n.s.	n.s.	n.s.	n.s.	*	*
Sampling Dates	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lab X Carbon	*	n.s.	n.s.	n.s.	n.s.	*	*
Lab X Day	n.s.	n.s.	n.s.	*	*	n.s.	n.s.
Carbon X Day	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lab X Carbon X Day	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* significant difference at 95% confidence level

Figure 1. Comparison of mean values for several parameters determined in four compost sources by a laboratory using TMECC methodologies and by a service laboratory using alternate methods. (* indicates significance)



Conclusions

The compost industry in the North Bosque River watershed has made substantial progress in improving the quality of the composts it produces from dairy manure. In the early stages, the manures obtained from dairies frequently contained excessive extraneous materials (bedding sand, limestone fragments), were stored in large, difficult to manage windrows or stockpiles, and often were not properly composted. As a consequence some of the resulting products were of low quality, not readily marketable and consequently, were stockpiled for two or more years. *Options for utilization of these stockpiled products included incorporating their use in production of CMT and ECC materials, in farm and ranch applications, and in improving their quality through screening, grinding and/or the addition of high carbon amendments. Although the latter option increased production costs, amended products can often be improved to meet standards and to be sold as GUC.*

In this study, significant differences existed in organic matter contents, pH, total N and C:N ratios between the four compost sources tested. Significant differences in organic matter, P, Ca, and Na levels, pH and cucumber seedling vigor occurred due to sampling date (0 and 30 DAI). This indicates high degrees of variation existed within the individual lots of compost. Adding 10% and 30% (v/v basis) of three high carbon materials resulted in significantly higher organic matter levels when analyzed between the four compost sources but only the higher (30%) rates of the amendments increased organic matter contents across compost sources. Of the treatments applied, only the 30% rate of peanut hulls resulted in a significant decrease in pH and in a significant increase in total N between compost sources; no significant effects for these parameters occurred across compost sources. *Addition of the organic amendments had no consistent effects on P, Ca, Na, soluble salts or on cucumber seedling vigor between or across compost sources.*

Results of this study showed that physical mixing of 10 to 30% (v/v) 3-high carbon amendments (peanut hulls, sawdust and wood chips) with 4-low quality dairy manure composts can increase organic matter content and alter C:N ratios but will have limited effects on pH, soluble salts and nutrients. With the exception of the 30% rate of peanut hulls (which significantly lowered pH and increased total N between compost sources), carbon sources had no significant impacts on the parameters tested between or across compost sources. When considered across all compost sources and high carbon amendments, adding 10 and 30% of the amendments to the composts increased the mean organic levels from approximately 9.8% to 11.3% and 14.6%, respectively. *On average, the blended materials met the modified (>10%) but not the base (25-65%) TX DOT specification for organic matter content. If adding higher rates of the amendments are cost prohibitive, a better application of low quality composts may be their use in the preparation of CMTs or ECCs.* Other studies have shown blending high carbon constituents with dairy manure prior to composting (Michel, et al, 2005) is also a viable option for improving compost quality.

TMECC have been adopted as the industry standards for compost testing by STA certified laboratories. Defining manure and compost quality through laboratory analysis can serve as a marketing tool and also as a valuable decision aid for compost facility managers. Cost and time requirement to obtain TMECC results have limited reliance on laboratory testing by compost facility managers. Service laboratories such as the TCE SWFTL often offer “analytical packages” for manure/compost testing at lower costs. Although services labs typically adhere to specific QA/QC standards, many are not STA certified for running TMECC procedures. A comparison of compost test results provided by SCL, a STA-TMECC certified facility and the TCE-SWFT lab showed that the values for selected nutrients (total N, P, Ca and Na), pH and soluble salts differed significantly between the two laboratories but there were no differences in organic matter levels. Numerically, the mean values obtained by SWFTL were higher for N (7.6%), P (14.8%), Na (59.3%), pH (1%), soluble salts (12.6%) and were lower for Ca (5.6%) and organic matter (5.9%), Figure 1. The difference in Na is attributed to a contamination problem that occurred at the time these analyses were conducted. Composters and retailers are often required to provide STA-TMECC results in marketing their products to provide users with information that can be used to equitably compare product qualities, determine use rates, etc. Service laboratories can also be effectively used to provide compost facility operators with low cost preliminary assessments of manure of compost qualities for use as management decision aids.

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Appendix E

Dairy Compost Use and Production Survey Results

Dairy Compost Use and Production Survey Results

Problem Definition/Background

The Bosque River and Leon River watersheds contain approximately 165 dairies with 100,000 cows. Studies by the Texas Commission on Environmental Quality (TCEQ), Texas State Soil and Water Conservation Board (TSSWCB), Brazos River Authority (BRA), Texas Institute for Applied Environmental Research (TIAER), and others demonstrated that excessive animal waste has contributed to water quality problems in the basin, specifically, segments 1226 and 1255. TCEQ has mandated major reductions in manure loadings within the Bosque River watershed.

As early as 1998, interest and support developed for the production of composted manure as a means for enhancing transport of animal waste out of the watershed. Incentives were provided to encourage manure transport to composting facilities, which have produced significant quantities of product. The goal of this project is to use the Texas Cooperative Extension (TCE) network and the technical capabilities of the Texas Agricultural Experiment Station (TAES) and a Compost Marketing Firm (CMF), in collaboration with the Texas State Soil and Water Conservation Board (TSSWCB) and Soil and Water Conservation Districts (SWCDs) to:

- Expand government and public markets for composted manure from the Bosque and Leon River watersheds by:
  - Increasing awareness of the benefits of compost, and
  - Publicizing the TCEQ Composted Manure Incentive Project to eligible state agencies and political subdivisions.
- Develop a Technical Assistance Program that will promote:
  - Cost-effective, beneficial and environmentally safe uses of dairy compost.
  - Production of quality compost meeting desired specifications by participating compost operations.
- And to, promote development of a sustainable regional market for composted dairy manure by identifying and linking the needs of governmental organizations with a competitive composting industry starting with the region surrounding Stephenville, Texas.

Overall, TWRI will work with the project cooperators to promote and expand the use of compost in sufficient quantities to make use of at least 50,000 cubic yards of composted manure. In an effort to meet the three major project goals, TCE will conduct a survey of the public entities within the Leon River and Bosque River watershed. The purpose of the survey was to identify and quantify the potential market for dairy compost within the watershed. In the process of the survey, TCE also was able to determine the current use and production of dairy compost by public entities. Furthermore, to more efficiently plan their efforts, TCE also conducted a supplemental survey of selected entities to identify key issues hindering dairy compost use in the area, such as the need for more compost research data, the lack of public information and the amount or availability of dairy compost within the area.

Survey Methodology

Two separate surveys were developed to be used to assess the potential market for dairy compost within the area. The first survey, Questionnaire for Compost Users, is included in Exhibit 1 and was the primary survey used consistently throughout the entire process. In the event that a public entity did not currently use compost or had discontinued use in the past, then a second survey, Supplemental Compost User Survey, which is included in Exhibit 2, was to be used. With this questionnaire, TCE attempted to assess and understand the rationale behind the lack of compost use within the watershed. However, due to the length and meticulous nature of the supplemental survey and the lack of cooperation by the entities, less specific information regarding the lack of compost use was collected and assessed with the supplemental survey. Regardless, TCE planned to use the information gathered from both surveys to determine what steps need to be taken to succeed in project efforts.

Initially, TCE identified the cities listed in Table 1 to be surveyed. In making this selection, TCE organized all of the cities within the watershed by population and divided the entities into four major groups as follows: (1) 1,000 to 5,000 people, (2) 5,000 to 10,000 people, (3) 10,000 to 20,000 people and (4) greater than 20,000 people. A minimum population size of 1,000 was set as it was determined that no significant market value exists in these areas. Approximately five cities were randomly selected from each population group to obtain a more representative sample of the cities within the watershed and to ensure statistical validity of the survey.

TCE submitted the original list (Table 1) to TCEQ in November 2002. TCEQ revised the list and added 23 additional cities to more thoroughly assess the potential markets within the watershed. Of the 102 public entities identified within watershed, TCEQ ultimately identified 40 entities total to be surveyed. The number of identified entities and the number of entities selected to be surveyed can be found in Table 2. To satisfy the primary purpose of the survey, which was to identify and quantify potential markets, priority was given to the cities with a population greater than 20,000. Therefore, a larger sample was taken out of this group to be surveyed.

Table 1. Population distribution and sample size of entities within the Leon River and Bosque River watershed and the entities initially selected by TCE to be surveyed.

Population Size	Identified Entities	Selected Entities	Names of Selected Entities
1,000 – 5,000	**51**	**5**	**Meridian, Goldthwaite, Glen Rose, Hamilton, Comanche**
5,000 – 10,000	**17**	**3**	**Granbury, Marlin, Hillsboro**
10,000 – 20,000	**12**	**5**	**Belton, Stephenville, Gatesville, Brownwood, Weatherford**
Greater than 20,000	**22**	**4**	**Cleburne, Georgetown, Waco, Fort Worth**

Table 2. Population distribution and sample size of each entity surveyed within Leon River and Bosque River watershed.

Population Size	Identified Entities	Selected Entities
1,000 – 5,000	51	9
5,000 – 10,000	17	5
10,000 – 20,000	12	6
Greater than 20,000	22	20

Survey Results

Using this selection technique, TCEQ identified 40% of the potential market within the watershed to be surveyed. However, when considering the large markets (population greater than 20,000), 95% were identified and contacted. Through telephone interviews, TCE contacted 85% of the identified entities. The remaining 15% were not contacted due to incorrect phone numbers or contact information. A list of contact names and numbers can be found in Exhibit 3. Cooperation by the entities varied resulting in less than 100% responses from the contacted entities. Overall, TCE received responses from 70% of the contacted entities. Table 3 lists the selected entities by population and the amount of contacted entities and positive responses.

TCE summarized the status of compost use or lack thereof in Table 4 for each entity. Of the 24 entities who responded to the survey, 15 use compost or at least some type of mulch product. Seven of the entities do not use any type of compost in their management systems. Hico was the only entity to report rarely using compost and Woodway was alone in reporting that they had previously used compost, but had since discontinued use.

Of the positive responses received by TCE, 63% use some type of organic material in their management practices. Consequently, 38% do not currently use any organic materials in their land and plant management programs. Of the 63% that do use organics, approximately half produce their own product. However, a majority of the entities that produce their own product produce a mulch product rather than a compost product. Generally, entities that produce their own products do so to conserve landfill space and money. Furthermore, the input costs for this production is low as entities receive materials from their citizens in the form of green waste from lawn and yard trimmings. Therefore, it is more economical for entities to produce a mulch type product rather than a compost type product. Some interest does exist for entities to start compost production given they can identify an available nitrogen source. This necessity does provide an alternative market for dairy manure within the watershed in that entities wishing to begin composting may be able to utilize dairy manure as a nitrogen source to add to their mulch products. However, this alternative does not provide for the use of dairy compost, the primary purpose of this project, and therefore should be considered as a secondary goal.

For the remaining half who use compost, but do not produce their own, TCE discovered that these entities purchase or receive their organic material from a variety of sources. For instance, Weatherford purchases material from Clear Fork Materials in Aledo, TX while the city of Georgetown receives free product from Texas Disposal Systems. The towns of Temple and

Table 3. Entities sorted by population selected within the watershed to be surveyed and amount of contacts and responses from each entity.

City	County	Population	Contacted	Responded
Hico	Hamilton	1341	✔	✔
Meridian	Bosque	1491		
Goldthwaite	Mills	1802	✔	✔
Glen Rose	Somervell	2122	✔	✔
De Leon	Comanche	2433	✔	
Hamilton	Hamilton	2977		
Clifton	Bosque	3542	✔	✔
Dublin	Erath	3754	✔	
Comanche	Comanche	4482	✔	✔
Granbury	Hood	5718		
Marlin	Falls	6628	✔	✔
Hillsboro	Hill	8232		
Woodway	McLennan	8733	✔	✔
Bellmead	McLennan	9214	✔	✔
Hewitt	McLennan	11085	✔	✔
Belton	Bell	14623	✔	✔
Stephenville	Erath	14921		
Gatesville	Coryell	15591	✔	✔
Brownwood	Brown	18813	✔	✔
Weatherford	Parker	19000	✔	✔
Benbrook	Tarrant	20208		
Burleson	Johnson	20976	✔	✔
Southlake	Tarrant	21085	✔	✔
Watauga	Tarrant	21908	✔	✔
Cleburne	Johnson	26005	✔	✔
Keller	Tarrant	27345	✔	
Mansfield	Tarrant	28031	✔	
Georgetown	Williamson	28339	✔	✔
Copperas Cove	Coryell	29455	✔	
Hurst	Tarrant	36273	✔	
Haltom City	Tarrant	39018	✔	✔
Grapevine	Tarrant	42059	✔	
Euless	Tarrant	46005	✔	
Bedford	Tarrant	47152	✔	✔
Temple	Bell	54514	✔	✔
North Richland Hills	Tarrant	55635	✔	
Killeen	Bell	86911	✔	
Waco	McLennan	113726	✔	✔
Arlington	Tarrant	332969	✔	✔
Fort Worth	Tarrant	534694	✔	✔

Table 4. The current status of compost use or lack thereof from the entities surveyed.

Compost use status	Number of Entities	List of Entities
Has never used compost	7	Clifton, Bellmead, Bedford, Watauga, Goldthwaite, Marlin and Gatesville
Has used compost rarely	1	Hico
Currently uses compost or some other type mulch product	15	Arlington Southlake, Haltom City, Hewitt, Burleson, Weatherford, Georgetown, Waco, Fort Worth, Comanche, Glen Rose, Cleburne, Brownwood, Belton and Temple
Previously used compost, but has since discontinued use	1	Woodway

Belton both contract with Brazos River Authority (BRA). Temple officials would not discuss the status of the contract with TCE, but Belton and BRA revealed that BRA provides Belton with 25% of the product and Temple receives 75% of the product. Hewitt recently entered a contract with TCEQ to utilize dairy compost, Arlington and Waco both purchase dairy compost from the watershed and Southlake does contract to purchase compost but would not disclose the type of compost purchased or their source.

In regard to the amount of compost purchased or used, TCE found that entities were not able to provide such information. Typically, personnel who were willing to participate in the survey did not have access to the information or the entity did not keep a record of the amount used. Moreover, the purpose for the use or production of compost varied in each city. A majority of the entities who produce compost or a mulch product gave or sold the product to its citizens or another entity (i.e. Highway Department). Waco, Arlington and Fort Worth were the only entities who stated they used a compost or mulch product in their land management needs such as city parks, football fields and local schools. This information is tabulated in Exhibit 4.

The 32% who do not currently use or produce compost provided several reasons behind their disinterest. The majority lacked the funds, personnel and public demand to warrant the production or the purchase of compost. Clifton and Woodway responded they have conducted city surveys and found little interest in compost from their citizens. Hico, Bellmead, Bedford Goldthwaite, Marlin and Gatesville all expressed that lack of funds and personnel are the primary reasons they do not utilize compost in their management systems. Furthermore, given the added funds, all three entities admitted that compost was not their most current priority. The city of Watauga also reported they lack the personnel, yet also do not consider the product readily available to them. Consequently, Watauga has previously used bagged fertilizer as a soil amendment in their management practices.

As stated earlier, the supplemental survey was not suitable for a telephone survey and therefore, such data was gathered by inquiring general information from the entities concerning their lack of compost use. To more efficiently assess the compost market, or lack thereof, TCE recorded comments and tabulated them in Exhibit 4. More specifically, Watauga and Burleson had contradictory views on some of the issues addressed by the supplemental survey. Burleson stated it the availability of vendors providing compost and their hauling services was extremely important to their potential compost use. Furthermore, they also rated the need for information regarding compost use, compost specifications and compost characteristics extremely important. Watauga, however, rated these issues as not important or not applicable to their needs. It is important to note here that Watauga is the city who does not consider dairy compost readily available to them and have previously used bagged fertilizer, which suggests their responses to the supplemental survey are the result of lack of information.

Given the above information for both compost users and non-users, TCE has identified some potential markets in the entities within the watershed. Watauga, for example, might be willing to try dairy compost if they are provided with accessible information regarding compost use. Currently, they use bagged fertilizer and through project efforts, dairy compost use may prove to more economical and efficient for Watauga. Clifton's and Woodway's citizens do not have interest in a compost product, but the possibility still exists that both of these entities could implement dairy compost use in their own management practices. Georgetown, although they currently have access to a free organic source, stated they would be willing to try dairy compost given the quality and market. Burleson is also interested depending on the price and quality of product. Although Weatherford currently purchases from Clear Fork Materials, they also stated they would be interested if dairy compost use is more economical. Finally, Glen Rose currently produces a mulch product and does have interest in producing a compost product. However, their compost production is a future venture and the city needs a compost source for the time being. Furthermore, Glen Rose and Brownwood both want to start compost production using their existing mulch product, but both entities lack a nitrogen source and as stated earlier, here in lies a potential market for uncomposted dairy manure from the watershed.

All raw data and results are included in Exhibit 4.

Conclusion

While interest does not exist throughout the entire watershed, TCE determined that some entities would be willing to purchase dairy compost on a trial basis given the proper quality and economics. The compost quality issue is being handled by other aspects of the project. Dairy compost production and marketing consultants are assisting compost producers within the watershed to ensure their production techniques are consistent with those necessary to produce a quality product. The purchase of dairy compost has the potential to be economical when public entities take advantage of the Composted Manure Incentive Program sponsored by TCEQ. Project literature and public workshops will be conducted to ensure that entities are made aware of the incentive program.

One barrier identified was the overall lack of interest or demand. To increase and/or develop interest, TCE will work with TAES to establish field research and demonstration plots in the project area to ensure environmentally sound application and use techniques are determined and to develop more efficient and productive dairy compost uses for the entities. Using these demonstration plots and through training workshops, TCE will inform both public entities and private individuals of the most environmentally sound application and use techniques, demonstrate applied benefits of compost use, establish cost effective methods of compost use and ultimately, supplement the promotion of a sustainable regional market for composted dairy manure. These applied research studies are outlined in the Research/Demonstration Design Plan (RDDP) submitted to TCEQ. Furthermore, TCE and TAES will compile publications following RDDP implementation to educate the end users of compost and to fill the void of public information concerning dairy compost.

R. Alexander Associates, Inc. (RAA) conducted dairy compost market research before his involvement with the TCE project and reviewed other related research. RAA found that peat, topsoil, bark products and other composted materials compete with the sale of dairy compost. This fact was further proven by the TCE survey results as more than half of the entities that produce their own product produce a mulch material rather than a compost material. Potential barriers to compost use identified by RAA include transportation costs, competition, a lack of public familiarity with the product and a low perceived value of dairy compost. To address some of the potential misconceptions, TCE and RAA will develop materials to promote and educate end-users of the benefits and practical uses of dairy compost. Secondly, taking advantage of the TCEQs Composted Manure Incentive Program, overall dairy compost costs may be reduced to compensate for related transportation costs.

Using their outreach network and coordinating with other activities involved in the marketing of dairy compost, TCE/TWRI hopes to establish a viable and sustainable market for dairy compost leading to less pollution in the Leon River and Bosque River watershed. The potential markets identified include:

- Support of the existing TxDOT market and the TSSWCB program
- Landscape architects within DFW region and watershed
- School districts, golf courses, and turfgrass managers through SAFE program
- Public land managers such as city park officials, county engineers, etc.
- Horticultural and residential urban applications
- Agricultural production within watershed

Exhibit 1

Questionnaire for Compost Users
(Government Entities)

Name of entity: ______________________ Date: ______________
Address: ______________________ Phone: ______________
____
____

Person interviewed: ______________________ Title: ______________
Population class: ______________________

1) Considering your use of compost, your organization

I. Has never used compost

______ Has used compost rarely (Approximately _______ times in the past)
______ Currently uses compost
______ Previously used compost, but has discontinued using it in recent years.

II. If so, why?

____

____

2) If your organization does not currently use compost products, please indicate which of the following is accurate. (mark all that apply)
______ Your organization does not have enough information about compost products to make a decision to try them.
______ Your (a) staff, (b) landscape contractors, or (c) landscape advisors have advised against the use of compost products as part of your landscape management program
______ Your organization has had one or more bad experiences with compost products
______ Your organization tried a compost product, but did not find it cost effective
______ Other ____

3) Who supervises these aspects of compost?

Acquisition: ______________ Use: ______________
Title: ______________ Title: ______________
Phone: ______________ Phone: ______________
Email: ______________ Email: ______________

4) From whom do you buy/obtain the compost?
*Municipality, commercial composter, agricultural producer, garden center, landscape contractor or other. Please include type of supplier if it is other.

Name______________ Name______________
Type of Supplier*______________ Type of Supplier______________
Address______________ Address______________
Phone______________ Phone______________

Name___________________________	Name___________________________
Type of Supplier_________________	Type of Supplier_________________
Address_________________________	Address_________________________
________________________________	_________________________________
________________________________	_________________________________
Phone___________________________	Phone____________________________
Name___________________________	Name___________________________
Type of Supplier_________________	Type of Supplier_________________
Address_________________________	Address_________________________
________________________________	_________________________________
________________________________	_________________________________
Phone___________________________	Phone____________________________

5) Considering the different types of compost, what type of compost or what brandname do you purchase, how much do you purchase per year and what is the price you pay?

Compost Type	**Supplier and/or brandname***	**Cubic yds purchased**	**Price per cubic yd**
Dairy Manure compost:			
Leaf/yard trimmings compost:			
Biosolids (sludge) compost:			
Multiple materials compost:			
Compost/soil blend:			
Compost/mulch blend:			
Other ___________________			
Other ___________________			

- Please include specifications or procurement bid information for each product type, if any. If your unit of government produces some of the compost you use, include it as appropriate in the supplier column. Please indicate if the unit of measurement is not cubic yards – i.e. tons

6) How do you typically use compost, and how much do you use for each use? Or if you have not previously used compost, what would be your primary use of compost?

Type of Use	Amount used
Soil amendment for gardens and/or landscapes	
Soil amendment for turf establishment	
Soil amendment for crop production	

Type of Use (cont'd.)	**Amount used (cont'd.)**
Soil amendment for upgrading marginal/disturbed soils	
Top-dressing or mulch for turf grass	
Top-dressing or mulch for planting beds	
Blended topsoil mix	
Container medium (potted plants)	
Sources of nutrients/fertilizer	
Erosion or sediment control	
Other ____	
Other ____	

7) What are the barriers to using compost or increasing compost use, for example ease of application, knowledge of compost, and sanitation? ________________________________

8) Have you previously used related soil additive products similar to compost and if so, how much of each product do you use annually?

Product type	**Amount***	**Cost**
Peat Moss		
Manure (not composted)		
Biosolids (not composted)		
Other organic matter		
Mulch (not composted)		
Potting Soil		
Topsoil		
Fertilizers		
Other _________________________		
Other _________________________		

- Please indicate the units of measurement used for each (cubic yds, tons, pounds, etc) and unit price.

9) Comments:

Exhibit 2

Supplemental Compost User Survey
(Government Entities)

1. Do you consider compost to be readily available to you?

2. Using the following scale, indicate the level of importance you would place on credible or authoritative information about the following in making decisions about using compost. (1 = Extremely important; 2 = Somewhat important; 3 = Slightly important; 4 = Not important; 5 = Not applicable)

Information or guidance about compost application rates	1	2	3	4	5
Information or guidance about compost application methods	1	2	3	4	5
Availability of vendors providing compost	1	2	3	4	5
Availability of vendors providing compost hauling services or availability of hauling equipment	1	2	3	4	5
Availability of vendors providing compost application services or availability of application equipment	1	2	3	4	5
Information about the cost-effectiveness of using compost, including how it can reduce other landscaping costs	1	2	3	4	5
Information about specifications for compost producers	1	2	3	4	5
Information about compost characteristics and what it contains	1	2	3	4	5
Information about how to determine whether a compost product has the right characteristics for its intended use	1	2	3	4	5
Information about the effectiveness of compost in regards to:					
Plant growth response	1	2	3	4	5
Plant health and/or disease resistance	1	2	3	4	5
Improvement in soil characteristics	1	2	3	4	5
Erosion control effects	1	2	3	4	5
Water conservation benefits	1	2	3	4	5
Other ________________________________	1	2	3	4	5
Information about the methods of using compost for the following purposes:					
Fertilizer for crops in lieu of or in combination with synthetic fertilizers	1	2	3	4	5
Garden prep or renovation	1	2	3	4	5
Soil preparation for sodding, seeding and planting	1	2	3	4	5
Top dressing of turf grass	1	2	3	4	5

Mulching or top dressing for planting beds	1	2	3	4	5
Erosion or sediment control	1	2	3	4	5
Container medium (potted plants)	1	2	3	4	5
Other ____	1	2	3	4	5
Health risks or safety problems (i.e. Potential for infectious diseases)	1	2	3	4	5
Potential odor problem	1	2	3	4	5
Potential pest problem (i.e. flies or other insects)	1	2	3	4	5
Aesthetic issues	1	2	3	4	5
Foreign material introduced in compost (i.e. sand, rocks, wood, plastic, etc.)	1	2	3	4	5
Potential damage to turf or landscape plants	1	2	3	4	5

Other: ____

3. What kinds of documented information would be most important to you in your decision making about compost use? Using the following scale, please indicate the level of importance. (1 = Extremely important; 2 = Somewhat important; 3 = Slightly important; 4 = Not important; 5 = Not applicable) If necessary, give more information when possible.

Research data from studies conducted locally on plant responses and soil impacts due to compost use	1	2	3	4	5
Research data from studies conducted in another part of Texas or nationally on plant responses and soil impacts due to compost use	1	2	3	4	5
Discussion with professional colleagues and peers	1	2	3	4	5
Professional workshops and conferences	1	2	3	4	5
Professional or technical periodicals and magazines	1	2	3	4	5
Government agency bulletins and research reports	1	2	3	4	5
Public media reports and articles	1	2	3	4	5

Other ____

Exhibit 3

Survey Participant Contact Information

City	Contact Person	Phone Number
Hico	City Hall	254.796.4620
Goldthwaite		
Glen Rose	Wade Busch	254.897.2239
De Leon		
Clifton	City Hall	254.675.8337
Dublin		
Comanche	Darwin Dickerson	915.356.2616
Marlin		
Woodway	Dena Forquer	254.772.4480
Bellmead		254.799.2436
Hewitt	Kenneth	254.666.2447
Belton	Sam Listi (BRA)	254.939.6471
Gatesville		
Brownwood	Tim Airheart	915.646.5775 x380
Weatherford	Scott Fairman	817.598.4243
Burleson	Peter Krause	817.295.8168
Southlake	Pedram Farahnak	817.481.2308
Watauga	Terry Wiley	817.514.5851
Cleburne	Larry Barham	817.645.0942
Keller	Dan Burger	817.337.4968
Mansfield	Cathy Anderson	817.276.4200
Georgetown	Jim Briggs	512.930.3889
Copperas Cove	Tom Comancho	254.518.4208
Hurst	Jerry Bradley	817.788.7027
Haltom City	George Fowler	817.831.6464
Grapevine	Larry Willhelm	817.410.3366
Euless	Ray McDonald	817.685.1650
Bedford	Don Henderson	817.952.2308
Temple	Kim Nuttenbring	254.298.5411
North Richland Hills		
Killeen	Peter Dillio & Malcolm Thompson	254.634.4536
Waco	Christian Heger	254.299.2612
Arlington	Scott Degrant	817.275.7041
Fort Worth	Melinda Adams	817.871.5700

Exhibit 4

Raw Survey Results

City	County	Pop.	Cont	Resp	Use comp	Type of compost used	Prod own	Do not use comp	Why they do not use compost or other miscellaneous comments	Interest in dairy compost
Hico	Hamilton	1341	yes	yes	--	--	--	✔	manpower; $; do not consider compost readily available within the town	
Meridian	Bosque	1491	no	no						
Goldthwaite	Mills	1802	yes	yes				✔	Not a primary concern for city – economics	potential
Glen Rose	Somervell	2122	yes	yes	✔	mulch-green waste	✔	--	Plan to compost, but not immed.; Do not have N source, will use dairy comp if econ.	Potential
De Leon	Comanche	2433	yes	no						
Hamilton	Hamilton	2977	no	no						
Clifton	Bosque	3542	yes	yes	--	--	--	✔	conducted town survey — no interest in compost or recycling program	
Dublin	Erath	3754	yes	no						
Comanche	Comanche	4482	yes	yes	✔	mulch — green waste	✔	--	Give away mulch to Hwy. Dept. Don't have interest in compost — no public demand	
Granbury	Hood	5718	no	no						
Marlin	Falls	6628	yes	yes				✔	Not a primary concern for the city at this time	potential
Hillsboro	Hill	8232	no	no						
Woodway	McLennan	8733	yes	yes	--	--	--	✔	No need for it; little interest from residents	
Bellmead	McLennan	9214	yes	yes	--	--	--	✔	$; not most important issue for them at moment	

Hewitt	McLennan	11085	yes	yes	✔	TCEQ contract	no	--	limited use/landscaping needs; $	
Belton	Bell	14623	yes	yes	✔	BRA contract	no	--	Produces to reduce landfill. Do have odor issues since the BRA plant is w/in city limits	No potential interest – already has contract

City	County	Pop.	Cont	Resp	Use comp	Type of compost used	Prod own	Do not use comp	Why they do not use compost or other miscellaneous comments	Interest in dairy compost
Stephenville	Erath	14921	no	no						
Gatesville	Coryell	15591	yes	yes				✔	Not a primary concern for the city right now	No potential
Brownwood	Brown	18813	yes	yes	✔	Mulch-plan to do compost in 2-3 yr	✔	--	Produce mulch to reduce landfill. If they use manure, they would utilize MSW first	Potentially — before they initiate MSW system
Weatherford	Parker	19000	yes	Yes	✔	purchase-Clear Fork Materials	no	--	Would like to start producing their own, but staffing problems	Potential — see if we can beat price
Benbrook	Tarrant	20208	no	no						
Burleson	Johnson	20976	yes	yes	✔	green waste, poultry litter;	✔		Produce own because they do not consider compost readily available to them	Very interested depend on price and product quality
Southlake	Tarrant	21085	yes	yes	✔	contract out — no other info avail.	?	--	--	
Watauga	Tarrant	21908	yes	yes	--	--	--	✔	do not consider it readily avail.; not enough manpower; have used bagged fert.	Please send info!
Cleburne	Johnson	26005	yes	yes	✔	mulch — city use and give away rest	✔	--	Produce mulch to reduce landfill; charge tipping fee to homeowners	
Keller	Tarrant	27345	yes	no						
Mansfield	Tarrant	28031	yes	no						
Georgetown	Williamson	28339	yes	yes	✔	Free-TX Disposal System	no	--	Would use dairy compost depending on market. Currently has free alternate source	potential
Copperas Cove	Coryell	29455	yes	no						
Hurst	Tarrant	36273	yes	no						
Haltom City	Tarrant	39018	yes	yes	✔	city green waste; manure	✔	--	--	

City	County	Pop.	Cont	Resp	Use comp	Type of compost used	Prod own	Do not use comp	Why they do not use compost or other miscellaneous comments	Interest in dairy compost
Grapevine	Tarrant	42059	yes	no						
Euless	Tarrant	46005	yes	no						
Bedford	Tarrant	47152	yes	yes	--	--	--	✔	$; manpower; small city-basic procedures	
Temple	Bell	54514	yes	yes	✔	BRA contract	no	--	Temple did not reply, but BRA contact did state they serve 75% Temple & 25% Belton	No potential interest – already has contract
N Richland Hills	Tarrant	55635	yes	no						
Killeen	Bell	86911	yes	no						
Waco	McLennan	113726	yes	yes	✔	prod mulch and buy dairy compost	no	--	Use mulch in city. Sell compost to citizens. Want to help — Dir of Water Utilities	Already utilize for citizens — potential city use?
Arlington	Tarrant	332969	yes	yes	✔	Erath Earth dairy compost	--	--	Use for football fields, had presentation last week-hoping more interest will develop	
Fort Worth	Tarrant	534694	yes	yes	✔	mulch and compost-beef	✔	--	Only use in city parks and given to schools; citizens want more compost; need more	not sure if city would take manure

Appendix F

County Compost Use Demonstration Reports

Comanche County

Coryell County

Erath County

McLennan County

Palo Pinto County

Somervell County

Stephens County

Tarrant County

COMANCHE COUNTY DEMONSTRATION
Comanche Post Office Lawn

LOCATION
The Comanche Post Office lawn Located at West Oak Avenue in Comanche, TX.

OBJECTIVE
The primary objective of this demonstration is to compare the effects of dairy manure compost and inorganic fertilizer on the growth and appearance of the turfgrass on a city post office lawn in Comanche, Texas.

INTRODUCTION
Given the close proximity and connection of Comanche to the dairy industry, the use of dairy manure compost by Comanche citizens would be an ideal market for the material. With this in mind, Robert Whitney, Comanche County Extension Agent, developed plots (Figure 1) on the post office lawn to demonstrate the potential benefits dairy compost can provide to soil and turfgrass. By utilizing the Post Office lawn for this demonstration, citizens could conveniently view the impacts of dairy manure compost on the appearance and growth habits of the turfgrass.

1	2	3
2	1	3
3	2	1

Figure 1. Plot design of the Comanche County turfgrass demonstration. Each plot was 20 ft by 9 ft. Numbers in figure represent various treatments and each treatment was replicated 3 times. A 3 ft alley separated each replication of treatments.

PROCEDURE
The demonstration consisted of nine plots (three treatments replicated three times each) and was established on the post office lawn in Comanche, Texas. Each of the three treatments were randomly assigned to the nine plots. Compost applications were applied on March 30, 2004 and inorganic nitrogen fertilizer treatments were applied on April 21, July 15, and September 15, 2004.

The three treatments included:
1. Inorganic nitrogen fertilizer (Figure 2)
2. Dairy manure compost applied once (Figure 3)
3. Dairy manure compost applied twice (Figure 4)

Dairy manure compost was applied at a rate of 20 tons per acre in both treatment 2 and 3. Also, both dairy manure compost treatments received subsequent timely applications of inorganic nitrogen fertilizer at a rate of 20 pounds per acres.

RESULTS

Few visual differences were noted throughout the growing season between each plot created on the post office lawn in Comanche, TX. In addition, no numerical data such as soil tests were obtained for the plots.

The only noticeable difference was in treatment 2, replication 2, where the St. Augustine grass grew into all surrounding plots. This was potentially due to high rainfall received during 2004 that favored the St. Augustine over Bermuda grass. Further, the St. Augustine plot was more dense than any other plot at the initiation of the demonstration.

All other plots except for the St. Augustine were somewhat thin and yellow.

CONCLUSION

The high amounts of natural nutrients present in the post office lawn potentially created a situation in which all plots performed equally well resulting in few visual differences. The thin and yellow appearance of most of the plots, although not verified with data, could have resulted from an iron deficiency caused by excess phosphorus.

Ideally, a new location, which contains lower soil nutrients, would be a better location for a demonstration in the future.

Figure 2: Treatment 1, which received an application of only inorganic fertilizer**.**

Figure 3: Treatment 2, which received a single application of dairy manure compost at 20 tons per acre rate followed by an inorganic nitrogen fertilizer application at a rate of 20 lbs per acre applied 4 times.

Figure 4: Treatment 3, which was treated twice with dairy manure compost at 20 tons per acre followed by an application of inorganic nitrogen fertilizer at 20 lbs. per acre applied 4 times.

CORYELL COUNTY DEMONSTRATION
Coryell County Courthouse

LOCATION
The Coryell County Courthouse lawn located on East Main in Gatesville, Texas.

OBJECTIVE
The primary objective was to demonstrate to Coryell County residents the benefits of dairy manure compost produced in the Bosque River Watershed when utilized as an amendment to improve vegetation and soil properties.

INTRODUCTION
Coryell County is located within the Leon River Watershed, which along with its neighboring North Bosque River Watershed, is dominated by the dairy industry. In an effort to prevent potential runoff from dairies, compost is being produced from dairy manure in both the Leon and Bosque River Watersheds. Given both watersheds benefit economically from the dairy industry, it is imperative that local support is given to the dairy and compost producers.

The Coryell County courthouse project allows residents to see the many benefits of dairy manure compost, specifically, its use to improve vegetation quality and soil properties. By utilizing dairy manure compost in local landscapes, the public is helping protect the environment while at the same time supporting the dairy industry.

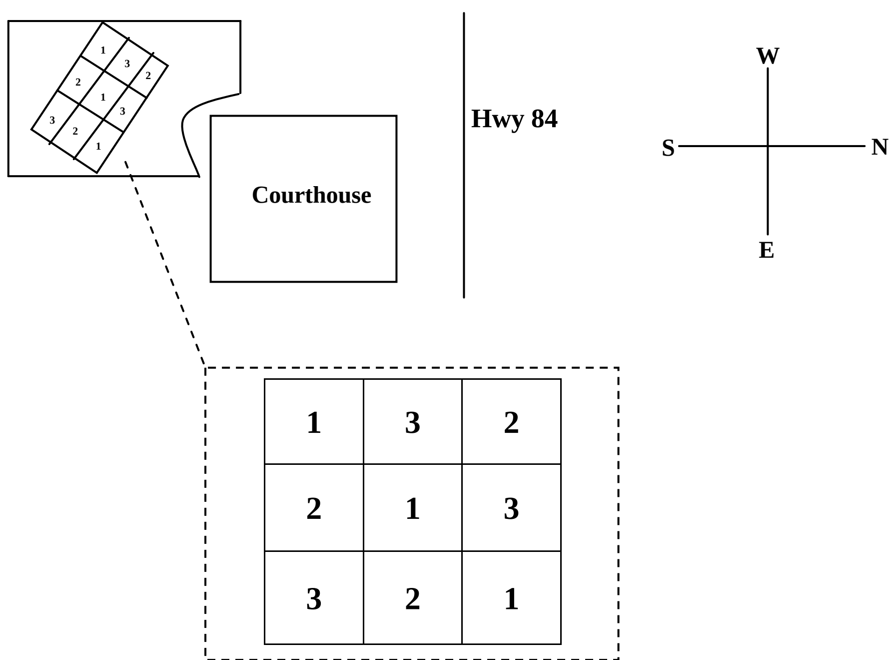

Figure 1. Demonstration location and plot design. Numbers in figure represent various treatments utilized in the demonstration

PROCEDURE

Nine plots, each measuring 20 feet by 10 feet, were established on the Coryell County courthouse lawn in Gatesville, Texas. Three different treatments were applied and each treatment was randomly assigned and replicated 3 times (Figure 1).

The three treatments utilized were:

1. Untreated
2. Compost at 20 tons per acre
3. Compost at 40 tons per acre.

Inorganic fertilizer (N-P-K) was applied as a part of the standard maintenance practices to the entire plot area and courthouse lawn (including the demonstration area) on April 26, 2004. Compost was evenly spread onto plots receiving treatments 2 and 3 using a rolling basket applicator (Figure 2) on April 27, 2004.


Figure 2: Dairy compost was applied using a rolling basket applicator.

Table 1. Soil analysis results for the Coryell County Courthouse lawn prior to compost application.

N	P	K	Ca	Mg	Na	Z	Fe	Cu	Mn	DM	LOI	pH	EC
		%					ppm			%			umhos/cm
0.785	0.1702	0.2735	2.6215	0.2098	0.2154	85.6	4785	35.81	119.1	63.7	18.9	8.1	1280

RESULTS

Visual differences between treatments were not evident due to several factors. TCE was not able to secure plot location prior to the spring fertilization and therefore, as a standard maintenance practice inorganic fertilizer was applied to the lawn before demonstration installation, which meant all plots (all treatments) also received inorganic fertilizer. Thus, the inorganic fertilizer provided adequate nutrients to the entire lawn resulting in little to no response from the nutrient benefits of compost.

Secondly, rainfall for the summer was well above normal, which also resulted in little to no visual growth response from compost applications. While no visual results were observed, the addition of dairy compost to the lawn did potentially benefit soil chemical and physical properties. Table 1 displays the soil analysis results of the compost applied to the courthouse lawn.

CONCLUSION

The dairy compost used on the Coryell County courthouse lawn did not result in visible differences when compared to the 'untreated' plot. Lack of results was most likely due to the application of inorganic fertilizer prior to compost application. Regardless of the lack of visible differences, the benefits of compost, the improved soil properties, were still a potential outcome.

As part of the objective to publicize the use of dairy compost, the Gatesville Messenger published an article highlighting the demonstration on May 15, 2004. This article can be found at http://compost.tamu.edu/demos/coryell_compost-study.pdf

ERATH COUNTY DEMONSTRATION
Lovell Lawn and Landscape Raises Oak Tress in Dairy Compost

LOCATION
The business of Lovell Lawn and Landscape located 6744 South U.S Highway 281 in Stephenville, TX.

OBJECTIVE
The primary objective of this demonstration was to evaluate the use of dairy manure compost and similar dairy manure products to enhance the production of Live Oak trees being grown at Lovell Lawn and Landscape.

INTRODUCTION
Jason Lovell, president of the Lovell Lawn and Landscape Company, primarily had been using bark mulch for potting his landscape plants. However, in working with Mr. Joe Pope, Erath County Extension Agent (retired), Mr. Lovell agreed to conduct a demonstration utilizing dairy manure compost and other products as an alternative potting mix.

Lovell compared bark mulch, dairy manure compost and Bovinite™ as growth media for approximately 100 Live Oak trees grown during the spring and summer of 2004. Bovinite™ is a commercial dairy compost product specially processed to reduce overall salt content and increase the nitrogen to phosphorus ratio. Further the material contains a high organic matter content, which decreases the overall density compared to the typical dairy manure compost produced in the Bosque River Watershed.

PROCEDURE
The three treatments compared by the landscape company included:
1. 100% general potting mix (bark mulch)
2. 100% Bovinite™ (commercial high organic matter material)
3. 100% Dairy Compost

Each treatment was introduced as growth media when the Live Oaks were repotted from 30-gallon to 45-gallon containers between February 2004 and September 2004. To improve validity of the demonstration, each treatment was replicated three times.

RESULTS
Initially, Pope and Lovell planned to take measurements on changes in tree diameter and other indicators of plant response. Opportunity to sell the trees, however, precluded collection of measured growth data. In the absence of measured data, landscape personnel did make the following visual observations.

Live oaks grown in Bovinite™ exhibited the best overall performance followed by those grown in the dairy manure compost. Trees grown in those media outperformed those potted in the bark mulch in rate of growth, root proliferation and overall appearance.

Specifically, trees grown in both Bovinite™ and the dairy manure compost required less frequent irrigation than those potted in the bark mulch, which therefore minimized moisture stress due to delayed water. In addition to improved performance, the use of the higher organic material also resulted in some time and labor savings
.

The dairy manure compost utilized in the demonstration had a higher inorganic (sand) content and lower organic matter content than both the Bovinite™ and bark mulch. Consequently, containers with live oaks potted in dairy manure compost were heavier than those trees potted in Bovinite™ and bark mulch**.**

CONCLUSION

The dairy manure compost and Bovinite™ produced in the Bosque and Leon River Watershed proved to be better potting materials than the bark mulch Lovell Lawn and Landscape was previously using. Both materials allowed for less irrigation and fertilization, which in turn decreased labor costs. Although the dairy compost did increase container weight due to the excess amount of inorganic material (sand), Lovell reported that customers were pleased with the condition of the Live Oaks and not concerned about weight differences.

As a result of the demonstration, Lovell Lawn and Landscape continues to buy about six truckloads of dairy manure compost a year from the commercial composting operations located in the North Bosque and Leon River watersheds. The majority of the compost is used in the maintenance and renovation of landscapes (lawns, flower beds, etc.) for customers that include private home owners and businesses in Stephenville and surrounding communities.

Currently, the company produces only a limited number of container grown trees. For this, Lovell utilizes a commercial potting media that contains dairy manure compost and is specifically formulated and marketed for that purpose by a local composter.

McLENNAN COUNTY DEMONSTRATION
Riesel ISD utilizes Dairy Compost to Maintain Football Practice Field

LOCATION
The Riesel Independent School District High School practice football field in McLennan County.

OBJECTIVE
The primary objective of this demonstration was to evaluate the health, density, and appearance of the practice football field following a top dress application of dairy manure compost alone and dairy manure compost combined with fertilizer on a.

INTRODUCTION
The Riesel Independent School District's high school practice football field was recently recrowned and in fair condition. School personnel wanted to maintain the field's excellent health and further improve the density of the existing turf. Further, the School realized the poor condition of their actual playing field and were exploring options to improve its quality. Treatment and maintenance of the practice field was an excellent opportunity to evaluate some of these management techniques, which would ensure they could choose the most effective and cost efficient method to improve their playing field.

With assistance from Mr. Will Kiker, McLennan County Extension Agent, and Dr. Jim McAfee, Texas Cooperative Extension Turfgrass Specialist, Riesel ISD formulated a plan to conduct a demonstration on the practice field and implement specific management practices for their playing field. Because of the Dairy Manure Compost Incentive Program, Riesel ISD elected to apply dairy manure compost on the practice field as an alternative nutrient source. Application of the compost, mechanical aeration and efficient irrigation were all components of the practice field demonstration.

PROCEDURE
The demonstration was initiated on June 22, 2005 when approximately 80 tons per acre of top-dress quality dairy manure compost was uniformly applied to the Riesel ISD practice football field. The compost was applied (Figure 1) utilizing a Turf Tiger® spreading unit (Figure 2) provided by the Agricultural Research Experiment Station in Stephenville. The compost spreader was purchased with grant funds provided by the Texas Commission on Environmental Quality through an US EPA Clean Water Act Section 319(h) Grant. Also in conjunction with the grant, Riesel ISD received a rebate of $5 per CY of compost purchased, which improved the economics of the demonstration and specifically, this management practice for the school.

The spreading unit was calibrated (Figure 3) prior to adding dairy manure compost to the field to ensure a uniform application. Subsequently, the field was mechanically aerated to partially incorporate the compost, enhance nutrient and water uptake and to reduce compaction.

Figure 1. Broadcast application of dairy manure compost on Riesel ISD practice football field.

Figure 2. Loading Turf Tiger® spreading unit with top-dress quality dairy manure compost.

Figure 3. To calibrate the spreader, dairy manure compost is applied into collection unit and weighed as indicated above. By calculating distance of spreader and amount applied, the spreader can be accurately calibrated to ensure a uniform application rate across the field.

Irrigation was applied (Figure 4) for the first time 3 weeks after compost application. As the season progressed, school personnel wanted to evaluate the addition of inorganic nitrogen fertilizer as well. Therefore, an application of inorganic nitrogen was applied to the south end of the field at a rate of 1 lb nitrogen per 1,000 square feet approximately 4 weeks after the compost application.

Figure 4. Irrigation was applied for the first time approximately 3 weeks after compost application.

Supplemental applications of inorganic nitrogen are typically utilized because the ratio of nutrient concentrations in a compost product is rarely an exact fit for turfgrass needs. An application of compost that meets nitrogen requirements will often provide excess phosphorus. As a result, compost application rates should be determined based on turfgrass phosphorus requirements and supplemented with a phosphorus free inorganic fertilizer to complete turfgrass nitrogen and/or potassium requirements.

In addition to the demonstration conducted on the practice field, TCE personnel also worked with the School to implement alternative management techniques on the playing field. Realizing the field potentially needed complete reconstruction, the school opted to implement inexpensive management techniques for the current year in order to bring the field to proper playing condition for the upcoming season. Throughout the summer of 2005, the school mechanically aerated the playing field on a frequent basis and TCE conducted an irrigation audit in July to ensure irrigation applications were both effective and efficient. By implementing these inexpensive management practices, the school was able to better arrange funding for pending future activities such as recrowning and / or dairy compost applications. Further, the school was able to evaluate the effects of dairy manure compost on the practice field without investing additional funds in the playing field.

RESULTS

A pre and post soil sample was collected from the practice field. The pre soil sample was collected in May 2005 and a follow-up soil sample was taken 6 months after demonstration installation. The post treatment soil sample was collected from both the North and the South ends of the football field. The North end as stated did not receive a supplemental rate of inorganic N, while the South end did receive the supplemental inorganic nitrogen application at a rate of 1 lb nitrogen per 1,000 square feet approximately 4 weeks after the compost application. All soil sample results are presented in Table 1.

Dairy manure compost was sampled prior to application in June 2005 and results for dairy manure compost characteristics are presented in Table 2.

Table 1. Laboratory analysis results of soil samples taken before (PRE) application of compost and 5 months after (POST) the application of compost.

		Nitrate-N	P	K	Ca	Mg	S	Na	pH	Cond.
		------------------------------------ppm-----------------------------								umho/cm
PRE	**Whole field**	19	87	320	4,381	186	28	240	7.8	291
POST	**North**	46	161	513	4827	251	50	402	7.9	465
	South	55	169	567	5650	281	70	357	7.8	516

Table 2. Laboratory analysis results of top-dress quality dairy manure compost based on an oven dried sample (% and ppm) and based on an as received basis (pounds per wet ton).

N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Moisture
------------------------------%------------------------------						--------------ppm--------------				%
1.3600	0.3915	1.4216	13.2474	0.6471	0.5650	140	8,095	59.5	260.5	11.9
----------------------------------lbs per wet ton of compost-----------------------------------										
23.97	15.80	30.07	233.48	11.40	9.96	0.247	14.267	0.105	0.459	NA

The dairy manure compost application, aeration and efficient irrigation resulted in improved turfgrass density and uniformity on the practice field (Figure 5). These improvements were noted as the field grew greener in color and the turf even began out competing some of the unwanted grass species. The post soil sample results did exhibit elevated levels of P. While these results were not at an environmentally harmful level, it should be noted that school personnel should avoid any applications of P or organic type fertilizers for several years or until soil tests indicate a need for P.

Figure 5. Riesel ISD practice football field overview prior (left) to and 1 month after (right) top dress quality dairy manure compost was applied.

CONCLUSION

By cooperating with TCE, Riesel ISD was able to evaluate various management techniques for the maintenance of their practice field and the recovery of their playing field in an economical manner. In addition, the School District was supporting a local industry and helping protect a neighboring natural water source.

PALO PINTO COUNTY DEMONSTRATION
Santo ISD Football Field

LOCATION
The Santo I.S.D. High School Football Field located at Farm-to-Market Road 2201 in Santo, TX.

OBJECTIVE
The primary objective of this demonstration was to evaluate the effects of proper management practices such as the addition of dairy manure compost and commercial (nitrogen) fertilizer, aeration and timely irrigation on the condition of the Santo ISD football field.

INTRODUCTION
The Fighting Wildcats of Santo High School played football on a field that was considered to be in “fair to poor” condition largely due to compacted soil and substandard turfgrass cover (Figure 1). Scott Mauney, Palo Pinto County Extension Agent, Texas Cooperative Extension, offered his assistance to the School Board in renovating the field. Mauney contacted Dr. Jim McAfee, Extension Turfgrass Specialist in Dallas, and together they formulated a sports field management program that included mechanical aeration of the football field, top-dress applications of dairy manure compost and commercial (nitrogen) fertilizer, timely applications of irrigation and efficient weed control practices.

Figure 1: A close-up photograph of the football field vegetation prior to demonstration initiation. Compacted soils reduced turfgrass stand, which led to bare areas and excess weed growth.

PROCEDURE

The demonstration was implemented in May, 2004, when top-dress quality dairy manure compost (Figure 2) was uniformly applied to the Santo High School football field at a rate of 80 tons per acre (approximately 108 cubic yards per acre) using a Turf Tiger® spreading unit (Figure 3).

The spreading unit was calibrated (Figure 4) prior to adding dairy manure compost to the field to ensure a uniform application (Figure 5). Subsequently, the field was mechanically aerated to partially incorporate the compost, enhance nutrient and water uptake and to reduce compaction. Immediately following compost application and aeration, the field received an application of 20 pounds per acre of inorganic nitrogen fertilizer (Figure 6). As the season progressed, the field received an additional 20 pounds of inorganic nitrogen fertilizer per acre and was mechanically aerated a second time.

The supplemental rate of inorganic nitrogen is typically utilized because the ratio of nutrient concentrations in a compost product is rarely an exact fit for turfgrass needs. An application of compost that meets nitrogen requirements will often provide excess phosphorus. As a result, compost application rates should be determined based on turfgrass phosphorus requirements and supplemented with a phosphorus free inorganic fertilizer to complete turfgrass nitrogen and/or potassium requirements.

Figure 2. Top-dress quality dairy manure compost prior to application

Figure 3. Tractor pulled Turf Tiger® mechanical spreading unit.

Figure 4. Calibration of the spreading unit to ensure accuracy

Figure 5. Uniform application of dairy manure compost across the football field.

Figure 6. Application of inorganic nitrogen fertilizer following the dairy manure compost application.

RESULTS

The treatments and timely maintenance resulted in improved turfgrass coverage and uniformity. Improvements were noted in grass density, health, color and overall appearance (Figure 7).

Unfortunately, the condition of the field has again declined primarily due to overuse this last season. Athletes from a newly constructed school were temporarily reassigned to the Santo ISD field and it was also utilized by community soccer programs. The expectation is that with the addition of new sports facilities in the community, use of this field will again be largely limited to varsity sporting events and field health can once again improve.

It is at this point that the board expects their investment in the dairy manure compost application to pay dividends. The one-time heavy application of compost is expected to improve chemical and physical properties of the soil, which will potentially hasten the recovery of the field from damage caused by overuse or other stresses such as climate. In addition, large compost applications can improve turfgrass health and optimize turfgrass response to fertilization, irrigation, aeration, and other management practices. Thus, standard fertilizer treatments and management practices (e.g. irrigation, aeration, etc.) can maintain the field for several years before re-treatment with compost is again necessary.

CONCLUSION

The members of the Santo ISD board were satisfied with the improvements the addition of dairy manure compost, inorganic nitrogen fertilizer, and proper management techniques had on the Santo High School football field.

Because of the positive results, the Santo ISD School Bard considered a similar compost-fertilizer-management program for the baseball field in 2005. However, plans, to construct a new field were also under consideration. Thus, the board decided to delay the substantial investment of a dairy compost application until baseball field construction plans were finalized.

The costs of purchasing and hauling dairy compost can be substantial, especially for smaller school districts with limited budgets. Figure 8 is an example of the itemized costs associated with compost purchase and transport.

Figure 7. Santo ISD football field closeup (left) and overview (right) several months after implementation of the sports field management program, which included applications of dairy manure compost and inorganic nitrogen fertilizer.

Compost Budget Sheet

Compost (200 CY @ $16.00/CY).................	$ 3,200.00
Freight (50 Mi @ $3.00/loaded Mi X 3 loads)..	$ 450.00
Sub-total (before rebate)....................	$ 3,650.00
Composted Manure Incentive Payment (Rebate of $5.00/CY)..................	-$ 1,000.00
TOTAL COSTS.................................	**$ 2,650.00**

Figure 8. Estimated costs for the purchase and transportation of dairy manure compost. Costs are related based on a top-dress application on a football field at a rate of 80 tons per acre.

SOMERVELL COUNTY DEMONSTRATION
City Park Soccer Field

LOCATION
The dairy compost demonstration was located near the Glen Rose City Soccer Field located on Texas Drive in Glen Rose, TX.

OBJECTIVE
The primary objective of this demonstration was to evaluate the effects of dairy manure compost on the growth and appearance of turfgrass on a city soccer field in Glen Rose, Texas.

INTRODUCTION
In cooperation with the City of Glen Rose, Mr. Joe Geistweidt, Somervell County Extension Agent (retired), selected an area immediately adjacent to the city soccer field for the dairy manure compost demonstration. Given the extensive use of city sports fields, Geistweidt was unable to utilize the actual field for the demonstration. However, by implementing the plots beside the field, he would be able to compare the effects of dairy manure compost to the standard management program of the soccer field. Finally, the use of an organic amendment, such as dairy manure compost, on such sports fields was an ideal fit given their high traffic patterns and the desire to reduce inorganic chemical use.

1	**2**	**3**	**4**
2	**4**	**1**	**3**
3	**1**	**4**	**2**

Figure 1. Plot design of the Somervell County turfgrass demonstration. Each plot was 10 ft by 10 ft. Numbers in figure represent various treatments and each treatment was replicated 3 times. A 3 ft alley separated each replication of treatments.

PROCEDURE
Twelve plots (Figure 1) were established immediately adjacent to a city soccer field in Glen Rose, Texas. The four treatments, each replicated three times, were randomly assigned to the 12 plots.

The four treatments used included:
1. Untreated (no compost or fertilizer)
2. Inorganic Fertilizer
3. Dairy manure compost applied once
4. Dairy manure compost applied twice

Both dairy manure compost treatments were applied at a rate of 20 tons per acre and both were supplemented with inorganic fertilizer at 20 pounds nitrogen per acre applied 4 times throughout the growth season.

To accurately determine the application rates, compost was weighed in the field and applied using a basket spreader (Figure 2).

The data collected throughout the demonstration included a pre (approximately March) and post (approximately November) soil sample analyzed for nutrients, pH, organic matter and salinity, In addition, turf color, quality and density and weed presence were rated every 2 weeks from April thru July. Color, density and quality ratings were conducted on a scale of 1 to 9 with a higher number representing better color, density or quality. A good rule of thumb is any rating of 6 or higher represents a turf that would be acceptable in the average yard. Weed presence ratings were also conducted on a scale of 1 to 9 where 1 represents no weeds present and 9 represents excessive weed growth within the plot. Finally, photo documentation was collected throughout the season.

Figure 2. Dairy manure compost being weighed (left) and applied (right) utilizing a basket spreader.

RESULTS

Data from all four ratings are presented in Tables 1 through 4. Standard deviations between means are also listed to show significance difference.

In all rate timings presented, plots treated with inorganic fertilizer and compost had significantly better color than the untreated plot. However, no significant differences were observed between the dairy manure compost and the inorganic fertilizer treatments.

Turf density displayed similar results with the exception of the June 16 rating. The inorganic fertilizer treatment yielded significantly better turf quality than the untreated at all three ratings. However, compost treated plots had variable turf quality results compared to both the untreated and the inorganic fertilizer treated plot.

Finally, weed presence was variable across all four treatments.

Rating Date	Treatments				STD DEV
	Untreated	IF	DMC once	DMC twice	
May 18	5.3	6.7	7.7	7.0	0.98
June 16	5.0	6.3	6.3	6.7	0.74
July 13	5.0	7.3	7.0	7.0	1.07

Table 2. Turf density evaluations

Rating Date	Treatments				STD DEV
	Untreated	IF	DMC once	DMC twice	
May 18	7.0	7.7	8.0	7.7	0.42
June 16	7.7	8.0	7.3	7.0	0.43
July 13	7.3	7.7	8.0	7.7	0.27

Table 3. Turf quality evaluations.

Rating Date	Treatments				STD DEV
	Untreated	IF	DMC once	DMC twice	
May 18	5.0	5.7	6.3	5.3	0.57
June 16	5.0	5.3	5.0	5.0	0.17
July 13	5.0	5.3	5.3	5.0	0.19

Table 4. Weed presence evaluations.

Rating Date	Treatments				STD DEV
	Untreated	IF	DMC once	DMC twice	
May 18	3.3	3.3	2.3	3.7	0.58
June 16	2.7	2.3	3.0	3.0	0.32
July 13	3.0	2.3	1.7	2.7	0.57

CONCLUSION

Visual differences in turf color, density and quality between treatments during the first year resulted primarily from the addition and availability of nutrients. While both dairy manure compost and inorganic fertilizer provide such nutrients, the inorganic nutrients are more immediately available and therefore, these plots typically showed visual differences. Photo documentation throughout the demonstration illustrated this point (Figure 3).

Organic amendments, such as dairy manure compost, provide long term benefits such as the addition of micronutrients and improvements in soil tilthe, which enhances the water holding capacity of the soil and its aeration. However, these benefits were not recorded given the limited evaluation period of the demonstration. Further, such benefits are difficult to measure especially given the limited scope of the demonstration.

Regarding weed density, results were considered typical as none of these treatments should immediately affect weed presence. However, the consistent use of any nutrient amendment can potentially provide weed control over time. Essentially, turf density and quality responds to the nutrient inputs and out competes foreign species. The limited evaluation period for this demonstration, however, does not allow these benefits to be seen.

A second purpose for obtaining weed presence ratings was to determine if viable weed seed was present in the dairy manure compost. During the composting process, temperatures should reach adequate levels to destroy viable weed seeds and thus, produce a weed free material. Given the demonstration setting, however, Geistweidt utilized the opportunity to verify the dairy manure compost was weed free. With the weed ratings, it was determined only pre-existing weeds were present in the plots and therefore, the dairy manure compost was weed free.

Figure 3. Plot overview taken in May (left) and then taken in October (right). Nutrient availability in May was more consistent as noted by no visual differences between plots. However, plot boundaries are distinctly obvious in October picture. Plots with dark green color signify those that received subsequent nitrogen applications and therefore, had higher nutrient availability.

STEPHENS COUNTY DEMONSTRATION
Breckenridge ISD Practice Football Field

LOCATION
The Breckenridge High School football practice field located at 500 Block 2nd Street in Breckenridge, TX.

OBJECTIVE
The primary objective of this demonstration was to evaluate the effects of compost, and fertilizer on the health, density, and appearance of the turfgrass on the Breckenridge High School practice football field.

INTRODUCTION
The Buckaroos of Breckenridge High School had been practicing football on a field with compacted soil and poor grass cover and density on many sections. In conjunction with the Dairy Compost Utilization Project, Phillip Bales, Stephens County Extension Agent, offered to work with the school district to address these problems. With inputs from Dr. Jim McAfee, Extension Turfgrass Specialist in Dallas, Bales formulated a turf management demonstration that included mechanical aeration of the field, fertilization with dairy manure compost supplemented with inorganic nitrogen, and timely irrigation.

1	2	3
2	1	3
3	2	1

Figure 1. Plot design of the practice field demonstration at Breckenridge High School. Numbers in figure represent various treatments in the demonstration

PROCEDURE
Nine equally sized plots were developed within the 50’ by 100’ area high school football practice field in Breckenridge, TX (Figure 1). Each of the nine plots was randomly assigned one of the three treatments allowing for three replications of each treatment.

The treatments applied included:
1. Compost at 40 tons per acre
2. Compost at 40 tons per acre plus inorganic Nitrogen at 20 lbs N per acre
3. Inorganic Nitrogen at 60 lbs N per acre

The compost spreader and scale were calibrated to ensure accurate amounts of dairy compost were applied (Figure 2). Compost was applied with a tractor pulled Turf Tiger® spreading unit (Figure 3) provided by the Dairy Compost Utilization Project funds.

Figure 2: The compost spreader (left) and scale (right) were calibrated to ensure accuracy.

Figure 3: The tractor pulled rotary spreader.

RESULTS

Visual assessments of turf stand, density, color, and weed presence were collected through the summer and fall growing seasons. Overall health of practice field vegetation has improved across all treatments. Specifically, turf density improved providing coverage on many previously bare areas and the improvement was sustained even after athletic activity was resumed this school year.

Figure 4: Treatment 1.

Figure 5: Treatment 2.

CONCLUSION

Unfortunately the dairy compost used in the trial was not of top-dress quality, which resulted in some unintended consequences. This "general use" grade material contained small rock (limestone or caliche) fragments, which had to be removed by hand. Also, the appearance of some weeds in the turf suggested that the product was not fully composted, e.g. proper temperatures were not maintained. When composted correctly, dairy manure compost should not contain any viable weed seeds. While use of this product could be effective in other situations, such as cases where it would be incorporated into the soil, its use as a top-dress would not be recommended.

Tommy Wolfe, Director of Maintenance and Transportation, Breckenridge Independent School District, said that $200 was spent annually to purchase and apply inorganic fertilizer to the football field before the demonstration and the $150 spent on irrigation annually was not affected. Because the price of the compost exceeds the amount budgeted for the practice field every year, it is not likely that Breckenridge ISD will purchase more and it has recently been decided that artificial turf will soon be used on the field.

TARRANT COUNTY DEMONSTRATION
Hurst Courthouse Lawn and Flowerbeds

LOCATION
The lawn area and perennial flowerbeds of the Tarrant County Northeast Sub-Courthouse located at 645 Grapevine Highway in Hurst, TX.

OBJECTIVE
The primary objective of this demonstration was to improve the growth habits and healthy appearance of turfgrasses and perennial flowers at the Tarrant County Northeast Sub-Courthouse.

INTRODUCTION
The landscape maintenance staff for the Tarrant County Northeast Sub-Courthouse continually encountered problems in maintaining good growth and healthy appearance of turfgrasses and perennial flowers at the facility. When increasing the irrigation schedule from once to twice per week failed to improve plant performance and appearance, Dotty Woodson, Tarrant County Extension Agent, suspected problems related to fertility and soil conditions.

To address these landscape issues, Woodson established test plots to demonstrate the use of dairy manure compost combined with recommended rates of commercial fertilizer on turfgrass (Figure 1) and perennial flowerbeds (Figure 2). The dairy manure compost was purchased from a commercial composter located in the North Bosque River Watershed. Research and demonstration trials conducted at the Dallas Research and Extension Center showed dairy manure compost used in combination with inorganic fertilizer optimized plant growth, prepared soil for new plantings, and renovated problem areas in turfgrass and flower beds.

PROCEDURE
For both the perennial flowerbed and the lawn area, project personnel utilized different combinations of inorganic nitrogen fertilizer and dairy manure compost as a soil and vegetation amendment. By comparing different mixtures, personnel could determine the most beneficial mixture required to optimize and improve turfgrass and perennial growing conditions.

The treatments utilized in the turfgrass demonstration were:

1. Inorganic fertilizer only
   A recommended rate of 8 pounds nitrogen per 1,000 square feet applied twice during the growing season
2. Dairy manure compost applied once
   A rate equivalent to 20 tons per acre
3. Dairy manure compost applied twice
   A rate equivalent to 20 tons per acre

1	2	3
2	1	3
3	2	1

Figure 1. Plot design of the turfgrass demonstration. Numbers in figure represent various treatments in demonstration.

In addition, both dairy compost treatments also received 20 pounds of inorganic nitrogen applied twice during the growing season. The supplemental rate of nitrogen is typically utilized because the ratio of nutrient concentrations in a compost product is rarely an exact fit for crop needs. An application of compost that meets nitrogen requirements will often provide excess phosphorus. As a result, compost application rates should be determined based on crop phosphorus requirements and supplemented with a phosphorus free inorganic fertilizer to complete crop nitrogen and/or potassium requirements.

The treatments utilized for the perennial flowerbeds included:

1. Inorganic fertilizer only
   A rate of 8 pounds of nitrogen per 1,000 square feet
2. Dairy manure compost
   At a rate equivalent to 100 tons per acre and incorporated to a 6 inch depth
3. Dairy manure compost plus 20 pounds of inorganic nitrogen
   At a rate equivalent to 100 tons per acre and incorporated to a 6 inch depth

To convert the application rate to a smaller scale for the flowerbeds, Woodson determined the 100 ton per acre rate is equivalent to approximately a 6 inch layer of the material evenly applied on the soil surface.

If the specified use or surrounding vegetation allows for incorporation of compost, it is recommended as incorporation of organic amendments, such as dairy compost, typically provides greater benefit than topdress applications.

Bed 1	1	2	3
Bed 2	2	1	3
Bed 3	3	2	1

Figure 2. Plot design of the perennial flowerbed demonstration. Numbers in figure represent treatments in demonstration

RESULTS

Turfgrass growth improved in vigor and color in the demonstration plots where compost and fertilizer were added. The differences were clearly visible and prompted many clients visiting the sub-courthouse to comment about the improved appearance of the turfgrass.

The growth and vigor of the ornamental plants were also greatly improved in the plots where compost and compost plus fertilizer were added.

CONCLUSION

In the flowerbed demonstration incorporation of the compost into the top 6 inches of soil created a much improved environment for plant growth and development. The dairy manure compost provided essential nutrients required by plants, added organic matter that improved soil physical properties, and increased water infiltration and retention within the soil.

Dotty Woodson said the county staff has decreased water costs after the demonstrations plots were established on the sub-courthouse turfgrass and flowerbeds. In the past, the staff watered twice a week, and following the demonstration the staff decreased watering to once a week. Woodson was unsure of the water savings in dollars for the county as a result of the education programs and demonstrations, but she was sure her time with the staff throughout the education programs and demonstrations helped decrease the volume of irrigation water and saved the county money.

In addition to water savings for Tarrant County, the use of dairy manure compost also benefited neighboring counties by recycling and removing the valuable nutrients and organic material produced cooperatively by the dairy operations and compost facilities in the North Bosque Watershed.

Appendix G

Are you Specifying Texas Compost Yet?

Article provided for the Texas Chapter of the American Society of Landscape Architects

Are YOU Specifying Texas Compost Yet?

Ron Alexander, R. Alexander Associates, Inc.

The Texas composting industry has expanded significantly over the past 10 years. Its growth, in many ways, can be attributed to the popularity of the *composting process* as a popular method of transforming various organic by-products (e.g. yard trimmings, manure, etc.) into high quality soil amendment products. A great effort has gone into composting manure generated in the Bosque and Leon watersheds, including much hard work by the Texas Commission on Environmental Quality (TCEQ) to reduce the amount of organic residuals being discarded in the landfill. US EPA funds were even obtained to provide an incentive for the transport of manure to regional composting facilities and to provide incentives for state and local government to buy this compost. High quality composts are now being produced from these feedstocks. In fact, the product is so popular with TX DOT (having been able to re-vegetate sites which were barren for 30 years) that they purchased over 250,000 cubic yards in 2002.

For this reason, many are working hard to educate the *green industry* about the numerous benefits; environmental, agronomic and financial, that are realized when compost is specified and used in place of topsoil or peat moss. It is very clear, based on experience in other parts of the country, that landscapers and landscape architects can play a large role in developing markets for compost. The subsequent article will describe a variety of landscape uses of compost, as well as its many benefits.

Compost provides many benefits to the soil, the plants, the environment and to the pocketbook of the user. It is readily available in most parts of the state and its use should be considered in every project for which you write specifications.

What is Compost?

Compost is the product resulting from the controlled biological decomposition of organic material. Higher quality composts are stabilized to the point that they are beneficial to plant growth, and bear little physical resemblance to the organic materials from which they were produced. These materials may include yard trimmings, biosolids, manure, and other feedstocks. Compost is primarily used for its soil conditioning properties, but it can also provide significant amounts of plant nutrients.

How is Compost Produced?

All compost, regardless of the original feedstock, is produced through the activity of aerobic (oxygen requiring) microorganisms. These microbes require oxygen, moisture and food in order to grow and multiply. When these resources are maintained at optimal levels, the natural decomposition process is greatly accelerated. Their activity generates significant heat, as they transform the organic feedstocks into a stable soil conditioner. The composting process, when properly managed, includes a high temperature phase that sanitizes the product and encourages a high rate of decomposition, and a lower temperature phase that allows the compost to stabilize and become agronomically viable.

Compost Benefits and Applications

As previously mentioned, the use of compost can provide many 'soil' benefits. It improves the physical, chemical and biological characteristics of the soil and media to which it is blended. Most of these benefits are listed in the table below.

Prepared in cooperation with the Texas Commission on Environmental Quality and U.S. Environmental Protection Agency.
The preparation of this report was financed through grants from the U.S. Environmental Protection Agency
through the Texas Commission on Environmental Quality.

Benefits to Compost Use

- Improves the soil structure, porosity, and bulk density — creating a better plant root environment
- Increases moisture infiltration and permeability of heavy soils — improving drainage and reducing erosion and runoff
- Improves moisture holding capacity of light soils — reducing water loss and nutrient leaching
- Improves and stabilizes soil pH
- Improves cation exchange capacity (CEC) of soils — improving their ability to retain nutrients for plant use
- Supplies a variety of macro and micro nutrients
- Supplies significant quantities of organic matter
- Supplies beneficial microorganisms to the soil — improving nutrient uptake and suppressing certain soil-borne diseases
- Binds and degrade specific pollutants

Compost is primarily used as a soil amendment, but can be used on the soil surface as a topdressing material (if finely screened) or erosion control product (if left coarser or blended with mulch), as a planting mix or manufactured soil component, or even as a decorative mulch.

Soil Conditioning

The classic landscape construction project usually starts with an area of land that has been stripped of exactly what it needs to support plant growth — the topsoil. Frequently, the general contractor sells off or improperly stores the topsoil from the construction site, rendering it unavailable or of questionable quality. The classic remedy for this situation has been to specify the importation of topsoil removed from a farm, another construction project, or from who knows where*! Trying to determine whether this soil is rich in organic matter, of overall poor quality (physical and/or chemical), or contaminated with herbicides and pesticides can prove to be difficult to determine (especially on larger projects).*

Most of the specifications written for topsoil will contain reference to organic matter content and perhaps a pH value, but often nothing more. This purchased topsoil will then be delivered and spread, usually to a depth of about 6”, and planted with turf, shrubs, flowers or any combination of the above. In addition, more often than not, the contractors installing the plants or laying the sod will continually drive over the topsoil layer, compacting it and destroying its structure. We then cross our fingers after all of this occurs and hope that nature will prevail, and the plants will thrive, provided they receive enough fertilizer and water. There is a better way to go about doing this. **Specify compost instead!**

A rule of thumb to use when specifying compost is to apply a 2” layer of compost, then incorporate it into 6” to 8” of site soil (a 20-30% inclusion rate to improve the physical characteristics of the soil).

This application rate has proven to be effective in almost any type of soil, from the densest clays to beach sand, by over 20 years of compost field experience as well as through extensive university research. Composts derived from any variety of organic feedstocks will be effective in this application. Always refer to the compost producer’s specific use recommendations before finalizing your specification, and evaluate the characteristics of the product in relation to the requirements of the plant species to be established.

It should be noted that manure-based composts, like those produced in the Stephenville area, are typically rich in nutrients, often supplying the nitrogen requirements of plants for two years and phosphorous needs for 3-5 years. Also, the finished “manufactured” topsoil (compost/site soil blend) will typically be superior to any topsoil that you could have purchased. This method of soil improvement can be used for growing turf, landscape plants and even garden vegetables.

Compost Quality

All composts are not created equal. There can be a wide variability in the characteristics and quality of compost products. This is the result of the variety of organic materials that go into making compost, and the variety of processes for producing it. As a result of this variability, the question becomes “How do I specify a compost that meets my projects needs?” One answer is to specify only compost that complies with the terms and conditions of the US Composting Council’s Seal of Testing Assurance Program (“STA”). In summary, the STA program is a compost testing and labeling program that will give you the information you need to make an informed specifying and purchasing decision about the compost products you are considering for a landscape project.

STA participants are:

1. Required to test their compost on a regular basis, with testing frequency being dictated by the volume of product that they produce
2. Make all test data available to all interested prospective users of the product, and
3. Include product use information and directions for their compost product(s)

All composts allowed for use on TX DOT landscaping projects now have to be certified through the STA Program. Essentially, the STA program is designed to raise the professionalism of the compost industry and treat compost just like any other commercial or consumer product. Look for the STA logo on all of the compost products that you are considering specifying.

We also believe that if end users know what they are buying, and landscape architects know what’s available, they’re more likely to use it properly and realize the full benefit of compost products. Additionally, LA specs have been developed through the efforts of the US Composting Council which are available to Texas landscape architects.

How much compost do you need to specify?

The amount of compost that you will require for a specific landscape project will vary depending on what you are planting, how you are planting it (e.g. beds, planters, individual plants, etc.), the existing soil and the compost you specify. Always request a product analysis and suggested application rates from your compost supplier. Some general compost application rates are:

- 1 cubic yard spread at a 1” depth covers 324 square feet
- You will need about 3 cubic yards to cover 1,000 sq. ft, at a depth of 1”
- You will need about 134 cubic yards to cover 1 acre, at a depth of 1”

For additional information:

- USCC Seal of Testing Assurance Program or STA certified composters in Texas– http://www.compostingcouncil.org or Al Rattie at 215-258-5259 (turflife@aol.com)
- Manure compost sources from the Bosque and Leon watersheds – http://compost.tamu.edu/producers.php or contact Cecelia Gerngross at cecilia@tamu.edu
- Landscape architect specifications for compost used in landscaping or erosion control – Ron Alexander at 919-367-08350 (alexassoc@earthlink.net)

Appendix H

Article Series for Texas Nursery and Landscape Association

Are you Using Texas Compost Yet?
Part 1 through 6

Are You Using Texas Compost Yet? – Part 1

Compost and its Benefits

Texas has taken a very aggressive approach to solving four challenges currently faced by the state. These issues are:

1. How does Texas handle the growing quantity of animal manure produced on a daily basis throughout the state?
2. How can Texas increase its recycling rates?
3. What can be done to improve soil conditions throughout the state?

- How can Texas reduce manure-related impacts on water quality?

While these challenges have complex solutions, there is one common piece to each solution that links them all together. That common thread is **composting**!

Commercial composting has existed for a long time in both Texas and the rest of the United States. It has come to the forefront in Texas, thanks to the joint efforts of the TCEQ and the TXDOT, over the past two years as one of the key components in addressing the challenges listed above.

One of the best and most environmentally sound methods to manure management is composting. First, the composting process destroys harmful pathogens and typically stabilizes nutrients, which reduces the potential for runoff pollution. Secondly, the volume of waste material (manure) is greatly reduced. Finally, composted manure can be an excellent and versatile soil amendment that provides many benefits to both the soil and its vegetation.

This article will be the first in a series published by the Texas Nursery and Landscape Association to help its membership become more aware of the many uses of composted products, as well as the related activities taking place related to compost within the State (e.g., TXDOT usage, Composted Manure Incentive Program). These articles will teach you about these products, how to use them and how to select the appropriate compost for any given application.

What is Compost?

Compost is the end product resulting from the controlled biological decomposition of organic material. This organic matter is degraded and sanitized through the generation of heat resulting from intense microbial activity. Good quality compost is stabilized to the point where it is beneficial to plant growth and bears little physical resemblance to the organic residuals from which it came. These organic residuals may include manure, yard trimmings, biosolids, food and other related feedstocks. Compost is used primarily for its soil conditioning properties, but can also provide significant levels of plant nutrients, both macro and micro, depending on its feedstock source.

How is Compost Produced?

All compost, regardless of the original organic feedstock, is produced through the activity of aerobic (oxygen requiring) microorganisms. These “bugs” need oxygen, moisture and food in order to grow and multiply. Their activity generates heat, water vapor and carbon dioxide as they transform raw organic residuals into a stable soil conditioner. The natural decomposition process is greatly accelerated when these resources are maintained at optimal levels by controlling the compost “recipe” and properly managing the daily activities of the composting process.

Compost products are safe to use as the US EPA, and other state regulatory bodies (including the

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TCEQ), have established public health and safety standards that facilities must meet in order to be approved for general distribution. These standards typically apply to specific feedstocks, including composting biosolids and mixed municipal solid waste. These product safety "checks and balances," together with proper specification and inspection of the product, assures you that not only will you have a very safe product, but also have one that will be effective for a variety of soil conditioning uses.

Compost Benefits and Applications

The use of compost, as previously mentioned, can provide many benefits. It improves the physical, chemical and biological properties of the soil and the media to which it is blended. Some of these benefits are listed in the table below (these will be discussed in more detail in future articles).

Benefits of Compost Use

- Improves the soil structure, porosity, and bulk density — creating a better plant root environment
- Increases moisture infiltration and permeability of heavy soils — improving drainage and reducing erosion and runoff
- Improves the moisture holding capacity of light soils — reducing water loss and nutrient leaching and helping to conserve water
- Improves and stabilizes soil pH – creating a better environment for overall plant health
- Improves cation exchange capacity (CEC) of soils — improving their ability to retain nutrients for plant use
- Supplies a variety of macro and micro nutrients – reducing initial fertilizer needs in some applications
- Supplies significant quantities of organic matter – the essence of healthy soil
- Supplies beneficial microorganisms to the soil — improving nutrient uptake and suppressing certain soil-borne diseases
- Binds and degrades specific pollutants – a pollution reducing benefit

We hope that we will begin to generate a higher level of interest and enthusiasm in composted products as a result of these articles. Please visit the following websites for additional information on compost and the variety of state programs supporting compost use, http://www.compostingcouncil.org, http://compost.tamu.edu, and http://www.tnrcc.state.tx.us/water/quality/nps/compost/index.html . We have found that once someone uses a high quality compost product, they rarely revert to planting without it again. Compost is good for your plants, good for your soil and good for Texas!

Are You Using Texas Compost Yet? – part 2

The STA Program

This is the second article in a series published by the Texas Nursery and Landscape Association to help its membership become more aware of the many uses of commercial compost products. In this article we will explain the US Composting Councils' Seal ("USCC") of Testing Assurance Program ("STA") and its significance and impact for the landscape and nursery industry in Texas.

PROGRAM HISTORY & GOALS

In order to help compost become a mainstream consumer product, the composting industry needed to accomplish several things, including:

- Raise the professionalism of the composting industry
- Produce consistently high quality products, and
- Assist end users in purchasing appropriate products for their needs

The USCC developed the STA Program to help facilitate this process. The Seal of Testing Assurance Program began in 2000, with financial assistance provided by the US Environmental Protection Agency. The Program is seen by many as the first step towards the establishment of national compost standards. In its current form, the STA Program is a compost testing and information disclosure program that uses uniform testing and sampling protocols that were developed through a consensus of leading compost research scientists across the nation. These test methods and sampling procedures are outlined in the USCC's *Test Methods for the Evaluation of Composting and Compost* (TMECC). Some of these tests are compost specific, and did not formally exist prior to the TMECC being completed. More information on this can be found on the USCC website at: http://www.compostingcouncil.org.

The goal of the USCC, and it's STA Program, is to allow compost buyers to more easily purchase the products they desire or require for a particular project. It is also a goal to allow buyers (and specifiers) to more systematically compare compost products, allowing for an educated purchasing decision, just as they do when purchasing any other product for their professional or home use. Both goals are achieved through the use of a uniform product label, which allows for easy comparison between products. This label contains test analyses data, end use instructions and an ingredient statement, thereby providing the information required to make educated purchasing decisions, which promotes successful utilization of compost 'in the field'.

Something even more important to the composting industry itself is that the overall program is encouraging needed consistency within the composting industry — consistency in product sampling, lab testing methodologies and product labeling. Only through this type of industry wide consistency will the 'green industry' become dependant upon the composting industry as a respected and on-going supplier of materials. Therefore, the success of the STA Program goes far beyond the success of any individual composter. It works towards the goal of bringing necessary consistency to the composting industry. This, in turn, benefits the 'green industry', since it can now depend on the composting industry to be a mainstream supplier.

The STA Program in Texas

The State of Texas has embraced the STA Program. The Texas Department of Transportation (TX DOT), has become the largest public user of compost in the nation. Texas has more STA Program certified composting facilities than any other state in the US. At last count, 20 Texas

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composters and 34 compost products participated in the STA program.

Many articles have been written that illustrate the success that TX DOT has had with compost used both as a soil amendment and erosion control material. We'll explore these uses in more detail in future articles. With all of its success in using compost, TX DOT knew that receiving and using poor quality composts could ruin the success of their program. Having already established their compost specifications, TX DOT saw the STA Program as a way to assist in implementing the use of its specifications throughout Texas. Because the program requires uniform and on-going testing of compost products and uniform product labeling, it provided a means for TX DOT project engineers to evaluate potential compost products for their specific projects, as well as inform TX DOT field inspectors of the particular characteristics possessed by the products delivered to a project site.

There is both a cost and time commitment required to participate in the STA program. Composters must test their products at an approved STA laboratory anywhere from once/quarter to as frequently as once/month. Testing frequency is dictated by the volume of compost produced. There is also an annual membership fee paid to participate in the STA Program. The information that they receive from their lab analysis, as well as the other required program information (compost content and use directions) must, under program rules, be made available to any interested compost prospect. This commitment encourages composters to pay more attention to what they are producing, and hopefully, results in a higher quality and more consistent compost product.

The current list of Texas STA participating compost facilities includes the following members:

- ***Aqua Zyme Services, Van Vleck***
- ***Back to Nature, Inc., Slaton (2 products)***
- ***Black Gold Compost, Godley***
- ***Brazos River Authority, Belton***
- ***City of Denton, Denton***
- ***Garden Success, Houston (5 sites)***
- ***Garden-Ville, San Antonio***
- ***Geosource, Inc., Bulverde***
- ***Letco, Inc., Houston (8 sites)***
- ***Natural Fertilizer Co, Wildorado (3 sites)***
- ***Nature Life, Inc., Ropesville***
- ***Neches Compost Facility, Neches***
- ***New Earth, LLC, San Antonio***
- ***Novus Wood Group, Houston***
- ***O'Neals Compost, Hico***
- ***Organic Residual Reclamation, Dublin***
- ***City of Plano, Plano***
- ***R.J. Smelley Co., Fort Worth***
- ***Texarkana Water Utilities, Texarkana,***
- ***Timber Solutions, Conroe***

We hope that we will begin to generate a higher level of interest and enthusiasm in composted products as a result of these articles. Please visit the following websites for additional information on compost and the variety of state programs supporting compost use.

http://www.compostingcouncil.org
http://compost.tamu.edu
http://www.tnrcc.state.tx.us/water/quality/nps/compost/index.html

We have found that once someone uses a high quality compost product, they rarely revert to planting without it again. Compost is good for your plants, good for your soil and good for Texas!

<u>Are You Using Texas Compost Yet?</u> – part 3

The DMES Program

This is the third article in a series published by the Texas Nursery and Landscape Association to help its membership become more aware of the many uses of composted products. This article concentrates on animal manure-based products produced in Texas and the concerns about the growing volume of manure being generated, its negative impact on the environment and the limited alternatives available to help solve this problem. Converting this agricultural by-product into a valuable product, by composting it, was ultimately determined by many to be the best way to manage it where land application is not possible. The State of Texas and the federal government have supported manure composting programs in Texas. More specific information and the details of these programs are contained in the following paragraphs.

The **Texas State Soil and Water Conservation Board (TSSWCB)** initiated the **Dairy Manure Export Support (DMES) program** in an effort to bring an innovative solution to the problem of elevated phosphorus levels in the **North Bosque and Leon River watersheds**. The objective of the program is to export dairy manure from the North Bosque River watershed that would otherwise be land applied. The DMES program offers financial incentives to commercial manure haulers to support the transport of raw manure from dairy farms in the North Bosque and Leon River watersheds **to commercial composting operations.** The raw manure is then improved through a composting process, so it may be put to beneficial use outside the watershed. Public entities such as the **Texas Department of Transportation (TxDOT)** and municipalities also benefit from a compost purchasing rebate program offered by the Texas Commission on Environmental Quality (TCEQ). In addition agricultural producers, the landscape/nursery industry and the general public are potential purchasers of the composted product.

The export of this surplus manure (and the nutrients contained in the manure helps to address concerns regarding potential non-point source water quality impacts associated with traditional on-farm land application of manure in the region.

The overall program management is controlled through the TSSWCB. The TSSWCB has contracted the everyday activities to the **Texas Institute for Applied Environmental Research (TIAER)** at Tarleton State University. In April 2001, TIAER subcontracted many aspects of the program to the **Foundation for Organic Resources Management (FORM)**, which was replaced by **imanage, LLC** in July 2003. Both FORM, and later imanage, LLC, have managed the DMES program at the local level through a program office located in Stephenville, Texas.

ELIGIBILITY REQUIREMENTS

<u>Dairies</u>:
A part of the dairy must be located in the North Bosque or Leon River watersheds. The dairy must have (or have applied for) a valid Water Quality Management Plan or a Nutrient Utilization Plan/Permit Nutrient Management Plan.

<u>Composters:</u>
Each composting facility must be compliant with all state regulations regarding compost facilities and be approved by the **Texas Commission on Environmental Quality (TCEQ)** for participation in TCEQ's **Composted Manure Incentive Project (CMIP)**.

<u>Haulers</u>:
Haulers must attend a workshop convened by TSSWCB's contractor. They must also obtain a vendor number from the State Comptroller and authorize direct deposit.

REIMBURSEMENT PROCESS
Individual hauling jobs are coordinated through manure haulers that make arrangements with dairies and commercial composting operations. A manure hauler completes a **"job notification form"** which is then submitted to the DMES office for approval. Once approval is received, the manure hauler performs the work and submits to the DMES office an invoice signed by a representative of the dairy, accompanied by **load tickets signed by a representative of the composting facility**, and a **scale ticket for each load**. The DMES office prepares semi-monthly reimbursement request summaries, has them approved by TIAER, then submits them to the TSSWCB for payment. Because the TSSWCB is using **Clean Water Act, §319(h)** funding from the **U.S. Environmental Protection Agency (EPA)**, the TSSWCB must then request that the funds be released from EPA to the TSSWCB. The TSSWCB then issues reimbursements via **direct de posit** to the manure haulers.

FINANCIAL INFORMATION
Two sources of funding have been used for the DMES Program. Funding from three CWA§319(h) grants (1999, 2000, and 2002 fiscal years) totaling $2,696,885 has been approved by EPA for the DMES Program. Also, an appropriation of $1,131,726 was provided to the TSSWCB by the Texas Legislature during the 77th Regular Legislative Session. However, $500,000 was returned to the State Treasury in the spring of 2003 due to budget cuts. There is $729,496.75 remaining for the DMES Program.

RESULTS
The initial target amount of manure to be exported from dairy farms participating in the program was **300,000 tons** during a 36-month program period from October 2000 through October 2003. Hauling of dairy manure under the DMES program has proceeded at a much faster rate than originally anticipated. In fact, as of October 31st, 2003, over **670,000 tons** of manure, or more than double the target amount, has been hauled under this program. The average support cost is about **$3.25 per ton**. *For more information on the DMES Program, please contact Mr. John Foster at jfoster@tsswcb.state.tx.us.*

WHAT DOES THIS MEAN TO YOU AS A NURSERY and/or LANDSCAPE BUSINESS?
There are a variety of benefits that you can derive from the program described above. Some of them include:

1. Your water and the environment in Texas will be cleaner and safer. This directly benefits you and your family.
2. The program is helping Texas dairy farmers deal with a challenge that they could not solve alone. This helps their business and the overall economy of the state.
3. You now have an abundant supply of a variety of compost products to choose from for your business needs. **Please review the list of STA compost producers that was contained in the last article.** Are any of them near you? Contact them and request pricing and compost quality data. Request a sample of a couple of products and see how they work in your business.
4. These are your tax dollars at work, both state and federal, doing something that directly benefits the environment and you. Take full advantage of the products being made and the price discounting that's being offered to you as a result of this program. **Try some compost in your business today!**

Are You Using Texas Compost Yet? – part 4

Compost Use in Landscaping

Part 4 of this series of articles will get down to the 'nuts and bolts' of compost use and review specific uses, and **suggested compost application rates***, in landscaping. The use of compost in landscape applications is the largest public and private use of these valuable products in the nation. Compost is being used on a massive scale to replace topsoil, mulch and a variety of soil amendments in applications limited only by the imagination of the landscaper and the availability of compost products in the area that they are working. We hope that these articles and the information listed below will encourage you to try some compost on a landscape project soon. As we've stated previously, **the many benefits of compost for the soil, the plants, the environment and your bottom line will quickly become obvious!**

Soil Conditioning — On Site Topsoil 'Manufacturing'

The classic landscape construction project usually starts with an area of land that has been stripped of exactly what it needs to grow (regardless of what it is that you wish to grow) — **the topsoil**. Frequently, the general contractor sells off or improperly stores the topsoil from the construction site, rendering it unavailable or of questionable quality. The classic remedy for this situation has been to import topsoil removed from a farm, another construction project, or from *who knows where*! Since the topsoil industry is greatly unregulated, buyers can only wonder whether the topsoil they buy is rich in organic matter, of overall poor quality (physical and/or chemical), or contaminated with herbicides and pesticides.

This purchased topsoil will then be delivered and spread, usually to a depth of about 6", and planted with turf, shrubs, flowers or any combination of the above. In addition, more often than not, the landscapers installing the plants or laying the sod will need to continually drive over the topsoil layer, compacting it and reducing its effectiveness. We then cross our fingers after all of this occurs and hope that nature will prevail, and the plants will thrive *(provided they receive the proper care).* But there is a better way to go about doing this. **Specify compost instead!**

A general, predictable rule of thumb to use when specifying compost is a*pply 2" of compost and incorporate it into 5" to 7" of site soil*

This application rate of compost has proven to be effective in conditioning a variety of soils, from the densest clays to beach sand, by over 20 years of field experience and extensive university research. Composts derived from any variety of organic feedstocks will be effective in this application. ***Always refer to the compost producer's specific use recommendations before finalizing your application rate, and evaluate the characteristics of the product in relation to the requirements of the site soil and the plant species to be established.**

The variation in the depth of incorporation will be dictated by:

- the quality of the existing project site soil (the higher organic matter content of the site soil = the less compost you will need)
- the quality of the compost (organic matter, salt or nutrient content. Compost that is higher in salt content, for example, will need to be incorporated deeper)
- the sensitivity of the plants being installed (the more delicate and salt sensitive the plants = the more dilute the compost:soil ratio)

ALL compost, like soil, contains soluble salts (in the form of nutrients in compost). The operative word here is soluble. The salts in compost are typically leached out rapidly during the

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initial few waterings. Do not be alarmed by the salt content analyses from a compost sample that may be somewhat higher than you are used to seeing in traditional topsoil analysis.

Material Reduction

You should also notice that you will be using only 1/3 of the volume of material when applying compost, then you would if laying down a 6" layer of topsoil to the landscape site. While there will be some additional handling because of the need to incorporate the compost into the site soils, but you should still be able to significantly reduce your overall project costs. Also, the finished "manufactured" topsoil (compost/site soil blend) will typically be superior to any topsoil that you could have purchased.

Compost Application Rates

Here's an easy reference table to help you determine how much compost you will need for a landscape project:

- **1 cubic yard of compost spread at a 2" depth will cover about 162 square feet**
- **6.17 cubic yards of compost will be needed to cover 1,000 square feet at a 2" depth**
- **269 cubic yards of compost will be needed to cover an acre at a 2" depth**

Off Site Topsoil 'Manufacturing'

There will be landscape projects where, due to space or operational constraints, that the above "on site manufacturing" technique will not be practical or cost effective. There is a very viable alternative in this situation. You can 'manufacture' you compost manufactured topsoil offsite and simply deliver and apply it as you would with conventional topsoil. Here's how this process works:

1. Determine how much finished soil you will need for your landscape project. Add about 15% to 20% to this figure to account for 'shrinkage' and loss.
2. Purchase enough compost to equal 20% to 30% of this volume of soil. Purchase less expensive soil products (subsoil, sandy fill or other similar products) to blend with the compost.
3. Use a front end loader, or other suitable piece of heavy equipment, to thoroughly blend the compost and subsoil together.
4. Deliver and apply your 'manufactured' topsoil to the landscape project.

Your finished product should wind up being a highly organic, pH neutral, and nutrient rich manufactured topsoil. It should also cost you no more than, if not less than, purchasing an equal amount of commercial topsoil.

Other Landscape Uses for Compost

The use of 'manufactured' topsoil is the largest use of compost in landscape applications. It is not, however, the only way to use compost. Other applications include using compost as a backfill mix, in planters, as mulch and to topdress turf areas. We'll look at each of these in the next article.

Are you using Texas compost yet? – part 5

Compost use by Professional Growers — Nursery and Greenhouse

The benefits that compost offers to the professional grower are many and varied. A superior growing medium can be produced in many cases and often at a lower cost. Care must be taken, however, to move slowly and carefully when incorporating the use of compost in nursery situations. A potted ornamental plant is far more sensitive to changes in its environment than a plant growing outside in a landscape setting. The gradual introduction of compost into growing media, while adopting the changes needed in watering and fertilizer requirements and recognizing other related handling issues, will ultimately pay off in equal or superior plant health and an improved bottom line!

The authors are NOT implying nor providing specific compost use directions in this article. That information can only come from the compost producer and through your own practical experience as you try compost products. Most of the available compost produced in Texas will have very similar characteristics, but not identical characteristics. It will only be

General Nursery Stock Compost Use Suggestions

First and foremost, compost is to be used as a soil mix component and NOT as a soil mix by itself! **Compost should NEVER be used by itself as a growing medium.**

Start Slowly — We suggest you introduce compost to your growing mix as part of an *in-nursery* trial. Isolate a few dozen plants and pot them in 2 or 3 different compost based growing mixes. Learn how to water these. Experiment with reduced fertilizer application rates. Often, when compost is introduced to a growing mix, addition of macronutrients (other than nitrogen) and micronutrients can be reduced or eliminated. The addition of nitrogen can often be delayed. Work with your compost supplier and your County Agriculture or Horticulture Extension Agent so that you will be comfortable and operationally prepared to introduce compost amended growing media throughout your nursery.

Professional nursery growers across the country have used compost successfully at incorporation rates ranging from 10 to 50 percent by volume, by. Some of these growers prepare the mixes themselves, others specify it in a mix that they purchase from a growing media company. **The key is to start slowly and learn how the compost changes the daily needs of your nursery operation. The percentage of compost in the mix will be dependant upon the plant species (and its requirements) and the characteristics of the compost.**

Mixes to Consider — The ingredients blended with the compost will vary by region, depending on what is available and affordable in your area. **All mix ‘recipes’ are suggested on a ‘volume basis’.** Some typical compost mixes, used by nurseries across the country are listed below. They contain 20 to 50 percent compost, by volume, and would primarily be used in a container mix. Again, proceed slowly, with lower compost addition rates during your ‘compost learning curve’:

*A combination of peat moss and pine bark, or either component alone, can be used for this portion of your growing mix. A good ‘Rule of Thumb’ to follow when using compost in a growing media is that – the bigger the pot/container – the greater the percentage of compost can be used (and the coarser the compost can be).

Watering — The majority of compost products produced in Texas are manure based, which potentially leads to a material that contains a higher soluble salt concentrations than what you and your plants are accustomed to. Test the compost to determine its soluble salt concentration and compare it to your current media. Also, determine what level of salts your plant can tolerate

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and in the event you discover the concentration may be too high, then there is a technique that allows you to still use this material and maintain a healthy plant. To alleviate a potential soluble salt problem, **you need to make sure to water your plants very well, perhaps more heavily than you typically do, during the first 2-3 waterings.** This practice will serve to leach out the soluble salts to a desirable concentration· You should then be able to return to your regular watering practices after this initial period of leaching. Some growers like to use a wetting agent, either as a part of their mix in a dry form, or added to their watering system to assure a thorough drenching and leaching of their growing mix.

Fertilizer Programs — Most of the compost produced in Texas, or across the nation for that matter, contains about 1% to 2% N and P. In a container mix with 20% compost or more, there should be a sufficient quantity of nutrients in the compost to supply all of your plants needs for the first 2 — 3 weeks after potting. After that, some additional nitrogen will likely be needed, and some plants may require other nutrient supplements as well. Again, make sure to carefully review the analysis that your compost supplier provides to you, to confirm this.

Most nursery stock growers that are having success with compost based media are using a low phosphorus content, slow release granular fertilizer to feed their plants. These can either be blended at the manufacturers recommended rates or applied as a topdress after potting. Sulfur coated fertilizers may be applied immediately after potting as a top dressing because they also have a delayed release period. **Make sure that there is NO fast release component in the fertilizer product that you select.**

Liquid fertilizer applications to compost amended growing mixes will typically be delayed at least 2 -3 weeks after potting. They can be applied either as part of a constant feed process, or at weekly or biweekly rates based on manufacturers recommendations.

Micro/Secondary Elements – When utilizing compost, you may find that there is no need to apply any micro or secondary elements as part of your fertilizer program. Most compost products contain an adequate supply of micronutrients, even when used as a part of a growing mix, to meet plant requirements throughout its nursery life. This is yet another instance where you will need to study the compost analysis, and even your final growing mix analysis, to make this final determination.

Weed Control — When processed correctly, compost is pasteurized, which effectively destroys all weed seeds. You do not need to sterilize it prior to blending it with the other components of your growing mix**.**

Fungal Pathogen Control — Research conducted at several major agricultural universities has also clearly shown that compost contains naturally occurring fungicidal properties. You may be able to reduce or totally eliminate your use of chemical fungicides when using compost in your growing mix! This is another benefit of compost that you want to explore when you conduct your nursery trials.

Greenhouse Crop Production Using Compost

Most of the suggestions listed above for nursery crop production using compost based mixes, also applies to greenhouse crops. Greenhouse crops include anything from bedding plants to poinsettias, mums, ornamental house plants, and everything in between. Their ‘world’ is just a little smaller than most nursery plants, and hence, they are even more sensitive to change.

All of the precautions and suggestions listed above concerning; starting slowly with a greenhouse trial, the need for higher levels of initial watering, micro/secondary element needs and weed control apply here as well. There has, however, been a different history of growing mix percentages that use less compost in the mix. **Greenhouse crops typically only use a maximum of 25 to 33 percent compost, by volume, although some growers have been successful using higher rates for more tolerant crops.** Some mixes that have been successful for greenhouse growers in other areas are listed below:

Fertilizer Programs — **You will not, as with nursery stock, typically need to apply any fertilizer to your compost amended growing medium for at least the first 2 — 3 weeks after transplanting.** Some plants may require nitrogen fertilizing ONLY after this point. Others may require a more complete fertilizer application. You'll need to look at what the compost contains, and what the plants needs are to make this determination. This should become evident during your greenhouse trial. Keep in mind that compost possesses a high cation exchange capacity (CEC) which can greatly improve the efficiency of nutrient retention and uptake by roots, further reducing the amount of nutrient supplements needed.

We hope that we have inspired you to take a serious look at the use of compost in the nursery and the greenhouse. Some research has shown that compost amended growing mixes can, through the reduced cost of mix components, fertilizer and trace elements needs, save you between $10 to $20/cubic yard. You will also be producing a comparable, if not a superior plant to what you have grown in traditional peat based mixes. Some studies have shown that compost amended plants may have a 'shelf life' of up to 2 -3 weeks longer than plants grown in traditional, soil less media.

There is a definite 'learning curve' that each individual must experience to become comfortable with using compost in your nursery or greenhouse operation. Your compost supplier and County Agriculture or Horticulture Extension Agent can provide technical support, and possibly even operational support, to you during this important process. You will discover, if this process is done thoroughly and accurately, that compost has a definite place in your business!

<u>Are you using Texas compost yet?</u> – part 6

Selling Compost through Landscape Suppliers (Garden Centers and Topsoil Dealers)

This is the final article in this 6 part series about the benefits, uses and opportunities provided to the landscape and nursery industry as a result of the increasing supply of high quality compost in the state of Texas. This article will focus more on the business opportunity of supplying compost that is now available to landscape supply centers (garden centers, topsoil dealers, nursery suppliers, etc.). There is an opportunity to increase your profitability by providing compost to fill smaller user needs, which can be quickly realized with a little work, ingenuity and product promotion. *This article deals primarily with the distribution of bulk compost, because bagged compost products are already extensively marketed by this business sector, and because mass merchants are less likely to distribute bulk products.*

The producers of large quantities of bulk compost, and there are many in the state of Texas, must establish channels of distribution in order to both accommodate the inventory constraints of their facilities and to adequately service market demand. Compost production facilities cannot, and should not, attempt to service the very small bulk customer. The potential liability of having small landscaper trucks, or worse, weekend gardeners visit a large compost production facility complete with its share of heavy equipment and visual obstacles is an accident waiting to happen. Yet, the compost producer needs to establish a business relationship with these very market segments. Two reasonable options for the compost producer to infiltrate this market are to either open a retail or small wholesale supply yard, or deal with an existing business already servicing these market segments. It is the second option that most choose to pursue.

The landscape supply center that services either or both retail and commercial customers provides the ideal link between the compost producer and the 'less than truckload' bulk compost user. A truckload is defined, for the purposes of this article as a 20 to 50 cubic yard load. For a landscape supply center to deal in bulk compost, it must have the space to accept bulk loads of this size and the loading equipment (small loader, skid steerer, etc.) to fill their customer orders. If both of these conditions can be met, then the landscape supplier has an opportunity to provide both unblended compost, and derivative products, to an array of 'less than truckload' customers who visit their facility, and reap the accompanying financial rewards.

<u>Products and Market Segments</u>

<u>Products</u> — The variety of compost products that a landscape supplier can stock and sell will be dictated by; the type of compost products that are available to them, their physical limitations (storage space, equipment, personnel) and the competitive products they already stock. Lets review some of those options and provide some guidance about what might work, assuming that certain conditions prevail.

> <u>General Use Compost</u> — The easiest and most obvious product to carry, but not necessarily the first priority, would be pure compost as delivered to your facility by the compost producer. The assumption being made here is that the compost is stable/mature and has been screened through a ½" — 3/8" screen, making it ideal for a variety of uses, described in previous articles. The more coarsely screened, ½" size, may even be suitable for use as a decorative mulch depending upon its 'look' and if properly promoted.
>
> Selling unblended compost may require more of a marketing effort on the part of the landscape supplier especially if the concept of compost use *as a soil amendment* in not

widely known in your area. Assistance with marketing, including literature, banners and technical advice, should be provided or supported by the compost producer. However, literature or technical support from the landscape supplier themselves can be very beneficial.

‘Manufactured’ Topsoil — An easier, product to market might be a manufactured topsoil which can be made by blending 25 to 33 percent compost by volume with native subsoil, or an inexpensive fill material. All market segments, both retail and commercial, already understand and use topsoil. It will require little more than a competitive price and a simple, one-page piece of literature explaining its benefits over conventional topsoil. Manufactured soil made from inert soil blended with mature compost cab be promoted as weed-free topsoil with high organic matter – a very desirable combination that is difficult to achieve without compost. It is possible that you might be able to work with the compost producer to have them produce this at their facility, if they have the time and desire to do so. Otherwise, that task will be the responsibility of the landscape supplier.

Other Compost Products — You can also stock other compost products, if your space and market demands support doing so. These may be available directly from the compost producer, or may require additional handling on your part. Two options to consider here are erosion control compost and compost topdress.

The TXDOT has a specification for erosion control compost. It is, in the simplest terms, merely a coarser grade of compost that is produced to stabilize slopes and to construct filter berms on construction projects. Article #5 in this series presented a very detailed description on the uses and characteristics of this form of compost. This would, more than likely, need to be delivered to you in the proper form by the compost producer.

Topdress grade compost is merely a more finely screened grade, generally to ¼” size, of general use compost. It can be screened by either the compost producer or by the landscape supplier, if they have the equipment. This product may also be blended with sand to produce a topdressing. Topdressing is widely used on golf courses and is becoming a more accepted landscape maintenance practice on athletic fields and on commercial lawns.

Markets — If you are a landscape supplier, you already are well acquainted with the variety of potential market segments that can purchase the products listed above. They, however, may not be aware of the many benefits and uses that compost and compost-derived products offer to them. It is your job to convey this message. If you can educate you clients about compost, your market will grow and you will reap the financial benefit of your efforts.

Your market segments will include landscapers, homeowners, general contractors and more specialized users, such as golf courses and athletic field maintenance . You have the opportunity to make long-term customers out of many of these market segments by teaching them about compost and then providing them with a consistent supply of high quality compost, and/or compost derived products for many years to come. Many homeowners will respond favorably to these unique, natural or environmentally sensitive products.

The previous articles in this series included: Compost Benefits and Uses; Texas Composters and the USCC, Seal of Testing Assurance Program; The Manure Composting Incentive Program; Compost Use in Landscaping; Compost Use in Erosion Control and Compost Use in Nurseries and Greenhouses. We hope that you have enjoyed the series and have a better understanding of how high quality compost products can benefit your business.

Appendix I

News Releases

Compost: Something Every Soil Can Use (May 2004)

Composting is a natural, biological process through which microorganisms break down solid organic material into a humus-like substance. Grass clippings, leaves, prunings, bark, fruit and vegetable waste, crop residue, woodchips, sawdust, chopped brush and various other organic residues can be used to create good compost. By composting, the volume of organic residues disposed in landfills is reduced, which conserves landfill space and produces a beneficial product-compost.

Compost, a dark, organically rich material that has been used for decades, serves as a soil amendment and as a nutrient source for plants. It can be applied as a mulch layer to reduce evaporation, or incorporated into the soil to increase soil organic matter, thereby improving soil structure and water-holding capacity. Compost also enhances the chemical character of soil by buffering soil pH (preventing rapid pH changes) and serving as a source of essential plant nutrients including nitrogen, phosphorus and potassium. Since most soils are deficient in organic matter, just about any soil type will benefit from the addition of compost.

One of the most abundant sources of material for producing compost in Central Texas is the dairy industry. Several commercial operations produce dairy manure compost for sale to the public. Composting removes much of the moisture from dairy manure, which makes it easier and cheaper to transport. In addition, composting virtually eliminates odors and kills most weed seeds, bacteria and other potential pathogens, resulting in a rich-textured product with an earthy smell.

Dairy manure compost is produced in the Bosque River Watershed to provide an alternative outlet for dairy manure, which decreases the amount of phosphorus potentially released by dairy farms within the Watershed. Phosphorus is an important plant nutrient, but in excess can pose a threat to water quality in streams, rivers and lakes. By utilizing dairy manure to produce compost for application off the farm, both dairies and compost users are benefiting.

Dairy manure compost can be utilized for agricultural, horticultural and landscaping applications. For instance, dairy manure compost can be applied and incorporated for production of row crops such as corn, grain sorghum and cotton. In addition, it can be incorporated for establishment of perennial forage crops like Bermudagrass or topdressed onto existing stands. Compost can be incorporated prior to establishment or topdressed on lawns, athletic fields, and golf courses. In some cases, compost is used to control erosion and promote revegetation of disturbed sites such as road right-of-ways. In cities, filter berms made of compost are used around construction sites to reduce erosion, and once building is complete, are simply incorporated into the soil to promote revegetation.

Rates of compost application will vary depending on the particular site and purpose. Because some compost contains plant nutrients, both an analysis of the compost (usually available from the supplier) and a soil test should be obtained to match rates of application with plant needs. Several methods exist for applying compost, ranging from hand application for small jobs involving only a few cubic yards to high capacity spreaders and blower trucks for material to large areas.

Most composting operations allow on-site pickup of small quantities of compost, and many offer a delivery service for larger amounts. For more details, contact your local County Extension Office or visit http://compost.tamu.edu.

Local Soil & Water Conservation District offers Payment for Compost (June 2004)

Private citizens living outside the Bosque River Watershed who are interested in using compost for agricultural purposes now have the funds available to do so. Individual landowners within the participating Soil and Water Conservation Districts are eligible to receive a reduced price of $4 per cubic yard on compost purchases up to 4,000 cubic yards.

To apply for the reduced price, participants must first request assistance from their local Soil and Water District for the development of a certified "Water Quality Management Plan". This plan will help the producer determine the amount of compost needed. Following approval of their Plan, the producer simply contacts an approved dairy manure compost facility to arrange purchase, delivery and application of the material. By participating in this program, producers receive a reduced price and the associated benefits of applying compost.

In addition to the necessary forms, private producers may also be required to complete a pre and post compost use assessment survey. Permitted CAFOs and AFOs are not eligible for this reduced price.

The program is available through the Upper Leon, Cross Timbers or Hamilton-Coryell Soil and Water Conservation Districts. The purpose of the incentive is to utilize the abundant dairy manure in the Bosque River Watershed by applying it as compost to landscapes in other watersheds.

Those interested in participating in the incentive program should contact the Upper Leon Soil and Water Conservation District (attention: Missy Jones) at 325-356-5186 extension 3 or the Texas Water Resources Institute (attention: Cecilia Gerngross) at 979-458-1138. Also, additional information may be found at http://compost.tamu.edu.

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Incentives Exist for Dairy Compost Purchasers (July 2004)

Compost is a dark, organically rich material that has been used for decades as a soil amendment and nutrient source for plants. When applied as a mulch layer, compost helps reduce evaporation, or when incorporated into the soil, compost increases soil organic matter, thereby improving soil structure and water-holding capacity. Compost also enhances the chemical character of the soil by buffering soil pH (preventing rapid pH changes) and serving as a source of essential plant nutrients including nitrogen, phosphorus and potassium.

Dairy manure compost is produced in and near the Bosque River Watershed to provide an alternative outlet for dairy manure, decreasing the amount of phosphorus and other nutrients on dairy farms within the Watershed. Phosphorus is an important plant nutrient, but in excess can pose a threat to water quality in streams, rivers and lakes.

Several local operations are producing dairy manure compost: Bosque River Compost, Organic Residual Reclamation, Erath Earth Inc., Gustine Compost, O'Neals Compost, Producers Compost, and Texas Best Compost. These facilities are located in Stephenville, Dublin, Hico, and Gustine.

By purchasing dairy manure compost from one of the approved facilities, participants are eligible to receive incentives for supporting their local economy and helping keep a safe and healthy environment.

For a limited time only, the Composted Manure Incentive Program, funded by the Environmental Protection Agency and Texas Commission on Environmental Quality, is offering public entities an incentive payment of $5 per cubic yard of dairy manure compost purchased from the Bosque Watershed.

Through this same Program, a similar incentive exists for private producers. The Upper Leon, Cross Timbers and Hamilton-Coryell Soil and Water Conservation Districts provide a $4 per cubic yard price reduction on dairy manure compost purchases. Private producers within one of these Soil and Water Conservation Districts and outside of the Bosque River Watershed may receive the reduced price given all related requirements are met.

For more information on purchasing dairy manure compost or the related incentive programs, contact your local Extension office or visit http://compost.tamu.edu.

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TCEQ Announces Rebate for Compost Purchases (November 2005)

Up to $180,000 available for distribution to large compost consumers

Rebates on composted manure purchases by agricultural producers, landscapers, retail distributors of lawn and garden products, and other large compost consumers located outside the North Bosque River valley are available for a limited-time. Rebate funds are provided through Clean Water Act grants from the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality to improve water quality in the North Bosque River. Storm-water runoff containing manure has been a significant source of phosphorus in the North Bosque River. By composting the manure, a problem becomes a valuable resource.

The rebate of $3 per cubic yard is available for purchases of qualifying composted dairy manure up to a total of 4,000 cubic yards per customer. The rebate is distributed through some of the Texas State Soil and Water Conservation Board’s conservation districts until August 31, 2006, or until the rebate fund is exhausted, whichever comes first.

To qualify for the rebate, an agricultural producer first develops a “Nutrient Management Plan” with assistance from a participating Soil and Water Conservation District. This plan will help the producer determine the amount of compost needed. (This requirement does not apply to retail distributors and landscapers.) The buyer then contacts a participating dairy manure compost facility to arrange purchase, delivery, and application of the material. Compost buyers also complete rebate forms noting how the compost is used and the total cost of using the compost. Permitted Concentrated Animal Feeding Operations and Animal Feeding Operations are not eligible for this rebate.

For more information, go to:http://compost.tamu.edu/rebate_program.php. To find out if you qualify, contact Missy Jones at the Upper Leon Soil and Water Conservation District—325-356-5186 extension 3 or Cecilia Gerngross at Texas Cooperative Extension—979-458-1138.

Appendix J

Example Story Tip

Dairies provide more than just milk
Utilizing dairy manure as a compost source

Dairy manure compost demonstration sites have been set up at numerous locations throughout the Bosque River Watershed. Extension specialists are using data collected from Texas A&M researchers to display the various uses and proper application of dairy manure compost. Public entities can attend plot demonstrations to see dairy compost being used in agricultural, horticultural, commercial and residential settings. Using the Turf Tiger, specialists address the different equipment available to apply dairy manure compost, whether in a large or small area. Demonstration plots are provided as part of a public educational resource to show others how dairy manure compost can be used in daily activities. By helping market dairy manure compost to the public, less manure is present in the Bosque River Watershed, decreasing water quality concerns.

Contact: Cecilia Gerngross
Phone: (979) 458-1138
E-mail: cecilia@tamu.edu

Appendix K

Case Studies

Breckenridge ISD demonstrates Dairy Manure Compost on Football Field

The Buckaroos of Breckenridge High School, 500 West Lindsey, Breckenridge, had been practicing football on a field with compacted soil and poor grass cover and density on many sections.

Phillip Bales, Stephens County Extension Agent – Agriculture, Texas Cooperative Extension, offered to work with the school district to address these problems. With inputs from Dr. Jim McAfee, Extension Turfgrass Specialist in Dallas, Bales formulated plans for a turf management demonstration that included mechanical aeration of the field, fertilization with dairy manure compost supplemented with inorganic nitrogen, and other practices such as timely irrigation.

The demonstration was initiated in May 2004, and turf response ratings were taken through September 2004. This trial compared dairy manure compost applied alone, dairy manure compost amended with inorganic fertilizer, and inorganic nitrogen fertilizer alone. The treatments were (a) 40 tons/acre dairy manure compost, (b) 40 tons/acre dairy manure compost followed by 20 pounds/acre inorganic nitrogen and (c) 60 pounds/acre inorganic nitrogen.

Through a program funded by the Texas Commission on Environmental Quality and designed to assist public entities with utilization of composted dairy manure, Bales was able to provide the dairy manure compost utilized in the demonstration.

Visual assessments were made of turf stand, density, color, and weed presence. Overall health of the practice field vegetation improved across all treatments. Specifically, turf density improved providing coverage on many previously bare areas. Bales reported that the improvement was sustained even after athletic activity resumed in 2005.

Tommy Wolfe, Director of Maintenance and Transportation, Breckenridge Independent School District, said that $200 was spent annually to purchase and apply inorganic fertilizer to the football field before the demonstration. Because dairy manure compost provides plant essential nutrients in organic form, the school purchased less inorganic fertilizer following the compost demonstration. The benefit of utilizing less inorganic fertilizer has the potential to last 2 to 3 years as the phosphorus and potash provided by dairy manure compost can persist beyond one year. Wolfe indicated that irrigation costs (estimated at $150/year) were not affected by treatments.

Unfortunately the dairy compost used in the trial was not of top-dress quality, which resulted in some unintended consequences. This “general use” grade material contained small rock (limestone or caliche) fragments, which had to be removed by hand. Also, the appearance of some weeds in the turf suggested that the product was not fully composted, e.g. proper temperatures were not maintained. When composted correctly, dairy manure compost should not contain any viable weed seeds. While use of this product could be effective in other situations, such as cases where it would be incorporated into the soil, its use as a top-dress would not be recommended.

Dairy manure is transformed into compost by several commercial businesses located in the North Bosque and Leon River watersheds. Different grades of compost are available for a variety of applications, including top dressing, soil amendment and erosion control. Top-dress quality products are available and typically are made from selected feed stocks that are rock free and screened to insure product uniformity.

PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

The preparation of this report was financed through grants from the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality.

City of Waco sells Dairy Manure Compost to Citizens

The City of Waco initiated a project in spring 2002 to provide dairy manure compost to local homeowners for use on their lawns, landscapes and gardens. The material was purchased from commercial compost facilities located in the North Bosque and Leon River watersheds. The City's cost of the material was reduced by $5 per cubic yard, thanks to the Texas Commission on Environmental Quality (TCEQ) Dairy Compost Rebate Program funded through an EPA grant.

Dairy manure compost contains many of the essential nutrients needed by "yard" plants, including lawn grasses, ornamentals, trees, shrubs and garden crops, and organic matter that improves soil tilthe and water holding capacity. Additionally, because most of the nutrients contained in the compost are gradually released over time, need for re-treatment is minimized as well as potential for off-site movement of the more mobile nutrients (such as nitrate nitrogen).

Research and demonstration trials conducted by the Texas Agricultural Experiment Station and Texas Cooperative Extension have shown that dairy manure compost is a good substitute for inorganic fertilizers. It can be used by homeowners in combination with inorganic fertilizers to balance nutrients, optimize plant growth, prepare areas for new plants or renovate problem areas in lawns, flower beds and gardens.

This city project is now in its fourth year. Christian Heger, Solid Waste Services, City of Waco, said that with the aid of the TCEQ Compost Rebate Program, the city purchased dairy manure compost for resale to its citizens during two weekends in February 2005. Its citizens bought about 1,200 cubic yards of dairy manure compost in bags and truckload lots ranging from 1-cubic foot to about 9-cubic yards.

Heger said a city that has interest in initiating a similar project with dairy manure compost should consider several factors. First, take advantage of the TCEQ Dairy Compost Rebate Program as long as it's available. Next, buy the dairy compost from a reliable and reputable composter that is recommended by TCEQ and which meets homeowners' quality needs. Heger's city bought dairy manure compost that contained small "rocks" in 2002. That material might have been suitable for constructing a new flower bed where it would be incorporated into the soil but it was not acceptable for use in top dressing lawns.

Heger also noted that the distribution site needs to be located in an area that is well suited for storing and dispensing the compost. The site needs to be somewhat isolated from city activities but readily and easily accessible to the citizens who will purchase dairy manure compost.

When possible, involve volunteers in the project. They can help with numerous activities including collecting money from citizens who purchase the material, directing traffic, and helping load the material. Heger said his city had volunteers who were college students, Master Composters and others.

Timing of the sale is also important. In 2005, the city of Waco scheduled the dairy compost sale for two weekends in February. Due to the cool, wet conditions, Heger said the sale would have been even more successful had it been scheduled for two weekends in March when citizens were more likely to start working on their lawns and gardens.

Heger said his city neither gained nor lost money when it sold dairy manure compost bought through the TCEQ Compost Rebate Program. The city made the dairy manure compost available to its citizens at cost so they might have greater access to a valuable local resource that provides an alternative to

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inorganic fertilizers. In addition, by utilizing this local resource, the city and its citizens are helping protect local water quality and maintain the viability of a vital part of the economy.

The dairy compost not purchased by citizens was donated to public works such as landfills and parks. However, the 2005 sale was the only sale where leftover dairy compost existed and had to be donated to the public works. In previous sales, Heger said no compost was available to be donated as all of the material was bought by the citizens.

In a small but important way, this project provided an avenue for removing composted dairy manure from the impaired regions of the North Bosque and Leon River watersheds while providing citizens of Waco, who depend on water from these watersheds, with quality organic fertilizer and soil amendments. Additionally, it demonstrates to other local communities how to actively involve its citizens in using a natural resource on their own land while simultaneously supporting the Central Texas dairy industry.

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Lovell Lawn and Landscape raises Live Oaks in Dairy Compost

Joe Pope, Erath County Extension Agent – Agriculture (retired), Texas Cooperative Extension, worked with Lovell Lawn and Landscape, a small landscaping business located at 6744 South U.S. Highway 281, Stephenville, to evaluate the use of dairy manure compost as a potting media for small Live Oak trees.

Jason Lovell, president of the landscape company, primarily had been using bark mulch for potting his plants. As part of the Dairy Manure Compost Utilization Program funded through a Clean Water Act Section 319(h) Grant by US EPA through the Texas Commission on Environmental Quality, Mr. Lovell agreed to work with Pope in conducting a demonstration.

The demonstration compared the use of bark mulch, dairy compost and Bovinite™ as growth media for several hundred Live Oak trees being grown by Lovell. Bovinite™ is a commercial dairy compost product specially processed to reduce overall salt content and to increase the nitrogen to phosphorus ratio. Further, the material is much less dense than typical dairy manure compost and contains high organic matter content.

Each treatment was introduced as the growth media when the Live Oaks were repotted from 30-gallon to 45-gallon containers between February 2004 and September 2004.

Initially, Pope and Lovell planned to take measurements on changes in tree diameter and other indicators of plant response. Opportunity to sell the trees, however, precluded collection of measured growth data but the following observations were made.

Lovell noted that Live Oaks grown in the Bovinite™ exhibited the best overall performance followed by those grown in dairy compost. Trees grown in those media outperformed those potted in the bark mulch in rate of growth, root proliferation and overall appearance.

Specifically, Live Oak trees grown in the dairy manure compost and Bovinite™ required less frequent irrigation and were less likely to stress for moisture due to delayed watering than those potted in the bark mulch. In addition to improved performance, the use of dairy compost and Bovinite™ also resulted in some time and labor savings.

The dairy manure compost utilized in the demonstration had a lower organic matter and higher inorganic (sand) content than the Bovinite™ or bark mulch. Consequently, containers with Live Oaks potted in dairy manure compost were heavier than those with the trees potted in the bark mulch and the Bovinite™.

However, Lovell reported that his customers were pleased with the condition of the Live Oaks potted in the dairy manure compost and unaware or unconcerned about the weight differences.

Lovell Lawn and Landscape continues to buy about six truckloads of dairy manure compost a year from the commercial composting operations located in the North Bosque River watershed. The majority of the compost is used in the maintenance and renovation of landscapes (lawns, flower beds, etc.) for customers that include private home owners and businesses in Stephenville and surrounding communities.

Currently, the company produces only a limited number of container grown trees. For this, Lovell utilizes a commercial potting media that contains dairy compost and is specifically formulated and marketed for that purpose by a local composter.

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Santo ISD Utilizes Dairy Manure Compost in Sports Field Management

The Fighting Wildcats of Santo High School, Farm-to-Market Road 2201, Santo, TX played football on a field that was considered to be in "fair-to-poor" condition largely due to compacted soil and substandard turfgrass cover.

Scott Mauney, Palo Pinto County Extension Agent – Agriculture, Texas Cooperative Extension, offered his assistance to the school board in renovating the field. He contacted Dr. Jim McAfee, Extension Turfgrass Specialist in Dallas, and together they formulated a sports field management plan that included mechanical aeration of the football field, a top-dress application of dairy manure compost and commercial (nitrogen) fertilizer, timely applications of irrigation and efficient weed control practices.

As part of the Dairy Manure Compost Utilization Program, a project funded through a Clean Water Act Section 319(h) Grant by the US EPA through the Texas Commission on Environmental Quality, Santo ISD and Texas Cooperative Extension cooperatively demonstrated the use of dairy manure compost on the field. Further, Santo ISD was able to receive a $5 rebate for each cubic yard of compost purchased.

The demonstration was implemented in May, 2004, when top-dress quality dairy manure compost was uniformly applied to the surface of the field at a rate of 80 tons per acre. Subsequently, the field was mechanically aerated to partially incorporate the compost, enhance nutrient and water uptake and to reduce compaction. As the season progressed, the field received two additional applications of 20 pounds per acre of inorganic nitrogen fertilizer and was mechanically aerated a second time.

The treatments and timely maintenance resulted in better turfgrass coverage and uniformity. Improvements were noted in grass density, health, color, and overall appearance. Ray Hollis, Maintenance Supervisor with the Santo ISD, even noted that the football players liked the added cushion of the healthy turf stand, which aided in fewer injuries when falling during play.

Unfortunately, the condition of the field has again declined primarily due to overuse this last season. Athletes from a newly constructed school were temporarily reassigned to the Santo ISD field and it was also utilized by community soccer programs. The expectation is that with the addition of new sports facilities in the community, use of this field will again be largely limited to varsity sporting events and field health can once again improve.

It is at this point that the board expects their investment in the dairy manure compost application to pay dividends. The one-time heavy applications of compost are expected to improve chemical and physical properties of the soil, which will potentially hasten the recovery of the field from damage caused by overuse or other stresses such as climate. In addition, large compost applications can improve turfgrass health and optimize turfgrass response to fertilization, irrigation, aeration, and other management practices. Thus, standard fertilizer treatments and management practices (e.g. irrigation, aeration, etc.) can maintain the field for several years before re-treatment with compost is necessary.

Due to the positive results on the football field, the Santo ISD School Board considered a similar compost-fertilizer-management program for the baseball infield in 2005. However, plans to construct a new field were also under consideration. Thus, the board decided to delay the substantial investment of a dairy compost application until baseball field construction plans were finalized.

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The costs of purchasing and hauling dairy compost can be substantial, especially for smaller school districts with limited budgets. Figure 1 is an example of the itemized costs associated with compost purchase and transport.

Compost Budget Sheet

Compost (200 CY @ $16.00/CY)................	*$ 3,200.00*
Freight (50 Mi @ $3.00/loaded Mi X 3 loads)..	*$ 450.00*
Sub-total (before rebate)...................	*$ 3,650.00*
Composted Manure Incentive Payment	
(Rebate of $5.00/CY)..................	*-$ 1,000.00*
TOTAL COSTS................................	***$ 2,650.00***

Figure 1. Estimated costs for the purchase and transportation of dairy manure compost. Costs are related based on a top-dress application on a football field at a rate of 80 tons per acre.

This example does not include the equipment and labor costs associated with compost application, which can also pose difficulty when utilizing compost. For example, compost spreaders were not readily available to Santo ISD but as part of the demonstration, TCE provided a small compost spreader. Mauney reports though that applying the 80 tons per acre compost treatment with the small research-type spreader required two people and nearly two days to accomplish.

The final question is will the school board realize the long term responses to the dairy compost applications they are anticipating? Research studies conducted at the Texas A&M Research and Extension Center at Dallas confirm that incorporation of dairy compost 6-inches deep into the soil does indeed provide such long term benefits. This and other demonstrations have shown that dairy compost is a good source of nutrients that are released for plant use over time. When supplemented with periodic commercial fertilizer applications, specifically nitrogen, turfgrass responses (growth, color, density) are typically better than those obtained following only commercial fertilizer use. Long term improvements in soil physical and chemical properties, however, are less likely to result from surface applications then from incorporation of dairy compost into the soil.

Citizens and Compost Beautify Tarrant County Courthouse

The landscape maintenance staff for the Tarrant County Northeast Sub-Courthouse, 645 Grapevine Highway, Hurst, Texas encountered problems in maintaining good growth and healthy appearance of turfgrasses and perennial flowers at that facility. When increasing the irrigation schedule from once to twice per week failed to improve plant performance and appearance, Dotty Woodson, Tarrant County Extension Agent – Horticulture, Texas Cooperative Extension, suspected problems related to fertility and soil conditions.

To address these landscape issues, Woodson established test plots to demonstrate the use of dairy manure compost combined with recommended rates of commercial fertilizer on turfgrass and perennial flowerbeds. Research and demonstration trials conducted at the Dallas Research and Extension Center showed dairy manure compost used in combination with inorganic fertilizer optimized plant growth, prepared soil for new plantings, and renovated problem areas in turfgrass and flower beds. These trials and Woodson's demonstration were components of the Dairy Manure Compost Utilization Project, which was funded through a Clean Water Act Section 319(h) Grant provided by the US EPA through the Texas Commission on Environmental Quality.

The treatments Woodson chose for the turfgrass demonstration were a) inorganic fertilizer only at the recommended rate of 8 pounds of nitrogen per 1,000 square feet applied two times during the growing season, b) dairy manure compost applied once at a rate equivalent to 20 tons per acre plus 20 pounds of inorganic nitrogen (N) applied twice during the growing season, and c) dairy manure compost applied twice at a rate equivalent to 20 tons per acre plus 20 pounds of inorganic nitrogen applied twice during the growing season. A 20 ton per acre rate of dairy manure compost is equivalent to about 1/2 inch of compost spread evenly over the grass surface.

The flowerbeds' treatments were a) inorganic fertilizer only at a rate of 8 pounds of nitrogen per 1,000 square feet, b) dairy manure compost at a rate of 100 tons per acre incorporated to a depth of 6 inches, and c) 100 tons dairy manure compost per acre plus 20 pounds of inorganic nitrogen incorporated to a depth of 6 inches. To convert the application rate to a smaller scale for the flowerbeds, Woodson determined the 100 ton per acre rate is equivalent to approximately a 6 inch layer of the material evenly applied on the soil surface.

By incorporating the compost into the top 6 inches of soil, Woodson created a much improved environment for plant growth and development. The dairy manure compost provided essential nutrients required by plants, added organic matter that improved soil physical properties, and increased water infiltration and retention within the soil.

The dairy manure compost was purchased from a commercial composter located in the North Bosque River Watershed. State agencies and local governments that purchase dairy manure compost from qualified vendors are eligible for the $5 per cubic yard rebate available through the Dairy Compost Incentive Program managed by the Texas Commission on Environmental Quality.

A highly regarded and effective Extension educator, Woodson has conducted numerous turf and ornamental plant management workshops for various groups, including the Tarrant County grounds maintenance staffs, Sheriff's department staff, individuals required to perform community service and Tarrant County jail inmates participating in a "from-jail-to-work" program.

She initiated the dairy manure compost demonstration project at the sub-courthouse with assistance from county community service participants who

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attended her workshops. With Woodson's guidance, the participants established the test plots by applying the dairy manure compost and fertilizer treatments. The grounds maintenance staff at that facility were also actively involved and able to apply their knowledge acquired from their training in the day-to-day care of the demonstration plots.

Turfgrass growth improved in vigor and color in the demonstration plots where compost and fertilizer were added. The differences were clearly visible and prompted many clients visiting the sub-courthouse to comment about the improved appearance of the turfgrass.

The growth and vigor of the ornamental plants were also greatly improved in the plots where compost and compost plus fertilizer were added.

In one problem area, grass seed was sown in an attempt to establish turf where it had not grown before. However, a large rain storm washed away some of the grass seed and the area is still bare. Woodson plans to apply more compost and grass seed to this area to help control erosion and establish turf.

Woodson said the county staff decreased water costs by an estimated 30-50 percent after the demonstration plots were established on the sub-courthouse turfgrass and flowerbeds. In the past, the staff watered twice a week, and now the staff only waters once a week. The compost increased the infiltration rate and water holding capacity of the soil. Woodson was unsure of the water savings in dollars for the county as a result of the education programs and demonstrations. However, she was sure her time with the staff throughout the project helped decrease the volume of irrigation water and saved the county money, as well as contributed to the beauty of their landscapes.

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Appendix L

Initial Fact Sheets

Compost Sampling Guideline
Using Compost for Erosion Control and Revegetation
Incentives to Purchase Dairy Compost
Using Organic Matter to Improve Sports Fields
Using Compost in the Urban Environment

Compost Sampling Guideline

Dairy Compost Utilization

C.A. Gerngross, M.L. McFarland and W.H. Thompson

The sampling of compost is an essential aspect of process monitoring, quality control, marketing, labeling of product and regulatory compliance. This sampling guide should be used to assess the quality of a finished product. By following these guidelines, the compost facility initiates the first step in participating in the US Composting Council's *Seal of Testing Assurance Program ("STA")*.

Please consult *Test Methods for the Examination of Composting and Compost*, Method 02.01-B online at http://tmecc.org/tmecc/ for original information related to this sampling guideline.

MATERIALS

- Front-end loader
- 15 cup-size compost samples per cut
- Sterilized sampling tool or glove
- Sterilized collection bucket(s) for cut areas
- 2, 5-gal sterilized mixing pails
- 2, 1-gal sample storage containers, (e.g., resealable plastic containers)
- 5% bleach solution
- Aluminum foil
- Newspaper, Butcher or Kraft paper
- Rigid shipping container, (e.g., cardboard box, etc.)
- Frozen ice packs
- Packing tape

WHAT TO SAMPLE

TMECC Method 02.01-B describes composite sampling to assess in-process compost and finished compost product. However, this sample guideline addresses the procedure for sampling a finished product.

A composite sample is a single sample composed of multiple, well-blended subsamples that, after thorough mixing, represents the traits of interest for an entire pile or windrow.

Select a screened pile or a finished windrow waiting to be screened. Avoid sampling from areas that are excessively wet, i.e., greater than about 60% moisture.

WHERE TO SAMPLE

Using a front-end loader, cut into the pile or windrow in at least 5 locations (figure 1). The 5 cuts must be randomly assigned and may be selected from either side of the windrow or pile. Cut into the entire depth of the pile and at least into half of the width of the pile. The cut should expose the middle of the pile from its natural base to its natural peak.

Take all necessary precautions that the walls of each cut are stable to prevent the potential for collapse. Also, make certain the sampling area is well ventilated to avoid exposure to potentially harmful gases.

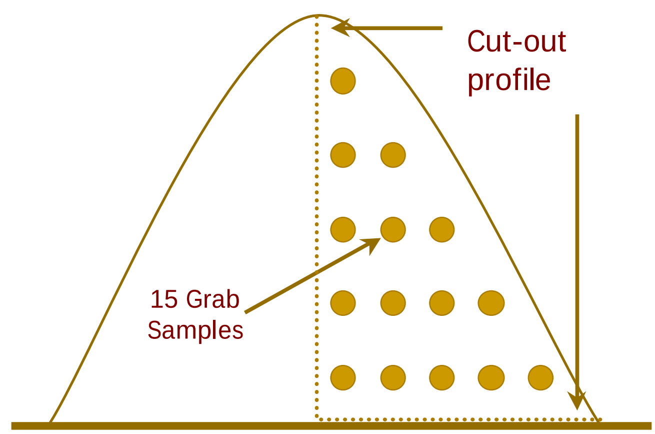

Figure 1. Cross-sectional illustration of one cut-out from an inverted "V" compost window. Circles represent 15 uniformly dispersed grab samples. Avoid collection of samples from pile or windrow surfaces.

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HOW TO SAMPLE

Collect 15 uniformly dispersed 1-cup samples from within one side of each of the 5 cut areas as illustrated in figure 1. Combine and thoroughly mix the 15 grab samples in the sterilized collection bucket. Repeat this process for each cut area.

In the 2 sterilized 5-gal mixing pails, combine all samples from the 5 cuts and thoroughly mix to make one composite sample. If balls form when mixing, the compost is too wet and should be partially air-dried prior to further mixing. Sample integrity is diminished and nitrogen loss should be anticipated when a sample is air-dried prior to shipping.

Quarter the composite sample by repeatedly dividing it in half until you have a 2-gal sample. Gently transfer the 2-gal sample into the 2 1-gal plastic resealable storage containers. Do not compact the compost samples.

7 Steps to Compost Sampling

1. **Select 5 areas of sample pile and cut into pile**
2. **Take 15 uniformly dispersed 1-cup samples from each of 5 cut areas**
3. **Thoroughly mix 15 grab samples from each cut together**
4. **Blend all samples to form 1 composite sample**
5. **Quarter the composite sample to 2-gal for testing**
6. **Cool 2-gal sample to 39°F**
7. **Package samples and ship by 1-day delivery to selected STA-approved laboratory for analysis.**

SANITATION PROCEDURES

Use a sterilized sampling tool and collection bucket made of stainless steel, plastic, glass or Teflon® to avoid sample contamination. Sterilize all sampling equipment before sampling and between different windrows or piles. To sterilize, wash sampling tools with soap and water, rinse with 5% bleach solution and then triple rinse with fresh water.

Wear appropriate protective clothing and use care when handling bleach or any other chemicals.

SAMPLE PRESERVATION

After packaging samples in 1-gal containers, chill them to about 4°C (39°F). Separately wrap each chilled sample container together with an ice pack, using multiple layers of newspaper, butcher or kraft paper. Line the inside of a rigid shipping container and its lid with aluminum foil. The paper and foil will help to insulate the shipping container. Place wrapped samples in the shipping container, filling voids between the sample containers and shipping container walls and lid with crumpled newspaper, butcher or kraft paper. Seal the lid on the shipping container with packing tape. Send the shipping container by 1-day delivery to your selected laboratory for analysis.

Laboratories that follow TMECC protocols must be approved through the STA program. A list of participating laboratories is available online at http://tmecc.org/sta/

WHEN TO SAMPLE

This is an end-process sampling so only material that is ready for market should be tested. According to STA program requirements, sampling frequency should be based on a facility's production capacity.

- 1 to 6,250 tons – sample once per quarter
- 6,250 tons to 17,500 tons – sample once per 2 months
- 17,500 tons and above – sample once per month

For more information concerning the Marketing Dairy Compost project or the STA program, please contact Cecilia Gerngross by email (cecilia@tamu.edu) or phone (979.458.1138).

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Using Compost for Erosion Control and Revegetation

S. Mukhtar

Dairy Compost Utilization

WHAT IS COMPOST?

Composting refers to the biological decomposition and stabilization of organic materials by microorganisms under aerobic (in the presence of oxygen) conditions. During the composting process biologically produced heat, under proper moisture and aeration conditions, accelerates decomposition of raw material followed by stabilization and well-managed curing of the product. As a result, good quality compost is produced that is biologically stable, relatively uniform in appearance, free of most pathogens and weed seeds, and has benefits as a soil amendment material with essential nutrients for plant growth. Thus, compost from various feed stocks including yard trimmings, manure, food processing residuals and other organic materials has been used to improve soil quality and productivity as well as prevent and control soil erosion.

COMPOST FOR EROSION CONTROL

Soil erosion from construction sites can be as much as 10 to 20 times greater than that from agricultural lands. Research reports from academia, the EPA, state departments of transportation (DOTs) and other sources suggest compost can be effective in controlling erosion and managing storm water from construction sites, including road rights-of-way, general construction and land development.

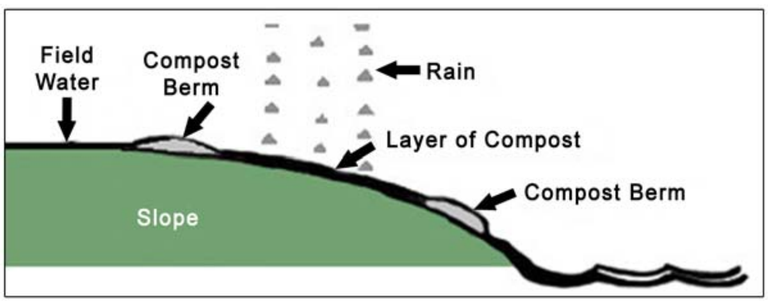

Figure 1. Compost filter berms and blankets (layer of compost covering the soil) for sediment and erosion control on steep slopes.

Figure 1 illustrates the use of compost as immediate, temporary erosion and sediment control in filter berms and compost blankets on top of existing soil on a steep slope. The berms or filter socks manage storm water run-on and retain sediment from above the slope, as well as retain runoff and sediment from the slope itself. The compost blanket controls slope erosion by reducing water flow velocity and the volume of sediment coming off of the slope.

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Compost can also be incorporated as a soil amendment or topsoil blend to improve soil structure. Both practices help establish a protective vegetation cover, which provides long-term erosion and sediment control. Due to compost's nutrient value and abundant organic matter, vegetation established in compost-amended soils grows healthier, faster. It is better able to endure extreme climatic conditions compared to vegetation planted in soil that receives commercial fertilizer as a sole nutrient source.

The same characteristics that benefit vegetation may also create water quality problems. Therefore, it is important to analyze the nutrient (N, P, K and other micronutrients), pH and soluble salt content of the compost before selecting and establishing its application rate for sediment or erosion control. Biosolid composts also require analysis for heavy metals. Lower nutrient composts should be considered for use on nutrient impacted areas. For example, a two-inch layer of compost weighing 1,500 pounds per cubic yard, applied over one acre will equal an application rate of nearly 200 tons per acre. If the compost contains average to high nutrient concentrations, this rate of application may be higher than the nutrient requirements of vegetation used for soil stabilization. This could lead to negative water quality impacts. The blending of compost with wood chips as an erosion-control blanket material may reduce the amount of nutrients applied per acre and their rate of release.

STORM WATER MANAGEMENT APPLICATIONS

New federal storm water permit requirements for general construction activities and for municipalities have placed much greater responsibility on local governments and construction contractors to put effective erosion and sediment controls in place. At the same time, research has been demonstrating the effectiveness of several practices using compost to stabalize soil, reduce suspended solids and sediment in runoff, reduce chemical loads and delay the onset and volume of runoff. Guidelines and specifications for the use of compost in erosion and sediment control applications can be found in the TCEQ reference document *BMP Finder*, http://www.tnrcc.state.tx.us/water/quality/nps/nps_stakeholders.html#bmp%20finderD.

Figure 2. Grass seed and compost being applied as a compost blanket for erosion control and revegetation of a road right-of-way.

DEPARTMENT OF TRANSPORTATION APPLICATIONS

The use of compost in erosion and sediment control has been extensively applied and studied in the stabilization of highway rights-of-way during construction or maintenance. In 1997, a survey of trends in using compost for road side applications revealed nearly 70 percent of the nation's DOTs were either experimenting with or routinely using compost. Some of the uses listed by these DOTs were:

- Mulch or top dressing
- Erosion control blankets for steep slopes
- Filter berms to control sediment movement (similar to silt fences)
- Hydroseeding (seed, water and compost mixed and sprayed on ground to establish vegetation)
- Wetlands mitigation
- Bioremediation (composted organic matter can break down pollutants into simpler, safer forms)
- Filter socks (mesh sock containing compost or mulch material)

Figure 3. Grass seed and compost being applied as a filter berm in a city park waterway to control runoff and sedimentation.

In Texas, the DOT has used composted dairy manure, feedlot manure, chicken litter, cotton gin burs, yard trimmings, and municipal biosolids as compost blankets for hydroseeding road rights-of-way to control soil erosion from steep slopes (Figure 2), and as filter berms to control erosion and sedimentation from low volume runoff (Figure 3). Recent projects utilize filter socks rather than berms as socks have a greater ability to withstand concentrated flows and retain sediment (Figure 4). In other applications, a West Texas municipal landfill uses compost produced from a mixture of poultry manure, sawdust and other wood residuals to control erosion, as a soil amendment and to create a vegetated cover over closed landfill cells.

Figure 4. Compost and wood chip mixture applied in a mesh casing as a filter sock to control runoff and sedimentation.

The Texas DOT (TxDOT) accepts high-quality compost such as dairy manure compost for use in compost manufactured topsoil (CMT), in erosion control compost (ECC) and as general use compost (GUC) (TxDOT Special Specification 1058, Compost). Compost is also used by TxDOT in the form of filter berms for erosion and sedimentation control (TxDOT Special Specification 1059, Compost/Mulch Filter Berm). A one-time use Special Specification is available from TxDOT regarding the use of filter socks. TxDOT requires all compost to be sampled and tested according to the Test Methods for Examination of Composting and Compost (TMECC) and must be Seal of Testing Assurance (STA) Program certified.

For TxDOT contracts, the CMT should consist of 75 percent topsoil blended with 25 percent compost on a volume basis. For ECC, 50 percent untreated woodchips are blended with 50 percent compost by volume. When used as GUC, 100 percent of the material should be compost. The compost filter berm will be a combination of 50/50 compost and wood chips. Table 1 provides general physical requirements for compost to be used for TxDOT contract work. For a detailed description of all the requirements, see TxDot Specifications 1058 and 1059 at http://www.dot.state.tx.us/des/landscape/compost/specifications.htm.

Table 1. Physical and chemical requirements of compost utilized in TxDOT Special Specification 1058*.

Property	Requirements
Particle Size	95% passing $^5/_8$" sieve, 70% passing $^3/_8$" sieve
Heavy Metals	Pass in accordance with TMECC Method 04.06
Soluble Salts	$\leq$ 5.0 dS/m ($\leq$ 10.0 dS/m accepted for CMT)
pH	5.5-8.5
Maturity	80%
Organic Matter	25-65% (dry mass basis)
Stability	$\leq$ 8
Fecal Coliform	Pass in accordance with TMECC method 07.01-B

*TxDOT Specification 1059 defines placement and use of compost as a filter berm. Such compost must still meet guidelines outlined in TxDOT Specification 1058. See TxDOT Specification 1059 for additional requirements.

Incentives to Purchase Dairy Compost

The Bosque River and Leon River watersheds are home to over 165 of Texas' dairy operations. In an effort to more effectively utilize dairy manure and halt the steady decline of water quality, the Texas Water Resources Institute (TWRI) and Texas Cooperative Extension (TCE) are working to market dairy compost. Incentive payments are available to both public and private sectors for participation in this environmentally friendly program.

PUBLIC ENTITIES

Through the Composted Manure Incentive Program, the Texas Commission on Environmental Quality (TCEQ) offers an incentive payment that is available for all Texas state agencies, local governments, cities, counties, regional planning agencies, special districts, school districts, and universities. These entities can employ the dairy compost for erosion control and landscaping purposes, which help to improve water quality throughout Texas.

The incentive payment offers $4 per cubic yard of dairy compost purchased from TCEQ-approved compost facilities. A list of participating compost facilities can be accessed at http://compost.tamu.edu.

Entities wishing to participate in the incentive program must comply with the guidelines set forth by the Composted Manure Incentive payment:

- Total cost of compost, shipping and application must be a minimum of $6.67.
- The Purchase Notification Form and Grant Application Form must be faxed to TCEQ no later than one week following compost delivery.
- Accurate records should also be kept to ensure proper and efficient use of the dairy compost.

PRIVATE ENTITIES AND INDIVIDUALS

Through the Dairy Compost Utilization Project, private producers, such as individual landowners, outside of the Bosque River Watershed and within the Upper Leon, Cross Timbers or Hamilton-Coryell Soil and Water Conservation District (SWCD) are eligible to receive a $3 per cubic yard rebate. Baggers and retail distributors of compost are also eligible to participate in the program.

Private purchasers of dairy compost follow the same TCEQ incentive payment guidelines; however, additional specifications must also be followed in order to ensure proper use of the program and its benefits:

- Land application of compost requires a Texas State Soil and Water Conservation Board certified Nutrient Management Plan.
- Apply for a rebate on a maximum of 4,000 cubic yards of compost.
- Complete a pre and post compost use assessment survey.

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The Texas A&M University System

Using Organic Matter to Improve Sports Fields

J.A. McAfee and C.A. Gerngross

Dairy Compost Utilization

CREATING A SUCCESSFUL SPORTS FIELD

One of the keys to establishing a successful sports field is the selection of a good quality soil for the rootzone. Unfortunately, the majority of high school and city park sports fields are currently constructed on native type soils, which may contain excess clay or sand.

Clay soils can compact, which impedes drainage and infiltration of water and causes a reduction in nutrient uptake and root growth. Additionally, compacted soils increase potential for player injury and increase the amount of nutrients, pesticides and water required to properly maintain a quality turfgrass stand. While a good aeration program will help alleviate soil compaction problems, the addition of organic matter in conjunction with aeration is the best method to correct such problems associated with heavy clay soils.

While soils high in clay content are a major problem for growing good turfgrass, soils high in sand content also can be a problem. Although sandy soils are less likely to compact and have better water infiltration and percolation rates, these soils still require an organic matter source to maintain an optimum playing field. Organic-matter deficient, sandy soils have little nutrient and water holding capacity. Increasing this capacity through the addition of organic matter will reduce the amount of fertilizer and water required to maintain healthy turfgrass on the field.

SOURCES OF ORGANIC MATTER

There are many organic matter sources for use on sports fields such as peat, rice hulls, sawdust, composted manures and yard trimmings. Table 1 provides an outline of recommended characteristics to consider when selecting an organic matter source.

COMPOST AS AN ORGANIC MATTER SOURCE

Composting is the biological decomposition of organic materials such as manure to a relatively stable endpoint. Fresh livestock manure is a mixture of urine and feces, varying in chemical and biological composition which is determined by the species of animal and their diet. Because bedding material is consequently harvested with raw manure during traditional collection practices, resulting compost contains additional components such as straw or sand. Biological activity, ventilation and heat generated during the composting process remove much of the moisture in raw manure, reduce odors, and kill most weed seeds and most disease microbes and parasites. In addition, composting reduces the total volume of manure by as much as 50 percent.

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Composted manure can be a significant source of essential plant nutrients including nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, as well as, micronutrients such as zinc, iron, copper and manganese. However the nutrient concentrations can vary widely from one manure compost to another. To determine appropriate compost application rates, it is important to obtain laboratory nutrient analysis of the production field and selected compost product. Table 2 shows the average and range in nutrient concentrations in composts made from different materials. The ratio of nutrient concentrations in a compost product is rarely an exact fit for crop needs. In particular, an application of compost that meets nitrogen requirements will often provide excess phosphorus. As a result, compost application rates should be determined based on crop phosphorus requirements and a phosphorus-free inorganic fertilizer should be utilized to complete crop nitrogen and/or potassium requirements.

Nutrient levels in compost are generally organic. Therefore, it is important to account for their slow release rate. Preliminary research using dairy manure compost in the production of warm-season grasses has indicated that nitrogen release rates are in the range of 30-35 percent of total N in the first year with decreasing rates the following years. As a result, fast-growing, high-nutrient demand crops such as corn typically require some amount of supplemental inorganic fertilizer to achieve optimum yields.

In addition to serving as a nutrient source, compost supplies stabilized organic matter, which is an important component of soils. Organic matter serves a special role in soils acting in the formation of very small soil clods, called aggregates, which improve soil structure and tilth, and increase water infiltration and water holding capacity. Organic matter also functions similar to clay in soils by increasing the cation exchange capacity, or the nutrient holding potential of a soil. Increasing soil organic matter with compost or other supplements is particularly important for maintaining soil quality in cropping systems where most of the above-ground biomass is removed, such as silage or hay.

APPLICATION OF ORGANIC MATTER

Two primary methods of adding organic matter to sports fields are soil incorporation and topdressing. Incorporation is the most effective method to improve poor quality soils as it provides direct improvement in soil structure, porosity and infiltration rates. Ideally, blend organic matter with soil off site to insure uniform mixing. On-site mixing can create “hot spots”, which are detrimental to plant growth. For best results, thoroughly incorporate 1 to 3 inches organic matter into 6 to 8 inches of soil prior to turfgrass establishment. Always consult a soil test and product analysis to determine exact rates as nutrient content will vary depending on product selection. Add enough product to increase organic matter content to a 2 to 5 percent range for heavy clay soils and up to 5 percent for sandy soils, depending on the type of sand used in construction.

Once turfgrass is established, adding significant amounts of organic matter to the soil becomes difficult. Topdressing with organic matter or a mixture of sand plus organic matter followed by aeration and dragging will help move organic matter into the soil over time. Ideally, apply a $^{1}/_{8}$- to $^{1}/_{4}$-inch layer of an organic matter source during each topdress application. Because cool season grasses are maintained at a higher cut, an application of up to ½-inch may be appropriate.

Applications of organic matter can be made one to three times per year depending on the composition and quality of the product.

Table 1. Recommended characteristics of organic matter sources.

Parameter	Optimum Range	Considerations
Moisture Content	30-50%	Material clumps when excessively wet and is dusty when excessively dry making application difficult.
Color	Dark brown to black	Sources such as rice hulls, sawdust, yard waste or manures should be fully composted.
Odor	No foul odor	Material should have an earthy smell.
Organic Matter	$\geq$ 25%	Source should have no more than 75% ash content.
C:N Ratio	$\leq$ 25:1	If C:N is too high, plants may show nitrogen deficiency.
pH	6-8	A neutral to acidic pH is preferred as some common turfgrass diseases are associated with an alkaline pH
Heavy Metals	low	
Salinity Level	low	Lab should test for both salt level and salt type.
Particle Size	$^3/_8$ - ½ to incorporate $^1/_8$ - ¼ to top dress	Contaminants such as rock or other debris can damage mowing equipment in topdress material.
Nutrient Content	low to medium	Nutrient content varies. Establish application rate from soil nutrient requirements, specifically nitrogen and phosphorus, and the corresponding nutrient content of the organic matter source.

Table 2. Average and range ( ) in nutrient values for various composts (McFarland, 2003; Risse, 2003; Brodie et al., 1996).

Compost Type	Dry Matter	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	%		lbs/ton	
Dairy Manure	**70 (58-80)**	**16 (11-23)**	**18 (6-31)**	**21 (8-48)**
Beef Manure	65 (54-72)	10	22	28
Poultry Litter	30 (22-36)	18 (11-25)	31 (11-52)	17 (10-21)
Municipal Solid Waste	40	24	15	6
Yard Waste	38	26 (6-84)	9 (2-23)	9 (1-65)

Using Compost In the Urban Environment

J.J. Sloan, K. Ong, C. McKenney, W.A. Mackay

Dairy Compost Utilization

WHAT IS COMPOST?

Compost is an organically rich soil amendment produced by the decomposition of waste materials from landscapes, animal feeding operations, municipal wastewater treatment facilities, and food industries. A properly composted product is dark colored and does not resemble the original parent materials. It is generally composed of 50 to 80 percent hemi-cellulose and lignin, which are stable and slow to decompose plant components. The remaining 20 to 50 percent are water-soluble compounds that soil microorganisms quickly break down. Fully decomposed materials do not tie-up plant nutrients when mixed with soil or produce any undesirable odors. Compost provides a slow release source of nutrients; hence, in the past it was called “black gold” by farmers.

BENEFITS

- ***Environmentally sound method of recycling plant and animal wastes.***
  Composting urban yard waste diverts plant materials from municipal landfills, which may reduce homeowners’ utility fees. Composting animal wastes for urban uses removes manure from agricultural watersheds, which may improve water quality in certain impacted rivers and lakes.

- ***Compost improves soil physical properties.***
  Organic matter is an essential component of soil. As compost decomposes in the soil, it releases organic molecules that bind soil particles together increasing soil aggregation. As a result, water and air infiltrate clay-textured soils more easily and sand-textured soils retain more plant available water. Accordingly, these effects improve the root zone environment.

- ***Compost can serve as a slow release source of plant nutrients.***
  Plant tissues or animal manures used to produce compost inherently contain plant essential macro- and micro-nutrients. The composting process retains these nutrients, which are slowly released to plants during their life cycle as the compost decomposes in the soil.

- ***Compost increases the nutrient retention capacity of the soil***
  Compost increases soil organic matter. Soil organic matter provides many cation exchange sites where plant nutrients are protected from being washed from the soil by rainfall or irrigation. The nutrients are held in the soil until they are utilized by the plant. Hence, compost increases the amount of plant nutrients retained in the soil root zone.

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- ***Compost suppresses plant diseases***
  Compost can control or suppress certain soil-borne plant pathogens such as Fusarium, Phytophthora, Pythium, and Rhizoctonia. The use of compost for disease control is theoretically sound, but its mode of action is poorly understood. Control of plant diseases by compost can be explained by five potential modes of action: (1) competition by beneficial microorganisms for space and nutrients; (2) antibiosis where beneficial microorganisms produce antibiotics that kill possible pathogens; (3) predation where beneficial organisms prey and feed on possible pathogens; (4) plant defense activation by elicitors in the composts; and (5) production of by-products in the compost that are detrimental to possible pathogens.

TIPS ON URBAN COMPOST USAGE

Compost quality depends on the feedstock used to produce it. Table 1 provides an outline of recommended characteristics to consider when selecting an organic matter source.

Table 1. Recommended characteristics of organic matter sources.

Parameter	Optimum Range	Considerations
Moisture Content	40-50%	Material clumps when excessively wet and is dusty when excessively dry making application difficult.
Color	Dark brown to black	Feedstock sources such as rice hulls, sawdust, yard waste or manures should be fully composted.
Odor	No foul odor	Material should have an earthy smell.
Organic Matter	$\geq$ 25%	Source should have no more than 75% ash content.
C:N Ratio	$\leq$ 25:1	If C:N is too high, plants may show nitrogen deficiency.
pH	6 - 8.5	
Heavy Metals	low	
Salinity Level	low	Lab should test for both salt level and salt type.
Particle Size	$^{3}/_{8}$ - ½ to incorporate $^{1}/_{8}$ - ¼ to top dress	Contaminants such as rock or other debris can damage mowing equipment in topdress material.
Nutrient Content	low to medium	Nutrient content varies. Establish application rate from soil nutrient requirements, specifically nitrogen and phosphorus, and the corresponding nutrient content of the organic matter source.

As stated in the table above, there are many factors to consider when selecting compost or an organic material. In order to achieve an effective compost application, the nutrient and salinity content and stability of the product and the soil type must be considered.

Product stability is important because compost products can vary widely in their degree of decomposition. A properly stabilized (C:N < 25:1) material prevents nutrient immobilization in the soil. If unstable compost (C:N ratio greater than 25:1) is added to the soil, soil microorganisms will temporarily tie up plant available nutrients in the soil, especially nitrogen, as they break down the unstable organic matter. In the short term, this nitrogen deficiency can cause severe yellowing of plants.

While several organic matter sources exist, not all provide plant essential nutrients as do most composted materials. Typically, composted animal manures have higher nutrient levels than other composted materials. However, understanding the nutrient and salinity content of your product is critical in achieving the maximum benefit from the material. Excessive nutrients, especially phosphorus, can tie up micronutrients in the soil, causing plant deficiencies. Such deficiencies can occur with repeated heavy applications of high phosphorus composts. Certain poultry litter composts may contain excessive salinity, which can be detrimental to seed germination, stunt plant growth and cause premature death.

Most soils can benefit from the addition of compost, but clay and sandy soils benefit more than loamy soils. Regardless of the soil type, it is important to begin with a laboratory analysis of the soil in order to determine pH, salinity, fertility levels, organic matter content and soil texture. The Texas Cooperative Extension's Soil, Water & Forage Testing Laboratory, accessible by the Web at http://soiltesting.tamu.edu, can provide a soil analysis that identifies existing nutrient levels in the soil, recommends additional fertility requirements, and identifies potential salinity problems. If the soil already contains high levels of phosphorus and nitrogen, it is best to use low-nutrient compost, such as composted municipal yard trimmings.

APPLICATION OF COMPOST

Compost is most easily used as a topdress for lawns and professional turf or as a mulch for bedded areas. Applying compost to the surface of the soil will reduce the risk of nitrogen immobilization by soil microbes due to unstable organic matter (C:N > 25:1). The compost will continue to decompose slowly on the soil surface. Rain and irrigation water will wash nutrients and organic compounds into the root zone. During the next growing season, this organic matter can be safely mixed into the soil prior to planting.

If the compost is stable and of good quality (as indicated in Table 1), then incorporating the material is the most effective method of adding organic matter to the soil profile. Prior to application, kill any existing perennial weeds, such as Bermudagrass, with an appropriate herbicide. After two weeks or effective weed kill has been established, cultivate soil with a roto-tiller to remove annual weeds and rocks and breakup compacted areas. Apply a one to four inch layer of compost to the cultivated soil and incorporate to a depth of eight to 12 inches. Initially, determine nutrient content of soil and compost, and, if necessary, apply synthetic fertilizers to meet additional nutrient requirements of selected vegetation. Also, apply lime or other soil amendments at this time if necessary. Rake and level soil surface to establish a smooth, firm planting bed and finally, plant seeds or transplants directly into prepared soil.

Appendix M

Compost Sampling Guideline
Economics of Using Composted Dairy Manure
Using Compost for Erosion Control and Revegetation
Using Organic Matter to Improve Sports Fields
Using Compost in the Urban Environment
Establishing Landscapes with Dairy Manure Compost
Using Dairy Manure Compost for Corn Production
Using Dairy Manure Compost for Forage Production
Using Dairy Manure Compost for Specialty Forages
Improving Compost Use through Application Methods

Compost Sampling Guideline

Dairy Compost Utilization

C.A. Gerngross, M.L. McFarland and W.H. Thompson

The sampling of compost is an essential aspect of process monitoring, quality control, marketing, labeling of product and regulatory compliance. This sampling guide should be used to assess the quality of a finished product. By following these guidelines, the compost facility initiates the first step in participating in the US Composting Council's *Seal of Testing Assurance Program ("STA")*.

Please consult *Test Methods for the Examination of Composting and Compost*, Method 02.01-B online at http://tmecc.org/tmecc/ for original information related to this sampling guideline.

MATERIALS

- ♦ Front-end loader
- ♦ 15 cup-size compost samples per cut
- ♦ Sterilized sampling tool or glove
- ♦ Sterilized collection bucket(s) for cut areas
- ♦ 2, 5-gal sterilized mixing pails
- ♦ 2, 1-gal sample storage containers, (e.g., resealable plastic containers)
- ♦ 5% bleach solution
- ♦ Aluminum foil
- ♦ Newspaper, Butcher or Kraft paper
- ♦ Rigid shipping container, (e.g., cardboard box, etc.)
- ♦ Frozen ice packs
- ♦ Packing tape

WHAT TO SAMPLE

TMECC Method 02.01-B describes composite sampling to assess in-process compost and finished compost product. However, this sample guideline addresses the procedure for sampling a finished product.

A composite sample is a single sample composed of multiple, well-blended subsamples that, after thorough mixing, represents the traits of interest for an entire pile or windrow.

Select a screened pile or a finished windrow waiting to be screened. Avoid sampling from areas that are excessively wet, i.e., greater than about 60% moisture.

WHERE TO SAMPLE

Using a front-end loader, cut into the pile or windrow in at least 5 locations (figure 1). The 5 cuts must be randomly assigned and may be selected from either side of the windrow or pile. Cut into the entire depth of the pile and at least into half of the width of the pile. The cut should expose the middle of the pile from its natural base to its natural peak.

Take all necessary precautions that the walls of each cut are stable to prevent the potential for collapse. Also, make certain the sampling area is well ventilated to avoid exposure to potentially harmful gases.

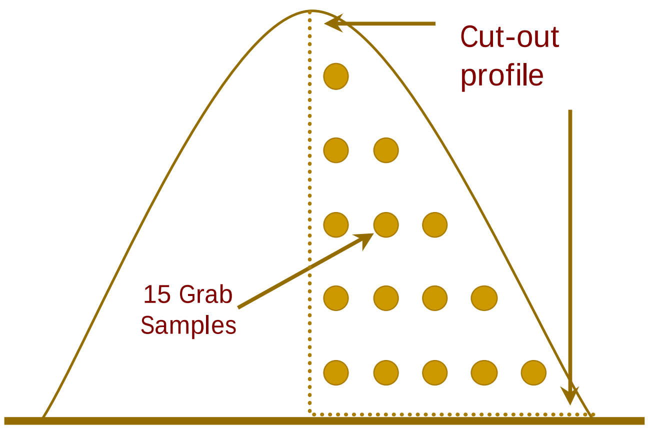

Figure 1. Cross-sectional illustration of one cut-out from an inverted "V" compost window. Circles represent 15 uniformly dispersed grab samples. Avoid collection of samples from pile or windrow surfaces.

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HOW TO SAMPLE

Collect 15 uniformly dispersed 1-cup samples from within one side of each of the 5 cut areas as illustrated in figure 1. Combine and thoroughly mix the 15 grab samples in the sterilized collection bucket. Repeat this process for each cut area.

In the 2 sterilized 5-gal mixing pails, combine all samples from the 5 cuts and thoroughly mix to make one composite sample. If balls form when mixing, the compost is too wet and should be partially air-dried prior to further mixing. Sample integrity is diminished and nitrogen loss should be anticipated when a sample is air-dried prior to shipping.

Quarter the composite sample by repeatedly dividing it in half until you have a 2-gal sample. Gently transfer the 2-gal sample into the 2 1-gal plastic resealable storage containers. Do not compact the compost samples.

7 Steps to Compost Sampling

1. **Select 5 areas of sample pile and cut into pile**
2. **Take 15 uniformly dispersed 1-cup samples from each of 5 cut areas**
3. **Thoroughly mix 15 grab samples from each cut together**
4. **Blend all samples to form 1 composite sample**
5. **Quarter the composite sample to 2-gal for testing**
6. **Cool 2-gal sample to 39°F**
7. **Package samples and ship by 1-day delivery to selected STA-approved laboratory for analysis.**

SANITATION PROCEDURES

Use a sterilized sampling tool and collection bucket made of stainless steel, plastic, glass or Teflon® to avoid sample contamination. Sterilize all sampling equipment before sampling and between different windrows or piles. To sterilize, wash sampling tools with soap and water, rinse with 5% bleach solution and then triple rinse with fresh water.

Wear appropriate protective clothing and use care when handling bleach or any other chemicals.

SAMPLE PRESERVATION

After packaging samples in 1-gal containers, chill them to about 4°C (39°F). Separately wrap each chilled sample container together with an ice pack, using multiple layers of newspaper, butcher or kraft paper. Line the inside of a rigid shipping container and its lid with aluminum foil. The paper and foil will help to insulate the shipping container. Place wrapped samples in the shipping container, filling voids between the sample containers and shipping container walls and lid with crumpled newspaper, butcher or kraft paper. Seal the lid on the shipping container with packing tape. Send the shipping container by 1-day delivery to your selected laboratory for analysis.

Laboratories that follow TMECC protocols must be approved through the STA program. A list of participating laboratories is available online at http://tmecc.org/sta/

WHEN TO SAMPLE

This is an end-process sampling so only material that is ready for market should be tested. According to STA program requirements, sampling frequency should be based on a facility's production capacity.

- 1 to 6,250 tons – sample once per quarter
- 6,250 tons to 17,500 tons – sample once per 2 months
- 17,500 tons and above – sample once per month

For more information concerning the Marketing Dairy Compost project or the STA program, please contact Cecilia Gerngross by email (cecilia@tamu.edu) or phone (979.458.1138).

Economics of Using Composted Dairy Manure

Dairy Compost Utilization

A variety of soil amendment products and potential nutrient sources provide flexibility for agricultural and horticultural systems. However, comparing the cost and value of these different soil amendments is not as simple as it might seem. Dairy manure compost, for example, supplies not only the major nutrients (nitrogen, phosphorus and potassium) but also a broad range of secondary nutrients, micronutrients and organic matter. These plant nutrients have an economic value, which can be utilized to estimate compost value for comparisons with traditional fertilizer materials. Organic matter applications, such as dairy manure, can also improve soil's water and nutrient holding capacity, reduce erosion and reduce fluctuations in soil pH.

Nutrients in compost products are more stable and typically released gradually over three or more years; whereas inorganic fertilizers are generally formulated to release nutrients within a year of application. Thus, a realistic assessment of compost value requires at least a three-year time frame. Also, since compost nutrient ratios and release rate may not be optimal for crop needs, some supplemental inorganic fertilizer (particularly nitrogen) may be necessary.

The following information provides steps to determine the economic feasibility of utilizing dairy compost as an alternative or a supplement to inorganic fertilizers.

STEP 1: UNDERSTAND NUTRIENT REQUIREMENTS AND AVAILABILITY

Soil nutrition specialists price nutrients on a per pound of nutrient basis; thus, dairy compost can be valued based on nutrient content. Before using dairy compost or any soil amendment, obtain a nutrient analysis of the material from the supplier or a local testing laboratory. Knowing the nutrient content will be valuable in determining application rates. A local County Extension Agent will be able to provide information on obtaining such analysis. Compost releases its nutrients slowly (over several years) as the material decomposes, while inorganic fertilizers typically release everything in one year. Table 1 presents nutrient availability from dairy manure compost over a three year period.

Table 2 presents basic costs associated with purchasing, transporting and applying dairy manure compost. Combine this information with table 1 to determine the initial value and cost of utilizing dairy manure compost.

Table 1. Estimated nutrient availability from 1 ton of dairy manure compost

Nutrient	Year 1	Year 2	Year 3
		lb	
N	9.38	4.69	2.34
P_2O_5	12.20	6.10	3.05
K_2O	15.90	7.95	3.98

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Table 2. Estimated costs related to the purchase, transportation and application of compost

Service	Price
Compost FOB	$10 per ton
Application	$2 per ton
Transportation	$2.50 per loaded mile

STEP 2: DETERMINE SPECIFIC NUTRIENT REQUIREMENTS

In addition to determining the nutrient content of the dairy manure compost, it is equally important to obtain a soil sample analysis of the intended application site. With the soil sample results, a local County Extension Agent can provide nutrient recommendations for a given crop or advise which nutrients are critical for a specific growing season.

With this information, you can estimate the costs associated with meeting specific nutrient requirements. Table 3 presents a cost analysis of utilizing inorganic fertilizer to meet specific requirements and since compost mineralizes over several (three) years, the cost analysis in Table 3 is evaluated over a three-year period.

STEP 3: DETERMINE APPLICATION RATE

Information about your soil and the compost discussed in Steps 1 and 2 provide a means to determine the application rate for composted dairy manure that would best meet nutrient needs of your desired crops. The selected rate typically satisfies the smallest of the NPK requirements (usually P) for an entire three-year cropping period. The analysis will also reveal whether there is anything about the compost that would require a lower rate of application, such as pH or salt content.

Once the compost application rate is determined, an inorganic fertilizer application may be recommended (primarily N) to maintain the best nutrient balance for your crops over the three year period.

Table 3: Example nutrient recommendations following soil analysis and cost of using an inorganic fertilizer to meet nutrient requirements

	Soil Test Recommendations	Nutrient Cost	Year 1 Cost	Year 2 Cost	Year 3 Cost	Total Cost[1]
	lb/A	$/lb	$/A			
N	300	$.29	$87	$87	$87	$261
P_2O_5	100	$.23	$23	$23	$23	$69
K_2O	300	$.15	$45	$45	$45	$135
Spreading			$3	$3	$3	$3
Hauling			0	0	0	0
Total			$158	$158	$158	$474

[1] Excludes the per Acre Cost of an optional Nutrient Management Plan

STEP 4: CALCULATE COST BENEFIT OF COMPOST AS A NUTRIENT SOURCE

Once nutrient recommendations and application rates are determined, a cost comparison can be developed. In this example, the per-acre cost of fertilizing coastal Bermudagrass at an agronomic rate with inorganic fertilizer alone to the cost of doing so with composted dairy manure supplemented by inorganic fertilizer is presented.

Table 4 provides a preliminary TAMU cost analysis for application of typical composted manure with the nutrient release rates shown in Table 1, along with the added cost of supplemental inorganic nitrogen applications in each of the three years. Because the transportation cost of compost is a significant part of its total cost, Table 4 provides three separate cost estimates representing the hauling cost at a distance of 10, 20, and 30 miles.

Table 4. Estimated costs at 3 distances (10, 20 and 30 miles) of using dairy compost with supplemental inorganic fertilizer as a nutrient source for coastal Bermudagrass production

Year	Application Rate	Hauling Distance	Hauling Cost	Compost[1]	Supplemental Inorganic Fertilizer	Total[2]
	ton/A	miles	$/A			
1	16	10	$15.50	$192	$43.50	$251.00
1	16	20	$31.00	$192	$43.50	$266.50
1	16	30	$46.50	$192	$43.50	$282.00
2	0				$65.00	$65.00
3	0				$87.00	$87.00

[1] Includes both cost of material and cost of application
[2] Excludes the per Acre Cost of an optional Nutrient Management Plan

Table 5 provides the net benefit or net saving of using compost as a primary nutrient source (at three different hauling distances) over a three year period. The net savings was calculated by subtracting the cost of utilizing compost supplement with inorganic fertilizer (Table 4) from the higher cost of utilizing inorganic fertilizer alone (Table 3). In this example, a combined program of compost and supplemental inorganic nitrogen fertilizer saves the producer approximately $40 to $71 per acre.

Note the cost of transportation is an important consideration. In this example, the cost of using the compost with supplements is equal to the cost of using inorganic fertilizer alone when the compost is transported 56 miles.

Table 5. Estimated cost comparison of a compost & supplemental inorganic fertilizer program to an inorganic fertilizer alone program. Savings are presented on a per acre basis and are calculated over a three year period

Distance	Compost Cost[1]	Supplemental Fertilizer Cost	TOTAL[2] Compost & Supplemental Fertilizer	TOTAL[2] Inorganic Fertilizer Only	Savings from Compost
miles			$/A		
10	$208	$196	$403	$474	**$71**
20	$223	$196	$419	$474	**$56**
30	$239	$196	$434	$474	**$40**

[1] Includes cost of transportation and application of compost
[2] Excludes the per Acre Cost of a Nutrient Management Plan

STEP 5: ESTIMATE THE ADDITIONAL VALUE OF COMPOST

The cost benefit estimated in Table 5 considers only the nutrient value of composted dairy manure. Dairy compost can provide economic benefits in addition to nitrogen, phosphorus and potassium. For example, compost applications can supply the soil and plants with secondary macronutrients and micronutrients. Also, water holding capacity of soil may be improved following the addition of organic materials, such as dairy compost, resulting in a decrease in irrigation costs. When mixed with a coarse mulch material, such as woodchips, dairy compost may also provide erosion control and support vegetation establishment, which may further reduce erosion. Finally, when utilized to establish landscapes, dairy compost may improve long-term performance of ornamental and turf plants.

If any of these additional benefits potentially provide a significant savings for your intended use, you may wish to experiment with composted dairy manure and determine the cost benefit for your particular application. A County Extension Agent can help with selecting a compost application rate to serve some of these purposes in addition to supplying nutrients.

For additional information on the use of compost, visit http://compost.tamu.edu.

Using Compost for Erosion Control and Revegetation

S. Mukhtar

Dairy Compost Utilization

WHAT IS COMPOST?

Composting refers to the biological decomposition and stabilization of organic materials by microorganisms under aerobic (in the presence of oxygen) conditions. During the composting process, biologically produced heat under proper moisture and aeration conditions, accelerates decomposition of raw material followed by stabilization and well managed curing of the product. As a result, good quality compost is produced that is biologically stable, relatively uniform in appearance, free of most pathogens and weed seeds, and has benefits as a soil amendment material with essential nutrients for plant growth. Thus, compost from various feed stocks including yard, manure, food processing residuals and other organic materials has been used to improve soil quality and productivity as well as prevent and control soil erosion.

COMPOST FOR EROSION CONTROL

Soil erosion from construction sites can be as much as 10 to 20 times greater than that from agricultural lands. Research reports from academia, the EPA, state departments of transportation (DOTs) and other sources suggest that compost can be effective in controlling erosion from construction sites including road rights-of-way, general construction and land development.

Figure 1 illustrates the use of compost as immediate, temporary erosion and sediment control in filter berms and compost blankets on top of existing soil on a steep slope. The berms or filter socks manage storm water run-on and retain sediment from above the slope, as well as retain runoff and sediment from the slope itself. The compost blanket controls slope erosion by reducing water flow velocity and the volume of sediment coming off of the slope.

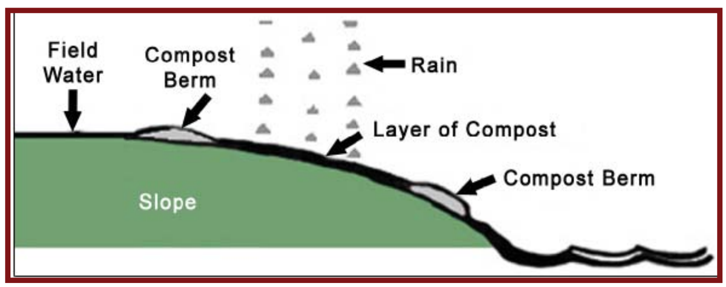

Figure 1. Compost filter berms and blankets (layer of compost covering the soil) for sediment and erosion control on steep slopes.

Compost can also be incorporated as a soil amendment or topsoil blend to improve soil structure. Both practices help establish a protective vegetation cover, which provides long-term erosion and sediment control. Due to compost's nutrient value and abundant organic matter, vegetation established in compost amended soils grows healthier, faster. It is better able to endure extreme climatic conditions compared to vegetation planted in soil that receives commercial fertilizer as a sole nutrient source.

The same characteristics that benefit vegetation may also create water quality problems. Therefore, it is important to

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analyze the nutrient (N, P, K and other micronutrients), pH and soluble salt content of the compost before selecting and establishing its application rate for sediment or erosion control. Biosolid composts also require analysis for heavy metals. Lower nutrient composts should be considered for use on nutrient impacted areas. For example, a two-inch layer of compost weighing 1,500 pounds per cubic yard, applied over one acre will equal an application rate of nearly 200 tons per acre. If the compost contains average to high nutrient concentrations, this rate of application may be higher than the nutrient requirements of vegetation used for soil stabilization. This could lead to negative water quality impacts. The blending of compost with wood chips as an erosion-control blanket material may reduce the amount of nutrients applied per acre and their rate of release.

STORM WATER MANAGEMENT APPLICATIONS

New federal storm water permit requirements for general construction activities and for municipalities have placed much greater responsibility on local governments and construction contractors to put effective erosion and sediment controls in place. At the same time, research has been demonstrating the effectiveness of several practices using compost to stabilize soil, reduce suspended solids and sediment in runoff, reduce chemical loads and delay the onset and volume of runoff. Guidelines and specifications for the use of compost in erosion and sediment control applications can be found in the TCEQ reference document BMP Finder, http://www.tnrcc.state.tx.us/water/quality/nps/nps_stakeholders.html#bmp%20finderD.

DEPARTMENT OF TRANSPORTATION APPLICATIONS

The use of compost in erosion and sediment control has been extensively applied and studied in the stabilization of highway rights-of-way after construction or maintenance. In 1997, a survey of trends in using compost for road side applications revealed that nearly 70 percent of the nation's DOTs were either experimenting with or routinely using compost. Some of the uses listed by these DOTs were:

- Mulch or top dressing
- Erosion control blankets for steep slopes
- Filter berms to control sediment movement (similar to silt fences)
- Hydroseeding (seed, water and compost mixed and sprayed on ground to establish vegetation)
- Wetlands mitigation
- Bioremediation (composted organic matter can break down pollutants into simpler, safer forms)
- Filter socks (mesh sock containing compost or mulch material)

Figure 2: Grass seed and compost being applied as a compost blanket for erosion control and revegetation of a road right-of-way.

In Texas, the DOT has used composted dairy manure, feedlot manure, chicken litter, cotton gin burs, yard trimmings, and municipal biosolids as compost blankets for hydroseeding road rights-of-way to control soil erosion from steep slopes (Figure 2), and as filter berms to control erosion and sedimentation from low volume runoff (Figure 3). Recent projects utilize filter socks rather than berms as socks have a greater ability to withstand concentrated flows and retain sediment (Figure 4). In other applications, a West Texas municipal landfill uses compost produced from a mixture of poultry manure, sawdust and other wood residuals to control erosion, as a soil amendment and to create a vegetated cover over closed landfill cells.

Figure 3: Grass seed and compost being applied as a filter berm in a city park waterway to control runoff and sedimentation.

The Texas DOT (TxDOT) accepts high-quality compost such as dairy manure compost for use in compost manufactured topsoil (CMT), in erosion control compost (ECC) and as general use compost (GUC) (TxDOT Special Specification 1058, Compost). Compost is also used by TxDOT in the form of filter berms for erosion and sedimentation control (TxDOT Special Specification 1059, Compost/Mulch Filter Berm). A one-time use Special Specification is available from TxDOT regarding the use of filter socks. TxDOT requires all compost to be sampled and tested according to the Test Methods for Examination of Composting and Compost (TMECC) and must be Seal of Testing Assurance (STA) Program certified.

For TxDOT contracts, the CMT should consist of 75 percent topsoil blended with 25 percent compost on a volume basis. For ECC, 50 percent untreated woodchips are blended with 50 percent compost by volume. When used as GUC, 100 percent of the material should be compost. The compost filter berm will be a combination of 50/50 compost and wood chips. Table 1 provides general physical requirements for compost to be used for TxDOT contract work. For a detailed description of all the requirements, see TxDot Specifications 1058 and 1059 at http://www.dot.state.tx.us/des/landscape/compost/specifications.htm.

Figure 4. Compost and wood chip mixture applied in a mesh casing as a filter sock to control runoff and sedimentation.

Table 1. Physical and chemical requirements of compost utilized in TxDOT Special Specification 161.

Property	Requirements
Particle Size	95% passing $^5/_8$" sieve, 70% passing $^3/_8$" sieve with TMECC Method 02.02-B
Heavy Metals	Following Pass in accordance with TMECC Method 04.06 Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pb), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Selenium (Se) and Zinc (Zn)
Soluble Salts	$\leq$ 5.0 dS/m ($\leq$ 10.0 dS/m accepted for CMT) with TMECC Method 04.10-A
pH	5.5-8.5 with TMECC Method 04.11-A
Maturity	80% with TMECC Method 05.05-A
Organic Matter Content	25-65% (dry mass basis) with TMECC Method 05.07-A
Stability	$\leq$ 8 with TMECC Method 05.08-B
Fecal Coliform	Pass in accordance with TMECC method 07.01-B

TxDOT Specification 1059 defines placement and use of compost as a filter berm. Such compost must still meet guidelines outlined in TxDOT Specification 161. See TxDOT Specification 1059 for additional requirements.

Using Organic Matter to Improve Sports Fields

J. A. McAfee and C. A. Wagner

Dairy Compost Utilization

CREATING A SUCCESSFUL SPORTS FIELD

One of the keys to establishing a successful sports field is the selection of a good quality soil for the root zone. Unfortunately, the majority of high school and city park sports fields are currently constructed on native type soils, which may contain clay or sand to a degree that affects the ability to grow and sustain quality turfgrass.

Clay soils can compact, which impedes drainage and infiltration of water and causes a reduction in nutrient uptake and root growth. Additionally, compacted soils increase potential for player injury and increase the amount of nutrients, pesticides and water required to properly maintain a quality turfgrass stand. While a good aeration program will help alleviate soil compaction problems, the addition of organic matter in conjunction with aeration is the best method to correct such problems associated with heavy clay soils.

While soils high in clay content are a major problem for growing good turfgrass, soils high in sand content also can be a problem. Although sandy soils are less likely to compact and have better water infiltration and percolation rates, these soils still require an organic matter source to maintain an optimum playing field. Organic matter deficient sandy soils have little nutrient and water holding capacity. Increasing this capacity through the addition of organic matter will reduce the amount of fertilizer and water required to maintain healthy turfgrass on the field.

Breckenridge High School employees apply inorganic nitrogen fertilizer to the football practice field after composted dairy manure was applied. Supplemental nitrogen is often required because the nutrient ratio in compost is rarely an exact fit for turfgrass needs.

SOURCES OF ORGANIC MATTER

There are many organic matter sources for use on sports fields such as peat, rice hulls, sawdust, composted manures and yard trimmings. Table 1 provides an outline of recommended characteristics to consider when selecting an organic matter source.

COMPOST AS AN ORGANIC MATTER SOURCE

Composting is the biological decomposition of organic materials such as manure to a relatively stable endpoint. Fresh livestock manure is a mixture of urine and feces, varying in chemical and biological composition which is determined by the species of animal and their diet. Because bedding material is consequently harvested with raw manure during traditional collection practices, resulting compost contains additional components such as straw or sand. Biological activity, ventilation and heat generated during the composting process remove much of the moisture in raw manure, reduce odors, and kill most weed seeds and most disease microbes and parasites. In addition, composting reduces the total volume of manure by as much as 50 percent.

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Texas Cooperative EXTENSION
The Texas A&M University System

Table 1. Recommended characteristics of an organic matter source, specifically compost

Parameter	Optimum Range	Considerations
Moisture Content	30-50%	Material clumps when excessively wet and is dusty when excessively dry making application difficult.
Color	Dark brown to black	Feedstock sources such as rice hulls, sawdust, yard waste or manures should be fully composted.
Odor	No foul odor	Material should have an earthy smell.
Organic Matter	≥ 25%	Source should have no more than 75% ash content.
C:N Ratio	≤ 25:1	If C:N is too high, plants show nitrogen deficiency.
pH	6-8	A neutral to acidic pH is preferred as some common turfgrass diseases are associated with an alkaline pH
Heavy Metals	low	
Salinity Level	low	Lab should test for both salt level and salt type.
Particle Size	⅜ - ½ to incorporate ⅛ - ¼ to top dress	Contaminants such as rock or other debris can damage mowing equipment in topdress material.
Nutrient Content	low to medium	Nutrient content varies. Establish application rate from soil nutrient requirements, specifically nitrogen and phosphorus, and the corresponding nutrient content of the organic matter source.

Composted manure can be a significant source of essential plant nutrients including nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, as well as, micronutrients such as zinc, iron, copper and manganese. However, the nutrient concentrations can vary widely from one manure compost to another. To determine appropriate compost application rates, it is important to obtain laboratory nutrient analysis of the sports field and selected compost product. Visit: http://soiltesting.tamu.edu for more information about laboratory analysis. Table 2 shows the average and range in nutrient concentrations in composts made from different materials. The ratio of nutrient concentrations in a compost product is rarely an exact fit for crop needs. In particular, an application of compost that meets nitrogen requirements will often provide excess phosphorus. As a result, compost application rate should typically be determined based on crop phosphorus requirements and a phosphorus free inorganic fertilizer should be utilized to complete crop nitrogen and/or potassium requirements.

Nutrient levels in compost are generally organic. Therefore, it is important to account for their slow release rate. Preliminary research using dairy manure compost in the production of warm-season grasses has indicated that nitrogen release rates are in the range of 30-35% of total N in the first year with decreasing rates the following years. As a result, fast growing, high nutrient demand crops typically require some amount of supplemental inorganic fertilizer to achieve desired growth.

Table 2. Average and range ( ) in nutrient values for various composts (McFarland, 2003; Risse, 2003; Brodie et al, 1996)

Compost Type	Dry Matter	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	%	lbs/ton		
Dairy Manure	**70 (58-80)**	**16 (11-23)**	**18 (6-31)**	**21 (8-48)**
Beef Manure	65 (54-72)	10	22	28
Poultry Litter	30 (22-36)	18 (11-25)	31 (11-52)	17 (10-21)
Municipal Solid Waste	40	24	15	6
Yard Waste	38	26 (6-84)	9 (2-23)	9 (1-65)

In addition to serving as a nutrient source, compost supplies stabilized organic matter, which is an important component of soils. Organic matter serves a special role in soils acting in the formation of very small soil clods, called aggregates, which improve soil structure and tilth, and increase water infiltration and water holding capacity. Organic matter also functions similar to clay in soils by increasing the cation exchange capacity, or the nutrient holding potential of a soil.

APPLICATION OF ORGANIC MATTER

Two primary methods of adding organic matter to sports fields are soil incorporation and topdressing. Incorporation is the most effective method to improve poor quality soils as it provides direct improvement in soil structure, porosity and infiltration rates. Ideally, blend organic matter with soil off site to insure uniform mixing. On-site mixing can create "hot spots", which are detrimental to plant growth. For best results, thoroughly incorporate 1 to 3 inches organic matter into 6 to 8 inches of soil prior to turfgrass establishment. Always consult a soil test and product analysis to determine exact rates as nutrient content will vary depending on product selection. Add enough product to increase organic matter content to a 2 to 5% range for heavy clay soils and a 10 to 20% range for sandy soils, depending on the type of sand used in construction.

A scarab mixes the dairy manure during the composting process to aerate the windrow which ensures proper composting.

Once turfgrass is established, adding significant amounts of organic matter to the soil becomes difficult and will require multiple years of application. Topdressing with organic matter or a mixture of sand plus organic matter followed by aeration and dragging will help move organic matter into the soil over time. Ideally, apply a ⅛- to ¼-inch layer of an organic matter source during each topdress application. Because cool season grasses are maintained at a higher cut, an application of up to ½-inch may be appropriate.

Applications of organic matter can be made 1 to 3 times per year depending on the composition and quality of the product. Due to nutrient composition of dairy manure compost, it typically provides more phosphorus than the turfgrass requires. Thus, soil tests must be conducted prior to multiple compost applications in subsequent years.

Santo High School Football Field Improved with Dairy Compost

A Texas Cooperative Extension employee spreads compost on the Santo High School football field to help improve the field's playing surface.

The Fighting Wildcats of Santo High School, Santo, TX, implemented a sports field management plan in 2004 with the help of Texas Cooperative Extension to improve its football field. The plan included mechanical aeration of the football field, a top-dress application of dairy manure compost and inorganic nitrogen fertilizer, timely applications of irrigation and efficient weed control practices.

District employees uniformly applied dairy manure compost to the field's surface at a rate of 80 tons per acre. As the season progressed, the field received two additional applications of 20 pounds per acre of inorganic nitrogen fertilizer.

The treatments and timely maintenance combined to give the field better grass density, health, color, and overall appearance. Ray Hollis, Santos ISD maintenance supervisor noted that the football players liked the added cushion of the healthy turf stand, which helped when falling during play.

For more information on the Santo ISD Football field dairy manure compost demonstration, visit http://compost.tamu.edu/demos_palopinto.php.

Using Dairy Manure Compost in the Urban Environment

J.J. Sloan, K. Ong, C. McKenney, W.A. Mackay

WHAT IS COMPOST?

Compost is an organically rich soil amendment produced by the decomposition of waste materials from landscapes, animal feeding operations, municipal wastewater treatment facilities, and food industries. A properly composted product is dark colored and does not resemble the original parent materials. It is generally composed of 50 to 80 percent hemi-cellulose and lignin, which are stable and slow to decompose plant components. The remaining 20 to 50 percent are water-soluble compounds that soil microorganisms quickly break down. Fully decomposed materials do not tie-up plant nutrients when mixed with soil or produce any undesirable odors. Compost provides a slow release source of nutrients and hence, in the past was called "black gold" by farmers.

BENEFITS

- **Environmentally sound method of recycling plant and animal wastes.**
  Composting urban yard waste diverts plant materials from municipal landfills, which may reduce homeowners' utility fees. Composting animal wastes for urban uses removes manure from agricultural watersheds, which may improve water quality in impacted rivers and lakes.
- **Compost improves soil physical properties.**
  Organic matter is an essential component of soil. As compost decomposes in the soil, it releases organic molecules that bind soil particles together increasing soil aggregation. As a result, water and air infiltrate clay-textured soils more easily and sand-textured soils retain more plant available water. Accordingly, these effects improve the root zone environment.
- **Compost can serve as a slow release source of plant nutrients.**
  Plant or animal tissues used to produce compost inherently contain plant essential macro- and micro-nutrients. The composting process retains these nutrients, which are slowly released to plants during their life cycle as the compost decomposes in the soil.
- **Compost increases the nutrient retention capacity of the soil.**
  Compost increases soil organic matter. Soil organic matter provides many cation exchange sites where plant nutrients are protected from being washed from the soil by rainfall or irrigation. The nutrients are held in the soil until they are utilized by the plant. Hence, compost increases the amount of plant nutrients retained in the soil root zone.

Soil physical properties like water infiltration and water retention capacity are improved as compost decomposes in the soil and releases organic matter. In turn, the root zone environment improves.

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- **Compost suppresses plant diseases.**
  Compost can control or suppress certain soil-borne plant pathogens such as Fusarium, Pythopthora, Pythium, and Rhizoctonia. The use of compost for disease control is theoretically sound, but its mode of action is poorly understood. Control of plant diseases by compost can be explained by five potential modes of action: (1) competition by beneficial microorganisms for space and nutrients; (2) antibiosis where beneficial microorganisms produce antibiotics that kill possible pathogens; (3) predation where beneficial organisms prey and feed on possible pathogens; (4) plant defense activation by elicitors in the composts; and (5) production of byproducts in the compost that are detrimental to possible pathogens.

TIPS ON URBAN COMPOST USAGE

Compost quality depends on the feedstock used to produce it. Table 1 provides an outline of recommended characteristics to consider when selecting an organic matter source.

Product stability, defined by the ratio of carbon to nitrogen (C:N), is particularly important because compost products can vary widely in their degree of decomposition. A properly stabilized (C:N < 25:1) material prevents nutrient immobilization in the soil. If unstable compost (C:N ratio greater than 25:1) is added to the soil, soil microorganisms will temporarily tie up plant available nutrients in the soil, especially nitrogen, as they break down the unstable organic matter. In the short term, this nitrogen deficiency can cause severe yellowing of plants.

A rotating basket type spreader is an effective unit for topdress applications of compost or any sand based mix. Its small size and ease of handling makes it effective for applications in small areas.

While several organic matter sources exist, not all provide plant essential nutrients. Typically, composted animal manures have higher nutrient levels than other composted materials. However, understanding the nutrient and salinity content of your product is critical in achieving the maximum benefit from the material. Excessive nutrients, especially phosphorus, can tie up micronutrients in the soil, causing plant deficiencies. Such deficiencies can occur with repeated heavy applications of high phosphorus composts. Certain poultry litter composts may contain excessive salinity, which can be detrimental to seed germination, stunt plant growth and cause premature death.

Most soils can benefit from the addition of compost, but clay and sandy soils benefit more than loamy soils. Regardless of the soil type, it is important to begin with a laboratory analysis of the soil in order to determine pH, salinity, fertility levels, organic matter content and soil texture. The Texas Cooperative Extension's Soil, Water & Forage Testing Laboratory accessible at http://soiltesting.tamu.edu can provide a soil analysis that identifies existing nutrient levels in the soil, recommends additional fertility requirements and identifies potential salinity problems.

APPLICATION OF COMPOST

Compost is most easily used as a topdress for lawns and professional turf or as a mulch for bedded areas. Applying compost to the surface of the soil will reduce the risk of nitrogen immobilization by soil microbes due to unstable organic matter (C:N > 25:1). The compost will continue to decompose slowly on the soil surface. Rain and irrigation water will wash nutrients and organic compounds into the root zone. During the next growing season, this organic matter can be safely mixed into the soil prior to planting.

If the compost is stable and of good quality (as indicated in Table 1), then incorporating the material is the most effective method of adding organic matter to the soil profile. Prior to application, kill any existing perennial weeds or undesirable plants, with an appropriate herbicide. After two weeks or effective weed kill has been established, cultivate soil with a roto-tiller to remove annual weeds and rocks and breakup compacted areas. Apply a 1 to 4 inch layer of compost to the cultivated soil and incorporate to a depth of 8 to 12 inches. Determine nutrient content of soil and compost and apply synthetic fertilizers if required to meet additional nutrient requirements of selected vegetation. Also, apply lime or other soil amendments at this time if necessary. Rake and level soil surface to establish a smooth, firm planting bed and finally, plant seeds or transplants directly into prepared soil.

Table 1. Recommended characteristics of an organic matter source, specifically compost

Parameter	Optimum Range	Considerations
Moisture Content	40-50%	Material clumps when excessively wet and is dusty when excessively dry making application difficult.
Color	Dark brown to black	Feedstock sources such as rice hulls, sawdust, yard waste or manures should be fully composted.
Odor	No foul odor	Material should have an earthy smell.
Organic Matter	≥ 25%	Source should have no more than 75% ash content.
C:N Ratio	≤ 25:1	If C:N is too high, plants show nitrogen deficiency.
pH	6 - 8.5	
Heavy Metals	low	
Salinity Level	low	Lab should test for both salt level and salt type.
Particle Size	⅜ - ½ to incorporate ⅛ - ¼ to top dress	Contaminants such as rock or other debris can damage mowing equipment in topdress material.
Nutrient Content	low to medium	Nutrient content varies. Establish application rate from soil nutrient requirements, specifically nitrogen and phosphorus, and the corresponding nutrient content of the organic matter source.

Using Compost to Establish New Landscapes

J.J. Sloan, K. Ong, C. McKenney, W.A. Mackay

Establishment of a healthy landscape involves more than selecting plants that will thrive in the intended location and climate. Dedicating substantial effort towards soil and landscape preparation will ensure that turf and other ornamental plants are better prepared for long-term healthy growth.

Typically in a newly constructed home or business landscape, the surrounding soil is severely disturbed and often, the subsoil and construction debris are mixed with or completely replace the original top soil. Ornamental plants and turf grasses planted in these disturbed soils may perform well in the short term due to abundant watering and fertilization, but they frequently decline with time when heat and drought stress become prevalent. Turf grass, perhaps is the single most important plant established in a new urban landscape due to the large area it occupies and its ability to protect the soil surface from erosion. Installation of sod following construction of a new home or business is an effective way to quickly protect soil that was severely disturbed and degraded by the construction process.

The aesthetic value and environmental protection of vegetation, however, is only as good as the landscape in which it is planted. Thus, the best time to amend and/or improve your landscape is before establishing any ornamental plants or turf grass. By incorporating organic amendments prior to vegetation establishment, soil properties such as organic matter, water holding capacity, fertility and buffering capacity can be enhanced. Dairy manure compost is one type of organic amendment that can be utilized to improve the soil.

Following construction of a new home or business, many times little effort is put towards landscape preparation, particularly the soil. Mixing dairy manure compost in the landscape prior to establishing vegetation, will enhance soil properties and prepare turf and ornamental plants for healthy growth.

WHAT IS COMPOST?

Compost is an organically rich soil amendment produced by the decomposition of waste materials from landscapes, animal feeding operations, municipal wastewater treatment facilities, and food industries. A properly composted product is dark colored and does not resemble the original parent materials. It is generally composed of 50 to 80 percent hemi-cellulose and lignin, which are stable and slow to decompose plant components. The remaining 20 to 50 percent are water-soluble compounds that soil microorganisms quickly break down. Fully decomposed materials do not tie-up plant nutrients when mixed with soil or produce any undesirable odors. Compost quality depends on the feedstock used to produce it. Table 1 provides an outline of recommended characteristics to consider when selecting an organic matter source.

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pH	6 - 8.5	
Heavy Metals	low	
Salinity Level	low	Lab should test for both salt level and salt type.
Particle Size	⅜ - ½ to incorporate ⅛ - ¼ to top dress	Contaminants such as rock or other debris can damage mowing equipment in topdress material.
Nutrient Content	low to medium	Nutrient content varies. Establish application rate from soil nutrient requirements, specifically nitrogen and phosphorus, and the corresponding nutrient content of the organic matter source.

APPLICATION OF COMPOST

Application rates of compost will vary depending on nutrient content of the compost and the soil. The nutrient concentrations can vary widely from one manure compost to another as noted in Table 2. Thus, it is important to begin with a laboratory analysis of the soil in order to determine pH, salinity, fertility levels, organic matter content and soil texture.

Once an application rate is determined, it is best to incorporate the compost 4 to 6 inches into the soil for best results. Because most vegetation established in landscapes will be permanent, (ie. turf grass), this will be the only opportunity to amend your landscapes surface and subsoil.

BENEFITS OF ESTABLISHING LANDSCAPES WITH DAIRY MANURE COMPOST

Scientists at the Texas A&M Agricultural Research and Extension Center in Dallas evaluated soil characteristics and plant performance following three dairy manure compost application rates (2, 4 and 6 lbs per ft^2) to construct new landscapes. Assuming an average density of 1,100 lbs per cubic yard, these rates are equivalent to applying compost at ½, 1 and 1-½ inches, respectively, to the surface of the soil. The compost was then incorporated or mixed into the soil at a 3 inch depth. Given the nutrient content of the dairy manure compost, all three applications supplied large amounts of N, P, and K to the soil.

Table 2. Average and range ( ) in nutrient values for various composts (McFarland, 2003; Risse, 2003; Brodie et al., 1996)

Compost Type	Dry Matter	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	%	lbs/ton		
Dairy Manure	**70 (58-80)**	**16 (11-23)**	**18 (6-31)**	**21 (8-48)**
Beef Manure	65 (54-72)	10	22	28
Poultry Litter	30 (22-36)	18 (11-25)	31 (11-52)	17 (10-21)
Municipal Solid Waste	40	24	15	6
Yard Trimmings	38	26 (6-84)	9 (2-23)	9 (1-65)

Water infiltration and moisture content. Water infiltration in the silty clay soil at Dallas was significantly increased by application of dairy manure compost 18 months after application. Consequently, rainfall and irrigation water infiltrated the compost-amended plots more quickly reducing the possibility of loss due to runoff or evaporation. This suggests that soil moisture levels following rainfall or irrigation would be elevated in the compost-amended plots, especially in the subsoil where water was able to infiltrate more easily.

Soil Compaction. Soil resistance measurements in the upper 8 inches were significantly reduced with the addition of dairy manure compost—especially with the highest rate of 6 lb per ft^2. Reduced penetration resistance in soil can increase root length by making it easier for roots to expand into the soil. Soil resistance is influenced by soil moisture, especially in clay soils like those in these study plots. It is likely that increased subsoil water content in the compost-amended plots reduced soil resistance measurements.

Soil Fertility. One of the greatest advantages of dairy manure compost is that it is a safe source of nearly all the essential plant nutrients, including some (Fe, Zn, Cu) that are frequently limiting in calcareous soils typical of the Blacklands Resource area. Continued availability of essential plant nutrients in compost-amended soils is one of the reasons it makes sense to use a large application of compost when initially establishing urban landscapes. As the compost organic matter continues to mineralize over subsequent growing seasons, there will continue to be an elevated concentration of plant available nutrients in the compost-amended soils, which reduces the need for subsequent fertilization.

Plots at the Texas A&M Agricultural Research and Extension Center in Dallas compared various rates of dairy manure compost to establish landscapes of turfgrass and perennial and annual ornamental plants.

Soil Phosphorus. Consequently, the continued source of plant nutrients provided by compost can also potentially pollute water quality. Phosphorus is the primary nutrient of concern because excessive soil P can reduce surface water quality when soluble and particulate forms of P reach surface water bodies. Dairy manure compost applications significantly increased soluble P in the soil in the Dallas Study. The plant available P in the upper 3 inches of compost-amended plots exceeded the critical P level (45 mg per kg) for soils, demonstrating that even modest applications of dairy manure compost can supply adequate P. Large dairy manure compost applications (more than 6 lb per ft^2) may actually add excessive P to the soil. Consequently, large repeated applications of dairy manure compost should be avoided because they can elevate soil P to levels that increase the risk of surface water quality degradation.

Dr. Cynthia Mckenney of the Texas A&M Agricultural Research and Experiment Station at Dallas discusses the use of dairy manure compost to establish newly constructed landscapes at the center's annual turf and ornamental field day.

Ornamental Plant Response. In general, the annual and perennial plants demonstrated positive responses to dairy compost applications. Out of all ornamental plants evaluated, Lantana had the greatest response to compost, followed by Pentas (Egyptian Star flower) and Dwarf Burford Holly. Their was sufficient evidence in the plant growth indicators to conclude that incorporation of dairy manure compost into the soil when establishing an urban landscape improved subsequent establishment and growth of ornamental plants.

Turf grass Response. Dairy manure compost significantly increased Bermuda grass color and quality ratings during the first year after application and also increased turf density during the later part of the growing season. The greatest effect on turf color, density, and quality ratings occurred during the second year after application, but the effects were still visible after 3 years, especially for color and quality ratings. In the absence of additional supplemental fertilization, Bermuda grass growth was significantly increased by dairy manure compost. The large effect of dairy manure compost on Bermuda grass ratings was mostly due to the large amount of N, P, K and micronutrients supplied by the compost.

CONCLUSION

Based on the data, there was ample evidence to conclude that amending an urban soil with an abundant amount of dairy manure compost prior to installing ornamental and turf plants will improve the long-term performance of those plants. Turf grass benefits, for example, persisted 3 years after application with no additional fertilization. The increased performance is probably due to greater levels of soil fertility, including major and minor essential plant nutrients, and improved soil physical properties, such as increased water infiltration and reduced soil compaction. Large repeated applications of dairy manure compost should be avoided to prevent excessive accumulation of soil phosphorus. However, given proper soil test results, an application of 2 to 4 lbs per ft^2 dairy manure compost (equivalent to ½ to 1 inches) is a very effective way to create and sustain a high-quality urban landscape.

Using Dairy Manure Compost for Corn Production

T.J. Butler, M.L. McFarland, and J. P. Muir

Corn is an important grain crop in Central Texas and the preferred silage crop due to its high yield and high-energy content. Corn silage can yield 20-25 tons of forage per acre based on 35% dry matter content. The kind and amount of fertilizer required for corn grain or silage will depend on the fertility status of the specific field, the cropping program, and whether compost or other organic nutrient sources will be used along with inorganic fertilizer. However, accurate fertilizer recommendations can be made only if soil test results are available for each production field.

Livestock manures have been used for centuries in crop production systems as a source of nutrients and organic matter. However, raw manure typically has a high moisture content, which increases transportation costs and can be a significant source of soluble nutrients, viable weed seeds and fecal bacteria that may be conveyed to surface water in runoff. Increasingly, composting is being utilized to improve the characteristics of manure for beneficial reuse in crop production systems.

BENEFITS OF COMPOSTED MANURE

Composting is the biological decomposition of organic materials such as manure to a relatively stable endpoint. Fresh livestock manure is a mixture of urine and feces, varying in chemical and biological composition, which is determined by the species of animal and their diet. Because bedding material is consequently harvested with raw manure during traditional collection practices, resulting compost contains additional components such as straw or sand. Biological activity, ventilation and heat generated during the composting process remove much of the moisture in raw manure, reduce odors, and kill most weed seeds and most disease microbes and parasites. In addition, composting reduces the total volume of manure by as much as 50%.

Composted manure can be a significant source of essential plant nutrients, including nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, as well as micronutrients as zinc, iron, copper and manganese. However, nutrient concentrations can vary widely from one manure compost to another. To determine appropriate compost application rates, obtain a laboratory nutrient analysis of the production field and selected compost product. Table 1 shows the average and range in nutrient concentrations in composts made from different materials. The ratio of nutrient concentrations in a compost product is rarely an exact fit for crop needs. In particular, an application of compost that meets nitrogen requirements will often provide excess phosphorus. As a result, compost application rates should be determined based on crop phosphorus requirements and a phosphorus free inorganic fertilizer should be utilized to complete crop nitrogen and/or potassium requirements. Two of the most important nutrients in compost, nitrogen and phosphorus, may be predominantly in organic forms in compost. Therefore, it is important to account for a slower release rate than is

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expected from inorganic fertilizer. Research using dairy manure compost in the production of warm-season grasses has indicated that nitrogen release rates are in the range of 30-35% of total N in the first year with decreasing rates the following years. As a result, fast growing, high nutrient demand crops such as corn typically require some amount of supplemental inorganic fertilizer to achieve optimum yields.

In addition to serving as a nutrient source, compost supplies stabilized organic matter, which is an important component of soils. Organic matter serves a special role in soils acting in the formation of very small soil clods, called aggregates, which improve soil structure and tilth, and increase water infiltration and water holding capacity. Organic matter also functions similar to clay in soils by increasing the cation exchange capacity, or the nutrient holding potential of a soil. Increasing soil organic matter with compost or other supplements is particularly important for maintaining soil quality in cropping systems where most of the above-ground biomass is removed, such as corn silage or hay.

Table 1. Average and range ( ) in nutrient values for various composts (McFarland, 2003; Risse, 2003; Brodie et al., 1996)

Compost Type	Dry Matter	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	%	lbs/ton		
Dairy Manure	**70 (58-80)**	**16 (11-23)**	**18 (6-31)**	**21 (8-48)**
Beef Manure	65 (54-72)	10	22	28
Poultry Litter	30 (22-36)	18 (11-25)	31 (11-52)	17 (10-21)
Municipal Solid Waste	40	24	15	6
Yard Trimmings	38	26 (6-84)	9 (2-23)	9 (1-65)

CORN NUTRIENT REQUIREMENTS

Corn has a high demand for nitrogen (N), phosphorous (P_2O_5), and potassium (K_2O), because of its high yield potential and the amount of dry matter produced. Obtain regular soil tests to predict the amount and type of fertilizer needed. Corn yields are often limited by inadequate supplies of nitrogen because it is commonly the single most deficient nutrient in soils and is required in the greatest amounts. Corn extracts less than 15 percent of its seasonal nitrogen uptake before rapid vegetative growth begins, with maximum nitrogen use occurring just before pollination. Thus, split application of nitrogen fertilizer is often recommended to improve nitrogen use efficiency.

Typically, one third of the total N and all of the P & K are applied at planting and the remaining two thirds of the N is applied at the V5 to V8 growth stage (5 to 8 emerged leaves with collars present), which occurs about 25 to 35 days after emergence. Corn requires 1.2 lbs N per bushel when yields exceed 150 bushels; 1.1 lbs N per bushel for yields of 100 to 150 bushels; and 1 lb N per bushel for yields less than 100 bushels per acre.

Table 2 provides average nutrient requirements for corn grain and silage based on yield goal. For example, if corn is producing 150 bushels per acre, 165 lbs of N, 95 lbs of P_2O_5, and 140 lbs of K_2O are needed per acre. Likewise, a 25-ton yield of corn silage requires approximately 250 lbs of N, 100 lbs of P_2O_5, and 140 lbs of K_2O per acre. Continuous corn silage production may require an increase in N, P, and K fertilizer rates compared to conventional grain production due to removal of the whole plant and all the nutrients contained therein.

Average nutrient values for dairy compost from Table 1 (16, 18, and 21 lbs/ton for N, P_2O_5, and K_2O, respectively) can be used along with the estimated nutrient requirements for corn in Table 2 to develop the proposed compost use rates presented in Table 3. An estimated 35% N release rate for compost was used for the calculations. It is important to note that because compost nutrient concentrations vary, estimated rates listed in Table 3 should be adjusted based on nutrient analysis of compost and application site. If the C:N ratio of the compost is greater than 25:1 (or unknown) then supplemental N should be applied along with the compost. When the C:N ratio is greater than 25:1, soil microbes will tie up the N to break down organic matter, which can result in a N deficiency.

Table 2. Estimated nutrient requirements for corn grain and silage (Texas A&M University Soil, Water and Forage Testing Laboratory)

Grain Yield	N	P_2O_5	K_2O	Silage Yield*	N	P_2O_5	K_2O
bu/A	lbs/A			ton/A	lbs/A		
70	70	65	80	**5**	50	45	55
90	95	75	90	**10**	100	65	75
110	120	85	110	**15**	150	85	100
125	145	90	130	**20**	200	95	120
150	165	95	140	**25**	250	100	140
190	210	100	150	**30**	300	105	160

*Based on 35% dry matter content.

Based on the rates used in Table 3, a single application of compost typically will provide enough P & K for three or more growing seasons. However, the nitrogen based loading rate should only be used on soils testing very low or low in plant available phosphorus and with composts having a low salt index. Accumulation of soluble salts near seed can reduce germination and/or kill young seedlings.

Table 3. Estimated rates of compost application for production of corn grain or silage based on crop N requirements and assuming a 35% N release rate from compost

Grain Yield	Compost Rate		Silage Yield	Compost Rate	
	Dry	Wet*		Dry	Wet*
bu/A	tons/A		ton/A	tons/A	
70	12.5	17.9	**10**	17.9	25.5
110	21.4	30.6	**20**	35.7	51.0
150	29.5	42.1	**25**	44.6	63.8
190	37.5	53.6	**30**	53.6	76.5

*Based on 30% moisture content in compost. Moisture content of compost may vary and should be determined to develop accurate rate recommendations.

Most often, compost rates are calculated based on the phosphorus requirements of the crop and supplemental N is applied to balance the ratio of nutrients that the crop needs. Calculations developed in Table 4 are based on an estimated 75% phosphorus availability rate from compost.

It is recommended to use this strategy when nitrogen release rates of compost are not known, or when the soil test indicates that phosphorus levels are moderate or higher. Listed rates may be multiplied by 2 or 3 to provide P for multiple years from one single application on sites where compost will be applied and thoroughly incorporated into the soil. However, compost application rates should always be based on annual crop phosphorus requirements in watersheds of streams or lakes that are nutrient impaired or on land that is subject to significant surface runoff. Also, select a fertilizer with a low phosphorus value to provide the indicated supplemental N.

Table 4. Estimated rates of compost application for production of corn grain or silage based on P & K requirements and with recommended supplemental N fertilizer rates

Grain Yield	Compost Rate		Fertilizer	Silage Yield	Compost Rate		Fertilizer
	Dry	Wet*			Dry	Wet*	
bu/A	tons/A		lbs N/A	ton/A	tons/A		lbs N/A
70	4.8	6.9	43	**10**	4.8	6.9	73
110	6.3	9.0	85	**20**	7.0	10.0	161
150	7.0	10.0	126	**25**	7.4	10.6	209
190	7.4	10.5	169	**30**	7.8	11.1	256

*Based on 30% moisture content in compost. Moisture content of compost may vary and should be determined to develop accurate rate recommendations.

SUMMARY

Manure compost can be a valuable addition to a crop production system by modifying and improving soil physical properties and serving as a source of plant nutrients. Because crops such as corn and corn silage have a high nutrient demand, supplemental nitrogen in the form of inorganic fertilizer often will be required to produce optimum crop yields. Use soil testing to determine nutrient needs in each field and for each crop based on a realistic yield goal. In addition, test compost prior to use to determine the nutrient composition and salt index. Compost application rates are most often based on the phosphorus requirements of the crop, with supplemental inorganic nitrogen applied to meet expected crop demands. Finally, avoid over application of nutrients such as hosphorus, whether from organic or inorganic sources, particularly in sensitive or impaired watersheds.

Using Dairy Manure Compost for Forage Production

T.J. Butler, J.P. Muir, T.J. Helton, C.A. Wagner, and M.L. McFarland

Dairy Compost Utilization

Forage crops make up a significant part of the total agricultural land in Texas and provide a critical food supply for the livestock industry. Most improved forages, such as the improved bermudagrasses, have been selected for their response to fertilizer inputs. Providing an adequate and balanced nutrient supply to these crops is important to produce high yields of quality forage while optimizing economics. The kind and amount of fertilizer required for forage crops depends on the fertility status of the specific field, the management system, and whether compost or other organic nutrient sources are to be used along with inorganic fertilizer. However, accurate fertilizer recommendations can be made only if soil analysis results are available for each production field.

Livestock manures have been used for centuries in crop production systems as a source of nutrients and organic matter. However, raw manure typically has a high moisture content, which increases transportation costs and can be a significant source of soluble nutrients, viable weed seeds and fecal bacteria that may be conveyed to surface water in runoff. Increasingly, composting is being utilized to improve the characteristics of manure for beneficial reuse in crop production systems.

BENEFITS OF COMPOSTED MANURE

Composting is the biological decomposition of organic materials such as manure to a relatively stable endpoint. Fresh livestock manure is a mixture of urine and feces, varying in chemical and biological composition which is determined by the species of animal and their diet. Because bedding material is consequently harvested with raw manure during traditional collection practices, resulting compost contains additional components such as straw or sand. Biological activity, ventilation and heat generated during the composting process remove much of the moisture in raw manure, reduce odors, and kill most weed seeds and most disease microbes and parasites. In addition, composting reduces the total volume of manure by as much as 50%.

Nutrient concentrations can vary widely from one manure compost to another but their outcomes are beneficial when applied at appropriate rates.

Composted manure can be a significant source of essential plant nutrients including nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, as well as, micronutrients such as zinc, iron, copper and manganese. To determine appropriate compost application rates, it is important to obtain laboratory nutrient analysis of the production field and selected compost product. Table 1 shows the average and range in nutrient concentrations in composts made from different materials. The ratio of nutrient concentrations in a compost product is rarely an exact fit for crop needs. In particular, an application of compost that meets nitrogen requirements will often provide excess phosphorus. As a result, compost application rate should be determined based

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on crop phosphorus requirements and a phosphorus free inorganic fertilizer should be utilized to complete crop nitrogen and/or potassium requirements.

Two of the most important nutrients in compost, nitrogen and phosphorus, typically are in organic forms in compost. Therefore, it is important to account for a slower release rate than is expected for inorganic fertilizer. Research using dairy manure compost in the production of warm-season grasses has indicated that nitrogen release rates are in the range of 30-35% of total N in the first year with decreasing rates the following years. As a result, fast growing, high nutrient demand crops typically require some amount of supplemental inorganic fertilizer to achieve optimum yields.

In addition to serving as a nutrient source, compost supplies stabilized organic matter, which is an important component of soils. Organic matter serves a special role in soils acting in the formation of very small soil clods, called aggregates, which improve soil structure and tilth, and increase water infiltration and water holding capacity. Organic matter also functions similar to clay in soils by increasing the cation exchange capacity, or the nutrient holding potential of a soil. Increasing soil organic matter with compost or other supplements is particular important for maintaining soil quality in cropping systems where most of the above-ground biomass is removed, such as through grazing, silage or hay.

Table 1. Average and range ( ) in nutrient values for various composts (McFarland, 2003; Risse, 2003; Brodie et al., 1996)

Compost Type	Dry Matter	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	%		lbs/ton	
Dairy Manure	**70 (58-80)**	**16 (11-23)**	**18 (6-31)**	**21 (8-48)**
Beef Manure	65 (54-72)	10	22	28
Poultry Litter	30 (22-36)	18 (11-25)	31 (11-52)	17 (10-21)
Municipal Solid Waste	40	24	15	6
Yard Trimmings	38	26 (6-84)	9 (2-23)	9 (1-65)

FORAGE NUTRIENT REQUIREMENTS

There are numerous species of forages with varying nutrient requirements, but they can be classified into two main groups: warm-season or cool-season. The most common warm-season grasses are bermudagrass, kleingrass, Old World Bluestems, and bahiagrass while the most common cool-season grasses are oats, rye, ryegrass, wheat, tall fescue, and tall wheatgrass.

The ratio of nutrients required is similar within each group, so yield potential is the primary factor determining differences in total nutrient requirements among the various species within a group. Typically, warm-season forages require 50 lb N, 14 lb P_2O_5, and 42 lb K_2O per ton of forage produced while cool-season forages require 60 lb N, 20 lb P_2O_5, and 32 lb K_2O per ton of forage produced (Table 2). The yield potential will vary slightly for species within a group. The major difference among warm-season grasses is that bermudagrass responds more to higher N rates compared to other grasses. The major factor determining bermudagrass yield potential is the amount of rainfall within a given year. In general, other introduced grasses have a maximum yield potential of approximately 4 ton/A.

Table 2. Estimated nutrient requirements for introduced warm-season and cool-season grasses (Texas A&M University Soil, Water and Forage Testing Laboratory)

Yield	Warm-Season			Yield	Cool-Season		
	N	P_2O_5	K_2O		N	P_2O_5	K_2O
tons DM/A		lbs/A		tons DM/A		lbs/A	
1	50	14	42	1	60	20	32
2	100	28	84	2	120	40	64
4	200	56	168	3	180	60	96
6	300	84	252	4	240	80	128
8	400	112	336				

The average nutrient values of dairy compost (Table 1: 16, 18, and 21 lbs/ton for N, P_2O_5, and K_2O, respectively) have been used along with the estimated nutrient requirements (Table 2) to develop the recommended compost use rates presented in Table 3. Most often, compost rates are calculated based on the phosphorus requirements of the crop and supplemental N is applied to balance the ratio of nutrients that the crop needs. Calculations developed in Table 3 used an estimated 75% phosphorus availability from compost.

This strategy is typically recommended to ensure that phosphorus levels added to the soil are not excessive. Listed rates may be multiplied by 2 or 3 to provide P for multiple years on sites where compost applications are thoroughly incorporated into the soil, or where surface applications have little potential for runoff. However, base application rates on annual crop phosphorus needs in watersheds that are nutrient impaired or on land that is subject to significant surface runoff. In addition, the use of buffer zones or filter strips is recommended where surface applications are made.

An estimated 30% N release was used to calculate the supplemental N rates presented in Table 3. If the carbon to nitrogen (C:N) ratio in compost is greater than 25:1 (or unknown) then supplemental inorganic N rates applied along with the compost may need to be increased accordingly. This is because when C:N ratios are greater than 25:1, soil microbes can tie up N to break down the organic C, which can lead to a N deficiency in the crop. Application of supplemental inorganic N will ensure that adequate N is available to supply the crop and to promote nutrient release from the compost.

Table 3. Estimated rates of compost application for production of warm-season or cool-season grasses based on P requirements and with recommended supplemental N rates

Warm-season Yield	Compost		Fertilizer	Cool-season Yield	Compost		Fertilizer
	Dry	Wet*			Dry	Wet*	
ton/A	ton/A		lbs N/A	ton/A	ton/A		lbs N/A
2	2.1	3.0	90	**1**	1.5	2.1	53
4	4.2	6.0	180	**2**	3.0	4.3	106
6	6.2	8.9	270	**3**	4.5	6.4	158
8	8.3	11.9	360	**4**	6.0	8.6	211

*Based on 30% moisture content in compost. Moisture content of compost may vary and should be determined to develop accurate rate recommendations.

Compost rates ranging from 16 to 32 wet tons/acre with supplemental N applied at rates of 50, 75 and 100 lbs/acre produced forage yields equal to a balanced (N:P:K) application of inorganic fertilizer at recommended rates. These studies indicated that compost supplied sufficient P to provide for the needs of the crop over two growing seasons. On some soils, supplemental K may be needed in the second season to obtain optimum yields. Annual soil testing should be used to determine supplemental inorganic K application rates.

SUMMARY

Manure compost can be a valuable addition to a crop production system by modifying and improving soil physical properties and serving as a source of plant nutrients. Because the ratio of N:P:K in compost is typically not an exact fit for crop needs and because the compost nutrient release rate is slow, supplemental inorganic fertilizer often will be required to produce optimum crop yields. Use soil testing to determine nutrient needs in each field and for each crop based on a realistic yield goal. In addition, test compost prior to use to determine the nutrient composition and predict nutrient supplying potential. Most often, base compost application rates on the phosphorus requirements of the crop, with supplemental inorganic nitrogen applied to meet expected crop demands.

Field studies conducted at the Stephenville Research Center have shown that dairy manure compost applied in combination with supplemental inorganic N can be effective for producing Coastal bermudagrass.

Using Dairy Manure Compost for Specialty Forages

J. Muir, T. Butler, and M. McFarland

Specialty forages are those that do not have a wide application in animal production systems of Texas. Other than beef cattle, systems that use cultivated forage can be considered atypical in our state. These include white-tailed deer, game birds (quail or turkey), exotic game, goats, sheep, domesticated rabbits or any other species that is primarily an herbivore. These animals generally require greater quality in their diets than do bulk (undiscriminating) grazers such as cattle, horses, donkeys, bison or Asiatic water buffalo. Selective grazers/browsers (the latter pluck individual leaves off forbs, bushes, trees and grass) usually harvest individual plant parts such as seeds, fruits or new leaves, which provide a greater concentration of available nutrients but are more difficult to collect. Grasses and legumes more palatable to selective grazers tend to be more difficult to maintain in pastures or range since they are generally less adapted to local conditions and are grazed (browsed) out more easily.

The fertilizer requirements of specialty forages will depend on the fertility status of the specific field, the plant species, the type and degree of grazing, and whether compost or other organic nutrient sources are to be used along with inorganic fertilizer. Livestock manures have been used for centuries in crop production systems as a source of nutrients and organic matter. However, raw manure typically has a high moisture content, which increases transportation costs and can be a significant source of soluble nutrients, viable weed seeds and fecal bacteria that may be conveyed to surface water in runoff. Increasingly, composting is used to improve the characteristics of manure for beneficial reuse in crop production systems. However, the first step in developing an effective nutrient management plan is to obtain a soil analysis for each production field.

BENEFITS OF COMPOSTED MANURE

Composting is the biological decomposition of organic materials such as manure to a relatively stable endpoint. Fresh livestock manure is a mixture of urine and feces, varying in chemical and biological composition which is determined by the species of animal and their diet. Because bedding material is consequently harvested with raw manure during traditional collection practices, resulting compost contains additional components such as straw or sand. Biological activity, ventilation and heat generated during the composting process remove much of the moisture in raw manure, reduce odors, and kill most weed seeds and most disease microbes and parasites. In addition, composting reduces the total volume of manure by as much as 50%.

Composted manure can be a significant source of essential plant nutrients including nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, as well as, micronutrients such as zinc, iron, copper and manganese. However, the nutrient concentrations can vary widely from one manure compost to another. To determine appropriate compost application rates, it is important to obtain laboratory nutrient analysis of the production field and selected compost product. Table 1 shows the average and range in nutrient concentrations in composts made from different materials. The ratio of nutrient concentrations in a compost product is rarely an exact fit for crop needs. In particular, an application of compost that meets nitrogen requirements will often provide excess phosphorus. As a result, compost application

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rate should be determined based on crop phosphorus requirements and a phosphorus free inorganic fertilizer should be used to complete crop nitrogen and/or potassium requirements.

Nutrient levels in compost are generally organic. Therefore, it is important to account for their slow release rate. Preliminary research using dairy manure compost in the production of warm-season grasses has indicated that nitrogen release rates are in the range of 30-35% of total N in the first year with decreasing rates the following years. As a result, fast growing, high nutrient demand crops typically require some amount of supplemental inorganic fertilizer to achieve optimum yields.

In addition to serving as a nutrient source, compost supplies stabilized organic matter, which is an important component of soils. Organic matter serves a special role in soils acting in the formation of very small soil clods, called aggregates, which improve soil structure and tilth and increase water infiltration and water holding capacity. Organic matter also functions similar to clay in soils by increasing the cation exchange capacity, or the nutrient holding potential of a soil. Increasing soil organic matter with compost or other supplements is particularly important for maintaining soil quality in cropping systems where most of the above-ground biomass such as through grazing.

Table 1. Average and range ( ) in nutrient values for various composts (McFarland, 2003; Risse, 2003; Brodie et al., 1996)

Compost Type	Dry Matter	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	%		lbs/ton	
Dairy Manure	**70 (58-80)**	**16 (11-23)**	**18 (6-31)**	**21 (8-48)**
Beef Manure	81	10	14	12
Poultry Litter	30 (22-36)	18 (11-25)	31 (11-52)	17 (10-21)
Municipal Solid Waste	40	24	15	6
Yard Trimming	38	26 (6-84)	9 (2-23)	9 (1-65)

SPECIALTY FORAGE DATA FROM STEPHENVILLE

The forage program at Stephenville has focused on specialty systems for the past five years. Most of these systems were legumes originally intended for wildlife plots, but they also have wider application such as for small ruminant systems. Due to the seasonal nature of their production, species adapted to cool-season and warm-season were studied separately. As indicated in Table 2, cultivated cool season legumes generally had very high quality indicators such as low levels of acid detergent fiber (quicker passage rates through digestive tracts) and high crude protein concentrations. Some of the medics and all the annual clovers had lower levels of lignin (indigestible fiber) than the vetches. The warm season legumes studied in Stephenville were also of general high quality (Table 2) while non-leguminous forbs were slightly lower. Legumes did not receive N fertilizer while the non-leguminous forbs did receive commercial rates of N.

BENEFITS OF INCORPORATING COMPOST INTO SPECIALTY FORAGE SYSTEMS

Application of dairy manure compost at rates of 18 tons/acre/year for two years to dryland cool season legumes increased yields by 48%, making this investment worthwhile (Table 3). In contrast, compost at 10 tons/acre/year over two years had no noticeable effect on warm-season dryland forage legumes. Lack of moisture (yields were generally low in drought years) appears to inhibit positive legume response to compost application since the same forages, when grown under more ideal irrigated conditions, did respond positively to compost application at 11 tons/acre/year, increasing yields by an average of 13%.

A review of the research to date at Stephenville indicates that, at least in the short term (all experiments were conducted for only two years) and at the levels applied (10 to 18 tons/ac.), compost did not improve forage quality. Even P levels in the forage did not improve, despite large increases in plant-available P in the soils. Other experiments have indicated that increasing soil P will often improve legume growth in infertile soils because this element is important for proper rhizobium development. However, the amounts of compost applied and the duration of the trials may not have given these crops sufficient time to show an effect of compost on nutritive quality.

SUMMARY

Application of dairy manure compost can significantly increase herbage yields of some specialty forage crops. This is especially apparent in the case of cool-season legumes, where compost nearly doubled yields under dryland conditions. Irrigated warm-season forbs appear to respond to dairy manure compost application more readily than do dryland systems, especially in drought years when moisture stress masks the benefits of compost. Although the growth response to compost addition was substantial for most crops, compost did not affect the nutritive value of these crops.

Table 2. Forage crude protein (CP), acid detergent fiber (ADF) and lignin concentration of cool season annual legumes, compiled from various experiments at Stephenville, TX

Forage Variety	CP	ADF	Lignin
		% of forage	
Cool-Season Legumes			
Medics			
Jemalong Barrel Medic	23.4	26.7	5.1
Little Medic, Devine	18.9	28.6	6.4
Black Medic, Beeville	23.5	25.0	5.6
Estes Button Medic	24.1	20.1	4.1
Button Medic, Stephenville	24.8	21.7	4.5
George Black Medic	20.9	20.7	4.9
Armadillo Burr Medic	24.6	29.9	6.6
Burr Medic, Stephenville	23.3	29.9	6.1
Burr Medic, Beeville	23.1	32.8	7.5
Spotted Medic, Stephenville	22.0	25.8	6.6
Cogwheel Medic, Stephenville	14.0	30.7	6.2
Clovers			
Dixie Crimson Clover	20.4	29.8	4.9
Overton R18 Rose Clover	17.1	35.5	4.2
AU Sunrise Crimson Clover	21.3	28.6	5.3
Common Ball clover	22.3	26.9	5.3
Vetches			
Common (narrowleaf) vetch	17.8	31.5	7.7
Hairy vetch	22.1	38.3	8.3
Llama vetch	17.4	36.8	8.6
Deerpea vetch (native)	18.4	32.6	7.9
Warm-Season Legumes			
Partridge Pea	18.1	19.4	5.9
Peanut	20.0	24.3	3.6
Phasey Bean	19.3	21.4	6.4
Tecomate lablab	19.7	23.7	4.5
Soybean (forage)	11.0	19.6	4.2
Iron-clay cowpea	18.7	21.3	3.9
Kudzu	15.3	25.1	6.1
Rayado bundleflower	16.9	17.1	4.4
Illinois bundleflower	13.5	19.3	5.0
Other Forbs			
Sunflower (oil type)	9.2	32.4	6.1
India Kenaf	14.9	26.9	3.6

Table 3. Forage dry matter yield of specialty forages grown with and without dairy manure compost in various experiments at Stephenville, TX

Forage Variety	Control Yield	Compost Yield
	lb/A	
Warm-Season Legumes (dryland) @ 10 tons compost per acre		
Partridge Pea	1050	NS[1]
Peanut	1350	NS
Phasey Bean	620	NS
Tecomate lablab	1400	NS
Soybean (forage)	600	NS
Iron-clay cowpea	1850	NS
Warm-Season Forbs (irrigated) @ 11 tons compost per acre		
Sunflower (oil type)	4650	5350
Kenaf (India)	12800	14750
Lablab (Tecomate)	7350	8500
Cowpea (Iron-clay)	4000	4600
Cool-Season Legumes (dryland) @ 18 tons compost per acre		
Yuchi arrowleaf clover	1850	3300
Common vetch	440	600
Armadillo burr medic	200	450
Estes button medic	500	1250
Black medic (North Texas)	100	250
Little burr medic (Devine)	100	250

[1]Compost plots produced greater (P>0.05) yields unless noted as not significant (NS).

Improving Compost Use through Application Methods

R. Alexander, C. Wagner

In the past, inefficient application methods have been a major barrier to the increasing use of compost in agriculture and horticulture, but that barrier is rapidly fading. Not only is special equipment becoming available, but compost producers and marketers often provide spreading services in combination with compost purchases.

Spreading equipment currently available varies in size, cost, technique and purpose and the efficacy of the compost application often depends on proper equipment selection. Being more knowledgeable of application equipment increases the value of the compost purchase and allows a user to take full advantage of the benefits of a compost material. The specific application method and selection of equipment compost depends upon several factors.

In large applications, the composted material is typically delivered to the application site in large trucks. Additional equipment is then often needed to load the compost into the unit for application.

- Know the **characteristics of the product**. Application equipment is specially designed to handle excessively dry or moist products. Particle size is also important. Most equipment is designed for products with consistent characteristics; thus, contaminants such as stones and sticks can efficacy.
- Know the **conditions of the application area**. Compost application equipment varies in size and spreading capability. Therefore, accessibility and size of the application area is an important factor. Finally, the equipment may be self propelled, tractor pulled or manually driven, which also affects equipment selection.
- Know the **desired amount and rate of compost**. For small projects, compost may be obtained in bags, but for larger projects, compost may be obtained in bulk and transported to the site by truck. The desired rate is also important as application equipment varies in ability to accurately apply very small or very large rates.
- Know about **past experience or use of equipment**. Some equipment used to apply compost today has not been specifically designed with compost in mind. The majority of units was engineered to apply agricultural by-products, such as manure, lime, fertilizer, mulch, or sand-based mixes and was modified to apply compost.

AGRICULTURAL APPLICATIONS

Two main types of compost applications in agriculture involve broadcast and row applications. For example, crops such as coastal Bermuda grass typically require a broadcast application in which compost is applied topically over a large area, yet specialty crops such as watermelons utilize row applications to concentrate compost in smaller, defined areas.

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Broadcast applications such as flail, slinger and spinner-type units project the compost from the rear of the spreader into the air. Flail units, which use paddles to broadcast the product from the rear of the unit, were developed to apply products with a higher solids content and are able to apply wider strips in the application area. Slinger units have a spinning drum with teeth that slings product up to 200 feet. These units can handle materials with higher moisture content such as ash, wet lime and biosolids. Spinner units rely on centrifugal force to project product from the rear of the unit. They work best on drier, denser materials that are fine in texture. Spinner units are typically used to apply compost in agricultural applications and at application rates of five to ten tons per acre or less.

This broadcast application, utilizes a spinner unit, which projects compost from the rear of the spreader at a calibrated rate of 10 tons per acre.

Topdressing units for broadcast applications include brush and cylinder-type units, in which a rotating, cylindrical brush projects the compost down towards the soil surface. Both broadcasting and topdressing units have the ability to apply low (1/4 to ½ inch layer) or high (1 inch layer) rates of compost. When rates of one inch or more are desired, piles of compost are strategically placed throughout the site and a grading blade, York rake or front-end loader/bull-dozer blade is used to spread the compost. While this method may not provide an accurate application rate, it is typically more efficient as most large-scale compost spreading units are not able to apply rates greater than 1 inch and thus would require multiple application trips through the field.

Moisture content and particle size of the compost is very important when broadcasting compost. For example, "box spreaders" or modified agricultural spreaders (used for commercial fertilizer or lime applications) often have difficulty spreading coarse or wet compost.

Row applications use both flail and slinger-type units, which can discharge compost from the side of the unit. Flail units with a side discharge were developed to apply products possessing higher solids content in narrow strips, or rows. Tractor trailers have even been fitted with flails to allow large volumes of compost to be spread. The most common slinger unit also side discharges manure. It applies a thin layer of material between planting rows and can apply compost to a depth of ½ to one inch over a raised nursery bed.

TURFGRASS APPLICATIONS

The best time to add organic matter in the form of compost to turfgrass is before planting or during establishment. In such cases, compost can be added at higher rates and incorporated thoroughly into the soil. Once the turfgrass is established, however, topdress applications of compost can be effective.

These topdress applications often use brush or beater drum/rotating cylinder-type units, which were designed to apply sand-based mixes for golf courses and athletic fields. Brush units use a spinning bristled brush to project materials at the soil surface. These units can handle product with a moisture content of over 50 percent, as well as somewhat coarse materials. The units are typically used to apply a one-eighth to one-half inch layer of compost, wood chips or sand/compost blends. Beater drum/rotating cylinder type units were designed to apply thicker application rates of high bulk density (sand-based) mixes over large open turf areas. The unit is extremely versatile, having the ability to apply a $^{1}/_{64}$ to three-inch layer of various materials. The unit is primarily used for golf course and athletic field applications and may be fitted with a finishing brush to break up product clumps and project the material more uniformly onto the soil surface. Blower type units can also apply compost for topdressing, however, obtaining accurate application rate with a blower type unit can sometimes be difficult.

Turfgrass application units, like this one shown above, are extremely versatile and can accurately apply compost at varying rates.

SPECIALIZED APPLICATIONS

Compost is often used as a mulch material to manage erodible soils, for decorative purposes or to provide organic matter to vegetated beds. Such applications often require special placement of compost around existing plants or release of compost in inaccessible areas.

Smaller units like this pneumatic/blower, propel compost through a wide hose which can be directed around plants and other objects. It also works well when applying compost to slopes and roadsides.

For erosion control berm applications, a pneumatic/blower type unit works well in that it can apply materials precisely and in inaccessible areas, using a hose of up to 300 feet in length. Larger blower-type units have been used to propel the compost up to 200 feet. This newly marketed technology was designed for products with a particle size of two inches or under in length and those possessing a moisture content of no more than 40 to 45 percent. Since typical composts do not meet these requirements, it is a common practice to combine compost with wood chips, sawdust or other wood material to create a mulch-type material. Larger capacity units (truck and trailer mounted units have a 20 to 60 cubic yard capacity) can also reduce the need to reload during application, which significantly improves efficiency. In the instance when such large applications are not required, applying the material by hand or with a basket type spreader is appropriate. In addition to blower units, newer slinger-type units have recently been fitted with devices that allow them to create berms as well.

Roadside slope applications use slinger units to apply the material. These are usually larger, pull-behind and truck-mounted units for use on highway and reclamation applications. These units can handle materials at higher moisture content such as ash, wet lime and biosolids. They can treat steep slopes and sites where accessibility is limited.

SELECTING AN APPLICATION METHOD

The key to efficient application of compost, as well as other products, is making sure the product being applied is compatible with the equipment being utilized. If it is not, an alternate piece of equipment should be used or the product's qualities should be modified. This typically can be accomplished by screening the product or by drying it to reduce its moisture content.

Finally, rely on the compost manufacturer and/or marketer as a resource for compost application services. Combining the compost purchase with the application service may prove to be more economical. However, if application services are not provided with your purchase, the compost producer will likely be able to direct you towards a business or individual who can meet your application needs.

Similar to the unit equipped with a hose, this roadside application is also spread with the pneumatic/blower technology. However, in this application, the unit is equipped with a side blower allowing for more coverage and mechanized application.

Appendix N

Texas Sales Calls and Literature Distribution

LAST NAME	FIRST NAME	TITLE	ORGANIZATION	ADDRESS	CITY	ZIP	INFO SENT*
Allen	Sharla	Director of Parks/Rec	City of Corsicana	200 North 12th Street	Corsicana	75110	F, U, S, E, I
Anderson	Amy	ED of Assoc. and City Recycle Coord.	Keep Copperas Cove Beautiful Ass.	Postal Drawer 1449	Copperas Cove	76522	F, U, S, E, I
Anderson	Dana	Superintendent	Dew ISD	Rt. 2, Box 60	Teague	75860	F, U, S, E, I
Anderson	Mark	Superintendent	Moody ISD	107 Cora Lee Lane	Moody	76557	F, U, S, E, I
Bailey	Mike	Business Manager	Cleburne ISD	103 S. Walnut Street	Cleburne	76033	F, U, S, E, I
Baker	Daryl	Planner	City of Dallas—Parks & Rec Dept.	1500 Marilla Street	Dallas	75201	F, U, S, E, I
Bark	Jerry	Director of Parks/Rec	City of Harker Heights	307 Millers Crossing	Harker Heights	76548	F, U, S, E, I
Barker	Jerry	Director Community Development	City of Hillsboro	PO Box 568	Hillsboro	76645	F, U, S, E, I
Barkley	Tommy	Maintenance Supervisor	Salado ISD	PO 98	Salado	76571	F, U, S, E, I
Barnes	Michael	Director Public Works	City of Richland Hills	3200 Diana Drive	Richland Hills	76118	F, U, S, E, I
Barrow	Ken	Principal	Kopperl ISD	PO 67	Kopperl	76652	F, U, S, E, I
Bechthold	Gary	Parks Maint. Supt.	City of North Richland Hills	6720 NE Loop 820	N. Richland Hills	76180	F, U, S, E, I
Bell	Keith	Director of Maint.	Gatesville ISD	311 S. Lovers Lane	Gatesville	76528	F, U, S, E, I
Bell	Sam	Superintendent	Hamilton ISD	400 S College	Hamilton	76531	F, U, S, E, I
Bellinger	Dee Ann	Business Manager	Blum ISD	PO 520	Blum	76627	F, U, S, E, I
Black	Rusty	Director Parks & Rec	City of Waco	PO Box 2570	Waco	76702	F, U, S, E, I
Bohannon	Dale	Assistant Superintendent	Marlin ISD	130 Coleman Street	Marlin	76661	F, U, S, E, I
Boudreau	Brian	City Manager	City of Dublin	213 East Blackjack Street	Dublin	76446	F, U, S, E, I
Box	Michael	Director of Public Works	City of Everman	212 North Race Street	Everman	76140	F, U, S, E, I
Bradley	Jerry	Assistant Director of Parks	City of Hurst	1505 Precinct Line Road	Hurst	76054	F, U, S, E, I
Browne	Jim	Parks Director	City of North Richland Hills	6720 NE Loop 820	N. Richland Hills	76180	F, U, S, E, I
Buchanan	Kim	Athletic Director	Aledo ISD	1000 Bailey Ranch Road	Aledo	76008	F, U, S, E, I
Buffe	Linda	Superintendent	Malone ISD	202 Apple Street	Malone	76660	F, U, S, E, I
Bush	Peggy	City Secretary	City of Glen Rose	PO Box 87	Glen Rose	76043	F, U, S, E, I
Canfield	Kevin	Maintenance Supervisor	Killeen ISD	110 N. WS Young Drive	Killeen	76543	F, U, S, E, I
Connor	Dean	Director Parks & Rec	City of Woodway	924 Estates Drive	Woodway	76712	F, U, S, E, I
Cook	Brad	Superintendent	Evant ISD	PO 339	Evant	76525	F, U, S, E, I
Cordell	Charles	Maintenance Supervisor	Hubbard ISD	PO 218	Hubbard	76648	F, U, S, E, I
Daly	Mary	City Manager	City of Alvarado	104 West College	Alvarado	76009	F, U, S, E, I
Doyan	Dan	Superintendent	Bruceville-Eddy ISD	61 Eagle Drive	Eddy	76524	F, U, S, E, I
Ericson	Shirley	Mayor	City of Covington	PO Box 443	Covington	76636	F, U, S, E, I
Fadden	Jennifer	Asst. Director Parks & Rec	City of Arlington	PO 90231	Arlington	76004	F, U, S, E, I
Fedro	Tim	Property Admin.	Methodist Home	1111 Herring Ave.	Waco	76708	F, U, S, E, I
Fletcher	R.C.	City Manager	City of Robinson	111 West Lyndale Street	Robinson	76706	F, U, S, E, I
Fowler	George	Director Parks & Rec	City of Haltom City	4839 Broadway Ave.	Haltom City	76117	F, U, S, E, I
Frazier	Pam	Business Manager	Covington ISD	PO 67	Covington	76636	F, U, S, E, I
French	Jamie	Mayor	City of Millsap	PO Box 57	Millsap	76066	F, U, S, E, I
Funderburke	Bill	City Administrator	City of Springtown	PO Box 444	Springtown	76082	F, U, S, E, I
Garik	Phil	Superintendent	Mt. Calm ISD	PO 105	Mt. Calm	76673	F, U, S, E, I
Garland	Marie	Business Manager	Meridian ISD	PO 306	Meridian	76665	F, U, S, E, I
Garner	Janet	City Administrator	City of Bruceville-Eddy	143 A Wilcox Drive	Eddy	76524	F, U, S, E, I
Gregory	Marvin	Public Works Director	City of River Oaks	4900 River Oaks Blvd.	Fort Worth	76114	F, U, S, E, I
Gropp	Mark	City Administrator	City of Itasca	126 No. Hill Street	Itasca	76055	F, U, S, E, I
Gwaltney	Jim	Superintendent	Aquilla ISD	404 N. Richards	Aquilla	76622	F, U, S, E, I

Haley	Melody	Assistant Superintendent	Whitney ISD	PO 518	Whitney	76692	F, U, S, E, I
Hallbauer	Les	Director of Pub Works	City of Belton	PO 120	Belton	76513	F, U, S, E, I
Harris	Ron	Maintenance Supervisor	Fairfield ISD	615 Post Oak Rd.	Fairfield	75840	F, U, S, E, I
Hatchel	John	Interim City Manager	City of Hamilton	200 E. Main Street	Hamilton	76531	F, U, S, E, I
Hawkins	Donna	City Secretary	City of Beverly Hills	3418 Memorial Drive	Beverly Hills	76711	F, U, S, E, I
Hendricks	Randy	Superintendent	Academy ISD	704 E. Main St.	Little River	76554	F, U, S, E, I
Hightshoot	Tim	Parks Superintendent	City of Colleyville	5109 Bransford Road	Colleyville	76034	F, U, S, E, I
Hughes	James	Parks Manager	City of Bedford	2000 Forest Ridge	Bedford	76021	F, U, S, E, I
Hughling	John	Groundskeeper	University of Mary Hardin Baylor	900 College, Station Box 8009	Belton	76513	F, U, S, E, I
Hunt	Robert	Superintendent	Belton School District	1220 Huey Road	Belton	76513	F, U, S, E, I
Iglehart	Ray	Director of Maint.	Temple ISD	505 S. 5th	Temple	76504	F, U, S, E, I
Jecmenek	Richard		Rogers ISD	210 Alvin Ailey	Rogers	76569	F, U, S, E, I
Jeter	Neil	Assistant Superintendent	Troy ISD	PO 409	Troy	76579	F, U, S, E, I
Johnson	Dee	Business Manager	Cranfills Gap ISD	PO 677	Cranfills Gap	76637	F, U, S, E, I
Jones	Georgia	City Secretary	City of Rio Vista	PO Box 129	Rio Vista	76093	F, U, S, E, I
Jones	Tom	Pubic Works Director	City of Nolanville	PO 128, 100 N Main	Nolanville	76559	F, U, S, E, I
Jones	Troy	Athletic Fields Superintendent	Tarleton State University	PO T0080	Stephenville	76402	F, U, S, E, I
Judy	Kenneth	Superintendent	Crawford ISD	200 Pirate Drive	Crawford	76638	F, U, S, E, I
Kenney	Donna	Director Parks & Rec	City of Keller	PO Box 770	Keller	76244	F, U, S, E, I
King	Bob	Maintenance Supervisor	Goldthwaite ISD	PO 608	Goldthwaite	76844	F, U, S, E, I
King	Dale	Conservation Specialist	U.S. Army Corps of Engineers	1801 N. Mill Street	Lewisville	75057	F, U, S, E, I
Krause	Peter	Parks & Rec. Director	City of Burleson	141 West Renfro	Burleson	76028	F, U, S, E, I
Kubala	Kenneth	City Secretary	City of West	PO Box 97	West	76691	F, U, S, E, I
Kueluar	Ronald	Business Manager	Burleson ISD	1160 SW Wilshire	Burleson	76028	F, U, S, E, I
Loftice	Nathan	Sol. Waste Coordinator	City of Grapevine	PO Box 95104	Grapevine	76099	F, U, S, E, I
MacDonald	William	City Manager	City of Hubbard	118 Magnolia Ave.	Hubbard	76648	F, U, S, E, I
McClain	Aaron	Parks & Rec. Superintendent	City of Granbury	401 N. Park St.	Granbury	76048	F, U, S, E, I
McDonald	Ray	Director of Parks & Comm. Serv.	City of Euless	201 N. Ector Drive	Euless	76039	F, U, S, E, I
McGehee	Charles	Superintendent	Morgan ISD	PO 300	Morgan	76671	F, U, S, E, I
Meaders	Steve	Parks & Rec. Director	City of Cedar Hill	502 Cedar Street	Cedar Hill	75104	F, U, S, E, I
Mennor	Michael	Director	BLORA	3rd Corp @ Fort Hood, PO 5779	Ft. Hood	76544	F, U, S, E, I
Michel	Sherry	Business Manager	Bosqueville ISD	7636 Rock Creek Road	Waco	76708	F, U, S, E, I
Miller	Gail	Business Manager	Jonesboro ISD	PO 125, 1 Eagle Drive	Jonesboro	76538	F, U, S, E, I
Mims	David	Superintendent	Iredell ISD	PO 39	Iredell	76649	F, U, S, E, I
Moon	Robert	Consultant		2526 Sir Turquin	Lewisville	75056	F, U, S, E, I
Moore	Joe	Assistant Director of Parks	City of Grapevine	PO Box 95104	Grapevine	76099	F, U, S, E, I
Moran	John	City Manager	City of Lorena	114 E. Center Street	Lorena	76655	F, U, S, E, I
Mosby	Kathy	Parks & Rec. Director	City of Weatherford	PO Box 255	Weatherford	76086	F, U, S, E, I
Neeley	Demaris	Main Street Director	City of Clifton	PO 231	Clifton	76634	F, U, S, E, I
Nelson	Judy	City Secretary	City of Whitney	PO Box 2050	Whitney	76692	F, U, S, E, I
Newton	Mike	Grounds Superintendent	Tarleton State University	PO 530	Stephenville	76402	F, U, S, E, I
Norr	Tracy	City Secretary	Town of Pantego	1614 South Bowen Road	Pantego	76013	F, U, S, E, I
O'Brien	James	Facilities Manager	Central Texas College	PO 1800	Killeen	76540	F, U, S, E, I
Phillips	Gene	Athletic Director	Azle ISD	1200 Boyd Road	Azle	76020	F, U, S, E, I
Pitchford	Harold	Act. Assistant Director Planning & Rec	City of Fort Worth	4200 S. Freeway	Fort Worth	76102	F, U, S, E, I
Powell	Skeet	Bldg. and Grounds Official	Temple College	2600 S. 1st St.	Temple	76504	F, U, S, E, I

Ragsdale	Joe	City Manager	City of San Saba	303 S. Clear Street	San Saba	76877	F, U, S, E, I
Reagan	Johnny	Director	Watauga—Public Wks & Pks Dept.	7800 Virgil Anthony Jr. Blvd.	Watauga	76148	F, U, S, E, I
Reed	Ann	City Secretary	City of McGregor	PO Box 192	McGregor	76657	F, U, S, E, I
Reed	Sandy	Director of Econ. Develop.	City of Dublin	403 East Blackjack Street	Dublin	76446	F, U, S, E, I
Reinhart	Jan	Director of Grounds	Mexia State School	PO 726	Wortham	76667	F, U, S, E, I
Rinehart	Keith	Director of Recreation	City of Saginaw	PO Box 79070	Saginaw	76179	F, U, S, E, I
Roaming	Val	Parks Superintendent	City of Temple	3210 E Ave H, Bldg. A, Ste 130	Temple	76501	F, U, S, E, I
Robertson	Max	Parks Superintendent	City of Cleburne	PO 677	Cleburne	76033	W
Rodriguez	Mario	Parks Dept. Superintendent	City of Benbrook	911 Winscott Road	Benbrook	76126	F, U, S, E, I
Sanders	Jeff	Athletic Director	Blum ISD	PO 520	Blum	76627	F, U, S, E, I
Schronk	Odell	Director Maint. & Trans.	Itasca ISD	123 N. College St.	Itasca	76055	F, U, S, E, I
Scott	Cindy	City Administrator	City of Kerens	PO Drawer 160	Kerens	75144	F, U, S, E, I
Sexton	Jamie	Director Public Works	City of Lake Worth	3805 Adam Grubb Street	Lake Worth	76135	F, U, S, E, I
Sheppard	Bill	Superintendent	Valley Mills ISD	PO 518	Valley Mills	76689	F, U, S, E, I
Skinner	Larry	Director Parks & Rec	City of Ennis	PO 220	Ennis	75120	F, U, S, E, I
Sowell	Ricky	Public Works Director	City of Hico	PO 533	Hico	76457	F, U, S, E, I
Spitzer	Kitsy	Business Manager	Clifton ISD	1102 Key Street	Clifton	76634	F, U, S, E, I
Sullivan	Barry	Assistant City Manager	City of Hewitt	PO Box 610	Hewitt	76643	F, U, S, E, I
Taylor	Lahoma	Admin Assistant	Chilton ISD	PO 488	Chilton	76632	F, U, S, E, I
Taylor	Linda	City Secretary	City of Venus	PO 380	Venus	76084	F, U, S, E, I
Tharp	Rich	Parks Superintendent	City of White Settlement	214 Meadow Park Drive	White Settlement	76108	F, U, S, E, I
Thomas	Charlie	Assistant Director of Public Works	City of Southlake	1400 Main Street, Suite 320	Southlake	76092	F, U, S, E, I
Thomason	Jack	Superintendent	Wortham ISD	PO 247	Wortham	76693	F, U, S, E, I
Thompson	Malcolm	Park & Pub. Ground Superintendent	City of Killeen	2201 E. Veterans Memorial	Killeen	76543	F, U, S, E, I
Timmons	Terry	Superintendent	Abbott ISD	PO 226	Abbott	76621	F, U, S, E, I
Townsend	Rod	Supt. & Maint. Supervisor	Hico ISD	PO 218	Hico	76457	F, U, S, E, I
Wallace	Marla	Business Manager	Rosebudd-Lott ISD	PO 638	Rosebud	76570	F, U, S, E, I
Wells	Drew	Director of Community Services	City of Stephenville	298 West Washington	Stephenville	76401	F, U, S, E, I
West	Stephanie	Bldg. Official	City of Nolanville	PO 128	Nolanville	76559	F, U, S, E, I
Whalen	Reggie	Superintendent	Westphalia	124 CR 3000	Lott	76656	F, U, S, E, I
Wilhelm	Larry	Compost Coordinator	City of Grapevine	PO Box 95104	Grapevine	76099	F, U, S, E, I

37 leads (highlighted in yellow) were deemed to be for immediate follow-up, with landscape projects pending between now and the fall of this year
* **F**-facilities, **U**-urban, **S**-sports fields, **E**-erosion, **I**-incentives, **W**-Web site

Appendix O

Practice Verification Study Reports

The individual study manager processed and analyzed data contained in the verification study reports. Information within the report was also reviewed for accuracy by the principal investigators, project manager and project quality assurance officer.

Urban Uses for Composted Dairy Manure

John J. Sloan, Cynthia McKenney, Wayne Mackay, and Steve George
Texas A&M University Research and Extension Center at Dallas

BACKGROUND

Construction of new homes and businesses is a continuous process in rapidly growing urban areas such as the Dallas metropolis. Post-construction landscaping is usually approached from only the plant-selection viewpoint and little effort is devoted to the severely disturbed soil. Subsoil and construction debris are often mixed with or completely replace the original top soil. Although ornamental plants and turf grasses planted in these disturbed soils may perform well in the short term due to abundant watering and fertilization, they frequently decline with time when heat and drought stress become prevalent. Dairy manure compost (DMC) is a readily available soil organic matter amendment in many areas due to the presence of large dairy operations. These dairy operations need alternative ways to dispose of their manure because soils surrounding the diary operations are often elevated in soil P. Consequently, dairy farmers and state regulatory agencies are considering urban markets for composted dairy manure.

OBJECTIVES

The objective of this study was to evaluate the effect of large single applications of DMC on the establishment and subsequent growth of typical urban landscape plants and to evaluate the effects on soil chemical and physical properties.

PROCEDURE

Experimental plots measuring 6x6 m were established on a fallow agricultural field. Dairy manure compost purchased from Erath Earth Compost, Dublin Texas was applied at rates of 0, 9, 18, and 27 kg m^{-2} and incorporated into the soil using a field cultivator. Selected chemical and physical properties of the compost are shown in Table 1. Compost applications supplied large amounts of N, P, and K to the soil (Table 2). Following the application and incorporation of compost, half of each plot was established with bermudagrass sod and the other half was established with 9 different ornamental plants consisting of annual, perennial, and woody species (Fig. 1). Plant performance data was collected for three summers. Soil samples were collected each summer for nutrient analysis. Soil compaction was measured using a hand-held penetrometer and infiltration rate was measured with a Guelph infiltrometer.

RESULTS

Soil properties

Infiltration Rate and soil moisture: Water infiltration into the Austin silty clay soil was significantly increased by application of dairy manure composts 18 months after application (Fig. 2). Consequently, rainfall and irrigation water infiltrated the compost-amended plots more quickly reducing the possibility of loss due to runoff or evaporation. This suggests that soil moisture levels following rainfall or irrigation would be elevated in the compost-amended plots, especially in the subsoil where water was able to infiltrate more easily.

Soil moisture measurements during the first two growing seasons verified that soil moisture in the surface (0-7.5 cm) and subsurface (7.5-15 cm) were elevated in compost-amended plots (Fig. 3). Soil moisture was measured twice during the first growing season after application of the dairy manure compost and once during the second growing season. Soil moisture was measured at depths of 0-7.5 cm (0-3 inches) and 7.5-15 cm (3 to 6 inches). Soil moisture was seldom limiting during either growing season because plots were irrigated weekly with 2.5 to 5 cm water (1 to 2 inches). Soil moisture at both depths consistently increased with increasing rates of dairy manure compost for both irrigated growing seasons, but the relationship was not always statistically significant due to a large degree of variability in the data (Fig. 3). In contrast, during the 2005 growing season, turf plots were not irrigated so that we could observe the effect of compost amendments under natural rainfall conditions. Under conditions of no irrigation, soil moisture decreased with compost application rate (July 24, 2005). This decrease in soil moisture in the absence of irrigation can be attributed to greater transpiration by the healthier, more vigorous turfgrass growing on the compost plots.

Soil compaction: Addition of organic matter to soil may have the positive benefit of reducing soil compaction and soil resistance to penetration. To evaluate this possibility, soil resistance to penetration was measured in 5 cm increments to a depth of 45 cm using a hand-held cone penetrometer (Spectrum Technologies). Soil resistance measurements in the upper 20 cm were significantly reduced with the addition of dairy manure compost—especially with the highest rate of 27 kg m^{-2} (Fig. 4) Below 20 cm, there appeared to be a trend towards reduced soil resistance in the compost-amended plots, but the effect was not statistically significant. Reduced penetration resistance in soil can increase root length by making it easier for roots to expand into the soil (Bradford, 1980). Soil resistance is influenced by soil moisture, especially in clay soils like those in these study plots (Lowery and Morrison, 2002). Soil moisture was not measured at the same time the penetrometer measurements were collected, but data collected at other times showed that compost application increased water infiltration rate (Fig 2) and water content in the upper 15 cm of the soil (Fig. 3). It is likely that increased subsoil water content in the compost-amended plots reduced soil resistance measurements collected with the penetrometer.

Soil Phosphorus: Dairy manure compost contains high concentrations of plant nutrients (Table 1), so large application rates will result in a significant input of nutrients to the soil (Table 2). Phosphorus is the primary nutrient of concern because excessive soil P can potentially reduce surface water quality when soluble and particulate forms of P reach surface water bodies.

Soluble P was measured two times during the first growing season after application of the dairy manure compost. At both dates, dairy manure compost significantly increased soluble P in the upper 7.5 cm of the soil, but there was no effect at deeper depths (Fig. 5). This suggests that the compost was mostly incorporated into the upper 7.5 cm of the soil. Soluble P numbers in the upper 7.5 cm were higher for the second sampling date, suggesting that there was considerable mineralization of the dairy manure compost between the first and second date.

Plant available P was measured along with other soil nutrients at the end of the second growing season. Composite soil samples were extracted from the 0-7.5, 7.5-15, and 15-22.5 cm depths and sent to the Texas Cooperative Extension Soil, Water, and Forage Testing Laboratory in College Station, Texas for a routine soil fertility analysis. Dairy manure compost significantly increased Mehlich 3 extractable plant available P at the 0 to 7.5 cm depth and also the 7.5 to 15 cm depth (Table 3). Plant available P ranged from 89 to 170 mg kg^{-1} in the upper 7.5 cm of compost-amended soil, and from 34 to 64 mg kg^{-1} in the 7.5 to 15 cm depth. Plant available P in the upper 7.5 cm of compost-amended plots exceeded the critical P level of 45 mg kg^{-1}, demonstrating that even modest applications of dairy manure compost can supply adequate P. Large DMC applications ($\leq$27 kg m^{-2}) may actually add excessive P to the soil. Consequently, large repeated applications of DMC should be avoided because they can elevate soil P to levels that increase the risk of surface water quality degradation. Dairy manure compost had no effect on plant available P at the 15 to 22.5 cm depth (data not shown).

Soil fertility: Dairy manure compost was an excellent source of essential plant macro- and micro-nutrients. Plant available K, S, Fe, Zn, and Cu in the upper 15 cm of soil were all increased by DMC applications (Table 3). Dairy manure compost also increased soil NO_3-N, although the effect was only significant at the 7.5-15 cm depth. One of the greatest advantages of DMC is that it is a safe source of nearly all the essential plant nutrients. In the calcareous clay soils typical of the Blacklands Resource area, certain plant nutrients, such as Fe, Zn, and Cu are frequently limiting.

The soil samples represented in Table 3 were collected at the end of the second growing season following DMC application to this Austin silty clay soil, and at that time, there was still a greater concentration of essential plant nutrients in the DMC-amended soils. Continued availability of essential plant nutrients in compost-amended soils is one of the reasons it makes sense to use a large application of compost when initially establishing urban landscapes. As the compost organic matter continues to mineralize over the next few growing seasons, there will continue to be an elevated concentration of plant available nutrients in the compost-amended soils. This will reduce the need for subsequent fertilization. The organic matter content of the DMC-amended soils was significantly greater than un-amended soil (Table 3), suggesting that the compost will continue to supply essential plant nutrients as the compost organic matter continues to mineralize in the soil.

Compost application rate had no significant effect on soil pH or electrolytic conductivity (EC) at the 0-7.5 cm depth, but decreased soil pH and increased EC at the 7.5-15 cm depth (data not shown). Austin silty clay soil tends to be calcareous in nature with pH values that typically range from 7.8 to 8.2. Soil amendments that decrease soil pH would be beneficial to this soil. Even though soil EC was slightly increased by compost applications at the 7.5 to 15 cm depth, the range in values (408 to 533 µS cm^{-1}) showed that excessive salinity was not a concern in these soils.

Ornamental Plants

Ornamental plants showed varying degrees of response to dairy manure applications based on the four plant growth indicators that were used in this study (overall rating, plant growth index, percent flowering, and chlorophyll index). Two plant species (Crape myrtle and Shasta daisy) showed no response to DMC applications for any of the plant growth indicators. Each of these indicators is discussed below. In general, the annual and perennial plants were more likely to demonstrate positive responses to dairy manure applications. Out of all the ornamental plants evaluated, Lantana was the most likely to respond to diary manure applications, followed by Pentas (Egyptian Star flower) and Dwarf Burford Holly. The was sufficient evidence in the plant growth indicators to conclude that incorporation of dairy manure compost into the soil when initially establishing an urban landscape will improve the subsequent establishment and growth of ornamental plants.

Overall rating: The overall rating of a plant is a visual rating based on the vegetative (foliage) and flowering parts of the plant. A maximum rating of 10 would be given to a plant that has optimum vegetative and flowering properties. For non-flowering plants, like the Burford Holly and Yaupon Holly, the overall rating is based only on the vegetative part of the plant. The overall rating of Burford Holly, Lantana, Penta, and Rose plants was significantly increased in the compost-amended soils (Fig. 6).

Plant growth index: The plant growth index (PGI) demonstrates how the overall size of the plant was affected by DMC applications. The PGI is based on the height and width of the plant. Burford Holly, Lantana, Penta, and Yaupon Holly all responded significantly to dairy manure applications, indicating that their growth was increased by the addition of DMC to the soil (Fig. 7).

Percent flowering: Percent flowering is a visual estimation of the percentage of the plant that is covered with flowers. Flowering in the Lantana, Penta, and Rose plants was significantly increased in the compost-amended soils (Fig. 8).

Chlorophyll rating: The chlorophyll rating was an actual measurement taken with a chlorophyll meter (SPAD-502, Spectrum Technologies, Inc, Plainfield, Illinois). The SPAD meter estimates the amount of chlorophyll in a leaf by measuring light absorbance at two wavelengths characteristic of chlorophyll. Chlorophyll measurements are directly correlated to the nutritional status of the plant, especially as it relates to nitrogen concentration. Only Echinacia (Purple coneflower) and Lantana had greater chlorophyll contents in the compost-amended soils (Fig. 9). Both these plants exhibit most of their growth in the spring and summer months, so they would be most likely to benefit from adequate nitrogen availability in the soil.

Lantana: Lantana was the ornamental plant that responded most favorably to dairy manure applications. During the winter months in North Texas, above-ground parts of Lantana plants die, which causes the leaves to drop to the ground leaving behind only dried stems (Fig. 10). When these stems were harvested and weighed, there was a strong correlation between stem weights and dairy manure compost application rate (Fig. 11). When winter conditions are not too harsh, Lantana will survive and re-grow in the spring. In the compost plots, Lantana was not well protected from the winter elements, so it tended to die during the winter months. However, visual observations in the spring showed that some Lantana plants survived in plots that received 18 and 27 kg m^{-2} of DMC (Fig. 12).

CONCLUSIONS

Based on two years data, there was ample evidence to conclude that amending an urban soil with an abundant amount of dairy manure compost prior to installing ornamental and turf plants will improve the long-term performance of those plants. The increased performance is probably due to greater levels of soil fertility, including major and minor essential plant nutrients, and improved soil physical properties, such as increased water infiltration and reduced soil compaction. Large repeated applications of dairy manure compost should be avoided to prevent excessive accumulation of soil phosphorus.

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Lowery, Birl and J.E. Morrison, Jr. 2002. Soil Penetrometers and Penetrability. p. 363-388. *In* J.H. Dan and G. Clark Topp (eds). Methods of Soil Analysis. Part 4. Physical Methods. Soil Sci. Soc. Am., Inc. Madison, WI.

Table 1. Selected chemical and physical properties of composted dairy manure applied to landscape plots.

Parameter		**Mean**	**SD**
Total N (g kg^{-1})		9.0	(4.3)
Total P (g kg^{-1})		1.04	(0.08)
Total K (mg kg^{-1})		4.90	(0.48)
Ash Content (%)		81.3	(1.1)
OM Content (%)		18.7	(1.1)
Wet Bulk Density (kg m^{-3})		792	(19.9)
Moisture Content (%)		34.3	(1.4)

Table 2. Composted dairy manure application rates and corresponding N, P, and K rates.

Compost Rate	**N Rate**	**P Rate**	**K Rate**
(kg m^{-2})	(g m^{-2})	(g m^{-2})	(g m^{-2})
9	81	9.4	44
18	162	18.8	88
27	243	28.2	132

Table 3. Effect of dairy manure compost on plant available nutrients at the end of the second growing season.

Compost Rate	**OM**	**NO3-N**	**P**	**K**	**S**	**Fe**	**Zn**	**Cu**
(ton/A)	(%)	----------	----------	----------	mg/kg	----------	----------	----------
				0-7.5cm				
0	3.9	4.8	40	392	39.0	16.6	0.6	0.7
9	5.0	4.0	89	414	47.5	18.4	1.6	0.8
18	5.0	4.0	128	567	48.5	23.1	3.5	1.3
27	5.2	5.0	177	583	52.5	23.5	4.5	1.5
	†	ns	***	***	**	**	***	***
				7.5-15cm				
0	3.9	3.0	18	353	34.5	16.5	0.3	0.7
9	3.8	3.0	34	410	37.5	17.7	0.7	0.8
18	4.1	3.8	58	532	40.3	19.1	1.5	0.9
27	4.1	3.8	64	577	40.3	18.6	1.8	1.0
	ns	**	***	***	**	*	***	***

ns, † ,*, **, *** Not significant and significant at the 0.10, 0.05, 0.01, and 0.001 level of probability, respectively.

	
Ilex cornuta ‘Burfordii Nana’ – “Dwarf Burford Holly”	*Ilex vomitoria* –“Dwarf Yaupon Holly”
	
Pentas lanceolata – “Egyptian Star Flower”	*Lantana* ‘New Gold’ – “New Gold Lantana”
	
Echinacea purpurea ‘Magnus’ – “Purple Coneflower”	*Leucanthemum x superbum* ‘Crazy Daisy’ – “Shasta Daisy”
	
Rosa ‘Knockout’ – “Knockout Rose”	*Lagerstroemia indica* – “Crapemyrtle”

Fig. 1. Species and common names of the eight ornamental plants used in the dairy manure compost urban landscape plots. Plants are shown one day after transplanting during the first growing season. Annual plants were replaced each spring.

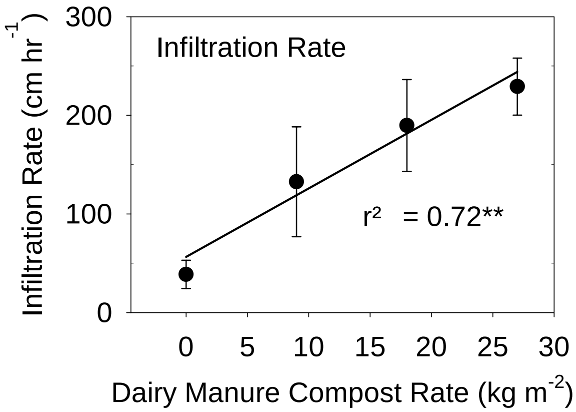

Fig. 2. Effect of dairy manure compost application rate on water infiltration eighteen months after application.

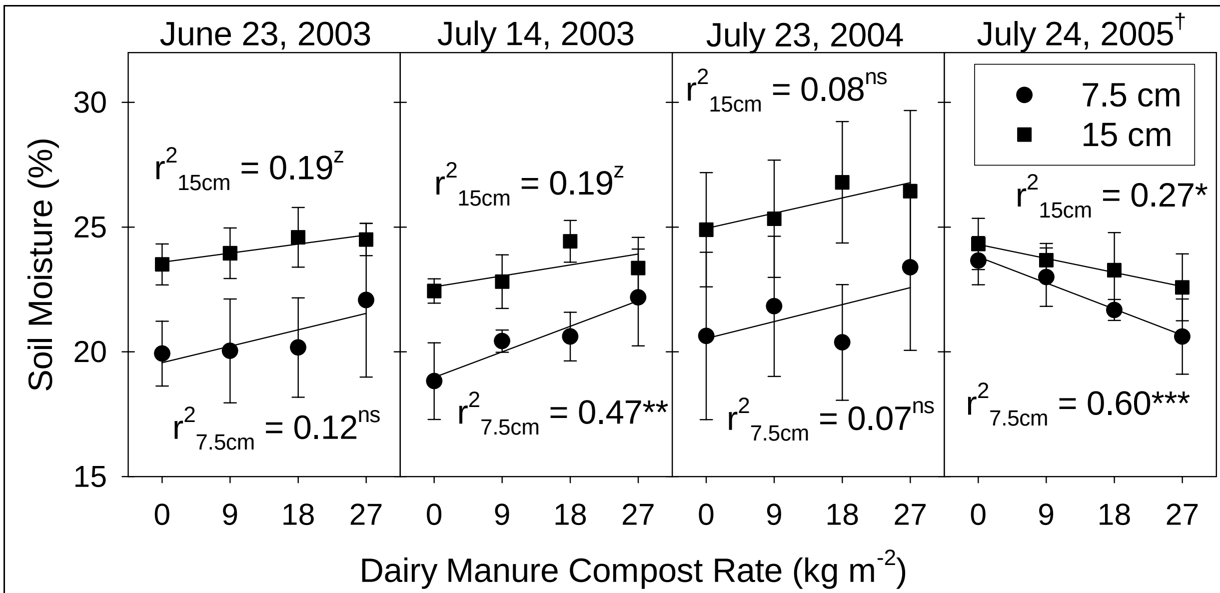

Fig. 3. Effect of dairy manure compost application rate on soil moisture at 7.5 and 15 cm depths at two sampling dates during the first growing season, one sampling date the second growing and third growing seasons. †Irrigation was not applied to turf plants during the 2005 growing season. (ns, z, and ** not significant or significant at the 0.10 and 0.01 levels of probability, respectively.)

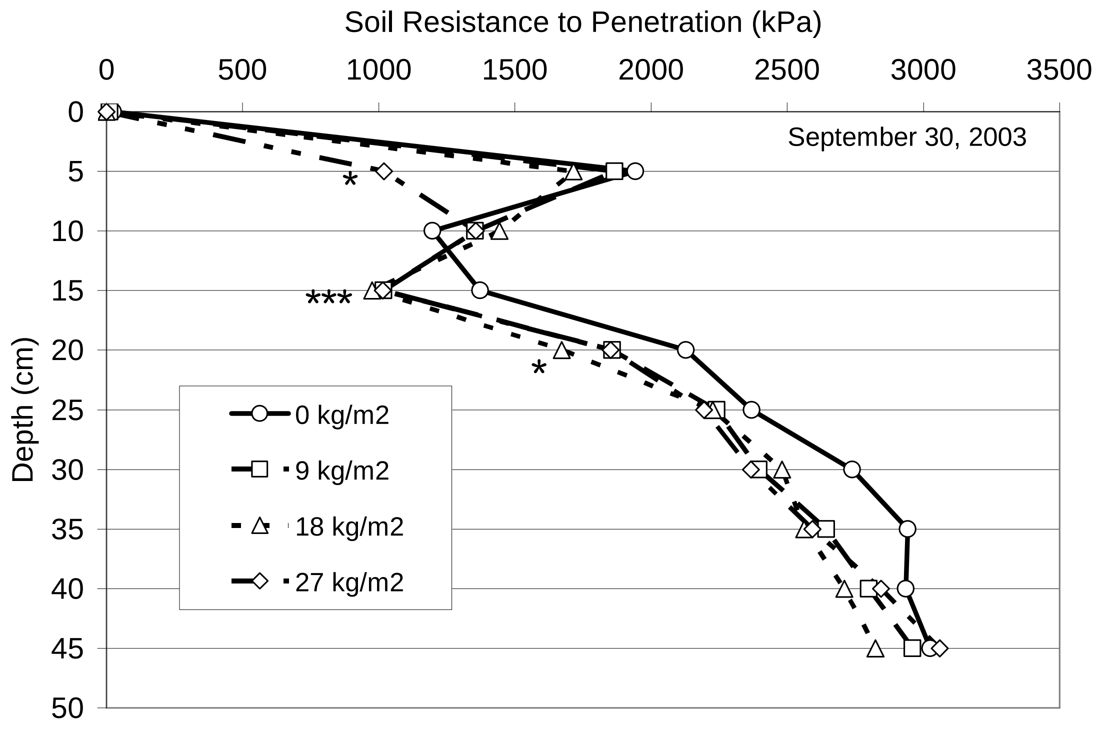

Fig. 4. Effect of dairy manure compost on soil compaction after the first growing season (2003). *, *** Dairy manure compost significantly reduced penetrometer measurements at the 0.05 and 0.001 levels of probability, respectively.

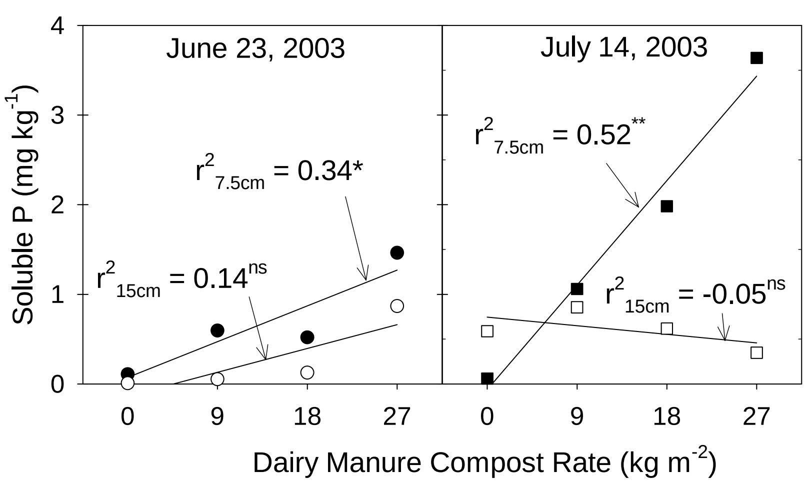

Fig 5. Effect of dairy manure compost application rate on soluble P at 7.5 and 15 cm depths at two sampling dates during the first growing season. (ns, *, ** -- not significant and significant at the 0.05 and 0.01 levels of probability, respectively.)

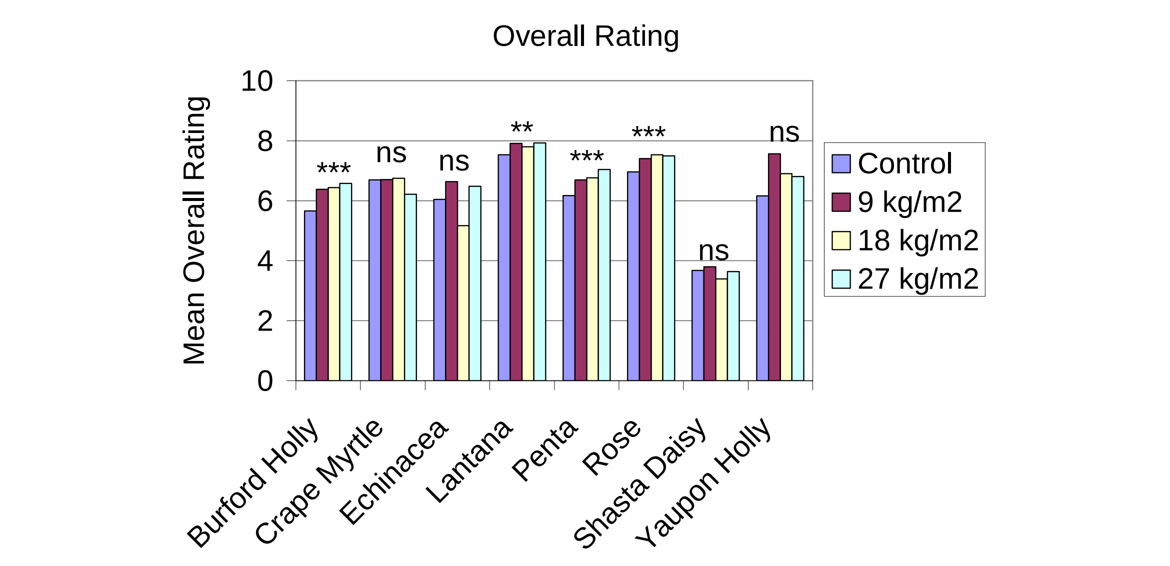

Fig. 6. Effect of dairy manure compost on the two-year mean overall rating for eight ornamental plant species. (ns, **, *** Not significant or significant at the 0.01 and 0.001 levels of probability, respectively.)

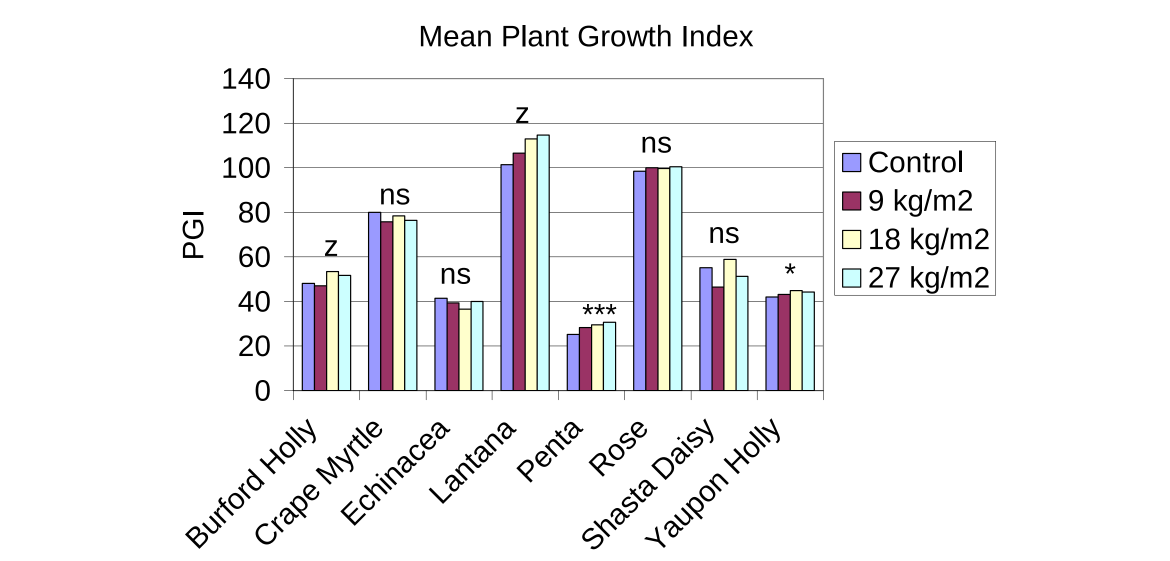

Fig. 7. Effect of dairy manure compost on the two-year overall plant growth index average for eight ornamental plant species. (ns, z, *, *** Not significant or significant at the 0.10, 0.05, and 0.001 levels of probability, respectively.)

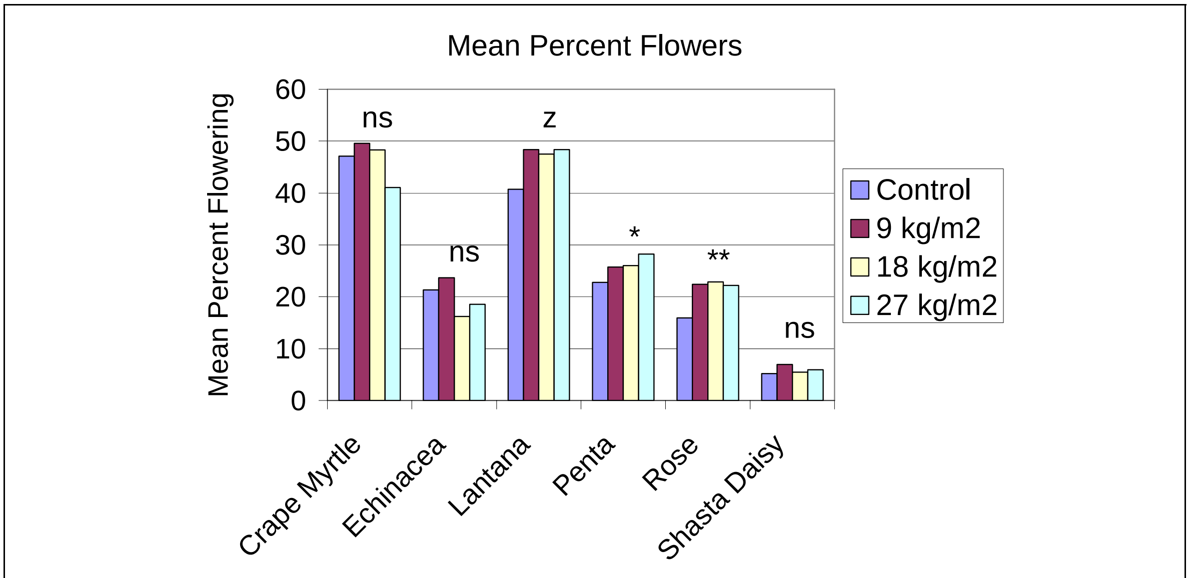

Fig. 8. Effect of dairy manure compost on the two-year overall mean percent flower coverage for six ornamental plant species. (ns, z, *, ** Not significant or significant at the 0.10, 0.05, and 0.01 levels of probability, respectively.)

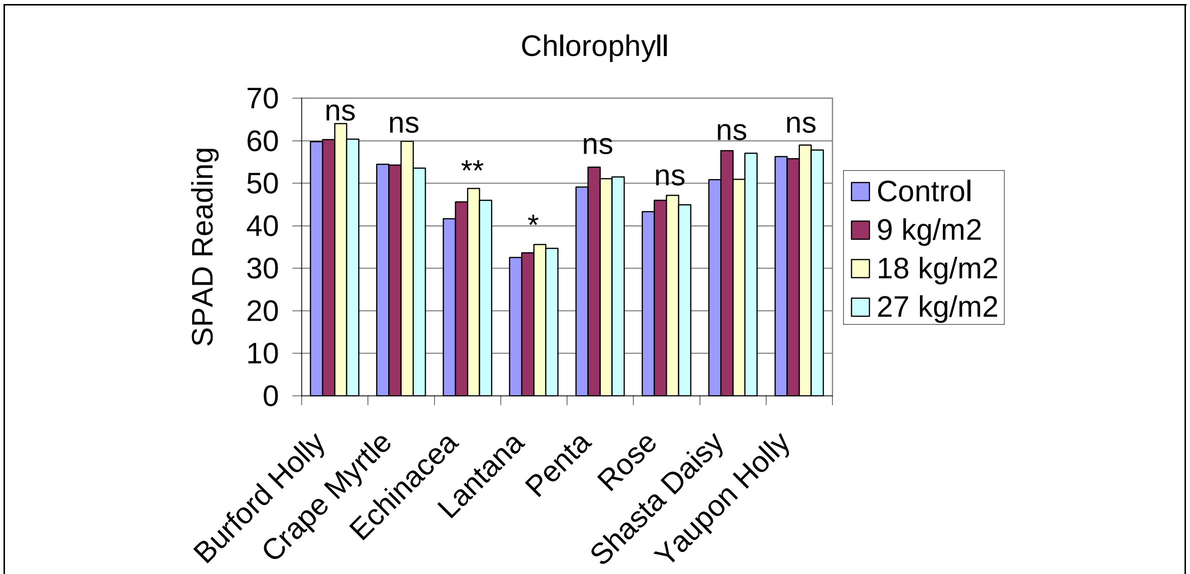

Fig. 9. Effect of dairy manure compost on the two-year mean chlorophyll rating for six ornamental plant species. (ns, *, ** Not significant or significant at the 0.05, and 0.01 levels of probability, respectively.)

Fig.10. Lantana stems shed their leaves during the winter months leaving behind dead and dry stems in the spring.

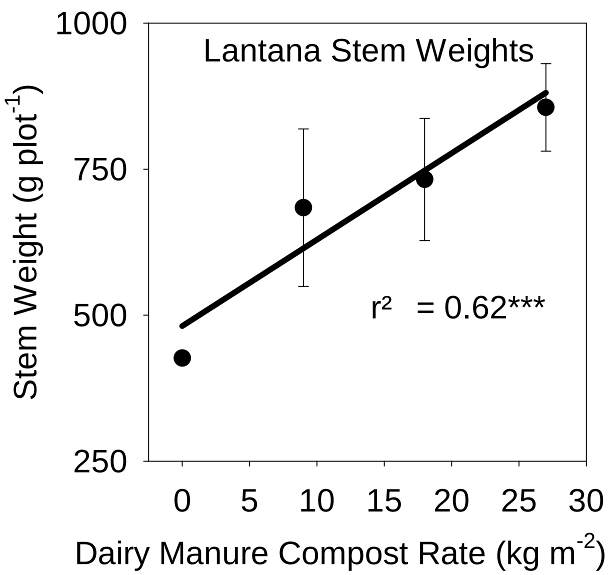

Fig. 11. The weight of harvested Lantana stems significantly increased with increasing dairy manure compost application rate ($p<0.001$).

Fig. 12. Lantana plants reemerging in the spring from a plot that initially received 27 kg m^{-2} dairy manure compost.

Urban Uses for Composted Dairy Manure: Effects on Turfgrass

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BACKGROUND

Turf grass is perhaps the single most important plant in the urban landscape due to the large area it occupies and its ability to protect the soil surface from erosion. Installation of sod following construction of new homes and businesses is an effective way to quickly protect soil that was severely disturbed and degraded by the construction process. Unfortunately, very little post-construction landscaping is devoted to improvement of the soil so that turf and other ornamental plants will be better prepared for long-term healthy growth. Surface soil is commonly removed prior to construction and the remaining subsoil is often mixed with construction debris prior to establishing plants in the landscape. Although ornamental plants and turf grasses planted in these disturbed soils may perform well in the short term due to abundant watering and fertilization, they frequently decline with time when heat and drought stress become prevalent. Dairy manure compost (DMC) is a readily available soil organic matter amendment in many areas due to the presence of large dairy operations. These dairy operations need alternative ways to dispose of their manure because soils surrounding the diary operations are often elevated in soil P. Consequently, dairy farmers and state regulatory agencies are considering urban markets for composted dairy manure.

OBJECTIVES

The overall objective of this study was to evaluate the effect of large single applications of dairy manure compost on the establishment and subsequent growth of typical urban landscape plants and to evaluate the effects on soil chemical and physical properties. This report covers the turf grass component of the research project. Several specific objectives were addressed with the turf grass research.

1. How did increasing rates of dairy manure compost affect the color, density and quality of turf during each year after application?
2. Did the effect of dairy manure compost on turf growth decrease over time after the initial application?
3. How did dairy manure application rate affect turf response to supplemental inorganic N fertilization during the second year of the study?
4. What were the effects of dairy manure application rate on turf biomass production and nutrient content three years after application?

PROCEDURE

Experimental plots measuring 6x6 m were established on a fallow agricultural field. Dairy manure compost purchased from Erath Earth Compost, Dublin Texas was applied at rates of 0, 9, 18, and 27 kg m^{-2} (equivalent to 0, 40, 80, and 120 ton $acre^{-1}$ or approximately 0, 0.5, 1, and 2 inches). Compost was incorporated into the soil using a field cultivator. Selected chemical and physical properties of the compost are shown in Table 1 of the main project summary. Compost applications supplied large amounts of N, P, and K to the soil (Table 2 of main project summary). Following the application and incorporation of compost, one half of each plot (3x6 m) was established with Bermudagrass sod. The other half was established with a variety of ornamental plants and those results are reported in the main project summary.

Data collection began following establishment of sod on the research plots. Turf color, density and quality were rated with a scale of 1 to 9 with 1 indicating complete loss of turf and 9 indicating optimal turf condition. Turf ratings were performed every two weeks during the 2003 and 2004 growing season, and once during the 2005 season. Additionally, percent weed cover was evaluated two times during the third (2005) growing season. Grass clippings were collected one time during the third (2005) growing season. Clippings were weighed to determine above-ground biomass production. A sub sample of the clippings was dried, ground, and analyzed for total nutrient content (N, P, K, and Zn).

RESULTS

Color, Density, and Quality

Dairy manure compost significantly increased Bermuda grass color and quality ratings during the first year after application (Fig. 1, Fig. 2A and 4A) and also increased turf density during the later part of the growing season (Fig. 3A). DMC amendments had the greatest effect on turf color, density, and quality ratings during the second year after application (Figs. 2B, 3B, and 4B), but the effects were still visible 3 years after application, especially for color and quality ratings (Figs. 2C, 3C, and 4C). Turf ratings were only collect one time during the third (2005) growing season, but the results are meaningful given the fact that no irrigation was applied to the turf plots during that atypically dry summer. The 2005 data also shows the effect of supplementing the turf plots with 15 g/m^2 N during the 2004 growing season (Figs. 2C, 3C, and 4C). Supplemental N increased the color, density, and quality ratings for the control plots, but its effect was less apparent in the plots amended with dairy manure compost. The large effect of DMC on bermudagrass color, density, and quality ratings was mostly due to the large amount of N, P, K and micronutrients supplied by the compost. The fact that the effects persisted 3 years after application with no additional fertilization supports the idea of using DMC to establish urban landscapes.

Turf Biomass

Bermuda grass clippings weights were measured during late summer of the third year after application of dairy manure compost. In the absence of additional supplemental fertilization, Bermuda grass growth was significantly increased by dairy manure compost (Fig. 5A). Obviously, the level of nutrients in the soil three years after compost application was sufficient to promote healthy turf growth. The dry matter content of the Bermuda clippings (Fig. 5B) decreased with DMC application rate showing that DMC also increased the lushness, and thus quality, of Bermuda grass. An adequate supply of nitrogen is particularly important for healthy, succulent, plant growth.

Turf Nutrient Content

Dairy manure compost significantly increased the concentration on major and micro nutrients (N, P, K, and Zn) in Bermuda grass clippings collected during the third year after application (Fig. 6). Turf tissue analysis shows that nutrients supplied by dairy manure compost remain available to plants three years after application and eliminate the need for additional fertilization. The data also suggests that the DMC nutrients will continue to be adequate for plant growth in subsequent growing seasons with little or no need for supplemental fertilization. The turf tissue analysis corroborates the visual ratings of turf color, density, and quality, and also explains the increase in turf biomass production with increasing rate of DMC application.

Weed Invasions

Turf grass that becomes stressed due to lack of water and nutrients is susceptible to invasion by undesirable weeds. During the middle of the third growing season (June 2005) after application of dairy manure compost, the percentage of each turf plot covered with weeds was visually estimated (Table 1). Half of each plot had received supplemental nitrogen during the second growing season (3 applications of 5 g/m^2). Weed invasions were generally low (≤2%) in all plots that were previously amended with dairy manure compost, regardless of whether or not they received supplemental N fertilization. Weed invasion was also low for the control plot that received supplemental fertilization during the second growing season. However, in the control plot that received no dairy manure compost and no supplemental N fertilizer, there was a significantly greater percentage of weed coverage (Table 1 and Fig. 1). The weed data shows the importance of nitrogen fertilization for maintaining high quality turf that will not be susceptible to weed invasions, especially during droughty conditions such as those prevalent during the third (2005) growing season when no irrigation was applies to the turf plots.

CONCLUSION

Amending a calcareous clay-textured soil with dairy manure compost had a beneficial effect on the establishment and subsequent 3-year performance of Bermuda grass turf. Turf in the compost-amended soils was greener, exhibited more growth, and contained more nutrients than turf growing in unamended soil. Inorganic nitrogen fertilizer produced many of the same beneficial affects observed for dairy manure compost, but N fertilization was unnecessary in the compost-amended plots. It is likely that Bermuda grass turf will continue to perform well in soils amended with dairy manure compost due to the elevated levels of available plant nutrients. Given the positive effects of dairy manure compost on Bermudagrass turf performance, along with the improved growth of ornamental plants reported in the main project summary, it is clear that the application of 9 to 20 kg/m^2 dairy manure compost (equivalent to 0.5 to 2 inches) is a very effective way to create and sustain a high quality urban landscape.

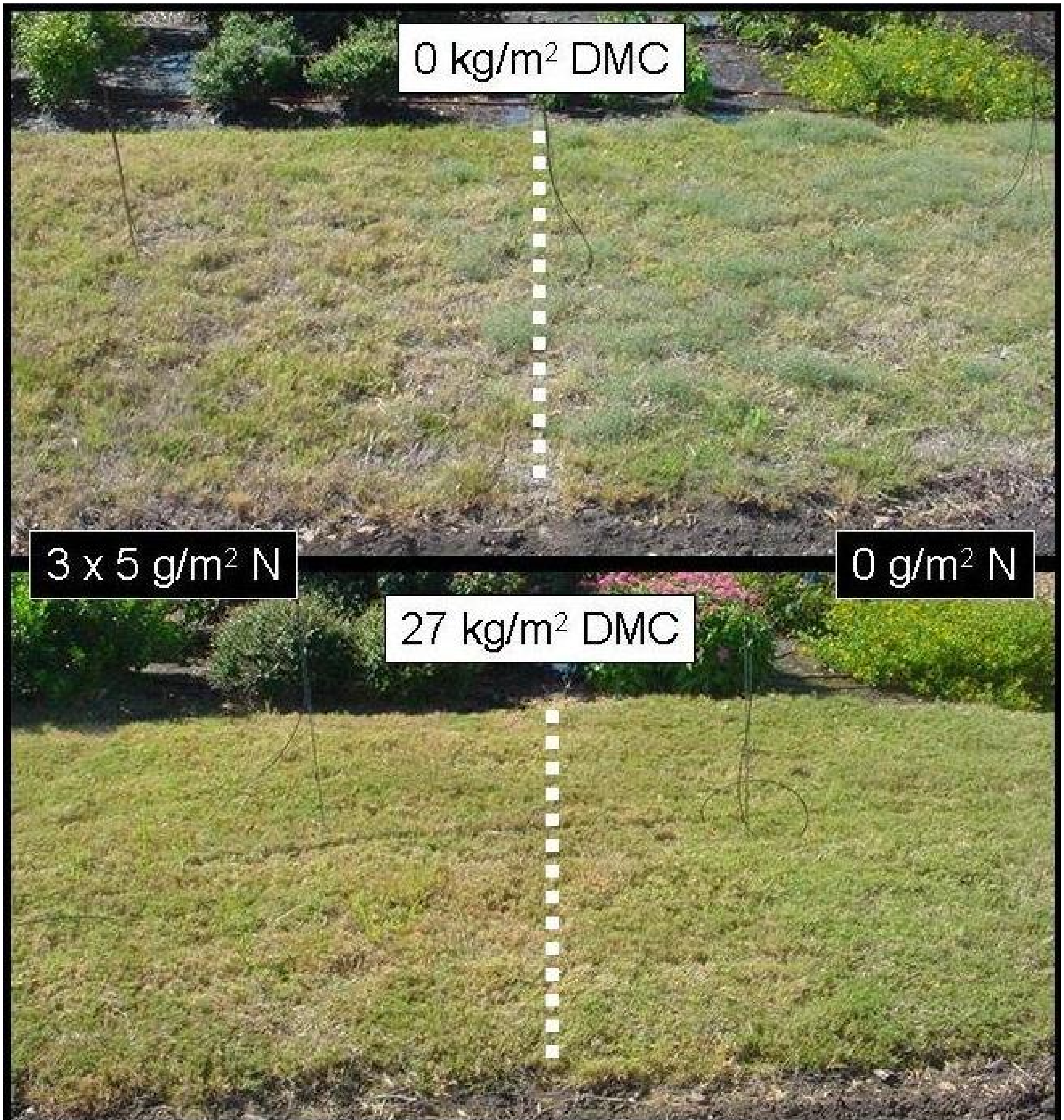

Fig. 1. Comparison of Bermuda grass quality three years after application of 0 and 27 kg/m^2 dairy manure compost. The left half of each plot was supplemented with a total of 15 g/m^2 N during the second growing season.

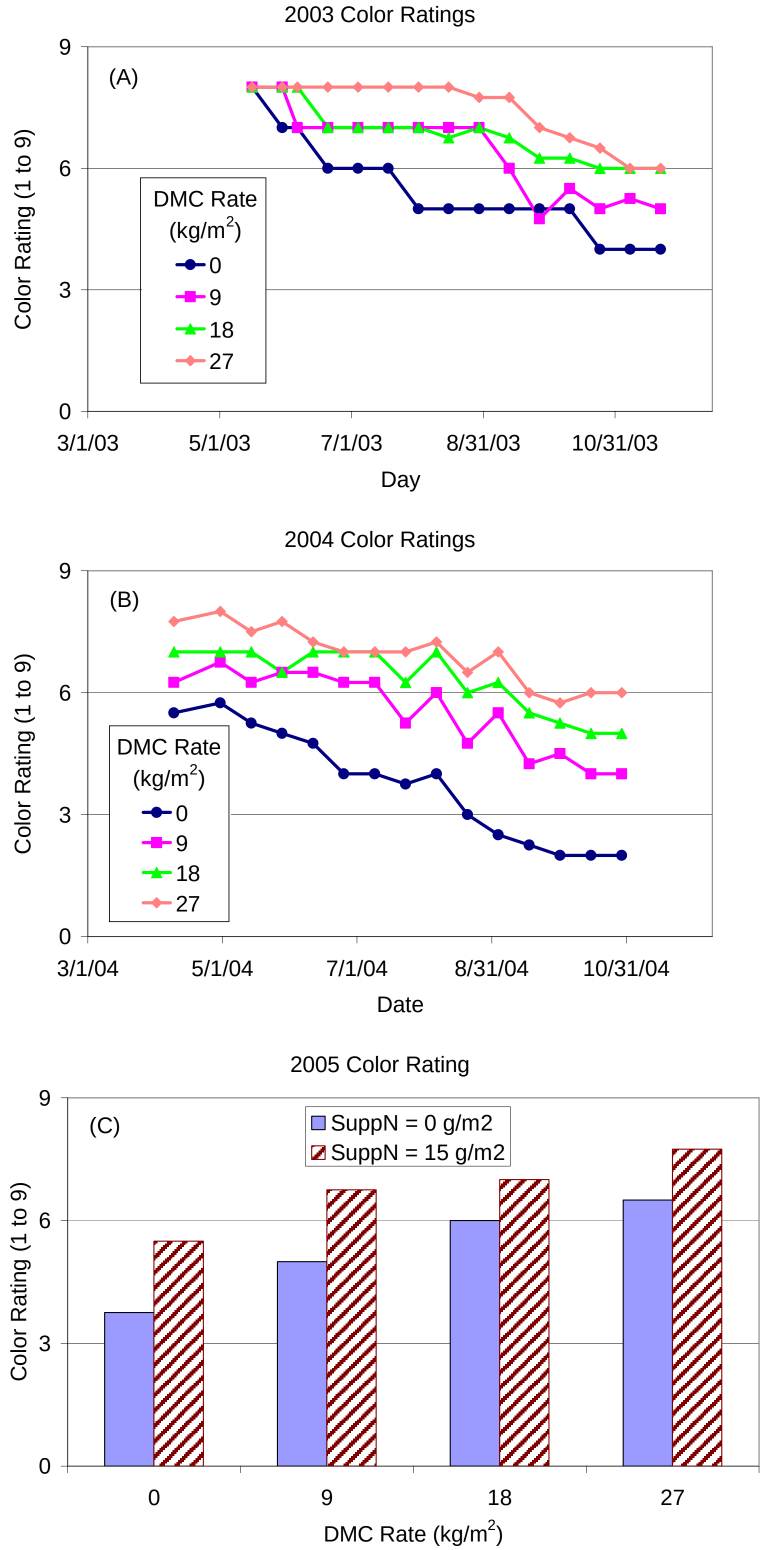

Fig. 2. Effect of 0, 9, 18, and 27 kg/m^2 dairy manure compost (DMC) on Bermudagrass turf color ratings during the year of application (A) and two (B) or three (C) years after application.

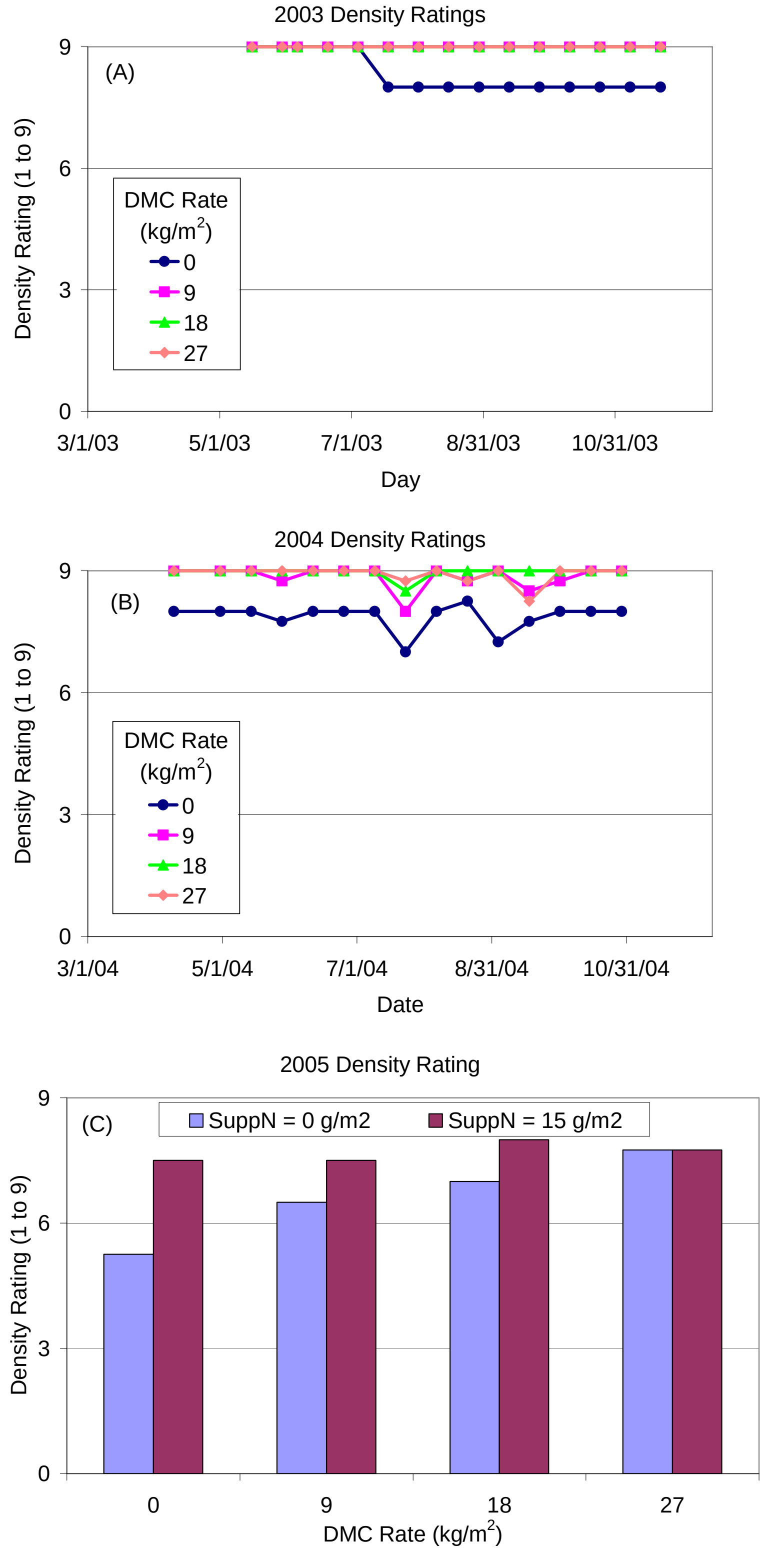

Fig. 3. Effect of 0, 9, 18, and 27 kg/m^2 dairy manure compost (DMC) on Bermudagrass turf density ratings during the year of application (A) and two (B) or three (C) years after application.

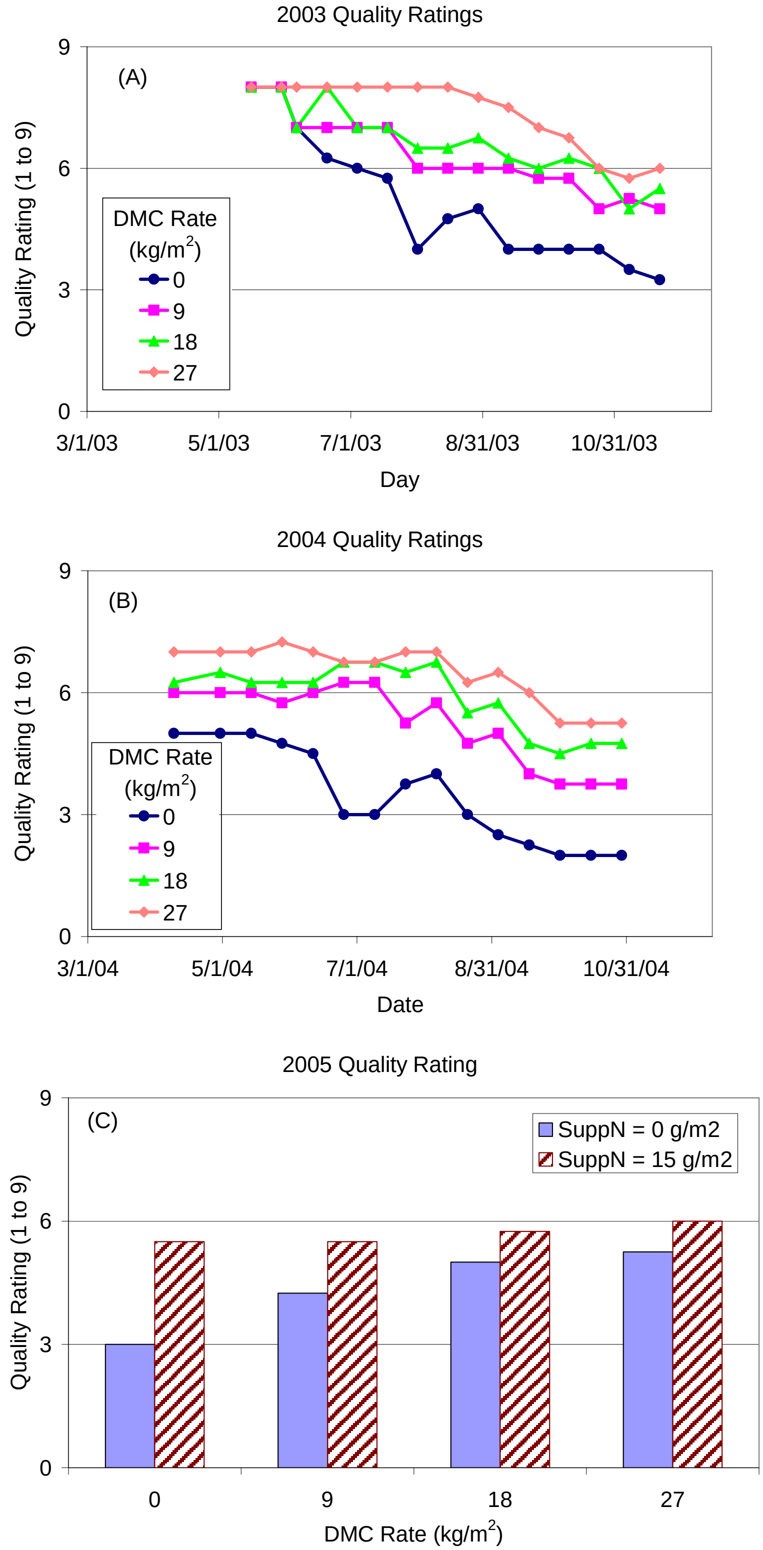

Fig. 4. Effect of 0, 9, 18, and 27 kg/m^2 dairy manure compost (DMC) on Bermudagrass turf quality ratings during the year of application (A) and two (B) or three (C) years after application.

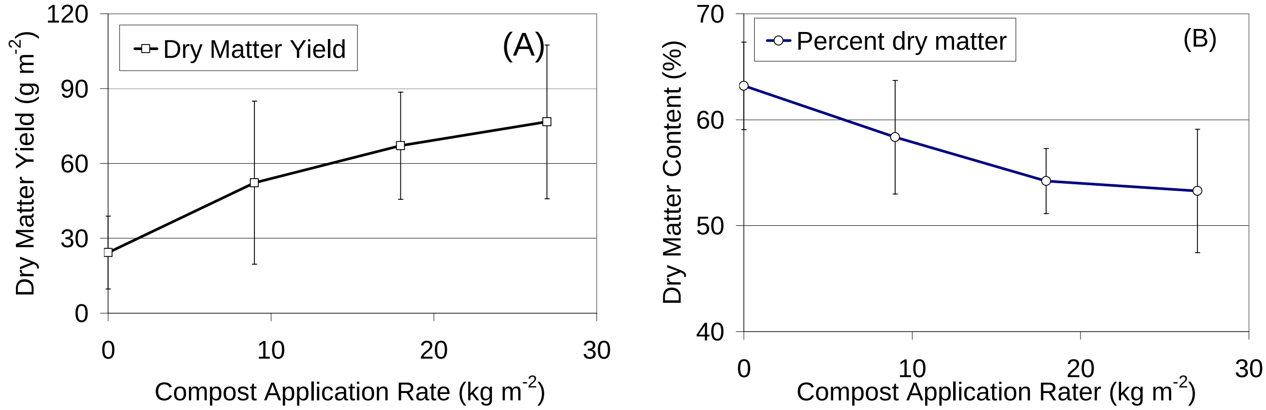

Fig. 5. Effect of dairy manure compost application rate on (A) bermudagrass clipping weights and (B) dry matter content of grass clippings.

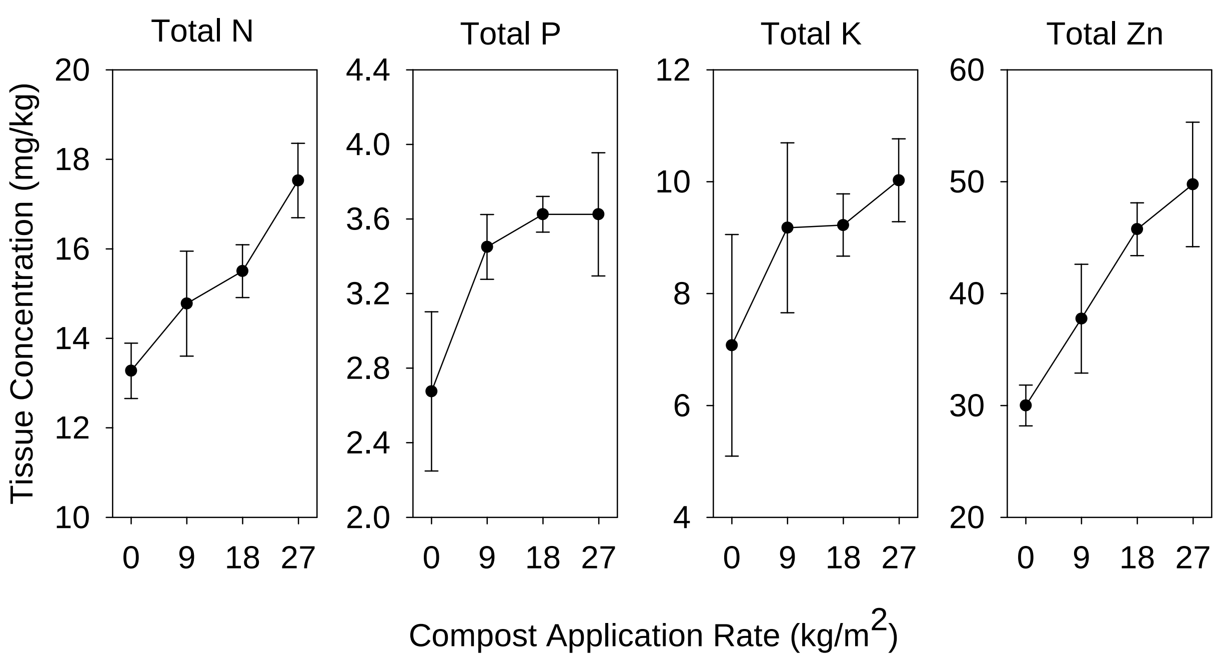

Fig. 6. Effect of 0, 9, 18, and 27 kg/m^2 dairy manure compost on the concentration of N, P, K, and Zn in Bermuda grass tissue harvest near the end of the third growing season after application.

Table 1. Effect of dairy manure compost rate and the addition of supplemental N on weed invasions during the third year after compost application. Values within a column followed by the same letter are not statistically different (LSD, $p \leq 0.05$).

DMC Rate	Weed Coverage (%)[z]	
(kg/ha)	0 g/m^2 N	15 g/m^2 N[y]
0	13 a	<1 a
9	<1 b	2 a
18	<1 b	<1 a
27	<1 b	<1 a

[z] Statistical analysis was performed on log transformed data.

[y] Supplemental N was applied during the second growing season in three applications of 5 g/m^2.

Effects of Dairy Manure Compost Application Timing on Coastal Bermudagrass

INTRODUCTION

Dairy manure compost is a good source of nutrients for vegetation especially when supplemented with commercial nitrogen fertilizer. The level of nitrogen supplementation required can vary based on the forage producer's yields and goals for overall quality. By determining the best possible dairy manure compost and nitrogen fertilizer rates and timings, better recommendations can be made to those utilizing the compost on their property. Research was conducted to compare the effects of composted dairy manure and raw dairy manure alone, or in combination with supplemental inorganic fertilizer on soil chemical properties, and Coastal Bermudagrass yield and quality.

OBJECTIVE

The primary objective of this demonstration was to determine the effects of compost application timing and rate on yield of coastal Bermudagrass.

MATERIALS AND METHODS

This study was conducted at the Stephenville Research and Demonstration Center in Erath County which consists of a May fine sandy loam with a 0 to 1 percent slope.

The study consisted of 27 treatments that included three compost rates applied at three different times and supplemented with 0, 50, and 100 lbs/acre of a commercial nitrogen fertilizer (Table 1) The dairy manure compost was hand applied on November 20, 2002, January 22, 2003, and March 10, 2003. The commercial fertilizer applications were also made of March 10, 2003.

Plots were harvested by cutting a 4.33 foot strip from the center of each plot with an Almaco forage harvester. A grab sample was also taken to determine the moisture content and forage quality of the Bermudagrass.

RESULTS

Comparison yields in 2003 showed no significant differences between November and March applications of compost. Also, there was no significant difference between the supplemental rate on 50 or 100 lbs nitrogen per acre with the exception of the January application at the 200 N rate (Table 2) In all cases, the 50 and 100 lb rates of supplemental nitrogen were statistically lower than both the November and March application under all supplemental nitrogen applications.

Again in 2004, there was no significant difference in yield between the November and March applications of compost at all rates. In three of six instances, the application of 100 lbs of supplemental nitrogen was statistically better than the 50 lb rate indicating that the compost's ability to supply adequate nitrogen in the second year is somewhat reduced. In all cases, supplemental nitrogen at the 50 and 100 lb rates produced significantly better yields than compost without supplemental nitrogen. The January compost application again produced unusual results with the yields being reduced as application rates went up.

Table 1. Displays the application timing, compost rate, and fertilizer rate applied to each treatment.

Treatment Number	**Application Timing**	**Compost Rate ton/A**	***Rate of Fertilizer per cutting* lb/A**
1	Nov 20, 2002	8	0-0-0
2	Nov 20, 2002	8	100-0-0
3	Nov 20, 2002	16	0-0-0
4	Nov 20, 2002	16	100-0-0
5	Nov 20, 2002	32	0-0-0
6	Nov 20, 2002	32	100-0-0
7	Jan 22, 2003	8	0-0-0
8	Jan 22, 2003	8	50-0-0
9	Jan 22, 2003	8	100-0-0
10	Jan 22, 2003	16	0-0-0
11	Jan 22, 2003	16	50-0-0
12	Jan 22, 2003	16	100-0-0
13	Jan 22, 2003	32	0-0-0
14	Jan 22, 2003	32	50-0-0
15	Jan 22, 2003	32	100-0-0
16	Mar 10, 2003	8	0-0-0
17	Mar 10, 2003	8	50-0-0
18	Mar 10, 2003	8	100-0-0
19	Mar 10, 2003	16	0-0-0
20	Mar 10, 2003	16	50-0-0
21	Mar 10, 2003	16	100-0-0
22	Mar 10, 2003	32	0-0-0
23	Mar 10, 2003	32	50-0-0
24	Mar 10, 2003	32	100-0-0
25	Untreated Check	0	0-0-0
26	Control	0	100-0-0
27	Control	0	100-100-150

Table 2. Effects on N Rate and Application Timing on Coastal Bermudagrass Yield (lbs/acre)- Compost at 200 N Rate, 2003

Application Timing	Nitrogen Rate			
	0*	50	100	Average
November*	10,040 ab B	----	17,092 A	13,566
January	9,042 b C	15,725 B	17,913 A	14,227
March	10,422 aB	16,533 A	17,637 A	14,864
Average	9,835	16,129	17,547	

*Means within a column followed by a similar lower case letter or with in a row followed by a similar upper case letter do not differ (P=.05, LSD)

CONCLUSION

Effects of compost application timing should be most prevalent in the first season after applications. The results of this study do not provide any clear statistical data that application in November, January, or March significantly affected forage yields in 2003. While there are some statistical differences when comparing the January to November and March applications, these do not follow a pattern that one would expect when considering possible nutrient loss from early applications or lack of nutrient availability from late applications. Application timing also had little influence on crude protein levels.

Compost without supplemental nitrogen produced good yields in 2003 with averages in the 4 to 5 ton range, but crude protein levels were 10% or less. The addition of 50 lbs of nitrogen made significant improvements in both yields and crude protein levels. In most instances in 2003, the application of 100 lbs of supplemental nitrogen did not significantly increase forage yield although crude protein levels were higher in all cases. In 2004, average yields without supplemental nitrogen had fallen to less than 4 tons/acre. These yields were doubled by the application of 50 lbs of supplemental nitrogen. In this second year, 100 lbs of supplemental nitrogen was significantly better than 50 lbs of nitrogen in 50% of cases. There results would be expected as the nitrogen in the compost becomes depleted.

Dairy manure compost is a good source of nutrients especially when supplemented with commercial nitrogen fertilizer. The level of supplementation depends on the forage producer’s yield and quality goals. It would be necessary to increase supplementation as nitrogen levels are depleted over time to maintain yields and crude protein levels. Timing of compost application showed little influence on forage yields. Climatic conditions such as temperature and rainfall following the application can have large influences on both the loss of nutrients (especially nitrogen) if the compost is applied too early and the availability of nutrients if the compost is applied too near the growing season. Producers should also consider costs associated with transport and application of this material and weigh them against the cost of commercial fertilizers.

Effects of Dairy Manure Compost Application Rate on Coastal Bermudagrass

INTRODUCTION

Livestock manure has been applied throughout recorded history as a soil amendment to improve soil quality, and supply nutrients to forage and row crops. However, long term application of livestock manure to field can cause an accumulation of nutrients in excess of what the plant requires for growth and sustainability. The dairy industry in North Central Texas faces significant environmental challenges related to management of livestock manure generated by concentrated animal feeding operations. To add to the management challenges, manures are expensive to transport because they generally have high moisture content (50-80%) and low nutrient concentrations compared to inorganic fertilizer. Although removal and utilization of manure outside the Bosque watershed is a preferred solution, transportation costs limit the distribution radius and economic feasibility of this option.

This field study was conducted on an established non-irrigated Coastal Bermudagrass field at the Texas A&M University Agricultural Research and Extension Center near Stephenville, Texas in 2002 and 2003. Research was conducted to compare the effects of composted dairy manure and raw dairy manure alone or in combination with supplemental inorganic fertilizer on soil chemical properties, and Coastal Bermudagrass yield and quality.

OBJECTIVE

To evaluate various compost rates on the establishment and growth of coastal Bermudagrass as well as evaluate various application methods and timings of compost on coastal Bermudagrass.

METHODS AND MATERIALS

Sixty-six plots, each 3- by 6-m, were established at the site and received treatments containing dairy manure compost or raw dairy manure alone or in combination with supplemental rates of inorganic N, P and/or K. Soils were sampled from test plots in Stephenville prior to treatment. Dairy compost and raw manure were applied at various rates and Coastal Bermudagrass were planted at typical seeding rates. Plots were harvested monthly with an ALMACO forage harvester and samples were taken from each plot. Supplemental rates of synthetic fertilizer per treatment were added following each harvest. Treatments were arranged in a randomized complete block design with three replications. Initial compost, manure and inorganic fertilizer treatments were surface applied by hand at spring green up with subsequent applications of inorganic fertilizer for selected treatments being applied after each harvest. Dairy manure compost and raw manure were applied only at the initiation of the study with the exception of the two C1 (14.3 Mg ha^{-1}) treatments, which were applied annually. A summary of all treatments applied is provided in Table 1.

Table 1. Treatment Summary.

Treatment Number	Treatments	Year 1 Harvest			Year 2 Harvest		
		1	2	3	1	2	3
1	Manure (32 tons/A)	X					
2	Manure (32 tons/A)	X	N	N	N	N	N
3	Manure (32 tons/A)	XN_1	N_1	N_1	N_1	N_1	N_1
4	Manure (32 tons/A)	X	N_2	N_2	N_2	N_2	N_2
5	Manure (32 tons/A)	X	NP	N	NP	N	N
6	Manure (32 tons/A)	X	NK	NK	NK	NK	NK
7	Compost (16 tons/A)	X	--	--	--	--	--
8	Compost (16 tons/A)	X	N	N	N	N	N
9	Compost (16 tons/A)	XN_1	N_1	N_1	N_1	N_1	N_1
10	Compost (16 tons/A)	X	N_2	N_2	N_2	N_2	N_2
11	Compost (16 tons/A)	X	NP	N	NP	N	N
12	Compost (16 tons/A)	X	NK	NK	NK	NK	NK
13	Compost (32 tons/A)	X	--	--	--	--	--
14	Compost (32 tons/A)	X	N	N	N	N	N
15	Compost (32 tons/A)	XN_1	N_1	N_1	N_1	N_1	N_1
16	Compost (32 tons/A)	X	N_2	N_2	N_2	N_2	N_2
17	Compost (32 tons/A)	X	NP	N	NP	N	N
18	Compost (32 tons/A)	X	NK	NK	NK	NK	NK
19	Compost (8 tons/A)	XN_1	N_1	N_1	XN_1	N_1	N_1
20	Compost (8 tons/A)	X	N	N	XN	N	N
21	Untreated check	--	--	--	--	--	--
22	Commercial Fertilizer (100-100-150)	X	XF_1	XF_1	XF_2	XF_1	XF_1

X = Treatment applied
N = Nitrogen (100 lbs/A)
N_1 = Nitrogen (50 lbs/A)
N_2 = Nitrogen (75 lbs/A)
P = P_2O_5 (100 lbs/A)
K = K_2O (100 lbs/A)
F_1 = Commercial Fertilizer at 100-0-100
F_2 = Commercial Fertilizer at 100-100-100

RESULTS

Comparison of yields in 2003 showed no significant difference between November and March applications of compost. Also, there was no significant different between the supplemental rate of 50 or 100 lbs N/acre with the exception of the January application at the 200 lbs N rate.

Composted dairy manure (28.7 and 57.3 dry Mg ha-1) or raw manure alone increased cumulative forage yields compared to the untreated check in both years of the study, but were less than those obtained using only inorganic fertilizer. Application of 56 kg N ha-1 cutting-1 or more of supplemental N to compost (28.7 and 57.3 dry Mg ha-1) or manure produced forage yields that were equal to or greater than those obtained using inorganic fertilizer alone. However, increasing compost rate did not increase tissue N concentrations regardless of supplemental inorganic N rate. Yield and tissue K concentrations were increased in the second growing season when supplemental inorganic K was applied to 29 Mg ha-1 of compost or 54 Mg ha-1 of raw dairy manure. No yield response was observed when supplemental inorganic P was applied to compost or manure.

Soil pH and concentrations of NH4, NO3, K, Ca, Mg and Mn were increased by application of compost or manure. Soil P concentrations in the 0 to 5-cm zone exceeded 200 mg kg-1 when compost was applied at the high rate. Dairy manure compost was an effective nutrient source for Bermudagrass hay production, but will require the use of supplemental N and, in some cases, K to achieve yields comparable to inorganic fertilizer. The results on the coastal Bermudagrass plots can be seen from the plot overviews in Figure 1.

Figure 1: Stephenville plot overview.

CONCLUSION

Raw and composted manures generally act as slow release nutrient sources which can improve nutrient stability in the event of significant rainfall, but also may affect their ability to support rapidly growing, warm season crops. Forage yields produced by compost and raw dairy manure alone were significantly greater than the untreated check, but significantly less than inorganic fertilizer in both years. Increasing supplemental N fertilizer rates produced forage yields in compost and manure plots that were equal to or greater than those in inorganic fertilizer, but may not be adequate to offset increased input costs. Tissue nitrogen concentrations also tended to increase with increasing rates of supplemental N applied to compost or manure.

Using Dairy Manure Compost for Corn Silage

T.J. Butler, J.P. Muir, and L. Lastly

INTRODUCTION

The dairy industry represents a significant component of the southern agricultural economy, having total sales in excess of $24.8 million (USDA, 2001). Erath County contains over 200 dairy cattle operations, each with an estimated 1500 to 2000 cows. With approximately 200,000 cattle in confined animal feeding operations (CAFOs) an estimated 1.8 million metric tons/yr of manure is created (Brazos River Authority, 1993). The USEPA, in a compilation of state reports, has identified agricultural runoff as the cause of impairment of 55% of surveyed river length and 58% of surveyed lake area (USEPA, 1990). There are few options for disposing of waste thus fueling a controversy over the contamination of drinking water. The Upper North Bosque River watershed, located in Erath county, is a small, 160 km long ephemeral river that flows from north of Stephenville south to Lake Waco, and is the sole source of drinking water for about 150,000 people (Siebert, 2002).

Elevated levels of nitrogen (N) and phosphorus (P) concentrations have been reported in several reservoir and stream sites in the Upper North Bosque River watershed (McFarland and Hauck, 1999). As the concentrations of these nutrients increase, there is the potential for eutrophication, a condition where a body of water ceases to sustain a diverse ecosystem due to the concentrations of these nutrients. This promotes algal blooms and reduces dissolved oxygen causing “smelly water” or fish kills as well as human infections from pathogens in animal fecal material. Although many factors contribute to the eutrophication process, economically feasible controls relate to the supply of N and P (Stumm and Morgan, 1981). With potential health threats and an increasing concern about the environment, composting has become an attractive option to turn problem materials and waste into a valuable product, which can then be returned to the land.

OBJECTIVE

The objectives of this study were to 1) determine the optimal composted manure rate on corn silage and 2) evaluate the two compost sources with varying levels of organic matter.

MATERIALS AND METHODS

The field experiment was conducted in 2003, 2004, and 2005 at the Texas A&M Research and Extension Center at Stephenville, TX [32° 13’, 38” N, 98° 12’, 9” W and, 401 m elevation]. The experiment was arranged in a split-plot design with four replications (Hoshmand, 1994). The main plots consisted of varying rates of compost, while subplots consisted of varying rates of N.

In each year, plots consisted of four 3.66 m by 9.14 m rows of corn with 0.91 m between rows and 1.52 m alleys between each replication. In 2003, the main plots consisted of four levels (0, 45, 90, and 135 Mg ha^{-1}) of a commercial source of composted dairy manure from Producers Compost, Stephenville, TX. In 2003 (Study I), Compost analysis averaged 15% OM, 78.2% dry matter (DM), 0.72% N, 0.39% P, and 1.57% K, which contains 5.11 kg N, 6.29 kg P_2O_5 , and 13.43 kg K_2O per wet ton. Subplots consisted of two randomized nitrogen levels (224 kg ha^{-1} and 336 kg ha^{-1}). These treatments were compared to a commercial fertilizer (336-224-112 kg ha^{-1} of N-P_2O_5-K_2O respectively) standard and a true standard (0-0-0). N was applied as a blend of ammonium sulfate and urea 33.5-0-0-12, P was applied as triple super phosphate 0-46-0 and K was applied as muriate of potash 0-0-60.

In 2004 (Study II) main plots consisted of four levels (0, 45, 90, and 135 Mg ha^{-1}) of a commercial source of high quality composted dairy manure (HQC) from Organic Residual Reclamation, Dublin, TX, and three levels (0, 45, and 90 Mg ha^{-1}) of low quality composted dairy manure (LQC) from Producers Compost, Stephenville, TX. The HQC Compost analysis averaged 57% OM, 41.3% DM, 2.40% N, 0.45% P, and 1.36% K, which contains 8.99 kg N, 3.88 kg P_2O_5, and 6.13 kg K_2O per wet ton. The LQC Compost analysis averaged 17% OM, 74.1% DM, 1.13% N, 0.40% P, and 2.02% K, equivalent to 7.60 kg N, 6.14 kg P_2O_5, and 16.34 kg K_2O per wet ton. The subplot treatments in 2004 consisted of 112, 224, 336 Kg ha^{-1} N. These treatments were compared to a commercial fertilizer check (336-224-112, 168-112-100 and 0-0-0 Kg ha^{-1} of N-P_2O_5-K_2O respectively). Compost was disked in 15 cm approximately two months before planting along with a commercial application of $P_2O_5$and K_2O as recommended by the soil test. Half of the N fertilizer was applied the day of planting and the other half was surface applied one month after planting as NH_4NO_3.

Corn variety Triumph 2011RR was seeded (23,000 seeds/acre) in March each year, with a John Deere MaxEmerge 2 planter. After seeding corn in each year, weeds were controlled with a pre-emergent application of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) at 1.12 Kg ai ha^{-1}. Herbicide applications were applied at 262 kPa with a tractor mounted sprayer equipped with flat fan nozzles (Teejet 8003 flat fan nozzle, Spraying Systems, Co., Wheaton, IL) at 140 L ha^{-1}. Weeds were also controlled with a post-emergent application of glyphosate [N(phosphonomethyl)glycine] at 1.54 kg ai ha^{-1}. Herbicides applications were applied at 207 kPa with a CO_2 backpack sprayer equipped with 4 flat-fan nozzles spaced 48.26 cm apart (Teejet 8002 flat fan nozzle, Spraying Systems Co., Wheaton, IL) at 140 L ha^{-1}.

At harvest, a 3.05 m section of the inner two rows in each subplot were hand-harvested at a 5.08-7.62 cm stubble height when kernels reached one-half milkline. A representative sample of three plants was ground through a three-way Chipper Shredder (MTD Products, Inc., Cleveland, OH.) and a representative sub-sample was collected. Each sample was oven dried at 55°C for three days. Yields were calculated on a DM basis and then converted to Mg ha^{-1} at 35% DM.

RESULTS AND DISCUSSION

Compost Rate - Study I

Year X compost rate and year X N rate interactions were significant; therefore means are reported by year. Compost rate X N rate interaction and N rate effect were not significant, thus means are pooled across main effects. In 2003 (growing season following compost application), corn silage yields increased as compost rate increased, when N was not limiting. The low (45 Mg ha^{-1}) compost rate increased corn silage yield by 27% when compared to no compost applied, which did not differ from the moderate (90 Mg ha^{-1}) compost rate. The high (135 Mg ha^{-1}) compost rate increased corn silage yields by 44% when compared to no compost application and 11% over the moderate (90 Mg ha^{-1}) compost rate. The moderate (39.7 Mg ha-1) and high (135 Mg ha-1) levels of compost were similar to the high, 336-224, 112, commercial fertilizer rate (40.1 Mg ha-1).

In 2004, (in the second growing season after application), the low, moderate, and high compost rates increased corn silage yields by 58-75% compared to the no compost rate, however these three compost rates did not differ from each other. The two N rates evaluated (224 and 336 kg ha-1) did not differ. Only the moderate (90 Mg ha-1) compost rate was similar to the high, 336-224-112, commercial fertilizer rate.

In 2005, (in the third growing season after application), the low, moderate, and high compost rates increased corn silage yields by 39-69% compared to no compost application, however these yields were 17-42% lower than the high commercial fertilizer rate. The two N rates evaluated did not differ from each other. Based on the results of this study, the optimal compost rate was 90 Mg ha-1, which was equivalent to the high commercial fertilizer treatment in the first and second growing season, however by the third growing season it yielded less than the commercial fertilizer, which indicates that compost would need to be reapplied after two seasons of corn silage.

Compost Quality by Rate - Study II

Significant interactions were observed between year and compost quality, thus data are reported by year. In 2004, (the first growing season after application), corn silage yields in the HQC plots yielded 7-18% higher than plots treated with LQC. In 2004, the optimal compost rate was 45 Mg ha^{-1} for both LQC and HQC, which yielded 38% more corn silage than when compost was not applied. The optimal N rate for both LQC and HQC was 224 kg N ha^{-1}, which did not differ from 336 kg N ha^{-1}. The high commercial fertilizer rate (336-224-112) yielded 15% more corn silage than the LQC, but did not differ from the HQC in 2004.

In 2005, (the second season after application), the moderate and high rates of LQC yielded 9 and 15%, respectively more corn silage than the same rates of HQC, which is the reverse of the previous year. The HQC apparently had greater nutrient release rates compared to the LQC in the first season, however these nutrients were not available the second growing season. In 2005, the optimal N rate was 224 kg N ha^{-1}, which did not differ from 336 kg N ha^{-1}. In 2005, only the moderate compost rate (90 Mg ha-1) yielded equal corn silage to the high commercial fertilizer rate (336-224-112). When averaged across both years, compost qualities did not differ. The LQC averaged 43.4, 59.3, and 61.0 Mg ha-1 for no compost, low rate (45 Mg), and moderate rate (90 Mg ha^{-1}), respectively compared to the same rates of HQC which averaged 44.4, 59.6, and 62.7, respectively.

Table 1. Effect of dairy manure compost on corn silage during the 2003, 2004, and 2005 growing seasons, at Stephenville, TX.

	Growing Season		
Study I	2003	2004	2005
	Mg ha^{-1} @ 35% DM		
Compost Rate[a]			
135 Mg ha^{-1}	44.1 a[b]	65.2 a	56.4 a
90 Mg ha^{-1}	39.7 b	72.4 a	53.5 a
45 Mg ha^{-1}	39.0 b	67.6 a	46.5 b
0 Mg ha^{-1}	30.7 c	41.4 b	33.4 c
N rate			
224 kg N ha^{-1}	38.8 a	61.4 a	47.3 a
336 kg N ha^{-1}	38.0 a	62.0 a	48.4 a
Fertilizer[c]			
336-224-112	40.1 a	75.3 a	66.3 a
0-0-0	23.3 b	26.6 b	21.5 b

a Compost Applied in 2003
b Means within column and main effect followed by the same letter do not differ at the 0.05 significance level
c Commercial fertilizer applied kg N, P_2O_5, K_2O ha^{-1}

Table 2. Effect of compost quality on corn silage yields during the 2004 and 2005 growing seasons, at Stephenville, TX.

	Growing Season			
Study II	2004[a]		2005[b]	
	LQC[c]	HQC	LQC	HQC
Compost Rate	Mg ha^{-1} @ 35% DM			
135 Mg ha^{-1}	.	70.3 a[d]	.	52.4 a
90 Mg ha^{-1}	61.2 a B	72.4 a A[e]	60.7 a A	53.0 a B
45 Mg ha^{-1}	64.5 a B	69.6 a A	54.0 b A	49.5 b B
0 Mg ha^{-1}	47.1 b A	50.5 b A	39.6 c A	38.4 c A
N rate				
112 kg N ha^{-1}	.	63.0 b	.	45.0 b
224 kg N ha^{-1}	59.2 a B	67.6 a A	62.0 a A	50.0 a B
336 kg N ha^{-1}	56.0 a B	66.5 a A	61.9 a A	49.9 a B
Fertilizer[f]				
300-200-100	73.9 a	70.3 a	60.0 a	62.0 a
150-100-50	60.7 b	62.0 b	49.1 b	49.1 b
0-0-0	21.5 c	24.9 c	20.7 c	19.9 c

a First season after application
b Second season after application
c LQC, low quality compost; HQC, high quality compost
d means within column followed by the same lower case letter do not differ at the 0.05 significance level
e Means within year and row followed by the same upper case letter do not differ at the 0.05 significance level
f Commercial fertilizer applied kg N, P_2O_5, K_2O ha^{-1}

Dairy Manure Compost Improves Soil and Increases Tall Wheatgrass Yield

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ABSTRACT

There is a need to identify alternative uses for composted manure applications. The objectives in this study were to 1) document the effect of composted dairy manure on soil agronomic characteristics, and 2) evaluate tall wheatgrass yield response to six rates of composted dairy manure. A field trial with a split-plot randomized complete block design and four replications was initiated on a Windthorst sandy loam soil (Udic Paleustalfs) in north-central Texas near Stephenville in September of 2001. Main plots were 1 by 7 m and received a single application of composted manure prior to planting Tall wheatgrass at 17 kg ha^{-1}. Composted dairy manure rates of 0, 11.2, 22.4, 44.8, 89.6, and 179.2 Mg dry matter (DM) $ha^{-1}$of a commercial source were applied. Subplots were 1 by 3.5 m and received annual split applications of 224 or 336 kg N ha^{-1} yr^{-1}. Application of compost improved or increased soil OM, soil pH, soil infiltration, soil P levels, and soil K levels, which, in turn increased tall wheatgrass DM yields (by 96% at the greatest rate compared to the control in 2002-03 and by 58% in 2003-04) yielding up to 9536 kg DM ha^{-1} in 2002-03 and 6097 kg DM ha^{-1} in 2003-04. Compost also increased the concentration of forage P (by 56 and 64%) and K (by 40 and 29%) at the greatest compost rate in 2002-03 and 2003-4, respectively. Tall wheatgrass responded to improved soil fertility, and could be utilized to grow forage of high nutritive value (up to 231 g CP kg^{-1} for the greatest compost rate in 2002-03, a 11.6% increase over the control, and a 9.5% increase, 175 g CP kg^{-1}, in 2003-04).

In areas of intensive agricultural and livestock production, soils with plant-available P exceeding the levels required for optimum crop yields have increased (Alley, 1991; Sims, 1992). For example, approximately 200,000 cattle in confined animal feeding operations generate an estimated 1.8 million metric tons yr^{-1} of manure in Erath county, TX (Brazos River Authority, 1993), which has led to an excess buildup of composted dairy manure. In order to avoid environmental problems related to P surface water runoff (Sharpley and Withers, 1994), there is a need to identify alternative uses for composted manure, especially where soil P levels are low.

The use of compost promotes soil aggregation, which improves soil structure and pH, increases water infiltration, and improves water holding capacity (Murray, 1981; USDA NRCS, 2004). The N-P-K percentages of finished compost are relatively low, but their benefit lies in the slow release of N and P in the soil so that plants can use them effectively before they are lost through leaching (Gershuny and Martin, 1992).

Forage P uptake from soils is highly variable and is a direct function of soil P content, soil physical properties, forage biomass, and forage P concentration, the latter often species-specific (Pierzynski and Logan, 1993). The application of dairy manure compost to soils can increase forage yields resulting in greater plant P concentrations and P yields, a phenomenon observed when compost is applied to summer annual dicots (Muir et al., 2001a), annual monocots (Muir et al., 2001b) or perennial grass (Sanderson and Jones, 1997). The efficacy of using composted manure on cool-season perennial grasses, however, has not been widely tested. Tall wheatgrass is a cool-season perennial grass that may have potential to provide forage of high nutritive value during the winter months, when the dominant warm-season grasses are dormant. However, the P fertility requirement and P removal rate for tall wheatgrass are unknown.

Two soil P testing methods, historically used to measure soil-P for both agronomic and regulatory purposes, ammonium acetate-ethylenediaminetetraacetic acid (NH_4OAc-EDTA) (Hons et al., 1990) and Mehlich III (Mehlich, 1984), can vary considerably in their estimation of plant-available soil-P (Butler et al., 2006). It is unclear which soil testing method should be utilized to predict available soil P. The objectives in this study were to 1) document the effect of composted dairy manure on selected Windthorst soil characteristics, 2) determine the appropriate soil test for measuring soil P in a Windthorst soil, and 3) evaluate tall wheatgrass yield response to six rates of composted dairy manure.

MATERIALS AND METHODS

A field study was initiated on a Windthorst sandy loam soil (Udic Paleustalf) in north-central Texas near Stephenville (N 32^o 15’, W 98^o 12’, altitude 395 m) in September of 2001. Initial soil test indicated pH= 5.1, 6 mg N kg^{-1}, 6 mg P kg^{-1} (NH_4OAc-EDTA extractant), and 205 mg K kg^{-1}. Treatments were arranged in a split-plot randomized complete block design with four replications, six main treatments (compost application rate) and two sub-treatments (N fertilizer rate). Main plots were 1 by 7 m and received a single application of composted manure prior to planting tall wheatgrass at 17 kg ha^{-1}. Composted manure rates of 0, 11.2, 22.4, 44.8, 89.6, and 179.2 Mg ha^{-1}of a commercial source of composted dairy manure from Producers Compost, Stephenville, TX, was incorporated to 15 cm depth using a roto-tiller. Compost analysis averaged 150 g kg^{-1} OM, 782 g kg^{-1} DM, 7.2 g kg^{-1} N, 3.9 g kg^{-1} P, and 15.7 g kg^{-1} K. Subplots were 1 by 3.5 m and received annual split applications of 224 or 336 kg N ha^{-1} yr^{-1}. Nitrogen (urea-ammonium sulfate blend) applications were surface-applied, with half applied in October and the remainder in February. Tall wheatgrass was sprayed with diclofop-methyl 2-[4-(2,4-dichlorophenoxy) phenoxy]propanoate at 0.84 kg ai ha^{-1} at the 5th-leaf stage to control annual ryegrass (*Lolium multiflorum* Lam.), since annual ryegrass will out-compete tall wheatgrass during establishment (Butler et al., 2005).

Plots were harvested with an Almaco small-plot harvester (Almaco, Nevada, IA) three times (December through May) during 2002-03 and 2003-04. Plots were not harvested during the establishment year, since tall wheatgrass is slow to establish. Sub-samples were used to determine forage DM yield by drying approximately 400 g of plant material in a forced-air oven at 55°C until weight loss ceased. Total aboveground DM production was estimated each year by totaling all yields from each year. Representative forage sub-samples from each sub-plot and year were ground through a Wiley mill (Thomas-

Wiley Co., Philadelphia, PA) equipped with 1-mm screen. Samples from each treatment and harvest were analyzed for N, P, K, and S. Nitrogen concentration was multiplied by 6.25 and reported as crude protein (CP) (Van Soest, 1994). Concentrations of these plant components are reported as season-long weighted averages for each subplot.

Approximately 15 soil cores were taken to a 15 cm depth for each subplot at the end of each growing season and composited by subplot to determine treatment differences. Soils were analyzed for pH using 1:2 ratio of soil to deionized water (Schofield and Taylor, 1995), NO_3-N by Cd reduction (Kenney and Nelson, 1982), and P, K, S, Na, Mg, and Ca based on two soil-extractant methods, acidified NH_4OAc-EDTA (TAMU) and Mehlich III (Mehlich, 1984; Hons et al., 1990). Elements in both extractants were measured using ICP-OES (Spectro Radial Modula ICP, Spectro Analytical Instruments, Marlborough, MA.). Soil OM concentration was determined by using the Loss-On-Ignition Method (LOI) (Nelson and Sommers, 1996). Soil samples were air dried and ground to <0.4 mm. A 1.00 to 3.00 g sample for each subplot was placed in a crucible and heated in an oven for 24 h at 105°C. Samples were then cooled in a dessicator and weighed to a tolerance of 0.1 mg. Samples were then placed in a muffle furnace for 16 h at 400°C, cooled, dessicated, and weighed. Infiltration rate of water into the soil was measured with a Turf-tec double ring infiltrometer obtained from Turf-tec International (Coral Springs, FL), by averaging three readings from each subplot at the end of each growing season. The infiltration rate was determined as the amount of water per surface area and time unit which penetrated the soil (Bouwer, 1986).

Data were subjected to analyses of variance using PROC GLM (SAS, 1999) with differences less than P=0.05 reported as significant. Means, where appropriate, were separated using Fisher's Protected LSD test at P=0.05 level of significance. Differences in rainfall distribution (but not total) among growing seasons (September-June) were apparent (Figure 1). Precipitation in the 2002-03 season totaled 782 mm and the 2003-04 season totaled 787 mm, however there was poor distribution of moisture in the early months of 2003-04.

RESULTS AND DISCUSSION

Soil Nutrient Status

Year, year X compost rate, year X N rate, and year X compost X N rate interactions were not significant (Table 1), therefore data are pooled across years for soil pH, N, P, K, OM, and infiltration. Soil S, Na, Mg, and Ca, and did not differ among year, compost level, or extraction method (data not shown).

Soil OM

Soil OM increased as composted dairy manure rates increased (Table 4). Soil OM in the untreated plots averaged 13 g kg^{-1} compared to 20 g kg^{-1} in the plots with the greatest compost rate. The addition of compost OM to the soil can increase CEC from 20 to 70% of the original CEC (Mott, 1974; Halvin et al., 1999). Not all composted manures increase soil OM or organic carbon (Helton, 2004), primarily because some composts have low levels of OM since they originate from drylot scrapings high in soil content.

Soil pH

Soil pH increased as composted dairy manure rates increased (Table 4). Soil pH in the untreated plots averaged 4.5 compared to 7.0 at the greatest compost rate (179.2 Mg ha^{-1}), and increased an average 0.5 unit as compost rate doubled in magnitude from 11.2 to 179.2 Mg ha^{-1}. Seedling establishment and soil pH were also increased with applications of compost elsewhere (Murray, 1981). The increase in soil pH can be partially attributed to the increase in soil OM and the high pH of the compost itself, a result of a high concentration of calcareous soil particles in the dairy compost generated by north Texas dairies (Helton, 2004). Soil pH decreased as N rate increased from 224 to 336 kg ha^{-1}, which was expected in the top 15 cm of soil (Haby et al., 1999). Dairy manure and its compost have the potential to raise pH of acidic soils receiving N fertilizer (Sanderson and Jones, 1997; Helton, 2004) or mitigate the acidification of soils receiving soil-acidifying forms of N fertilizer.

Soil Infiltration

Soil infiltration with water increased linearly (Table 4) with increasing rates of compost dairy manure. Infiltration increased by 100%, 242%, 292%, 408%, and 550% for 11.2, 22.4, 44.8, 89.6, and 179.2 Mg ha^{-1}, respectively, when compared to the untreated control. Increase in infiltration can be attributed to increased OM. Improvements in soil moisture retention due to the increase in soil OM have been reported by others (Hoitink and Fahy, 1986; Boehm et al., 1993).

Soil NO_3-N

Dairy manure compost had little effect on soil N levels, although there was a numeric trend for greater compost manure rates having lower soil N levels, which could be related to greater forage DM yields in those plots. Composting dairy manure tends to lower NH_4–N levels vis-à-vis the original manure, but NO_3-N tends to be more stable in compost; in at least one study looking at both dairy manure and its compost, however, NH_4–N concentrations were more stable in the soil than was NO_3-N (Helton, 2004). Soil N level with 336 kg ha^{-1} was 41% greater than at the 224 kg ha^{-1} rate.

Soil-P

Soil P levels increased with both soil extractants, as composted dairy manure increased (Table 4); however, soil extractants differed in their estimate of plant-available P. At very low soil P levels, the Mehlich extractant soil P was approximately 1.5 times greater than the EDTA extractant P, but there were no differences between extractants when available soil P was very high with the heaviest compost rate (Table 2). The highest compost rate (179.2 Mg ha^{-1}) which yielded 124 mg P kg^{-1} soil, did not exceed the maximum soil P threshold of 200 mg P kg^{-1} allowed by environmental regulatory agencies in Texas (Texas Administrative Code, 1997), indicating that these low-P soils can incorporate very high rates of compost before this limit is reached. In contrast, Helton (2004), in a perennial warm-season grass study in which he surface-applied 57 Mg compost ha^{-1} to a similar Windthorst soil with a control plot containing 22 mg P kg^{-1} soil, measured plant-available P well in excess of the 200 mg P kg^{-1} soil limit (EDTA) in the top 15 cm. The main difference may have been that Helton (2004) did not incorporate compost to a 15-cm depth as was done in the present study.

Fertilizer N rate had little effect on plant-available soil P. The Texas Cooperative Extension Soil, Water and Forage Testing Laboratory adopted the statewide use of the Mehlich III method in Jan. 2004, following the determination that the NH_4OAc-EDTA method dissolved non-plant available apatite in certain calcareous soils (personal communication, T. Provin, 2004).

Soil-K

Soil K levels also increased as compost rate increased (Table 4), a phenomenon observed in other compost studies (Schlegel, 1992; Helton, 2004); however, the extractants differed in their estimation of plant-available K. The EDTA extractant measured greater levels of plant-available K compared to the Mehlich extractant, which is the reverse trend of plant-available soil P. Mehlich III uses a 5-minute shaking time compared to 45 minutes for the EDTA, resulting in a more complete release of soil-bound K (Mehlich, A. 1984; Hons et al., 1990) which tends to be more weakly bound to soil particles compared to P in its HPO_2 and H_2PO_4 forms (Pierzynski et al., 2005). Soil K levels were adequate even in the untreated plots; therefore it is unlikely that the increased levels of K influenced crop yield. Nitrogen fertilizer rate had little effect on available soil K.

Tall Wheatgrass

Year and year X compost interactions were apparent for DM yield, N removal, P removal, and K removal (Table 1), therefore data are reported by year. Sulfur concentrations of tall wheatgrass tissue and S levels of soil did not differ among treatments, so S removal rates are not reported.

Forage DM Yield

In both growing seasons, DM yield increased with application of composted dairy manure (Table 3; Table 4). Forage DM yield was lowest where compost was not applied (4857 kg ha^{-1} for 2002-03 and 3858 for 2003-04) and increased by 32, 44, 64, 85, and 96% with 11.2, 22.4, 44.8, 89.6, and 179.2 Mg compost ha^{-1}, respectively in 2002-03 and by 31, 33, 37, 42, and 58% in 2003-04 (Table 4). The greatest DM yields occurred with the highest compost rate (179.2 Mg ha^{-1}) with yields of 9536 and 6097 kg ha^{-1} in each growing season respectively, which is similar to the maximum yields reported for other cool-season grasses. Reported yearly DM yields of timothy (*Phleum pretense* L.), orchardgrass (*Dactylis glomerata* L.), reed canarygrass (*Phalaris arundinaceae* L.), smooth brome (*Bromus inermis* Leyss.), and tall fescue (*Festuca arundicaea Schreb*.) averaged 9770, 7970, 9707, 7881, and 9968 kg DM ha^{-1}, respectively (Cherney and Cherney, 2005). Butler et al., (2006) reported DM yields of annual ryegrass (*Lolium multiflorum* Lam.) under the same environment as this study, which ranged from 4550 to 10510 kg DM ha^{-1} when fertilizer rates ranged from 0 to 40 kg P ha^{-1}. Forage yields did not differ between the N rates in either year, indicating that N rates lower than 224 kg ha^{-1} may suffice to attain maximum forage yields. These data illustrate that tall wheatgrass responds to application of composted manure, which improves soil fertility, especially soil P, and that tall wheatgrass has forage potential for the region.

Crude Protein and N removal.

Forage CP concentration (Table 3) was greater in 2002-03 (ranging from 207 to 231 g CP kg^{-1}) compared to 2003-04 (158 to 175 g CP kg^{-1}); however, all CP values would be considered adequate for most livestock classes (Ball et al., 2002). These relatively high values are greater than those reported for other cool-season perennial grasses. Cherney and Cherney (2005) reported CP values for timothy, orchardgrass, reed canarygrass, smooth brome, and tall fescue that averaged 105, 122, 123, 132, and 110 g kg^{-1}, respectively. Butler et al. (2006) reported CP values ranging from 202 to 248 g kg^{-1} for annual ryegrass. Crude protein was greatest at the two highest compost rates (89.6 and 179.2 mg ha^{-1}) in 2002-03 but did not differ between compost rates in the 2003-04 growing season (Table 4). Crude protein values did not differ between the two N rates in 2002-03. However, CP was 10% greater with the 336 kg N ha^{-1} rate in 2003-04, but this is probably not of biological importance.

The amount of N removed, which is a function of N concentration and DM yield, followed a similar trend to that of yield. As compost rate increased, the amount of N removed also increased up to 119%, ranging from 161 to 353 kg N ha^{-1} in 2002-03 and 98 to 169 kg N ha^{-1} in 2003-04 (72% increase) (Table 4). Nitrogen rate did not affect N removal in 2002-03, however the 336 kg N ha-1 rate removed 17% more N due to the greater concentration of N in forage that season. These data illustrate that the amount of nutrient removal is closely related to DM yield, and, as yield increases, the nutrient removal rate also will increase.

Phosphorus concentration and P removal.
Forage P concentrations (Table 3) in 2002-03 ranged from 1.8 to 2.8 g P kg^{-1}, greater than in 2003-04 (ranging from 1.4 to 2.3 g P kg^{-1}). These values are similar to those reported for grasses other than wheatgrass. Cherney and Cherney (2005) reported that P concentrations of timothy, orchardgrass, reed canarygrass, smooth brome, and tall fescue averaged 2.35, 2.87, 3.20, 3.08, and 2.78 g K kg^{-1}, respectively and ranged from 2.41 to 3.32 g P kg^{-1} depending on the year. Butler et al. (2006) reported that annual ryegrass, when grown in the same environment as this study and fertilized with 0 to 48 kg P ha^{-1} yr^{-1}, had P concentrations from 1.9 to 4.0 g P kg^{-1}. These values are slightly greater than the values measured in the present study with tall wheatgrass. Tall wheatgrass P concentrations increased 6 to 56% in 2002-03 and 14 to 64% in 2003-04, from the lowest to highest compost rate (Table 4).

The amount of P removed ranged from 5.4 to 26.7 kg P ha^{-1} and increased with compost rate (Table 3), primarily due to greater forage yields and P concentrations resulting from compost application. Butler et al. (2006) also reported that annual ryegrass removed from 8 to 40 kg P ha^{-1}, depending on the P fertilizer rate. In the 2002-03 growing season, removal of P increased by 40 to 206% as compost rate increased and by 50 to 159% in 2003-04 (Table 4). However, the cumulative P recovery rates when combining P removal for both growing seasons were 0.141, 0.106, 0.084, 0.058, 0.038 for composted manure rates of 11.2, 22.4, 44.8, 89.6, 179.2 Mg ha^{-1}, respectively. Fertilizer N rate had little effect on P concentration or the amount of P removed from the soil. These data indicate that tall wheatgrass could potentially be utilized on high P soils to remove excess P.

Potassium Concentration and K removal

Forage K concentration followed a similar trend as P, ranging from 19.7 to 27.5 g kg^{-1} in 2002-03 and from 18.9 to 24.4 g kg^{-1} in 2003-04. Cherney and Cherney (2005) reported K concentrations of timothy, orchardgrass, reed canarygrass, smooth brome, and tall fescue averaging 14.5, 15.9, 16.3, 17.8, and 15.1 g kg^{-1}, respectively and varying from 14.1 to 21.4 g K kg^{-1}, depending on the year. In the present study, K concentration increased by 9 to 40% in 2002-03 and 6 to 29% in 2003-04 from the lowest to highest rate of compost application. The amount of K removed ranged from 96 to 262 kg K ha^{-1} in 2002-03 and 73 to 149 kg K ha^{-1}. Cherney and Cherney (2005) also reported that timothy, orchardgrass, reed canarygrass, smooth brome, and tall fescue removed from 100 to 159 kg K ha^{-1} from the soil. Several cool-season grasses have been reported to be luxury consumers of K (Cherney et al., 1998). Tall wheatgrass could also be considered a luxury consumer since for K concentrations increased as soil K increased with compost rates despite adequate soil K the untreated plots. Nitrogen fertilizer had little effect on K concentrations or the amount of K removed from the soil.

CONCLUSIONS

Application of dairy manure compost increased soil OM, soil pH, soil infiltration, soil P levels, and soil K levels, which, in turn, increased tall wheatgrass DM yields and P and K concentrations in the forage. Tall wheatgrass is similar to other cool-season grasses in that it will respond to improved soil fertility, especially soil P, and could be utilized to provide forage of relatively high nutritive value with similar DM yields and P removal rates to that of other cool-season grasses.

TABLES & FIGURES

Table 1. Analysis of variance for soil and forage parameters of Jose tall wheatgrass in the 2002-04 growing seasons at Stephenville, TX.

	Soil Parameters										
					P		K		S		
Source	pH	OM	Infiltration	NO_3-N	EDTA	Mehlich	EDTA	Mehlich	EDTA	Mehlich	EC
Year	NS†	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Compost	***	***	***	***	***	***	***	***	NS	NS	NS
Year*Compost	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N rate	***	NS	NS	***	NS	NS	NS	NS	NS	NS	NS
Year* N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Compost*N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Year*Compost*N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

	Forage Parameters								
	DM yield	N %	N removed kg ha^{-1}	P %	P removed kg ha^{-1}	K %	K removed kg ha^{-1}	S %	S removed kg ha^{-1}
Source									
Year	***	***	***	***	***	***	***	***	***
Compost	***	NS	***	***	***	***	***	**	***
Year*Compost	***	NS	***	NS	***	NS	*	NS	*
N rate	NS	**	***	NS	*	NS	*	NS	*
Year* N	NS	NS	NS	NS	NS	NS	NS	NS	NS
Compost*N	NS	NS	NS	NS	NS	NS	NS	NS	NS
Year*Compost*N	NS	NS	NS	NS	NS	NS	NS	NS	NS

†NS, not significant; *, **, ***, 0.05, 0.01, and 0.001 level of significance, respectively; OM, organic matter; DM. dry matter; EDTA, ethylenediaminetetraacetic acid; EC, electric conductivity

Table 2. Response of soil parameters (pH, NO3-N, P, K, OM†, and infiltration) to dairy manure compost averaged over the 2002-03 and 2003-04 growing seasons in Stephenville, TX.

	Soil							
	OM	Soil	Infiltration	NO_3-N	P (mg kg^{-1})		K (mg kg^{-1})	
Compost Rate	%	pH	mm	mg kg^{-1}	EDTA	Mehlich III	EDTA	Mehlich III
0 Mg ha^{-1}	1.3	4.5	12	43	8	21	220	200
11.2 Mg ha^{-1}	1.4	5.0	24	39	11	26	265	245
22.4 Mg ha^{-1}	1.5	5.2	41	38	13	30	270	242
44.8 Mg ha^{-1}	1.6	5.9	47	30	20	40	294	269
89.6 Mg ha^{-1}	1.9	6.5	61	29	58	79	338	314
179.2 Mg ha^{-1}	2.0	7.0	78	31	124	122	400	368
LSD	0.2	0.3	4	NS	17	13	45	45
N Rate								
224 kg ha^{-1}	1.7	5.7	43	29	38	53	300	274
336 kg ha^{-1}	1.7	5.5	44	41	39	54	295	272
LSD	N.S.	0.2	N.S.	9.0	N.S.	N.S.	N.S.	N.S.

†OM, organic matter; EDTA, ethylenediaminetetraacetic acid; NS, not significant.

Table 3. Response of Jose tall wheatgrass to compost and nitrogen treatments at Stephenville, TX in the 2002-03 and 2003-04 growing seasons.

			2002-03				
Compost Rate	kg DM† ha^{-1}	CP $g\ kg^{-1}$	N removal $kg\ N\ ha^{-1}$	P $g\ kg^{-1}$	P removal $kg\ P\ ha^{-1}$	K $g\ kg^{-1}$	K removal $kg\ K\ ha^{-1}$
0 $Mg\ ha^{-1}$	4857	207	161	1.8	8.7	19.7	96
11.2 $Mg\ ha^{-1}$	6400	203	208	1.9	12.2	21.4	137
22.4 $Mg\ ha^{-1}$	7003	208	233	2.1	14.7	23.0	161
44.8 $Mg\ ha^{-1}$	7970	218	278	2.3	18.3	24.4	194
89.6 $Mg\ ha^{-1}$	8989	223	321	2.5	22.5	25.8	232
179.2 $Mg\ ha^{-1}$	9536	231	353	2.8	26.7	27.5	262
LSD	1475	10	46	0.2	3.3	2.1	33
N Rate							
224 $kg\ ha^{-1}$	7379	220	260	2.3	17.0	23.6	174
336 $kg\ ha^{-1}$	7540	217	262	2.2	16.6	23.6	178
LSD	N.S.	N.S.	N.S.	N.S	N.S.	N.S.	N.S.
			2003-04				
Compost Rate	kg DM† ha^{-1}	CP $g\ kg^{-1}$	N removal $kg\ N\ ha^{-1}$	P $g\ kg^{-1}$	P removal $kg\ P\ ha^{-1}$	K $g\ kg^{-1}$	K removal $kg\ K\ ha^{-1}$
0 $Mg\ ha^{-1}$	3858	158	98	1.4	5.4	18.9	73
11.2 $Mg\ ha^{-1}$	5055	165	133	1.6	8.1	20.1	102
22.4 $Mg\ ha^{-1}$	5126	169	139	1.7	8.7	21.2	109
44.8 $Mg\ ha^{-1}$	5301	170	144	2.0	10.6	21.4	113
89.6 $Mg\ ha^{-1}$	5486	175	154	2.2	12.1	24.3	133
179.2 $Mg\ ha^{-1}$	6097	173	169	2.3	14.0	24.4	149
LSD	563	N.S	14	0.1	1.1	1.2	18
N Rate							
224 $kg\ ha^{-1}$	4956	160	127	1.8	8.9	22.0	109
336 $kg\ ha^{-1}$	5303	176	148	1.8	9.5	22.1	117
LSD	N.S.	8	9	N.S.	N.S	N.S.	N.S.

†DM, dry matter; CP, crude protein.

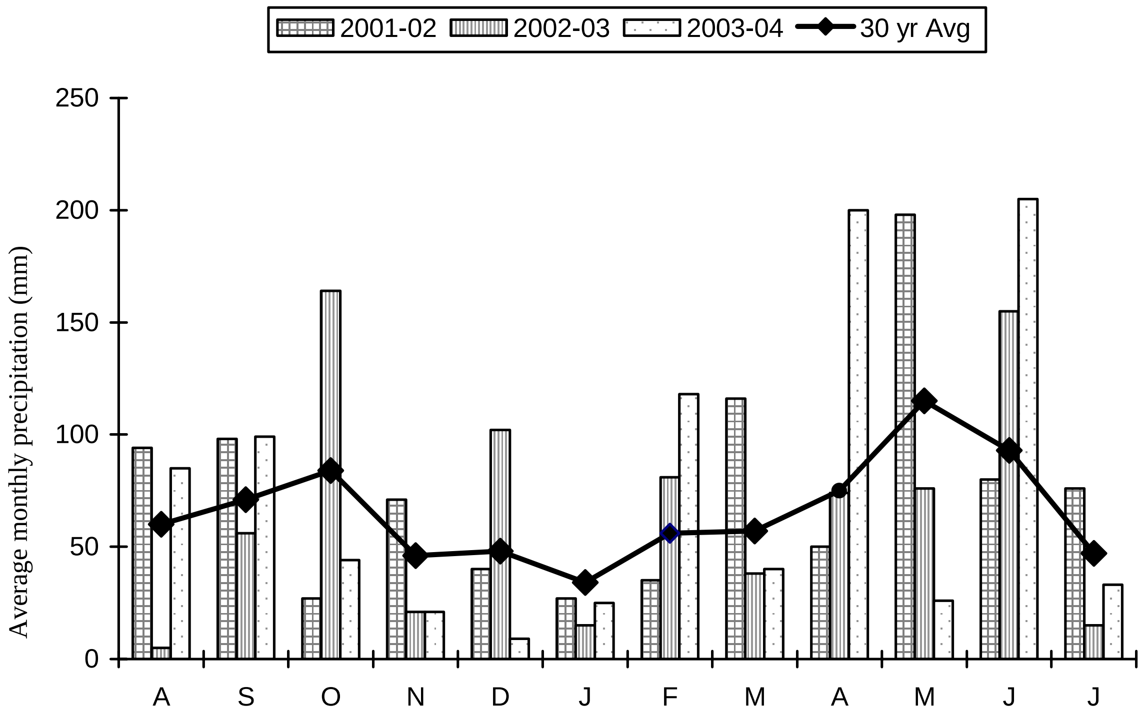

Figure 1. Monthly precipitation from August to July during three years and 30-yr average trend line at Stephenville, TX, USA.

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Efficacy of Using Dairy Manure Compost as Erosion Control and Revegetation Material.

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INTRODUCTION

Several watersheds with large and concentrated animal feeding operations (CAFOs) in the USA are faced with a challenge to either reduce manure application rates on agricultural soils that test high in phosphorous (P) or find alternatives to manure utilization by row crops and pastures. The Bosque and Leon River watersheds in central Texas are home to nearly 100,000 lactating dairy cows that reside on 165 farms. Most of these cows are housed either on openlots or hybrid systems of openlots and freestall barns. Manure from openlots is scraped and stock piled while liquid waste (manure, process generated wastewater from flushed freestalls, milking parlors and paved alleyways in openlots, and any runoff water) is stored in waste storage or treatment structures (lagoons). In general, a majority of the dairy manure from these operations is handled as solid manure. Traditionally, solid manure and liquid waste have been spread and irrigated, respectively to waste application fields (WAF) as nutrients for crops and pastures, and to meet the plant water requirements. The North Bosque River (NBR) basin has the highest concentration of dairy cows in the area. Water quality studies in the watershed indicated that P was the limiting nutrient in this basin and dairy WAFs and municipal waste treatment plants were considered major non-point and point sources of P to the NBR, respectively (McFarland and Hauck, 1999a, 1999b). In 1998, segments 1226 and 1255 of the NBR and Upper NBR, respectively were deemed "impaired segments" on the State of Texas Clean Water Act Section 303(d) under water quality standards related to nutrients and aquatic plant growth (TNRCC, 1998).These findings led to the US Environmental Protection Agency’s approval for the two Total Maximum Daily Loads (TMDLs) for P in the NBR (TNRCC, 2001). In December 2002, the Texas Commission on Environmental Quality (TCEQ, previously known as the Texas Natural Resource Conservation Commission or TNRCC) approved the implementation plan for the two TMDLs. The goal of these TMDLs was to achieve a reduction of total annual loading and annual average concentrations of soluble reactive P (SRP) by approximately 50%. The Bosque River Advisory Committee, a group of scientists, engineers and other stakeholders, expects that both point and nonpoint sources will have to make significant reductions in their P contributions to achieve this goal.

As a result of poor water quality conditions in the NBR watershed, the TCEQ rules implemented in 1999 required that every new or expanding CAFO in the watershed must remove 100% of the collectible manure produced in the facility. Manure should be disposed of beneficially outside the watershed (landfills), delivered to a composting facility or applied as fertilizer to WAFs that have not received manure previously and have less than 200 ppm of extractible P in the top six inches of soil (TNRCC, 1999). Consequently, a voluntary program called the “Compost Program” was initiated by the TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) with a goal to remove nearly 50% of the manure generated by the CAFOs in the NBR watershed as an ‘efficient way’ of dairies to meet these new rules (TCEQ, 2003). In 2000, as part of this program, the TSSWCB launched the Dairy Manure Export Support (DMES) project that provided financial support to haul surplus manure from dairies in the NBR watershed to the TCEQ permitted composting facilities in the NBR watershed. These composting facilities provide dairies an alternative to direct application of manures on soil testing high for P in the watershed. The TCEQ portion of the program strived to create a sustainable market for compost from dairy manure.

Recently published works by Persyn et al. (2004) and Risse and Faucette (2003) cite use of compost from various organic materials including animal manure for erosion control and revegetation of highway construction sites. Compost from cattle feedlot, dairy and poultry manure mixed with woodchips, cotton burs and yard trimmings has been utilized by many state transportation departments for erosion control of road rights-of-way and to establish vegetation on severely eroded soils (Block, 1999, 2000; Mitchell 1997). Departments of transportation from several states have developed compost use specifications (USEPA, 2003) for construction related projects. Texas Department of Transportation (TxDOT) accepts organic composts including dairy manure compost (DMC) for use in compost manufactured top soil (CMT), in erosion control compost (ECC), as general use compost (GUC) and compost in the form of filter berms for erosion and sedimentation control. For the TxDOT contracts, the CMT should consist of 75% topsoil blended with 25% compost on a volume basis and for ECC, 50% untreated woodchips are blended with 50% compost by volume (Special Specifications 1058 for compost and 1059 for compost/mulch filter berm, TxDOT, 2002). The TxDOT specifies the use of ECC to be limited to slopes of 3:1 or flatter allowing an application of a 2” uniform layer of compost and woodchips blend. These specifications provide an opportunity to remove DMC (hence dairy manure) out of the NBR and use it on the TxDOT projects, as an alternative to manure utilization on traditional crop and pasture land in the watershed. Large quantities of DMC will be used as CMT or ECC to vegetate and protect slopes such as the road rights-of-way. Little information is available on physicochemical quality of runoff from these CMT and ECC treated slopes using blends of DMC and woodchips.

OBJECTIVE

The objective of this study was to examine the efficacy of using composted dairy manure for stabilization and revegetation of steep slopes. Results of runoff and its physicochemical constituents from filed plots amended with DMC, DMC/Woodchips blend, and commercial fertilizer (CF) and subjected to simulated rainfall are presented in this paper.

MATERIALS AND METHODS

Experimental plots and treatment set-up

Twelve plots, each 1x 2m were established on an embankment with 3:1 side slope and constructed to mimic a road right-of-way (Li et al., 2003) at the Riverside campus of the Texas A&M University near College Station. The embankment soil was clayey with an average pH of 8.13 from the 0-15-cm (0-6”) depth and devoid of vegetation. Average sand, silt and clay contents from the 0-15 cm depth were 26%, 27%, and 47%, respectively. Each plot was isolated from overland flow using 15-cm (6”) metal borders installed 10-cm above and 5-cm below the ground level. At the downstream end of each plot, a parabolic shaped gutter made from a 10-cm PVC pipe, spliced in half longitudinally, was installed to convey plot runoff to plastic buckets. Four treatments namely, erosion control compost {ECC, per TxDOT (2002) specifications}, compost manufactured topsoil {CMT, per TxDOT (2002) specifications}, agronomic rate compost (ARC) and commercial fertilizer (CF) were replicated (blocks) three times and randomly assigned to 12 plots, in a ‘randomized block’ design (Figure1). For each CMT treatment plot, a 2.5-cm (1") layer of DMC was incorporated in to 8-cm (3") of the topsoil using a heavy duty garden hoe. For each ECC treatment plot, a blend of 50% DMC and 50% woodchips by volume was applied as a 5-cm (2") thick layer of erosion control blanket on top of the existing undisturbed soil. Dairy manure compost at a rate of 39.5 t/ha (16 t/ac) was applied on undisturbed soil of each ARC treatment. Each CF treatment plot received mineral fertilizer at the rate of 112kg/ha (100 lb/ac) for nitrogen (N), 49 kg/ha (44 lb/ac as P or 100 lb/ac as P_2O_5) for phosphorus (P), and 83 kg/ha (83 lb/ac as K or 100 lb/ac as K_2O) potassium (K), respectively. Table 1 shows application rates (kg/ha) of N, P, and K for each treatment.

Rainfall simulation and surface runoff sampling

Two rainfall simulators (Figure 2), similar to those used in the National Phosphorous Research Project (Sharpley and Klienman, 2003) and described by Humphry et al. (2002) were used simultaneously to conduct rainfall simulation and runoff sampling experiments on experimental plots. Each simulator was designed and equipped with one HH-SS50WSQ nozzle (Spraying Systems Co., Wheaton, IL).

The simulator frame, a 2.8 m (L) by 2.3 m (W) by 3 m (H) aluminum structure, was fitted with plastic tarps (walls) to minimize wind interference during the rainfall event. Each simulator was leveled on its telescopic legs (pegs) and installed so that the nozzle was centered above the plot. A 1,025-gal capacity water tank and de-ionizing system were used to supply water with a pH of 5.6 and an electrical conductivity of 0.015 $\mu S\ m^{-1}$. Prior to rainfall simulation, volumetric soil moisture was determined at the 0-5-cm (0-2") depth from each treatment plot using a capacitance sensor (Theta Probe, Delta-T Devices, Cambridge, UK) at five locations within a plot (Table 1).

On each plot, simulated rainfall of 92 mm h^{-1} (3.6" h^{-1}) average intensity (25-yr return frequency of a 1-h storm at the experimental site) from an average height of 3.22 m (10.6 ft) above plot surface was applied to cover a 4-m^2 footprint, which ensured complete coverage of the 1 x2 m plot. Rainfall with this intensity was applied on each plot until 30-min of runoff was obtained.

Table 1. Nitrogen, P and K application rate (kg/ha) and moisture content at 0-5 cm depth of treatment plots.

Treatment	**N,** kg/ha (lb/ac)	**P,** kg/ha (lb/ac)	**K,** kg/ha (lb/ac)	**Moisture** % (v/v), n=15
CMT	1,635 (1,459)	545 (486)	3,493 (3,116)	21.35 ±4.07*
ECC	2,976 (2,665)	903 (806)	5,985 (5,340)	14.37 ±2.75
ARC	199 (178)	66 (59)	425 (379)	27.44 ±5.18
CF	112 (100)	49 (44)	93 (83)	27.21 ±3.6

*Standard deviation

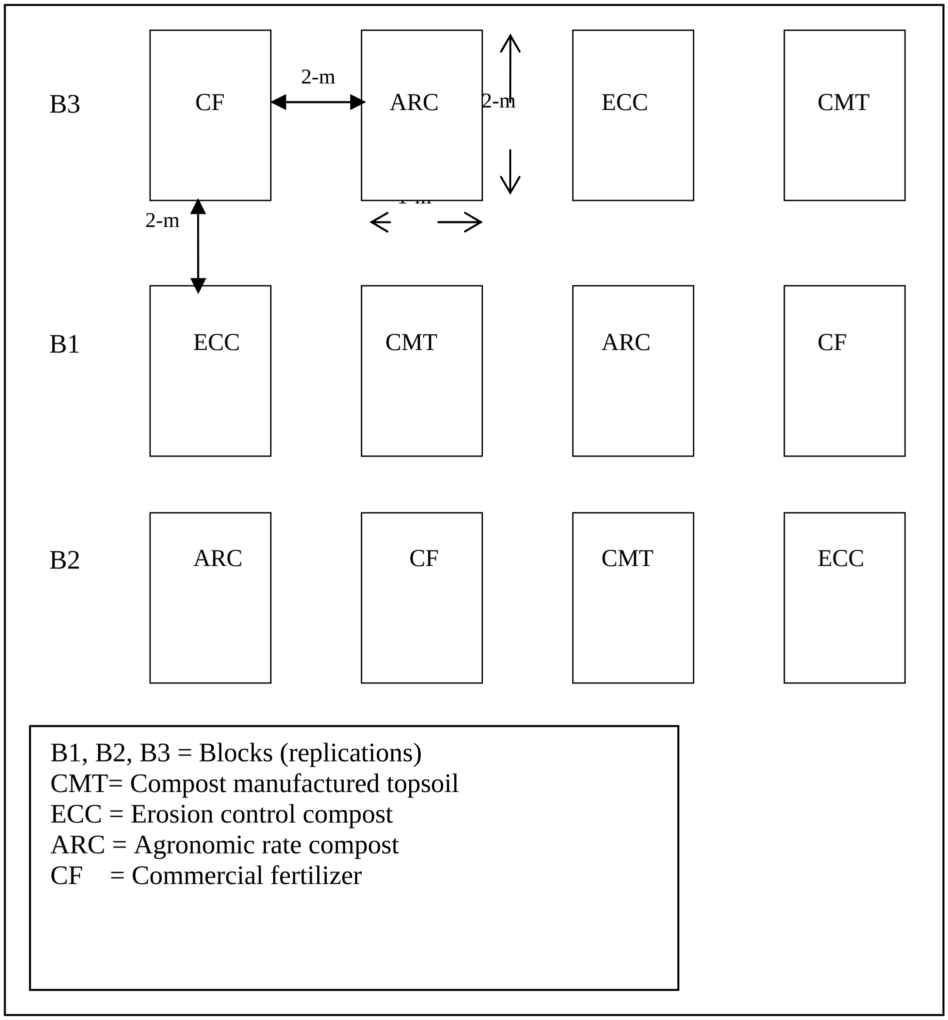

Figure 1. Experimental plots and treatment set-up (dimensions are not to scale)

Figure 2. Two rainfall simulators wrapped in plastic tarps, and a nozzle in use at the runoff plots.

After the start of rainfall on a plot, the time to initiate runoff (time difference between start of rainfall and beginning of overland flow) was recorded and the first liter of this runoff (the 'first flush') was collected directly in a plastic bottle. The remaining runoff was conveyed from PVC gutters to a plastic bucket and pumped to 26-L plastic containers. Total mass and volume of 30 min of overland flow from each plot was measured by weighing the containers. After weighing, the contents of all containers were emptied in a 136-L plastic drum, thoroughly agitated to resuspend solids and a representative 'sub sample' was collected in a plastic bottle. The entire procedure for rainfall simulation and runoff sampling was repeated for 12 plots.

Soil, compost, woodchips, and runoff analysis procedure

All soil, compost, compost/woodchips blend and runoff samples were analyzed for various physicochemical properties at the Soil, Water, and Forage Testing Laboratory, Department of Soil and Crop Sciences at the Texas A&M University. Additionally, runoff samples were also analyzed for total solids (TS) and total suspended solids (TSS) at Inter-Mountain Laboratories Inc., in College Station. Three composite soil samples were taken with a hand probe from 0 to 15-cm depths at the experimental site near bordered plots. Each core was divided into 0-5cm and 5-15 cm in depth. The soil samples were analyzed for extractable soil P (Hons et al., 1990) through Inductively Coupled Plasma Optical Emission Spectroscopy (ICP) and NO_3-N was analyzed using a modified version of Keeney and Nelson (1982) where 1M KCl was substituted for 2M KCL.

Three representative samples of dairy manure compost (DMC) and two representative samples of DMC/woodchips blend were also collected. These samples were pulverized to finer than 100 mesh, to decrease heterogeneity and 0.5 g of the pulverized sample was digested as received with sulfuric acid/selenium/lithium sulfate Kjeldahl digest (Parkinson and Allen, 1975). Total Kjeldahl Nitrogen (TKN) was determined colorimetrically using a Technicon Auto Analyzer II (Technicon Instruments Corporation, Tarrytown, NY). Total elemental P and K were analyzed using ICP.

A portion of 'first flush' and 'rest of the runoff' samples was filtered through a 0.45-micron pore-diameter filter. The unfiltered samples were blended and digested as received and analyzed for TKN, P and K using the same procedure used for the compost and woodchips samples. The filtered samples were analyzed for total dissolved P DP), dissolved K (DK), Nitrate-nitrogen (NO_3-N) and ammonium –nitrogen (NH_4-N) using ICP.

Total solids and TSS were determined from the unfiltered samples of the first flush and the rest of the runoff using Standard Methods (APHA, 1995) 2540B and 2540D, respectively. For TS, a sample was well mixed and dried to a constant weight at 105 ^{O}C. The dried sample contents represented TS. For the TSS determination, a well-mixed sample was filtered through a glass-fiber filter. The residue retained on the filter was dried to a constant weight at 105 ^{O}C. The dried sample contents represented TSS. For liquid samples, pH was measured directly using a probe and for solid samples it was determined from 2:1 water to solid paste.

Statistical analysis

A complete randomized block design was used to compare treatment effects on various physicochemical parameters in this rainfall-runoff study. Fisher's least significant difference

(LSD) method was used to compare treatment means. The data were analyzed using ANOVA procedure on Stat View software by SAS Inc.

RESULTS AND DISCUSSION

After initiation of the runoff from a simulated rainfall event, water leaked out of the borders from one experimental plot assigned to the CMT treatment. Therefore, only two replications for this treatment were included in the statistical analysis for all parameters related to runoff sampling and analysis.

Time to initiate runoff

The total time to initiate runoff, total mass of runoff, TSS and TS, and their respective standard deviations for each treatment are plotted in Figure 3. The average time to initiate runoff from the CMT plots was significantly higher ($p \leq 0.05$) than that from all other treatment plots while it was statistically similar among the ECC, ARC and CF treatment plots. The average time to initiate runoff from the ECC plots was the shortest (3.66 min) of all treatments. In fact, as compared to the ECC plots, it took more than twice as much time for the runoff to begin from the CMT (7.7 min) plots.

For the ECC plots, this may have been due to a lack of moisture absorption by the woodchips in the blanket (compost and woodchip mixture) as it was observed that at the beginning of the rainfall, this blanket was somewhat hydrophobic. On the other hand, the tillage induced conditions including reduced soil moisture (Table 1), increased surface roughness and reduced crusting and sealing may have resulted in increased infiltration of the CMT treatment plots, thereby delaying runoff time. Significantly higher initial infiltration from tillage as compared to no-till surface has been observed by Mukhtar et al. (1985).

Total runoff, TS and TSS

The total runoff mass from within each treatment varied highly (Figure 3) and was statistically similar among all treatments. Overall, average total runoff mass from CF was higher than and from ECC was lower than all other treatments.

The CMT plots had the second lowest total runoff mass followed by ARC and CF treatment plots. Although runoff initiated most quickly from the ECC plots, these plots contributed the smallest mass (and volume) of runoff. This in part was due to the fact that ECC plots had the lowest TS and TSS in runoff than those from all other treatment plots (Figure 3). The reduction in TS and TSS (hence erosion) from the ECC plots was due to the reduced raindrop impact. Because the soil surface was covered by the erosion control blanket, this resulted in less detachment and transport of sediment. Additionally, absorption of moisture by dairy manure compost in the ECC and CMT plots may also have contributed to relatively smaller amount of total runoff. Overall, TS amount from the CF treatment plots was significantly higher ($p \leq 0.05$) than that from all other treatments. The TSS amount from the CF plots was significantly higher than that from the ECC plots and higher but statistically similar to that from the rest of the treatments. Lower runoff rates and volumes and reduced soil erosion from organic compost treated soils compared to control treatments have been reported in several studies (Demars et al., 2000, Storey et al., 1996, Risse and Faucette, 2003 and Persyn et al., 2004). Figure 3 also shows that nearly all (2.38kg of 2.46kg) the solids in the runoff from the CMT plots were characterized as suspended solids while TSS amounts in the runoff from all other treatment plots were between 50% and 75% of TS. Additionally, little soil could be detected in the runoff samples from the ECC treatment plots.

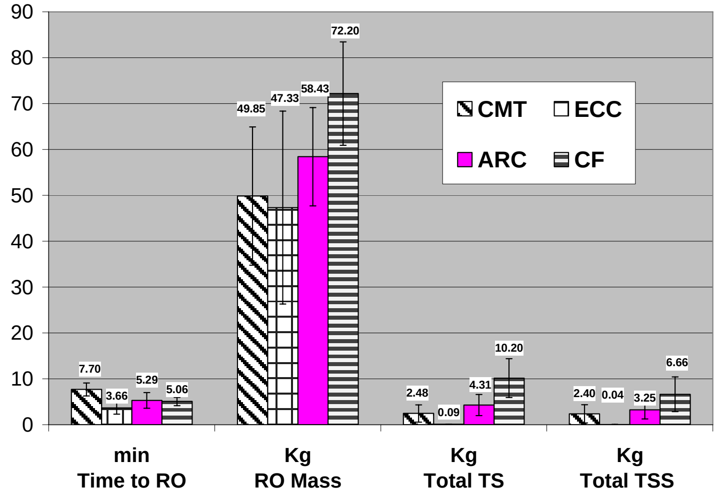

Figure 3. Time to initiate runoff, total mass of runoff and TS and TSS as affected by different treatments.

Runoff Quality

Table 2 presents physicochemical properties of runoff from the first flush (first liter of runoff collected directly from each plot) and from the subsequent runoff (total remaining runoff) samples. Treatment means and standard deviations of several parameters along with their statistical significance are shown in this table. All values represent total amounts (concentration x total runoff volume) of each parameter in the first flush and the subsequent runoff.

pH

Although the average pH for the rainwater was 5.6, the pH values for the runoff from all treatment plots were neutral or alkaline. This was due to the interaction of rainwater with alkaline soil (pH=8.13) and slightly alkaline compost, and compost/woodchips mix from different treatment plots during simulation runs. The pH for the first flush from the ECC plots was significantly lower than that for the first flush from the CF plots while all other treatments had statistically similar but lower pH values than the CF plots. In the remaining runoff, pH for all treatments increased as compared to the first flush and the remaining runoff from the ECC plots had significantly lower pH than that from all other treatment plots. The highest pH value measured from the remaining runoff was from CF plots. The increase of pH for all treatments in the remaining runoff was due to their higher TS and TSS content as compared to the first flush (Table 2). Also, the first flush and remaining runoff pH being the highest from the CF and the lowest from the ECC plots correspond to the highest TS and TSS in first flush and remaining runoff from the CF and the lowest TS and TSS in first flush and remaining runoff from the ECC plots.

TS and TSS

Total solids and TSS in the first flush from the ECC plots were significantly lower than those in the first flush from the CF plots while all other treatment had lower but statistically similar first flush TS and TSS than those in the first flush from CF plots. A similar trend for these parameters was observed in the remaining runoff from all treatment plots with the exception that the remaining runoff TS from the CF plots was significantly higher than that in remaining runoff from all other treatment plots. The TS and TSS in the first flush and the remaining runoff from all treatment plots followed a trend similar to the total mass of runoff (Figure 3). Table 3 also shows that most of the solids in first flush and remaining runoff from the CMT plots were measured as TSS and overall, plots amended with dairy manure compost or a compost/woodchip blend had lesser soil erosion than the CF treatment plots with no such amendments. This effect is also illustrated in Figure 4 that shows most (CF) to least (ECC) eroded surface conditions post rainfall.

Table 2. Total amounts of physicochemical constituents in runoff from different treatments.

	First Flush					Remaining Runoff			
PARAMETERS	CMT	ECC	ARC	CF		CMT	ECC	ARC	CF
pH	7.15[ab*] (±0.92)**	7.0[a] (±0.17)	7.53[ab] (±0.23)	7.7[b] (±0.36)		7.95[a] (±0.21)	7.27[b] (±0.15)	7.83[a] (±0.12)	7.97[a] (±0.12)
TS (Kg)	0.024[ab] (±0.02)	0.003[a] (±0.00)	0.032[ab] (±0.02)	0.06[b] (±0.04)		2.46[a] (±1.88)	0.09[a] (±0.04)	4.28[a] (±2.29)	10.14[b] (±4.25)
TSS (Kg)	0.019[ab] (±0.02)	0.001[a] (±0.00)	0.024[ab] (±0.01)	0.04[b] (±0.02)		2.38[ab] (±1.98)	0.043[a] (±0.02)	3.23[ab] (±1.98)	6.62[b] (±3.78)
TKN (mg)	13.95[a] (±11.38)	17.73[a] (±3.93)	18.6[a] (±12.49)	54.73[b] (±26.38)		1,649[a] (±1,517)	673[a] (±276)	1,806[a] (±756)	5,801[b] (±1947)
NO_3-N (mg)	2.9[a] (±0.89)	24.7[a] (±32.2)	29.1[a] (±5.08)	30.9[a] (±22.27)		1,556[a] (±400)	873[a] (±1,007)	871[a] (±475)	1,588[a] (±974)
NH_4-N (mg)	0.4[a] (±0.4)	2.9[a] (±4.7)	0.7[a] (±0.3)	9.4[a] (±9.8)		205[a] (±257)	6.7[a] (±4.69)	16.1[a] (±12.63)	430[a] (±404)
P (mg)	3.85[a] (±3.36)	5.91[a] (±1.05)	6.4[a] (±3.03)	17.9[b] (±8.71)		515[a] (±317)	258[a] (±115)	582[a] (±166)	1,998[b] (±883)
DP (mg)	0.36[a] (±0.03)	3.84[a] (±3.31)	1.83[a] (±1.33)	6.5[a] (±6.38)		57.07[a] (±62.61)	66.26[a] (±65.59)	69.52[a] (±74.62)	516.65[a] (±528.8)
K (mg)	267[a] (±204)	498.5[a] (±20.02)	348.2[a] (±84.37)	476.2[a] (±177.2)		24,297[ab] (±12,868)	16,400[a] (±7,052)	24,545[a] (±1,478)	50,883[b] (±16,914)
DK (mg)	4.1[a] (±2.16)	75.6[a] (±119.79)	120.5[a] (±106.39)	68.9[a] (±102.13)		560[a] (±419)	2,152[a] (±3,275)	2,437[a] (±3,519)	465[a] (±72)

* Averages in rows followed by different letters are different at 5% level. **Standard deviation

Figure 4. Post-rainfall plot surface conditions of each treatment.

Nitrogen, P and K

As mentioned earlier, all forms of N, P and K in Table 2 are total quantities determined from either the first flush (1-L) or remaining runoff from different treatment plots. As shown in Table 1, the highest rate of N, P and K was applied to the ECC plots followed by the CMT, ARC and CF plots. The TKN in the first flush and remaining runoff from the CF plots was significantly greater than that in the first flush and remaining runoff from all other treatments. The TKN in both forms of runoff from all other treatments was statistically similar. Despite much larger nitrogen applications to the ECC and CMT plots compared to the CAR and CF plots, the TKN, NO_3-N and NH_4-N in runoff from the ECC and CMT treatment plots were always lower than those in the runoff from the CF plots. This is attributed to the significantly higher solids and higher runoff mass from the CF treatment plots. Though highly variable within treatments and statistically similar among treatments, NO_3-N and NH_4-N in the first flush and the remaining runoff from the CF treatment plots were generally higher than those in the runoff from all other treatment plots. If NO_3-N in the first flush (1-L volume) and the remaining runoff from all treatment plots were converted to mg/l (total NO_3-N, mg divided by the remaining runoff mass, L), then with the exception of the first flush from the CMT plots, NO_3-N in runoff from all treatments will be above the 10 mg/l limits for the drinking water quality standards set by the US Environmental Protection Agency (EPA, 1994).

Total P in both forms of runoff from the CF treatment plots was significantly greater than that in runoff from all other treatment plots. The dissolved fraction of P (DP) was highly variable within treatments and statistically similar for either form of runoff from all treatment plots. Generally, DP in runoff was higher from the CF plots than all other treatment plots. As discussed above for the NO_3-N, if total P in either form of runoff were converted to mg/l, it will range from 3.86 ±3.36 mg/l in the first flush from the CMT plots to 27.02 ±8.4 mg/l in the remaining runoff from

the CF plots. These concentrations of total P, if introduced to receiving waters of lakes, streams and reservoirs will be much greater than the total P concentration of 100 µg/L, the upper limit of acceptable P to avoid eutrophication of such water bodies (Correll, 1998).
Total and dissolved K in the first flush and the remaining runoff were highly variable within each treatment and statistically similar for K in the first flush and DK in both forms of runoff from all treatments. Total K in the remaining runoff from CF plots was significantly higher than that in the runoff from the ECC and ARC treatments and higher but statistically similar from K in the runoff from the CMT plots.

CONCLUSION

Despite the shortest time to initiate runoff, the ECC plots had smaller total runoff mass than all other treatments and significantly lower TS and TSS in the runoff (first flush and the remaining) as compared to those in the runoff from CF plots. In the remaining runoff, TS from the CMT and ARC plots and TS and TSS from the CMT plots were also significantly lower than those from the CF plots. Overall, plots amended with DMC or DMC/woodchips blend produced less runoff and sediment in the runoff as compared to the mineral fertilizer plots without any organic amendment. All plots amended with organic materials received greater amounts of N, P and K as compared to the mineral fertilizer plots. Application rates for N, P and K for the ECC and CMT plots were generally one to two folds higher than those for the CF plots. Despite these very high application rates, TKN in runoff (first flush and the remaining) from the ECC, CMT and ARC plots was significantly lower than that in runoff from the CF plots. Also, statistically similar but lower NO_3-N and NH_4-N were measured in runoff from these treatment plots than those in the runoff from the CF plots. Total P in the CF plots' runoff was significantly higher and DP in runoff from the same plots was higher than but statistically similar to that in the runoff from all other treatments. Significantly higher K in the remaining runoff from the CF plots compared to that in the remaining runoff from the ECC and ARC plots was measured. Dissolved K in the first flush and the remaining runoff was statistically similar for all treatments but generally higher for ARC and ECC as compared to CMT and CF.

The ECC plots had smaller total runoff mass than all other treatments and significantly lower TS and TSS in the runoff as compared to those in the runoff from CF plots. Overall, plots amended with DMC or DMC/woodchips blend, though much higher in N, P and K, produced smaller runoff, and lesser sediment and nutrients in the runoff, as compared to the mineral fertilizer plots without any organic amendment. It was concluded that the ECC and CMT treatments established to control erosion and revegetate, respectively, a newly constructed road-right-of-way and shortly there after, subjected to rain (a worst case scenario) will be effective in erosion control. Although compared to the CF treatment, generally smaller quantities of N, P and K concentrations were measured in the runoff from the ECC and CMT treatment plots, N and P concentrations in the runoff were high from the standpoint of water quality.

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Use of Dairy Manure Compost as Erosion Control Material Under Vegetated and Non Vegetated Conditions

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INTRODUCTION

Many watersheds in the USA with large and concentrated animal feeding operations (CAFOs) face the challenge of reducing manure application rates on agricultural soils that test high in phosphorous (P) by identifying alternatives for manure utilization. Water quality studies in the Bosque River watershed, home to more than one hundred dairy operations, indicated that P was the limiting nutrient and that dairy waste application fields (WAFs) and municipal waste treatment plants were the major nonpoint and point sources of P, respectively, to the North Bosque River (McFarland and Hauck, 1999a, 1999b).

Studies by Persyn et al. (2004) and Risse and Faucette (2003) cite use of compost from various organic materials including animal manure for erosion control and revegetation of highway construction sites. Construction and erosion control applications of dairy manure compost (DMC) could provide an opportunity to remove large quantities of manure from the North Bosque River Watershed and help reduce the need for repeated application of manure to the same parcels of land in the watershed. However, very little information is available regarding runoff quantity and quality resulting from the use of manure-based compost materials, particularly on steep slopes and disturbed soils associated with roadway construction.

OBJECTIVES

The objectives of this study were to:

1. Examine the efficacy of using an erosion control treatment system containing composted dairy manure for stabilization and revegetation of steep slopes.
2. Compare results of runoff volume and concentrations and loadings of physicochemical constituents from experimental plots amended with a DMC/woodchips blend (designated as erosion control compost or ECC) or inorganic fertilizer (IF) subjected to simulated intense rainfall under non-vegetated and vegetated conditions.

METHODS AND MATERIALS

Experimental plot construction and set-up, treatment installation and vegetation establishment

Eight, 3 by 6-ft (0.9 by 1.8-m) plots were established on a custom built steel bed {9.1m (30ft) × 1.8m (6ft) × 228.6mm (9in) deep} divided with metal borders and lined with a 5 mil plastic tarp (Fig. 1a). At the downslope end of each plot, a triangular tray and downspout (Fig. 1b) were constructed to convey runoff to a sampling container.

Figure 1. Custom built steel bed lined with plastic tarp (a) and a triangular tray with downspout for coneying runoff to sampling containers (b).

Soil used to fill each divided metal bed (plot) was excavated from a constructed hillside at the Riverside campus in College Station, Texas, used by the Texas Transportation Institute (TTI) for runoff studies. Three composite soil samples were collected for laboratory analysis. Soil texture was clay loam containing an average 27, 35 and 38 percent sand, silt, and clay, respectively (Table 1). Additional soil chemical analyses conducted are listed in Table 2.

Table 1. Textural analysis of soil utilized to prepare sediment bed.

Plot ID	**Sand**	**Silt**	**Clay**	**Texture**
	---------------------------%	---------------------------		
Soil Sample 1	26	34	40	Clay loam
Soil Sample 2	28	34	38	Clay loam
Soil Sample 3	28	36	36	Clay loam
Std Dev	*1.2*	*1.2*	*2.0*	
Average	27	35	38	

Table 2. Chemical analysis of soil utilized to prepare sediment bed.

Plot ID	**pH**	**EC**	**NO_3+NO_2**	**P extractable**	**K**	**Ca**	**Mg**	**SO_4-S**	**Na**	**B**	**OM**
Soil Sample 1	7.8	2246	43	7	239	9476	426	1213	215	0.44	1.53
Soil Sample 2	7.7	2118	60	8	229	8318	413	1356	242	0.41	1.59
Soil Sample 3	7.7	2094	50	8	230	8644	414	1902	181	0.47	1.60
Std Dev	*0.1*	*81.71*	*9.0*	*1*	*5.5*	*597*	*7.2*	*364*	*30.6*	*0.03*	*0.04*
AVERAGE	7.73	2153	51	8	233	8813	418	1490	213	0.44	1.57

In each plot, soil was added to a height of 7 inches (18 cm) and tamped down to a height of 4 inches (10 cm) with a 25 lb (11.4 kg) hand tamper (Fig 2a). The two treatment systems were erosion control compost (ECC); a 1:1 (v:v) blend of dairy manure compost (DMC) and woodchips, and inorganic fertilizer (IF). For the purpose of this paper, these treatment systems will be referred to as treatments. Both treatments were replicated four times and randomly assigned to these plots (Fig. 3). For each ECC plot preparation, the bed was filled up to 2 inches below the top of the bed by adding more soil to the previously tamped layer. A 150-lb (68 Kg) hand drum roller (22 inches wide) was used to break clods and level the soil surface (Fig. 2b). A similar procedure was used for IF plot preparation, but soil was filled to the top of the bed for this treatment. The procedure used to prepare the sediment beds was consistent with that utilized by TTI for bed preparation when conducting TxDOT approved research.

Figure 2. Soil compaction with hand tamping (a) and soil leveling with a drum roller (b).

For ECC plots, the blend of DMC and woodchips was applied on top of the soil as a 2-inch (5-cm) layer equivalent to 126 t/ac (91.1 t/ac DMC + 34.8 t/ac woodchips) or 283 mt/ha (Fig. 4). Based on chemical analysis of the DMC (Table 3a and 3b), this resulted in nutrient application rates of 1786 lb N/ac (2002 kg N/ha), 1272 lb P_2O_5/ac (1426 kg P_2O_5/ha), and 2678 lb K_2O/ac (3002 kg K_2O/ha). For the IF plots, granular fertilizer was hand broadcast and then lightly raked into the soil surface at rates of 100 lb N/ac (112 kg N/ha) as ammonium nitrate, 100 lb P_2O_5/ac (112 kg P_2O_5/ha) as triple superphosphate, and 100 lb K_2O/ac (112 kg K_2O/ha) as potassium chloride (Fig 4). These treatments were established 6 days prior to the first rainfall event. Total amounts of nutrients per plot and per acre for each treatment are presented in Table 3c. As noted in the table, due to the composition of the DMC, the ECC treatment resulted in substantially greater nutrient application rates compared to the IF treatment.

After establishment of treatments, all plots were seeded on the same day with a Texas DOT recommended seed mix (tall fescue, wheat, oats) with the addition of ryegrass to ensure vegetation establishment (Fig. 5a). The mixture was broadcast (Fig. 5b) and lightly raked into the surface of each plot. All plots were monitored for seed germination, moisture and insect management.

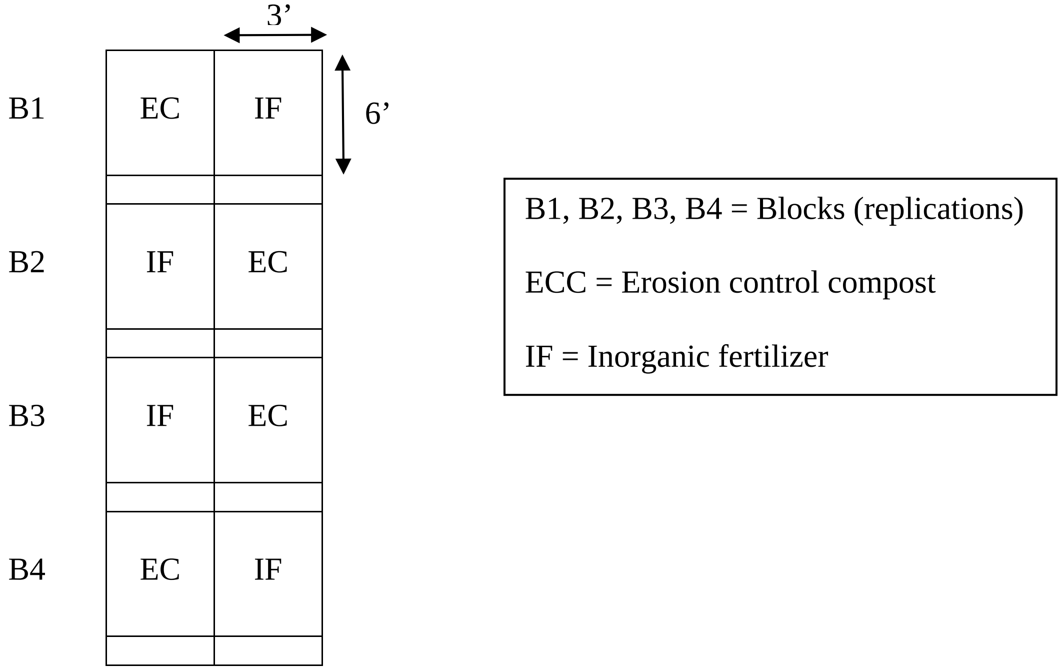

Figure 3. Experimental plots and treatment set-up (dimensions are not to scale)

Vegetation Response and Soil Sample Data Collection

Information on plant height and percent of canopy coverage is provided in Table 6. Average plant heights were measured from 10 individual plants randomly selected in each plot 47 days after planting (Fig. 6a). Percent canopy cover was measured by using a point method and ranking system; 1 for vegetation and 0 for no vegetation. Twenty-four individual points, 6 inches (15.2 cm) apart on the two 7-feet (2.1 m) diagonals crossing each plot were ranked (Fig. 6b). Measurements were made starting 6 inches away from plot borders to eliminate edge effects.

In addition to the initial composite soil samples collected and analyzed (Table 1 and 2), composite soil samples were collected from each plot at three stages of the study. Samples were collected (1) following the first rainfall simulation event; (2) after vegetation establishment, but prior to second rainfall simulation event; and (3) following the second rainfall simulation event. Each composite sample was collected by thoroughly mixing 10 subsamples collected at a 6 inch depth in each plot. Soil samples were submitted to TCE Soil, Water and Forage Testing Laboratory and analyzed according to the approved Marketing Composted Manure to Public Entities Quality Assurance Project Plan.

Table 3a. Laboratory analysis of dairy manure compost utilized in the rainfall simulation study. Parameters listed were determined on a wet weight basis.

Parameter	Units	Wet Weight Basis
Total N	%	0.98
Ammonia	mg/kg	584
Nitrate	mg/kg	8
Organic Nitrogen	%	0.92
Phosphorus as P2O5	%	0.69
Phosphorus	mg/kg	3048
Potassium as K2O	%	1.5
Potassium	mg/kg	12250
Calcium	%	9.1
Magnesium	%	0.52
Sulfate (SO4)	mg/kg	449
Copper	mg/kg	29
Zinc	mg/kg	90
Iron	mg/kg	5855
Manganese	mg/kg	153
Boron	mg/kg	19
Sodium	%	0.27
Chloride	%	0.17
pH	units	9.06
EC	mmhos/cm	4.165
Bulk Density	lb/cu ft	47
Carbonates as CaCO3	lb/ton	67
Organic matter	%	20.7
Organic Carbon	%	14.2
Ash	%	58.8
C:N Ratio	ratio	14
Moisture	%	20.5

Table 3b. Laboratory analysis of dairy manure compost utilized in the rainfall simulation study. Parameters listed were determined on a dry weight basis

Parameter	Units	Dry Weight Basis
Arsenic	mg/kg dw	3
Cadmium	mg/kg dw	less than 1
Chromium	mg/kg dw	6
Copper	mg/kg dw	36
Lead	mg/kg dw	2
Mercury	mg/kg dw	less than 1
Molybdenum	mg/kg dw	1
Nickel	mg/kg dw	5
Selenium	mg/kg dw	less than 1
Zinc	mg/kg dw	114
Cobalt	mg/kg dw	2
Total Solids	%	79.5
Fecal Coliform	mpn/g dw	17
Salmonella	mpn/4 g dw	less than 3
Respiration	mg CO2-C/g OM/day	7
Biological Avail. Carbon	mg CO2-C/g OM/day	7.2
Emergence	%	100
Relative Seedling Vigor	%	100
Description of plants	NA	Healthy
0.25" to 0.38"	% by weight	0
	% by volume	0
	Bulk Density (g/cc)	0
0.16" to 0.25"	% by weight	1.8
	% by volume	1.6
	Bulk Density (g/cc)	0.7
0.08" to 0.16"	% by weight	18.8
	% by volume	21.3
	Bulk Density (g/cc)	0.56
<0.08"	% by weight	79.4
	% by volume	77.1
	Bulk Density (g/cc)	0.65

Table 3c. Application rates of nitrogen (in the form of N), phosphorus (in the form of P_2O_5), and K (in the form of K_2O) per plot and per acre for each treatment, ECC and IF.

	N		P_2O_5		K_2O	
	lbs/plot	**lbs/A**	**lbs/plot**	**lbs/A**	**lbs/plot**	**lbs/A**
ECC	0.74	1786	0.53	1272	1.11	2678
IF	0.04	100	0.04	100	0.04	100
	lbs/plot		**lbs/plot**		**lbs/plot**	
Ratio of ECC:IF	18.5		13.25		27.75	

Figure 4. Metal bed plots with the IF treatment incorporated into soil and the ECC treatment applied on the soil surface.

Figure 5. Grass seed (left) being braodcast on IF treatment (right).

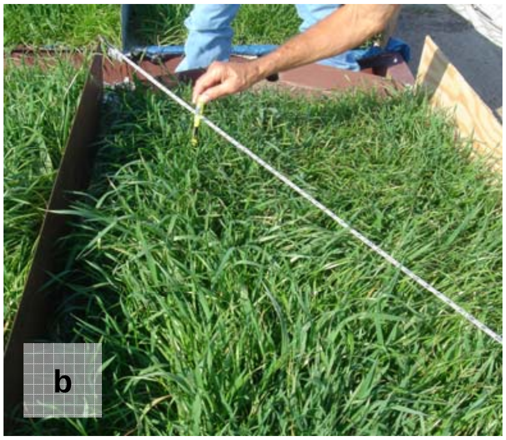

Figure 6. Plant height (a) and percent of canopy coverage (b) measurement .

Rainfall simulation and surface runoff sampling

In the fall of 2005, an indoor rainfall simulation facility owned and operated by TTI at Riverside campus was used to conduct rainfall simulations and runoff sampling experiments on non-vegetated and vegetated ECC and IF plots on September 26 and November 15, respectively. A detailed description of this facility is provided by Li et al. (2003).

An oscillating rain rack (Fig. 7), suspended 14 feet (4.3 m) above the test surface (ECC and IF plots) is equipped with drip emitters that produce 0.12 to 0.16 inch (3mm to 4mm) droplets to mimic a rainfall intensity of 3.5in/hr (88.9 mm/hr), which corresponds to a 25-yr return frequency of a 1-hr storm at the experimental site. Oscillation of the rack provides a randomized raindrop pattern for uniform coverage of treatment plots. The 25-yr 1-hr storm event is the typical rate used in highway roadside erosion control material testing in the TTI rainfall simulation facility (Li et al. 2003).

The steel bed with established treatements was hoisted under the rain rack (Fig. 7 and 8 for non-vegetated and vegetated conditions, respectively) at a 3:1 side slope to mimic road right-of-way.

Tap water was used for both rainfall simulation events. Chemical analysis of tap water samples collected at the time of each rainfall simulation event are presented in Table 8.

At the downstream end of each plot, a reinforced 2-inch diameter plastic hose was connected to the downspout of each plot to collect the first flush (first litre of runoff) and the subsequent total runoff for a period of 30 minutes following runoff initiation.

For both rainfall events, time to initiate runoff (time difference between start of simulated rainfall and beginning of overland flow) for each plot was recorded. Runoff was collected for a total of 30 minutes. The first liter of runoff (first flush) was collected directly in a plastic bottle (Fig. 9a) and subsequent runoff from each plot was collected into individual clean 30-gallon (113 L) plastic containers (Fig. 9b) and weighed for total runoff mass (Fig 10a). After weighing, contents of each container were thoroughly agitated to re-suspend solids, and a representative sub-sample was collected in a plastic bottle (Figs. 10a-c). This procedure of weighing and sampling was repeated for all plots during both rainfall events.

Because the sediment beds were to be placed outdoors between rainfall events, 3 small incisions (approximately 3 cm in length) were placed in the plastic lining under each plot. The cuts aided water flow through the plots so rainfall and irrigation applied to the bed would not pool in each plot. Prior to the second rainfall event, each incision was sealed with caulking to avoid leaks during rainfall simulation.

Figure 7. Oscillating rain rack with emitters (left) and non-vegetated treatment plots (right) hoisted under the rack at a 3:1 sideslope.

Figure 8. Rainfall simulation on vegetated ECC and IF treatment plots.

Analysis of soil, compost and runoff

Soil, compost and runoff water sample collection and laboratory analyses followed approved procedures and methodologies described in the Marketing Composted Manure to Public Entities Quality Assurance Project Plan. Table 4 lists analytes determined for soil and runoff water samples and the corresponding procedure for the analysis of each parameter. Three composite samples of dairy manure compost were collected prior to treatment installation and analyzed by Soil Control Laboratories. Parameters and laboratory methodology as defined by the Test Methods for the Examination of Compost and Composting are listed in Table 5.

Figure 9. Samples of first flush (a) and subsequent runoff (b) being collected during rainfall simulation event.

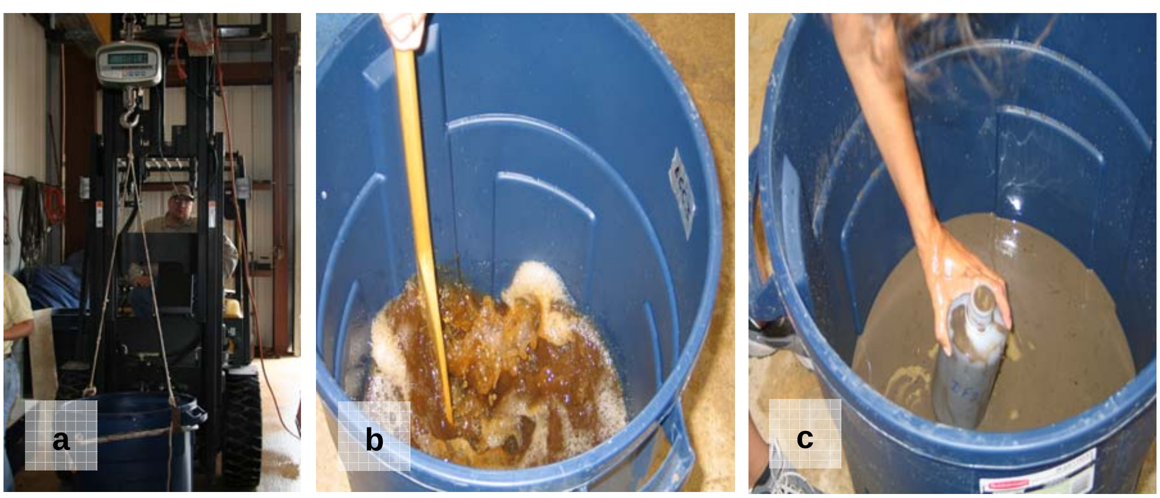

Figure 10. Weighing (a), mixing (b) and sub-sampling (c) of total runoff mass.

Table 4. Soil and runoff water sample parameters analyzed and the corresponding methodology as defined by the Soil, Water and Forage Testing Laboratory.

Parameter	SWFTL[a] Method
Soil	
pH	0015
Electrical Conductivity	0015
NO_3–N + NO_2–N (NNN)	0014
Extractable Phosphorus	00079 & 00081
Water Soluble P (CaCl)	0064
Potassium	00079 & 00081
Calcium	00079 & 00081
Magnesium	00079 & 00081
Sodium	00079 & 00081
Sulfate-Sulfur	00079 & 00081
Boron	0022 & 00081
Moisture	NA
Organic Matter	NA
Water	
pH	0041
Electrical Conductivity	0040
NO_3–N + NO_2–N (NNN)	0038
Total Phosphorus	0037
Ortho-phosphate	0061 & 0062
Potassium	0037
Calcium	0037
Magnesium	0037
Sodium	0037
Sulfate-Sulfur	0037
Total Solids	0057[b]
Total Suspended Solids	0057

[a] SWFTL = Soil, Water and Forage Testing Laboratory SOP code
[b] Standard Operating Procedure 0057 based on Standard Method 2540 (Franson 1989)

Table 5. Dairy manure compost sample parameters analyzed and corresponding methodology utilized by Soil Control Laboratories.

Parameter	**CL[a] Method (TMECC[b] Method)**
Chemical Properties	
Electrical Conductivity	04.10-A
PH	04.11-A
Organic Properties	
Organic Matter	05.07-A
Fecal Coliform	07.01-B
Metals	
Magnesium	04.12-B/04.14-A
Sodium	04.12-B/04.14-A
Manganese	04.12-B/04.14-A
Copper	04.12-B/04.14-A
Calcium	04.12-B/04.14-A
Zinc	04.12-B/04.14-A
Iron	04.12-B/04.14-A
Arsenic	04.12-B/04.14-A
Chromium	04.12-B/04.14-A
Cadmium	04.12-B/04.14-A
Lead	04.12-B/04.14-A
Mercury	04.12-B/04.14-A
Molybdenum	04.12-B/04.14-A
Nickel	04.12-B/04.14-A
Selenium	04.12-B/04.14-A
Nutrients	
Total Nitrogen	04.02-D
Total Phosphorus	04.12-B/04.14-A
Total Potassium	04.12-B/04.14-A
Physical Properties	
Particle Size	02.02-B
Maturity	05.05-A
Stability	05.08-B
Moisture	03.09-A

[a] CL = Control Laboratories
[b] TMECC = Test Methods for the Examination of Composting and Compost

Statistical analysis

Data were analyzed using the ANOVA procedure for a randomized complete block design in Stat View (SAS Inc.), and means were separated using Fisher's least significant difference (LSD) method.

RESULTS AND DISCUSSION

Vegetation response

Vegetation response data are presented in Table 6. Average plant height for the ECC plots (15.6 inches) was significantly greater than that for the IF (11.7 inches) plots. This may have been influenced by moisture conservation due to the mulching effect of the ECC and/or by the greater nutrient levels in that treatment. However, percent canopy cover was not affected by treatment, averaging 98% for both ECC and IF.

Table 6. Plant height and canopy coverage data.

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Statistics
			Plant heights (in)		
ECC	14.5* ±1.53**	15.0 ±1.59	16.3 ±1.42	16.4 ±1.31	15.6 ±1.63
IF	13.2 ±1.74	11.7 ±1.98	12.2 ±1.95	9.7 ±1.18	11.7 ±2.12
			Canopy coverage (%)		
ECC	98%*	96%	97%	99%	
IF	97%	98%	98%	98%	

* Average; ** SD

Soil Characteristics

Soil sample results from the three sampling events are presented in Tables 7a, 7b and 7c. Application of the ECC treatment significantly increased percent organic matter in ECC plots compared to soil sample results prior to treatment. The application of ECC and IF treatments had no effect on soil pH levels and minimal effect on EC levels. Compost used in this study had a pH of 9.06 (Table 3a), which is above the TxDOT compost specification (pH must be between 5.5 and 8.5). Data presented here warrants further investigation of the pH specification as vegetation response and soil sample results indicated no harmful effects from utilizing a high pH dairy compost based material.

The drain holes did preclude development of a mass balance of soil nutrients for the plots. However, soil sample data as listed in Tables 7a, 7b and 7c provide information about the effects of compost and inorganic fertilizer on soil characteristics.

Table 7a. Composite soil sample characteristics of individual plots following first rainfall simulation event. Samples were collected and submitted to laboratory on September 28, 2005.

Plot ID	pH	EC	NO_3+NO_2	P[a]	P[b]	K	Ca	Mg	SO_4-S	Na	B	OM
		umho/cm	ppm									%
ECC Rep 1	7.7	1801	39	430	10.51	994	7424	680	2542	510	2.26	7.60
ECC Rep 2	7.7	1904	38	412	4.96	758	7897	668	2812	403	1.87	6.34
ECC Rep 3	7.7	2131	61	188	3.93	646	7954	516	3812	366	1.62	4.27
ECC Rep 4	7.7	1765	32	367	6.60	709	8004	646	2794	406	1.63	5.62
Std Dev	*0.0*	*164.7*	*13*	*111*	*2.89*	*152*	*267*	*75.7*	*562*	*61.9*	*0.30*	*1.39*
AVERAGE	7.7	1900	43	349	6.50	777	7820	628	2990	421	1.85	5.96
IF Rep 1	7.5	1986	89	36	<1	230	8481	419	5019	224	0.93	1.82
IF Rep 2	7.5	1998	102	19	<1	289	8730	410	5237	240	0.82	1.84
IF Rep 3	7.4	1969	99	21	<1	262	9436	436	6543	208	0.86	1.81
IF Rep 4	7.1	1306	111	17	8.25	251	7518	377	3767	234	0.95	1.93
Std Dev	0.19	339.4	9.1	8.7	-	24.6	793	24.8	1137	14.0	0.06	0.19
AVERAGE	7.38	1815	100	23	-	258	8541	411	5141	227	0.89	7.38

Table 7b. Composite soil sample characteristics of individual plots prior to second rainfall simulation event. Samples were collected and submitted to laboratory on November 11, 2005.

Plot ID	pH	EC	NO_3+NO_2	P[a]	P[b]	K	Ca	Mg	SO_4-S	Na	B	OM
		umho/cm	ppm									%
ECC Rep 1	7.5	1892	3	505	9.28	1210	7220	702	2132	655	2.556	2.6
ECC Rep 2	7.8	1498	3	403	4.34	766	7652	644	2521	547	1.87	6.78
ECC Rep 3	7.5	1669	46	368	2.28	687	8169	652	2770	526	1.711	5.44
ECC Rep 4	7.6	802	7	398	1.87	866	7278	632	2192	505	1.676	6.37
Std Dev	*0.14*	*471*	*21*	*59.9*	*3.40*	*230*	*437*	*30.8*	*298*	*66.7*	*0.41*	*1.88*
AVERAGE	7.6	1465	15	418	4.44	882	7580	658	2404	558	1.95	5.30
IF Rep 1	7.5	1574	15	22	<1	202	7148	310	2812	290	na	1.83
IF Rep 2	7.7	1805	3	28	1.67	229	8208	367	4297	312	0.823	1.73
IF Rep 3	7.4	2066	41	24	<1	229	8668	348	4405	312	0.975	1.78
IF Rep 4	7.6	1717	51	25	<1	248	8730	402	4722	342	0.987	2.17
Std Dev	*0.13*	*206.9*	*22*	*2.4*	-	*19.0*	*732*	*38.2*	*851*	*21.4*	*0.09*	*0.20*
AVERAGE	7.55	1791	27	25	-	227	8189	357	4059	314	0.93	1.88

Table 7c. Composite soil sample characteristics of individual plots following second rainfall simulation event. Samples were collected and submitted to laboratory on November 22, 2005.

Plot ID	pH	EC	NO_3+NO_2	P[a]	P[b]	K	Ca	Mg	SO_4-S	Na	B	OM
		umho/cm	ppm									%
ECC Rep 1	7.8	1889	4	792	8.45	1327	8598	916	2752	816	2.01	10.09
ECC Rep 2	7.7	2210	4	252	1.14	625	8800	578	4357	534	1.28	4.52
ECC Rep 3	7.7	2340	6	318	1.92	576	8969	645	4057	593	1.37	4.92
ECC Rep 4	7.6	2390	7	288	1.5	651	9453	628	4713	518	1.16	4.36
Std Dev	*0.1*	*225.3*	*2*	*254*	*3.48*	*356*	*365*	*152*	*855*	*138*	*0.38*	*2.76*
AVERAGE	7.7	2207	5	413	3.25	795	8955	692	3970	615	1.46	5.97
IF Rep 1	7.5	2320	13	38	0.15	304	9551	408	5303	383	0.91	1.74
IF Rep 2	7.5	2530	14	19	0.1	280	9749	442	5647	393	0.68	1.81
IF Rep 3	7.5	2920	16	21	0.26	280	10334	411	7522	364	0.77	1.89
IF Rep 4	7.6	2740	17	34	0.26	306	10354	427	6336	417	0.78	1.7
Std Dev	*0.0*	*259.7*	*1.8*	*9.4*	*0.08*	*14.5*	*409*	*15.7*	*979*	*22.1*	*0.09*	*0.08*
AVERAGE	7.53	2628	15	28	0.19	293	9997	422	6202	389	0.79	1.79

[a] extractable; [b] water soluble

Runoff volume characteristics of non-vegetated and vegetated ECC and IF treatments

Time to initiate runoff, total amount of rainfall, total mass of runoff water and runoff rate from ECC and IF treatment plots resulting from simulated rainfall under non-vegetated and vegetated conditions are presented in Table 8.

Both systems (IF and ECC) received the same intensity of rainfall (3.5 in/hr). However, due to the inherent hydrophilic property of organic matter and prevention of soil surface sealing by the 5-cm thick erosion control blanket in the ECC system, considerably more time was required to initiate runoff from ECC plots compared to IF plots. Therefore, the ECC plots received rain for longer duration than the IF plots. Thus, ECC received a greater amount of rainfall under both vegetated and non-vegetated conditions.

Non-vegetated conditions: The average time to initiate runoff from non-vegetated ECC plots was nearly twice that of the IF plots, but was not significantly different due to large within treatment variation for ECC plots. The within treatment variation observed for ECC during the non-vegetated simulation was attributed in part to preferential flow or channeling along borders of selected plots, which was corrected for the vegetated simulation. Regardless, average total runoff mass from IF was significantly greater ($P \leq 0.05$) than that from ECC indicating more water infiltrated into the ECC plots than IF plots.

Runoff rates (cm/h) from ECC and IF plots were calculated from total runoff water mass (converted to volume using density of water), surface area (18 ft^2 or 1.67 m^2) and the time (30 min.) for runoff collection from each plot. During the non-vegetated rainfall event, average runoff rate for ECC was significantly lower than IF. Surface sealing due to raindrop impact on the bare soil surface of IF treatment plots reduced infiltration and rain water and initiated quicker overland flow as compared to ECC where the woodchips and compost protected the soil surface. Figure 11 illustrates post rainfall evidence of sealing and rill formation due to detachment and transport of sediment on IF plot surfaces as compared to no visible structural damage to the soil protected by ECC treatment. In addition, the significantly higher organic matter content (5.96%±1.68 for ECC vs. 1.85% ±0.05 for IF, n=4) and the hydrophilic nature of compost in the ECC treatment resulted in a significantly lower runoff rate and less total runoff water mass from ECC plots as compared to the IF plots.

Vegetated conditions: Similar to results observed for non-vegetated conditions, simulated rainfall on vegetated plots resulted in greater average time to initiate runoff from ECC compared to IF plots, but differences were statistically significant in this case (Table 8). The substantial delay in initiation of runoff from ECC plots indicated that such treatments may completely prevent runoff when exposed to rainfall of this intensity for short periods of time (less than 20 minutes) as compared to exposed soil (IF treatment).

Considerably more time (>20 minutes longer) was required to initiate runoff from vegetated ECC plots compared to vegetated IF plots. Thus, ECC plots received a much greater amount of rainfall, which resulted in increased runoff rate and mass. As a result, the total mass of runoff water and runoff rate from vegetated ECC plots were significantly greater than from vegetated IF plots despite the fact that ECC plots absorbed and retained more of the rainfall applied than the

IF plots. As noted in Table 8, the ECC plots absorbed more water than the IF plots during the entire vegetated rainfall simulation event.

Comparison of non-vegetated and vegetated conditions: Vegetated IF plots initiated runoff sooner (about half the time observed for non-vegetated IF plots) but had less than half the runoff rate and total mass of runoff water as compared to the non-vegetated IF plots. Surface sealing caused by raindrop impact on the exposed soil of the non-vegetated IF plots likely explain this result. Established vegetation on the IF plots slowed runoff rate and improved water infiltration.

Vegetated ECC plots took much longer to initiate runoff and had twice the runoff rate and total runoff mass compared to the non-vegetated ECC plots. The ECC treatment coupled with vegetation improved infiltration and substantially delayed runoff for vegetated ECC plots compared to non-vegetated ECC plots (~15 minutes to runoff under non-vegetated conditions versus ~26 minutes to runoff for vegetated conditions). This delay in runoff led to increased rainfall exposure time for vegetated ECC plots (~45 minutes rainfall exposure for non vegetated conditions versus ~56 minutes rainfall exposure for vegetated conditions). Although no data were collected to determine the saturation point of the plots, the behavior of the ECC plots during the second rainfall simulation event implies the plots reached a saturation point prior to producing runoff, thereby suggesting that once runoff was initiated, the amount of runoff collected was directly proportional to the amount of rainfall applied contributing to greater runoff volume and mass.

In comparing IF and ECC treatments, ECC retained greater amounts of rainfall than IF under both vegetated and non-vegetated conditions. This indicates that the ECC treatment in contrast to the IF treatment would prevent runoff from equal intensity, relatively short duration rainfall events, especially under vegetated conditions. This is further corroborated by greater water retention within ECC plots and thus, significantly greater delay in initiation of runoff under vegetated conditions from ECC plots compared to IF plots.

A final observation following non-vegetated and vegetated rainfall simulation events occurred when the incisions were made in the plastic lining to allow for drainage after and between rainfall or irrigation events. When the incisions were made, water immediately drained from the plots indicating thorough infiltration. In deeper profiles, it is possible that more water would have saturated the soils and produced less runoff. The plots in the constructed sediment bed, however, mimic those possible on road right-of-ways with profile limiting conditions, such as shallow soils (e.g. depth to bedrock) or compacted subsoils.

Table 8. Time to initiate runoff, total runoff mass, and runoff rate from non-vegetated and vegetated ECC and IF treatment plots.

	Non-Vegetated		Vegetated	
Parameters	**ECC**	**IF**	**ECC**	**IF**
Time to Runoff[3] (min.)	15.11[1] (±11.03)[2]	8.84 (±1.28)	26.49[a] (±1.34)	4.82[b] (±1.57)
Total Rain Water (kg or L[4]) ***applied to plot***	112.36 (±27.40)	96.81 (±3.19)	140.36[a] (±3.10)	86.81[b] (±3.65)
Total Runoff Water (kg) ***received from plot***	24.84[a] (±7.68)	48.62[b] (±5.30)	48.38[a] (±5.69)	20.98[b] (±3.26)
Runoff Rate (cm/hr)	2.97[a] (±0.92)	5.81[b] (±0.64)	5.79[a] (±0.68)	2.51[b] (±0.39)

1 Non-vegetated or vegetated ECC and IF treatment means within a row followed by different letters are significantly different at the 5% level.
2 Standard deviation.
3 Time to runoff was calculated by determining the amount of time lapsed between the rainfall simulation system being fully charged and the point at which runoff from the plot began. Rainfall simulation system was fully charged within 1 min 45 sec and 1 min 15 sec of first drop during the first and second rainfall simulation events, respectively.
4 Liters of water converted to kg water assuming density of water is 1 kg/L

Figure 11. Post rainfall IF and ECC treatment plot surface conditions from non-vegetated simulation event.

Runoff Quality of non-vegetated and vegetated ECC and IF treatments

The physicochemical parameters analyzed in the tap water used for the rainfall simulation, and for first flush and remaining runoff samples during non-vegetated and vegetated rainfall simulation events on ECC and IF plots are presented in Table 9. All analytes for ECC and IF except solids, pH and ECC in Table 9 are concentrations (mg/L) determined from either the first flush (1-L) or remaining runoff from non-vegetated or vegetated rainfall simulation events. All solids are total quantities determined from either the first flush or the total mass of remaining runoff from ECC and IF treatments. Analysis of the tap water revealed alkaline (pH: 8.1) water with trace amounts of TKN, nitrite + nitrate (NNN), P, K, Ca, and S. Tap water TS was mostly dissolved solids and Na was a major constituent of the tap water TDS.

pH, Sodium and Electrical Conductivity

Under non-vegetated conditions, the pH of first flush and remaining runoff samples from ECC plots was significantly greater than that in corresponding samples from IF plots (Table 9). Greater sodium and elevated total salt concentrations resulting from the compost component of the ECC treatment likely were contributing factors. In contrast, pH values for both first flush and remaining runoff samples from vegetated plots were greater for IF than ECC. However, sodium and total salt levels were greater in ECC plots. The transition in pH, therefore, was likely due to two modifying factors related to the compost. First, organic matter decomposition, which likely occurred in ECC plots, results in the release of organic acids which can have a direct impact on runoff pH. Organic acids can chelate certain inorganic minerals, thereby reducing effective salt loads and altering the pH effects typically associated with soluble salts. Secondly, substantially greater nitrogen concentrations in the ECC plots, as evidenced by elevated runoff TKN concentrations, likely resulted in lower pH levels due to nitrification of ammonium.

Total Solids, Total Dissolved Solids and Total Suspended Solids

As noted above, due to the physical characteristics of the manure and woodchips mixture in the ECC system, considerably more time was required to initiate runoff from ECC plots compared to IF plots. Therefore, the ECC plots received rain for longer duration than the IF plots. Thus, ECC received a greater amount of rainfall under both vegetated and non-vegetated conditions.

Non-vegetated conditions: Under non-vegetated conditions, TS and TSS were significantly lower in the first flush and remaining runoff from the ECC plots compared to IF plots (Table 9). Total dissolved solids in ECC runoff tended to be slightly higher but were statistically similar to IF runoff. Differences between concentration of solids within ECC treatments could have resulted from the preferential flow or channeling along the plot border, which resulted in quicker runoff from 2 of the 4 replications. Most TS from ECC runoff was in the form of dissolved solids while most TS from IF runoff was in the form of TSS. This suggests that a majority of solids in the runoff from the ECC plots were constituents in dairy manure compost that dissolved in the rainwater, while most solids in the IF runoff were eroded soil sediment detached due to the direct impact of the simulated rainfall and transported out of the IF plots by the overland flow. Overall, lower sediment yield in the first flush and remaining runoff from ECC followed a trend similar to the runoff rate and total mass of runoff water (Table 7) from these non-vegetated plots. All ECC plots had less soil disturbance from raindrop impact than IF plots. This effect is visually illustrated by plot photographs in Figure 11 which show the more eroded surface conditions for IF compared to ECC plots post simulated rainfall under non-vegetated conditions.

Vegetated conditions: Following establishment of vegetation, simulated rainfall produced significantly higher TDS in the first flush from ECC plots than IF plots, while TS and TSS in the first flush from ECC plots were statistically similar to those from IF plots (Table 9). The remaining runoff from vegetated ECC plots had significantly higher TS and TDS than those in the runoff from vegetated IF plots. This trend was due to significantly higher runoff rate and total runoff volume from vegetated ECC plots than those from the vegetated IF plots. However, TSS in the remaining runoff from vegetated IF plots again were significantly higher than those from vegetated ECC plots. As in the non-vegetated rainfall event, solids in the runoff from vegetated ECC plots were primarily in the form of dissolved solids, while solids in the runoff from vegetated IF plots were dominantly in the form of suspended solids.

Comparison of non-vegetated and vegetated conditions: Lower overall total solids (sediment) in the runoff from IF plots under vegetated conditions as compared to non-vegetated conditions were due to the vegetative cover that reduced overland flow (runoff rate and total mass of runoff water, Table 8) and reduced soil erosion from these plots as compared to the non-vegetated IF plots (Table 9). In contrast, vegetated ECC plots had greater overall total solids in the runoff under vegetated conditions compared to non-vegetated conditions but most of the vegetated ECC plot runoff solids were in the form of dissolved solids. Greater total mass of runoff as a result of higher runoff rate from vegetated ECC (Table 8) plots versus non-vegetated ECC plots resulted in higher TS from the vegetated ECC. Greater time to initiate runoff for vegetated ECC plots as compared to the non-vegetated ECC plots (Table 8) also provided more interaction time between compost and rainwater enhancing the dissolution of soluble compost constituents and their transport in overland flow.

Nitrogen, Phosphorous and Potassium

Due to the nutrient composition of the dairy manure compost used in the study, very high rates of N, P, and K were applied to the ECC plots as compared to IF plots. In addition, due to the inherent property of the ECC system, considerably more time was required to initiate runoff from ECC plots compared to IF plots. Thus, ECC received more rainfall under both vegetated and non-vegetated conditions.

The TKN in the first flush and remaining runoff from non-vegetated and vegetated ECC plots was significantly greater than that in corresponding IF plots. The TKN in first flush and remaining runoff from the vegetated ECC and IF plots decreased as compared to corresponding first flush and remaining runoff from non-vegetated ECC and IF plots. The percentage decrease was greater for the ECC treatment compared to the IF treatment.

The NNN in the first flush and remaining runoff from non-vegetated ECC plots was statistically similar to that in corresponding non-vegetated IF plots (Table 9). In contrast, NNN in the first flush and remaining runoff from vegetated ECC plots was significantly lower than that from vegetated IF plots.

Soluble P (ortho P) concentrations in the first flush from non-vegetated ECC plots tended to be greater, but were statistically similar to those in corresponding non-vegetated IF plots. However, ortho P concentrations in the remaining runoff from non-vegetated ECC plots were significantly greater than those in corresponding IF plots. Similarly, for the vegetated plots, ortho P concentrations in the first flush and remaining runoff of ECC plots were significantly greater than those in corresponding IF plots. Concentrations of ortho P from vegetated plots remained fairly consistent in both first flush and remaining runoff for ECC and IF treatments.

Total P concentrations in the first flush remaining runoff from non-vegetated ECC plots were significantly greater than those in the remaining runoff from the non-vegetated IF plots. A similar trend was observed for total P in first flush samples, although differences were not significant. For vegetated conditions, total P concentrations in the first flush and remaining runoff from ECC plots were significantly greater than those from corresponding IF plots. Total P concentrations in the first flush and remaining runoff from both ECC and IF plots were considerably lower once vegetation was established.

Potassium (K) concentrations in the first flush and remaining runoff from the non-vegetated and vegetated ECC plots were significantly greater than those in corresponding IF plots. Concentrations of K in the first flush and remaining runoff from the vegetated ECC plots were about one half of those in the first flush and remaining runoff from the non-vegetated ECC plots. Conversely, K concentrations remained effectively unchanged in the first flush and remaining runoff from the vegetated IF plots.

Total masses of primary nutrients (N, P and K) were determined by summing weights calculated using runoff volume and nutrient concentrations for first flush and remaining runoff for each treatment under non-vegetated and vegetated conditions (Table 10). The ECC plots substantially delayed runoff and therefore received more rainfall than the IF plots. In addition, due to higher nutrient levels in the compost, the ECC plots received substantially greater nutrient applications (Table 3c) than the IF plots. Both factors contributed to the greater total nutrient mass losses of nitrogen, phosphorus and potassium. Total masses of TKN were significantly greater for ECC under both non-vegetated (4 fold) and vegetated (7 fold) conditions compared to IF. Total masses of nitrate and nitrite (NNN) were not different for ECC compared to IF under non-vegetated or vegetated conditions. Total masses of ortho P and total P were not different for ECC compared to IF for non-vegetated conditions; however, ECC produced significantly greater masses (more than 10 fold) of both ortho P and total P compared to IF under vegetated conditions. Total masses of K were significantly greater (more than 10 fold) for ECC than IF under both vegetated and non-vegetated conditions. For comparison, Table 11 provides the concentration of primary nutrients (N, P and K) on a mass per acre or hectare basis.

Due to differences in rainfall exposure time on ECC and IF plots under vegetated conditions, ratios of total mass of TKN, total P and K losses in the runoff from these treatments were compared to ratios of rainfall exposure time, runoff mass and total water retained (difference between average total rainfall applied to a plot and average total runoff collected from a plot).

Results of these calculations are presented in table 12. In addition, the ratio of total N, P_2O_5 and K_2O applied in the ECC and IF systems were compared and presented in table 3c.

While the ratio of rainfall exposure time was similar for non-vegetated conditions, runoff mass was only half for ECC compared to IF. Nevertheless, TKN and total K losses from ECC plots were nearly 4.7 and 17.9 times greater than IF plots, respectively. Total P losses were similar from both treatment systems.

Under vegetated conditions, ECC had a total rainfall exposure time 1.6 times and total runoff mass 2.3 times greater than IF. But, ECC nutrient losses were 8, 13, and 33 times greater than IF for TKN, total P, and total K, respectively.

Under both non-vegetated and vegetated conditions, ECC plots received 1.16 and 1.62 times more rainfall than IF plots, yet retained 1.82 and 1.40 times more water than IF plots, respectively. ECC yielded greater nutrient losses under both conditions.

A comparison of nutrient ratios for ECC and IF treatments indicates that despite more rainfall exposure time, lower total runoff mass and greater water retention under non vegetated conditions and greater rainfall exposure time, total runoff mass and water retention under vegetated conditions, the ECC plots yielded much greater nutrient losses as compared to IF plots. These greater nutrient losses from ECC plots were most likely due to the fact that when compared to the IF treatment, the ECC treatment resulted in 18.5, 13.25 and 27.75 times greater rates of application of N, P_2O_5 and K_2O, respectively (Table 3c). Chastain et. al. (2006) determined that a 5 cm application of an erosion control blanket (a mixture of composted cow manure with wood waste) resulted in application rates of P_2O_5 and K_2O that were in excess of agronomic rates for the crop.

Sulfur, Calcium, Magnesium

Sulfur and sulfate concentrations in the first flush of non-vegetated IF plots were greater than those in ECC plots; however, concentrations were not different in remaining runoff. Under vegetated conditions, both sulfur and sulfate concentrations were significantly greater in the first flush and remaining runoff of ECC plots compared to corresponding IF plots. Calcium concentrations in the first flush collected from the ECC plots during the non-vegetated rainfall event were significantly lower than the first flush collected from the IF plots. All other calcium concentrations under non-vegetated conditions tended to be consistent in runoff; however, Ca concentrations in both first flush and remaining runoff of vegetated plots were significantly greater from ECC treatments. This may have been due to Ca additions from the compost application and/or Na substitution for Ca in ECC plots, which had greater Na levels. A similar response was observed for Mg under vegetated conditions.

Table 9. Total mass or concentration of physicochemical constituents in first flush, remaining runoff and tap water.

	Non-Vegetated				**Vegetated**				**Tap Water**
Sample ID	**First Flush**		**Remaining Runoff**		**First Flush**		**Remaining Runoff**		**1-L n=2$^{\#}$**
Parameters	**ECC**	**IF**	**ECC**	**IF**	**ECC**	**IF**	**ECC**	**IF**	
pH	8.6*^{a} (±.0001)**	7.9^{b} (±.096)	8.4^{a} (±.29)	7.9^{b} (±.0001)	8.2^{a} (±.082)	8.6^{b} (±.082)	8.0^{a} (±.0001)	8.4^{b} (±.082)	8.1
EC µmohs/cm	1742 (±387)	1343 (±48)	2183 (±623)	1248 (±65)	2365^{a} (±525)	907^{b} (±38)	2885^{a} (±176)	903^{b} (±76)	843
TS (Kg)	0.003^{a} (±.0001)**	0.019^{b} (±.01)	0.084^{a} (±0.03)	0.671^{b} (±0.147)	0.0024 (±0.0004)	0.0027 (±0.003)	0.132^{a} (±0.003)	0.034^{b} (±0.004)	0.0005 (±0.0001)
TDS (Kg)	0.002 (±0.0006)	0.001 (±0.0001)	0.061 (±0.036)	0.048 (±0.0005)	0.0022^{a} (±0.0005)	0.0005^{b} (±0.0002)	0.128^{a} (±0.005)	0.013^{b} (±0.003)	0.0005 (±0.0001)
TSS (Kg)	0.0017^{a} (±0.0003)	.0182^{b} (±0.006)	0.026^{a} (±0.005)	0.6^{b} (±0.002)	0.0004 (±0.0002)	0.0025 (±0.002)	0.011^{a} (±0.003)	0.027^{b} (±0.006)	--
TKN (mg/L)	48.7^{a} (±19.92)	6.65^{b} (±0.73)	52.1^{a} (±10.64)	5.90^{b} (±0.00)	15.18^{a} (±2.29)	4.83^{b} (±1.09)	17.53^{a} (±2.91)	4.98^{b} (±0.88)	2.7 (±0.42)
NNN (mg/L)	0.63 (±0.68)	1.52 (±0.24)	1.36 (±0.99)	0.42 (±0.06)	0.81^{a} (±0.54)	2.97^{b} (±1.11)	0.95^{a} (±0.42)	1.54^{b} (±0.48)	0.2 (±0.16)
Ortho P (mg/L)	1.59 (±0.27)	0.84 (±0.36)	1.57^{a} (±0.49)	0.94^{b} (±0.19)	1.92^{a} (±0.68)	0.38^{b} (±0.19)	2.36^{a} (±0.40)	0.40^{b} (±0.14)	0.047 (±0.024)
Total P (mg/L)	13.25 (±3.39)	5.49 (±3.12)	11.61^{a} (±2.72)	5.36^{b} (±1.34)	1.89^{a} (±0.38)	0.46^{b} (±0.17)	2.29^{a} (±0.30)	0.40^{b} (±0.08)	0.21 (±0.02)
S (mg/L)	31.26^{a} (±14.11)	132.3^{b} (±52.56)	121.2 (±110.07)	100 (±16.63)	256.4^{a} (±75.02)	15.73^{b} (±4.57)	384.8^{a} (±23.06)	16.20^{b} (±14.84)	3.47 (±0.48)
SO4-S (mg/L)	93.6^{a} (±42.24)	396.2^{b} (±157.39)	362.9 (±329.60)	299.1 (±49.81)	767.6^{a} (±224.65)	47.1^{b} (±13.69)	1152^{a} (±69.04)	48.5^{b} (±44.44)	10.4 (±1.43)
K (mg/L)	219.3^{a} (±95.65)	8.11^{b} (±2.16)	229^{a} (±26.64)	6.70^{b} (±0.89)	104.42^{a} (±43.27)	10.29^{b} (±1.32)	117.3^{a} (±33.55)	7.98^{b} (±1.41)	3.2 (±0.87)
Ca (mg/L)	11.68 (±2.76)	172 (±54.74)	124 (±135.88)	125.6 (±20.02)	277.6^{a} (±78.94)	34.04^{b} (±8.37)	411^{a} (±64.98)	30.05^{b} (±12.84)	3.15 (±0.28)
Mg (mg/L)	3.80^{a} (±1.052)	10.40^{b} (±2.51)	14.12 (±12.45)	7.33 (±0.96)	27.72^{a} (±9.25)	2.05^{b} (±0.51)	39.1^{a} (±4.96)	1.81^{b} (±0.75)	0.53 (±0.007)
Na (mg/L)	285.2^{a} (±28.91)	223.2^{b} (±3.58)	283.23^{a} (±18.60)	224^{b} (±2.25)	303^{a} (±56.84)	201.5^{b} (±4.18)	299^{a} (±37.75)	200^{b} (±2.82)	219 (±22)

* Means within non-vegetated and vegetated categories and sampling periods (first flush or remaining runoff) followed by different letters are significantly different at the 5% level.

** Standard deviation

\# For tap water, n= 1 for pH and EC

Table 10. Total mass of nitrogen, phosphorus and potassium parameters in first flush and remaining runoff under non-vegetated and vegetated conditions.

	Non-Vegetated		Vegetated	
Parameters	**ECC**	**IF**	**ECC**	**IF**
TOTAL WATER [Kg]	24.84[a*] (±7.68)**	48.62[b] (±5.31)	48.38[a] (±5.69)	20.98[b] (±3.27)
TKN [mg]	1349[a] (±647)	287.6[b] (±31.05)	834[a] (±55.85)	104.8[b] (±28.60)
NNN [mg]	38.72 (±33.64)	21.43 (±4.91)	44.30 (±14.94)	32.7 (±5.38)
Ortho P [mg]	36.76 (±6.02)	45.90 (±11.43)	112.3[a] (±11.16)	8.20[b] (±2.35)
Total P [mg]	275.6 (±38.66)	262.2 (±74.32)	109.4[a] (±9.97)	8.26[b] (±1.10)
K [mg]	5829a (±2303)	325.9b (±43.51)	5582a (±1405)	167.4b (±21.18)

* Non-vegetated or vegetated ECC and IF treatment means within a row followed by different letters are significantly different at the 5% level.

** Standard deviation.

Table 11. Rate of nutrient loss (lbs/ac or kg/ha) contained in runoff from non-vegetated and vegetated ECC and IF plots. (Calculations based on total mass presented in Table 7).

	Non-Vegetated		Vegetated	
Parameters	**ECC**	**IF**	**ECC**	**IF**
	lb/A			
TKN	7.20[a] (±3.45)	1.53[b] (±0.17)	4.45[a] (±0.30)	0.56[b] (±0.15)
NNN	0.21 (±0.18)	0.11 (±0.03)	0.24 (±0.08)	0.17 (±0.03)
Ortho P	0.20 (±0.03)	0.24 (±0.06)	0.60[a] (±0.06)	0.04[b] (±0.01)
Total P	1.47 (±0.21)	1.40 (±0.40)	0.58[a] (±0.05)	0.04[b] (±0.01)
K	31.10[a] (±12.29)	1.74[b] (±0.23)	29.79[a] (±7.50)	0.89[b] (±0.11)
	kg/ha			
TKN	8.07[a] (±3.86)	1.72[b] (±0.19)	4.99[a] (±0.33)	0.63[b] (±0.17)
NNN	0.23 (±0.20)	0.13 (±0.03)	0.26 (±0.09)	0.20 (±0.03)
Ortho P	0.22 (±0.04)	0.27 (±0.07)	0.67[a] (±0.07)	0.05[b] (±0.01)
Total P	1.65 (±0.23)	1.57 (±0.44)	0.65[a] (±0.06)	0.05[b] (±0.01)
K	34.84[a] (±13.76)	1.95[b] (±0.26)	33.37[a] (±8.40)	1.00[b] (±0.13)

* Non-vegetated or vegetated ECC and IF treatment means within a row followed by different letters are significantly different at the 5% level.

** Standard deviation.

Table 12. Comparison of ratios of rainfall exposure time, runoff mass and nutrient losses for ECC and IF treatments under non-vegetated and vegetated conditions.

Parameter	**Ratio of ECC:IF**							
	non–vegetated				**vegetated**			
		TKN	**Total P**	**K**		**TKN**	**Total P**	**K**
Ratio of rainfall exposure time*	**1.16**	4.69	1.05	17.89	**1.62**	7.96	13.24	33.35
Ratio of runoff mass	**0.51**	4.69	1.05	17.89	**2.31**	7.96	13.24	33.35
Ratio of total Water Retained**	**1.82**	4.69	1.05	17.89	**1.40**	7.96	13.24	33.35

A measurement of total rain water applied
** The difference between total rainfall volume and the runoff volume

SUMMARY

Simulated rainfall was applied to constructed plots set on a 3:1 slope that received an application of either erosion control compost (dairy manure compost/woodchips; 1:1 volume mixture) or inorganic fertilizer under non-vegetated and vegetated conditions. Time to initiate runoff was greater for ECC than IF under non-vegetated and vegetated conditions. Runoff rate and total runoff were greater for IF under non-vegetated conditions, but the reverse was true under vegetated conditions. Because considerably more time (>20 minutes longer) was required to initiate runoff from vegetated ECC plots compared to vegetated IF plots, the ECC plots received greater amounts of rainfall which resulted in increased runoff rate and mass.

Water pH values fluctuated somewhat for ECC and IF treatments for the non-vegetated and vegetated rainfall simulations, with values being higher for ECC under non-vegetated conditions and higher for IF under vegetated conditions. Higher initial Na and total salt levels in runoff from ECC plots during unvegetated rainfall simulation likely were offset by release of organic acids and nitrification, reducing pH values at the vegetated rainfall simulation. Total salt levels remained high in runoff from the vegetated ECC plots and were significantly greater than those in IF plots, which were similar to tap water.

Total suspended solids and TS in first flush and remaining runoff were significantly greater for IF plots than ECC plots under non-vegetated conditions due to substantially greater soil loss. In contrast, TS in remaining runoff of vegetated ECC plots were significantly greater than those in IF plots, but the bulk of the TS was in the form of TDS. Higher nutrient and salt levels in the compost likely contributed to this result.

Concentrations of TKN in the first flush and remaining runoff from both non-vegetated and vegetated ECC plots were significantly greater than those in corresponding IF plots. In addition, ortho P and total P concentrations in the remaining runoff from non-vegetated plots and both the first flush and remaining runoff of vegetated plots were significantly greater for ECC plots compared to IF. Likewise, K concentrations in the first flush and remaining runoff from non-vegetated plots were significantly greater for ECC than IF treatments, with similar results for vegetated plots although concentrations in ECC plots decreased by about 50%. Increased nutrient concentrations in runoff from the ECC plots compared to IF were most likely due to substantially greater total nutrient loadings as a result of the chemical composition of the manure-based compost utilized in the ECC treatment (ECC treatment application contained 18.5, 13.25 and 27.75 times greater rates of N, P_2O_5 and K_2O, respectively).

Total masses of TKN and K were significantly greater for ECC compared to IF under both non-vegetated and vegetated conditions. Total masses of both ortho P and total P were not different for ECC compared to IF under non-vegetated conditions, but were significantly greater for ECC than IF under vegetated conditions. Here again, the substantially greater total nutrient loadings resulting from use of manure compost in the ECC treatment likely explain these results. Numerous studies have reported a direct correlation between phosphorus losses, both in the dissolved and suspended solids fractions, as soil test phosphorus levels increase (Schwartz and Dao, 2005; Vietor, et al. 2003; Vietor, et al. 2002). Vietor et al, (2004) found no significant differences in P losses in the first runoff solution from plots which received similar P rates of inorganic fertilizer and composted dairy manure. However, P levels were significantly greater in runoff from the composted dairy manure plots compared to inorganic fertilizer plots for subsequent runoff events.

Due to the significant differences in rainfall exposure time on ECC and IF plots under vegetated conditions, ratios of total mass of TKN, total P and K losses in the runoff from these treatments were compared to ratios of rainfall exposure time, runoff mass and total water retained (difference between average total rainfall applied to a plot and average total runoff collected from a plot). This comparison of nutrient ratios for ECC and IF treatments indicates that due to greater rainfall exposure time, total runoff mass and water retention under vegetated conditions, and due to a greater application rate of N, P_2O_5 and K_2O, the ECC plots yielded greater nutrient losses as compared to IF plots.

This study supports previous work that has shown the benefits of organic soil amendments for reducing soil erosion, particularly from highly erodible surfaces. In the absence of vegetation, the ECC treatment significantly reduced the loss of solids during a runoff event. In addition, when vegetated, the use of an ECC material delayed runoff for a substantially longer time period than IF. Under both non-vegetated and vegetated conditions, the ECC treatment retained greater amounts of rainfall than the IF treatment.

However, when runoff events of equal duration, but disparate rainfall exposure time, under vegetated conditions were compared, the ECC plots produced more runoff than the IF plots. In addition, losses of N, P and K were greater for the compost amended plots (ECC) compared to IF. The continued mineralization of nutrients from compost over time may result in considerably greater nutrient loadings in runoff over the life of the treatment. Thus, reduced rates of compost and/or the use of compost materials with lower nutrient levels may be warranted where significant runoff is anticipated.

Data and nutrient balance calculations performed by Chastain et. al. (2006) clearly demonstrate that amendment application recommendations based on a prescribed volume (blanket depth) are not useful. Rather, application rates of nutrient rich materials, such as compost, should be determined based on the analysis of: (1) plant nutrients in the product, (2) nutrient requirements of the intended vegetation, and (3) soil-test results. Findings of this study support the recommendation made by Chastain et. al. (2006). A total nutrient analysis of proposed compost/organic soil amendments should be utilized in the selection of the material and in determination of proper loading rates for erosion control and the enhancement of vegetative cover. Total N and P rates within an erosion control system should be based on projected nutrient release to provide available N and P to maximize erosion control, yet reduce nutrient loss under runoff events. This more conservative approach, such as increasing the wood chip to compost ratio, will minimize offsite losses of N and P during initial establishment, but more importantly, will limit long-term losses of these nutrients as organically bound fractions are released through mineralization.

Finally, additional data should be collected to further evaluate DMC as an erosion control treatment. To compensate for the delay in runoff from the ECC treatment under vegetated conditions, the study methodology should be modified to expose the sediment bed to a fixed duration of rainfall, collect runoff for the duration of the rainfall and in addition, collect runoff sub-samples at set time intervals during the event. This modification will determine changes, if any, in the loss of sediment and/or nutrients over time and allow for the comparison of runoff constituents from the entire rainfall event.

LIMITATIONS OF THE STUDY DESIGN

(Information below provided by reviewers at the Texas Commission on Environmental Quality)

"The design of this study provided for the experimental plots to be subjected to rainfall of uniform intensity but varying duration. The average duration of rainfall exposure for the compost treatments was substantially greater than for the control treatments. This study does not provide a basis for predicting the relative performance of the two treatments in any single, defined rainfall event or in any representative set of rainfall events.

The results of this study raise concerns about the potential release of nutrients from erosion control compost (ECC) containing 50% composted manure in extended, high-intensity storms. However, the substantial difference in average duration of rain exposure experienced by the treatments limits the use of the study results in evaluating the probable effects of using this treatment as an alternative to the control treatment – either in regard to erosion control or in regard to nutrient loadings in runoff. Neither does it provide a basis for recommending modifications of the ECC treatment. Such evaluation will require, at a minimum, the testing of the recommended modifications of the ECC treatment alongside treatments using the current ECC specifications. Because of these design limitations, the Texas Commission on Environmental Quality cannot apply the information and conclusions described in this study about the performance of the two treatments to water quality management practices.

Conclusive evaluation of the use of composted manure as a water quality management tool – comparing its average life-cycle rate of release of nutrients in particular applications with that of control treatments – will require either an extended outdoor field trial or sequential testing with multiple simulated rainfall events on the same set of plots in a representative set of rain events until the soil nutrient concentrations in the compost-treated plots fall within agronomic levels."

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Appendix P

Revegetation of Drastically Disturbed Roadsides on Fort Hood, TX

Revegetation of Drastically Disturbed Roadsides on Fort Hood, TX

DEMONSTRATION PROJECT

TAES/TCEQ initiated the implementation of vegetation buffers on approximately 5 miles of roadside at Fort Hood, Texas (Figure 1 & 2) using dairy manure compost provided by six vendors from the North Bosque River Basin. All vendors were TCEQ approved facilities and were eligible to participate in the Composted Manure Incentive Program. In September, 2004, the bare buffer strips were treated with dairy manure compost at a rate equivalent to 405 yd^3/ac (Figure 3). The compost treated sites were then seeded with oats during the subsequent winter and overseeded with a native seed mix (Table 1) in the spring 2005 to assist in establishment of vegetation buffers. Because of the previous lack of vegetation and thus, potential erosion, vegetation establishment was essential to stabilize compost treatments. Further, the established vegetation provided additional erosion protection along the roadside. Due to factors outside control of the program administrators, all sites were impacted by livestock grazing (Figure 3).

All expenditures (projected and spent) are detailed in Table 2. Funds provided for this project were used for compost purchase, land preparation, compost application and personnel salary, benefits and travel.

No measurement data were collected as application area precluded the establishment of replicated treatments, randomized plot design, or even similar application sites. Thus, comparison between compost sources (e.g. high organic matter content versus low organic matter content material) was not possible. However, visual observations in the form of photographs were collected following seed application and initial vegetation establishment. Photos document the establishment of vegetation in areas where compost was applied versus the areas where compost was not applied. Sites will continue to be photo monitored through 2005.

Figure 1. Representative sites for roadside revegetation programs with compost spreader (Photo by Jason McAlister).

Figure 2. Immediately post-treatment. (Photo by Jason McAlister)

Figure 3. Roadside revegetation post-application and seeding with oats. (Photo by Jason McAlister)

Table 1. Roadside revegetation seed mix (developed by NRCS)

Fort Hood Experimental Seed Mix - 255 Acres TA 44 (FY 2005)				
Species	**Full PLS Seed Rate**	**% Mix**	**lbs. PLS per Acre**	**Total PLS lbs.**
Grasses				
Sideoats Grama	4.5	50	1.13	288
Little Bluestem	3.4	5	0.34	87
Indiangrass	4.5	5	0.45	115
Buffalograss	6	25	1.5	383
Tall Dropseed	1	5	0.05	13
Switchgrass	3	5	0.3	77
Green Sprangletop	1.7		1	255
Forbs				
Illinois Bundleflower	4	2	0.08	20
Awnlsss Bushsunflower	4	2	0.04	11
Partridge Pea	4	1	0.04	11
Overseed				
Oats			2	

Table 2. Cost justification for Fort Hood activities

Compost Purchase & Transportation					PROJECTED		ACTUAL
	Distance (miles)	**Hauling Rate ($3/ld mi)**	**hauling cost**	**compost cost[a]**	**Total**	**compost cost[b]**	**Total**
O'Neals	69	$ 3.00	$ 3,933	$ 6,000	$ 9,933	$ 5,700	$ 9,633
Producers	87	$ 3.00	$ 4,959	$ 6,000	$ 10,959	$ 5,700	$ 10,659
Bosque	79	$ 3.00	$ 4,503	$ 6,000	$ 10,503	$ 5,700	$ 10,203
Organic Residual Reclamation	80	$ 3.00	$ 4,560	$ 6,000	$ 10,560	$ 5,700	$ 10,260
Dairy Cow Compost	80	$ 3.00	$ 4,560	$ 6,000	$ 10,560	$ 5,700	$ 10,260
Gustine Compost	61	$ 3.00	$ 3,477	$ 6,000	$ 9,477	$ 5,700	$ 9,177
TOTALS	456		$ 25,992	$ 36,000	**$ 61,992[a]**	$ 34,200	**$ 60,192[b]**
Application of compost					**$ 29,800[c]**		**$ 16,272[d]**
Application Area					**8.44[e]**		**8.89**
Personnel Costs					**$ 11,881[f]**		**$ 8,059[g]**
TOTAL					**$ 103,673**		**$ 84,523**

[a] Total compost estimated to be purchased from each facility was 600 CY (a total of 20 truck loads per facility)

[b] Total compost actually purchased from each facility was 570 CY (a total of 19 truck loads per facility). Amount purchased from each facility was decreased from initial estimates because estimates for application services were slightly beyond budget means. Project personnel needed adequate funds to cover application service bids.

[c] Given 3,420 cy were purchased, application costs were estimated @ $8.00/cy to apply compost plus $1000 for land preparation

[d] Winning bid was considerably lower than estimates and provided application costs @ $4.30/cy to apply compost plus $1566 for land preparation

[e] Acreage based on calculated rate of 3 inch application is equivalent to 405 cy/A

[f] 3 months salary and benefits

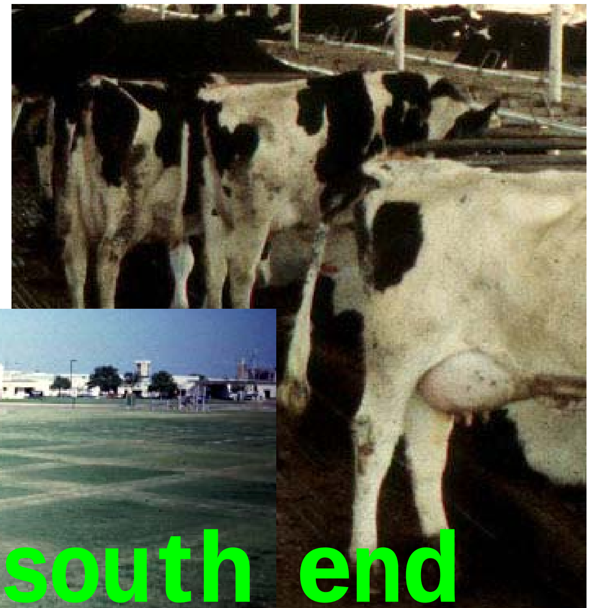
[g] 2 months salary and benefits and travel costs

Figure 4. Livestock grazing roadside revegetation areas. (Photos by Jason McAlister (first) and Don Jones (second))

Appendix Q

Green Turf: From the South end of a North facing cow

GREEN TURF



From the south end of a north-facing cow

D.M. Vietor, R.H. White, C.L. Munster, T.L. Provin, and B.T. McDonald.

Benefits of compost, including composted manures, have been evaluated and documented in relation to soil properties and turfgrass establishment, maintenance, and quality over the past two decades. Yet, assessments of turfgrass benefits in relation to composting and livestock industries are new. Recent research and collaborations among turfgrass, livestock, and composting industries demonstrated turfgrass sod offered both environmental and economic advantages over other crops. First, removal of a thin soil layer and associated nutrients with each sod harvest can export more of the nitrogen and phosphorus applied as composted manure than annual harvests of any other crop. Up to 77% of phosphorus applied in manure was exported through harvest of perennial bluegrass sod produced in Erath county (Vietor et al., 2002). In addition, the phosphorus, potassium, and other manure nutrients transplanted with sod will reduce or eliminate applications of fertilizer forms of the respective nutrients during establishment and maintenance of transplanted sod. The export of excess manure nutrients from impaired watersheds through sod and the reduced imports of soluble inorganic fertilizers on urban landscapes receiving sod are win-win opportunities for environmental improvement.

Turfgrass production on agricultural lands within the Upper North Bosque watershed offers the economic advantage of proximity to both compost manure sources and to sod markets in the Dallas-Ft. Worth Metroplex. Hauling distances between composted manure sources and sod fields need to be minimized to limit compost-associated costs. Fortunately, maps developed through geographic information systems indicate large land areas suitable for sod production are located proximate to dairies on the Upper North Bosque watershed (Hanzlik et al., 2004). Sod production on lands proximate to other agricultural operations on the watershed offers yet another economic advantage. Sod production enterprises can time- and cost-share equipment and labor with existing crop and livestock enterprises. Collaboration and cost and profit-sharing among dairy, composting, and sod operations is another advantage of their proximity. Discounts on manure or compost prices and land costs could encourage application and export of relatively large compost amounts per acre in harvested sod. The collaborative efforts to export manure nutrients will enable compliance with TMDL implementation plans for soluble reactive P on the Upper North Bosque watershed.

Although Metroplex sod markets are up to 100 miles away, hauling distances from sod production sites on the Upper North Bosque are less than those required for more than one half of the sod delivered in the Dallas-Ft. Worth area (Munster et al., 2004). A 50% reduction of sod hauling costs enables compost-grown sod from the Bosque watershed to compete with sod produced and hauled 200 or more miles from the Texas Gulf Coast.

Figure 1. Topdressing of dairy manure before regrowth of Tifway Bermuda

Figure 2. Composted dairy manure produces high-quality sod for harvest through commercial practices.

In addition to quantifying export of manure nutrients through sod, plot- and field-scale studies of turfgrass and environmental responses have yielded recommendations for compost and fertilizer management (Vietor et al., 2002, Vietor, 2004). Composting of dairy manure and screening to exclude pebbles enables topdressing through soil and sand spreaders designed for turfgrass (Fig. 1). Although composted dairy manure can supply the seasonal phosphorus, potassium, and micronutrient requirements for sod production, supplemental nitrogen fertilizer is required to achieve rapid sod regrowth. Turf quality during production and at harvest are comparable between compost-grown sod supplemented with fertilizer N and sod grown with recommended rates of inorganic fertilizer (Fig. 2). Despite the large N requirements of turfgrass, rates of composted manure are phosphorus-based to prevent excessive phosphorus runoff loss during sod production and after transplanting of manure-grown sod. Yet, up to 180 pounds per acre of manure phosphorus can be top-dressed on a sod crop without increasing mass loss of runoff phosphorus above that of sod top-dressed with fertilizer P during production and after transplanting (Vietor et al., 2004). A field-scale assessment revealed only 3.5% of the total phosphorus applied in composted manure was lost as dissolved and sediment-bound P in runoff during production of a Tifway Bermudagrass sod crop (Choi, 2005).

In summary, the mutual benefits of compost and turfgrass contribute to the environmental and economic feasibility of exporting manure nutrients from the Upper North Bosque watershed through sod. Educational programs are needed to inform livestock, compost, and turfgrass producers about opportunities for collaborations that make both business and environmental cents.

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