An Economic Analysis of the Development and Management of a University Vermicomposting System: A Self-Sustaining Environmental and Waste Management Educational Tool

John E. Montoya[1]
Tina M. Waliczek[2,*]
Jean-Marc A. Gandonou[3]

[1] *Graduate Student, Texas A&M University, 2133 TAMU, College Station, TX 77843-2133.*
[2]*Professor, Department of Agriculture, Texas State University, 601 University Drive, San Marcos, TX 78666.*
[3]*Assistant Professor, Eastern New Mexico University, 1500 S Ave K, Portales, NM 88130.*

ABSTRACT

Vermicomposting is a process in which red wiggler, white worms, or earthworms break down organic material and transform it into vermicompost, a valuable horticultural product, while diverting a significant amount of organic matter from the waste stream. The purpose of this study was to: 1) establish the vermicomposting system at Texas State University using red wiggler worms and cafeteria food waste as a primary feedstock, 2) determine the potential economic potential of the system to the university, and 3) determine the value of the system as a teaching tool and service learning opportunity for students. Twenty-five pounds of food waste were collected weekly from one cafeteria on campus and combined with shredded university paper waste. Vermicomposting bins and systems were initially reviewed and a layered bin system was constructed in a small shed using recycled five-gallon food service buckets from university cafeterias. Worms were checked two to three times weekly and rotated through the system in approximately three to four months. Vermicompost was harvested, weighed, and packaged in five-gallon zip lock bags. Worm castings were also integrated into the university gardens and greenhouse. Economic analysis results demonstrated the value of the operation to the university in terms of the product generated for use for sale as a fertilizer and the diverted cost of waste disposal versus the costs of operation. Students provided feedback as to the educational value of the system.

KEY WORDS: worms, service-learning, sustainability, horticulture, organic, vermicastings

INTRODUCTION

The disposal of organic wastes from domestic, agricultural, and industrial sources has caused environmental and economic problems (Dominguez and Edwards 2004). Organic food waste is the single largest component of the waste stream in the United States

* Corresponding author: (512) 245-3324, tc10@txstate.edu

and costs the nation approximately $1 billion in disposal fees annually (USEPA 2009). University cafeterias generate a large volume of food waste (360 million tons annually, 2% of the entire waste stream), which could otherwise be utilized in a composting system (Saphire 1998).

Vermicomposting is a process in which earthworms, primarily the species *Eisenia fetida*, break down organic material and transform it into vermicompost (worm castings), a valuable horticultural product (Edwards et al. 2004). Studies conducted on vermicastings show that they contain increased levels of potassium (Basker et al. 1993), ammonium, and nitrates (Bohlen and Edwards 1995). In soils enhanced with vermicompost, phosphorus was converted into forms more available to plants. Soils amended with vermicompost have greater water-holding potential (Elliot et al. 1990) and the pH is neutralized (Basker et al. 1993). Nutrients in vermicompost are released slowly and are readily available for plants to obtain (Abbot and Parker 1981). The castings have more beneficial microbes when compared to either the existing soil or the earthworm's gut (Logsdon 1994). Yield increased in crops where earthworms were inoculated into soils (Edwards and Lofty 1980).

E. fetida is the primary worm species used in vermicomposting systems because they are "litter dwellers" and feed on coarse organic matter and undecomposed leaf litter (Dominguez and Edwards 2004, p. 371). In addition, their high reproductive and metabolic rates combined with adaptability to a wide range of environmental conditions and ability to endure handling makes them optimal for a vermicomposting system (Dominguez and Edwards 2004).

Previous work has found vermicomposting can divert a significant amount of organic matter from the waste stream (Dominguez and Edwards 2004). Regulations in Austin, Texas (Zero-Waste Strategic Plan: Austin, Texas 2008; USEPA 2006) and at least 23 states in the United States are now requiring organic matter (sometimes referred to as "green waste") be diverted from landfills. Vermicomposting this material on campus meets these requirements, and can also provide a valuable educational tool to agriculture, environmental, and sustainability students, among others at the university. Students can be educated on vermicomposting using a "hands on" approach method, which can be integrated into horticulture coursework (Waliczek and Zajicek 2010) as an alternative agricultural commodity. The vermicompost industry has grown in the past few decades and is thought to have opportunity for more production with the growth in organic agriculture (Barbour 1996).

Service learning has been shown to improve the academic performance of students as well as strengthen the relationship between the student and the community (Eyler and Giles 1999). A number of studies have shown service learning improves students' academic understanding (Akujobi and Simmons 1997; Billig and Klute 2003; Bringle and Hatcher 1995). However, there have been mixed results on the impact of service learning on the grade point average of students (Astin and Sax 1998; Vogelgesang and Astin 2000).

Service learning demonstrates the "real world" application of concepts taught academically (Sandy and Holland 2006). In the field of agriculture, service learning is seen as being even more important given the potential for direct practical application of concepts (Waliczek and Zajicek 1999). On campus, students have the opportunity to learn skills involving real world problems. In a survey conducted by researchers at Western Washington University, it was found that college graduates with service learning experience found jobs faster and those jobs were in a field related to the student's major (Western Washington University 2011). However, with great strides in recognizing the value of service learning to students, more research is needed to establish the value of applied field approaches to learning and teaching (Furco and Root 2010).

At Texas State University, the Bobcat Blend Composting project began in 2008 (Montoya et al. 2013; Texas State University Agriculture Department 2016) with the hopes of developing a campus-wide waste management composting and education program which would reduce the amount of organic waste entering the landfill from campus. When the project was initiated, cafeteria waste from two dining halls and invasive species (e.g., *Eichhornia crassipes*, water hyacinth, *Hydrilla verticillata*, hydrilla and *Pistia stratiotes*, water lettuce) from the San Marcos River (Montoya et al. 2013; Meier et al. 2014), which runs through campus, were some of the original feedstocks used in compost piles. However, the project has expanded to include collections from five of six campus cafeterias. Additionally, the project collects leaves and tree trimmings from the Grounds and Agriculture Department, coffee grounds from the Honors Department, food waste from the Child Development Center and the Nutrition Labs, and grass clippings from the sports fields and golf course. Between August 2013 and May 2014, six to eight students collected and processed approximately 140.5 tons of food waste to produce Bobcat Blend compost (an increase from 80.7 tons in 2012-2013, 57 tons in 2011-2012, and 27 tons in 2010-2011). The compostable materials were taken to the compost site 10 miles from campus and processed in a traditional windrow pile.

Given the success of the Bobcat Blend Composting program, a vermicomposting project was initiated allowing students to construct and manage a unique on-campus composting system. The purpose of this study was to: 1) establish the vermicomposting system at Texas State University using red wiggler worms and cafeteria food waste as a primary feedstock, 2) determine the potential economic potential of the system to the university, and 3) determine the value of the system as a teaching tool and service learning opportunity for students.

MATERIALS AND METHODS

Funds to cover initial costs for materials were obtained through the Texas State University's Environmental Service Committee, which appropriates funds from a campus green fee. Each semester, $1 of each student's fees is collected and used for various sustainability or recycling projects such as rain-water collection systems, electricity and water saving technologies, and waste-reduction and recycling initiatives (Texas State University Environmental Service Committee 2015). All materials and costs are listed in Table 1.

Structure. An 8 ft x 10 ft shed was built by an Agriculture Engineering class for the cost of materials ($650). The structure was then wired for climate control and lighting using acquired Environmental Service Committee funds ($500). A window air conditioning unit was used to keep the structure cool during the summer (Table 1). A heating unit was not required in this pilot program given expected low temperatures for the region (USDA Plant Hardiness Zone 8a/8b), but may be necessary in colder climates. Worms require temperatures between 65 °F and 80 °F (Dickerson 2001). Shelving was built inside the structure to allow for buckets to be stacked four buckets high, maximizing the production area within the shed structure. The shelving was built along the back wall of the shed structure approximately 2 ft x 10 ft (Figure 1). The remaining open space in the shed was used for tool and material storage.

Table 1. Materials and costs associated with the Bobcat Blend university educational and waste management vermicomposting program.

Materials	Cost	Quantity	Source
8’ x 12’ shed with shelving for five-gallon buckets	$650	1	Built in an Agriculture Engineering class; cost based on reimbursement for materials
Red wiggler (*Eisenia fetida*) worms	$120	6 pounds	Texas Red Worms (San Antonio, TX)
Rainwater	$0	2 gallons per month	Existing rainwater collection tank within Horticulture Gardens
Food waste	$0	100 pounds per month	University cafeterias
Shredded paper/dried leaves (bedding)	$0	22 gallons per month (dry)	Donated/recycled from the university offices/Grounds Department
Five-gallon buckets	$0	35	Donated/recycled from the cafeterias
A/C unit	$120	1	Sears (Hoffman Estates, IL)
Electricity to worm shed	$14.90 per month (original wiring and electricity hook-up was $500)	n/a	n/a
Student worker	$90 per month ($9 per hour, 2.5 hours per week)	1	n/a

Buckets. Five-gallon plastic food service buckets were collected from the university cafeteria. Buckets have successfully been used in large vermicomposting systems in the past (Jouquet et al. 2011) and it was determined that this readily available material could be incorporated into the university vermicomposting system. Approximately one-half inch holes were drilled in the bottom of each bucket to allow for drainage and airflow. Buckets were numbered to track age and progression of decomposition. A total of 35 buckets were used during the experiment.

Worms. To minimize costs, six pounds of red wiggler worms (*Eisenia fetida*) were initially purchased at $25 per pound (TexasRedWorms.com, San Antonio, Texas). One pound of red wigglers usually contains between 600 to 1000 individual worms (TexasRedWorms.com, San Antonio, Texas). The red wiggler worms purchased were allowed to reproduce and grow in numbers for four months prior to the pilot project. The life cycle of *E. fetida* is typically 45-51 days, reaching sexual maturity in 21-30 days with an average life expectancy of around 600 days (Dominguez and Edwards 2004).

Figure 1. Shelving used for vermicomposting buckets in the study of an economic analysis of the development and management of a university composting system: a self-sustaining environmental and waste management educational tool

Bedding materials. Bedding material serves several purposes; it helps control excess moisture, provides the worms suitable living conditions, helps manage pest problems, and serves as a bulking agent (Dominguez and Edwards 2004). Bulking agents are lightweight, usually carbon-based, materials used to increase air flow and prevent settling and compaction by smaller particles (Myers 2013). Shredded document paper from the university was obtained and used as a primary bedding material for the vermicomposting system. This material was moistened to the consistency of a wrung-out sponge to reduce sharp edges and to provide optimum moisture content for worms. Using paper as an exclusive bedding material proved to be problematic as the paper had a tendency to clump together. Leaf litter from the university gardens was later utilized as the primary bedding material in conjunction with paper as a topdressing bedding material and resolved the clumping issue. A handful of sand was added to each bucket to aid worms in digestion.

Food waste. Vegetable matter from the university cafeteria salad bar was used as the primary feedstock for the vermicomposting system. Approximately 25 pounds of food waste was collected by an undergraduate student worker per week. Meats and dairy products were avoided, as they are known to have the potential to be problematic in vermicomposting systems due to the large amount of protein which can cause protein poisoning (Munroe 2007). In addition, pineapple and large amounts of citrus were avoided. Pineapple contains an enzyme known to harm the skin of the red wigglers and large amounts of citrus could cause the pH to become to acidic, reducing pH below the ideal pH of 5 (Dominguez and Edwards 2004).

Vermicompost system. A student worker coordinated with the pilot cafeteria to pick up salad bar food waste weekly. Student worker weekly duties consisted of transporting food waste from the cafeteria to the vermicomposting structure, adding rainwater as necessary to maintain optimum moisture levels and collecting bedding material (shredded paper, dried leaves). A rainwater collection system located adjacent to the worm shed structure was used in the vermicomposting system because it was preferred over paying for municipal water and provides a more ideal source of water free of salts, chlorine, and other microbe inhibiting substances.

Shredded paper and/or dried leaves were moistened with rainwater to the consistency of a well wrung out sponge and added to the buckets to approximately half capacity. Three-quarters pound of worms and approximately 10 pounds of food waste were then weighed on a triple beam balance (OHAUS, Parsippany, NJ) and added to each bucket and mixed by hand (Figure 1). Food waste and bedding material were added to five-gallon buckets in a manner similar to recommended techniques used in past research (The Worm Guy 2015). Buckets were checked three times a week to check for pests and to monitor the vigor of the worms. Common pests included centipedes, which will eat cocoons and worms, ants which will compete with the worms for the available food and attack the worms, and red mites, which are parasitic to worms (Munroe 2007). After half of the buckets were created, it was found that using shredded paper as a primary bedding material was somewhat problematic, as it tended to clump together. As a result, leaves were used as a replacement of shredded paper for a primary source of bedding; the worms broke down the leaf material faster and were found to be more active. Shredded paper was still utilized; it was added to the top of the buckets as a bio-filter to reduce the presence of fungus gnats and other pests.

Vermicompost was harvested monthly and screened to ¼ inch using a custom-made hand screener (Figure 2). Vermicompost was considered mature when food particles could no longer be seen and was of a black humic consistency. The vermicompost was bagged into five-gallon zip lock bags.

Economic analysis. An economic analysis was then conducted to determine the minimum amount of vermicompost production required to be profitable at a given selling price using break-even analysis (Beierlein et al. 2008). A break-even analysis determines the sale amount required to cover total costs (Beierlein et al. 2008). Variables in the analysis included the shed structure, electricity, and student worker stipend.


Figure 2. Hand screener used in screening vermicomposting castings in the study of an economic analysis of the development and management of a university vermicomposting system: a self-sustaining environmental and waste management educational tool.

RESULTS

Production and revenue. A total of 400 pounds of food waste was collected from one of six cafeterias on campus (approximately 100 pounds per month). A total of 30 five-gallon zip lock bags of vermicompost were harvested during the pilot semester. Vermicompost was sold on campus at varying horticulture and campus events at $10 per five-gallon zip lock bag, totaling $300 for the initial semester. Weight of the castings varied by moisture content with each gallon of castings weighing 5-7 pounds and the price averaging about $2 per pound.

Service and academic learning. Red wiggler worms were used for educational demonstrations on campus at Earth Day events and the campus Farmer's Market. Demonstrations of the vermicomposting system were given to new-student orientation campus tours, field trips for visiting elementary school groups and to tours of high school advisors. Students enrolled in the Organic Gardening class in the horticulture program utilized the vermicomposting system in one of the scheduled lab periods. The various elements and day-to-day operations of the system were reviewed during this instructional lab. In addition, students learned how to make a home vermicomposting system. Vermicompost is also used in a second lab session to make compost tea, a liquid where beneficial microbes and nutrients are extracted and multiplied (Gomez-Brandon et al. 2015), in order to apply to the campus gardens.

In order to assess learning, students reported in qualitative reports the value of the vermicomposting activity. One student reported, "My experience with the worms has dispelled some misconceptions of vermiculture and reminded me that composting can be accomplished by very simple methods. I've not only learned about worms but other beneficial decomposers like the black soldier fly larva."

Another student talked about the value of the program as a growing and changing system by stating, “The vermicomposting program at Texas State University was much more than food recovery or worm casting production; it was a laboratory and a sandbox to experiment, succeed and fail, learn and teach, and to develop professional skills. For example, the shed provided an opportunity and the space to experiment with the rate of biomass production in various bedding types, nutritional feedstocks, worm species, and pathogen control. The results and observations from these experiments were shared with hundreds of horticulture students, master composter students, and campus visitors.

Another student discussed the vermiculture production unit as an ecosystem when he reported, “I not only learned how to build a proper vermicomposting environment, but also how the different factors associated with the environment worked together to form a symbiotic relationship to amplify and maintain the biodiversity of microbes in the soil. Tangible, real world projects like the worm shed really bring the information forward much more than a book ever could and I’m thrilled to have had the hands-on opportunity to learn about vermicomposting and its benefits to the soil.”

Economic analysis. In the break-even analysis, it was determined that each pound of vermicompost could be sold for $2.76 with 40 pounds of monthly production and given the current costs for electricity, labor, rent, and depreciation. However, at 70 pounds of monthly production, vermicompost could be sold at $1.58 per pound, which is within normal competitive rates of $1.30 - $2.00 per pound to meet the break-even price. At this rate, a profit of $15.70 per month would be generated given a selling price of $1.80 per pound. Therefore, additional buckets were added to the system, increasing the number of buckets to a total of 60, in order to maximize production capacity. These additional buckets did not result in any additional investment because the worms had multiplied in the existing system and the buckets and bedding materials were available at no cost. Once a desired population is reached, additional revenue could be generated by selling the red wiggler worms for fishing bait or to people interested in creating their own vermicompost systems. Fishing is a hobby claimed by over 30 million Americans and worth $40 billion per year (Hansen 2015). One pound of red wiggler worms sells for approximately $30 in a commercial market (Uncle Jim’s Worm Farm 2016).

CONCLUSIONS AND DISCUSSION

Results showed that vermicomposting systems could be implemented at universities to offer students an example of this emerging alternative agricultural and waste-management industry (Riggle and Holmes 1994). These systems would accomplish several goals. Organic matter would be diverted from the landfill, as it is now becoming required by law in many regions of the country (Zero-Waste Strategic Plan: Austin, Texas 2008; USEPA 2006). Organic waste such as yard trimmings and food residuals are thought to constitute the largest component of our trash, up to 24% of the waste stream in the United States (USEPA 2006). Besides being able to create a valuable by-product for our soils, the organic matter that ends up in landfills creates methane, a greenhouse gas that contributes to global warming (USEPA 2007) at a rate 21 times more potent than carbon dioxide. Diverting organic waste will also extend the life of landfills. A district in Canada extended the life of its landfill by 15 years by diverting organics (Younie 2012).

Programs such as these educate students on the economic and hands-on lessons of vermicomposting systems, which are becoming a growing area of interest by students and the agricultural and horticultural industry, but result in positive life lessons for all. Residents in Canada involved in an organics diversion program reported becoming more aware of their wasted food and strived towards better meal planning once the diversion program was implemented (Younie 2012). Students involved in a college composting program had better compost knowledge, compost awareness, and more positive environmental attitudes and locus of control compared to those at universities where campus composting was not offered (McFarland et al. 2016).

The vermicompost program created a living laboratory and educational tool for students, while also generating fundraising opportunities and producing a valuable horticultural product that was utilized on campus.

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