2012 Research Report

# Closing the Food Cycle Loop: Connecting Campus Food Residue Composting at the Student Organic Farm and the Bailey GREENhouse Project

By

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## I. Background and Objective

Residential and Hospitality Services (RHS) including Food Stores, the Office of Campus Sustainability (OCS), MSU Recycling and Surplus Store (RSS), the Student Organic Farm (SOF) and the Environmental Studies Specialization (RISE) partnered to connect Operations and Academics and provide students with food related experiential learning opportunities by using campus food residuals to make compost at the SOF that was then used to grow culinary herbs within a few hundred yards of where the food is prepared and consumed.

The SOF is a 10 acre diversified vegetable and fruit farm located at the Horticulture Teaching and Research Center on south campus. Since 2003 produce has been marketed with a unique 48 week community supported agriculture (CSA) program and since 2007 at a campus farm stand. Since 2009, salad greens, vegetables and culinary herbs purchased from the SOF on south campus have been served at two dining facilities on north campus about 4 miles away. Starting in 2010 kitchen preparation residue from the two facilities are also transported to the SOF where it is either hot composted outside or vermicomposted in a passive solar greenhouse (PSGH) so the organic matter and nutrients can be returned to the soil for future food production. Worm composting in a PSGH was initiated in the fall of 2010 with close to 14,000 lbs of produce composted the first academic year.

The Environmental Studies Specialization and the freshman Residential Initiative for Study of the Environment (RISE) have used the SOF as a living laboratory for student engagement since the start of the farm. Plans for the relocation of the Environmental Studies Specialization to the newly remodeled Liberty Hyde Bailey Residence Hall included the construction of a passive solar greenhouse adjacent to the hall as a method to engage freshman students seeking experiential learning activities but without transportation to the SOF. Based on planning and discussion between the project partners the initial production was planned to focus on certified organic culinary herbs for Brody Market Place and Kellogg Conference Center. When proposed the PSGH was referred to as the Bailey Herb House but early in 2012 the name changed to the Bailey GREENhouse.

The purpose of the 2012 research was to develop the necessary components of the system and to inform the development of student centered experiential learning activities that allow students to participate in the food cycle loop - ie the movement of food from farm to fork and the return of appropriate food residue to the farm for the purpose of increasing soil organic matter and essential plant nutrients. The foundation of the research is the cultivation of a strong partnership between operations (RHS, RSS, OCS) and academics (SOF, RISE). The model can be reproduced by education programs across the US seeking to provide students with experiential education and connections to local food systems.

The research had two primary objectives:

1. Expanded food residue collection and composting with an emphasis on vermicomposting;
2. Use of compost for production of organic culinary herbs in partnership with the Environmental Studies specialization and sale of worm compost at the Recycling Center.

## II. Methods

(Numbering of Objectives and Project Areas correspond to Proposal)

**Objective 1. Food Residue Collection and Composting.** The research is a continuation of development of vermicomposting methods suitable for year-round processing of food residue for small scale intensive farming (rural and urban). In the first winter (2010-11) worm composting activity was maintained by using a single layer polyethylene film covered unheated greenhouse structure or passive solar greenhouse (PSGH) and an interior polyethylene tent over the worm beds. Bed temperature was maintained at 45 to 50$^{o}$F and vermicomposting proceeded but slowly. The limited size of the worm bed and lack of replication limited the conclusions possible. The size of the operation was significantly expanded for the second (2011-2012) and third winters (2012-2013).

**1A. Collection.** Kitchen preparation residue collection methods during January thru March 2012 continued with SOF employees picking up 18 gallon plastic totes of kitchen preparation material that represented a portion of the total available at Landon Hall and Brody Market Place. After spring break (March 10) RHS and the RSC started collection in 65 gallon rolling carts that allowed collection and composting of all the kitchen preparation residue. The carts were transported to the South Campus Compost Facility from March thru June and to the SOF from July thru December. Weights of each delivery were measured and recorded by RSS staff.

**1B. Vermicomposting.** Development of vermicomposting techniques and capacity continued with several methods. Detailed background and methods description including pictures are available in a separate document (Biernbaum, 2012).

*Methods.*

- *Large Beds.* Fresh food residue was either placed on the surface or buried in the bed either weekly or biweekly in a trench in the original (2011) large ground beds (two at 4' x 20') contained by cement blocks and lined with landscape fabric. Finished compost (2 to 3 cubic yards) was removed and collected during April and held in a wood box. Screening of the compost for sale in occurred in October. An additional batch of 2 to 3 yards is ready to harvest in January.
- *Wood Beds South.* Six wood beds (3'x7') constructed in summer and fall 2011(south side) and stocked with worms from Pear Tree Farm were maintained through the winter 2012 with low tunnel covers made from electrical metal tubing using the Johnny's Quick Hoop Bender. Approximately 40 to 50 pounds of kitchen preparation residue and bedding material was placed on the surface or buried in a trench in each bed every two to three weeks.
- *Wood Beds North.* Six new wood beds (3'x7') (north beds; 2012) with direct ground contact were constructed in May and June. Pine wood 4"x4"x84" long was obtained from MSU Recycling. Each piece was notched and drilled on the ends to provide interlocking pieces and a stable bed. Beds were filled with a bedding mixture made from compost, shredded office paper, leaves and horse manure. Worms were collected from the active south six beds and transferred to the new beds using bulb crates of fresh bedding to attract and transfer worms.
- *Compost Collection and Restart*. Worm composting by the remaining reduced population in the six south side beds (2011) was allowed to complete during July and August with no additional feeding. Compost was collected and screened during September and placed in 5 gallon buckets for sale. Samples were collected for nutrient analysis. The beds were restocked with a bedding mixture made from compost, shredded office paper, leaves and horse manure. Worms were collected in bulb crates from the north six beds and transferred to the south beds.

- *Raised Wood Beds.* Wooden boxes, 4' x 8' and 24" tall, with no direct ground contact (wood bottoms off the ground) were constructed from 2"x6" by 8' long wood and deck screws. Initially 10 lbs of composting worms were purchased at a cost of $270 including shipping and introduced into one of the beds. Bedding was a mixture of leaves, paper, coffee grounds and peatmoss with no manure. The first bed was started June 1 and the second bed was started by splitting the contents of the first bed on September 14. The second of the two beds was lined with polyethylene to compare the impact on worm growth, water and nutrient management.
- *Vermiwash System.* A 100 gallon stock watering tank (Rubbermaid) was used to create a "vermiwash system" to allow collection of leachate or water passed through an active worm bed. The leachate is used as a plant fertilizer and or a biological inoculant. The drain was fitted with 1.25" pvc pipe and a quarter turn valve. A 4" layer of washed gravel was placed in the bottom and covered with landscape fabric. A 3" layer of sand was then placed over the gravel and fabric and covered with another layer of landscape fabric. Then 12" of bedding mixture from leaves, paper, coffee grounds, peatmoss and horse manure was added. Five pounds of worms collected from Pear Tree Farm were introduced into the system on October 4.
- *Bag Culture.* On October 25th woven vinyl greenhouse root media transport bags approximately 4' x 4' bottom and 4' tall were filled with mixed bedding (compost, leaves, paper, horse manure, peat, coffee grounds) approximately 12" deep and ~2.5 pounds of worms from Pear Tree Farm added to each of two bags. One bag was placed in direct contact with the ground and one bag was placed on a wooden pallet. Both bags were in the center of the Worm PSGH Kitchen Preparation Residue was added by burying in the center of the bag.
- *Organic Certification.* While compost cannot be certified as organic, the methods used to make compost suitable for use in an organic systems plan must be reviewed as part of the certification process. Necessary documentation of methods was submitted as part of the SOF Organic Systems Plan. An inspection and review occurred late in November.
- *Chemical Analysis of Compost and Worm Compost.* Four samples of food waste hot compost made in fall 2011 and finished in 2012 were submitted to the MSU Plant and Soil Analysis Laboratory in June. Six additional vermicompost samples and samples from the Bailey GREENhouse were submitted for analysis in December. Available nutrients were determined by the Saturated Medium Extract method, total nitrogen by Kjeldahl method, organic matter by ashing, and total nutrients by ashing and emission spectrometry.

*Additional Vermicomposting Procedures.* Each of the vermicomposting systems were managed over time to investigate vermicomposting strategies for minimizing objectionable odors and insects(fruit flies) during the compost process, and maximizing the labor efficiency of producing a quality end product. Variables included a) either burial or surface application of food residue, b) addition of bedding / bulking materials, c) moisture and temperature management strategies.

*Feedstocks / Bulking Materials.* A goal of the research is to identify other materials available on campus that might be available for combining with kitchen preparation residue for composting. Three materials were obtained through Landscape Services: leaves, wood chips and top soil. Two materials were obtained from the Recycling Center: newspaper and shredded office paper. Additional work proposed included comparisons of moisture content and the use of pile covers.

*Commercial Composting Site Visits.* Five commercial compost facilities were visited during spring 2012. Currently there are over 150 such sites registered with the Michigan Department of Agriculture and Resource Development. Site selection was based on prior or current research and outreach relationships and the potential to identify sources of quality compost for future research and organic farmers. The facilities were not specifically focused on food composting but all were either starting food composting or considering it. Only one of the operations was using vermicomposting. Worm operations identified in Michigan were primarily focused on raising worms for sale as bait and not composting.

- Morgan Composting, Sears
- Renewed Earth, Otsego
- Tuthill Farms, South Lyons
- McKay Composting, Swartz Creek
- South Oakland County Resource Recovery Authority (SOCRRA), Rochester Hills
- Granger Composting, Lansing

**1C. Integrated Approaches of Food Residue Recycling.** Meetings in early 2012 focused on transport methods with the 35 and 65 gallon carts used to transport materials from kitchen to the anaerobic digester or SOF. Food preparation compostables from additional dorms brought on-line during the year went to the anaerobic digester at the South Campus Compost Facility. There were no additional meetings during the fall of 2012 regarding adjustments to or additional methods. An experiment was completed at the ADREC where vermicompost was added to laboratory digesters to measure any effects on methane production. A group meeting is scheduled for early January.

**1D. Anaerobic Digester Effluent.** Liquid and solid digestate from an anaerobic digester may be a valuable addition to compost. One experiment reported below in 2A was completed but additional research work was not undertaken primarily due to priorities in other project areas and because a screw press system for removing solids has not been made operational at the anaerobic digester.

**Objective 2. Use of Compost and Bailey GREENhouse for Culinary Herbs.**

Completing the food cycle loop is made possible by using the compost for growing crops. While compost addition to soil has been used as a gardening and farming practice for thousands of years, growing of crops in 100% compost or "*compostponics"* has not been formerly trailed,l documented or researched, although there is some evidence of crop production in compost in urban farming practices.

**2A. Growing Methods Using Compost.**

Certified organic crop production requires use of soils that have been managed organically for three years or have no non-allowed or restricted use materials applied for three years. For small scale intensive urban farming in beds or containers, the use of compost as a growing medium can meet the organic certification requirement. Compost is not generally used as a growing medium without first mixing with top soil. A limitation of mixed compost soil media compared to peat- or bark based greenhouse or nursery container media is the increased weight (bulk density) which limits the volume of growing containers that can be manually managed or moved. Research was initiated to test small scale crop production systems that use compost or compost mixes as the growing medium. One method tested was the addition of small amounts of soil as a feedstock during the composting process.

*Compost in bulb crates.* Michigan greenhouse businesses import millions of tulip, daffodil and hyacinth bulbs from the Netherlands (collectively known as "Dutch bulbs"). The Dutch bulbs are packaged in plastic crates approximately 11"x22" by 6" deep which hold approximately a cubic foot of volume. The crates are available for repurposing and make a practical growing container for crops when filled with root medium. The crates were filled with one of seven composts for comparison of growth potential of the composts. In order to improve water management strategies, four of the composts were tested in crates lined with either 1) newspaper, 2) woven heavy weight landscape fabric, 3) mesh light weight landscape fabric, 4) black plastic (polyethylene) film, or 5 ) the same film with 24 small equally distributed holes for aeration. Six basil seedlings were transplanted into each bulb crate on June 21. Basil shoot tips were harvested sequentially and weighed.

*Raised beds with polyethylene liners.* Originally planned to be a major component of the research, due to higher priority aspects of the overall research, this became a preliminary trial to form a basis of future work. The indoor bulb crate method above was extrapolated to make 4' x 8' wooden raised beds from 2"x10" x 8' long lumber in a garden setting. The iInitial goal was to evaluate the probability that flooding from rainfall or lack of aeration would limit production. A second goal was to evaluate productivity when placing the bed under a large shade tree where roots from the tree would normally compete for water and minerals. A third goal was to evaluate winter survivability with and without a cover.

Two 4' x 8' and 8" deep wood frame raised beds were constructed in May under the shade of a large maple tree in the spot of a previously unsuccessful raised bed. The beds were lined with plastic film (polyethylene) and filled with worm composted horse manure. Scallions, lettuce, cilantro, spinach, chard and parsley were either transplanted or direct sown and harvested when mature. Two additional beds were constructed in September in a full sun location and planted with lettuce, cilantro and spinach. One of the beds was covered with polyethylene film to allow winter harvesting.

*Bailey GREENhouse Growing Medium from Compost.* Food waste based compost initially formulated and managed at the SOF during fall 2011 and covered and stored outside during the winter of 2012 was mixed and turned during spring 2012 to complete the composting and maturation process. Batches of compost were mixed together and additional purchased leaf mulch was added at 10-15% by volume. The mixed medium was loaded onto a dump truck and transported to campus in three loads of approximately 15-20 cubic yards each. On July 9$^{th}$, the medium was placed in two raised beds approximately 11'x 60' x 1' deep that made up the foundation of the Bailey GREENhouse.

*Additional Compost for Future Research.* During the second half of the year additional batches of KPR compost with either a) horse manure and paper bedding or b) leaves and wood chips were hot composted and managed by turning the piles with a front end loader. In December the compost was piled and placed under a moveable greenhouse with polyethylene cover for winter storage. At least four types of compost of varying ages are set aside for use in 2013 as mature compost. Samples were submitted to the MSU Soil and Plant Analysis Lab for nutrient characterization.

**2B. Preparation of Culinary Herb Transplants and Herb Production.**

For the Bailey GREENhouse to be ready for immediate impact, culinary herb transplant production was started nearly a year in advance.

*Planning, Preparation and Propagation.* Rosemary, oregano, thyme, sage, lemon verbena, spearmint and peppermint were propagated by vegetative cuttings in the fall of 2011 and tarragon and chives by divisions in the summer of 2012. Vegetative cuttings were collected from Pear Tree Farm and managed at the Plant and Soil Sciences Building Teaching Greenhouses by a horticulture undergraduate student as part of an independent study. The number of cuttings per crop ranged from 75 to 150. Methods used were suitable for organic certification. Cuttings were maintained in early 2012 in a heated greenhouse at the PSSB Teaching Greenhouse Range. In February plants were moved from 128 or 48 cell propagation trays to 5" square pots (8 per tray). Compost and peat were mixed to make potting medium acceptable for organic certification. In May the plants were transported to the Worm-house at the SOF and maintained there through August. Tarragon and chive plants were divided and potted during June in the same pot size and growth medium. Soil fertility was managed through the application of vermicompost to the root medium surface.

*Planting.* The herbs listed above plus seedlings of basil and parsley and direct seeded cilantro and salad greens were planted in the Bailey GREENhouse. Initial planting was August 3rd and 7th.

Equal plant spacing was maintained using row markers. Planting holes for plants in larger pots were prepared using a post-hole digger.

*Harvest and Marketing.* Herb harvest and handling protocols were initially developed during June and July using plants grown at the Worm-house. Samples and packing methods were provided to chefs at Brody Market Place and Kellogg Conference Center for review and approval. Initially sealable plastic bags were used for 4, 8 or 16 ounce samples. Product for sale was place in non-sealed plastic bags. Herbs were typically harvested early morning and walked to the Brody Market Place or Kellogg Center for mid or late morning delivery, usually by placing in a designated refrigerator.

**2C. Educational Materials and Signage**

Educational efforts with Laurie Thorp and Matt Raven were directed at the RISE Freshman Seminar during fall semester with two sections and 70 total students. John Biernbaum made a presentation to each section and students developed composting proposals for the Bailey Site. Proposals will be reviewed in winter 2013 and used to develop a final plan for implementation of one or more outdoor composting systems during spring 2013.

**2D. Compost screening and sales**

Separation of worms from compost was completed using three main methods: 1) light to drive worms down out of compost or 2) using fresh bedding and food to move worms out of compost using a wedge system or 3) using fresh bedding and food in plastic bulb crates to move worms up out of compost.

After worms were removed, compost was screened by one of three methods. First method used in early 2012 was a 3'x4' wood frame made from 2"x4" lumber and covered with 1/4" hardware cloth that was placed over a wheel barrow with compost loaded and sieved by hand. The second was a swinging sieve constructed in May primarily from 2"x4" lumber and hardware cloth for approximately $150 materials cost. These two screening methods were used for the first cubic yard of worm compost provide to the SOF for spring transplant production and the preparation of 2 pound sealed plastic bags (one quart) sold at the SOF Farm Stand on campus for $5.

The third screening method was a commercially manufactured metal trammel screen with variable sized screens (1/8, ¼, ½ inch hardware cloth) that was purchased from Jet Harvesters for approximately $3200 plus $1000 crating and shipping. For screener information see: http://www.jetcompost.com/harvesters/index.html Model 3620. The unit arrived September 4th. Air dried worm compost was shoveled into the screener. Worm compost passing a 1/8 inch screen was collected in 18 gallon plastic totes beneath the screener. The screened compost was mixed and placed in five gallon buckets holding 25 pounds of compost for storage and transport. Larger particles not passing the 1/8" screen were stored in wooden bulk bins for future use or research. Three main batches were processed in September and October.

The MSU Recycling Center and Surplus Store (RSS) provided a method for marketing the worm compost. Bulk compost was made available for customers to purchase in their own container for $2 per pound.

**2E. Presentation at National Vermicomposting Conference.** Rhonda Sherman at North Carolina State University has organized and hosted an annual National Vermicomposting Conference since 2000. The 2012 conference was held November 4 and 5 in Chapel Hill North Carolina. Details are available at: https://www.bae.ncsu.edu/bae/workshops/worm_conference/

## III. Results

The majority of the project funding (60%) was allocated for a full time temporary staff position. After discussion with five candidates, Brendan Sinclair was selected as the Vermicomposting and Herb Manager. Project funding was also used for undergraduate employees. Three RISE students with prior experience at the SOF were selected in April as the first members of the Bailey GREEN Team and started work in August. They were involved in herb harvests and day to day management of the herbs and worms. Additional RISE students participated as volunteers.

**Objective 1. Food Residue Collection and Composting.**

1. **1A. Collection.** Weights of each delivery were measured and recorded by Recycling and Surplus Store staff. Nearly 100,000 pounds or 50 tons of preconsumer KPR was transported for use at the Student Organic Farm from March 10 to December 20. Approximately 10 to 15 % was fed directly to worms and the remainder was hot composted with either a) horse manure with newspaper as a carbon source or b) leaves and wood chips from campus as a carbon source. Over 32 weeks with 3 deliveries per week the weight delivered ranged from 200 to 2000 pounds and the average delivery was 1000 pounds or about 1 cubic yard. The estimated landfill and transportation savings is at least $3000.

**1B. Vermicomposting.**

*Methods.*

- *Large Beds.* Over 2 cubic yards of vermicompost was collected from the initial worm beds. The compost was allowed to dry over the summer and was screened in the fall resulting in 40 five gallon buckets of screened material (about one cubic yard or 1000 pounds).
- *Wood Beds South.* Composting continued through the fall. In late December temperatures in the beds were approximately 40 to 45$^{o}$F, similar to the larger beds at that time and to bed temperatures during the winter the previous season.
- *Compost Collection and Restart for South wood beds*. The finished worm compost was easily shoveled from the beds, moved to the compost screener and screened. Beds 1 to 3 (primarily hot composted food waste as bedding) were handled separate from 3 to 6 (primarily horse manure bedding) to allow future evaluation of compost differences. Beds 1-3 yielded 20 and 4-6 yielded 25 five gallon buckets of screened material. The greater recovery from 3-6 was due to a second screening after breaking up materials not passing through the screen the first time.
- *Wood Beds North.* Temperature of the beds with individual covers (North side) at the end of December is similar to those under one large frost fabric cover (South side) but lower than the large beds covered with a polyethylene interior cover.
- *Raised Wood Beds.* Wooden boxes, 4' x 8' and 24" tall covered with quick hoops and an interior layer of frost fabric and a second layer of 1 mill plastic film are maintaining temperatures in the 40 to 45$^{o}$F range, similar to the other beds with ground contact.
- *Vermiwash System.* A worm bed in a 100 gallon stock watering tank (Rubbermaid) are maintain good activity and temperatures in the bed are similar to the other small beds wood beds. (results – temperature, nutrient analysis? )
- *Bag Culture.* Worm activity and temperatures at the end of December are comparable to other systems. The worm population appears to be normal and reproducing.
- *Organic Certification.* We were able to answer the inspector's questions. Results of the inspection and review have not been returned.
- *Chemical Analysis of Compost and Worm Compost.* An outcome of this research is the chemical characterization of the worm composts compared to other composts. Results are presented in the following tables.

Table 1. Vermicompost Organic Matter, Carbon, C:N and N

| **Worm Compost** | ID | % OM | % C | C:N | % N |
|---|---|---|---|---|---|
| Compost+Horse Man (Sum 2010) | W1 | 30.1 | 17.4 | 13.2 | 1.32 |
| Horse+pulper in Bins (Win 2011) | W2 | 31.1 | 18.0 | 10.5 | 1.71 |
| Horse in Bins (Win 2011) | W3 | 28.4 | 16.5 | 11.4 | 1.44 |
| KitchenPrepResidue (Win 2011) | W4 | 38.0 | 22.0 | 10.5 | 2.10 |
| Plant/leaf Compost (Sum 2011) | W5 | 47.6 | 27.6 | 17.2 | 1.60 |
| Cow Manure (Sum 2011) | W6 | 41.5 | 24.1 | 16.6 | 1.45 |
| Mix of W1 & W4 (for SOF) | W7 | 37.6 | 21.8 | 14.1 | 1.55 |
| Horse manure PTF 2010 | W8 | 18.9 | 11.0 | 11.7 | 0.94 |
| Sieved from Win 2012 | W9 | 33.4 | 19.4 | 13.1 | 1.48 |
| Sieved from Beds 4-6 (Win 2011-12) | W10 | 20.9 | 12.1 | 10.4 | 1.16 |
| Sieved from Beds 1-3 (Win 2011-12) | W11 | 33.5 | 19.4 | 9.5 | 2.05 |
| Average of all | Mean | 32.8 | 19.0 | 12.6 | 1.53 |

Organic matter is as expected in the 30 to 40% range and the C:N is as expected in the 10 to 20% range. The kitchen preparation residue is the main production from 2011 and it is good to see the high nitrogen content (2.1%). Future research will need to test whether the coffee grounds contributed to the higher nitrogen concentration.

Table 2. Vermicompost Total Nutrients by Ashing (macros as % and micros as ppm).

| **Worm Compost** | ID | N | P | K | Ca | Mg | Na | S | Fe | Zn | Mn | Cu | B | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Compost+ Horse Man (Sum 2010) | W1 | 1.32 | 0.30 | 0.76 | 2.12 | 0.51 | 0.03 | 0.19 | 3849 | 81 | 240 | 29 | 16 | 2328 |
| Horse+pulper in Bins (Win 2011) | W2 | 1.71 | 0.49 | 0.75 | 2.34 | 0.73 | 0.07 | 0.26 | 4093 | 104 | 289 | 31 | 19 | 2108 |
| Horse in Bins (Win 2011) | W3 | 1.44 | 0.44 | 0.63 | 2.05 | 0.55 | 0.05 | 0.20 | 4053 | 81 | 225 | 28 | 16 | 2104 |
| KitchenPrepResidue (Win 2011) | W4 | 2.10 | 0.38 | 1.60 | 2.45 | 0.64 | 0.12 | 0.24 | 3920 | 61 | 210 | 18 | 21 | 1839 |
| Plant/leaf Compost (Sum 2011) | W5 | 1.60 | 0.36 | 0.72 | 2.15 | 0.47 | 0.05 | 0.24 | 3851 | 94 | 234 | 31 | 21 | 2116 |
| Cow Manure (Sum 2011) | W6 | 1.45 | 0.60 | 1.49 | 3.49 | 0.88 | 0.14 | 0.35 | 4325 | 140 | 342 | 58 | 20 | 1759 |
| Mix of W1 & W4 (for SOF) | W7 | 1.55 | 0.30 | 0.96 | 2.04 | 0.71 | 0.06 | 0.19 | 4467 | 69 | 197 | 26 | 16 | 2265 |
| Horse manure PTF 2010 | W8 | 0.94 | 0.29 | 0.57 | 1.94 | 0.49 | 0.01 | 0.13 | 3399 | 58 | 197 | 14 | 10 | 1864 |
| Sieved from Win 2012 | W9 | 1.48 | 0.24 | 0.78 | 3.23 | 0.85 | 0.10 | 0.18 | 4449 | 58 | 195 | 21 | 13 | 1817 |
| Sieved from Beds 4-6 (Win 2011-12) | W10 | 1.16 | 0.34 | 0.55 | 2.27 | 0.83 | 0.05 | 0.15 | 3979 | 62 | 215 | 19 | 12 | 1871 |
| Sieved from Beds 1-3 (Win 2011-12) | W11 | 2.05 | 0.26 | 0.94 | 3.39 | 0.95 | 0.12 | 0.23 | 4336 | 56 | 224 | 24 | 17 | 1737 |
| Average of all | Mean | 1.53 | 0.36 | 0.89 | 2.50 | 0.69 | 0.07 | 0.21 | 4066 | 79 | 233 | 27 | 16 | 1983 |

The following evaluation and comparison of the worm composts are based on comparison with a data set of analyses of 23 composts in 2003 and 23 composts in 2010. The average carbon, C:N, and total nutrient concentration of the 11 worm composts collected over the past two years are similar to the averages of the two prior data set means. Worm composts are typically reported to be of higher nutrient concentration. Looking at the three data sets overall, the feedstocks used to make the compost, for example the addition of animal manure from animals on high protein diets, appears to have a larger effect on nutrient concentration then the method of composting. The higher N and K concentration in the kitchen preparation residue compost from the main composting bed cannot be fully explained at this point. One possibility as mentioned above is the contribution of coffee grounds which were not a feedstock for W1 to W3. Another is that the compost was managed for a longer time than other systems sampled with more total food residue added to those beds. The high concentration of P, K, Ca, and micronutrients in the vermicomposted cow manure is expected based on the dairy cow diet and provides evidence for the high commercial sale value of dairy manure vermicompost. Approximately 4 cu ft of dairy manure was used for this trial. The worm activity and reproduction in the sample was very high. Further research that would allow comparison of samples of dairy manure composted at the SCCF or worm composted is recommended.

Table 3. Vermicompost Saturated Media Extract or Water Soluble Nutrients

| **Worm Compost** | ID | pH | EC | NO3-N ppm | NH4-N ppm | P (ppm) | K (ppm) | Ca (ppm) | Mg (ppm) | Na (ppm) | Cl (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Compost+ Horse Man (Sum 2010) | W1 | 6.5 | 8.92 | 850 | 7.5 | 93 | 2106 | 900 | 177 | 105 | 352 |
| Horse+pulper in Bins (Win 2011) | W2 | 7.2 | 4.67 | 272 | 4.1 | 147 | 985 | 420 | 126 | 128 | 290 |
| Horse in Bins (Win 2011) | W3 | 7.1 | 5.15 | 371 | 1.5 | 182 | 1080 | 420 | 149 | 97 | 255 |
| KitchenPrepResidue (Win 2011) | W4 | 7.6 | 11.8 | 834 | 1.7 | 90 | 3498 | 1260 | 93 | 312 | 1175 |
| Plant/leaf Compost (Sum 2011) | W5 | 6.5 | 5.15 | 410 | 1 | 100 | 1061 | 480 | 120 | 70 | 178 |
| Cow Manure (Sum 2011) | W6 | 8.7 | 7.51 | 294 | 4.4 | 138 | 2052 | 900 | 113 | 220 | 513 |
| Mix of W1 & W4 (for SOF) | W7 | 7.0 | 9.39 | 694 | 1 | 122 | 2388 | 960 | 137 | 188 | 588 |
| Horse manure PTF 2010 | W8 | 8.0 | 4.67 | 280 | 0.8 | 35 | 1251 | 420 | 67 | 40 | 297 |
| Sieved from Win 2012 | W9 | 6.5 | 12.89 | 904 | 6.5 | 124 | 2357 | 1500 | 247 | 433 | 1441 |
| Sieved from Beds 4-6 (Win 2011-12) | W10 | 6.9 | 6.99 | 450 | 5.3 | 124 | 1326 | 750 | 176 | 138 | 467 |
| Sieved from Beds 1-3 (Win 2011-12) | W11 | 6.4 | 11.69 | 748 | 5.3 | 124 | 1971 | 1200 | 194 | 333 | 1088 |
| Average of all | Mean | 7.1 | 8.07 | 555 | 3.6 | 116 | 1825 | 837 | 145 | 188 | 604 |

Compost pH in 6.5 to 7.6 range is desired. The average pH for the worm composts is similar to the average for the previous data sets. The higher pH in cow and horse manure composts is consistent with previous observations. More mature or older composts also tend to have a lower pH in this data set as in the previous data sets. Low ammonium nitrogen concentrations (< 5 ppm) and increased nitrate nitrogen concentrations are also a good indication that composting is complete.

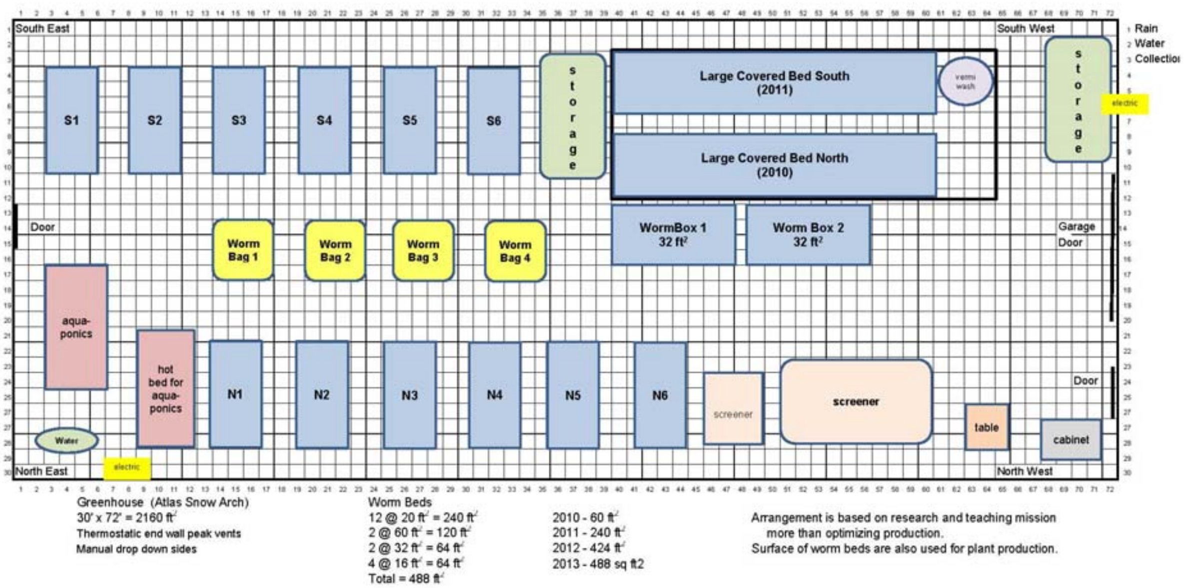
The kitchen preparation residue sample has the highest EC and nitrate nitrogen which in this case is considered desirable for nutrient recovery. The total soluble salts are a good indicator of the fertilizer value of the worm composts. There are 3 composts with EC over 10 mmhos and 3 additional between 8 and 10 which is high compared to values in previous data sets of primarily hot composts.

Previous data sets have included compost samples with nitrate nitrogen concentrations in the 2000 to 4000 ppm concentration so the values in this data set are not excessive. The owner and manager of the largest worm composting facility in the US who sells worm compost to greenhouse operators has proposed that the higher nitrate nitrogen content of worm compost compared to other composts is one of the primary values or selling points. This is another area where further research and analysis is recommended.

Based on both individual worm compost samples and the data set averages, there is a trend of higher soluble phosphorus in the worm composts which is consistent with previous reports.

*Total Worm Bed Area.* Total worm bed surface area in the Wormhouse was expanded from 280 to 500 square feet during 2012. An additional 240 square feet of bed space in a 16' x 22' mobile hightunnel that was used during the fall of 2011 and spring of 2012 was discontinued due to repurposing of the structure for a different use on the SOF. This is the maximum worm composting space anticipated under a research arrangement.

Figure 1. Worm-house layout December 2012.




*Procedures.* Each vermicomposting system was managed over time to investigate vermicomposting strategies for minimizing objectionable odors and insects during the compost process, and maximizing labor efficiency of producing a quality end product. Surface application of mixed KPR and bedding material worked well during winter months but led to fruit flies during warmer months. Burying the KPR eliminated fruit flies. Using a pitch fork to dig a trench and then back cover the materials took a few minutes per bed and was a simple solution. Burying the mixture keeps the worms lower in the bed which does not appear to reduce activity significantly. Burying is contrary to organic certification recommendations for surface application in thin layers. Burying can also lead to an accumulation of soluble salts in the bed that would not be expected with surface application and upward movement of worms into fresh material. Decreased worm activity and small worm size in the large beds in December may be due to increased soluble salts. Samples from the north and south beds had a pH of 7.4 and 7.5 and EC of 2.3 and 3.5 mS or mmho using a 1:2 medium to water dilution method. The beds have been managed with burying for over 8 months. Worms will be extracted and compost harvested. Testing the effect of EC on worm growth is another area recommended for future research.

Maintaining a moisture content is beneficial to the worm activity and growth, particularly during the summer months when bed temperature is 80$^{o}$F or higher. Worm beds that contained precomposted food waste mixed with soil as a component of the compost were more difficult to keep moist without concern for negatively impacting the worm population by reducing aeration or leading to compaction of the bed.

*Feedstocks.* The leaves and wood chips both worked well when combined with KPR for hot composting. Aged leaves were also screened and the fine materials were added to KPR prior to adding to worm beds. Newspaper and shredded office paper where used as worm composting bedding materials. Both preformed best when soaked in water for one to two hours prior to use. After soaking and with agitation both papers would begin to degrade and mix well with other components. The two paper types were not compared side by side. Both appeared to decompose readily and be beneficial to worm size and population growth (reproduction).

*Commercial Composting Site Visits.*

The site visits provided important information for future research development.

- Two of the sites (Morgan and Tuthill) were currently accepting either grocery store discarded produce or kitchen preparation residue. Food residue composting of any volume of material was considered a new technique requiring additional research and experience on their part before any expansion. The other four sites had all been contacted by potential suppliers of FPR but were not currently accepting the material.
- There was a shared concern that food waste and other materials were being accepted by registered compost sites and tipping fees were being collected but the piled materials were not being properly managed with intent to sell finished compost. There was serious concern about negative impacts and publicity that would reflect on dedicated and successful compost operations and that low quality compost and low prices negatively impacted the potential for private compost business to be successful. Tax supported compost facilities that sell low priced compost can also influence the chance for financial success of commercial operations.
- Compost from all six of the facilities was being used by gardeners or commercial crop producers including for nursery and greenhouse crops in containers (Morgan, Renewed Earth). All the compost producers were interested in evaluation of the quality of their compost for crop production.
- Sites used a variety of strategies to manage rain water runoff including sloped surfaces that drained to a collection pond. None of the facilities had structures to cover piles or used blankets to cover piles. All were comfortable that environmental and regulatory requirements were being met.
- During low rainfall periods the rate of composting can be limited by lack of moisture because most of the facilities did not have the capacity for adding water to piles.
- Strategies for managing potential odors included location away from residential areas and making large piles that are turned primarily in the winter when odors are less likely to be noticed.
- All locations reported that with piles over 6 to 8' tall and some to 10 to 12' tall that composting continued through the winter with internal pile temperatures in the 110-120$^{o}$F range.
- Four of the six facilities were primarily using bucket loaders for constructing, turning and moving piles. Most of the facilities were managing piles for minimal turns and longer production times of 12 to 24 months. An exception was Morgan Composting that used PTO driven windrow turners and turned windrows as often as multiple times a week so that the composting area was able to be filled and emptied twice per season. SOCRRA used a dedicated windrow turner. Fuel prices and equipment maintenance were a significant component of business cost and decision making.
- Morgan, Tuthill, Renewed Earth and SOCRRA were able to market all the compost produced each year and had markets for additional compost.
- Particle size reduction was accomplished either by grinding of feedstocks or frequent turning.
- Screening of product added significantly to the quality and value of the compost but screening equipment is very high cost to both purchase and maintain.
- Renewed Earth was using large hoophouse storage facilities to protect product and insure product availability during the winter months.
- Only Morgan composting was using worm composting and the primary purpose was for sale of bait worms and the production of worm compost for direct sale or use in potting soils. Estimated value of finished vermicompost was at $800 per ton. Production was in a heated building and fuel costs were significant.

**1C. Integrated Approaches of Food Residue Recycling.** Nothing additional to report. Meeting scheduled for January 16.

**1D. Anaerobic Digester Effluent.** Preliminary data reported in 2A below. Solids removal from research digester had not started.

**Objective 2. Use of Compost and Bailey GREENhouse for Culinary Herbs.**

**2A. Growing Methods Using Compost.**

*Compost in bulb crates.*

Two of the composts tested in this trial were prepared during the Fall of 2011 to measure the effect of using anaerobic digester food waste liquid effluent as an addition to plant based compost.

Table 4. Total Nutrient Analysis of Plant Based Compost with water or AD effluent.

| Compost | % OM | % C | C:N | N | P | K | Ca | Mg | Na | S | Fe | Zn | Mn | Cu | B | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 55 | 32 | 31 | 1.04 | 0.06 | 0.40 | 3.56 | 1.14 | 0.04 | 0.10 | 3514 | 13.5 | 115 | 5.0 | 7.5 | 996 |
| Digestate | 62 | 36 | 18 | 1.99 | 0.08 | 0.72 | 3.44 | 0.99 | 0.18 | 0.13 | 2815 | 26.5 | 121 | 14.5 | 11 | 934 |
| Dif | 7 | 4 | -13 | 0.96 | 0.02 | 0.33 | -0.13 | -0.15 | 0.14 | 0.04 | -699 | 13 | 6 | 10 | 4 | -62 |
| %Change | 13 | 13 | -42 | 92 | 25 | 82 | -4 | -13 | 400 | 37 | -20 | 96 | 5 | 190 | 47 | -6 |

The most important horticultural differences are in the near doubling of the nitrogen (N) and potassium (K) concentration. The difference in sodium (Na), zinc and copper are also large but not expected to significantly impact plant growth. The increase in total extractable sodium (Table 5 below) is likely due to the addition of salt to the food.

Table 5. Saturated Medium Extract Analysis of Plant Based Compost with water or AD effluent.

| Compost | pH | EC (mmhos) | NO3-N ppm | NH4-N ppm | P (ppm) | K (ppm) | Ca (ppm) | Mg (ppm) | Na (ppm) | Cl (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | 6.0 | 3.51 | 271 | 1.5 | 31 | 538 | 360 | 100 | 59 | 201 |
| Digestate | 6.3 | 7.03 | 416 | 244 | 56 | 1069 | 720 | 67 | 316 | 610 |
| Dif | 0.4 | 3.52 | 145 | 243 | 26 | 531 | 360 | -33 | 257 | 409 |
| %Change | 6 | 100 | 54 | 16167 | 84 | 99 | 100 | -33 | 436 | 204 |

The doubling of electrical conductivity (EC) or soluble salts, potassium and calcium are all likely very important and possibly related to the increase in basil growth reported below. The high concentration of ammonium nitrogen present when these samples were analyzed in January was likely not still present when the compost was used in June. Ammonium over 20 ppm would be considered toxic to plants.

Basil shoot tips were harvested on July 16, 20 and 30; August 7, 21, and 23; and September 7. Plants in all treatments were infected with basil downy mildew after the last harvest and quality quickly declined. Total basil yield is reported in Table 3. Compost 1 is approximately the compost used for Bailey GREENhouse. Nutrient analysis for compost 1, 3, 4, 5 and 6 are provided in Table 2. The addition of anaerobic digester (AD) liquid effluent to compost feed stocks increased the basil yield by over 60%. The use of polyethylene liners in the bulb crates had no detrimental effect due to lack of aeration and instead increased the yield by approximately 15%, presumably due to better water and nutrient recovery. At two pounds per crate and $16 per pound the crop value was $32 per crate over approximately 10 weeks.

Table 6. Cumulative basil yield from seven sequential harvests of shoot tips.

| Description | Compost | Pounds per Crate | Percent over Compost 1 |
|---|---|---|---|
| Mixed food waste compost (3 & 4 below) | 1 | 1.72 | 0.0 |
| Morgan Composting Box Mix | 2 | 1.95 | 13.6 |
| Food Waste Compost with no soil added | 3 | 1.77 | 3.0 |
| Food Waste Compost with Soil Added | 4 | 2.11 | 22.6 |
| Plant Based Compost made with water Fall 2011 | 5 | 1.76 | 2.1 |
| Plant Based Compost made with AD Effluent | 6 | 2.89 | 67.8 |
| Plant Based Compost made Summer 2011 | 7 | 1.72 | 0.0 |
| | average | 1.99 | |
| | | | |
| **Crate Liner Method** | **Liner** | **Pounds per Crate** | **Percent over Liner 1** |
| Newspaper | 1 | 1.76 | 0.0 |
| Black Woven Landscape Fabric | 2 | 1.86 | 5.9 |
| Grey Pressed Landscape Fabric | 3 | 1.79 | 2.0 |
| Black Polyethylene Film | 4 | 2.03 | 15.2 |
| Black Polyethylene Film with air holes | 5 | 2.01 | 14.2 |
| | average | 1.89 | 7.5 |
| | | | |

The bulb crates were replanted with parsley in late September and have been maintained in a minimally heated greenhouse. The first parsley harvest was on December 20. The plants are productive with no additional fertilizer and any of the liners other than newspaper resulted in a greater retention of root media and increased yield. The food waste compost without soil (#3) has lost more volume than the other composts.

*Raised beds with polyethylene liners.* Crops grew and yielded according to expectations, even in the shade of a large tree. Plastic lined beds showed no sign of saturation or flooding even after 2 to 3 inches of rain in a 7 to 10 day interval. Irrigation was simplified since leaching was not a concern. The status of the beds and crops following the winter will inform future research directions. Continued review of the literature and discussions with urban farmers supported the perception that no one was currently using or considering this technique and that additional research is justified.

*GREENhouse Growing Medium from Hot Compost.*
The compost prepared for the Bailey GREENhouse growing bed continued to decrease in volume as it was turned and aerated through the spring and early summer season. Based on the inputs and the high temperatures that were maintained during composting, there was a concern that nitrogen levels may be excessive for crop production without dilution. The organic matter content is high as expected, except for where the soil has been added resulting in a much higher bulk density (weight/volume). Based on the total nutrients present (Table 7), the nitrogen content was 1% N or less, which is on the low to moderate side and lower than expected for the inputs used.

Table 7. Organic Matter, Carbon (C), Carbon to Nitrogen (C:N), and Nitrogen Content of composts sampled in June and growing medium from Bailey GREENhouse in December (best to compare to sample 3, the mixture).

| Compost | Organic Matter (%) | C (%) | C:N | N (%) |
|---|---|---|---|---|
| 1. Food waste with no soil | 35.4 | 20.5 | 20.5 | 1.00 |
| 2.Food waste with soil | 13.5 | 7.8 | 13.5 | 0.58 |
| 3. Mixture of 1 and 2 | 21.2 | 12.3 | 14.6 | 0.84 |
| 4.Food waste /soil covered | 29.7 | 17.2 | 17.2 | 1.00 |
| Average | 25.0 | 14.5 | 16.5 | 0.86 |
| GREENhouse Medium Root Zone | 17.4 | 10.1 | 10.0 | 1.01 |
| GREENhouse Medium Top Layer | 18.3 | 10.6 | 11.3 | 0.94 |

Table 8. Total Nutrients by Ashing

| Hot Compost | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | Na (%) | S (%) | Fe (ppm) | Zn (ppm) | Mn (ppm) | Cu (ppm) | B (ppm) | Al (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Food waste with no soil | 1.00 | 0.35 | 0.69 | 2.40 | 0.89 | 0.13 | 0.16 | 7358 | 64 | 279 | 27 | 6 | 2814 |
| 2.Food waste with soil | 0.58 | 0.25 | 0.45 | 2.42 | 0.74 | 0.08 | 0.13 | 7102 | 62 | 302 | 27 | 4 | 4186 |
| 3. Mixture of 1 and 2 | 0.84 | 0.26 | 0.48 | 2.27 | 0.74 | 0.08 | 0.12 | 6359 | 54 | 249 | 24 | 4 | 3632 |
| 4.Food waste covered | 1.00 | 0.37 | 0.42 | 3.18 | 0.95 | 0.13 | 0.2 | 7540 | 67 | 280 | 26 | 5 | 3878 |
| Average | 0.86 | 0.31 | 0.51 | 2.57 | 0.83 | 0.11 | 0.15 | 7090 | 62 | 278 | 26 | 5 | 3628 |
| GREENhouse Root Zone | 1.01 | 0.23 | 0.24 | 2.74 | 0.73 | 0.04 | 0.11 | 1 | 61 | 273 | 30 | 8 | 3108 |
| GREENhouse Top Layer | 0.94 | 0.25 | 0.31 | 3.18 | 0.91 | 0.07 | 0.15 | 1 | 71 | 283 | 34 | 9 | 3413 |

However, based on the water soluble nutrients (Table 8), the soluble salts are well above the recommended range of 2 to 4 mmhos. The ammonium (NH4-N) above 5 ppm is an indication that the compost is still maturing. The nitrate (NO3-N) is well above the recommended range of 100 to 200 ppm. Based on these results, aged leaf mould compost was added at 10 to 15% by volume as the composts were mixed in an attempt to decrease the soluble nutrients and to increase the volume of compost. The compost was not planted for a month after mixing and placing in the beds.

Table 9. Saturated Medium Extract – water soluble nutrients

| Hot Compost | pH | Soluble Salts (mmhos) | $NO_3$-N (ppm) | $NH_4$-N (ppm) | P (ppm) | K (ppm) | Ca (ppm) | Mg (ppm) | Na (ppm) | Cl (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Food waste with no soil | 7.7 | 11.3 | 435 | 41 | 75 | 2062 | 1800 | 120 | 600 | 1387 |
| 2.Food waste with soil | 7.3 | 9.4 | 477 | 1 | 17 | 1604 | 1680 | 150 | 512 | 1000 |
| 3. Mixture of 1 and 2 | 7.8 | 9.4 | 287 | 72 | 70 | 1800 | 1560 | 135 | 496 | 1145 |
| 4.Food waste covered | 7.1 | 9.4 | 525 | 1 | 51 | 1303 | 1560 | 165 | 488 | 927 |
| Average | 7.5 | 9.8 | 431 | 29 | 53 | 1692 | 1650 | 143 | 524 | 1115 |
| GREENhouse Root Zone | 7.8 | 2.57 | 101 | 1.5 | 19.7 | 420 | 450 | 60 | 163 | 247 |
| GREENhouse Top Layer | 7.7 | 5.15 | 187 | 9.1 | 9.4 | 663 | 840 | 131 | 343 | 717 |

Two samples were collected from the Bailey GREENhouse growing beds in early December after fall growth had slowed or nearly stopped. One was for the top 1" layer of growing medium and the other was for the remaining root zone layer from 2 to 9" deep. The percent organic matter and carbon decreased. Some decrease is expected but there is no prior data to determine how much decrease to expect. The total nutrient concentration appears to have changed little except for potassium. The soluble salts, nitrate nitrogen, phosphorus, potassium, calcium, magnesium, sodium and chloride all decreased. It is possible but not likely based on the method of irrigation that some of the salts leached down out of the root zone due to irrigation. It is more reasonable to propose that nutrient uptake due to rapid plant shoot and root growth caused the decrease. Future analysis will be needed to determine how nutrient availability is maintained and what nutrient levels are needed for growth.

*Additional Compost for Future Research.* During early December several compost samples were piled and covered for maturation and for research during 2013. FPR and horse manure and paper bedding is completed and a sample was submitted for analysis. FRP and leaves and wood chips was still composting at around 100-110$^{o}$F. Two additional piles of FRP and wood chips were still composting but will be available by summer. A pile of municipal compost amended with hay and straw is also available. Each pile is in the range of 6 to 8 cubic yards so adequate to fill several raised beds.

**2B. Preparation of Culinary Herb Transplants and Herb Production.**

*Planning, Preparation and Propagation.* A minimum of 48 pots of each crop were planted with greater numbers for rosemary and oregano. Root growth was excellent in the compost and peat media. Vermicompost was top dressed as needed to maintain plant growth and leaf color. Irrigation occurred 3 to 4 times per week using a hose and breaker. Growth rate of the species was similar.

*Planting and Early Growth.* Italian basil (2 beds early, 2 more beds later) and parsley (2 beds curly and 2 beds Italian or flat) were the first to be planted and established quickly in the PSGH and compost. Basil growth was very rapid.

The woody perennial herbs (rosemary (2 beds), thyme (1 bed), oregano 2 beds), sage (1 bed), and lemon verbena (1 bed)) established quickly in the compost medium and growth resumed within a few days from planting. The deciduous perennial herbs (tarragon (1 bed), spearmint (1 bed), peppermint (1 bed) and chives (2 beds) were variable in establishment rate. The mints established quickly and became overgrown and infested with aphids. The nitrogen was likely too high. The tarragon and chives were slow to establish before becoming dormant for the winter.

*Harvest and Marketing.* Basil harvest was first and all other herbs were harvested in September. Quality of the herbs was initially very high. An infestation of aphids and some disease infection by botrytis were evident during October and November, possibly in part due to the rapid growth rates and high fertility of the compost growing medium. As of December 17$^{th}$ a total of 200 lbs of herbs were sold and totaled $3195. The amount of each herb sold is presented in Table 10. Three crops, basil, cilantro and parsley, accounted for 75% of the weight and 65% of the dollar value sold to Brody Market Place and the Kellogg Center. This is consistent with prior purchasing data. Sale of other culinary herbs such as chives, rosemary, thyme and oregano were in the $100 to $200 range. Microgreens and baby arugula were identified as additional crops that are purchased.

*Student Involvement and Impact.* Four students from the Environmental Studies / RISE program and with prior experience at the SOF were employed as the first members of the GREEN Team to assist with management of the the Bailey GREENhouse and the Wormhouse. In addition to work with growing and harvesting, the students were available to talk with and share the GREENhouse with fellow RISE students and other visitors. Quantifying the impact on the student experience must be an important objective of future efforts.

Table 11. Total herb sales for September through December for Brody Market Place and Kellogg Conference Center.

| Crop | Pounds Sold | % of total Pounds | $/pound sale price | Total Sales | % of total Sales |
|---|---|---|---|---|---|
| Basil | 34.65 | 16.6 | $16 | $554.40 | 18.1 |
| Chives | 5.89 | 2.8 | $16 | $94.24 | 3.1 |
| Cilantro | 46.82 | 22.4 | $12 | $561.84 | 18.3 |
| Dill | 2.02 | 1.0 | $20 | $40.40 | 1.3 |
| Lemon Verbena | 4.41 | 2.1 | $24 | $105.84 | 3.5 |
| Microgreen | 3 | 1.4 | $48 | $142.08 | 4.6 |
| Oregano | 6.21 | 3.0 | $20 | $124.20 | 4.1 |
| Parsley | 74.06 | 35.5 | $12 | $888.72 | 29.0 |
| Pea Shoots | 1.48 | 0.7 | $48 | $71.04 | 2.3 |
| Peppermint | 0.29 | 0.1 | $16 | $4.64 | 0.2 |
| Rosemary | 8.74 | 4.2 | $20 | $174.80 | 5.7 |
| Sage | 0 | 0 | $16 | 0 | 0 |
| Salad Mix | 10.92 | 5.2 | $8 | $87.36 | 2.9 |
| Spearmint | 1.35 | 0.6 | $16 | $21.60 | 0.7 |
| Sunflower Shoots | 0.56 | 0.3 | $48 | $26.88 | 0.9 |
| Thyme | 8.27 | 4.0 | $20 | $165.40 | 5.4 |
| **TOTAL** | **208.63** | **100.0** | | **$3,063.44** | **100.0** |

**2C. Educational Materials and Signage**

A total of 20 groups of 3 to 5 students presented concepts and ideas for compost piles in oral power point presentations and written reports. The students demonstrated strong interest in developing actual outdoor composting at the Bailey GREENhouse site.

**2D. Compost screening and sales**

Screening from the six south small compost beds provided 50 five gallon buckets of screened compost and a smaller amount that did not pass through the screen. Screening from the large main bed from composting in 2011 and early 2012 resulted in 55 five gallon buckets of screened compost.

SOF farm stand sold 60 2-pound bags of vermicompst at $5 per bag for a total of $300. RSS sold 169 pounds for $354 from September through December. Total 2012 sales were $654.

There was little emphasis on marketing or advertising the vermicompost during 2012 since the production capacity and availability of material did not increase to the desired level until the end of 2012. The supply of compost will allow a greater emphasis on marketing during 2013 and a test of the size or the market or potential demand for the product. Nutrient analysis data will be used to support advertising and marketing at the RSS for the spring gardening season. A recommendation for future efforts is to install display raised bed gardens at the RSS to encourage sales.

**2E. Presentation at National Vermicomposting Conference.**

John Biernbaum and Brendan Sinclair attended the 13 annual National Vermicomposting Conference hosted by North Carolina State University at Chapel Hill North Carolina on November 4 and 5. Conference attendance was up from the normal 60 to 80 participants to 120 participants. Approximately 85-90% of the participants were using small scale vermicomposting methods similar to those used for our research at the SOF (less than 500 square feet of surface area) and most were new to vermicomposting or in business for 2 to 3 years or less. A Power Point slide presentation and a printed handout were prepared for the conference and other presentations. John Biernbaum made a 60 minute presentation with 110 power point images and slides followed by close to 30 minutes of questions and discussion.

## IV. Conclusions and Recommendations

The project and research have been successful in several respects.

1. Approximately 96,000 lbs or 48 tons of KPR was delivered by RSS staff for either vermicomposting or hot composting at the SOF Worm-house. Over 32 weeks with 3 deliveries per week the average delivery was 1000 pounds or about 1 cubic yard. The estimated landfill and transportation savings is at least $3000. Continued delivery to the SOF is planned for 2013.
2. Based on a second full year of vermicomposting research in a passive solar greenhouse, several viable methods have been identified. While feeding is reduced due to low temperatures in the winter months, KPR can be hot composted and fed when worm activity increases. A future recommendation is to compare winter and summer worm composting in an unheated building on a cement floor with the PSGH and to compare a mobile polyethylene film covered structure with a mobile corrugated steel sheet covered structure. Such research would provide a greater range of options for farmers and other FPR composters.
3. With the establishment of a kitchen food preparation residue composting program at the Student Organic Farm, students can be directly engaged in waste reduction and resource recovery strategies related to their campus food system. A key to long term sustainability is having a person in a staff position that can work with students on either a regular or an irregular schedule.
4. With the establishment of a unique PSGH worm composting research facility there is the potential for future research that can address important industry needs including:
   - Small scale worm raising and worm composting methods suitable for worm farms and composting operations or diversified farms.
   - Relationship of compost feedstocks and methods to worm compost output and quality.
   - Effect of specific KPR components such as coffee grounds or pineapple skins on the pH of the worm composting bed and feeding activity of the worms.
   - Continued study of methods and protocols for vermicomposting acceptable for organic systems plans.
   - Study of outdoor protected vermicomposting methods suitable for cold climates.
   - Connection of the compost production to ornamental and food crop production that highlights the cycling of nutrients and organic matter.
   - A lab based evaluation of the temperature response curve of KPR composting without and with worms over the range of $35^{o}$F to $95^{o}$F by $10^{o}$F increments. Understanding the temperature response curve can identify critical points were the rate of composting could be increased with external heat sources.
5. With the establishment of organic culinary herb production in a PSGH in the Brody Neighborhood, students can be involved in herb production, harvesting and processing that provides a daily connection to sustainable food production in an urban setting. Such connections can improve the undergraduate experience.
6. Important recommendations for future activities include the addition of new opportunities to engage more students such as:
   - Hot composting demonstration and education. (In development with RISE.)

- Vermicomposting demonstration and education. (In development with RISE.)
- Outdoor raised bed production of culinary, tea and fragrance herbs.
- Green roof production systems for culinary herbs and vegetables.
- Production, harvesting and processing of herbs for teas and herbal fragrance pillows.

7. Recommendation that as the Bailey GREENhouse site is further developed with incorporation of the wider diversity of projects, that the site be developed as an "Urban Farming" site that addresses garden and farming issues common in Michigan cities including access to land, water and light and the use of raised beds for plant production.
8. Additional work is necessary with the RSS staff in regards to education about worm composting and the value of worm compost. The classroom at the RSS provides an ideal venue for on campus and off campus audiences interested in vermicomposting. Raised bed production systems can be demonstrated as a classroom activity and on the grounds of the RSS to stimulate community engagement. The RSS staff has indicated strong desire to move forward with community education.
9. The three locations – 1) the Bailey GREENhouse and proposed "Urban Farm" in the Brody Neighborhood, 2) the Recycling and Surplus Store and 3) the Student Organic Farm and the Wormhouse provide a unique campus partnership that can continue to grow and be a national model of student engagement with food production, composting and other aspects of the food cycle loop.

## V. References


Biernbaum, J. 2012. Making and Using Worm Compost: Soil Fertility and Biology for Small Scale Intensive Organic Farming in Rural or Urban Settings. 20 page handout

Biernbaum, Power Point Presentation. Closing the Food Cycle Loop.

**Books Purchased as reference materials:**

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- Beyond Compost: Converting Organic Waste Beyond Compost Using Worms. 2009. Tom Wilkinson. Create Space Independent Publishing Platform. 116 pgs
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