DEVELOPMENT OF A BIOLOGICALLY-INTEGRATED FOOD-WASTE COMPOSTING SYSTEM

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Introduction

Sustainable agriculture and food systems depend upon the efficient use and recycling of nutrients in order to minimize dependence on non-renewable resources - such as fossil fuels and mined minerals - and to prevent contamination of ground and surface waters. Yet, as modern food systems continue to industrialize and globalize, environmentally sound nutrient cycling becomes increasingly difficult because of the massive scale and concentration of agricultural production enterprises, food processing facilities, distribution systems, and food service institutions. According to a recent analysis by the US Department of Agriculture, over one quarter of the total edible food in the US is lost to human use each year during the retail, food service, and consumer stages of the food system, resulting in nearly 100 billion pounds of waste (Kantor et al. 1997). Currently, most of this food either ends up directly in landfills as solid waste or finds its way there indirectly as sewage sludge (Gardener 1998). Changes in waste management systems must be instituted in order to turn food "waste" into a resource.

Innovative approaches to handling, processing, and re-routing these wastes can contribute significantly to reducing the waste stream into landfills (Vossen et al. 1999). Moreover, recycling these wastes back to cropland after proper processing can enhance soil fertility and reduce dependence on manufactured fertilizer, resulting in substantial energy savings. Processing food wastes through composting or digestion can also be used to generate energy that would otherwise need to be generated with fossil fuels.

The goal of this project was to develop a biologically-integrated food-waste composting system at Berea College, a small liberal arts institution in eastern Kentucky.

Food Waste at Berea College

The Berea College food service facility feeds about 1200 students during the fall and spring semesters and about 200 during the summer session. Both pre-consumer and post-consumer waste is generated during the process. Pre-consumer waste includes all foods prepared but not distributed to the students while post-consumer waste is all that remains on the plates when they are returned for washing. In previous years both of these waste streams ultimately flowed to the landfill as sewage sludge because all organic waste was disposed down the drain.

In the fall of 1998 students from the Department of Agriculture and Natural Resources of Berea College began a program to collect all pre-consumer waste from the kitchen and use it at the nearby greenhouse and garden area. Two 40-gallon, plastic buckets were placed in the kitchen – one in the preparation area and one next to the washing sink. Kitchen workers were asked to put all food waste in the buckets while trying to minimize the amount of non-organic waste such as plastic wrappers and gloves. Each day the buckets were collected, emptied at the greenhouse, washed, and returned to the kitchen. Because the greenhouse and garden area is located only about 200 yards from the food-service kitchen the buckets could usually be carted without the use of a motor vehicle, saving additional fossil fuels. This food-waste collection system has continued, more or less uninterrupted, since October, 1998.

The estimated amount of pre-consumer food waste generated per capita at Berea College is about one quarter pound per day. Over the course of a year this yields over 30 tons (wet weight) from the facility. Of course, not all of this waste consists of potentially edible food. Peelings, seeds, and bruised or spoiled produce typically comprise a significant portion of the waste collected. However, considerable amounts of grain products, such as bread, pasta, and rice, that are prepared but not distributed to students are found in the waste. (Post-consumer waste per capita is estimated to be at least as large, if not larger, than the pre-consumer waste.)

Comparing this estimate to food-waste data presented by the Economic Research Service of the US Department of Agriculture puts the value into some perspective. According to Kantor et al. (1997) the average American consumes about three pounds and wastes about one pound of food each day. Considering the fact that post-consumer food waste is not collected in this pilot project, the amount of food waste generated at Berea College appears to be comparable to or slightly higher than the national average. Data on post-consumer waste, as well as estimates from other college and university food services, are necessary before making definitive conclusions.

Processing and Composting the Waste

Once the food waste is collected it has a number of potential uses in the greenhouse and garden area including: 1) a feed for micro-livestock (chickens, ducks, and geese); 2) a raw material for composting high in nitrogen (N) and water; 3) a source of heat in a greenhouse during the composting process; and 4) a soil amendment or potting mix substitute after the composting process. During the warmer months of the year the food waste is either fed to poultry or composted outside. For composting, the food waste is mixed with dry materials that are high in carbon (C) such as straw, wood shavings, or landscape wastes from campus. During the colder months the operation is moved into an experimental glass greenhouse where the heat generated during the composting process, as well as that produced metabolically by the poultry, is used to heat the greenhouse for seed germination and transplant production (Fig. 1).

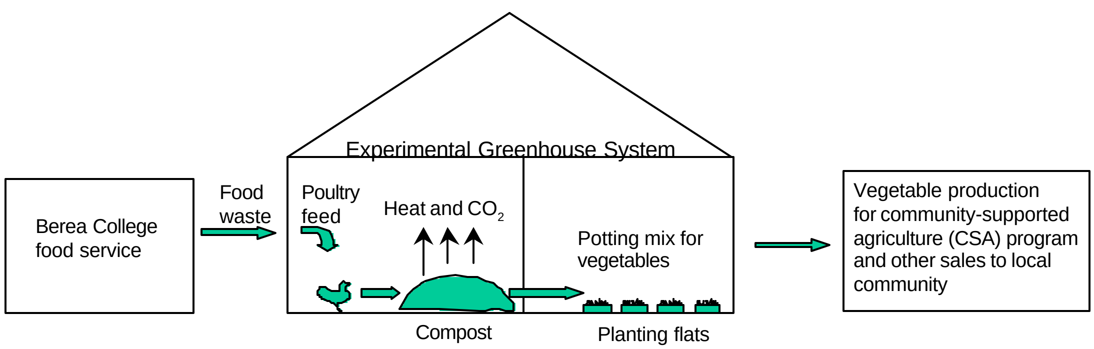


Figure 1. Food waste composting system at Berea College during the colder months.

Composting is an aerobic process in which microorganisms break down raw feedstocks to produce a stable organic material containing nutrients essential for plant growth. Depending upon the amount of food waste collected it takes 2-3 weeks to build a pile that is sufficiently large to allow the composting process to take place. Each day the food waste is layered with straw or wood shavings. Once the piles are 5-7 feet wide at the base and 2-3 feet high, the temperatures are monitored and the piles turned as necessary in order to reach and maintain temperatures of 150°F or more for several weeks. Water is added as needed during the process but the food waste usually contains adequate moisture to reach the high temperatures. After the heating period the piles are allowed to cool and cure for several months with occasional turning and watering.

During the winter, when the composting operation is situated in the experimental greenhouse, metal-mesh tables are placed over the piles. Flats are then set on the tables to promote germination and seedling growth of vegetables and ornamentals with minimal use of heat from natural gas (Fig. 2). A back-up heating system using natural gas was set to operate when the temperature dropped to 32°F (0°C).

Energy Savings

In order to estimate the amount of energy savings resulting from the use of compost-generated heat, natural gas use was compared during the 1998-1999 winter season between the experimental greenhouse and an adjacent greenhouse that used natural gas solely (control). The thermostats of both greenhouses were set at 65°F (18°C) from October through December allowing for the comparison of relative fuel-use efficiency. During this period (prior to the composting experiment) the experimental greenhouse used 20% less fuel than the control. Thus, it was assumed that this trend would continue throughout the winter and that the experimental greenhouse should use only 80% of the fuel used by the control. However, following the initiation of the composting operation in the experimental greenhouse in mid-January, fuel use in the experimental greenhouse was less than 5% of that in the control (Fig. 2).

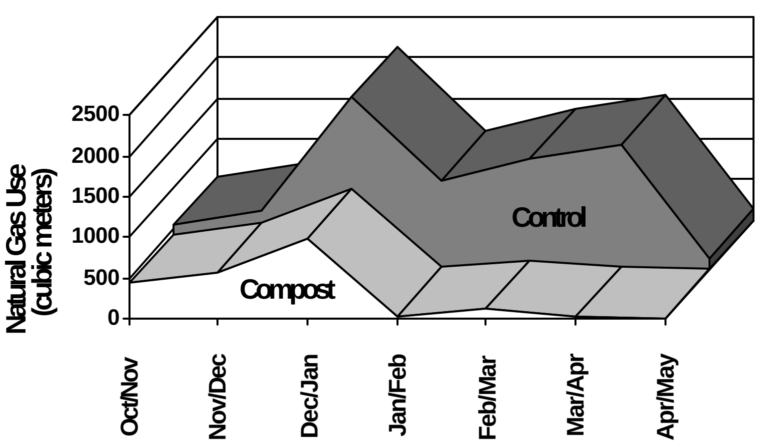


Figure 2. Natural gas use during the 1998-1999 winter in the experimental greenhouse heated by composting (compost) and the adjacent greenhouse heated with natural gas fuel (control). The composting operation in the experimental greenhouse began in mid-January, 1999.

The thermostat in the experimental greenhouse was set at 32°F (0°C) to prevent snow or ice accumulation on the glass or frost formation on the plants while the composting experiment was in progress (mid-January through early May). During this period the experimental greenhouse used only 136 m^3 of natural gas while the control greenhouse used over 4000 m^3. Air temperatures in the experimental greenhouse often dropped to near freezing, especially at sunrise, but soil temperatures in the flats on tables above the active compost piles could be maintained high enough for rapid seed germination (Fig. 3). And once germination had occurred the plants could tolerate air temperatures just above freezing.

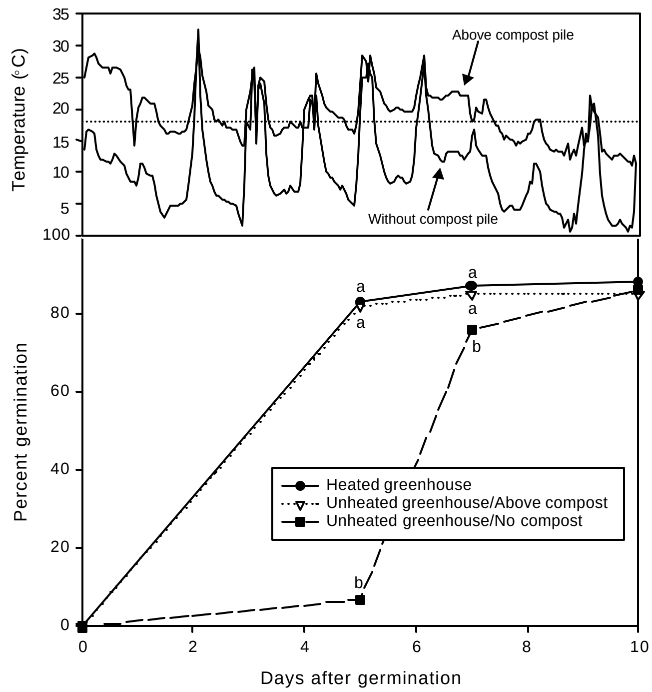


Figure 3. Temperature at the soil surface (top graph) and percent germination of lettuce (bottom graph) in flats on tables above and not above active compost piles in the experimental greenhouse. Lettuce germination rates in the adjacent heated greenhouse (maintained at or above 65°F or 18°C – see dotted line in top graph) were also tested at the same time for comparison. Soil surface temperatures in the flats above the compost piles rarely fell below 60°F or 15°C and cumulative percent germination was nearly identical to that in the heated greenhouse. By contrast, nighttime temperatures on the soil surface of flats not above compost piles were typically 18°F (10°C) less than those above the piles. N = 5 replicates for the three treatments; ANOVA and Student-Newman-Keuls test for mean separation, $P \leq 0.05$.

Using the Compost

The compost produced in this experimental system has been used as a soil amendment to build fertility in the garden area around the greenhouse and as a partial substitute for purchased commercial potting mix for starting vegetable transplants. The nutrient composition is comparable to commercial composts on the market (Table 1). Based on the estimated amounts of food waste generated at Berea College, the compost produced (≈5 tons per year) should be adequate to replace all nutrients currently exported from the gardens as vegetables, fruits, and flowers – thus eliminating the need to purchase manure, compost, or fertilizer.

Table 1. Nutrient composition of finished compost (on a dry-weight basis) produced from Berea College pre-consumer, food-service waste, 1998-1999.

Element	Content (%)	Pounds of Nutrients / Ton
Nitrogen (N)	2.38	47.6
Phosphorus (P)	0.62	12.4
Potassium (K)	1.13	22.6
Sulfur (S)	0.40	8.0
Magnesium (Mg)	0.48	9.6
Calcium (Ca)	3.66	73.2

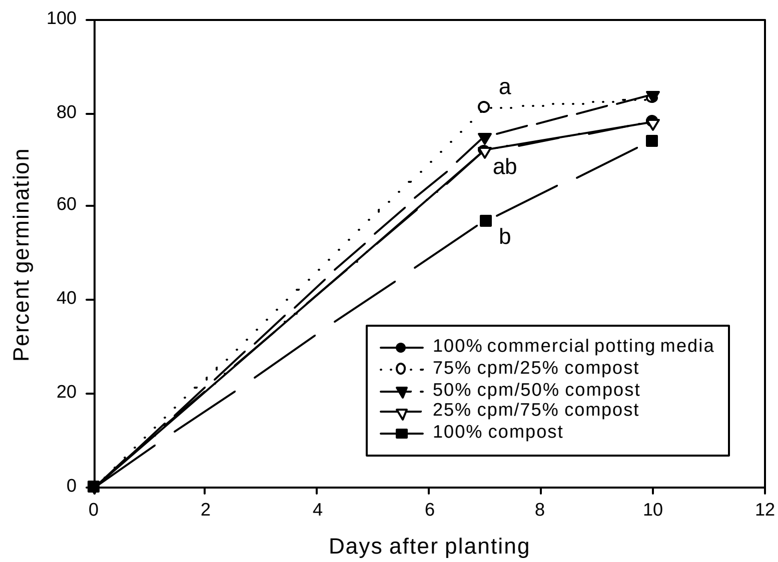
The finished compost was evaluated as a partial and full substitute for commercial potting mix in two replicated trials using lettuce as the crop. The first trial evaluated the relative effects of five "soil" treatments, representing different mixtures of commercial potting mix and compost, on the germination and growth of lettuce (Green Bibb) (Fig. 4). The results demonstrated that mixtures up to 75% compost had no significant effect on percent germination or germination rates but that 100% compost resulted in slower germination. However, lettuce growth, measured as leaf lengths 36 days after planting, showed that any amount of compost substituted for the commercial potting mix improved growth. Moreover, the treatment with 75% compost and 25% commercial potting mix demonstrated the fastest growth over the 36-day period.

In the second trial only three treatments were assessed and 'Red Romaine' was used as the test-lettuce variety (Fig. 5). This trial also demonstrated that the use of 100% compost resulted in slower germination than either a potting mix-compost mixture or 100% potting mix. Further, it demonstrated that a 50%/50% mixture of commercial potting mix and compost or the use of 100% compost resulted in faster lettuce growth, measured 37 days after planting.

Overall, these trials indicate that the use of 100% compost as a potting mix substitute will result in slower, and perhaps slightly lower, germination due to variable texture, which apparently leads to inconsistent soil-to-seed contact or uneven wetting. However, as a media for plant growth, the compost is superior to the commercial potting mix. Substituting compost for 50-75% of commercial potting mix should result in improved plant growth without reductions in percent germination or germination rates.

Economics

The economics of collecting, composting, and using the food waste from Berea College food service was initially assessed based on costs of acquiring and processing the waste and the value of the nutrients obtained. The costs included labor paid at $7.00 per hour and equipment (40-gallon, plastic buckets, dolly, and pitch fork) depreciated over 5 years. The value was determined based on plant-macronutrient content (nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium) with all macronutrients assumed to have equal value. Because much of the food waste was wheat-based (bread and pasta) it was assumed that the dry weight of the waste had the nutrient composition of wheat. It was also assumed that one-third of the nitrogen would be lost during the composting process; thus, this amount was subtracted from the estimated total nutrient content.



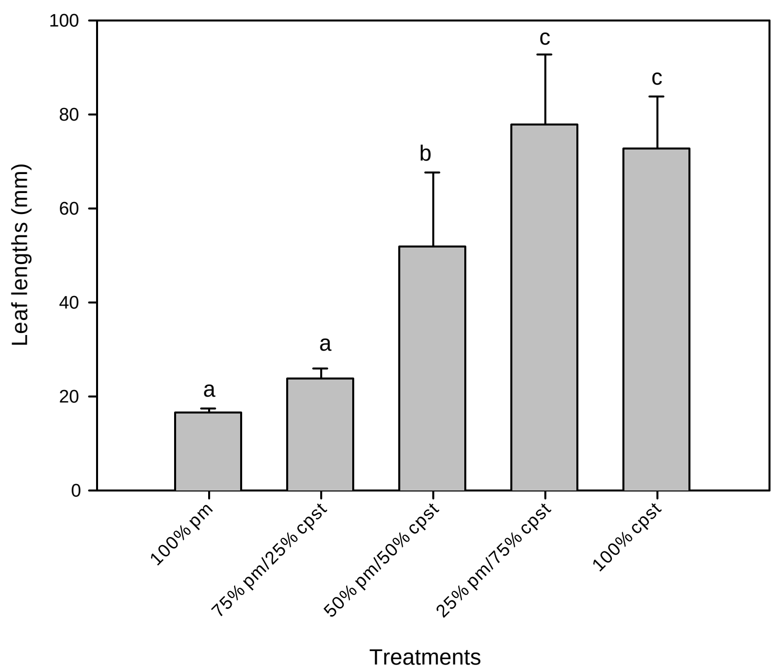
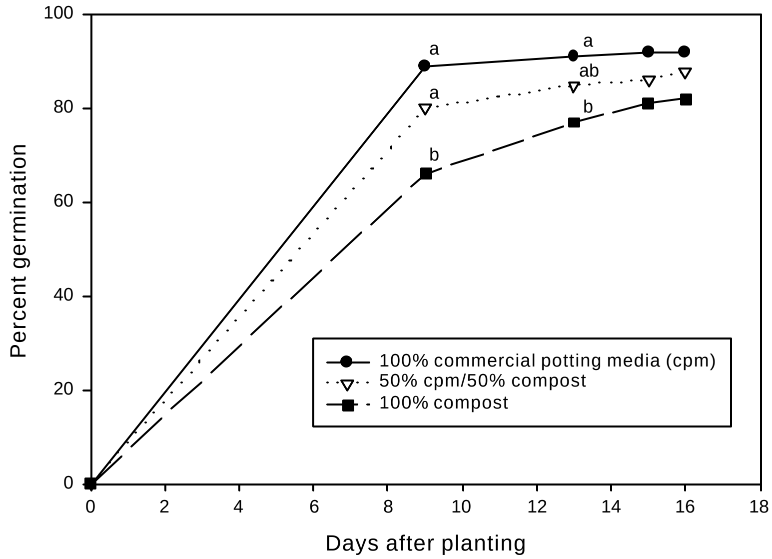


Figure 4. Percent germination (top graph) and plant growth based on leaf lengths (bottom graph) of lettuce (Green Bibb) grown in mixtures of commercial potting mix (pm) and compost (cpst) made of food waste from Berea College food service. Leaf lengths were measured 36 days after planting. N = 5 replicates for the 5 treatments; ANOVA on ranks and Student-Newman-Keuls test for mean separation, $P \leq 0.05$.



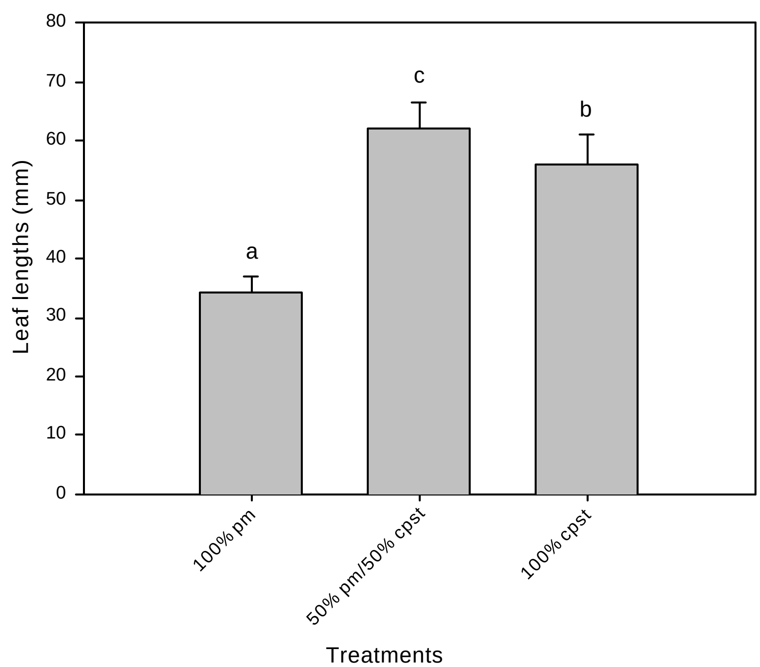


Figure 5. Percent germination (top graph) and plant growth based on leaf lengths (bottom graph) of lettuce (Red Romaine) grown in mixtures of commercial potting mix (pm) and compost (cpst) made of food waste from Berea College food service. Leaf lengths were measured 37 days after planting. N = 5 replicates for the three treatments; ANOVA and Student-Newman-Keuls test for mean separation, $P \leq 0.05$.

The estimated cost for the plant macronutrients collected was $1.76 per pound. This compared favorably with the costs of plant macronutrients in commercially available composts, which ranged from $2.00 to over $4.00 per pound. If the savings in natural gas use are factored into the equation the cost-benefit analysis for the collection, composting, and use of the food waste is extremely favorable. The use of the compost heating system in the experimental greenhouse saved over $900 in fuel costs from mid-January to early May. This exceeds the total food-waste collection costs for an entire year by over $100. Thus, the collection of the food-waste as a source of plant nutrients is essentially free when the savings in natural gas use are considered. Additional benefits not factored into this analysis include the improvements to soil tilth from compost applications and the reduction in solid waste generation from Berea College.

References

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