Low Technology Institute
Occasional Papers

Full-Circle Composting

Getting More than Just Fertilizer

№ 1

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A compost pile has been a ubiquitous part of the food system since we first domesticated plants, but we're missing out if we just use the finished material for fertilizer. Composting is a complex biological process that creates almost everything a plant needs to thrive: heat, moisture, nutrients, and carbon dioxide—the only thing missing is sunlight. We recently concluded a study that tested systems to capture and redirect these resources into grow beds directly from the compost pile. Although we hit a number of roadblocks, this full-circle composting idea has potential for those interested in growing more food in cooler climates and shoulder seasons.

The Concept

A long time ago (the 1980s) in a land far, far away (Cape Cod), the New Alchemy Institute (NAI) researched ways to live with less reliance on fossil fuels and outside inputs. They pioneered bioshelters and aquaponics before these were well known in alternative sustainability circles. They also created a composting greenhouse, which tested the premise that all of the products of compost could be used to grow plants through the winter.

Greenhouses (more technically "hothouses") have been heated by compost for hundreds of years, as mentioned in a 1693 English translation of a French gardening manual, for example (de la Quintine 1693:2:193). At the time, they would have recognized that the moisture from the compost was also beneficial for the plants, but they would not have known that the carbon dioxide off-gassing from the pile was also helping their growth until at least the 1800s. Eventually the advent of cheap and ready fossil fuels supplanted the more labor-intensive compost heat.

At the New Alchemy Institute, they recognized that they could create a system to

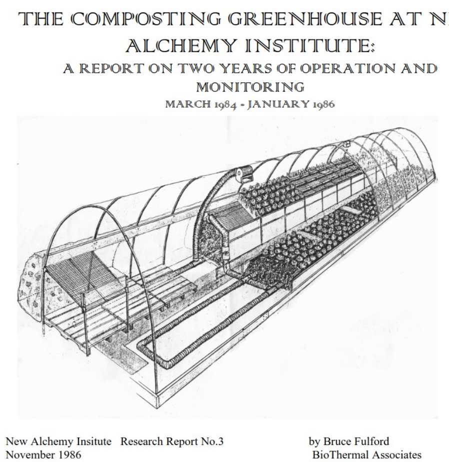


Figure 1: Composting greenhouse from New Alchemy Institute (NAI 1986:Frontispiece).

both compost large volumes of manure and capture all the beneficial products of that process to grow plants through the winter. The heart of their system was what is called today an aerated static pile (ASP). This type of composting set-up consists of a sealed bin with a perforated pipe below it (technically known as an "in-vessel bioreactor"). A blower pushes fresh air into the pile from the pipe (i.e., aerates it), feeding the composting microorganisms with fresh oxygen without needing to turn the compost (i.e., a static pile). Meso- and thermophilic (heat-loving) bacteria use that oxygen to break down organic compounds to create heat, carbon dioxide, water vapor, and nitrogen (although it is a more complex biological process, it is essentially: various CHO and N compounds + O_2 → nitrogen compounds (NH_3, NH_4^+, NO_2^-, NO_3^-) + CO_2 + H_2O + heat). With the fresh air coming in, the off-gasses must go out, and

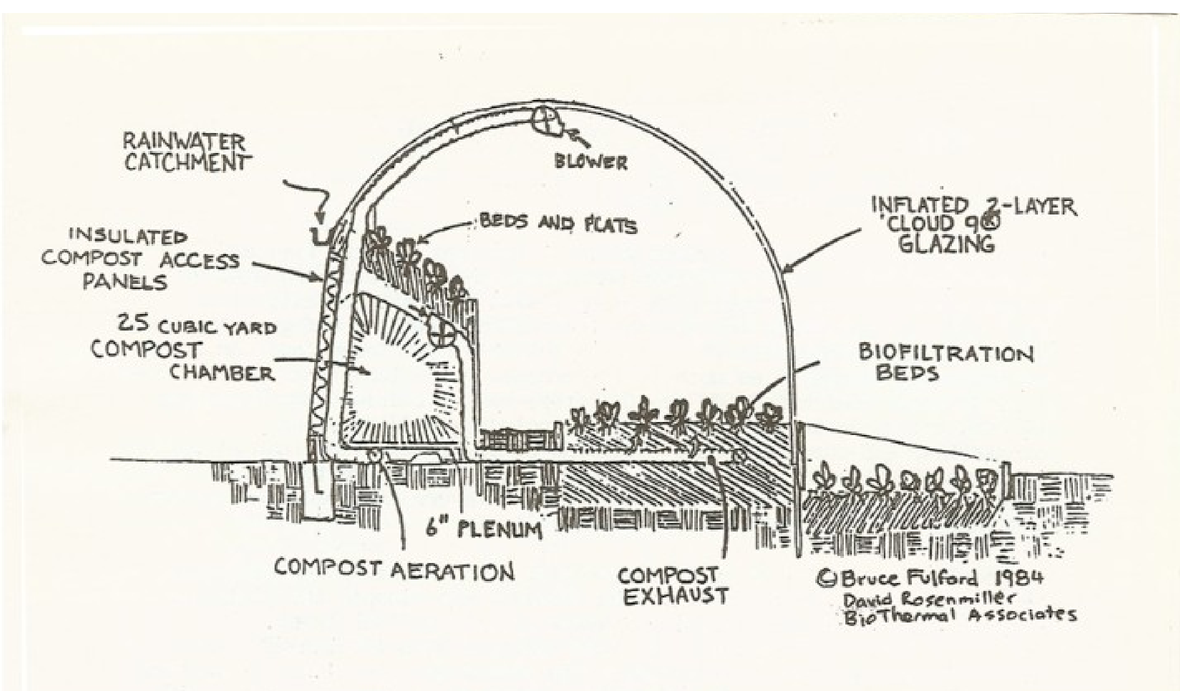


Figure 2: NAI greenhouse cross section (from NAI 1986: Figure 2).

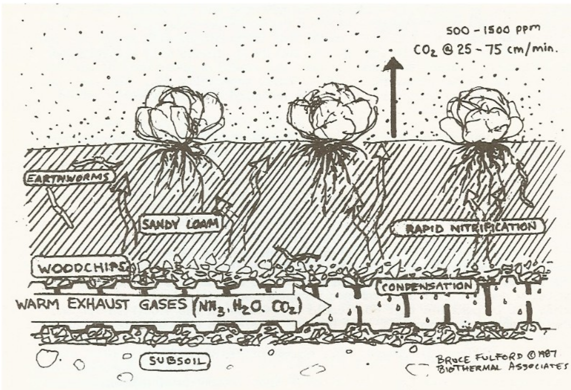


Figure 3: Biofilter cross-section (NAI 1986: Figure 5)

they do so through vents into woodchip beds. The shredded wood creates a biofilter by both providing carbon and an environment for bacteria that convert harmful nitrites and ammonia into plant-absorbable nitrates.

The greenhouse at NAI was custom built for this system. The 12-×-48-ft hoop house was oriented from east to west and had a 25-cubic-yard composting chamber along its north side. On top of the wood-framed, sealed chamber was a grow bed, consisting of 18 inches of woodchips under sandy loam supported by hardware cloth. As the compost chamber was filled with manure from nearby stables, blower motors pushed 12,000 cubic feet of air through the system each day (running 15 minutes every 6 hours). Much of the off-gasses went into the bed above the chamber, but another grow bed on the south half of the greenhouse was fed with underground distribution pipes and dedicated blowers. In the winters, they grew leafy greens and started seeds in this greenhouse and filled the space with cucurbits, peppers, and other heat-loving crops in the summer. The entire setup and details for their research project can be found in their third research report on their website: newalchemists.net/.

Our Study

In the spring of 2021, I began a study on a modular, scaled-down version of this composting system at the Low Technology Institute (LTI)—we called it the "hot box composting system." Imagine a cube measuring 4 ft on each side. On top of the cube is a rich bed in which edible greens are growing. The soil is watered and fertilized from below, plus carbon dioxide seeps up from the soil. The grow bed is warm, even though this box is in an uninsulated greenhouse. Inside the box is a cubic yard of compost, waiting for use in the spring. The whole thing is built on a pallet so a market gardener could move it in and out of a greenhouse as the seasons change. This was the initial idea of hot box composting.

I built and tested two different designs that summer. I cut and gathered composting feedstock, varying the size, assortment, air volume, and other variables to find what worked best. By the winter I had found a steady source of horse manure and built a small greenhouse to test the boxes over the winter. I quickly learned that a cubic yard was too small to reach critical mass for heat to build up and composting to take place

HOT BOX COMPOSTING DIAGRAM

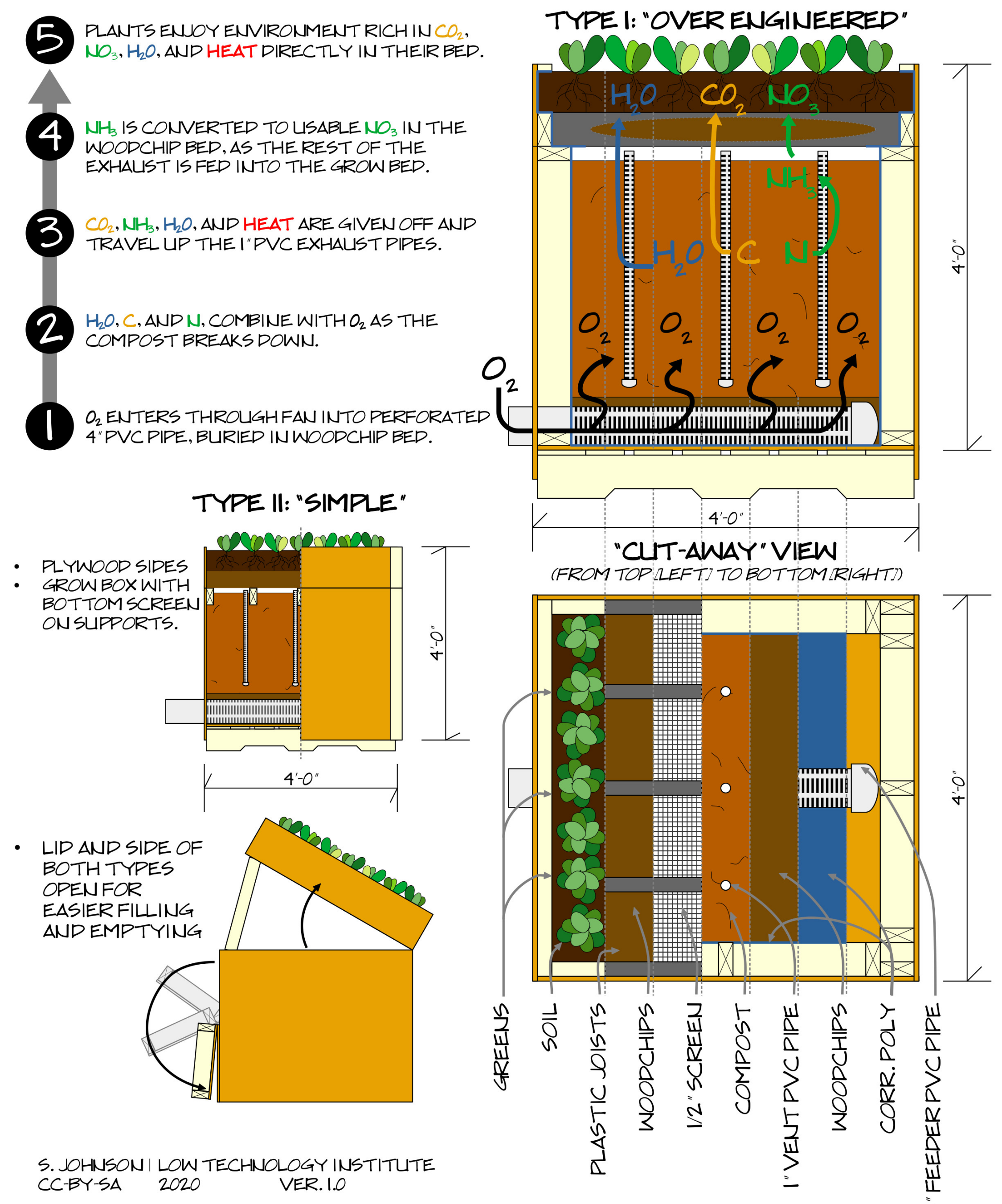


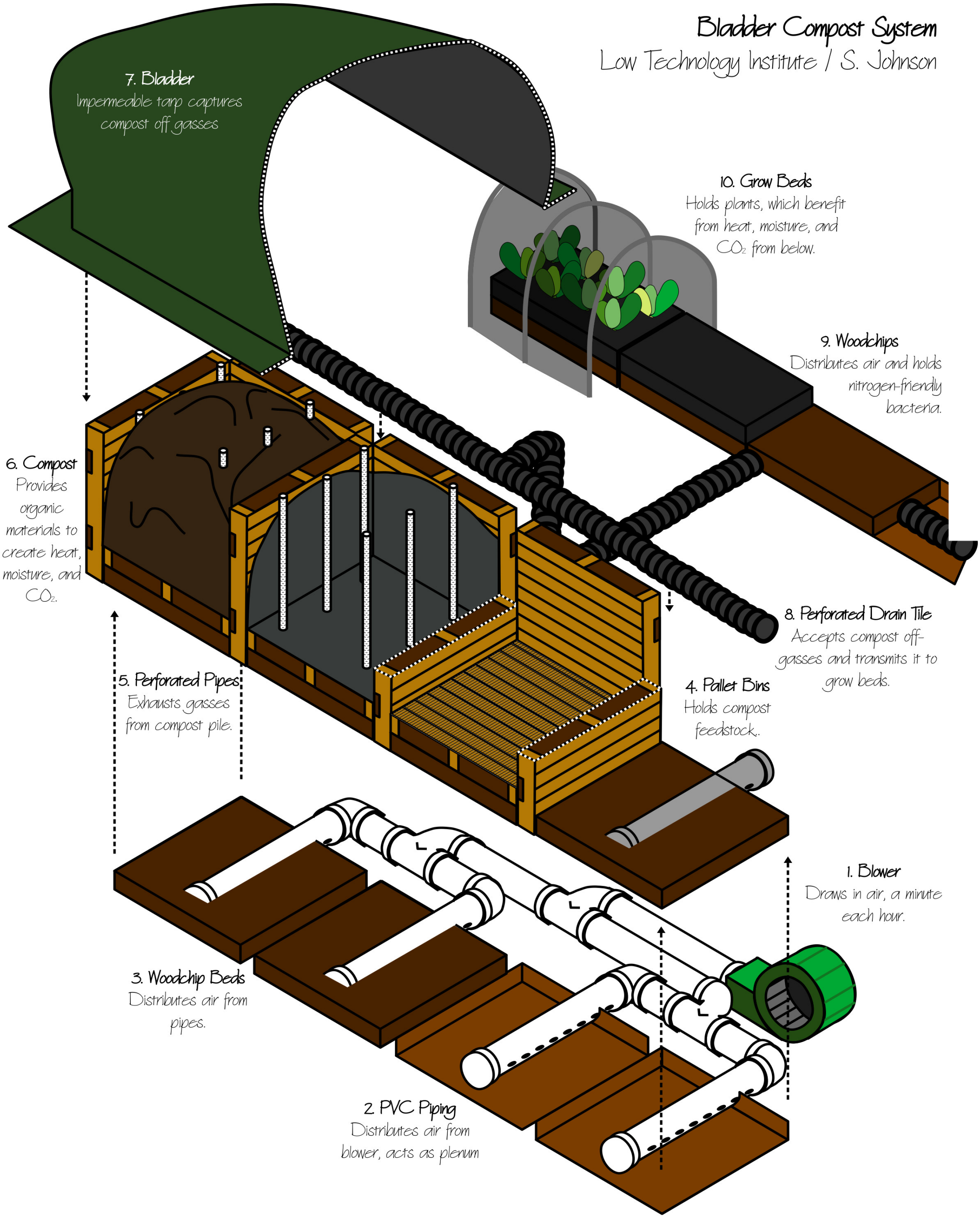
Figure 4: Loading and unloading the compost boxes.

in the winter. I tried adding boiling water, changing the air intake settings, and adding gallons of urine to jump start it—all to no avail. Additionally, the boxes were difficult to manipulate: the heavy box lid was a struggle to lift and prop open, and emptying the finished compost was cumbersome with only a portion of the front face opening up. Not to mention, they required an upfront investment of time and money to make. I decided to scrap this design and start again from the bottom up.

My new idea was to create a simple compost set-up with bays and forced air floors, and then cover the whole thing with a tarp to trap the carbon dioxide, heat, and moisture to be pumped under an adjacent bed. This set-up could still be modular and dismantled each summer for growers with limited hoop house real estate. Not only would this be easier to unload and reload each week, but it would be cheaper, because it would only need a dozen pallets, some hardware cloth, PVC pipe, a blower, wood chips, and a big tarp.

I built a four-bay test unit in the spring of ’22 and ran it through the summer, continuing to feed a yard of horse manure and bedding each week from our neighbors. This system functioned much easier than the bins: the trailer could be backed right up to the installation, the bins were easy to access with a shovel, the bladder helped distribute the moisture among the bins. The most challenging part was pinning down the tarp to avoid "blowouts," where the moist, warm, carbon-dioxide-rich air would escape under an edge of the tarp due to pressure. Two solutions worked well: using stakes pounded into the tarp, covered with logs and composted manure to seal it; and changing the blower to a shorter bursts of air more often to get the same amount of fresh air as longer, more infrequent runs.

By the fall of 2022, I was ready to install this into the hoop house of our collaborator, Terry at Parisi Family Farms. We installed the four-bin system with an attached grow bed and began to fill it each week with a yard of manure and bedding. Every week we also added 5-10 gallons of water to each bin to avoid them drying out. Throughout the entire series of tests, I measured the temperature, humidity, carbon dioxide, methane, ammonia, and nitrogen output of the system.



Bladder Compost System
Low Technology Institute / S. Johnson
7. Bladder
Impermeable tarp captures compost off gasses
10. Grow Beds
Holds plants, which benefit from heat, moisture, and CO2 from below.
9. Woodchips
Distributes air and holds nitrogen-friendly bacteria.
6. Compost
Provides organic materials to create heat, moisture, and CO2.
8. Perforated Drain Tile
Accepts compost off-gasses and transmits it to grow beds.
5. Perforated Pipes
Exhausts gasses from compost pile.
4. Pallet Bins
Holds compost feedstock..
1. Blower
Draws in air, a minute each hour.
3. Woodchip Beds
Distributes air from pipes.
2. PVC Piping
Distributes air from blower, acts as plenum

Results and Analysis

The data show that we were composting really well, but having trouble capturing all the benefits from this modular set-up. Even though our digital temperature and humidity recorders died after being enclosed in the system, our back-up data gathered by hand with an analog compost thermometer showed the classic compost temperature curve: ambient temperature at loading, quickly heating up to 160°F for a few weeks before slowly dropping down to 120°F four or five weeks later when it was ready to be unloaded. This meant that the bacteria were getting enough oxygen through our forced-air system. That was further shown by the absolute lack of ammonia or methane, as tested by a gas monitor, checked each week: these potent greenhouse gasses are only produced in anaerobic conditions. The nitrogen was going somewhere, as a laboratory analysis told us our manure was coming out as a 0.4–0.3–0.4 fertilizer with no volatile (uncomposted, easily evaporated) nitrogen compounds. Humidity and carbon dioxide production were literally off the charts, as inside the bladder was a constant 99 percent humidity and more than the 10,000 ppm CO_2 that our monitor could read (twice OSHA's allowable exposure limit!). Finally, the pH of the system hovered around 7–8 for the duration, ideal for compost

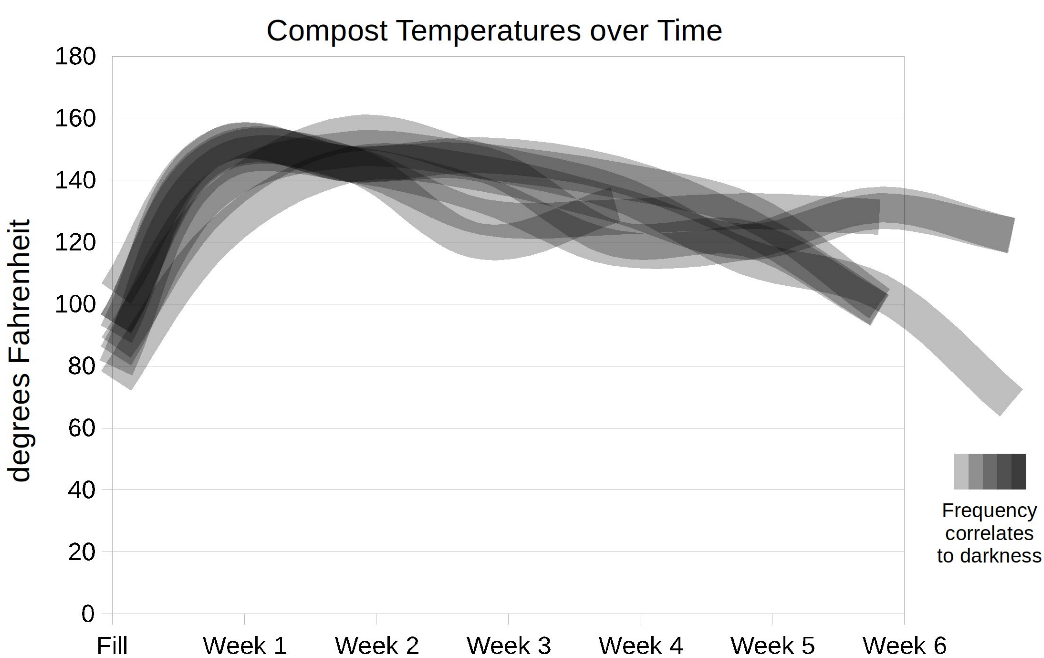


Figure 5: Temperature over time in study compost bins.

bacteria (pH: 5.5–8).

The goal, though, of this system was to capture all of these composting products and use them directly for growing plants in the off season. The custom-built greenhouse and initial hot-box systems certainly did a better job of this than the more user-friendly bladder version. Heat seeps easily into a grow bed installed above the compost piles, while pushing it down a pipe into a grow bed is significantly less efficient. With the gas-trapping tarp and transmission tube exposed to cooler air, moisture condensed on the surface. When water condenses, it gives up heat and the moisture can no longer travel through air, meaning neither heat nor moisture are not transferred to the grow bed but rather stay trapped in the composting chamber. The few bok choi that we were able to transplant into the study grow beds in the winter did not do well, but because the sample size was small, we could not tell if the withering of the hardy winter green was due to cold temperatures, transplant shock, or excessive CO_2. The bottom line is that although they are modular and easier to use, neither the boxes nor bladder system effectively trapped and transferred the heat and moisture to grow beds.

Ways Forward

This negative result does not condemn this system, however, as we have learned lessons that would help anyone interested in using compost to increase their growing season. Let's move from general to specific recom-

Figure 6: Weekly manure pick-up from Three Gaits Stables.

mendations based on this study.

This system is difficult to make modular, as the physics behind transferring the main benefits (heat, moisture, CO_2, and nutrients) require a dedicated set-up. It may not be necessary to build a new greenhouse from scratch, although that would be easier. An existing greenhouse could be retrofitted with composting bays along the northern side. In designing a system, one has the obvious things to consider, such as weight of the grow beds on top of the compost chambers (figure at least 100 lb per are worth highlighting.

First, this system creates a huge amount of moisture in the composting chamber, which will wreak havoc on any wood or metal that is not moisture resistant. Even pressure-treated and galvanized building materials exposed to this high-heat, high-moisture environment will break down more quickly than expected (not to mention

Figure 7: Bladder system open showing compost bays.

the introduction of the chemicals from those treatments into the food chain). Sealing the chamber with rigid poly sheets (and sealing the seams) to direct the moisture toward the beds is a worthwhile investment.

Second, both NAI and LTI researchers noted the labor involved in sourcing and moving yards of manure regularly. A minimum of one yard of feedstock should be added each week (after removing the composted equivalent). In the winter, at least up here, the only ready source of compostable material is animal manure. Since a yard of horse droppings and bedding weighs about 1000 lb or more and a horse produces about 50 lb of waste (feces plus urine), two or three horses would supply the needs of a small system, for example. A cow produces more per day (ca. 65 lb) but it needs an equal amount of carbon added to the mix for the N:C ratio to work. If you do not have animals, a regular source of this much manure should be identified before construction. Even with access to manure, moving literal tons of this stuff around requires a trailer plus a loader (whether that is a person with a shovel and lots of time or powered equipment).

Finally, it is important to make the manure bays accessible. This means a way for your vehicle and trailer and/or loader to drive right up next to the hatches. Plus they have to be easy to dig out, which requires an insulated, full-height hatch that opens to the ground and is high enough dig out and fill back up, whether by hand or with a bobcat bucket.

The bottom line is to ask oneself whether the investment is worth it. If one has animals and is already dealing with manure, this may be a good way to get more out of the local resources.

The study results also give us a few specific suggestions to improve these systems. One is to install a watering system. Whether this is a drip hose installed on the ground under the compost (where it dries out most quickly) or an overhead sprinkler system, this will save hauling buckets of water or dealing with a hose in the winter. A moisture meter installed on the floor could help assess when more water is needed.

Each system requires fine tuning as to the amount of air being fed into the system. We found that our 1170 cfm, 1-HP blower was more than enough, and we set it for 30 sec every 20 min in the summer, 25 sec every 25 min in the fall and spring, and only 20 sec every 30 min in the winter because introducing cold air chilled the compost bacteria. We never had methane or ammonia build-up, so we had more oxygen than the system needed. One could reduce the air intake until these products of anaerobic digestion appeared and then raise the blower levels a little bit to give the system enough oxygen. We tried to use a thermostatically controlled blower, with a sensor above and in the compost through the winter (it would turn on the blower when a high temperature threshold was met, but keep it off if it cooled down too much), but we could not find a consistent enough temperature reading to keep the system functioning smoothly.

Finally, a carbon-dioxide detector set to go off if the air within the chamber drops below 10,000 ppm would alert the operator to the fact that something in the system is off. It would then be easy to find out if a blower adjustment, need for new compost feedstock, or more water was needed.

Harnessing all the outputs of a compost system by combining an in-vessel aerated static pile with forced-air grow beds has been shown to produce excellent four-season growth in a cool climate, but my attempt to create a modular system was not successful. This easiest way to use this forward-thinking concept is to build a greenhouse with dedicated, permanent infrastructure, coupled with ready access to a source of winter manure. While it is likely possible to create a mobile version of this system, the amount of insulation and engineering involved would be significantly more trouble than the benefit of being able to gain a little space back in a hoop house for the summer.

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