# BEST MANAGEMENT PRACTICES:

# JOHNSON-SU COMPOSTING BIOREACTORS

All About Discovery!™
College of Agricultural, Consumer and Environmental Sciences

UNITED STATES DEPARTMENT OF AGRICULTURE • FARM SERVICE AGENCY

This page intentionally left blank

# BEST MANAGEMENT PRACTICES: JOHNSON-SU COMPOSTING BIOREACTORS

## NEW MEXICO STATE UNIVERSITY
## COLLEGE OF AGRICULTURE, CONSUMER, & ENVIRONMENTAL SCIENCES

In partial fulfillment of an outreach grant provided by the
U.S. DEPARTMENT OF AGRICULTURE – FARM SERVICE AGENCY

Prepared by David Johnson and Patrick DeSimio
June 28, 2017

This manual of best management practices was funded by an outreach grant provided by the U.S. Department of Agriculture Farm Service Agency and has been developed in tandem with a workshop on composting practices and Farm Service Agency operating loans, presented by Dr. David Johnson, Shahid Mustafa, and New Mexico Farm Service Agency staff. This workshop was held on Wednesday, July 28, 2017 at Taylor Hood Farms, 4225 County Road B-006, Las Cruces, NM 88005.

# Contents

## Introduction

Compost-amended soils have existed for over 5,000 years in the tropical soils (*terra preta*) of Amazonia, more than 4,000 years in Asia and Japan, over 2,500 years as *plaggen* soils in the Netherlands, more than 850 years in cultivated soils called *chinampas* in Meso-America, and 1,000 years in the *altiplanos* of Bolivia. Some of these soils, created as a consequence of human activity, remain more fertile and more productive than the surrounding soils to this day. This longevity of soil fertility provides good evidence that composting is beneficial, and if we are to achieve long term sustainability in our agricultural systems, it may be advantageous for us to start emulating the composting activities of nature and our ancestors.

### *Benefits of Composting*

Most composts are viewed as nutrient sources, and the recommendations for applying them are based on the composts' nitrogen and phosphorus content. However, in addition to composts' roles as nutrient sources, a growing body of research suggests that certain composts can provide soil microbial communities that bring many benefits for plants and soils. For instance, the enduring fertility of terra preta soils (which are still being mined and sold as soil amendments) is partially attributable to microbes, which metabolize and stabilize the original ingredients in terra preta. In these processes, fungi play an especially important role.[1]

The compost produced in the Johnson-Su composting bioreactor provides nutrients and, more importantly, results in a microbially diverse and fungal-dominant soil microbiome that can be applied at concentrations as low as 1 kg/hectare, a concentration at which it operates more as a microbial inoculation for soils than as a soil amendment. In other words, the compost introduces beneficial microbes to the soil like a baker introduces yeast to bread dough. The increased presence of fungi appears to be a key indicator for soil quality, both in the terra preta soils of the Amazon and the compost produced in the Johnson-Su bioreactor.

### *Benefits of the Johnson-Su Composting Bioreactor*

Typical commercial windrow composting processes are often designed and operated for speed and maximum product flow. This focus does not allow the compost to degrade sufficiently and produces an immature compost that in some cases is detrimental to plant growth. Most home composting methodologies require building a pile and turning it at regular intervals. Both of these composting processes (windrow and static pile) can produce undesirable smells, attract flies, and be problematic with neighbors.

In contrast, when built and maintained correctly, the static pile Johnson-Su bioreactor never needs turning, never has smells, and does not attract flies. This reactor design allows the material to be composted aerobically, allowing complete biological breakdown of compost materials and resulting in a microbially diverse, fungal-dominant compost product. The compost end product has the consistency of clay when mature (you can squeeze the end-product between your fingers and it oozes out like clay – see https://www.dropbox.com/s/2fhy9zex8f3345i/P1040302.MOV?dl=0). The mature compost can be applied as an extract, mixed as a slurry to coat seeds that you intend to plant in large farming operations, or be applied directly as a soil amendment. **The compost from Johnson-Su composting bioreactors improves seed germination rates when used to coat seeds, improves soil water infiltration and water retention by helping to increase soil carbon content, and increases plant health, plant growth rates, and crop production.**

## Definitions

| | | |
|---|---|---|
| ‘ | : | Feet |
| “ | : | Inches |
| **Aerobic** | : | Occurring in the presence of oxygen |
| **Anaerobic** | : | Occurring in the absence of oxygen |
| **Microbiome** | : | An ecosystem of fungi, bacteria, and other microorganisms |
| **Soil Microbial Communities** | : | Microbiomes in soils |
| **Thermophilic Phase** | : | A period of about four days to one week during which compost temperature can reach 145-165 °F |

## How to Build a Johnson-Su Composting Bioreactor

This manual’s design for a Johnson-Su bioreactor can be built in 4-5 hours by one person using simple tools and about $40 of readily available materials. The design is scalable for home, farm, or commercial settings. Just be sure that all of the compost in the bioreactor is within 12” of ambient air.

### *Safety*

WARNING!

**Be sure your tetanus shots are up to date. The tie wire and re-mesh cage can have many sharp ends that can puncture your skin and, if rusty, potentially infect an open wound.**

WARNING!

**Wear a dust mask to protect your respiratory system (lungs and sinuses), gloves to protect your hands, and safety goggles to protect your eyes.**

WARNING!

**Follow standard precautions for tool use and the instructions in the safety manuals of your particular tools.**

### ***Required Materials and Tools***

To build a Johnson-Su bioreactor, you'll need some readily available materials and a few tools.

Materials consist of

- Landscape cloth (woven, minimum 5 oz.):
  - Piece One: 13' x 6'
  - Piece Two: 6' x 6'
  - Piece Three: 6' x 6'
- One standard, sturdy shipping pallet with dimensions of approximately 40" x 48"
- Wire re-mesh (6" x 6" x 10-gauge wire), used to create a 5' x 12' 6" supporting wire cage. This type of re-mesh is normally used for reinforcing concrete. Be sure to use re-mesh as horse fencing or other similar wire fence products have insufficient vertical strength to hold the cage in position as you fill it.
- Four 10' lengths of perforated, bell-end, 4" septic system drain field piping
- PVC glue
- Tie wire (normally used to tie rebar together)
- Approximately 13' of ½" landscape water hose for the drip irrigation system
- Optional: A rebar jig (Figure 1) to hold the drain field pipes in place as you fill the Johnson-Su bioreactor. If you have helpers or if you are willing to adjust the pipes as you fill the bioreactor, you will not need the jig.

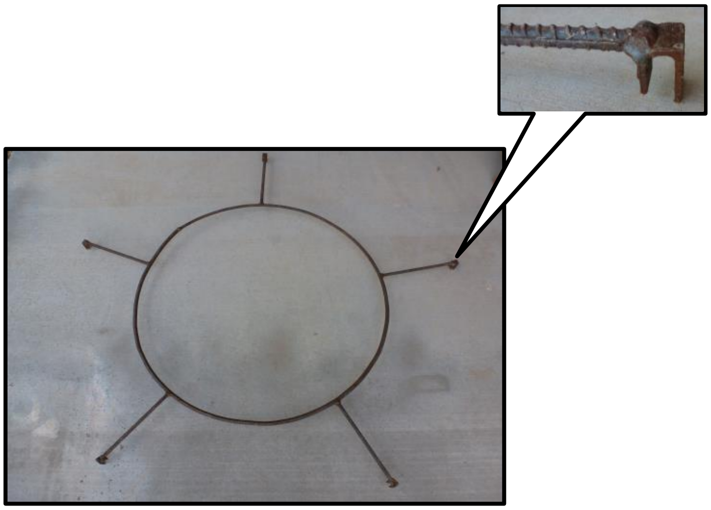

***Figure 1.*** *Rebar Jig*

Tools required are

- Small bolt cutters or heavy pliers for cutting the wire re-mesh
- Linesman’s pliers to cut and tie the tie wire for assembling the cage
- Circular saw
- Jigsaw for cutting the holes in the pallet
- Scissors for cutting the landscape cloth
- Tape measure
- Pen or pencil to mark places that will be cut

After you build a Johnson-Su bioreactor (Figure 2), you can reuse it many times.

***Figure 2.*** *A Johnson-Su Composting Bioreactor*

## ***Building the Bioreactor***

A YouTube video (https://youtu.be/DxUGk161Ly8) demonstrates the proper construction of the Johnson-Su bioreactor. Do not substitute other materials when building this system because some substitutions may undermine the integrity of the reactor, requiring it to be disassembled and rebuilt.

### *Building the Cloth and Re-mesh Cage*

With scissors, cut a piece of landscape cloth to 13’ in length and 6’ in height.

Using bolt cutters or pliers, cut the re-mesh to 12’6” in length and 5’ in height. Temporarily tie the wire cage ends together and stand the cage up like a cylinder.

Position the 13’ x 6’ piece of landscape cloth along the interior of the re-mesh cage and sew it into place using a long piece of tie wire with a sharpened point (cut at an angle using the pliers). Pierce the landscaping cloth very close to the top of the re-mesh cage, and sew the tie wire through the cloth and the re-mesh wire in an alternating pattern (in and out, close to the top of the wire cage) to the end of the 12’6” re-mesh. Repeat this step for the bottom of the cage and cloth.

After you have sewn the fabric to the wire mesh cage and before you get ready to fill the reactor, securely tie the ends of the re-mesh together at the 6” intervals using tie wire and pliers. Be sure to place a secure tie every 6”. Otherwise, the pressure that builds up when you fill the bioreactor can push this joint apart.

### *Preparing the Base*

The pallet serves as the base for the Johnson-Su bioreactor, and it supports both the remesh/groundcloth cylinder and the septic system drain field pipes. To let the pallet hold the pipes in place, you’ll use a jigsaw to cut six 4 ⅜” holes in the top of the pallet (as shown in Figure 3).

***Figure 3.*** *Positioning of Holes in Pallet*

To explore different hole placements and see how you can best avoid cutting completely through the pallet's planks, you can pivot a jig (Figure 4) around the center point of the pallet. If you'll be cutting a plank completely, try to place bricks or wooden blocks under the cut ends of the plank to support them as you fill the bioreactor.

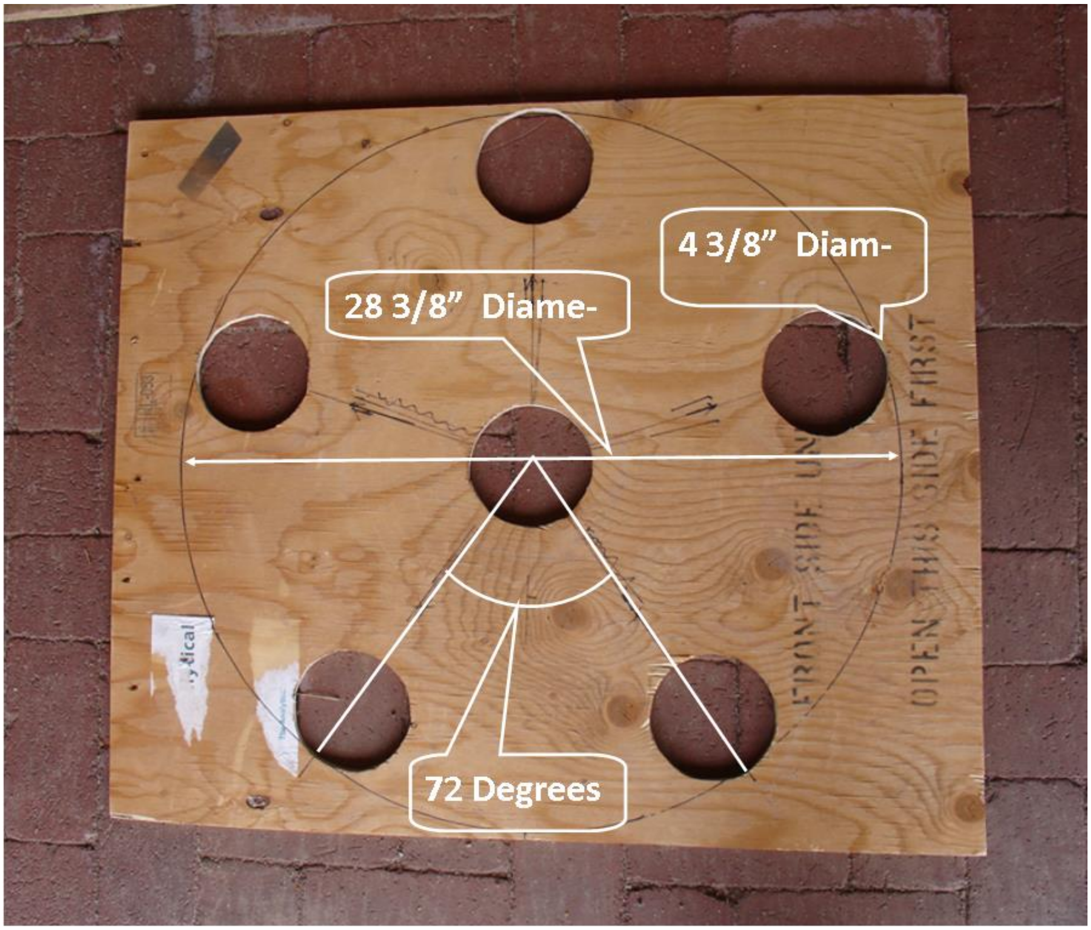


***Figure 4.*** *Jig for Holes in Pallet and Ground Cloth*

So that the bioreactor will not lean as you fill it, place the pallet on leveled ground or block it up with bricks to make sure that the pallet is well supported and level. Place a 6' x 6' piece of landscape cloth over the pallet, leaving plenty of cloth overlapping each edge of the pallet. Use scissors or a mini torch to cut holes in the cloth to match the holes in the pallet (refer to Figure 2).

Now, place the re-mesh/groundcloth cage on top of the pallet/groundcloth base. The wire cage is 4' in diameter and will overlap the pallet. Don't worry about this, since the bottom 6' x 6' piece of landscape cloth can be temporarily tucked in between the wire mesh cage and landscape cloth, keeping the fill material from falling through.

The cage itself is light and may shift in the wind or as you fill the bioreactor with compost, so to temporarily hold the cage in place, you may want to loosely screw the base of the cage to the planks of the pallet (Figure 5).

***Figure 5.*** *Screwing the Base of the Cage to the Pallet*

*Preparing and Placing the Pipes*

The pipes are only in place temporarily and are a form to ensure that six columns are formed to allow air flow up through the bioreactor. These pipes should be removed approximately 24 hours after finishing the filling of the bioreactor.

Using a circular saw, cut the 10’ pipes so that you have four 4’ pieces of pipe left with bell ends. Glue two of these 4’ pipes together, and then cut them to 6’ so that you have six 6’ pipes.

Place the 6’ septic system drain field pipes into the holes in the bottom pallet. If you are using a metal jig (Figure 1), secure the pipes to the metal jig with tie wire. The jig is not necessary, since you can have assistants hold the pipes upright; alternatively, the feed materials for the bioreactor can hold the pipes upright if you adjust the pipes as you fill the bioreactor.

After you fill the bioreactor, you can remove the pipes after one day and reuse them in another bioreactor. Fungal hyphae in the bioreactor will hold open the channels where the pipes were, leaving open columns that let air flow from the bottom of the pallet up through the compost. The spacing on these open columns provides adequate aeration for the pile to stay aerobic (the compost is never more than one foot from ambient air).

The reactor is now ready for filling.

**Tip:** Unless you’re feeling very energetic, you may want to fill the bioreactor on a different day than when you build it. It’s best to fill the bioreactor all at once, and the filling process can take several hours.

## How to Fill a Johnson-Su Bioreactor

Feed materials for Johnson-Su bioreactors can vary widely. The first mixes I used in this bioreactor were one-third by volume each of dairy manure, yard waste/leaves, and wood chips (smaller than 3/8” x 3/8”). You can use entirely leaves if you like, or you can add other materials that you may have available.

You can fit approximately 1,800 pounds of wetted material into one of these reactors, and it’s best to fill the reactor in one day if at all possible so that you can achieve thermophilic temperatures (140-165 °F) for the first 4-5 days of operation. Before starting the filling process, make sure that you have enough feed materials, plenty of energy, and several hours.

It is best to run all material through a chipper/shredder to ensure that all material is broken to make compost material accessible to microbes. It is also best to have the feed materials as clean as possible (no plastics, trash, etc.) so that you do not need to screen the product after composting.

### *Preparing Feed Materials*

For some materials, pre-treatments are necessary. Manure should be dried. Similarly, wet or soggy food scraps (e.g., orange peels, juicing waste, fresh-cut grass) are not recommended unless you have first dried them. Otherwise, these materials pack very tightly and provide locations in the compost pile that can go anaerobic and begin to putrefy, attracting pests. These materials can be composted, but I recommend air drying them first by spreading them out on the ground in the sun. Then, put the materials through a chipper shredder to open their structure for microbial degradation.

Tropical plant leaves, pine needles, pine cones, and heavy seed pods should all be run through a chipper shredder. Unless you create openings in the surfaces of these materials, they are so well protected with natural waxes and microbe-resistant structures that they can go through a composting process and decompose very little.

Try to prepare all of the material you need before you fill the bioreactor, since it is best to completely fill the bioreactor in one day.

Filling the Johnson-Su bioreactor described in this manual will require approximately 3 truckloads of material, or more than 75 five-gallon buckets of prepared and wetted material. This may seem like a lot of material, but you’ll find that you can never have enough of the resulting compost product.

**Tip:** If you don’t want a full-size bioreactor, you can scale the design down. Just remember that every part of the compost should be within 12” of ambient air. This is the distance that oxygen can penetrate into the compost, keeping the pile aerobic and preventing it from smelling and attracting flies.

### *Wetting the Feed Materials*

Before beginning to fill the bioreactor, it is crucial that you completely wet the feed materials. You have one chance to build this reactor, and thorough wetting is important so that you do not have to take the reactor apart and build it again. I suggest immersing the feed materials in a water bath, using one of the inexpensive plastic trays used for mixing small batches of concrete or mortar. I usually fill the tray with water and place 4-5 pitchforks of material into it. I then use a pitchfork to press the materials below the surface of the water and/or spray the material to ensure sufficient water penetration. It only takes about 60 seconds of immersion to wet the materials properly.

Once the feed materials are thoroughly wet, I use a pitchfork to lift them into a wheelbarrow that is braced into a tilted position (Figure 6) so that water can drain off of the feed material and back into the water-bath tray. This uses the water efficiently.

***Figure 6.*** *Setup for Wetting Feed Materials*

> **Tip:** If you have mature compost from a Johnson-Su bioreactor, you can inoculate your water bath with desirable microbes by tossing in occasional handfuls of mature compost.

From the wheelbarrow, I transfer the wetted feed materials to 5-gallon buckets and use these buckets to fill the bioreactor (Figure 7). You can see the wetting process from time markers 00:06:00 to 00:07:30 in the video at https://youtu.be/DxUGk161Ly8.

### *Filling the Bioreactor*

To make it easier and safer to lift and dump the 5-gallon buckets, I like to build a little scaffolding around the reactor. Stepladders work well, too.

Typically, I fill 6-9 buckets with wetted compost, dump each of these buckets into the bioreactor, then fill another 6-9 buckets and repeat the process.

***Figure 7.*** *Filling the Bioreactor*

If the substrates for composting are lightweight, like leaves that you have wetted, you can press or tamp these down as you fill the reactor so that you can get more into the bioreactor. If the substrates are heavy, you may want to allow the weight of the substrate to settle the pile. You want to avoid any heavy packing because this might lead to anaerobic spots that can cause unwanted odors and flies. You will gain experience as you build these piles as to how much you can compact the pile.

After you have filled the bioreactor, use the second 6' x 6' piece of groundcloth to cover the top of the bioreactor. This well help to keep the compost moist. To keep the groundcloth from blowing away, tuck the corners into re-mesh of the cage.

**Tip:** If you have several different feed materials, you can fill 3 buckets with one material, another 3 buckets with another material, another 3 buckets with another material, etc., and unload the buckets into the reactor in shifts. This effectively mixes multiple different components, giving you a more homogenous compost end product.

## How to Operate a Johnson-Su Composting Bioreactor

To operate a Johnson-Su composting bioreactor, keep the compost moist and add worms after the thermophilic phase has ended.

### *Moisture*

Once you have built the pile, you will need to install an irrigation system that will water the pile for one minute each day. It is very important to keep the pile adequately damp—not oozing out the bottom, but wet enough for the microbes to be happy (greater than 70% moisture content). The material should glisten when you grab a sample out of the reactor, and you should almost be able to squeeze a drop of water out of the material. If you have a soil moisture gauge, you can test different parts of the pile to make sure there is adequate water.

To irrigate the system, I use a circular piece of ½" landscape hose that snakes around the top perimeter of the bioreactor (Figure 8). I drill 1/16" holes into the bottom of the hose every 4-5", and also I drill some holes horizontally in the hose about every 6". The horizontal holes spray towards the center of the bioreactor to thoroughly wet all the material. I connect the ends of this hose with a plastic landscape *T*-hose fitting that has two ½" female push-compression fittings and a female hose-bib thread (Figure 9). Once the water has been sprayed onto the top of the compost substrate, gravity will pull the water from the top of the pile into the rest of the compost substrate.

***Figure 8.*** *Irrigation System for a Johnson-Su Composting Bioreactor*

***Figure 9.*** *T-hose Fitting for the Irrigation System*

The irrigation system adds sufficient water to the bioreactor when attached to a garden hose or typical ½" landscape irrigation hose with water pressure between 30-50 psi. It is best to hook this hose up to a timed sprinkler system (timed to irrigate the reactor 1 minute/day, or 2 minutes/day in temperatures above 100 °F) to ensure that the pile has adequate water and is not allowed to dry out.

Check your pile frequently to ensure that you are maintaining sufficient water for the material to compost effectively. Piles that dry out will have to be disassembled and rebuilt, because it is impossible to rewet the ingredients once they have dried out.

### *Vermicomposting*

Once the pile temperature drops below 80 °F, worms can be added to augment the composting process.

Feed materials should be composted in the bioreactor for at least nine months, and a one-year composting period is recommended since microbial populations and species richness increase significantly at about the one year threshold.

## How to Use Compost from a Johnson-Su Composting Bioreactor

After a composting period of 9 months to a year, the compost product from a Johnson-Su bioreactor (Figure 10) can be used as it is, made into a slurry to coat seeds, or used to make an extract that can be sprayed on a field or into the furrow as you plant seeds.

***Figure 10.*** *Mature Compost from a Johnson-Su Bioreactor. See also the video at [https://www.dropbox.com/s/2fhy9zex8f3345i/P1040302.MOV?dl=0](https://www.dropbox.com/s/2fhy9zex8f3345i/P1040302.MOV?dl=0).*

### *Direct Application*

Without any further treatment after the composting period, the compost product from the Johnson-Su bioreactor can be used as a growing media, spread onto soils at any desired rate, or used as a soil substitute. Mix in some native soil, about ⅓ by volume, to offer additional material from which the microbes can extract macro and micro-nutrients that are needed for plant growth.

### *Extract*

Compost product from a Johnson-Su bioreactor can also be used to create liquid extracts that contain a rich and diverse community of soil microbes, especially fungi. The compost extracts are especially useful for inoculating large areas with beneficial soil microbial communities.

An extract, or inoculum, can be made from this compost by vigorously mixing the compost with water. The extract can then be applied as a spray.

To produce the extract, add 2-3 heaping handfuls of mature compost to 5 gallons of water, and stir the mixture vigorously. I use a hand drill with a large paddle blade mixer for 4-5 minutes. The goal is to dislodge as many microbes as possible from the organic matter.

After vigorously mixing the compost and water solution, pour the mixture through a paint screen (such as a 5-gallon mesh bag from your local hardware store) into another container. After straining, the extract is ready to be sprayed through a sprayer or sprinkler onto the leaves of plants or onto soil plots. After spraying the extract, water it into the soil with a garden hose sprayer or sprinkler to ensure that the microbes have filtered down into the soil. On large acreages, the extract can provide very beneficial results when applied to directly into the furrow while planting, a process which ensures that microbes are right next to germinating seeds. Through the spray method, application rates of 1 kg of compost/hectare (1 pound/acre) have been implemented with success.

Beneficial microbes from the mature compost can also be applied directly to seeds before they are planted. To inoculate seeds, create a slurry with the following ingredients:

- About ½ cup of a milk/molasses mixture (8 parts milk to 1 part molasses)
- About a liter (or quart) of compost
- Water (amount varies - add the water while stirring until the compost slurry has a viscosity similar to pancake batter)

One liter (approximately a quart) of the resulting slurry can then be poured into a cement mixer with 50 pounds of seed and tumbled until the seeds are thoroughly coated. Smaller batches can be done by hand in a 5 gallon bucket. The coating process takes approximately 1-2 minutes, and then the seed can be air dried by spreading the seed out on a tarp in the shade and allowing it to dry, with occasional raking to expose wet areas. After drying, the seeds can be planted. Alternatively, if the seeds are large, they can be planted wet because the seed will flow well through a planter.

## Regulations

The compost from the Johnson-Su bioreactor complies with NOP 5021 Effective Date: July 22, 2011. Relevant sections of NOP 5021 are below:

*4.3 Vermicompost-*

> *1) It is made from allowed feedstock materials (either non-synthetic substances not prohibited at § 205.602, or synthetics approved for use as plant or soil amendments);*
>
> *2) Aerobic conditions are maintained by regular additions of layers of organic matter, turning, or employing forced air pipes such that moisture is maintained at 70-90%; and*
>
> *3) The duration of vermicomposting is sufficient to produce a finished product that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances.*

*4.4 Permitted Uses*

*Composts containing animal materials that do not meet the requirements at 4.2 and vermicomposts containing animal materials that do not meet the requirements at 4.3 of this policy may be permitted subject to restrictions of § 205.203(c) (1), similar to raw animal manure, provided all feedstocks are allowed materials (either non-synthetic substances not prohibited at § 205.602, or synthetics approved for use as plant or soil amendments).*

*Compost and vermicompost made without animal materials as feedstock are not restricted in use, in accordance with the provision for un-composted plant materials at § 205.203(c)(3), provided all feedstocks are allowed materials (either non-synthetic substances not prohibited at § 205.602, or synthetics approved for use as plant or soil amendments).*

## Additional Resources

For more information about Johnson-Su composting bioreactors, contact Dr. David Johnson at davidcjohnson@nmsu.edu.

---

[1] Bruno Glaser, (2012) State of the scientific knowledge on properties and genesis of Anthropogenic Dark Earths in Central Amazonia (terra preta de Índio) Geochimica et Cosmochimica Acta. 82: 39-51

All About Discovery!™
College of Agricultural, Consumer and Environmental Sciences

UNITED STATES DEPARTMENT OF AGRICULTURE • FARM SERVICE AGENCY