2011 Farm Walk Program

*Education for farmers, by farmers*

Presented by
Tilth Producers of Washington
& WSU Small Farms Program

**Early 2011 Schedule**

May 16, 2011
Inaba Produce Farms, Wapato

May 23, 2011
Red Dog Farm, Chimacum

June 6, 2011
Welcome Table Farm, Walla Walla

June 13, 2011
WSU Research & Extension Unit,
Mount Vernon

June 27, 2011
Templeton Farm, Chewelah

July 11, 2011
Cloudview EcoFarms, Royal City

July 18, 2011
Middleton Organic Orchard, Eltopia

**Inaba Produce Farms**
May 16, 2011
FARMER-TO-FARMER: PASSING ON THE WISDOM

2011 Farm Walk Education Series
Sponsored by the WSU Small Farms Team
(smallfarms.wsu.edu)
and Tilth Producers of Washington
(www.tilthproducers.org)

Inaba Farm Walk, May 16, 2011
Wapato, WA

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Farm Walk Evaluation form...

Please fill out and leave at the site!

Thank You!
Inaba Produce Farms, article from Sustainable Northwest book, *Renewing the Countryside*

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http://www.sustainablenorthwest.org/stories/inaba-produce-farms/

Inaba Produce Farms is a large, family-run operation in the arid Yakima Valley that grows, packs and ships a diverse variety of vegetables throughout the region. The Inabas have been experimenting with organic methods in an effort to improve the farm’s diversity and to reduce their dependence on chemical inputs. It is not an easy transition to make, but Inaba family farmers have survived challenges here before.

“We farm about 1200 acres, and it’s a family operation,” says third generation farmer, Lon Inaba. “I have two brothers: Wayne is our salesman, he’s the money guy; Norm is our computer guy, he has a degree in economics and computer sciences, and does our payroll and taxes. My mom is our office manager: she pays the bills, collects the money, does the shipping papers, and keeps us all in line.” Lon himself is the engineer, innovating and developing new things. He builds the greenhouses, drip irrigation systems, and composting operations.

Inaba Farms is made up of wide, flat fields, broken only by power lines and the occasional road. The surrounding hills are faintly visible in the distance. It is not hard to imagine the sagebrush country this once was. It takes several minutes for Lon to drive the entire length of a compost windrow in one of the fields. “We have about five miles of compost windrow,” Lon remarks. “We started composting as a way to build up our ground. We’ve used manure and cover cropping for probably the last 25 years; my grandfather used those practices almost 100 years ago.” Utilizing their waste products in the compost pile helps the Inabas reduce their chemical use.

Lon speaks familiarly about the relatives who worked this land over the last century. “My grandfather came from Japan in 1907 to the Yakima Valley because this was one of the last areas still in sagebrush and they were asking people to
immigrate here to help break and farm the ground,” he says. His grandfather broke 120 acres out of sagebrush, some of the ground they farm today. Lon continues, “My grandfather was doing pretty well, but then the 20s came around and they passed the alien land law that said that undesirable aliens couldn’t own or rent land.” Lon’s grandfather was reduced to sharecropping, and could no longer afford to rotate high value crops with soil-enriching hay. He had to move every couple years when the soil was worn out. This forced him to look for a high margin crop that he could justify with fewer acres, which is how the family got into the vegetable business.

Lon recounts, “They had moved to eight or ten different places before my dad’s cousin was old enough to sign for land. And by that time World War II came around and the Japanese bombed Pearl Harbor and there was a lot of animosity toward the Japanese people.” This time world events meant that Lon’s grandfather, father and mother had to move to an internment camp for several years. He says, “So we’ve seen adversity, and we can relate to our workers, most of whom are Hispanic migrants. Just like my grandparents, they gave up everything they had to come to this country to try and make a living.”

Lon left an engineering job to come back to the farm 20 years ago, when his dad decided he wanted to get into packing and selling his produce on his own. Lon recalls, “I took a six-month leave of absence to help build a cooler and a warehouse and I have been here ever since. I did more actual engineering during my first three weeks home on the farm than I had done in the previous three years!”

In 1982, the farm consisted of three crops: concord grapes, bell peppers and sweet corn. Today the Inabas produce nearly 20 different crops. “We try to do everything from start to finish and have something the consumer can put on their table,” explains Lon. “In our business the margins are pretty slim. If you take what the consumer pays and divide by about five, that’s about what the grower actually gets. People don’t realize that. We have to be vertically integrated to make this work financially.” The Inabas grow their own vegetable starts in greenhouses and have their own packaging plant. Merchants can come to the farm to pick up four or five things at a time and that helps them attract customers.

The Inabas farm both organically and conventionally; with about 10 to 15 percent of their crops in organic production. Lon says, “We do a little bit of almost everything organic. We’re pretty diverse to begin with and the organic thing makes us more diverse. We sell to major retailers in the Pacific Northwest and to a few throughout the western United States and Canada. The organic deal gives us more specialty items to sell.”

The harvest season begins in April with asparagus, before they move into cabbage, peas, green beans, cucumbers, yellow squash, zucchini, and then sweet corn, bell peppers, watermelons, tomatoes, and eggplants. Lon explains, “Our workforce is about 150 to 200 people and probably two-thirds of the same people come back every year. We get good people, and we try and take care of them.” Inaba Farms has
built quality housing for migrant workers and has even developed housing sites among the fields that they lease for a nominal fee to some of their most valued employees.

Lon also works to make sure Inaba Farms is a good place for insect families. “Squashes, cucumbers, and watermelon are crops that need bees for pollination,” explains Lon. “As we started adding those crops, we started looking at using less harsh chemicals in the remainder of our crops so we wouldn’t kill the bees.” Lon also is concerned about the health of his workers in regards to these chemicals. He says, “My dad taught us: you treat people the way you want to be treated. If we don’t want to spray or work around chemicals, we don’t want our workers to either.”

The Inabas try to use cultural controls and beneficial insects to control pest insects. Lon explains, “In on our organic fields, we’re trying to be diverse in our cropping structure and diverse in our management practices. I try to release beneficial insects early so we have second and third generations of these insects throughout the growing season. I release lacewings, parasitic wasps, midges, and ladybugs. Hopefully they won’t fly away. Hopefully when we have a problem they’ll be there to eat the undesirable guys.” Lon creates habitat for beneficial insects by walking through his fields and tossing handfuls of clover, alfalfa, yarrow, corn, wheat, and dill seed, hoping to garner diversity in the pollen and nectar sources for those insects he has released in his fields, as well as attracting other beneficial insects.

Lon seems to relish the challenges of farming with fewer chemicals, but it clearly is not easy. He says, “A lot of the stuff we’re doing for organics we do on faith because there is no instant result. You have to hope the beneficial bugs will stick around and that the decisions you make are going to be good – there is no instant verification of your results. I do a little bit of a lot of different things – the diversity approach – and hope that some of those things are working. And if you get the right conditions, one thing might work great and something else might not at all.”
Pesticide Disclaimer

Documents included in this packet may contain information regarding pesticides used in states other than Washington. It is the responsibility of the reader to determine whether those active ingredients or pesticide products are registered for use in Washington State.

Readers are reminded that all pesticide products, including products certified for use in organic production systems, must be registered by the Washington State Department of Agriculture’s Pesticide Division in order to be legal.

Exención de Responsabilidad por uso de plaguicidas

Los documentos incluidos en este paquete pueden contener información relativa a los plaguicidas utilizados en otros estados además de Washington. Es responsabilidad del lector determinar si los ingredientes activos de los plaguicidas o productos estén registrados para su uso en el estado de Washington.

Recordamos a los lectores que todos los plaguicidas, incluyendo los productos certificados para su uso en la producción orgánica, deben ser registrados por la División de Plaguicidas del Departamento de Agricultura del Estado de Washington para ser legales.
The Art and Science of Composting
A resource for farmers and compost producers

Leslie Cooperband
University of Wisconsin-Madison

Center for Integrated Agricultural Systems
March 29, 2002
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What is composting?

Composting is controlled decomposition, the natural breakdown process of organic residues. Composting transforms raw organic waste materials into biologically stable, humic substances that make excellent soil amendments. Compost is easier to handle than manure and other raw organic materials, stores well and is odor-free.

Composting is an ancient technology, practiced today at every scale from the backyard compost pile to large commercial operations. There are Roman and biblical references to composting. The nation’s first president, George Washington, was also the nation’s first recognized compostor. Washington recognized the degradative effects of farming on soil and he built a “dung repository” to make compost from the animal manures so he could replenish the soil’s organic matter.

Uses and markets for compost

As landfills reach their capacity and ban acceptance of organic wastes, composting is an increasingly viable means of organic waste management. Composting animal manures can also be a solution to manure management on the farm. Most importantly, the final product is a valuable soil resource. Compost can replace materials like peat and topsoil as seed starters, container mixes, soil amendments, mulches and natural fertilizers in commercial greenhouse production, farms, landscaping, turf and land remediation (Table 1).

There is a big potential demand for compost in plant production-related industries—close to 900 million cubic yards of compost could be used in agricultural and horticultural applications and 0.6 million cubic yards for land fill covers and surface mine remediation (U.S. EPA, 1998).

Benefits of adding compost to soils

Compost is an organic matter source with a unique ability to improve the chemical, physical, and biological characteristics of soils. It improves water retention in sandy soils and promotes soil structure in clayey soils by increasing the stability of soil aggregates. Adding compost to soil increases soil fertility and cation exchange capacity and can reduce fertilizer requirements up to 50%. Soil becomes microbially active and more suppressive to soil-borne and foliar pathogens. Enhanced microbial activity also accelerates the breakdown of pesticides and other synthetic organic compounds. Compost amendments reduce the bioavailability of heavy metals—an important quality in the remediation of contaminated soils.

The Composting Process

Composting occurs through the activity of microorganisms naturally found in soils. Under natural conditions, earthworms, nematodes and soil insects such as mites, sowbugs, springtails, ants, and beetles do most of the initial mechanical breakdown of organic materials into smaller particles. Under controlled conditions, composters break down large particles through grinding or chopping. Once optimal physical conditions are established, soil bacteria, fungi, actinomycetes and protozoa colonize the organic material and initiate the composting process (Figure 1. The Composting Process. Adapted from Rynk, 1992.

Table 1. Compost Markets and Use

<table>
<thead>
<tr>
<th>Market</th>
<th>Compost Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agronomic</td>
<td>Soil amendment</td>
</tr>
<tr>
<td>Horticultural</td>
<td>Seed starter, soil amendment, mulch, container mix, natural fertilizer</td>
</tr>
<tr>
<td>Urban/suburban landscaping</td>
<td>Soil amendment, mulch</td>
</tr>
<tr>
<td>Turf</td>
<td>Seed starter, soil amendment, topsoil, natural fertilizer, mulch</td>
</tr>
<tr>
<td>Forestry</td>
<td>Seed starter, soil amendment, topsoil, mulch</td>
</tr>
<tr>
<td>Land reclamation Bioremediation</td>
<td>Soil amendment, mulch</td>
</tr>
<tr>
<td>Land fill cover</td>
<td></td>
</tr>
</tbody>
</table>
1) These mesophilic organisms function best at warm temperatures (50-113°F).

**The active phase of composting**

As temperatures in the compost pile increase, *thermophiles* (microorganisms that function at temperatures above 113°F) take over. The temperature in the compost pile typically increases rapidly to 130-150 °F within 24-72 hours of pile formation, which is maintained for several weeks. This is called the *active phase* of composting (*Figure 2, 3)*.

In the active “thermophilic” phase, temperatures are high enough to kill pathogens and weed seeds and to break down phytotoxic compounds (organic compounds toxic to plants). Common pathogens killed in this phase are *Escherichia coli*, *Staphylococcus aureus*, *Bacillus subtilis*, and *Clostridium botulinum*. During this phase, oxygen must be replenished through passive or forced aeration, or turning the compost pile.

**The curing phase**

As the active composting phase subsides, temperatures gradually decline to around 100°F. The mesophilic microorganisms recolonize the pile, and the compost enters the *curing phase*. The rate of oxygen consumption declines to the point where compost can be stockpiled without turning. During curing, organic materials continue to decompose and are converted to biologically stable humic substances—the mature or finished compost. Curing is a critical and often neglected stage of composting. A long curing phase is needed if the compost is unfinished or immature. This can happen if the pile has received too little oxygen or too little or too much moisture. Immature composts can contain high levels of organic acids, high C:N ratios, extreme pH values or high salt contents, all of which can damage or kill plants if the compost is amended to container mixes or the soil.

There is no clearly defined time for curing. Common practices in commercial composting operations range from one to four months. Homeowner compost piles can cure for as long as six to twelve months.

**When is the compost finished?**

There is no fixed time to produce finished compost. Duration depends on feedstocks, composting method used and management. It can take as little as three months and as long as two years. Compost is considered finished when the raw feedstocks are no longer actively decomposing and are biologically and chemically stable. Some practitioners refer to finished compost as stable; referring to the state of biological activity. Maturity is usually defined as the degree of humification (conversion of organic compounds to humic substances, which are most resistant to microbial breakdown). It is easier to measure compost stability than maturity, so most composters measure temperature or compost respiration (oxygen consumption). When the temperature at the center of the pile returns to near-ambient levels and oxygen concentrations in the middle of the pile remain greater than 10-15% for several days, compost is considered stable or finished. These measurements should be taken when the compost pile has at least 50% moisture content by weight.

It is important to learn how to assess the maturity or stability of the compost because stability will affect many of the chemical and biological properties of the compost, and ultimately how the compost can be used. “Stability indices” and maturity/stability testing are available from compost research and education organizations (see Resources). Immature or biologically unstable composts can be used on farms as

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**Figure 2. Temperature changes in an average compost pile.**

A=mesophilic  
B=thermophilic  
C=mesophilic  
D-maturation

**Figure 3. Steaming compost pile during active, thermophilic phase of composting, when compost temperatures can reach as high as 150°F**
a soil amendment **ONLY IF** applied several months prior to planting. Immature composts can also be used in site remediation, and as land fill covers.

**Setting Up the Composting Environment**

Since composting is a microbial process, providing the right environment for microbes is crucial for successful composting. In other words, feed the microbes and let them do the work for you! Three factors interact in the making of good compost:

- the chemical makeup of the raw organic ingredients, called *feedstocks*
- the physical size and shape of the feedstocks (porosity of the pile)
- the population of organisms involved in the composting process.

**Aerobic vs. anaerobic composting**

Compost “happens” either aerobically (with oxygen) or anaerobically (without oxygen) when organic materials are mixed and piled together. Aerobic composting is the most efficient form of decomposition, and produces finished compost in the shortest time. If the proper amounts of food (carbon), nutrients, water and air are provided, aerobic organisms will dominate the compost pile and decompose the raw organic materials most efficiently. Pile “heat” is a by-product of biological “burning”—the aerobic oxidation of organic matter to carbon dioxide so that microbes can generate energy. Optimal conditions for rapid, aerobic composting are listed in **Table 2**.

**Feedstocks: the quality of the microbial “food”**

Composts can be made from most organic by-products. Common feedstocks are poultry, hog and cattle manures, food processing wastes, sewage sludge, municipal leaves, brush and grass clippings, sawdust, and other by-products of wood processing.

Ideally, several raw materials should be mixed together to create the “ideal” range of conditions listed in Table 2. However, in the real world this can’t always happen. Fortunately composting is a forgiving process that can occur over a wide range of conditions, and if you mix materials with an eye to an acceptable moisture content and *carbon-to-nitrogen ratio* (**Table 3**), you can produce acceptable compost with good management practices. In general, the combination of feedstock quality and compost management will determine the quality of the finished product.

The supply of carbon (C) relative to nitrogen (N) is an important quality of compost feedstocks. It is designated as the **C:N ratio**. The ideal starting range is C:N 25:1 to 35:1. As a general rule, if the C:N ratio is greater than 20:1, microbes will use all the N for their own metabolic needs. If the C:N ratio is lower than 20:1, they have surplus N and it can be lost to the atmosphere as ammonia gas and cause odor problems.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Acceptable</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td>C:N ratios of combined feedstocks</td>
<td>20:1 to 40:1</td>
<td>25-35:1</td>
</tr>
<tr>
<td>Moisture content</td>
<td>40-65%</td>
<td>45-60% by weight</td>
</tr>
<tr>
<td>Available oxygen concentration</td>
<td>&gt;5%</td>
<td>&gt;10% or more</td>
</tr>
<tr>
<td>Feedstock particle size</td>
<td>&lt; 1 inch</td>
<td>Variable</td>
</tr>
<tr>
<td>Bulk density</td>
<td>1000 lbs./cu yd</td>
<td>1000 lbs./cu yd</td>
</tr>
<tr>
<td>pH</td>
<td>5.5-9.0</td>
<td>6.5-8.0</td>
</tr>
<tr>
<td>Temperature</td>
<td>110-150°F</td>
<td>130-140°F</td>
</tr>
<tr>
<td></td>
<td>(43-66°C)</td>
<td>(54-60°C)</td>
</tr>
</tbody>
</table>

**Table 3. Common feedstocks and their characteristics**

(Adapted from Rynk, 1992, and other sources to illustrate representative values)

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Moisture content</th>
<th>C:N</th>
<th>Bulk Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>High in Carbon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay</td>
<td>8-10</td>
<td>15-30</td>
<td>-</td>
</tr>
<tr>
<td>Corn stalks</td>
<td>12</td>
<td>60-70</td>
<td>32</td>
</tr>
<tr>
<td>Straw</td>
<td>5-20</td>
<td>40-150</td>
<td>50-400</td>
</tr>
<tr>
<td>Corn silage</td>
<td>65-68</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>Fall leaves</td>
<td>-</td>
<td>30-80</td>
<td>100-300</td>
</tr>
<tr>
<td>Sawdust</td>
<td>20-60</td>
<td>200-700</td>
<td>350-450</td>
</tr>
<tr>
<td>Brush, wood chips</td>
<td>-</td>
<td>100-500</td>
<td>-</td>
</tr>
<tr>
<td>Bark (paper mill waste)-</td>
<td>100-130</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Newspaper</td>
<td>3-8</td>
<td>400-800</td>
<td>200-250</td>
</tr>
<tr>
<td>Cardboard</td>
<td>8</td>
<td>500</td>
<td>250</td>
</tr>
<tr>
<td>Mixed paper</td>
<td>-</td>
<td>150-200</td>
<td>-</td>
</tr>
<tr>
<td>High in Nitrogen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy manure</td>
<td>80</td>
<td>5-25</td>
<td>1400</td>
</tr>
<tr>
<td>Poultry manure</td>
<td>20-40</td>
<td>5-15</td>
<td>1500</td>
</tr>
<tr>
<td>Hog manure</td>
<td>65-80</td>
<td>10-20</td>
<td>-</td>
</tr>
<tr>
<td>Cull potatoes</td>
<td>70-80</td>
<td>18</td>
<td>1500</td>
</tr>
<tr>
<td>Vegetable wastes</td>
<td>-</td>
<td>10-20</td>
<td>-</td>
</tr>
<tr>
<td>Coffee grounds</td>
<td>-</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>Grass clippings</td>
<td>-</td>
<td>15-25</td>
<td>-</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>-</td>
<td>9-25</td>
<td>-</td>
</tr>
</tbody>
</table>
Green materials usually have lower C:N ratios than woody materials or dead leaves. Animal wastes are more N rich than plant wastes (Table 3).

The complexity of the carbon compounds also affects the rate at which organic wastes are broken down. The ease with which compounds degrade generally follows the order: carbohydrates > hemicellulose > cellulose = chitin > lignin. Fruit and vegetable wastes are easily degraded because they contain mostly simple carbohydrates (sugars and starches). In contrast, leaves, stems, nutshells, bark and trees decompose more slowly because they contain cellulose, hemicellulose and lignin.

The ideal moisture content of the compost pile is between 45-60% by weight. This should feel moist to the touch when you squeeze a handful of blended feedstocks. The material should hold together but not exude excess water.

Low moisture content will slow the composting process. Moisture also regulates temperature. Drier piles tend to heat up and cool down more rapidly than wetter piles, and excessive dryness makes piles susceptible to spontaneous combustion. Moisture content in excess of 60% means pore spaces in the compost pile will be filled with water rather than air, leading to anaerobic conditions.

Feedstocks with different moisture contents can be blended to achieve ideal moisture content.

Carbonaceous materials like newspaper, and wood by-products like sawdust can be used as bulking (drying) agents. Chipped brush, wood chips, and bark can be added to fine particle feedstocks to create large pore spaces. If you can’t achieve the ideal moisture content by blending feedstocks alone, you can add water to materials as you blend them. Take samples and measure moisture content by drying and weighing.

A common and effective feedstock combination on farms is manure (high in N, high in moisture), combined with straw bedding (high in C, low in moisture). Be sure there is enough straw or other dry material in the mixture.

The acidity or alkalinity of the organic materials, measured by the pH value, affects the growth of microorganisms. Bacterial decomposers prefer a pH range 6.0-7.5 while fungal decomposers prefer pH range 5.5-8.0. If the compost pH exceeds 7.5, gaseous losses of ammonia are more likely to occur. Certain materials such as dairy manure, paper processing wastes and cement kiln dust can raise pH, while food processing wastes or pine needles can lower pH.

Measure pH at the beginning and end of composting. Send samples to a soil lab for saturated paste pH and EC measurements (electrical conductivity or soluble salts). You can also monitor pH using the soil pH kits from farm and garden catalogs.

Ambient air temperatures affect microbial growth and activity in the compost pile, and hence the rate at which the raw materials decompose. In temperate climates, composting is fastest in spring, summer and fall months and is likely to come to a complete stand still in winter months. However, if pile size is increased in winter to 8-12 feet tall and 10-12 feet wide, piles can

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**Estimating the carbon content of feedstocks**

% carbon = \( \frac{\text{volatile solids}}{1.8} \)

where %volatile solids = 100 - %ash (material incinerated at 500°C)

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**How to calculate the moisture content of compost or feedstock**

Materials needed: small container, scale, samples of compost or feedstocks

1. Weigh the empty container.
2. Add 10 g of the material into the container (this is the wet weight).
3. Dry the sample for 24 hours in a 110°C oven.
4. Weigh the sample and subtract the weight of the container. This is the dry weight.

Determine the moisture content using the following equation:

\[
\text{Moisture content} = 100 \times \left(1 - \frac{\text{dry weight}}{\text{wet weight}}\right)
\]
retain heat and remain active.

**Determining compost mixes**
Many composters determine their feedstock mix by the look and feel of the mix. With an eye to optimizing C:N ratio and moisture content, and some experience with the raw materials, this trial and error approach can often work. For composters trying out new materials, for larger operations, or when composting needs to be efficient, more precise compost recipes can be calculated using formulas and computer spreadsheet programs that are based on the characteristics of the raw materials (see Resources).

**General Guidelines for Pile Management**

**Managing compost piles for good aeration**
A well-aerated compost pile has at least 5% oxygen content during the active phase of composting (ideally closer to 10%). Composts must be aerated either passively or actively as aeration is key to successful composting. As microbial activity increases in the compost pile, more oxygen will be consumed. If the oxygen supply is not replenished, composting can shift to anaerobic decomposition, slowing the composting process and foul odors.

Oxygen monitoring equipment is available, but is expensive. Temperature, odors and moisture are easy to measure and provide a good indication of active decomposition and adequate aeration. Monitor temperature at least weekly, using a thermometer with a three-foot stem and a range from 0 to 200 degrees F. Check the moisture content and odor. A compost pile is not odor-free, but a distinct foul odor usually means anaerobic conditions have developed. An ammonia smell can mean too much nitrogen is present, which can be corrected by mixing in carbon-rich materials. A putrid odor can mean too much water—correct by mixing in bulking materials (see Table 3).

Good aeration can also be achieved by managing pile porosity. Porosity is defined as the volume of pores divided by the total volume of compost. Some of those pores will be filled with water and the rest with air. The initial pile mix should have between 45-60% air-filled porosity and during the active phase of composting, it shouldn't drop below 35% (see sidebar: How to measure bulk density and porosity).

**Managing Pile Moisture**
Water will be given off as vapor during the active phase of composting, when temperatures are high. If you are turning piles, you can add water as you turn.

If you are using static aeration, it is much more difficult to add water to the compost pile. It is best to make initial feedstock blends on the wet side (65-70%) by weight, so that when they lose moisture vapor, they will still be wet enough to keep microbes active. Some commercial composters using forced aeration systems add moisture by introducing humidified air into pipes.
that blow air into the piles.

**Pile size**
The ideal height and width of the piles will depend on the porosity and moisture content of the raw materials, composting method and your specific equipment (Table 4). For example, a light, dry pile can be stacked higher than a wet, dense pile, without the risk of developing anaerobic conditions within the pile. Small piles will be able to maintain higher internal oxygen concentrations than large piles, but large piles will retain the higher temperatures better than small piles. For a pile to heat and stay hot, the minimum size should be one cubic yard.

The *particle size* of the feedstock will affect porosity, airflow, and the amount of microbial activity. Smaller particles have more surface area per unit volume and, therefore, microbes have more surface to colonize. However, if particles are too small, porosity will decrease and airflow within the compost pile will be restricted. A mix of particle sizes creates the most porous pile (Figure 4).

**Managing Foul Odors**
Good aeration promotes active aerobic decomposition. When piles are too wet, too large, not porous enough, or are degrading too quickly, aerobic bacteria can’t get enough oxygen and anaerobic bacteria take over. Sulfur compounds and other by-products of anaerobic respiration form and odors build. Odors can originate from specific incoming or stockpiled feedstocks (such as sewage sludge, liquid manure or fish by-products) or poorly aerated compost piles. Anaerobic respiration, and resulting odors, can also occur in standing pools of water around compost windrows and in water retention ponds. You can minimize odors by proper pile management. Once aerobic conditions are reestablished, the bacteria will “eat” the odorous compounds.

**Ammonia**
Ammonia odors can form independent of the aeration of the feedstocks or piles. Nitrogen-rich feedstocks usually have low C:N ratios. If N is in excess, nitrogen is metabolized in a way that gaseous N compounds (ammonia and nitrous oxide) are released. To minimize this, set pile C:N well above 10:1 (25-35:1 ideal) and try to blend feedstocks to keep the pile pH below 7.5.

**Siting Considerations, Technology Options and Management Intensity Levels**

**Siting Considerations**
In choosing a site, consider:

- Management operations: access to roads and ease of handling materials
- Water quality protection: siting is the first step in preventing leaching and run-off into

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**Table 4. Pile size guidelines**

<table>
<thead>
<tr>
<th>Composting method</th>
<th>Height (feet)</th>
<th>Width (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Piles</td>
<td>3-6</td>
<td>12</td>
</tr>
<tr>
<td>PAWS</td>
<td>3-6</td>
<td>10</td>
</tr>
<tr>
<td>Windrow Composting -</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor pulled</td>
<td>6-8</td>
<td>10</td>
</tr>
<tr>
<td>Self-propelled turner</td>
<td>3-9</td>
<td>9-20</td>
</tr>
<tr>
<td>Bucket loader</td>
<td>6-12</td>
<td>10-20</td>
</tr>
<tr>
<td>Aerated Static Piles</td>
<td>6-12</td>
<td>10-20</td>
</tr>
<tr>
<td>In-vessel</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

---

**Figure 4. How porosity affects aeration. From T. Richard, Cornell Waste Management Institute.**
surface or groundwater

- Neighborhood relations: odor, noise, dust, debris and appearance of your operation

Leaching of nitrates and other soluble nutrients is most likely to occur during curing phase and compost storage. Highly permeable soils are most at risk. Try to find a soil of intermediate permeability. Ideally, the site should be several feet above the seasonally high water table, and several hundred feet away from wells or surface water. Consider the slope of the site, especially the potential for water to run into the compost piles during storms or snowmelt. Plant grass buffer strips to slow run-off. Consider providing roofs over some of the composting area to divert precipitation and keep stored compost dry.

Site visibility and appearance can go a long way in maintaining a good perception of your operation. Use some of your compost to landscape the site, plant and maintain trees and grassy areas—these will also help control and filter run-off from the composting site. Choose a site with some consideration of the homes of neighbors and the direction of prevailing winds during warm weather. Plan grinding and turning for hours during the day in which neighbors are less likely to be affected by the odors and noise.

**Composting Technologies**

The most common composting technologies or methods are

- Static piles
- windrow composting
- passively aerated windrows
- forced aeration, static piles
- enclosed, or in-vessel, composting
- vermicomposting

Within these methods are ranges of technology options.

**Static Piles**

Static piles are the simplest form of composting and require little management and equipment. Once established, it is very difficult to adjust moisture, and static piles tend to go anaerobic in the center. Aerobic conditions can be achieved if the initial pile porosity is high (>60%) and there is a high proportion of bulking materials to keep pores open for air exchange. While simple, this method takes the longest to produce finished compost, and the composted material can be quite heterogeneous.

**Windrow Composting**

Windrow is the general term for an elongated pile of stacked raw materials. (**Figure 5**). Piles need to be small (3-6') and porous enough for air to pass through them over a long period of time.

A turned windrow is one that is mechanically turned using a bucket loader, manure spreader or a windrow turner (**Figure 6A, B**). Turning the windrow remixes the materials, allowing all the raw materials to be colonized by microorganisms in the warmer, more active internal part of the compost pile. Oxygen is reintroduced, heat, water vapor and gases escape. The most important part of turning the pile is the reestablishment of porosity and the ability of air to get into the pile.

**Passively aerated windrow system (PAWS)**

PAWS includes perforated pipes placed at the base of each windrow to promote convective airflow throughout the pile. The key to this system is thorough premixing of feedstocks before placing on the perforated pipes. Also, windrows need to be insulated with finished compost to ensure thermophilic temperatures reach the outer edges of the windrow (**Figure 6C**).

**Forced Aerated Static Piles**

Forced aerated static piles are similar to PAWS piles, but blowers are installed at the ends of perforated pipes or air ducts as shown in **Figure 7**. Air flow can be adjusted by changing the frequency and duration of the blower. Usually, blowers are set to turn on when the compost reaches a maximum temperature (e.g., 150°F).

**Enclosed Composting**

Enclosed, or in-vessel, composting is mainly for the commercial compost producer who needs more
environmental control during the composting process. Some large scale composting operations use completely enclosed in-vessel equipment to achieve maximum control of temperature, oxygen and moisture. Some farms have also successfully used the smaller, less expensive bin equipment. Equipment ranges from a simple enclosed bin, an agitated bin or reactor, to an entire building devoted to composting.

Vermicomposting

Vermicomposting is worm composting; in which red worms transform decaying organic matter into worm castings. The castings contain high concentrations of readily available nutrients for plants. Vermicomposting does not achieve the high (thermophilic) temperatures in windrow and aerated static pile composting because the worms can’t survive the high temperatures.

However, research has shown that both pathogens and weed seeds can be destroyed in vermicomposting. Vermicomposting is usually done in containers and can be done indoors and outdoors, allowing year round composting. The two types of worms best suited to worm composting are the red worms: Eisenia fetida (commonly known as red wiggler, brandling, or manure worm) and Lumbricus rubellus. They are often found in the litter layers of forests, manure piles and backyard compost heaps. For more information see Resources.

Choosing a composting method

Choose an approach that best suits your reasons for making compost, the location of the compost site and the amount of specialized equipment you have available to produce compost (Figure 8). Where you are located is important from environmental impact and potential nuisance perspectives. For example, composters located in rural areas need to be concerned that composting activities don’t adversely affect surface and ground waters, but they usually are
less concerned about neighbor complaints related to odors, noise and dust. Composting sites located in rural-urban and urban areas often are forced to use high technology options to minimize nuisance complaints.

The decisions about technology options and management intensity can be viewed as a continuum (Figure 8). If you are new to composting and want to make compost exclusively for your own use, you might start out at the low to intermediate scale. Later if you decide to make a saleable product or expand your site, you might decide that you can justify the costs of higher technologies and more intensive management.

“Low technology” composting
Low technology options usually go hand-in-hand with minimal management. Examples include static, passively aerated piles where you would use dry and large-particle size feedstocks to give the compost pile sufficient porosity. Use of a bucket loader to turn piles infrequently (every two weeks) would also be considered a low-technology option for on-farm composting. These options make the most sense for individuals in rural areas making compost largely for their own use.

“Intermediate” technology options
Intermediate technology - moderate management intensity includes turned windrow composting using non-specialized equipment. The most common example is building and turning piles using a manure spreader. These windrows would likely be turned once per week during the active phase of composting and then monthly during the curing phase. The passively aerated windrow system (PAWS) would also be considered an intermediate technology option because the composter will need some kind of equipment to premix feedstocks and will need to purchase perforated pipe for placement underneath the compost pile. Management of the PAWS system is intensive in the pile establishment phase, but minimal thereafter. Both of these intermediate technology options are suited to rural or rural-urban fringe locations. Composts produced using these methods would be best suited to internal use, unless the composter can demonstrate product consistency over time.

“High technology” composting
High technology options usually include specialized composting equipment: tractor-pulled or self-propelled windrow turners, forced aeration systems with perforated pipes and blowers and enclosed (or in-vessel) systems. These require serious financial and labor commitments. Use of these technologies are justified when the composter intends to make a saleable product and when the compost site is located either on the rural-urban boundary or within an urban setting. Management intensity of these systems is...
usually high. For turned windrow systems, windrows are usually turned 2-3x/week during the active phase of composting (minimum of 1x/week) and then 1-2x/month during curing. For the forced-aerated and enclosed technologies, you will need to monitor the equipment to make sure that air flow and moisture are optimized to produce the desired temperature range.

Studies comparing technology-management effects on compost quality.

There are several studies evaluating the effects of different composting technologies and management intensities on compost “process variables” (measurements used to assess how the process is progressing) and finished compost. Lopez Real and Baptista (1996) evaluated three composting methods to determine their effects on composting process variables and methane emissions. The methods included 1) minimal intervention or passively aerated stacked manure; 2) windrowing or turned mechanically with a manure spreader and 3) forced aeration using perforated pipes and a blower. They evaluated changes in the first 36 days of composting and found that windrowing produced the greatest change in total volume and volatile solids compared to minimal intervention and forced aeration (Table 5). Methane emissions from the passively aerated piles were over 100 times greater than the windrow turned piles and 1000 times greater than the forced aeration piles. Results showed that introducing air mechanically speeds up the composting process and greatly reduces emissions of a greenhouse gas (methane).

Woods End Research Labs in Maine presented findings from two manure compost studies using a range of composting technologies from no turning to highly specialized self-propelled windrow turners (Brinton, 1998). The evaluated compost pile temperature and oxygen, organic matter and nitrogen loss and operations & maintenance costs. Results showed that use of a turning machine reduced the time to finished compost by a few weeks compared to no turning or use of a manure spreader. When temperature profiles were compared, intensification of the composting process either through turning or adding bulking material to increase porosity decreased the time to “stable” compost by approximately 20 days. As management intensification increased, so did loss of organic matter and nitrogen (Table 6). However, the costs associated with technology and management also increased with intensification (Table 7). They concluded that if the goal for composting is nutrient management and on-farm use of compost, intensive technologies and management are not necessary.

Cost Considerations

These can be grouped into six general categories: 1) business and site development (most applicable to larger scale operations or permitted facilities), 2) feedstock costs, 3) equipment, 4) labor; 5) management (for large facilities) and 6) marketing and/

| Table 5. Percent change in compost total volume and volatile solids for three manure composting methods over a 36 day period. Average methane emissions over the same period. |
|-----------------|-----------------|-----------------|-----------------|
| Process variable | Minimal Intervention | Windrow | Forced Aeration |
| Volume reduction | 55 | 73 | 55 |
| Volatile solids | 12 | 22 | 15 |
| Average methane emission (ppmv) | 28,744 | 223 | 3 |

| ppmv = parts per million per volume |

| Table 6. Technology and management effects on total losses of organic matter and nitrogen during composting. |
|-----------------|-----------------|-----------------|
| Treatment       | Organic Matter loss (%) | Total Nitrogen loss (%) |
| Cow manure compost at 120 days | | |
| No turn | 70 | 51 |
| Bucket loader-turned | 78 | 60 |
| Turned 1x/2 weeks | 73 | 53 |
| Turned 2x/week | 80 | 64 |

| Poultry manure compost at 150 days |
| No turn | 75 | 72 |
| Bucket loader-turned | 79 | 76 |
| Turned 1x/2 weeks | 79 | 78 |
| Turned 2x/week | 88 | 86 |

Source: Brinton, 1998

| Table 7. Costs associated with varying technology and management intensities. |
|-----------------|-----------------|-----------------|
| Treatment       | Cost/wet ton ($) |
| No turn | 3.05 |
| Bucket loader-turned | 6.74 |
| Turned 1x/2 weeks | 14.34 |
| Turned 2x/week | 41.23 |

Source: Brinton, 1998
or compost use. For most feedstocks they will either be “free” or you will receive a “tipping fee.” However, in some cases, you will need to purchase bulking agents like wood chips or sawdust. Equipment costs include ownership, fuel and maintenance. Labor costs can divided into operations and maintenance. It is wise to estimate these costs before starting a new composting operation to determine feasibility and pricing of saleable compost products.

**Composting regulations and permits**

If you are composting on farm or compost small volumes of material (<20,000 cubic yards per year), you can compost without a special permit from the Wisconsin Department of Natural Resources (DNR). However, most states regulate large-scale composting. Many composting facilities must obtain composting permits to ensure minimal negative environmental impacts. For more information, contact your state Department of Natural Resources. In Wisconsin, on-farm composting of crop residues, manure and animal carcasses at the location where they are produced are exempt from regulations, IF

- The facility is operated in a nuisance-free, environmentally sound manner.
- The compost is land-spread in compliance with NR 518.04(1).
- Composting of animal carcasses complies with s. 95-50(1).
- Yard wastes and wood chips accepted from off-site are only used to increase C:N ratio of manure and the porosity of the pile, and meet minimum operation and design standards

**Qualities of the Finished Compost**

Not all composts are created equal. What goes in as feedstocks partly determines what comes out. Compost quality depends on the composting process used, the state of biological activity, and, most importantly, the intended use of the compost. Just as beauty is in the eye of the beholder, the end use defines compost quality.

There are some specific chemical, physical and biological parameters that can be used to evaluate compost quality. For on-farm use as a soil amendment, a moisture content, organic matter content, C:N ratio and pH should be determined before compost application (Table 8). High value markets like nurseries, landscaping, and turf require a high quality compost with specific qualities and characteristics suitable for plant growth.

<table>
<thead>
<tr>
<th>Quality</th>
<th>Optimum</th>
<th>How to test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of organic matter</td>
<td>Should have a good organic matter content</td>
<td>Have organic matter tested by a soil lab</td>
</tr>
<tr>
<td>Source of nitrogen</td>
<td>10-15:1 C:N ratio</td>
<td>Have C:N ratio checked by soil lab</td>
</tr>
<tr>
<td>Neutral pH</td>
<td>6-8</td>
<td>Use soil pH kit at home or soil lab</td>
</tr>
<tr>
<td>Low soluble salts</td>
<td>If compost will be spread in the fall, no test necessary. If compost will be spread before planting, have soil lab check that levels are below 10 dS</td>
<td></td>
</tr>
<tr>
<td>No phytotoxic compounds</td>
<td>Good seed germination</td>
<td>Plant 10 seeds in a small pot.</td>
</tr>
<tr>
<td>Weed-free</td>
<td>No or few weed seeds</td>
<td>Moisten compost and watch for weed seedling growth.</td>
</tr>
</tbody>
</table>

**Compost Quality Standards**

Aside from temperature requirements to kill pathogens (55°C for at least 72 hrs.) and general acceptance of US EPA 503 Biosolids rules for trace metal concentrations, there are no federal standards for finished compost. Some states are in the process of developing standards to minimize negative environment effects (pathogens, heavy metals and organic pollutants). Other states require tests for biological stability and compost-use related properties (salt content, pH, C:N ratio).

However, there are excellent programs dedicated to establishing marker-driven standards for the benefit of composters and compost users: Two of these programs are the Seal of Testing Assurance (STA) by the United States Composting Council and the Sohita Quality Seal of Approval by the Woods End Research Group.

**How the STA Program works**

Compost producers regularly sample and test their product, using STA Program approved labs, for chemical, physical and biological properties. All of these labs must use the same standardized testing methodologies. Testing frequency is based on the each production facility’s volume and can be as frequent as monthly for the largest producers, to quarterly for the
smaller composter. Compost use directions are provided with the test results. The goal of the program is to provide a standard STA label to allow end users to compare compost products and make an informed purchasing decision. See their web site under Resources for more detail.

**The Solvita Quality Seal of Approval**
The Woods End Solvita Quality Seal of Approval program is based on specific, identified uses. Six end-use categories are presently recognized. The program provides specific tests designed to assure users that a particular compost or product meets basic quality expected for that particular use. Anyone who produces or distributes a compost or soil amendment product, may seek the Solvita Quality Seal of Approval. See Resources for more information on their program.

**Summary**
Composting organic wastes is an environmentally sound means of recycling raw organic materials into valuable soil amendments with many uses. As you begin your composting operation, keep in mind these five points for a successful outcome:

- Be clear why you are making compost, and what you intend the final use of the compost to be.
- Choose equipment and management methods based on your location and the intended use of the finished product.
- Determine the right mix of ingredients to optimize C:N ratio, moisture content and porosity.
- Monitor the composting process: temperature, oxygen, moisture and odors.
- Test the finished compost to ensure it has the qualities you need for the intended use.

*To your compost's health!*
Resources


Composting for Manure Management.


Websites

The U.S. Composting Council
http://compostingcouncil.org/index.cfm
promotes research, public education, compost standards and expansion of compost markets.

Woods End Research Laboratory
pioneers in compost quality analysis and standards.
http://www.woodsend.org/

Cornell Composting
http://www.cfe.cornell.edu/compost/
Composting_homepage.html


The California Quality Compost Council http://www.ccqc.org/

WasteNOT Organics
www.wastenot-organics.wisc.edu/wno
Research-based information from the University of Wisconsin-Madison about organic by-products and their use as soil amendments.

BioCycle - Journal of Composting & Recycling on-line
http://www.jgpress.com/

Recycler's World - equipment and services
www.Recycle.net/recycle/organic

Composting News on-line newsletter for the composting industry http://www.recycle.cc/

Internet Recycling and Composting Resource Page - equipment and services http://www.recycle.cc/resource.htm

Vermicomposting

Worms for Composting from the ATTRA (Appropriate Technology Transfer for Rural Areas - pdf file 211K) www.attra.org/attra-pub/PDF/vermicomp.pdf

Worm Digest www.wormdigest.org/
Email: mail@wormdigest.org

Compost Recipes

Downloadable Excel spreadsheets with compost mixture calculations for up to four ingredients (Mac or PC)

Compost Recipe Maker by Herb Brodie. An excellent DOS-based computer software program. $40 from Pat Lupo, University of Maryland. Tel: 301-405-1198.

Compost Maturity

Solvita(r) Compost Maturity Test kits http://www.woodsend.org/solvita.htm

How Do I Know If My Compost Is Mature? The California Compost Quality Council's maturity index (pdf file- 100 K) http://www.ccqc.org/downloads.htm

Compost Quality Standards

Woods End Compost Research Lab http://www.woodsend.org
Solvita Quality Seal of Approval program http://www.woodsend.org/sqa.htm

Seal of Testing Assurance Program (STA) http://tmecc.org/sta/index.html (from The U.S. Composting Council at http://compostingcouncil.org/index.cfm)
References


Cornell Waste Management Institute http://www.cfe.cornell.edu/compost/odors/ inadep.porosity.html#txt1

Labor on the Farm

Running a Successful Farm Business

Labor laws can be a challenge to understand, especially given the seasonal and familial nature of farm work. The following information and regulations are for every classification of worker you might have on your farm. As an employer, farms have legal responsibilities when hiring employees, interns, apprentices and volunteers.

In this fact sheet, you will find information on:

- managing people;
- labor laws for employees;
  - Employer Identification Number (EIN);
  - minimum wage;
  - hiring young workers;
  - hiring family;
  - Labor and Industries requirements;
  - providing a safe workplace for your employees;
  - payroll taxes;
- labor laws for interns;
- labor laws for apprentices; and
- labor laws for volunteers.

Managing People

For any size of business or farm, it is a good idea to have a plan for managing employees, volunteers, interns, and even other family members. Although there may be implicit roles built up over a lifetime of working together, creating a more formalized management plan becomes increasingly useful when new people are added to the farm business.

Management plans build understanding about why and how decisions are made, and clarify exactly what each person’s responsibilities will be on the farm. By sharing ownership in the outcomes, employees are better able to understand the big picture and focus on the right priorities. Formal management plans and employee manuals may also help in securing funding, abiding by legal requirements with employees, and improving on-farm safety.

There are many ways to approach how to manage everyone working on or with your farm. If you are just getting started, there are seven key processes to focus on:

- create written job descriptions and an overall plan for how each job fits into the whole;
- create clear hiring protocols;
- provide an orientation to your farm and the job as well as ongoing training (informal and formal);
- develop clear employer/employee communication, including a written grievance policy;
- schedule times to review job goals and performance;
- clarify compensation and check related laws; and
- schedule times to review your management plan to keep it updated and relevant.

Managing people is a real skill and can be real work. However, having a productive team and avoiding personnel tension and even possible legal issues is a real benefit in the long run.

Labor Laws for Employees

An employee is generally someone for whom an employer determines their work schedule, hours, and job responsibilities.
In order to have employees, you must follow these legal requirements:
- have an Employer Identification Number (EIN);
- pay wages;
- pay Washington State Labor and Industries premium for workers compensation insurance that covers on the job injuries;
- provide a safe workplace for your employees; and
- file payroll tax forms and make payments.

The Department of Labor & Industries (L&I) has developed an Agricultural Employer Worksheet to help you know whether you are following state Agricultural Employment Standards and the Minimum Wage Act when you employ workers. It is available at [www. lni. wa. gov/ Forms/ pdf/ 700125af. pdf](http://www.lni.wa.gov/Forms/pdf/700125af.pdf).

For each new hire, employers need to have employees complete an Employment Eligibility Verification, Form I-9, from the Department of Homeland Security U.S. Citizenship and Immigration Services. Employees must also complete an IRS Employees Withholding Allowance Certificate, Form W-4. Employers must collect these, and keep them in each employee’s file.


**Employer Identification Number (EIN)**

Any business that hires employees must obtain a federal Employer Identification Number (EIN), also known as a Federal Tax Identification Number by filing Form SS-4 or applying online with the Internal Revenue Service (IRS). An EIN is a nine-digit number that IRS assigns in the following format: XX-XXXXXXX. It is used to identify the tax accounts of employers. Businesses that are not sole proprietorships are also required to have an EIN.

The federal identification number assigned to your business will be registered with the IRS, the Social Security Administration, and the US Department of Labor. While most applications take four weeks to process, if you apply online, most businesses will receive a number immediately.

Contact the IRS for more information such as help documents and videos, to apply online or to obtain an SS-4 form by visiting [www. irs. gov](http://www.irs.gov), or calling (800) 829-3676.

**Minimum Wage**

Employers are required to pay the state minimum wage to workers age 16 and older. Minimum wage is set annually by the Washington Department of Labor and Industries. The current minimum wage can be found online at [www. lni. wa. gov/ workplace rights/ wages/ minimum](http://www.lni.wa.gov/workplacerights/wages/minimum).

There are three exemptions to the state minimum wage for agricultural workers. They only apply if all three of the following requirements are met:

1. Workers are employed as hand-harvest laborers who are paid piece rate; and
2. They commute daily from their permanent residence to the farm; and
3. They were employed in agriculture less than 13 weeks during the preceding calendar year.

**Hiring Young Workers**

Workers under the age of 16 must be paid at least 85% of the state minimum wage. For a complete fact sheet showing employer requirements for hiring young workers ages 14 to 18 in agriculture such as the Minor Work Permit Endorsement, visit [www. lni. wa. gov/IPUB/ 700-096-909. pdf](http://www.lni.wa.gov/IPUB/700-096-909.pdf).
Children 12 and 13 years old are allowed to work only during non-school weeks and only for hand-harvesting berries, bulbs, cucumbers, and hand-cultivating spinach. Also, certain duties listed in the Minor Work Permit Endorsement are considered dangerous and prohibited for minors in agriculture.

**Hiring Family**
If you have relatives, including children, who work for you, they must be treated as employees with the same rights as any other paid worker in the state of Washington. This applies to anyone you expect to show up for work at a certain time. These requirements do not include family members who share ownership of a business, or children under the age of 18 who work on a farm owned by their parents. Children between ages 18 and 21 must be covered by workers’ compensation unless an application for exclusion is filed by the parents. At age 21, workers’ compensation coverage is mandatory. The Application for Exclusion/Inclusion of Mandatory Coverage form is available at your local Labor and Industries office. The family farm may be a sole proprietorship, partnership or corporation so long as the controlling interest is with the family.

For a complete fact sheet showing employer requirements for hiring family members visit www.lni.wa.gov/IPUB/101-077-909.pdf

**Labor and Industries Requirements**
L&I requires certain workplace posters to be posted for employees. A list of workplace posters required and recommended by L&I, other Washington State and federal agencies is available at www.lni.wa.gov/IPUB/101-054-000.pdf. All posters are free and available in both English and Spanish. Be aware that private companies will try to sell these to you.

L&I requires that employers maintain records of employees for three years. Records must include: employee name and address, occupation and L&I job classification, dates of employment, amount paid each pay period, wage rate or rates of pay, and total hours worked each pay period, and termination date and cause. These records are subject to audit.

L&I conducts workshops around the state designed for new businesses or businesses that plan to hire workers for the first time. It explains an employer’s rights and responsibilities and provides an overview of the services and resources available at Labor and Industries. It also covers workplace safety and health requirements, claims management strategies, risk management, quarterly reporting requirements and wage-and-hour laws. For complete information, please visit L&I online at www.lni.wa.gov or call (800) 574-2829.

L&I also has a webpage that leads new businesses or new employers through all of the needed information and steps at www.lni.wa.gov/Main/RunBusiness.asp or download the form available online called the Farm Labor Employer Packet at www.lni.wa.gov, or call the Washington State Department of Labor and Industries Employer Help Line at (360) 902-5316.

**Providing a Safe Workplace for Your Employees**
As an agricultural employer with one or more employees you are responsible for following guidelines and statutory requirements in order to maintain a safe workplace. There are specific workplace standards and reporting provisions with which an employer must comply. Details can be found on the L&I website under several different headings pertaining to on the job safety.

You may want to request a safety and health consultation from L&I. A consultant, not an inspector, will meet with you and conduct a walkthrough survey of your worksite to identify hazards and recommend remedies. You must correct in a timely manner any serious hazards found during the consultation, but the consultant will not issue a citation or fine you.
To request a free consultation, visit www.SafetyConsultants.Lni.wa.gov or call the L&I office nearest you and ask to speak to the Consultation Manager. In addition to safety and industrial hygiene consultations, specialists in ergonomics and risk management are available to assist employers as well.

To learn about the safety standards for agriculture and resources available for employee safety and health trainings visit www.Lni.wa.gov/safety/topics/atoz/default.asp?KWID=353. The WISHA rules are available in English or Spanish, through the L&I website at www.Lni.wa.gov/WISHA/Rules/agriculture/default.htm.

**Payroll Taxes**
Employers are required to withhold federal income, Social Security and Medicare taxes from employees’ wages. Employers are also required to pay worker’s compensation and state unemployment insurance. For more information, on your payroll responsibilities please see the Fact Sheet on Taxes.

**Labor Laws for Interns**

An intern must be registered in an internship program at an accredited educational institution such as a college, community college, or university where a student pays the school and receives academic credit.

An internship allows an employer to be exempt from:
- paying wages; and
- paying unemployment insurance tax through state Employment Securities (ESD) and federal FUTA.

An internship still requires that an employer:
- provide a safe workplace.

Washington Labor and Industries premium for workers compensation insurance that covers on the job injuries can be paid by the educational institution sponsoring the internship.

**Labor Laws for Apprentices**

The term “apprentice” is an employment classification with a formal structure set by federal and state law. The business employing the apprentice designs a personalized program that must be proposed to and approved by the Washington State Apprenticeship Council (a division of L&I).

In order to have apprentices, you must follow these legal requirements:
- Have an Employer’s Identification Number (EIN);
- Pay at least minimum wage with raises based upon demonstrated competencies;
- Pay Washington Labor and Industries premium for workers compensation insurance that covers on the job injuries;
- Pay Unemployment insurance tax through state Employment Securities(ESD) and federal (FUTA);
- Provide a safe workplace for your employees; and
- Provide 144 hours of pre-planned instructional time per year.

While there is no cost to register an apprenticeship program, it does take time. Plan for three to six months to create, register and approve an apprenticeship program.

The employer benefits from apprentices by building long-term labor support and training someone from the beginning with their knowledge and techniques. As a Washington State registered apprentice, an apprentice will receive a 50% tuition waiver at a Washington State community or technical college.
To create an apprenticeship program you will need to be either a farm, group of farms or trade organization.

Registered apprenticeship programs start with the formation of an apprenticeship committee. Committees develop program guidelines that include:
- Criteria for becoming an apprentice
- Skill and proficiency requirements to reach journey worker/professional level
- Number of apprenticeship openings
- Wage rates and progressions based upon demonstrated competencies
- Required course curriculum to complement on-the-job training
- Supervision methods
- Equal opportunity procedures

For a fact sheet on full apprenticeship requirements visit www.lni.wa.gov/TradesLicensing/Apprenticeship/files/pubs/RegisteredApprenticeshipemployerfactsheet.pdf. Or for a local apprenticeship consultant go to: www.lni.wa.gov/TradesLicensing/Apprenticeship/About/AppCoordinators/default.asp, or call (360) 902-5320.

**Labor Laws for Volunteers**

According to L&I rules, volunteers are not allowed in a “for-profit” business.

Employers must follow all state employee guidelines for people seeking to trade, barter or volunteer on their farm. Arranging for volunteer agricultural workers through established exchange programs does not exempt an employer from these requirements.

There are only two programs through L&I for volunteers that are not required to meet all other state employee guidelines. One is the Sports Teams and Youth Workers program and the other more applicable to farms is the K-12 Student Volunteers program for which information can be found at http://lni.wa.gov/FormPub/Detail.asp?DocID=1560. This can apply to 4-H projects.

For complete information about employment standards and workplace rights, contact L&I at (866) 219-7321.

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**Recommended Fact Sheet: Taxes**

For further assistance or to make suggestions on how to improve this fact sheet, please email smallfarms@agr.wa.gov or call (360) 902-2057 or (360) 676-2059.
Chapter 70.114A RCW
Temporary worker housing — health and safety regulation

RCW Sections

70.114A.010 Findings -- Intent.
70.114A.020 Definitions.
70.114A.030 Application of chapter.
70.114A.040 Responsibilities of department.
70.114A.045 Housing operation standards -- Departments' agreement -- Enforcement.
70.114A.050 Housing on rural worksites.
70.114A.060 Inspection of housing.
70.114A.065 Licensing, operation, and inspection -- Rules.
70.114A.070 Technical assistance.
70.114A.100 Rules -- Compliance with federal act.
70.114A.110 Cherry harvest temporary labor camps -- Rule making -- Definition -- Conditions for occupation--Application.
70.114A.900 Severability -- 1995 c 220.
70.114A.901 Effective date -- 1995 c 220.

70.114A.010
Findings — Intent.

The legislature finds that there is an inadequate supply of temporary and permanent housing for migrant and seasonal workers in this state. The legislature also finds that unclear, complex regulations related to the development, construction, and permitting of worker housing inhibit the development of this much needed housing. The legislature further finds that as a result, many workers are forced to obtain housing that is unsafe and unsanitary.

Therefore, it is the intent of the legislature to encourage the development of temporary and permanent housing for workers that is safe and sanitary by: Establishing a clear and concise set of regulations for temporary housing; establishing a streamlined permitting and administrative process that will be locally administered and encourage the development of such housing; and by providing technical assistance to organizations or individuals interested in the development of worker housing.
70.114A.020
Definitions.

The definitions in this section apply throughout this chapter.

(1) "Agricultural employee" means any person who renders personal services to, or under the direction of, an agricultural employer in connection with the employer's agricultural activity.

(2) "Agricultural employer" means any person engaged in agricultural activity, including the growing, producing, or harvesting of farm or nursery products, or engaged in the forestation or reforestation of lands, which includes but is not limited to the planting, transplanting, tubing, precommercial thinning, and thinning of trees and seedlings, the clearing, piling, and disposal of brush and slash, the harvest of Christmas trees, and other related activities.

(3) "Department" means the department of health.

(4) " Dwelling unit" means a shelter, building, or portion of a building, that may include cooking and eating facilities, that is:

(a) Provided and designated by the operator as either a sleeping area, living area, or both, for occupants; and

(b) Physically separated from other sleeping and common-use areas.

(5) "Enforcement" and "enforcement actions" include the authority to levy and collect fines.

(6) "Facility" means a sleeping place, drinking water, toilet, sewage disposal, food handling installation, or other installations required for compliance with this chapter.

(7) "Occupant" means a temporary worker or a person who resides with a temporary worker at the housing site.

(8) "Operator" means a person holding legal title to the land on which temporary worker housing is located. However, if the legal title and the right to possession are in different persons, "operator" means a person having the lawful control or supervision over the temporary worker housing under a lease or other arrangement.

(9) "Temporary worker" means an agricultural employee employed intermittently and not residing year-round at the same site.

(10) "Temporary worker housing" means a place, area, or piece of land where sleeping places or housing sites are provided by an agricultural employer for his or her agricultural employees or by another person, including a temporary worker housing operator, who is providing such accommodations for employees, for temporary, seasonal occupancy.

[1999 c 374 § 6; 1995 c 220 § 2.]

70.114A.030
Application of chapter.

Chapter 220, Laws of 1995, applies to temporary worker housing that consists of five or more dwelling units, or any combination of dwelling units, dormitories, or spaces that house ten or more
Advocates stress need for housing

Updated: Saturday, October 17, 2009 12:04 PM

Farmworker housing a must for ag, leaders say

By COOKSON BEECHER
Capital Press

Without farmland there can be no farmers. But without farmworkers, there can be no ag economy.

That was the message John Smith, former executive director of the Skagit County, Wash., Housing Authority, shared with the 65 people attending the recent Skagit Valley Farmworker Housing Forum. The group was made up of farmers, farmworkers, elected officials and others.

Before the meeting, Maria Siguenza, who works in sales and accounting at Mike & Jean's Berry Farm, said that because farmworkers are the "main players" in most farming operations, it's important that they have adequate housing.

"We really need their commitment to staying in agriculture," she said.

"If their housing needs aren't met, they have a low motivation to stay in agriculture," said Eric Sanchez, Siguenza's co-worker.

Their comments echoed one of the conclusions of the trust's recently released housing survey of farmworkers, "A Sustainable Bounty: Investing in Our Agricultural Future."

According to the survey, half of the almost 3,000 Washington farmworkers surveyed said they either plan to leave farmwork within the year or don't know how much longer they will work in farming. Yet 91 percent of those surveyed said that more and better housing would encourage them to stay in agriculture.

About 187,000 farmworkers are employed in Washington state each year.

Of those surveyed, 24.1 percent of migrant workers and 13.6 percent of local workers live in housing provided by the employer.

The trust has previously estimated that approximately 39,000 additional homes are needed -- 12,000 seasonal units for migrant workers and 27,000 for local workers.

Brien Thane, executive director of the Washington State Farmworker Housing Trust, a nonprofit organization formed in 2003, said that despite their value to agriculture and to the state's overall economy, many farmworkers live in substandard housing, pay too much rent and have to pack too many people into living quarters.

"This threatens the stability of the workforce and the health and education of the farmworker families," he said.
Thane told the group that he believes that farmworker-housing advocates can make significant progress. He also conceded that finding enough funding to do that is a major challenge.

As of 2008, the trust and its housing authority partners developed 1,002 community-based farmworker homes in 34 developments across the state. Funding sources include state and federal programs.

While agreeing with Thane on funding challenges, Skagit County grower Mike Youngquist told the group about another major obstacle: Finding locations for housing is difficult because of stereotypes about farmworkers.

"It seems unlikely that any site anywhere can be found that will not evoke strong NIMBY (not in my backyard) sentiment," he said. "That is why you as our leaders must recognize the real issues and not accept stereotypes from controlling the issue."

After the meeting, Skagit County Commissioner Sharon Dillon, the former mayor of Sedro-Woolley, which has two farmworker apartment complexes, said the city's police department gets the lowest number of calls -- almost zero -- from those complexes.

"That's important for people to know," she said. "We need to get rid of the stigma attached to farmworker housing."

Survey results

Income

According to the Washington State Farmworker Housing Trust's survey of farmworkers, the average household income earned last year by the farmworkers surveyed was $17,596 -- 88 percent of the 2006 federal poverty level of $20,000 for a family of four.

The survey also found that household income varied across regions, with farmworker households in north central Washington earning an average of just $12,791 last year, while those in Benton, Franklin and Walla Walla counties earned $21,425 on the average.

Housing

* 6 percent of those surveyed were living outdoors, in a shed or in a car, with 15 percent of migrant workers living in these conditions.

* 36 percent cited problems with their current housing conditions, with problems ranging from electrical and water problems to rat infestations.

* 32 percent lived in overcrowded units, largely to afford the rent.

* 42 percent of the renters were "cost-burdened," paying more than the federal standard of 30 percent of their income for housing costs. In addition, 19 percent paid more than 50 percent of their income for housing and utilities.

* 11 percent lived in a home they own in Washington.

Online

For more information about the Washington State Farmworker Housing Trust and its survey of farmworkers in agricultural regions across the state: www.farmworkerhousingtrust.org
Farmworker housing plays an increasingly crucial role in the success of many agricultural crops. As the labor market continues to tighten, the availability of housing is becoming a key advantage in recruiting. Growers who can offer safe housing to their seasonal and migrant farmworkers are generally more attractive to prospective workers.

Click the links below to learn more about Washington Growers League farmworker housing programs...

http://www.growersleague.org/farmworker-housing.html
Abstract: Appropriate production practices, careful harvesting, and proper packaging, storage, and transport all contribute to good produce quality. This publication covers postharvest practices suitable for small-scale operations, and points out the importance of production and harvesting techniques for improving quality and storability. Various methods for cooling fresh produce are discussed, and resources are listed for further information, equipment, and supplies.

By Janet Bachmann and Richard Earles
NCAT Agriculture Specialists
August 2000

Introduction

You have spent months working in the fields, and now have a bountiful harvest of beautiful fruits and vegetables. You want to ensure that your customers will also enjoy this healthy harvest. How can you best maintain the quality and safety of your produce as it travels from the field to the table? How can produce be stored so that it does not need to be sold immediately? High-quality, disease-free produce with a good shelf life is a result of sound production practices, proper handling during harvest, and appropriate postharvest handling and storage.

Production Practices

Production practices have a tremendous effect on the quality of fruits and vegetables at harvest and on postharvest quality and shelf life. To start with, it is well known that some cultivars ship better and have a longer shelf life than others. In addition, environmental factors such as soil type, temperature, frost, and rainy weather at harvest can have an adverse effect on storage life and quality. For example, carrots grown on muck soils do not hold up as well in storage as carrots grown on lighter, upland soils. Lettuce harvested during a period of rain does not ship well and product losses are increased (1).

Management practices can also affect postharvest quality. Produce that has been stressed by too much or too little water, high rates of nitrogen, or mechanical injury (scrapes, bruises, abrasions) is particularly susceptible to postharvest diseases. Mold and decay on winter squash, caused by the fungus Rhizoctonia, result from the fruits lying on the ground, and can be alleviated by using mulch. Broccoli heads are susceptible to postharvest rot caused by the bacteria Erwinia if nitrogen is applied as foliar feed—a grower should feed the soil, not the leaves. Beets and radishes are susceptible to soil-borne diseases when the soil...
temperature reaches 80°F; symptoms are black spots on these root crops (2).

Food safety also begins in the field, and should be of special concern, since a number of outbreaks of foodborne illnesses have been traced to contamination of produce in the field. Common-sense prevention measures include a number of don’ts (3):

- Don’t apply raw dairy or chicken manure or slurries to a field where a vegetable crop such as leafy lettuce is growing.
- Don’t apply manure to an area immediately adjacent to a field nearing harvest maturity.
- Don’t forget to clean equipment that has been used to apply manure to one field before moving it to another field in production.
- Don’t irrigate with water from a farm pond used by livestock.
- Don’t harvest fruit from the orchard floor for human consumption as whole fruit or nonpasteurized juices, especially if manure has been spread or animals allowed to graze.
- Don’t accumulate harvested product in areas where birds roost.

A grower should constantly evaluate water used for irrigation, and compost all animal manures before applying them to fields. There are many good sources of information on growing conditions and production practices that promote postharvest quality. Consult textbooks, Extension publications, and trade journals, and become involved with grower organizations to find out more.

Harvest Handling

Quality cannot be improved after harvest, only maintained; therefore it is important to harvest fruits, vegetables, and flowers at the proper stage and size and at peak quality. Immature or overmature produce may not last as long in storage as that picked at proper maturity (4). Cooperative Extension Service publications are an excellent source of information on harvest maturity indicators for vegetables and fruits.

Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept shaded in the field. Handle produce gently. Crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms as well.

Postharvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400% by a single bad bruise on an apple, and skinned potatoes may lose three to four times as much weight as non-skinned potatoes. Damage can be prevented by training harvest labor to handle the crop gently; harvesting at proper maturity; harvesting dry whenever possible; handling each fruit or vegetable no more than necessary (field pack if possible); installing padding inside bulk bins; and avoiding over or under-packing of containers (4).

Postharvest and Storage Considerations

Packaging

Packaging should be designed to prevent physical damage to produce, and be easy to handle. The American Vegetable Grower magazine’s annual product guide is a good source of information about suppliers (see Resources).

Temperature

Temperature is the single most important factor in maintaining quality after harvest. Refrigerated storage retards the following elements of deterioration in perishable crops:

- aging due to ripening, softening, and textural and color changes;
- undesirable metabolic changes and respiratory heat production;
- moisture loss and the wilting that results;
- spoilage due to invasion by bacteria, fungi, and yeasts;
- undesirable growth, such as sprouting of potatoes (5).
One of the most important functions of refrigeration is to control the crop’s respiration rate. Respiration generates heat as sugars, fats, and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavor, loss of salable weight, and more rapid deterioration. The respiration rate of a product strongly determines its transit and postharvest life. The higher the storage temperature, the higher the respiration rate will be (4).

For refrigeration to be effective in postponing deterioration, it is important that the temperature in cold storage rooms be kept as constant as possible. Appendix I charts the optimum temperature ranges for various crops. Exposure to alternating cold and warm temperatures may result in moisture accumulation on the surface of produce (sweating), which may hasten decay. Storage rooms should be well insulated and adequately refrigerated, and should allow for air circulation to prevent temperature variation. Be sure that thermometers, thermostats, and manual temperature controls are of high quality, and check them periodically for accuracy (5).

On-farm cooling facilities are a valuable asset for any produce operation. A grower who can cool and store produce has greater market flexibility because the need to market immediately after harvest is eliminated. The challenge, especially for small-scale producers, is the set-up cost. Innovative farmers and researchers have created a number of designs for low-cost structures. Some of these ideas are detailed in Appendix II and in the enclosures attached to this document. Additional designs are available in publications listed in the Resources section.

Pre-cooling

Pre-cooling is the first step in good temperature management. The field heat of a freshly harvested crop—heat the product holds from the sun and ambient temperature—is usually high, and should be removed as quickly as possible before shipping, processing, or storage. Refrigerated trucks are not designed to cool fresh commodities but only maintain the temperature of pre-cooled produce. Likewise, most refrigerated storage rooms have neither the refrigeration capacity nor the air movement needed for rapid cooling. Therefore, pre-cooling is generally a separate operation requiring special equipment and/or rooms (4, 5).

Rapid pre-cooling to the product’s lowest safe temperature is most critical for crops with inherently high respiration rates. These include artichokes, brussels sprouts, cut flowers, green onions, snap beans, asparagus, broccoli, mushrooms, peas, and sweet corn. Crops with low respiration rates include nuts, apples, grapes, garlic, onions, potatoes (mature), and sweet potatoes (4).

Appropriate pre-cooling methods as well as appropriate storage temperature and humidity for a number of fruits and vegetables are shown in Appendix I. The following methods are the most commonly used:

- **Room cooling**: Produce is placed in an insulated room equipped with refrigeration units. This method can be used with most commodities, but is slow compared with other options. A room used only to store previously cooled produce requires a relatively small refrigeration unit. However, if it is used to cool produce, a larger unit is needed. Containers should be stacked so that cold air can move around them, and constructed so that it can move through them. Used refrigerated truck bodies make excellent small cooling rooms (4).

- **Forced-air cooling**: Fans are used in conjunction with a cooling room to pull cool air through packages of produce. Although the cooling rate depends on the air temperature and the rate of air flow, this method is usually 75–90% faster than room cooling. Fans should be equipped with a thermostat that automatically shuts them off as soon as the desired product temperature is reached.

To avoid over-cooling and dehydration of produce, do not operate forced-air fans after the produce has been cooled to its optimum temperature [4].
- **Hydro-cooling**: Dumping produce into cold water, or running cold water over produce, is an efficient way to remove heat, and can serve as a means of cleaning at the same time. In addition, hydro-cooling reduces water loss and wilting. Use of a disinfectant in the water is recommended to reduce the spread of diseases. Hydro-cooling is not appropriate for berries, potatoes to be stored, sweet potatoes, bulb onions, garlic, or other commodities that cannot tolerate wetting.

Water removes heat about five times faster than air, but is less energy-efficient. Well water is a good option, as it usually comes out of the ground with temperatures in the 50–60°F range. Mechanical refrigeration is the most efficient method for cooling water. A thermal storage immersion hydro-cooler system can be fabricated economically to suit various volume requirements. Used stainless-steel bulk farm milk coolers may be an option. If hydro-cooling water is recirculated, it should be chlorinated to minimize disease problems (4).

A study compared sweet corn quality after hydro-cooling with ice water, well water cooling, and refrigerated air cooling, and subsequent refrigerated storage. Hydro-cooling with ice water lowered the temperature of the ears most quickly. Well water cooling followed by refrigerated storage appeared to offer no advantage over refrigerated storage immediately after harvest (6).

- **Top or liquid icing**: Icing is particularly effective on dense products and palletized packages that are difficult to cool with forced air. In top icing, crushed ice is added to the container over the top of the produce by hand or machine. For liquid icing, a slurry of water and ice is injected into produce packages through vents or handholds without removing the packages from pallets and opening their tops. Icing methods work well with high-respiration commodities such as sweet corn and broccoli. One pound of ice will cool about three pounds of produce from 85°F to 40°F (7, 8).

- **Vacuum cooling**: Produce is enclosed in a chamber in which a vacuum is created. As the vacuum pressure increases, water within the plant evaporates and removes heat from the tissues. This system works best for leafy crops, such as lettuce, which have a high surface-to-volume ratio. To reduce water loss, water is sometimes sprayed on the produce prior to placing it in the chamber. This process is called hydrovac cooling. The primary drawback to this method is the cost of the vacuum chamber system (9).

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**These products can be iced:**

- Artichokes
- Asparagus
- Beets
- Broccoli
- Cantaloupes
- Carrots
- Cauliflower
- Endive
- Green onions
- Leafy greens
- Radishes
- Spinach
- Sweet corn
- Watermelon
These items are damaged by direct contact with ice:

Strawberries
Blueberries
Raspberries
Tomatoes
Squash
Green beans
Cucumbers
Garlic
Okra
Bulb onions
Romaine lettuce
Herbs

Chilling injury

Many vegetables and fruits store best at temperatures just above freezing, while others are injured by low temperatures and will store best at 45 to 55 degrees F. Both time and temperature are involved in chilling injury. Damage may occur in a short time if temperatures are considerably below the danger threshold, but some crops can withstand temperatures a few degrees into the danger zone for a longer time. The effects of chilling injury are cumulative in some crops. Low temperatures in transit, or even in the field shortly before harvest, add to the total effects of chilling that might occur in storage.

Crops such as basil, cucumbers, eggplants, pumpkins, summer squash, okra, and sweet potatoes are highly sensitive to chilling injury. Moderately sensitive crops are snap beans, muskmelons, peppers, winter squash, tomatoes, and watermelons. These crops may look sound when removed from low temperature storage, but after a few days of warmer temperatures, chilling symptoms become evident: pitting or other skin blemishes, internal discoloration, or failure to ripen. Tomatoes, squash, and peppers that have been over-chilled may be particularly susceptible to decay such as Alternaria rot.

Preventing moisture loss

While temperature is the primary concern in the storage of fruits and vegetables, relative humidity is also important. The relative humidity of the storage unit directly influences water loss in produce. Water loss can severely degrade quality—for instance, wilted greens may require excessive trimming, and grapes may shatter loose from clusters if their stems dry out. Water loss means salable weight loss and reduced profit.

Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95%), but at this humidity, disease growth is encouraged. The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required. Maintaining high relative humidity in storage is complicated by the fact that refrigeration removes moisture. Humidification devices such as spinning disc aspirators may be used. Even buckets of water will increase humidity as the fans blow air across the water’s surface and increase evaporation. Keeping the floor wet is helpful, though messy and potentially hazardous to two-legged creatures; frequent cleansing with a weak chlorine solution will be needed to prevent harboring of disease organisms in water and produce scraps on the floor. Crops that can tolerate direct contact with water may be sprinkled to promote high relative humidity.

When it comes to maintaining appropriate humidity levels, “the biggest thing for small growers is going to be monitoring equipment,” says Kansas State University Extension Specialist Karen Gast. Humidity is measured by an instrument called a hygrometer. Several companies offer small, low-priced hygrometers.
suitable for small-scale producers (10). See Resources for more information.

Sanitation

Sanitation is of great concern to produce handlers, not only to protect produce against postharvest diseases, but also to protect consumers from foodborne illnesses. E. coli 0157:H7, Salmonella, Cryptosporidium, Hepatitis, and Cyclospora are among the disease-causing organisms that have been transferred via fresh fruits and vegetables (3, 11). Use of a disinfectant in wash water can help to prevent both postharvest diseases and foodborne illnesses.

Chlorine in the form of a sodium hypochlorite solution (for example, Clorox™) or as a dry, powdered calcium hypochlorite can be used in hydro-cooling or wash water as a disinfectant. Some pathogens such as Cryptosporidium, however, are very resistant to chlorine, and even sensitive ones such as Salmonella and E. coli may be located in inaccessible sites on the plant surface. For the majority of vegetables, chlorine in wash water should be maintained in the range of 75–150 ppm (parts per million.) The antimicrobial form, hypochlorous acid, is most available in water with a neutral pH (6.5 to 7.5).

The effectiveness of chlorine concentrations are reduced by temperature, light, and interaction with soil and organic debris. The wash water should be tested periodically with a monitoring kit, indicator strips, or a swimming pool-type indicator kit. Concentrations above 200 ppm can injure some vegetables (such as leafy greens and celery) or leave undesirable off-flavors.

Organic growers must use chlorine with caution, as it is classified as a restricted material. The California Certified Organic Farmers regulations permit a maximum of 4 ppm residual chlorine, measured downstream of the product wash (3). Growers certified by other agencies should check with their certifying agent.

Ozonation is another technology that can be used to sanitize produce. A naturally occurring molecule, ozone is a powerful disinfectant. Ozone has long been used to sanitize drinking water, swimming pools, and industrial wastewater. Fruit and vegetable growers have begun using it in dump tanks as well, where it can be thousands of times more effective than chlorine. Ozone not only kills whatever foodborne pathogens might be present, it also destroys microbes responsible for spoilage. A basic system consists of an ozone generator, a monitor to gauge and adjust the levels of ozone being produced, and a device to dissolve the ozone gas into the water. Systems cost anywhere from $10,000 to $100,000, and should be installed by an ozone sanitation company experienced in produce industry applications (12).

Hydrogen peroxide can also be used as a disinfectant. Concentrations of 0.5% or less are effective for inhibiting development of postharvest decay caused by a number of fungi. Hydrogen peroxide has a low toxicity rating and is generally recognized as having little potential for environmental damage. The ATTRA

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publication Sources for Organic Fertilizers and Amendments lists several sources of food-grade hydrogen peroxide.

Creative growers can customize their produce-washing system to promote sanitation and increase efficiency and ease of operation. At Drumlin Community Farm in Madison, Wisconsin, the crew “used to wash greens and small crops by the handfuls in wash tubs and air dry them on screen tables. Now they line harvest containers with a mesh produce bag, dunk the whole bagful at once, and dry two bagfuls at a time in an old washing machine set to spin cycle.” At another farm, loose greens are dumped into a 500-gallon bulk milk tank. The water in the tank is agitated with bubbling air from a jacuzzi motor. The washed greens are scooped out of the tank with a mesh bag-lined laundry basket, and the bags of greens are then spun dry in a washing machine. The grower removed the washer’s agitator to make more room for the produce (13).

This type of system has several advantages—it reduces handling (and potential damage) of the crop; it makes the washing process more time and labor efficient; and it enhances postharvest quality by getting the crop cooled down, washed, dried, and in cold storage much more quickly. Perhaps most importantly, washing greens in large batches rather than one-by-one reduces physical stress on the worker’s back and arms.

At a cost of $2–8 each, woven polyester or nylon bags are durable, lightweight, water-permeable, and fast-drying. Suitable mesh laundry bags may be found at hardware or discount stores (13). The Resources section lists two companies that sell mesh bags by mail order. Spin-drying can be done with a washing machine, honey extractor, or commercial salad spinner. A restaurant or industrial-scale salad spinner is an efficient machine for both washing and drying greens (available from restaurant supply stores; prices range from $650 to $1500).

Some further tips for postharvest handling of lettuce and other leafy greens: package in breathable or perforated plastic bags; refrigerate at 33° F; carry to market in a portable cooler, either refrigerated or with ice, and keep in the cooler until ready to display. If displaying unwrapped heads at a farmers’ market, mist occasionally with cold water.

**Ethylene**

Ethylene, a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it. The old adage that one bad apple spoils the whole bushel is true. Damaged or diseased apples produce high levels of ethylene and stimulate the other apples to ripen too quickly. As the fruits ripen, they become more susceptible to diseases.

Ethylene “producers” should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life, and specific symptoms of injury. Some examples of ethylene effects include:

- russet spotting of lettuce along the midrib of the leaves;
- loss of green color in snap beans;
- increased toughness in turnips and asparagus spears;
- bitterness in carrots and parsnips;
- yellowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower;
- accelerated softening of cucumbers, acorn and summer squash;
- softening and development of off-flavor in watermelons;
- browning and discoloration in eggplant pulp and seed;
- discoloration and off-flavor in sweet potatoes;
- sprouting of potatoes;
- increased ripening and softening of mature green tomatoes (8); and
- shattering of raspberries and blackberries (2).

Ethylene producers include apples, apricots, avocados, ripening bananas, cantaloupes, honeydew melons, ripe kiwifruit, nectarines, papayas, passionfruit, peaches, pears, persimmons, plantains, plums, prunes, quinces, and tomatoes (14). Produce that is sensitive to ethylene is indicated in Appendix I.
**Mixed loads**

When different commodities are stored or transported together, it is important to combine only those products that are compatible with respect to their requirements for temperature, relative humidity, atmosphere (oxygen and carbon dioxide), protection from odors, and protection from ethylene (4).

In regard to cross-transfer of odors, combinations that should be avoided in storage rooms include: apples or pears with celery, cabbage, carrots, potatoes, or onions; celery with onions or carrots; and citrus with any of the strongly scented vegetables. Odors from apples and citrus are readily absorbed by meat, eggs, and dairy products. Pears and apples acquire an unpleasant, earthy taste and odor when stored with potatoes. It is recommended that onions, nuts, citrus, and potatoes each be stored separately (4).

**Storage crops**

What about the crops that will not be transported and marketed fresh after harvest? Growers can extend their selling season into the winter months by growing root crops and other vegetables and fruits suited for long-term storage. The challenge is in keeping quality high by creating and maintaining the correct storage environment. As Growing for Market editor Lynn Byczynski notes,

> Most storage crops require low temperatures and high humidity, two factors that don’t come together easily. Several others require low humidity and low temperatures. And then there are a few that fall in between…Root crops such as beets, carrots, turnips, rutabagas, and leeks store best at 32°F and 90% humidity. Potatoes prefer temperatures of 40–60°F and 90% humidity. Onions and garlic like it cool – 32° — but require less humidity — about 65–75%. Winter squash prefer temperatures of 50–60°F, but dry. That’s four different types of storage for vegetables that will hold a month or more: cold and humid; cold and dry; cool and humid; cool and dry (10).

The two structural options for storage of these crops are coolers and root cellars. Byczynski provides an example of a farm using both: “The Seelys have a bank barn, which has the bottom floor built into a hillside…They have built both coolers and a dry storage room into the lower floor to provide different combinations of temperature and humidity for the vegetables they store.” Coolers used for root crop storage will require water added to the air and regular monitoring of the humidity level (see discussion under Preventing moisture loss above.) Some growers have used concrete basements of houses, closed off from heat and with ventilation to let in cold winter air, as root cellars. Another idea is to bury a big piece of culvert under a hillside (10).

Whatever the method, only “perfect” produce is suitable for long-term storage, so careful inspection is critical. Any damaged produce is going to spoil and induce spoilage in the rest of the crop. Byczynski advises growers to “either rub off soil and leave the crops somewhat dirty, or wash them and let them dry thoroughly before putting them in storage. With onions, garlic, winter squash, pumpkins and sweet potatoes, it’s important that they be cured thoroughly before storage” (10).

**Conclusion**

Postharvest handling is the final stage in the process of producing high quality fresh produce. Being able to maintain a level of freshness from the field to the dinner table presents many challenges. A grower who can meet these challenges, will be able to expand his or her marketing opportunities and be better able to compete in the marketplace. This document is intended to serve as an introduction to the topic and a resource pointer; the grower is advised to seek out more complete information from Extension and other sources.

**References:**


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**Enclosures:**


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**Resources:**

**Further Information**


detailed descriptions of proper temperature management for perishables and commercial cooling methods. Complete discussion of design for hydro-cooler and forced-air cooler systems, the two most commonly used cooling methods. 25 graphs and illustrations, 11 color plates, and 15 tables. Available for $10 plus $3.50 s/h. Make check payable to UC Regents and specify pub. #21567. University of California

ANR Communication Services
6701 San Pablo Avenue
Oakland, CA 94608-1239
(800) 994-8849
http://anrcatalog.ucdavis.edu

UC-Davis Produce Facts website
http://postharvest.ucdavis.edu/Produce/ProduceFacts/index.html

Separate postharvest fact sheets for a great variety of fruit, vegetable, and ornamental crops. Each fact sheet includes information about maturity and quality indices, optimum temperature and relative humidity, rates of respiration and ethylene production rates, responses to ethylene and controlled atmospheres, physiological and pathological disorders: causes and control, and other relevant information. Periodic updates of these fact sheets will be published as new information becomes available. The goal is to eventually post fact sheets for all major perishable crops.
Perishables Handling
Editor: Pam Moyer
Postharvest Technology
Dept. of Pomology
One Shields Ave.
Univ. of California
Davis, CA 95616-8683
(530) 752-6941

Perishables Handling, a quarterly publication from the UC-Davis Postharvest Outreach Program, reports research in progress, recent publications, and brief reviews of various aspects of postharvest technology of horticultural crops. A one-year subscription costs $25. Back issues are available for $8 each. Tables of contents of back issues may be reviewed on-line at:
http://postharvest.ucdavis.edu/Pubs/POSTPhn.html

Produce Handling for Direct Marketing
Natural Resource, Agriculture, and Engineering Service (NRAES)
For growers selling seasonal produce at farmers’ markets and roadside stands. Describes postharvest physiology, food safety, produce handling from harvest to storage, refrigeration, produce displays, and specific handling recommendations for over 40 fruits and vegetables. Includes eleven tables and eight figures.

Refrigeration and Controlled Atmosphere Storage for Horticultural Crops
1990. 44 p. NRAES-22
General construction procedures for storage facilities: structural considerations, site selection, thermal insulation, vapor barriers, and attic ventilation. Explanations of various refrigeration systems, with descriptions of equipment and operating procedures. Controlled atmosphere storage construction, testing, and operation, especially in relation to apple storage.

Both of these NRAES publications are available, for $8 each plus a total of $3.75 s/h, from:
NRAES
Cooperative Extension
152 Riley-Robb Hall
Ithaca, NY 14853-5701
(607) 255-7654
http://www.nraes.org

North Carolina Cooperative Extension Service.
Leaflets 800-804.

Five-part series: Quality Maintenance; Cooling; Handling; Mixed Loads; References. Available on-line at:
http://www.ces.ncsu.edu/depts/hort/hil/post-index.html

North Carolina State University also offers the following fact sheets on postharvest cooling and handling, at:
www5.baie.ncsu.edu/programs/extension/publicat/postharv/index.html

Apples AG-413-1
Strawberries AG-413-2
Peppers AG-413-3
Sweet Corn AG-413-4
Cabbage and Leafy Greens AG-413-5
Onions AG-413-6
Blueberries AG-413-7
Greenbeans and Field Peas AG-413-8
Tomatoes AG-413-9
Proper Postharvest Cooling and Handling Methods AG-414-1
Design of Room Cooling Facilities AG-414-2
Forced-Air Cooling AG-414-3
Hydrocooling AG-414-4
Crushed and Liquid Ice Cooling AG-414-5
Chlorination and Postharvest Disease Control AG-414-6
Cool and Ship: Low Cost Portable Forced Air Cool Unit AG-414-7
Packaging Requirements for Fresh Fruits and Vegetables AG-414-8

For information on ordering print copies of these publications, contact:

North Carolina State University
Dept. of Communication Services
Box 7603
Raleigh, NC 27695-7603
(919) 515-2861

Kansas State University offers the following publications on postharvest management of commercial horticultural crops. All are available on-line at:
http://www.oznet.ksu.edu/library

Containers and Packaging—Fruits and Vegetables MF979
Fruits and Vegetables—Precooling Produce MF1002
Harvest Maturity Indicators for Fruits and Vegetables MF1175
The University of Wisconsin has produced a very helpful set of “Work Efficiency Tip Sheets” for fresh-market vegetable growers. These materials were developed by the Healthy Farmers, Healthy Profits Project with the goal of sharing labor-efficiency practices that maintain farmers’ health and safety while increasing profits. Topics in the series include:

A Specialized Harvest Cart for Greens A3704-1
Stooping or kneeling and crawling to harvest salad greens requires a lot of time and energy. An alternative is to build a simple cart that allows you to sit and roll while you harvest. The cart also holds your harvest container, so it rolls along with you. Parts for the cart will cost about $150.

Mesh Produce Bags: Easy Batch Processing A3704-2
Elements and benefits of the batch method for washing greens, as discussed above under the heading “Sanitation.”

Standard Containers A3704-3
Standard containers for carrying and moving produce are made of molded plastic, have sturdy handles, and are stackable. They’re easier to use and more efficient than bushel baskets, buckets or wooden crates.

Narrow Pallet System A3704-4
If you currently carry boxes of produce by hand, switching to a narrow pallet system may save you time and money. With a hand pallet truck you can move up to 16 half-bushel boxes at a time. This system can cut your time spent moving boxes by more than 60% and will dramatically reduce the stress put on your body.

These tipsheets may be ordered from the following address, or accessed on-line at:
http://www.bse.wisc.edu/hfhp/
The ATTRA Project is operated by the National Center for Appropriate Technology under a grant from the Rural Business-Cooperative Service, U.S. Department of Agriculture. These organizations do not recommend or endorse products, companies, or individuals. ATTRA is located in the Ozark Mountains at the University of Arkansas in Fayetteville at P.O. Box 3657, Fayetteville, AR 72702. ATTRA staff members prefer to receive requests for information about sustainable agriculture via the toll-free number 800-346-9140.
## APPENDIX I

### Storage Conditions for Vegetables and Fruits

<table>
<thead>
<tr>
<th></th>
<th>Temperature F</th>
<th>% Relative humidity</th>
<th>Precooling method</th>
<th>Storage life Days</th>
<th>Ethylene sensitive</th>
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F = forced-air cooling, H = hydrocooling, I = package icing, R = room cooling, V = vacuum cooling, N = no precooling needed. Sources: USDA Agricultural Marketing Service, Kansas State University Cooperative Extension Service
The Portacooler

A portable precooler designed by USDA researchers can be built with readily available materials at a cost of around $1,200. The most expensive component is an air conditioner. If a used air conditioner is available, the initial investment will be decreased. The Portacooler can be towed to the field and used to reduce field heat of berries, vegetables, and other high-value crops immediately after picking.

The structure of the Portacooler is a basic wood frame and plywood panel construction (see diagram). The outside dimensions of the cooler are 4 feet high by 4 feet wide by 8 feet long. The frame is made of 2 by 3's spaced 2 feet on center, excluding the doorway and the air conditioner space. The frames are sheathed with 1/2 inch plywood. The precooler is insulated with 2-inch thick plastic foam that fits firmly between the frame studs.

After the frame and sheathing are completed, the electrical components can be installed (see diagram). The standard junction box, power switches, daily cycle timer, and industrial thermostat control box should be mounted on the outside of the front wall near the air conditioner. An adjustable, industrial thermostat control box should be mounted on the outside of the front wall near the air conditioner. An adjustable, industrial thermostat must be connected to the air conditioner to replace the existing thermostat. Mount strip heaters using copper wire so that they contact the cooling coils of the air conditioner. Mount the blower on the front inside wall, centered above the air conditioner so that the blower discharge is 12 inches below the inside ceiling.

All electrical components should be properly grounded, and wiring should comply with national and local electrical codes. Consult a licensed electrician for more information about how to install any components of the electrical system.

The Portacooler can be powered from either an electrical wall outlet or a gasoline-powered generator. The main electrical connection from the power source is split to the individual switches. From the switches, the power travels to the blower and to the air conditioner. The strip heaters and the thermostat are wired from the timer. The timer creates a defrost cycle by alternating power from the compressor to the strip heaters. (An interval of compressor shutdown time should be approximately 2.5 minutes during every 10 minutes.)

Once the cooler is assembled, and the electrical components hooked up, mount the air flow bulkhead. Mount the bulkhead with blower discharge hoe flush with the edge of the blower discharge, allowing a 6-inch-high return-air gap along the floor.

All wood surfaces should be coated with polyurethane and an all-weather sealer to prolong the useful equipment life.
General Material List

- air conditioner, 12,000 Btu, 115 V ................................................................. 1
- centrifugal blower, 1/3 hp, 1210 c.f.m. ................................................................. 1
- 20-amp wall switch, with boxes and covers ......................................................... 2
- 4 by 8 ft, exterior AC, 1/4-in plywood ................................................................. 11
- lumber, 2 by 3 in, 8 ft long ............................................................................... 30
- lumber, 2 by 4 in, 12 ft long ........................................................................... 3
- lumber, 2 by 6 in, 8 ft long ............................................................................... 1
- industrial wheels, 5-in diameter ......................................................................... 2
- industrial wheels, 5-in diameter, swivel .............................................................. 2
- dry wall screws, 2 1/2-in long ........................................................................... 5 lb
- dry wall screws, 1-in long ................................................................................ 1 lb
- water sealer ....................................................................................................... 1 gal
- polyurethane coating ....................................................................................... 1 gal
- weather stripping, 1-in wide roll ..................................................................... 1
- insulation, 2 in, 4 by 8 ft sheets ....................................................................... 5
- 1/4-in plywood, 4-in wide strips ...................................................................... 12 ft
- door latch, sliding bolt ..................................................................................... 1
- thermostat, 115 B, 16 amp, remote bulb ......................................................... 1
- strap hinges, screw fastened, 3-in long ............................................................. 4
- lumber, 2 by 10 in, 4 ft long ........................................................................... 1
- standard junction box ...................................................................................... 1
- strip heaters, 150 watt, 8 in, 115 B ................................................................. 2
- insulated wire .................................................................................................... 30 ft
- cycle timer, SPDT, 115 B, 20 amp, 1 hour ....................................................... 1

The design, construction, and research of the Portacooler was conducted by Joseph Anthony, Gerald Berney, William Craig, and Daniel P. Schofer. For further information, contact Daniel Schofer, Room 1211 South Bldg., 12 & Independence, Box 96456, Washington, D.C. 20090-6456.