Modular Agricultural Base Yard:
A Manual for Small-Scale Farmers in Hawaii
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# Acronyms

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<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADC</td>
<td>Agribusiness Development Corporation</td>
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<tr>
<td>CTAHR</td>
<td>College of Tropical Agricultural and Human Resources</td>
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<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>EIA</td>
<td>Energy Information Administration</td>
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<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>FDA</td>
<td>Food and Drug Administration</td>
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<tr>
<td>FRP</td>
<td>Fiberglass Reinforced Plastic</td>
</tr>
<tr>
<td>FSMA</td>
<td>Food Safety Modernization Act</td>
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<tr>
<td>GAP</td>
<td>Good Agricultural Practices</td>
</tr>
<tr>
<td>GHP</td>
<td>Good Handling Practices</td>
</tr>
<tr>
<td>HCEI</td>
<td>Hawaii Clean Energy Initiative</td>
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<tr>
<td>HDOA</td>
<td>Hawaii Department of Agriculture</td>
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<tr>
<td>ICS</td>
<td>Integral Collector-Storage</td>
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<tr>
<td>NASS</td>
<td>National Agricultural Statistics Service</td>
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<tr>
<td>NCSS</td>
<td>National Resources Conservation Service</td>
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<tr>
<td>NSF</td>
<td>National Sanitary Foundation</td>
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<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
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<tr>
<td>PHH</td>
<td>Post-Harvest Handling</td>
</tr>
<tr>
<td>PMRA</td>
<td>Pest Management Regulatory Agency</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation, and Air Conditioning</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
</tr>
<tr>
<td>SPCC</td>
<td>Spill Prevention, Control, and Countermeasure</td>
</tr>
<tr>
<td>UACDC</td>
<td>University of Arkansas Community Design Center</td>
</tr>
<tr>
<td>UARC</td>
<td>University of Arkansas Resiliency Center</td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>WPS</td>
<td>Worker Protection Standard</td>
</tr>
<tr>
<td>WWTP</td>
<td>Wastewater Treatment Plan</td>
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Small growers are central to ensuring Hawaii’s future food security.

This manual assists the small-scale farmer in becoming compliant, adaptable, and profitable through a common set of modular agricultural base yard designs that facilitate diversified crop production.
Chapter 1: Potential Production in Agricultural Lands

Pineapple farming on 66 State Hwy 801, Wahiawa, United States. Much of the acquired land for the Agricultural Parks Program is located in Central Oahu and was previously owned by Dole Food Company for pineapple production. Photo by Tom Henderson on Unsplash.
Opportunities for Food Production in Hawaii

The State of Hawaii’s Office of Planning reported in 2012 that 85-90% of the state’s food was imported from either the continental United States or foreign countries, amounting to more than 1.14 million tons with a 2010 value exceeding 4.52 billion dollars. Hawaii’s supply of food is vulnerable to disruptions in the supply chain, production fluctuations in the continental United States, severe weather conditions, and sudden spikes in the prices of food (Office of Planning, 2012). This fragility constitutes a risk to the well-being of the people of Hawaii.

The Hawaii Agribusiness Development Corporation (ADC), an agency of the State of Hawaii Department of Agriculture, is tasked with coordinating and facilitating the transition of Hawaii’s agricultural industry from producing sugar cane and pineapple to producing a variety of diversified crops using a small (less than 50 ha) producer model. The arable land in the preliminary phase of implementation on the Island of Oahu has limited infrastructure for production. The ADC has identified the need for small-scale, farm-level infrastructure (called a base yard) to support production. The specific needs for base yard infrastructure includes a portfolio of elements in order to allow producers to comply with Good Agricultural Practices (GAP), Food Safety Modernization Act (FSMA), and other farm-level market and regulatory production criteria. Existing design guidance for small-scale farm buildings are outdated or geographically inapplicable to Hawaii producers.

The Modular Agricultural Base Yard: A Manual for Small-Scale Farmers in Hawaii, and its supporting document, Modular Agricultural Base Yard: Building Plans for Small-Scale Farmers in Hawaii, were created through a partnership between ADC and The University Arkansas Resiliency Center (UARC) and UA Community Design Center (UACDC). The UARC is a student-centered research facility coordinating programs across the UA campus to design solutions for food and water systems to support resilient communities. The UACDC utilizes design, research, and education solutions to advance creative development in Arkansas.

The appropriate infrastructure for small-scale farmers is critical in the effort to increase Hawaii’s food security. The current demand for on-site agriculture production facilities is set to grow as the ADC supplies more land leases for those wanting to develop small farms. Existing design guidance for small-scale farm facilities are outdated or not applicable to Hawaii’s geographical conditions. Moreover, the current and pending FSMA requires food facilities from farms to points of purchase to implement new food contamination prevention standards — a task that producers in Hawaii are ill prepared for. The science-based protocols of FSMA elevate to an unprecedented level hazard analysis, preventive control throughout growing and production processes, and health and safety controls in facility design and operations. The proposed Modular Agricultural Base Yard gives farmers a manual to create compliant facilities optimized for efficiency and utility. Additional value-added systems and processes could be incorporated into a base yard and are proposed to offer more sustainable profit margins.

Modular Agricultural Base Yard: A Manual for Small-Scale Farmers in Hawaii details farm-level regulatory requirements, the intensities and organizational schemes that correspond with the base yard site plans, space programming, and concludes with a recommended area overview. This manual contains the more technical elements of implementing a modular agricultural base yard, whereas, Modular Agricultural Base Yard: Building Plans for Small-Scale Farmers in Hawaii is comprised of the building plans discussed throughout this manual (e.g., site plans, general building components, and module building plans).
This manual is intended to be used by agricultural producers to support decisions on infrastructure and process implementation at the field level. Chapter 1 presents a geospatial inventory of the participating Agricultural Parks Program lands proposed for development as small holder production. Critical production characteristic include moisture, precipitation, land categories, and soil types, are described. These characteristics support recommendations for producers of a diversified crop portfolio based on location. Chapter 2 describes the post-harvest handling systems of some of the recommended diversified crops. Chapter 3 summarizes requirements for compliance with FSMA and Good Agricultural Practices (GAPs). Provision in FSMA and GAPs that influence the design and construction of the base yard are highlighted, with other provisions summarized. The main programs in GAP are discussed, including harmonized GAP, Global GAP, and GroupGAP, and similarities and differences between FSMA and GAPs are described.

Chapters 4, 5, and 6 contain the design elements for the base yard. Chapter 4 presents the base yard modules and additional infrastructure inputs and outputs. Chapter 5 introduces five assemblages, including handling and cleaning, handling and processing, working, storage, and food tourism. These five assemblages are made up of the various modules as well as additional infrastructure inputs and output. Grouping modules under varying assemblages facilitates the understanding of how independent modules interact with each other to achieve the routine functions necessary for a thriving base yard operation. Last, Chapter 6 describes the varying base yard intensities (e.g., basic, intermediate, and comprehensive) and organizational schemes (e.g., parallel bar, four square, accordion, constellation, and fort).

Figure 1. Local food innovation value chain in relation to Modular Agricultural Base Yard operations.
Diversified Crop Production on Oahu

The island of Oahu has the most demand for food of all the Hawaiian Islands and is second to the island of Hawaii in production capacity. As sugar and pineapple production decreased, diversified crop production is increasing on Oahu. The HDOA defines diversified crops to include vegetable crops (e.g., leafy vegetables, dry land taro, potatoes, melons, cucumbers, and tomatoes) and smaller crops plantings (e.g., banana, tropical fruit, and papaya). There are several benefits to high intensity diversified agriculture production, including demand for pesticides, fertilizers, and other inputs (Melrose and Perroy, 2016).

The area of potential agricultural production for this phase of the project are located in the Wahiawa region in Central Oahu (Figure 2). The land is partially surrounded by residential areas, as well as agricultural land that was previously owned by Dole Food Company. Driving time from Whitmore Village to Haleiwa is about 20 minutes and from Whitmore Village to Honolulu is approximately 40 minutes, depending on traffic congestion.

Oahu has a range of temperatures and rainfall patterns well-suited for year-round production of a wide array of diversified crops. Food production success begins with understanding precipitation, soil type, air temperatures, and soil temperatures. There are at least 23 fruit and vegetable crops that could be planted and harvested within the Wahiawa/Haleiwa region of Oahu.

Figure 2. Lands with potential for diversified crops production. The ADC acquired lands are outlined in black. The Kamehameha Highway, Hwy 99, transects the lands and is shown in red. This region is in the north central area of Oahu Island in Hawaii.
Important Agricultural Lands

Hawaii has three classifications for important agricultural land. These classifications are prime, unique, and other. The agricultural lands with potential for production in Central Oahu are classified as prime or unique agricultural land (Figure 3). Prime agricultural land designation is assigned by the United States Department of Agriculture (USDA). It is characterized by land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops (Wikipedia, 2019).

Unique farmland is land other than prime farmland that is used for the production of specific high-value food and fiber crops, such as citrus, tree nuts, olives, cranberries, and other fruits and vegetables. This class of agricultural land has a combination of soil quality, growing season, moisture supply, temperature, humidity, air drainage, elevation, and aspect needed for to economically produce sustainable high yields of diversified crops. Availability of water that is dependable and of adequate quality is necessary for production. Finally, access to markets is an additional consideration. Hawaii uses the designation of other for lands that are suitable for agriculture but not categorized as prime or unique.

Climate and terrain indicators for crop selection include soil properties, moisture retention, drainage capability, slope, precipitation, air temperature, seasonality, and solar radiation. The air temperature in Oahu ranges between a high of approximately 80°F to 90°F during the year, while the low temperature ranges from approximately 66°F to 75°F. The low variability in temperature can be accredited to the little seasonality in Central Oahu. Daily sunlight, however, varies with the season with sunshine ranging from 6.5 hours in December to 10 hours in July and August.
Humidity

Humidity means level of moisture in the air. The areas for production in this phase of the project occur at an elevation less than 1,000 feet and west of the Ko’olau mountain range in the north central part of Oahu (Figure 4). One thousand feet of elevation is a mid-range elevation. The mountains to the east north central part of Oahu protect the region from excessive windward rain patterns. Much of the rain on Oahu comes from the east, called the “windward” side of the island because the rain comes with the “trade winds”. The trade winds come from the east. The Ko’olau mountain range protects the central valley region from the wind because they are higher than the valley and so they block the wind. The rain falls just over the top of the mountains. This keeps a lower moisture level near the beaches in the central valley and a higher level inland because the moisture does not get blown out. These moisture level gradations are evident in a map of the area’s moisture zones, as seen in Figure 4. Average annual humidity is between 65-73%. This makes the area feel somewhat humid inland. It is good for growing crops. It is categorized by the United States Geological Survey (USGS) as “seasonally mesic”. The term mesic is often used in characterizing environmental moisture levels. It means “characterized by, relating to, or requiring a moderate amount of moisture”. Moderate means "being within a middle range in size, amount, or degree; neither great nor little”.

The proposed production lands falls into three humidity USGS categories — very dry, moderate dry, and seasonally mesic. The area furthest north, closest to Haleiwa, is classified as very dry while the northern most part of the region along Farrington Highway is classified as moderately dry. The remaining land is classified as seasonally mesic. Mesic habitats are described as having a well-balanced supply of moisture (National Cooperative Soil Survey, 2017). Since the majority of the proposed production lands having mesic habitats, they are well-adapted to agriculture. Even the very dry area is acceptable for crop production if adequate irrigation is available.

Figure 4. Agricultural lands in the Wahiawa region and their relative moisture zones (Hawaii State Office of Planning, 2017).
Rainfall
The Agricultural Parks Program land falls into three humidity categories — very dry, moderate dry, and seasonally mesic by the USGS. The area furthest north, closest to Haleiwa, is classified as very dry while the northernmost part of the region along Farrington Highway is classified as moderately dry (Figure 5). The remaining land is classified as seasonally mesic. Mesic habitats are described as having a well-balanced supply of moisture and due to the majority of the acquired land having mesic habitats, they are well-adapted to agriculture. Even the very dry area is acceptable for crop production if adequate irrigation is provided to land.

Very dry zones receive only 20 inches of annual rain. In Agricultural Parks Program lands, which fall into moderately dry and mesic soil regimes, the average annual rainfall is between 40 to 80 inches. Oftentimes the rain falls in the night or early morning hours, which is ideal for plant growth.

Figure 5. Agricultural lands in the Wahiawa region and their average annual rainfall in inches (Hawaii State Office of Planning, 2017).
Land Categories
The Natural Resources Conservation Service (NRCS) categorizes terrain to create a consistent understanding of an area’s suitability for agriculture. This categorization makes use of moisture levels, drainage, slope, erosion, and soil textures as potential limitations to cultivation.

The Wahiawa region falls into two land categories: semiarid and sub-humid low mountain slopes, and humid and very humid low and intermediate mountain slopes. Rough mountainous land and intermediate mountain slopes fall to either side, precluding most cultivation there. However, in the acquired lands which are lowlands, erosion is not a problem and the drainage is good. The low elevation and soil type make these parcels very amenable to cultivation.

Knowledge of soil type is an integral component of agriculture, particularly when determining fertilization needs. Land is further classified into types of soil and degree of slope by the National Cooperative Soil Survey (NCSS). These major constituent soil types are grouped into geographic series and are additionally broken down incrementally by slope percentage. The Agricultural Parks Program region consists primarily of four soil series include Kolekole Silty Clay Loam, 12-25% slopes; Lahaina Silty Clay, 0-15% slopes (broken into three categories 0-3%, 3-7%, and 7-15%); Leiehua Silty Clay, 2-6% slopes; and Paaloa Silty Clay, 3-12% slopes (Figure 6). A slope of more than 15% is considered steep.

Figure 6. Agricultural lands in the Wahiawa region and their land categories (Hawaii State Office of Planning, 2017).
Soil Types
The Lahaina series makes up the majority of the stock, with some significant Leilehua series just north of Wahiawa (Figure 7). An important thing to note about the Lahaina series is that the soil drains well with moderate permeability and good structure (Soil Science Society of America, 2019). The Lahaina soil series also resist compaction. This tropical soil is derived from weathered rock and contains constituents such as, iron oxides, quartz, and highly weathered clay minerals such as kaolinite (Soil Science Society of America, 2019). It has a low pH, typically around 6.1, making the Lahaina soil series acidic. It is not a naturally fertile soil but can be made fertile through soil amendments. These soils are also known as Oxisols (i.e., old soils) because they are made up of weathered rock. Oxisols are high in aluminum and iron oxides. For plants that are sensitive to aluminum, liming is necessary (Woolfe, 1992).

Leilehua series soils are of very similar composition but are represented in a somewhat higher rainfall area. Structure and permeability are much like Lahaina series soils. They also require added soil amendments to be made productive (Soil Science Society of America, 2019). Kolekole silty clay and Paaloa silty clay soils are formed from alluvium and are somewhat more recent soils with comparable characteristics. These soils are also found on steeper slopes (Soil Science Society of America, 2019).

Figure 7. Agricultural lands in the Wahiawa region and their soil types (Hawaii State Office of Planning, 2017).
Recommendations for Diversified Crop Portfolio

Only about 15% of food and 35% of fruits and vegetables consumed in Hawaii are grown locally. The Hawaii 2050 Sustainability Plan asserts that the state is aiming to increase production and consumption of local foods and products. In Hawaii, about 50% of agricultural land is rented, making the emphasis on small plots of diversified crops achievable (Gupta and Jablonski, 2016). As of 2015, diversified crops were the sixth largest crop category in terms of land use in Hawaii, with most of them grown in Oahu (Melrose and Perroy, 2016).

Potential diversified crops for small-scale producers were determined based upon historic production in the region, potential for production based on climate, soils, and water, and processing necessary for access to markets. The most viable crops for this phase of production are asparagus, banana, blackberry, broccoli, cucumber, fig, ginger root, head cabbage, herbs, leaf lettuce, mango, orange, strawberry, sweet potato, taro, and tomato.

Data was gathered for yield, number of operations, acres harvested, harvests per year, pounds harvested per week, and pounds harvested per operation to better understand the seasonality and intensity of each diversified crop (Table 1). Data was collected from the United States Department of Agriculture’s (USDA) National Agricultural Statistics Service (NASS) Quick Stats database.

Then, each crop has specific categorical demands for soil, water, and solar radiation in the Wahiawa region (Table 2). Table 2 summarizes concerns and considerations of interest to potential growers, including post-harvest handling and likelihood for sustainable economic value.

Oahu’s tropical climate and soils are amenable to growing many types of fruits and vegetables. A number of small-scale growers have begun to have a lot of success in the area. Some additional crops which are already being grown and marketed in the area include papaya, liliko’i, citrus fruits, mango, cacao, jackfruit, vanilla, ginger root, kava, hearts of palm, taro, and exotic fruits like durian, rambutan, star fruit, cherimoya, figs, lychee, and dragon fruit. Some local crops such as papaya, pineapple, breadfruit, coconut, banana, mango, and guava have been successfully cultivated in similar soils and climates for more than a hundred years. Indigenous crops like `akala and `ohelo berries can be used for jams, jellies, and pie fillings. Ohi’a’ai, a native fruit tree, is also still grown throughout the state for its apple-like fruits. These plants thrive in the tropical climate and weathered soils of Oahu.

It should be noted that the recommendation to irrigate is often made here, despite the region having fairly abundant rainfall and consistent humidity. The reason for the suggestion to irrigate is one of control, since a successful fruit or vegetable crop requires water at specific times (i.e., early in the season after planting or later when fruiting occurs) and for specific amounts. Some plants need their roots to be maintained in a moist soil environment but cannot have retained moisture on their leaves due to the risk of introducing fungal diseases. In cases like this, drip irrigation can give the crop exactly the level of moisture it needs without exposing the rest of the plant to possible over-watering. It is also the case that weather can be unreliable and while most seasons have abundant rain, precipitation levels fluctuate considerably from year to year. Climate changes have made these erratic weather patterns even more likely. Irrigation is an assurance that a producer’s crops will have the best chance of success.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Year</th>
<th>State</th>
<th>Yield (lbs./acre)</th>
<th># of op.</th>
<th>Acres harvested/yr.</th>
<th>Lbs. harvested/wk.</th>
<th>Acres harvested/op.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus</td>
<td>2012</td>
<td>CA</td>
<td>3,584</td>
<td>140</td>
<td>10,587</td>
<td>5,212</td>
<td>76</td>
</tr>
<tr>
<td>Banana</td>
<td>2012</td>
<td>HI</td>
<td>11,100</td>
<td>970</td>
<td>600</td>
<td>1,327</td>
<td>1</td>
</tr>
<tr>
<td>Blackberry</td>
<td>2012</td>
<td>OR</td>
<td>6,380</td>
<td>465</td>
<td>6,300</td>
<td>1,662</td>
<td>14</td>
</tr>
<tr>
<td>Broccoli</td>
<td>2012</td>
<td>CA</td>
<td>17,920</td>
<td>617</td>
<td>106,271</td>
<td>59,356</td>
<td>172</td>
</tr>
<tr>
<td>Cucumber</td>
<td>2012</td>
<td>CA</td>
<td>175</td>
<td>718</td>
<td>7,884</td>
<td>37</td>
<td>11</td>
</tr>
<tr>
<td>Fig</td>
<td>2012</td>
<td>CA</td>
<td>952</td>
<td>240</td>
<td>6,071</td>
<td>463</td>
<td>25</td>
</tr>
<tr>
<td>Ginger root</td>
<td>2012</td>
<td>HI</td>
<td>30,000</td>
<td>34</td>
<td>53</td>
<td>899</td>
<td>2</td>
</tr>
<tr>
<td>Head cabbage</td>
<td>2016</td>
<td>CA</td>
<td>42,560</td>
<td>255</td>
<td>9,812</td>
<td>31,493</td>
<td>38</td>
</tr>
<tr>
<td>Herbs (basil)</td>
<td>2012</td>
<td>HI</td>
<td>1,090</td>
<td>8</td>
<td>18</td>
<td>47</td>
<td>2</td>
</tr>
<tr>
<td>Leaf lettuce</td>
<td>2016</td>
<td>CA</td>
<td>22,400</td>
<td>1,104</td>
<td>49,063</td>
<td>19,144</td>
<td>44</td>
</tr>
<tr>
<td>Mango</td>
<td>2012</td>
<td>HI</td>
<td>1,233</td>
<td>222</td>
<td>219</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>Orange</td>
<td>2012</td>
<td>CA</td>
<td>26,240</td>
<td>4,776</td>
<td>176,222</td>
<td>18,619</td>
<td>37</td>
</tr>
<tr>
<td>Strawberry</td>
<td>2012</td>
<td>CA</td>
<td>79,520</td>
<td>887</td>
<td>38,800</td>
<td>66,893</td>
<td>44</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>2012</td>
<td>HI</td>
<td>49,513</td>
<td>61</td>
<td>37</td>
<td>578</td>
<td>1</td>
</tr>
<tr>
<td>Taro</td>
<td>2018</td>
<td>HI</td>
<td>9,630</td>
<td>248</td>
<td>310</td>
<td>231</td>
<td>1</td>
</tr>
<tr>
<td>Tomato</td>
<td>2012</td>
<td>CA</td>
<td>10,0240</td>
<td>3,176</td>
<td>295,247</td>
<td>179,202</td>
<td>93</td>
</tr>
</tbody>
</table>

Note. Data compiled from the NASS Quick Stats database from 2012, 2016, and 2018.

Abbreviations: lbs.—pounds; op.—operation; yr.—year; wk.—week

1 Variables given as averages across the number of operations and acres harvested for the given crop.
Table 2. Diversified crop portfolio for small-scale producers in Hawaii.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Irrigation</th>
<th>Soil</th>
<th>Sun</th>
<th>Concerns</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus</td>
<td>Yes</td>
<td>Soil would need to be limed to a pH of 7.</td>
<td>Full</td>
<td>Lack of cold means plants may not live as long.</td>
<td>High</td>
</tr>
<tr>
<td>Banana</td>
<td>Yes, unless in the higher rainfall areas on the slopes of Kuualu mountains.</td>
<td>Ideal structure and pH.</td>
<td>Full</td>
<td>Banana plants can be labor intensive.</td>
<td>High</td>
</tr>
<tr>
<td>Blackberry</td>
<td>Yes</td>
<td>Needs good drainage.</td>
<td>Full</td>
<td>Very perishable, requires immediate refrigeration, labor intensive.</td>
<td>Possible with harvest refrigeration equipment. Or “Pick Your Own” is a marketing possibility.</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Yes</td>
<td>Needs well drained soil, needs soil amendment in this area.</td>
<td>Full</td>
<td>Broccoli bolts when temps go over 75F.</td>
<td>Possible in greenhouse with evaporative cooling system.</td>
</tr>
<tr>
<td>Fig</td>
<td>No</td>
<td>Ideal. Can grow in any of O’ahu’s soils and drought tolerant.</td>
<td>Full</td>
<td>The major challenge is bird damage from Mynah birds, White Eye birds and Cardinals.</td>
<td>High</td>
</tr>
<tr>
<td>Ginger Root</td>
<td>Yes</td>
<td>Well drained soil is imperative.</td>
<td>Partial</td>
<td>Sunlight is best</td>
<td>High</td>
</tr>
<tr>
<td>Head cabbage</td>
<td>Yes</td>
<td>Needs moist, well drained soil.</td>
<td>Full</td>
<td>Definitely a cold weather crop.</td>
<td>Low</td>
</tr>
<tr>
<td>Herbs (Basil)</td>
<td>Yes</td>
<td>Require consistent soil amendment.</td>
<td>Full</td>
<td>Choose tropical or Mediterranean herbs. Fungal wilts can be a problem.</td>
<td>High</td>
</tr>
<tr>
<td>Leaf lettuce</td>
<td>Yes</td>
<td>Soil temps too high.</td>
<td>Tolerates some shade.</td>
<td>A cold season crop.</td>
<td>Requires greenhouse. Can be grown hydroponically if water is cooled.</td>
</tr>
<tr>
<td>Crop</td>
<td>Irrigation</td>
<td>Soil</td>
<td>Sun</td>
<td>Concerns</td>
<td>Recommendation</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------</td>
<td>--------------------------</td>
<td>-----</td>
<td>--------------------------------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Mango</td>
<td>No</td>
<td>Ideal with addition of 10-20-20 fertilizer</td>
<td>Full</td>
<td>Does well even in drought.</td>
<td>High</td>
</tr>
<tr>
<td>Citrus trees (orange)</td>
<td>No</td>
<td>Best at elevations below 500’</td>
<td>Full</td>
<td>Asian citrus psyllid insect is a major issue, as is Tristeza disease and other fungal diseases in humid areas.</td>
<td>Possible</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>Yes</td>
<td>Moist soil. Needs to be limed.</td>
<td>Tolerates some shade in this climate.</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Taro</td>
<td>Yes unless grown in wetlands.</td>
<td>Needs abundant water, all soils can work.</td>
<td>Full</td>
<td>Do not over fertilise with nitrogen.</td>
<td>High</td>
</tr>
<tr>
<td>Tomato</td>
<td>Yes</td>
<td>Moist soil.</td>
<td>Full</td>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>
Rows of lettuce ready for harvest at Kaneshiro Farm in Koloa, HI. Photo by meerar on Flickr.
Introduction
This chapter reviews the post-harvest handling systems for a portfolio of diversified crops that are suitable for production in Hawaii as introduced in Chapter 1. An inventory of the post-harvest handling systems provided key insights into how the varying agricultural base yards were arranged to maximize utility and efficiency. Crops range from fruit vegetables, leafy greens, root vegetables, stem vegetables, berries, citrus, and fruits. An inventory of post-harvest activities was taken from harvest until transport off of the base yard (i.e., harvest, post-harvest handling activities, storage requirements, and load and transport). This inventory fostered the creation of the base yard modules which are introduced in Chapter 4 and spatial assemblages which are introduced in Chapter 5.

Blackberry & Strawberry
Berries in general are particularly sensitive to spoilage. Blackberries and strawberries follow the same post-harvest handling procedures and will therefore be combined under one section. Berries spoil easiest out of all crops due to harvest and handling, decay, and natural senescence (self-destruction).

In Field Activities: All berries are harvested as soon as they become ripe. After harvest, berries should be moved to a shaded area to prevent spoilage. Typically, berries are packed in the field and are immediately made ready for shipment. Hand sorting and grading is critical to separate healthy berries from diseased berries—with healthy berries being placed into small containers (Figure 8).

Post-Harvest Area Activities: Once placed in small containers, berries should be forced-air cooled to 32°F. Overcooling the produce could cause the fruit to dry out, so special care should be provided to ensure that the berries do not dry out during cooling (Kader, 2002).

Storage: Continuous temperature management is key to prevent rot and spoilage. Temperature management is the single most important factor in reducing produce loss when it comes to berries. Strawberries and blackberries should be stored at as close to 32°F as possible. There should be minimal fluctuation in temperature during storage (Kader, 2002).

Load and Transport: Maintaining low temperatures is critical when transporting strawberries and blackberries. Refrigerated holding rooms for berries being prepped for transport should be equipped with sealed loading doors so that the produce can remain refrigerated while being loaded. The transport vehicle should also be refrigerated and maintained at a low temperature. The transport vehicle and anything on it should be cooled before any berries are loaded onto it (Kader, 2002).

Figure 8. Worker harvesting ripe, healthy strawberries in the field. Photo by mhall209 on Flickr.
Oranges
Oranges are classified as citrus fruits and follow post-harvest activities typical of other citrus fruits.

In Field Activities: Harvested oranges are collected in canvas baskets to reduce bruising as well as preventing respiration and ethylene production. The oranges are then loaded into boxes and tightly packed to reduce surface abrasion. After packing, oranges are transported to the post-harvest handing area inside well-ventilated boxes in a covered truck (Malik et al., 2004).

Post-Harvest Area Activities: Upon arrival at the post-harvest handling area, the fruit is separated between the oranges that require degreening and oranges that do not. Degreening is the process of subjecting mature green oranges to a combination of controlled temperature, humidity, and ethylene gas conditions to progress the color from a green, to yellow, to the favored orange color. The oranges that require degreening are bulk dipped into fungicide then compiled with the rest of the oranges to be graded. It is important to note that the time between harvest and treatment with fungicide cannot be greater than twenty-four hours. The first grading includes composting all oranges that are damaged or deformed and are therefore, not suitable for market. After grading, the oranges are ready to be washed to remove soil, field spray residue, and disease spores. The water used for washing needs to be treated with a sanitizer to kill any free-floating spores. High pressure washers can be used to remove pests and diseases but also risk removing the natural wax layer of the fruit. To prevent the loss of wax on oranges they can be washed using low pressure sprayers in dump tanks. After washing all fruit goes through a general fungicide treatment to further prevent the spread of disease spores. A final step of sorting by size is done using belts or rollers that electronically weigh oranges (Hardy, 2004).

Storage: Once the oranges have been sorted, they are packaged into 30- or 15-quart cardboard cartons. The oranges are tightly packed in a single layer with no extra room to create friction and movement. If the oranges are not being directly transported, they are palletized then moved into climate-controlled storage. The storage temperature needs to be 37 to 46°F and may be stored for up to three months under ideal conditions (Hardy, 2004).

Loading and Transport: After the storage duration is completed, oranges are kept in the cardboard cartons which are then placed in boxes and loaded onto truck for transportation off site.

Banana
In Field Activities: Bananas are typically harvested with a large knife or machete before transport to the post-harvest area.

Post-Harvest Area Activities: After bananas are harvested, they are transported to the post-harvest handling area. Abrasion damage is minimized during handling by using padded trucks with additional padding between each bunch can be used. Once at the post-harvest handling area, bananas are graded by hand. Bananas not meeting fresh market grade can be composted. Fresh market grade banana hands are cut away from the stalk and floated in water to reduce latex staining that occurs after cutting. The bananas are then cut into finger cluster of four to ten and deformed or damaged bananas are sorted out. The bananas are then removed from the dehanding tank and labeled. Since the bananas soak in water, fungal diseases are a risk. To prevent this, the bananas are treated with a fungicide. Sodium hypochlorite can also be used in the water to combat spores. The chlorine concentration must be kept between 75 and 125ppm (Kader, 2002).

Storage: Bananas should not be stored for an extended amount of time, as quality will decrease. The fruit is also susceptible to chilling injury and should not be exposed to temperatures below 56°F. During storage and transport, bananas should be held at 57 to 59°F (Kader, 2002).
Loading and Transport: Bananas are typically packed in 40-pound corrugated fiberboard cartons lined with a thin polyethylene film to prevent abrasion damage.

**Fig**

In Field Activities: Figs are harvested manually in the field and packed into trays one layer deep.

Post-Harvest Area Activities: Once figs are harvested, they are moved to the post-harvest area in trays. Figs are susceptible to bruising and damage, so they should not be packed in any more than one layer deep. The figs can then be palletized, although this is less feasible in small-scale operations (Kader, 2012).

Storage: Figs are typically not susceptible to chilling injury. The optimal temperature range for storing figs is from 30 to 32°F. It is recommended that figs are cooled by forced air cooling or cold room storage at 32°F. Figs typically then undergo CO2 treatment, which aids in quality control and disease prevention (Crisosto, Mitchem and Kader, 1998).

Loading and Transport: Figs should be transported and packaged in a modified CO2 atmosphere at 32°F (Kader, 2012).

**Mango**

In Field Activities: Immediately after mango is harvested in the field, the fruits are placed into baskets to begin the process of latex removal. To remove latex, the stems of mangos are cut down to one centimeter and placed stem down on wire racks allowing for the latex to drip without coming in contact with the peel (Paltrinieri, no date). When no more liquid is dripping from the mango stem the latex removal is completed. After the latex has been removed, the mangos are collected into field lug boxes that are shaded to protect from sun damage and loaded into a transport truck. It is important that the truck has proper ventilation and the distance between the orchard and the post-harvest handling area is minimal. It is best to transport mangos during the coolest time of day to preserve shelf life from temperature exposure (Sargent et al., 2010).

Post-Harvest Area Activities: Upon arrival at the post-harvest handling area, the mangos are immediately unloaded into a large receiving area to prevent the mangos from heating up in the shipping trucks (mangos undergo the most compositional changes in the hours directly following harvest). Next, each crate is inspected for fruit fly infestation by slicing sequentially down to the seed for at least 25 mangos per load. This inspection is completed on a grading table, and the mangos are sliced with a large knife. Following the inspection, the mangos are transferred into a dump tank, which then travel through a spray and brush cleaning system to remove any remaining latex, soil, and other adherents. Before entering a hot water treatment, the mangos are then sized either manually or automatically by weight and dimension. The hot water treatment contains potable water at a temperature of exactly 115°F. Fruit that is greater than 500 grams takes 75 minutes, 501-700 grams takes 90 minutes, and 701-900 grams takes 110 minutes. Immediately after the hot water treatment, the fruits are hydrocooled. It is important that the hydrocooler water be sanitized with chlorine to prevent spread of decay and pathogens. Mangos remain in the hydrocooler for 30 minutes, or more depending on size, at a water temperature of 70 to 72°F. Each step in the process described—washing, hot water treatment, and hydrocooling—may be done in 100-150-gallon livestock tanks. After hydrocooling, the mangoes are removed from the water and go through a final grading. The mangos are then dumped onto the packing line by manually dumping the field boxes or by using an automated system (Sargent et al., 2010).
Storage: Mangos are packed into cartons tightly to immobilize the fruits and prevent surface abrasion injury. The mangoes are placed in cardboard boxes with ventilation holes, in single layers with the stem facing downward to reduce latex contamination. The cartons of mangos are unitized onto pallets where they are then moved into cold storage at a temperature of 50 to 54°F (Sargent et al., 2010). If mangos are held for more than a few days a humidifier providing a relative humidity range of 85-95% is needed to prevent excessive water loss from the high airflow rate of cooling. At these cool storage conditions mangoes will maintain acceptable conditions for up to four weeks and can then ripen at later higher temperatures. Storage depends on the maturity of the mango when harvested. Mangoes ripen within four to six days after harvest if harvested in the mature green stage of growth (Paltrinieri, no date).

Loading and Transport: Following temporary cold storage is the process of loading mangos for transport to market. This usually includes an initial step of palletization to ease loading and transport (Sargent et al., 2010).

Cucumber

In Field Activities: After harvesting by hand, cucumbers are placed into clean plastic trays or buckets. The fruit can either be packed in the field or transported to the post-harvest handling area. If cucumbers are packed in the field, damage is usually minimized, and product yield is higher. Fruit-vegetables packed in the field are often not washed. If cucumbers are transported to the post-harvest handling area, they can be immersed in clean water, spray-washed, or wiped clean. The product is then sorted by size and maturity while composting cucumbers found with defects. Cucumbers are then packed by weight or count into shipping containers. This can be done on small shared packing tables at the ends of rows. Additionally, the containers can be palletized if the operation allows for it (Kader, 2002).

Post-Harvest Area Activities: If in-field packing does not occur, the cucumbers are transported to the post-harvest handling area in stacked trays. Once in the post-harvest handling area, the trays are unstacked, and the cucumbers are either spray-washed or immersed in clean water. Next, the cucumbers are sorted by size and maturity and cucumbers with defects are composted. The inclusion of a post-harvest handling area in the operation typically leads to more uniform packing and a more consistent quality of product (Kader, 2002).

Storage: Cucumbers need to be cooled as soon as possible after harvesting in order to maintain quality and appearance. Forced-air cooling is common for immature fruit-vegetables, and cucumbers should be stored at 46 to 54°F. Cucumbers are susceptible to chilling injury and should not be stored below 45°F. Immature fruit-vegetables are packed by weight, volume, or count into shipping containers before being loaded and transported (Kader, 2002).

Loading and Transport: Cucumbers are typically part of low-volume operations, meaning that they are frequently transported as a part of mixed loads. This can present problems regarding shipment temperatures and chilling injury, and it must be considered when transporting the fruit-vegetable. If the product has been palletized, pallet blankets can be used to create a slightly warmer temperature around the shipment. Cucumbers are also extremely sensitive to ethylene, and exposure should be minimized during transport (Kader, 2002).
Tomato

Tomatoes are a fragile crop due to their thin skin. Tomatoes have a more specific handling standards under GAP and GHP. It is critical to handle and process tomatoes gently so as not to puncture the skin and introduce pathogens.

In Field Activities: After harvesting, tomatoes can be packed in the field or moved the post-harvest handling area. Tomatoes should be hand sorted and graded before field packing occurs. When field packing, the crop can either be washed in field then packed or immediately packed and rinsed off site. In most cases, if the crop is field packed, the tomato will be washed and sanitized off site. The tomato should be packed by weight in preparation for transport (Kader, 2002).

Post-Harvest Area Activities: In the post-harvest facility, tomatoes should be rinsed or sanitized with either sprayers or dump tanks. Dump tanks and sprayers allow for the crop to be washed without fear of breaking the skin. Sprayers and dump tanks should be prepared with the proper amount of sanitizing chemicals in accordance with the label. Sanitizer should rid the crop of any pathogens but diluted to a safe amount according to the EPA and the label of the chemical. Hand sorting and grading will occur before packing. A laminated table top is a good surface for sorting and grading due to its ability to limit the spread of pathogens and ease of cleaning. Tomatoes should be cooled overnight then packed and prepped for shipment (Kader, 2002).

Storage: Tomato harvest typically occurs in the afternoon so that they can be cooled overnight at 58°F. After tomatoes have been cooled overnight, packing will occur after so that condensation does not occur. After packing, tomatoes should have continued temperature management until they are transported off site (Kader, 2002) (Figure 9).

Load and Transport: A cooled transport vehicle should be provided for the transport of tomatoes. Chilling injury is a concern for fruit-vegetables such as tomatoes. Storage and transport temperature should be between 50 to 59°F (Kader, 2002).
Basil
Basil follows a generalized post-harvest handling flow that applies to many other fresh herbs. Operations for herbs intended for fresh market are typically smaller in scale, meaning that all activities (i.e., harvesting, grading, trimming, bunching, and packing) are usually done by hand.

In Field Activities: Basil is harvested in the field or in a greenhouse by hand. Typically, this herb is harvested using scissors, shears, or knives. Fresh herbs can be then bunched in bulk and packed in the field by hand, but this has the potential to significantly impact fresh appearance and reduce shelf life. If fresh herbs are packed in the field, the risk for water loss is especially high.

Post-Harvest Area Activities: If the herbs are not packed in field, they are taken in bulk to the post-harvest handling area. Basil can be brought to the post-harvest handling area in large plastic containers. Once in the post-harvest handling area, basil is trimmed, graded, and bunched. This part of the operation can take place on a table in the designated packing area. Fresh herbs, including basil, can be packed in bulk or in smaller bunches into polyethylene pouches or rigid plastic boxes before transport and shipment (Kader, 2002).

Storage: Basil, along with other fresh herbs, is extremely perishable, and many factors must be taken into consideration regarding storage and transportation. Basil is extremely susceptible to chilling injury, meaning its quality is severely reduced at 32 °F. This temperature sensitivity means that it cannot be stored with other herbs at this temperature without significantly decreasing appearance. It is recommended that basil be stored at 41 to 50 °F if it is necessary for it to be stored with other fresh herbs, but even this temperature can induce chilling in basil and increase deterioration rates of other herbs. The optimum storage temperature for basil is 50 °F. If basil is harvested cool in the early morning, the need for immediate cooling and refrigeration is mitigated. The best method for cooling for herbs with tender leaves, such as basil, is forced-air cooling or room-cooling. Another issue associated with the storage of fresh herbs is moisture loss. A way to combat this is to package fresh herbs in plastic films in order to retain moisture. Condensation and microbial growth present additional problems, and the films must allow for the transfer of water vapor so that condensation does not build up. This can be done by perforating the packaging or using a film that is permeable to water (Kader, 2002).

Loading and Transport: Sometimes fresh herbs are shipped with other leafy greens, but usually due to the perishability of the herbs, they are transported in special shipments by air to reduce transit time. The same temperature constraints for storage of basil must be taken into consideration for transport. Careful handling of basil must be maintained from harvest to market in order to minimize physical damage to the fragile leaves (Kader, 2002).

Head Cabbage
In Field Activities: Cabbage should be harvested promptly when the heads are firm and mature. Delaying harvest even a few days beyond maturity can result in split heads and increased incidence of field disease. Harvesting immature heads reduces yield, and the heads are too soft to resist handling damage. Immature heads also have a shorter shelf life than mature heads. A mature head of cabbage generally weighs three to five pounds, depending upon variety. The head is harvested by bending it to one side and cutting it with either a Russel knife or a common butcher knife. The stalk should be cut flat and as close to the head as possible, yet long enough to retain two to four wrapper leaves. After harvesting, care should be taken to minimize bruising, and this can be achieved by placing the cabbage with outer leaves intact directly into ventilated bags or containers (Boyette, Wilson and Estes, 1990).
Post-Harvest Area Activities: Preferably, head cabbage should be transported in refrigerated trucks, with ventilated crates rather than open trucks. Open body trucks can be used, but vehicles must be covered by a light-colored tarpaulin and transported during the coolest part of the day. Once in the post-harvest handling area, the cabbage must be washed to prevent dehydration and the torn, loose outer wrapper leaves should be removed so the head has a clean, compact, and fresh appearance. Only three to six tight wrapper leaves should be left on the head. Loose leaves interfere with ventilation between heads, which is important whether the cabbage is packed for market or put into storage. After this the produce should be sorted and graded. Heads with insect damage and other defects should be discarded. Cabbage is generally packed in 50-pound fiberboard cartons, 50-60-pound wire-bound crates, or mesh bags. Uniformity and the proper count per carton are important, 18 to 22 heads per 50-pound carton is customary (Boyette, Wilson and Estes, 1990).

Storage: Cabbage should be cooled immediately after packing. A climate-controlled storage area set to 32°F and 95% relative humidity is ideal. In this environment, the center of a medium-sized cabbage should take about 18 hours to cool from 80°F to 36°F. It is usually not necessary to cool cabbage by more rapid means, although some packers use forced-air cooling fans to greatly decrease cooling time. It is also important to keep adequate ventilation during storage to maintain very low ethylene levels since cabbage is especially ethylene sensitive (Campbellh, 2013).

Loading and Transport: Similar requirements for transporting produce to the post-harvest handling area apply when transporting head cabbage off-site. The preferred and recommended way to transport head cabbages is using refrigerated trucks, with ventilated crates (Campbellh, 2013).

Leaf Lettuce

In Field Activities: Leaf lettuce is harvested when the crop has reached the required size and before maturity. Different kind of lettuce will have different maturity indicators. Leaf lettuce can be harvested by hand or with a harvest machine. The crop is very fragile and should be handled as little as possible and taken to the post-harvest handling area immediately after being harvested (Gorny et al., 2006). Alternatively, leaf lettuce can field-packed into cartons. First, damaged areas are removed. Then, the rest of the leaves are trimmed, and tied into compact bundles before being placed into cartons. Field packing and palletizing eliminate a major source of mechanical damage, but they require specialized handling equipment and vacuum-cooling facilities to be practical (Smith, 2011).

Post-Harvest Area Activities: In the post-harvest handling area, leaves that are loose, discolored, damaged, soiled, and diseased are removed. After cutting and trimming, the produce needs to be washed with cold water or treated water. Treated water is composed of a chlorine-containing compound and/or an antioxidant or preservative. Centrifugate drying is implemented if needed to remove excess water. Leaf lettuce hearts are then film wrapped. They are then packaged in 20-25 pound or 24-count cartons. Various specialty products, such as individual leaves, are also packed for the food service industry. Leaf lettuce is highly perishable and should be cooled by hydrocooling, forced air cooling, or vacuum cooling before storage (Smith, 2011).

Storage: Leaf lettuce should not be stored with ethylene treated crops. Leaf lettuce should be kept between 32-34°F at 98% relative humidity. This will ensure quality produce for two to three weeks (SEMCO, 2014).

Loading and Transport: When lettuce is field packed, not all damaged leaves are removed. Several leaves are left as a wrapper to help cushion the produce during transport and avoid bruise. These leaves are later removed before sale (Smith, 2011).
**Ginger**

Ginger is classified as a root crop and has little to no specialized considerations. Ginger follows almost the same post-harvest processes as sweet potatoes and taro.

In Field Activities: After harvest, ginger goes through its first stage of grading. This grading is done on a grading table in the field, removing damaged rhizomes as well as ones that are too small for market. The ginger is then trimmed to remove the stem from the root and loaded into well-ventilated wooden field-crates. The crates of ginger are then loaded into trucks to be transported to the post-harvest handling area. Transportation in mesh sacks should be avoided, as it results in skin damage caused by abrasion between the ginger roots (Teferra et al., 2015).

Post-Harvest Area Activities: After arrival at the post-harvest handling area, the ginger needs to be cured either by sun drying, solar drying, or gas-heated dehydrators. Air drying requires an average temperature of 71.5 to 79°F with a relative humidity of 70-75% for three days. Artificial drying if more expensive and labor intensive but minimizes the loss of quality and the risk of microbial contamination (drying temperature, drying duration, and airflow all affect the flavor in ginger). In large-scale production, ginger is washed by entering floatation tanks with screens to separate soil and debris and then sprayed by mechanical washers to further clean the product. While mechanical dump tanks and sprayers are used in larger operations, different equipment is applied for small scale operations. Typically, ginger will be placed into a barrel washer or drum washer which rotates the ginger in a metal/wood cylinder while continuously spraying water across the roots. The centrifugal and frictional forces across the roots combined with water spraying removes most soil and adhered substrates from the ginger roots. While being washed in the barrel washer or drum washer, the ginger roots can also be sprayed with a hose to further remove soil. When exiting the washer, the ginger is placed in crates to be dumped in a 100-gallon livestock tank filled with clean water and disinfectant serving as a dump tank for the crop. The ginger goes through a final stage of grading by hand followed by sizing. The three categories of size are large, regular, and small. Large ginger consists of largely sized, high quality ginger, the regular consists of medium sized ginger, and the small consists of small and irregular sizes, including ginger off cuts. Ginger is then packaged in containers after checking for any possible retention of moisture that could lead to mold growth (Teferra et al., 2015).

Storage: The ginger is moved to cold storage, keeping the ginger at 55°F to prevent high moisture loss, sprouting, and surface shriveling. The market life of ginger in cold storage is less than one month. The storage room also needs a dehumidifier that provides a relative humidity below ten percent in the storage room, as well as a ventilation system (Teferra et al., 2015).

Loading and Transport: The containers being used to hold the ginger while being transported off site must be cleaned between loads to prevent the spread of bacteria. The containers being used should be well-ventilated to remove moisture from plant materials and to prevent condensation (Teferra et al., 2015).

**Sweet Potato**

Sweet potatoes are classified as root vegetables and follow almost the same post-harvest process as taro.

In Field Activities: The harvested sweet potatoes are loaded into wooden bins with 20-40 bushels per bin which are stacked and loaded onto a truck to be transported to the post-harvest handling area. Proper stacking of sweet potatoes into the bins includes avoiding overfilled bins to prevent damage when stacking occurs. Sweet potatoes have delicate, thin skin so care must be taken to avoid abrasions and cuts to the surface. If not handled with care potatoes can suffer from diseases entering through cuts, lower appearance value, and shrinkage (Edmunds et al., 2008).
Post-Harvest Area Activities: Once sweet potatoes arrive at the post-harvest handling area; the curing process begins. The potatoes are stored in a temperature-controlled room at 85 °F with a relative humidity of 85-90% with proper ventilation for two to five days. A heater capacity of 2,000 BTU is required to heat a 1,000-pound bin of sweet potatoes from 55°F to 85°F in 24 hours (Edmunds et al., 2008). On large operations, the sweet potatoes enter a dump tank either by a fork-lift mounted bin rotator device or being forklifted into an automatic bin rotator after curing. A submerged dunk limits the physical damage from dumping the potatoes. It is important to have chlorinated wash and flume waters for sanitation purposes and to prevent decay. Post-harvest fungicides can also be added at this stage of processing, as needed. Waterfall/curtains and normal to high-pressure spray washers are used to clean the outside of the potatoes.

As for small-scale operations, the sweet potatoes will first be moved to a barrel washer or drum washer which rotates the potatoes in a metal or wood cylinder while continuously spraying water across the roots (Figure 10). The centrifugal and frictional forces across the potatoes combined with the spraying of water removes most adhered soil. While being washed in the barrel washer or drum washer, the potatoes can also be sprayed with a hose to further remove soil. When exiting the washer, the potatoes are placed in crates to be dumped in a 100-gallon livestock tank filled with clean water and disinfectant serving as a dump tank for the crop. Next, the sweet potatoes move onto a table comprised of PVC rollers for sorting done by hand including the removal of unmarketable roots. Finally, the sweet potatoes are sized by diameter and the smaller sweet potatoes are separated from the larger potatoes (Blanchard, 2013).

Storage: After the separation of sweet potatoes by size and grade, the potatoes are packed into 40-pound corrugated fiberboard boxes. Smaller 14-pound cartons can also be used. Sweet potatoes that are packaged and awaiting transport need to be kept in climate-controlled storage. Storage conditions should have an average temperature of 55°F and 85% relative humidity. It is also important that the climate-controlled storage be located separate from the area where unwashed roots are stored while close to where the loading activities will occur (Edmunds et al., 2008).

Loading and Transport: Sweet potatoes are palletized and then loaded onto shipping vehicles that will then transport them to the marketable destination. It is important truckers and receivers understand the possible risk of ethylene damage to sweet potatoes as well as the temperature requirements and do not transport the potatoes with different varieties of vegetables that do not match the same physical requirements (Edmunds et al., 2008).

Figure 10. View of a barrel washer in a PHH area, photo taken from a farm tour hosted by Kansas Farmer’s Union. Photo by Kansas Farmers Union on Flickr.
Taro

Taro is similar to many other root crops and has little to no specialized considerations. Sweet potato and taro follow almost the exact same post-harvest processes.

In Field Activities: Taro is harvested and immediately brought to the post-harvest handling area. Taro may be loaded into wooden bins and transported by truck or stacked and transported by hand cart (similar to a dolly) depending on the resources of the farm.

Post-Harvest Area Activities: Once taro has arrived at the post-harvest handling area, taro, and root crops generally, are brush washed or barrel washed to remove dirt and debris. Sanitizers and cleaning chemicals approved for food use should be added to the water to prevent the spread of disease. Diseased parts of taro should be cut out and disposed of to prevent contamination of any other crop. Root crops, including taro, need to be cured to prevent water loss and decay. Curing should occur at 85°F with approximate humidity at 85-90%. Curing processes can occur in a temperature-controlled room or in the field with a canvas covering them to prevent sunburn (Kitinoja and Kader, 2002). For the agricultural base yard, curing will occur in a specialized curing container. Curing can take about three days. After curing, taro should be cooled to 45 to 50°F to prevent further water loss. Taro is then sorted by size, skin color, shape, and texture. Once sorted, taro should be packaged by grade (Gross, Wang and Saltveit, 2016).

Storage: Storage of taro should be between 55 to 59°F with a relative humidity of 85-90% to prevent water loss until transport. Taro and other root vegetables should be in breathable packaging to prevent spoilage. Taro can be stored under proper conditions for up to four months. Adequate circulation should be provided so that heat does not accumulate around the crop.

Load and Transport: Typically, root vegetables are loaded into large boxes (about 14 pounds produce each) and loaded onto the transport vehicle. Special care needs to be taken so that the crop can breathe. The transport vehicles should be temperature controlled to given storage temperatures (Kader, 2002).

Asparagus

In Field Activities: Asparagus is cut for three or four weeks the second year, i.e., after the plants have had one full year’s growth in the permanent bed (Thompson, 1942). The frequency of cutting depends on the rate of growth, which is determined largely by the weather. Usually the spears can grow to such length that they will be from seven to ten inches long after being trimmed. Asparagus spears are cut with a special long-handled asparagus knife (Figure 11). The cut spears may be placed in a basket or other receptacle as cut, or they may be held in one hand until the hand is full and then placed on the row, or in receptacles properly spaced along the rows. If spears are very dirty, they shall be dumped into a tank of water. The spears should be gathered and hauled to the post-harvest handling area as soon as possible after being cut (Thompson, 1942).

Post-Harvest Area Activities: Crooked spears, spears with open heads, and otherwise unmarketable asparagus should be discarded. Asparagus is sorted and graded according to USDA standards. Bunches are then plunged into disinfectant-treated water or sprayed with cold water to remove soil from the outside. Water disinfectants include chlorine, hypochlorite, chlorine dioxide, and peroxyacetic acid. Spears are then weighed and trimmed to the desired length with a large sharp knife or with a circular, power-driven knife. Next, spears can be placed in a buncher which ties the bunch with tape, raffia, or rubber bands. Optionally, bunching can be done by hand as long as bunches are well tied. Finally, parchment paper or cellophane wrap is used to wrap the bunches of asparagus. Cooling is needed before storage to avoid mold growth and chemical changes in asparagus (Aegerter et al., 2011).
Storage: Asparagus is chill sensitive and takes on a gray appearance after about ten days if stored below 32°F. To maintain optimal quality, asparagus should be stored between 32 to 36°F and 90-95% relative humidity for approximately 7-14 days. If asparagus is stored beyond that, it will start losing nutritional value and flavors including natural sugars and Vitamin C (Aegerter et al., 2011).

Loading and Transport: During transportation, use containers with an absorbent pad saturated with hydrocooling water to reduce moisture loss and maintain high relative humidity. For long distances, asparagus should be packed in pyramidal crates, holding a dozen bunches of 2.5 pounds each, on average. Crates have a partition in the center that divides it into two compartments. Usually wet moss is placed on the bottom of the crate and asparagus bunches are set upright with the butts placed on the moss (Aegerter et al., 2011).

Figure 11. Worker cutting asparagus for harvest. Photo by Ben Amstutz on Flickr.

Broccoli
In Field Activities: Broccoli is harvested when the central head is dark blue or green. If harvested too late or when the heads are over-mature, woodiness in the stem will develop. Broccoli heads are checked for worms, which tend to hide underneath the florets. Harvesting must be done by hand using a sharp knife while the head is still compact and before the flowers open (Figure 12). The stalk of the main head is cut at an angle, about five to eight inches below the head. This allows any subsequent rain or watering to slide harmlessly down the side. The produce is collected into large bins or trailers and taken to the post-harvest handling area (Kime et al., 2005).

Alternatively, two or four heads are bunched and secured with a rubber band in the field. These bunches are cut uniformly and packed in groups of 14 to 18 in a waxed-fiberboard carton. Finally, crushed ice is used to cool the packed broccoli which is then taken to the storage area (Le Strange et al., 2010).

Post-Harvest Area Activities: Once in the post-harvest handling area, broccoli is sorted and graded based on size and flower tightness. Broccoli is weighed, bunched, and trimmed uniformly. The produce should then be washed under cold, running water. Broccoli is packed in one-layer boxes with the heads upright to avoid scrubbing of the flowers. Polystyrene lidded boxes and waxed cartons are recommended, and ice should be added inside the boxes. Broccoli should be cooled with packed ice or using the hydrocooling method before taken to the storage area. Forced-air cooling may also be used, but temperature management during distribution is more critical than when ice is used (Le Strange et al., 2010).
Storage: Maintaining a low temperature is extremely important in achieving an adequate shelf life for broccoli. A temperature of 32°F with relative humidity of 95 percent or higher is required to optimize the broccoli storage life of 21 to 28 days. Heads stored at 41°F have their shelf life cut in half, only 10 to 14 days. The time from harvest to climate-controlled storage must be less than two hours to prevent loss of quality (Kime et al., 2005).

Loading and Transport: Florets are loosely packed in tote bags and packed into cardboard cartons. Three or four bags per carton usually weigh 9 to 18 pounds. Carton boxes are only recommended during cold season or for short journeys (Le Strange et al., 2010).

Figure 12. Workers picking broccoli from vegetable harvesting machine. Photo by NSW DPI Schools program on Flickr.
The portfolio of diversified crops was grouped into four categories for storage temperature requirements (1A, 1B, 2, and 3). Each category has an optimal temperature and relative humidity range (Table 3). Tables 4, 5, 6, 7, and 8 show groups 1A, 1B, 2, 3, respectively, along with other variables such as recommended cooling method, approximate storage life, and modified atmospheres.

### Table 3. Crop groups along with respective temperatures and relative humidity requirements (Kader, 2002).

<table>
<thead>
<tr>
<th>Group</th>
<th>Optimal Temperature Range (°F)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>32-36</td>
<td>90-98</td>
</tr>
<tr>
<td>1B</td>
<td>32-36</td>
<td>85-95</td>
</tr>
<tr>
<td>2</td>
<td>45-50</td>
<td>85-95</td>
</tr>
<tr>
<td>3</td>
<td>55-65</td>
<td>85-95</td>
</tr>
</tbody>
</table>

### Table 4. Crop group 1A and associated storage requirements (Kader, 2002).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cooling Method</th>
<th>Approximate Storage Life (days)</th>
<th>Modified Atmospheres (%O₂)</th>
<th>Modified Atmospheres (%CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus</td>
<td>Hydrocooling</td>
<td>14-21</td>
<td>21</td>
<td>10-14</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Forced-air cooling; Package icing</td>
<td>10-14</td>
<td>2</td>
<td>5-10</td>
</tr>
<tr>
<td>Head Cabbage</td>
<td>Forced-air cooling</td>
<td>21-42</td>
<td>2-3</td>
<td>3-4</td>
</tr>
<tr>
<td>Leaf Lettuce</td>
<td>Forced-air cooling</td>
<td>14-21</td>
<td>1-3</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 5. Crop group 1B and associated storage requirements (Kader, 2002).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cooling Method</th>
<th>Approximate Storage Life (days)</th>
<th>Modified Atmospheres (%O₂)</th>
<th>Modified Atmospheres (%CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig</td>
<td>Forced-air cooling</td>
<td>7-10</td>
<td>5-10</td>
<td>15-20</td>
</tr>
</tbody>
</table>
**Table 6. Crop group 2 and associated storage requirements (Kader, 2002).**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cooling Method</th>
<th>Approximate Storage Life (days)</th>
<th>Modified Atmospheres (%O₂)</th>
<th>Modified Atmospheres (%CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basil</strong></td>
<td>Forced-air cooling; Room cooling</td>
<td>7</td>
<td>2</td>
<td>0-10</td>
</tr>
<tr>
<td><strong>Cucumber</strong></td>
<td>Forced-air cooling; Forced-air evaporative cooling</td>
<td>10-14</td>
<td>3-5</td>
<td>3-5</td>
</tr>
<tr>
<td><strong>Orange</strong></td>
<td>Room cooling</td>
<td>28-56</td>
<td>5-10</td>
<td>0-5</td>
</tr>
</tbody>
</table>

**Table 7. Crop group 3 and associated storage requirements (Kader, 2002).**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cooling Method</th>
<th>Approximate Storage Life (days)</th>
<th>Modified Atmospheres (%O₂)</th>
<th>Modified Atmospheres (%CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Banana</strong></td>
<td>Forced-air cooling</td>
<td>7-28</td>
<td>2-5</td>
<td>2-5</td>
</tr>
<tr>
<td><strong>Ginger</strong></td>
<td>N/A</td>
<td>&lt;180</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Mango</strong></td>
<td>Forced-air cooling</td>
<td>14-21</td>
<td>3-5</td>
<td>5-10</td>
</tr>
<tr>
<td><strong>Sweet Potato</strong></td>
<td>Room cooling</td>
<td>&lt;180</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Taro</strong></td>
<td>Room cooling</td>
<td>&lt;120</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Tomato (ripe, partially ripe, mature green)</strong></td>
<td>Hydrocooling</td>
<td>14-35</td>
<td>3-5</td>
<td>3-5</td>
</tr>
</tbody>
</table>

**Table 8. Crops with no specific grouping and associated storage requirements including temperature and relative humidity (Kader, 2002).**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cooling Method</th>
<th>Approximate Storage Life (days)</th>
<th>Modified Atmospheres (%O₂)</th>
<th>Modified Atmospheres (%CO₂)</th>
<th>Optimal Temperature (°F)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blackberry</strong></td>
<td>Forced-air cooling</td>
<td>3-6</td>
<td>5-10</td>
<td>15-20</td>
<td>32</td>
<td>90-95</td>
</tr>
<tr>
<td><strong>Strawberry</strong></td>
<td>Forced-air cooling</td>
<td>7-10</td>
<td>5-10</td>
<td>15-20</td>
<td>32</td>
<td>90-95</td>
</tr>
<tr>
<td><strong>Sweet Potato (curing)</strong></td>
<td>Room cooling</td>
<td>4-7</td>
<td>N/A</td>
<td>N/A</td>
<td>86-90</td>
<td>85-90</td>
</tr>
<tr>
<td><strong>Tomato (firm-ripe)</strong></td>
<td>Hydrocooling</td>
<td>7-21</td>
<td>3-5</td>
<td>3-5</td>
<td>46-50</td>
<td>85-90</td>
</tr>
</tbody>
</table>
Chapter 3: Regulations & Standards for Small-Scale Farms

Food safety is essential to operating a profitable and successful farm operation. This chapter identifies the key elements in FSMA and GAPs a producer must be in compliance with as a legal requirement or as required to enter certain markets. Photo by Dmitry Dreyer on Unsplash.
Introduction
This chapter focuses on the Food Safety Modernization Act (FSMA) and Good Agricultural Practices (GAPs). Provisions in FSMA and GAPs that influence the design and construction of the base yard are highlighted and an overview of each provision is provided. This chapter also identifies the main GAP programs, including harmonized GAP, Global GAP, and GroupGAP. The regulations and standards introduced here are discussed further throughout Chapters 4, 5, and 6.

Food Safety Modernization Act
FSMA was signed into law in 2011, creating the first food safety requirements for farms producing fruits and vegetables. The Food and Drug Administration (FDA) under the Department of Health and Human Services (HHS), is charged with federal oversight and the Hawaii Department of Health and county health departments are the enforcers (National Sustainable Agriculture Coalition, 2016). FSMA is comprised of two different rules:

1. Produce Safety Rule (Produce Rule): Establishes science-based standards for growing, harvesting, packing, and holding produce. The rule is made up of food safety standards for farms to follow in an effort to reduce the risk of microbiological contamination on their farms. The scope of this manual and Modular Agricultural Base Yard: Building Plans for Small-Scale Farmers in Hawaii is compliance with the Produce Safety Rule. Compliance with the Facility Rule and other regulations falls outside the scope of this publication.

2. Hazard Analysis and Risk-Based Preventive Controls Rule (Facility Rule): Requires that food facilities have safety plans that set forth how they will identify and minimize hazards. The rule sets forth new and updates existing requirements for facilities that manufacture, process, pack, or hold food for human consumption (National Sustainable Agriculture Coalition, 2016).

Who is subject to FSMA?
The Preventive Controls for Human Food rule clarified the definition of a farm to cover two types of farm operations, primary production farms and secondary activities farms. The same definition is used in the Produce Safety rule (section 112.3(c)). Below are basic criteria that determine whether an operation that meets the definition of “farm” is subject to the produce rule (U.S. Food & Drug Administration, 2015). A basic criterion to determine whether an operation is subject to the Produce Rule and to what extent a farm is impacted. Each operation is different, and FSMA obligations may vary depending on the specifics of the operation.

The requirements for complying with FSMA criteria are relatively complex (Figure 13). The basic criterion to determine whether an operation is subject to the Produce Rule and to what extent a farm is impacted depend on the size, cropping system, and market for the produce. Each operation is different, and FSMA obligations may vary depending on the specifics of the operation.

The FDA has identified two categories of raw produce: Usually Consumed Raw, and Rarely Consumed Raw. Produce that is categorized as Usually Consumed Raw (see list in Box 1) is covered under the Produce Rule. If the FDA has identified produce as “rarely consumed raw,” the produce is not covered under the Produce Rule (Box 2) (U.S. Food and Drug Administration, 2015). FSMA includes new requirements to help prevent the contamination of sprouts, which have been frequently associated with foodborne illness outbreaks. Please note, sprouts are subject to different timelines and special requirements not addressed here. There are a number of allowable activities a farm may participate in under the Produce Rule that would trigger the effect of the Facility Rule (Table 9).
Box 1: Produce that is usually consumed raw
Almonds, apples, apricots, apriums, artichokes, Asian pears, avocados, babacos, bananas, Belgian endive, blackberries, blueberries, boysenberries, Brazil nuts, broad beans, broccoli, Brussels sprouts, burdock, cabbages, Chinese cabbages (bok choy, mustard, and Napa), cantaloupes, carambolas, carrots, cauliflower, celeriac, celery, chayote fruit, cherries (sweet), chestnuts, chicory (roots and tops), citrus (such as clementine, grapefruit, lemons, limes, mandarin, oranges, tangerines, tangors, and uniq fruit), cowpea beans, cress-garden, cucumbers, curly endive, currants, dandelion leaves, fennel-Florence, garlic, genip, gooseberries, grapes, green beans, guavas, herbs (such as basil, chives, cilantro, oregano, and parsley), honeydew, huckleberries, Jerusalem artichokes, kale, kiwifruit, kohlrabi, kumquats, leek, lettuce, lychees, macadamia nuts, mangos, other melons (such as Canary, Crenshaw and Persian), mulberries, mushrooms, mustard greens, nectarines, onions, papayas, parsnips, passion fruit, peaches, pears, peas, peas-pigeon, peppers (such as bell and hot), pine nuts, pineapples, plantains, plums, plumcots, quince, radishes, raspberries, rhubarb, rutabagas, scallions, shallots, snow peas, soursop, spinach, sprouts (such as alfalfa and mung bean), strawberries, summer squash (such as patty pan, yellow and zucchini), sweetsop, swiss chard, taro, tomatoes, turmeric, turnips (roots and tops), walnuts, watercress, watermelons, and yams; and mixes of intact fruits and vegetables (such as fruit baskets).

Box 2: Produce that is rarely consumed raw
Asparagus, black beans, great northern beans, kidney beans, lima beans, navy beans, pinto beans, garden (roots and tops) beets, sugar beets, cashews, sour cherries, chickpeas, cocoa beans, coffee beans, collards, sweet corn, cranberries, dates, dill (seeds and weed), eggplants, fig, ginger, hazelnuts, horseradish, lentils, okra, peanuts, pecans, peppermint, potatoes, pumpkins, winter squash, sweet potatoes, and water chestnuts.
Figure 13. A decision tree to determine whether a farm is subject to the Produce Rule and to what extent a farm may be impacted by FSMA rules. Note FSMA obligations are determined by reviewing a three-year average for annual sales and where the produce is sold or the type of processing an operation is doing (U.S. Food & Drug Administration, 2015).
Table 9. Allowable activities for FSMA Produce and Facility Rules (University of California Cooperative Extension, 2018).

<table>
<thead>
<tr>
<th>FSMA Produce Rule Activities</th>
<th>FSMA Facility Rule Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying/dehydrating</td>
<td>Baking</td>
</tr>
<tr>
<td>Labeling</td>
<td>Boiling</td>
</tr>
<tr>
<td>Packaging</td>
<td>Canning</td>
</tr>
<tr>
<td>Treating (with ethylene) to manipulate ripening</td>
<td>Cooking</td>
</tr>
<tr>
<td></td>
<td>Cooling</td>
</tr>
<tr>
<td></td>
<td>Cutting</td>
</tr>
<tr>
<td></td>
<td>Distilling</td>
</tr>
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Compliance with the FSMA Produce Rule
There are eight major provisions of the FSMA Produce Rule that are required for compliance. These are:
1. Personnel qualifications and training
2. Worker health and hygiene
3. Agricultural water used during growing, harvesting, packing, and holding
4. Biological soil amendments of animal origin (manure and compost)
5. Domesticated and wild animals
6. Growing, harvesting, packing, and holding, activities
7. Equipment, tools, and buildings
8. Record keeping

Each of these provisions have specific compliance criteria, including facilities, training, documentation, and reporting. They are summarized below, but full compliance requires training in each element. This information was summarized from the National Sustainable Agriculture Coalition (Understanding FDA’s FSMA Rule for Produce Farms, 2016. www.sustainableagriculture.net/publications) (National Sustainable Agriculture Coalition, 2016).

**Personnel Qualifications and Training**
The Personnel Qualifications and Training provision addresses qualification and training requirements for farm personnel who handle covered produce and/or food contact surfaces. Both supervisors and personnel must receive “adequate training as appropriate to [their] duties.” Such training must occur upon hiring, and periodically afterward, but at least once annually. Moreover, all personnel and supervisors must have “a combination of education, training, and experience necessary to perform the person’s assigned duties.” This means that not all farm employees must be trained in all aspects of food safety, but some degree of training is required based on the nature of their position on the farm.

**Health and Hygiene**
The Health and Hygiene provision includes required measures farms must take to protect against contamination from sick employees and visitors. These include, for example, excluding a sick person from working with covered produce if the person has (or appears to have) an applicable health condition (such as a communicable illness, infection, vomiting, etc.), and instructing personnel to notify their supervisor or other responsible party if they have — or there is a reasonable probability they have — such a condition. Visitor contamination prevention includes making visitors aware of policies and procedures in place to protect covered product and food contact surfaces from contamination and taking all steps reasonably necessary to ensure that visitors comply with such policies and procedures. You must also make toilet and hand-washing facilities accessible to visitors. It also addresses specific hygienic practices for personnel, which include: personal cleanliness, avoiding contact with animals, and taking appropriate steps to minimize that likelihood of contaminating covered produce when in direct contact with working animals; washing hands; removing or covering hand jewelry that cannot be adequately cleaned; and not eating, chewing gum, or using tobacco products in areas used for covered activities.

**Agricultural Water**
The Agricultural Water provision addresses water quality standards and inspection, maintenance, and testing requirements for water used during the production, harvest, and Post-Harvest Handling of produce. The FDA defines “agricultural water” as “water used in covered activities on covered produce where water is intended or likely to contact covered produce or food contact surfaces, including water used in growing activates and in harvesting, packing, and holding activities. In general, “all agricultural water must be safe and of adequate sanitary quality for its intended use”.
**Biological Soil Amendments of Animal Origin**
The Biological Soil Amendments of Animal Origin provision sets standards for handling, transporting, storing, treating, and applying biological soil amendments of animal origin. This applies to soil amendments that consist partially or entirely of materials of animal origin, which includes, but is not limited to raw and composted manure. The rule prohibits the use of human waste as a biological soil amendment, unless in the form of sewage sludge bio-solids.

**Domesticated and Wild Animals**
The Domesticated and Wild Animals provision of the rule sets out standards to minimize the food safety risks with wild or domesticated animals. The following requirements apply to growing, harvesting, packing, and holding when done in an outdoor area or partially enclosed setting, and when — under the circumstances — there is a reasonable probability that animals will contaminate covered produce. They do not apply to covered activities that take place in a fully enclosed building, or fish used in aquaculture. In the preamble to the rule, the FDA encourages the co-management of food safety, conservation, and environmental protection, “We consider it important to take into account the environmental practice standards and policies of other relevant agencies in the context of food safety”.

**Growing, Harvesting, Packing, and Holding Activities**
The Growing, Harvesting, Packing, and Holding Activities rule contains standards regarding certain growing, harvesting, packing, and holding activities. These include:
- Measures to avoid cross contamination between covered and not-covered produce;
- Measures to identify and not harvest covered produce that is reasonably likely to be contaminated;
- Handling harvested produce in a way that prevents against contamination with known or reasonably foreseeable hazards; and
- Using packaging adequate for its intended use (whether cleanable or single-use) and unlikely to support the growth or transfer of bacteria.

**Equipment, Tools, and Buildings**
The Equipment, Tools, and Buildings rule contains standards specific to tools or equipment intended to or likely to contact covered produce, and buildings (whether partially or fully enclosed, and including storage sheds). In general, it requires equipment and tools to be:
- Designed, installed, and stored to allow for adequate cleaning and maintenance; and
- Inspected, maintained, and cleaned when appropriate and as frequently as necessary to protect against contamination.

Buildings must be suitable in size, construction, and design to facilitate maintenance and sanitary operations; must provide sufficient space for storage of materials and equipment; permit proper precautions to be taken regarding the potential for contamination (e.g., separation of operations that introduce the potential for contamination by location, time, partition, etc.). This sections also contains standards regarding domesticated animals in fully enclosed buildings; pest control (e.g., taking measures reasonably necessary to protect against pest contamination, such as routine monitoring and exclusion); toilet and hand-washing facilities; sewage and waste disposal; plumbing; domesticated animal litter; and records — particularly relating to the date and method of cleaning and sanitizing equipment use in covered harvesting, packing, or holding activities.
**Record Keeping**

In addition to the specific record requirements discussed as a part of the various standards, there are general requirements that all records must include:

- The name and location of the farm;
- Actual values and observations obtained during monitoring;
- An adequate description of the relevant covered produce (i.e., commodity name and lot number or another identifier);
- The location of the growing or post-harvest area (e.g., specific field or packing shed), and;
- The date and time of the activity documented.

Records should be created at the time an activity is performed or observed; be accurate and legible; and be dated and signed or initialed by the person who performed the documented activity.

**FSMA Compliance Dates**

For covered activities, other than those involving sprouts (which have additional requirements and earlier compliance dates):

- January 26, 2018: Covered farms for which, on a rolling basis, the average annual monetary value of produce the farm sold during the previous 3-year period is more than $500,000.
- January 28, 2019: Covered farms for which, on a rolling basis, the average annual monetary value of produce the farm sold during the previous 3-year period is more than $250,000 but not more than $500,000 (small businesses).
- January 27, 2020: Covered farms for which, on a rolling basis, the average annual monetary value of produce the farm sold during the previous 3-year period is more than $25,000 but no more than $250,000 (very small businesses) (Center for Food Safety and Applied Nutrition, 2018).

**Good Agricultural Practices**

Good Agricultural Practices (GAP) and Good Handling Practices (GHP) were formally implemented by the USDA and FDA in 2002 (Olsen and Allen, 2017). GAP and GHP are voluntary audit program designed to verify that produce is grown, packed, and handled, and stored as safely as possible to minimize risks of microbial food safety hazards (USDA Agricultural Marketing Service, no date a). There are different GAP audit protocols such as harmonized GAP, Global GAP, and GroupGAP that may have slightly different requirements.

GroupGAP may be a beneficial opportunity for small-scale, diversified crop producers in Hawaii. The GlobalGAP protocol is unique in that it allows producers of all sizes to band together and pool resources to achieve USDA GAP certification. This, in turn, facilitates the access to food markets for producers to supply fresh, local produce to retail and institutional markets (USDA Agricultural Marketing Service, no date b).

**Working in a group allows producers to:**

- Share resources and certification costs;
- Operate under a single, central quality management system;
- Demonstrate a recognized commitment to food safety;
- Develop a pool of diverse product offerings; and
- Undergo an audit together to obtain GroupGAP certification.
GroupGAP certification allows producers to:

- Get USDA GAP-certified;
- Meet buyers’ food safety certification requirements;
- Demonstrate your adherence to FSMA requirements; and
- Open doors to new, large, more stable, and more profitable markets (USDA Agricultural Marketing Service, no date c).

The FSMA and GAP programs have many similar requirements and some slight differences (Table 20). For example, GAP is voluntary with audits being conducted by private companies, state departments of agriculture, and the USDA. FSMA, on the other hand, is a law and audits are conducted by the FDA or HDOA (Olsen and Allen, 2017).

Hawaii’s state sponsored GAP certification programs are approximately $250 annually for small farms. Many food vendors and buyers require GAP certification for market entry, making GAP certification critical for market access. When market access is limited, or nonexistent small-scale operations may close as a result.

The College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii offers a free-of-charge food safety coaching program for local food production operations. The coaching program prepares fruit and vegetable producers for GAP certification through the State of Hawaii. CTAHR’s coaching program enables food producers to meet GAP certification or other food safety audit standards required by food retailers and restaurants (Office of Planning, 2012).

**FSMA & GAP Spotlights**

GAP requirements that are not included in FSMA:

- Documented farm food safety plan, FSMA recommends it but does not require it;
- Designated food safety officer;
- Traceability records;
- Pesticide residue testing; and
- Mock recall plan.

Components to add to a GAP plan that will facilitate FSMA compliance:

- Test five surface water samples per year;
- Have one or more employees responsible for farm food safety;
- Develop a farm-specific food safety training program for employees; and
- Evaluate and document composting techniques (Olsen and Allen, 2017).
<table>
<thead>
<tr>
<th>Criteria</th>
<th>FSMA</th>
<th>GAP</th>
</tr>
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<tbody>
<tr>
<td><strong>Scope</strong></td>
<td>United States of America</td>
<td>International</td>
</tr>
<tr>
<td><strong>Structure</strong></td>
<td>Law</td>
<td>Voluntary</td>
</tr>
<tr>
<td><strong>Audit</strong></td>
<td>Unannounced</td>
<td>Announced &amp; unannounced</td>
</tr>
<tr>
<td><strong>Auditor</strong></td>
<td>FDA or HDOA</td>
<td>Private companies, HDOA, or USDA</td>
</tr>
<tr>
<td><strong>Proponent</strong></td>
<td>FDA law &amp; consumers</td>
<td>Buyers &amp; consumers</td>
</tr>
<tr>
<td><strong>Exemptions</strong></td>
<td>All produce unless deemed as “rarely consumed raw”. Sprouts have additional requirements.</td>
<td>Determined by buyers</td>
</tr>
<tr>
<td><strong>Covered produce</strong></td>
<td>All produce unless deemed as “rarely consumed raw”. Sprouts have additional requirements.</td>
<td>All produce being sold to buyer</td>
</tr>
<tr>
<td><strong>Food safety plan with risk assessment, operating procedures, and record keeping</strong></td>
<td>Hazard analysis similar to food safety and preventative controls for hazard analysis</td>
<td>Documented plan required</td>
</tr>
<tr>
<td><strong>Designated food safety officer</strong></td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td><strong>Traceability</strong></td>
<td>N/A</td>
<td>Documented plan</td>
</tr>
<tr>
<td><strong>Pesticide residue testing</strong></td>
<td>N/A</td>
<td>Required in Global GAP</td>
</tr>
<tr>
<td><strong>Mock recall</strong></td>
<td>N/A</td>
<td>Required</td>
</tr>
<tr>
<td><strong>Worker health and hygiene plan</strong></td>
<td>FDA accepted training for at least one food safety manager. Employees who contact. Produce must be trained annually to follow good hygiene and sanitation practices with documented trainings.</td>
<td>Designated food safety manager. Employees who contact produce must be trained to follow good hygiene and sanitation practices with documented trainings.</td>
</tr>
<tr>
<td><strong>Irrigation water assessment</strong></td>
<td>Surface water: 20 samples over 2-4 years to develop baseline of generic E. coli, then five samples per season. Ground water: Four samples over 1 year to develop baseline of generic E. coli, then one per season.</td>
<td>Generally, three water tests/year for generic E. coli.</td>
</tr>
<tr>
<td><strong>Post-harvest water use—washing, cooling, icing</strong></td>
<td>Culinary or potable water. No detectable E. coli.</td>
<td>Culinary or potable water. No detectable E. coli.</td>
</tr>
<tr>
<td><strong>Sewage treatment</strong></td>
<td>N/A</td>
<td>Review of farm sewage system</td>
</tr>
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Table 10 Continued. A comparison between the major provisions of FSMA and GAP.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>FSMA</th>
<th>GAP</th>
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<tr>
<td>Animals &amp; wildlife</td>
<td>Visible examination of contamination during the growing season of all growing areas and all produce to be harvested regardless of method. Must have a documented corrective action plan and keep record of examination.</td>
<td>Visible examination of contamination during the growing season of all growing areas and all produce to be harvested regardless of method. Record of examination.</td>
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<tr>
<td>Treated manure or other compost of animal origin</td>
<td>Must use one of two FDA suggested treatments, or provide documentation showing that another method results in compost of the same microbiological quality.</td>
<td>Manure/biosolids must be properly treated or composted using a documented process. Test results should be maintained.</td>
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<tr>
<td>Raw manure</td>
<td>Rule is currently under development by the FDA</td>
<td>Two weeks before planting or incorporated 120+ days before harvest</td>
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<tr>
<td>Soils</td>
<td>N/A</td>
<td>Review of previous land use and flood-prone areas</td>
</tr>
<tr>
<td>Field sanitation and hygiene</td>
<td>Field inspections records</td>
<td>Pre-harvest field assessment and field sanitation units</td>
</tr>
<tr>
<td>Field harvesting and transportation</td>
<td>Equipment tools should be cleaned, and if possible sanitized. Record of cleaning and sanitation activities should be kept.</td>
<td>Harvesting containers and harvesting equipment are clean.</td>
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<tr>
<td>Harvested product covered during transport</td>
<td>N/A</td>
<td>Required</td>
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<tr>
<td>Frequency of audit</td>
<td>Depends on size, anywhere from yearly to every ten years</td>
<td>At least annually</td>
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Visualizing design is critical for defining complex systems.

This manual uses the concept of **modularity** to **empower producers** to build what they need in their operation and allowing further expansion as their operation grows.
Chapter 4: Agricultural Base Yard Modules

Modules represent the independent critical functions of a base yard operation. For example, the Post-Harvest Handling Area is a module that carries out all post-harvest activities like washing and sorting produce.
Design Considerations
The process of development of modules for the development of base yard building designs required consideration of a number of design factors. The following factors that were used throughout the decision-making process for these designs included:

1. FSMA and GAP compliance;
2. Utility/efficiency for diversified crop operations;
3. Cost and availability of building materials;
4. Employee safety and wellbeing;
5. Value-added opportunities (e.g., agritourism, “low-risk” food processing); and
6. Decentralized resource efficiency (e.g., electricity, water, and sewage).

The site plans, module plans, and general building components were designed to be in compliance with the FSMA Produce Rule and common GAPs (e.g., harmonized GAP, Global GAP, and GroupGAP) as described in Chapter 3. This was particularly important in the design of the post-harvest handling (PHH) area, climate-controlled food storage, and curing room modules—where food is being handled and stored. The site plans include modules to provide ample room for various types of storage and sanitary operations.

Utility and efficiency in an agricultural base yard may be achieved by understanding the post-harvest crop flows throughout the site and the space programming needs of a small-scale diversified crop operation. There are countless other criteria that might be considered as part of any given base yard design decision process. The concept of modularity is central to this manual and throughout the building plans. Modularity empowers producers to build what they need in their operation and allowing for further expansion as their operation grows.

Repurposed shipping containers are the main structural component throughout the designs featured in the building plans. Utilizing and retrofitting shipping containers provides efficiency gains in their accessibility to Hawaii producers, as well as, their relative portability and structural integrity. The floor plans and other design elements can be utilized in any structure that provides protection from rainfall and contamination vectors such as reptiles, rodents, insects, and birds.

Site design constraints include access to power, water, and sanitary sewers. Providing decentralized electricity is achievable by installing photovoltaic (PV) panels with a controls and batteries. Similarly, a decentralized and efficient potable water and sewage system can be developed in a base yard without access to those resources. These elements are described separately in this chapter.
Figure 14. The planning and organizational vocabulary used to describe the structures and functions of a modular agricultural base yard. Modules make up spatial assemblages and spatial assemblages make up a base yard. Base yards are organized in one of five organizational schemes which may be constructed to meet (i.e., or grow overtime to become) a basic, intermediate, or comprehensive operation intensity.
Critical Functions

This chapter identifies fifteen different modules that each serve an independent critical function (Figure 15). These fifteen modules are categorized under five different spatial assemblages (e.g., handling and cleaning, holding and processing, working, storing, and food tourism) and infrastructure inputs and outputs which will be detailed in Chapter 5. By designing for modularity, producers may optimize the arrangement of their base yard to better serve their needs.

* Critical functions not housed in 20’-0” Shipping Containers
** Critical functions which may optionally be housed in 20’-0” Shipping Containers

Figure 15. Modules that serve independent critical functions in an agricultural base yard.
20-foot Shipping Containers
20-foot shipping containers are the building blocks of the Modular Agricultural Base Yard. Although not all shipping containers are identical, they all have a number of standard components. Similarly, shipping containers have a set industry standard for their exterior and interior dimensions, however, it is always important to record the measurements for any individual container. Figure 16 details some of the common components across all shipping containers as well as the exterior and interior dimensions for a standard 20-foot shipping container.

Figure 16. 20-foot shipping container interior, exterior, and frame components; noting the interior and exterior standard dimensions.
Post-Harvest Handling Area
Purpose and Functions
The PHH area is where produce from the field is brought immediately after harvest. The main activities that will occur within the PHH area are washing, sorting, and packing produce. Some crops will first be cured before washing, but most will be washed immediately. During the sorting process, crops are graded accordingly and crops that are not fit for market are composted. After crops make their way out of the post-harvest handling area they may be held in climate-controlled storage before being picked up and taken off site.

Recommended Area
• Basic: A covered exterior area of approximately 650 square feet.
• Intermediate: One whole shipping container and an exterior covered area of approximately 390 square feet (Figure 17).
• Comprehensive: One whole shipping container and an exterior covered area of approximately 390 square feet.

Components
• Location: The PHH area should be located away from areas that pose an increased risk of potential contamination and adjacent to other food areas such as the climate-controlled storage and curing room modules.
• Pest control: The Intermediate and Comprehensive Post-Harvest Handling Areas have comingling interior and exterior spaces, while the Basic Post-Harvest Handling Area is exclusively outside. FSMA categorizes these spaces as partially-enclosed buildings, to which the producer is responsible to take preventative pest control measures to avoid the establishment of pests in his or her buildings (U.S. Food and Drug Administration, 2015). For example, bird spikes should be used to prevent birds from nesting in the covered PHH area.
• Materials:
  - To prevent condensation, expansion and contraction, and potential of metal flakes, interior metal walls should be draped in a plastic vapor barrier prior to framing.
  - The interior walls and ceiling should be hard, flat, and smooth — free of defects — impervious and nonabsorbent. Fiberglass Reinforced Plastic (FRP) is a good choice because of its continuous, durable, cleanable surface.
  - Drains should be regularly maintained and remain in good repair. Typically, circular drains with catch baskets are recommended, as they are less prone to contamination (Schmidt and Erickson, 2008).
  - Commercial grade vinyl flooring should be installed for ease of cleaning.
  - The recommended light intensity is 30-40 foot-candles (322-430 lux) (Schmidt and Erickson, 2008). LED lights should be used to reduce heat produced and save on energy cost.
Figure 17. Perspective view of Intermediate PHH area.

Figure 18. View towards the PHH area.
Figure 19. View towards the PHH area.

Figure 20. Perspective diagram of exterior PHH area.
Climate-Controlled Food Storage

Purpose and Functions
The on-site climate-controlled food storage module will serve the purpose of providing short term temperature and humidity-controlled storage for fresh produce.

Recommended Area
- Basic: Not included.
- Intermediate: Half or two-thirds of a shipping container (Figure 21).
- Comprehensive: One whole shipping container.

Components
- Location: The climate-controlled food storage area should be located away from areas that pose an increased risk of potential contamination and adjacent to other food areas such as the PHH area and curing room.
- Product placement:
  - Provide six-inches of clearance between the product and the interior walls to allow for good air circulation.
  - Provide enough space for aisles in the climate-controlled storage module; aisles should be about three feet wide.
  - Produce should not be stored on the floor, but rather, on shelves or pallets.
- Temperature control: Refrigeration is provided using a 15,000 BTU window air conditioning unit and a CoolBot device.
- Materials:
  - To prevent condensation, expansion and contraction, and potential of metal flakes, interior metal walls should be draped in a plastic vapor barrier prior to framing.
  - Floors, walls, and ceilings should be insulated using extruded polystyrene ridged foam insulation boards should be used instead of fiberglass batts, as this material tends to attract pests.
  - The interior walls and ceiling should be hard, flat, and smooth — free of defects — impervious and nonabsorbent. FRP is a good choice because of its continuous, durable, cleanable surface.
  - Commercial grade vinyl flooring should be installed for ease of cleaning.
  - The recommended light intensity is 30-40 foot-candles (322-430 lux) (Schmidt and Erickson, 2008). LED lights should be used to reduce heat produced and save on energy cost.
  - Strip plastic doors should be installed to reduce infiltration during loading and unloading.
Figure 21. A perspective view of Intermediate Climate-Controlled Food Storage.

Figure 22. Workers preparing shipment at storage area.
Curing Room

Purpose and Functions
The curing room module provides a space to cure sweet potatoes, taro, and ginger.

Recommended Area
- Basic: Not included.
- Intermediate: Half of a shipping container (Figure 23).
- Comprehensive: One whole shipping container.

Components
- Location: The curing room should be located away from areas that pose an increased risk of potential contamination and adjacent to other food areas such as the PHH area and climate-controlled storage unit.
- Temperature and humidity controls:
  - To obtain the most uniform distribution of heat introduce heat near the floor level of the curing room. The heaters should be placed on the floor adjacent the produce bins.
  - A high relative humidity can be obtained by applying moisture to the floor or by using an evaporative cooler in the room without introducing outside air (Thompson and Spinoglio, 1996).
- Materials:
  - To prevent condensation, expansion and contraction, and potential of metal flakes, interior metal walls should be draped in a plastic vapor barrier prior to framing.
  - Floors, walls, and ceilings should be insulated using extruded polystyrene ridged foam insulation boards should be used instead of fiberglass batts, as this material tends to attract pests.
  - The interior walls and ceiling should be hard, flat, and smooth — free of defects — impervious and nonabsorbent. FRP is a good choice because of its continuous, durable, cleanable surface.
  - Commercial grade vinyl flooring should be installed for ease of cleaning.
  - The recommended light intensity is 30-40 foot-candles (322-430 lux) (Schmidt and Erickson, 2008). LED lights should be used to reduce heat produced and save on energy cost.
  - Storage facilities require adequate ventilation in order to help extend shelf life and maintain produce quality. Ventilation in storage structures is improved if air inlets are located at the bottom of the store, while air outlets are at the top (Potato Marketing Board, no date).
Figure 23. A perspective view of Intermediate Curing Room.

Figure 24. Employees preparing shipment at storage area.
Bathroom Facilities

Regulatory Requirements
There is an absence of regulation governing compostable toilets and other wastewater/sewage technologies; however, there are some recommended GAPs for toilets facilities and their use on food-production farms. As for using solid human waste in food production, there are some notable regulations. For example, farms cannot legally process human waste on-site for further use on food crops either by composting it or by other treatment process. Moreover, at the state-level, regulations explain, “It shall be unlawful to use human body discharges, whether in liquid or solid form, as a fertilizer for plants raised for human consumption” (Hawaii Department of Health, 2016). FSMA and other regulations do not have clear requirements for toilet facilities and their use on food-production farms. The HDOA has no jurisdiction over the safety or integrity of the raw food, other than when a pesticide is misused (Hollyer, Brooks and Castro, 2014). Occupational Safety and Health Administration (OSHA) requires proper toilets and hand-washing facilities on an “agricultural establishment where eleven or more employees are engaged on any given day in hand labor operations in the field (for three hours or more).” While most farms in Hawaii employ fewer than eleven employees, FSMA regulations state that toilets should be provided and designed to prevent cross contamination of covered produce and food contact surfaces. A common sense reading of this regulation suggests that toilet facilities should be provided in the Base Yard, regardless of operation size.

Recommended Area
• Basic: A bathroom equipped with a toilet, sink, and typical bathroom amenities shares a container with the office module. Locker columns to store personal belongings and other items are located in the office, immediately outside the bathroom.
• Intermediate: A bathroom equipped with two toilets, sink, lockers and typical bathroom amenities take up about three-fourths of the container. On the other side of the container, separated by a partition wall, is a shower (Figure 25).
• Comprehensive: Two containers each equipped with two toilets, one sink, two showers, and lockers provide a women’s and men’s bathroom.

Components
• Location: Employee facilities cannot open directly into food areas. The bathroom facilities should be adjacent to the office and break areas.
• Amenities: Bathroom facilities should include a wall-mounted paper towel holder and wall-mounted soap dispenser next to the sink. Each bathroom stall should have a wall-mounted toilet paper dispenser and each shower should include a towel rack close by.
• Materials:
  -The interior walls and ceiling should be hard, flat, and smooth — free of defects —impervious and nonabsorbent. FRP is a good choice because of its continuous, durable, cleanable surface.
  -Commercial grade vinyl flooring should be installed for ease of cleaning.
  -The recommended light intensity is 30-50 foot-candles (322-538 lux) (Schmidt and Erickson, 2008).
Figure 25. A perspective view of Intermediate Bathroom Facilities.

Figure 26. View toward bathroom facilities.
Break Area

Purpose and Functions
Break areas provide a space for employees and other guests to relax, socialize, and eat. These areas may also be used in value-added food tourism endeavors if the farm operator decides to pursue those activities.

If a producer seeks to engage in food tourism as an additional source of revenue, special attention must be given to the design of the break areas. Zones that are suitable for large groups of visitors to socialize, engage, and learn about the farm should be considered. Areas of shade and seating to accommodate visitors is encouraged. A base yard with a basic intensity may require a comprehensive-scaled break area if enough visitors are anticipated. Value-added activities involving visitors are discussed in greater detail in assemblage five—food touring.

Recommended Area
- Basic: An exterior area of approximately 640 square feet.
- Intermediate: An exterior area of approximately 680 square feet and one modified container (Figure 27).
- Comprehensive: An exterior area of approximately 680 square feet and one modified container.

Components
- Location: Break areas should be adjacent to the bathroom facilities and office.
- Amenities:
  - Basic: Shaded seating and table(s) should be provided.
  - Intermediate: Shaded seating and table(s) should be provided outside. The interiors should have a kitchenette for employee access, equipped with a sink, microwave, refrigerator, cabinets or shelving, and counter tops.
  - Comprehensive: Shaded seating and table(s) should be provided outside. The interiors should have a kitchenette for employee access, equipped with a sink, microwave, refrigerator, cabinets or shelving, and counter tops.

Figure 27. A perspective view of Intermediate Break Area.
Figure 28. View toward exterior break area.

Figure 29. View from exterior break area.
Office

Purpose and Functions
The office module will provide a space for the farm operator to conduct administrative and business affairs.

Recommended Area
- Basic: Half to three-quarters of a shipping container. The remaining part of the shipping container should be devoted to a bathroom.
- Intermediate: Half of a shipping container (Figure 30).
- Comprehensive: One whole shipping container.

Components
- Location: The office module should be adjacent to the bathroom facilities and the break areas.
- Amenities: It is suggested that the office be equipped with a desk, chairs, filing cabinet, and a computer.

Figure 30. A perspective view of Intermediate Office.
Equipment Storage

Purpose and Functions
The equipment storage module includes two components—an inside storage area and an outside storage area. The equipment storage inside a container will store hand-held tools, containers, irrigation pumps and hoses, sprinkler parts, etc., while the outdoor equipment storage area is where tractors and driven tools and equipment will be kept (Figures 32, 33, and 34).

Recommended Area
• Basic: Half of a shipping container and 800 square feet of exterior space.
• Intermediate: One shipping container and 1,300 square feet of exterior space (Figure 31).
• Comprehensive: Two shipping containers and 1,600 square feet of exterior space.

Components
• Location: The equipment storage should be adjacent to the fertilizer storage, pesticide and agricultural chemical storage, and water storage. The exterior area for driven equipment and implements should be on one side of the base yard perimeter.
• Product placement:
  - Pallets should be used to keep large drums or bags off of the floor. Smaller containers may be stored on shelves that have a lip to keep the containers from falling off easily.
  - Steel shelving is preferable, since it is easy to clean.
• Security: The container should be locked to protect from theft (UMass Extension, no date).
• Amenities: A workbench and shelving units are suggested interiors for the equipment storage module.
• Materials:
  - Electrical lighting should allow visibility into all areas and cabinets/shelves within the storage area (UMass Extension, no date). LED lights are preferred to save on energy costs.

Figure 31. A perspective view of Intermediate Equipment Storage.
Figure 32. Inventory of equipment for basic intensity.

Figure 33. Inventory of equipment for intermediate intensity.

Figure 34. Inventory of equipment for comprehensive intensity.
Fertilizer Storage
Purpose and Functions
The fertilizer storage module will be the dedicated space for storing fertilizers and other soil amendments. It should be located near the equipment storage and the pesticide and agricultural chemical storage modules. Fertilizers should not be stored in the same space as some agricultural chemicals. If agricultural chemicals and fertilizers are stored in the same container, a solid partition should be constructed to separate the two functions.

Recommended Area
- Basic: Half of a shipping container.
- Intermediate: Half of a shipping container (Figure 35).
- Comprehensive: One shipping container.

Components
- All lighting, materials, and security requirements from the previous section – equipment storage – apply to fertilizer storage modules.
- Location: The fertilizer storage module should be adjacent to the equipment storage, pesticide and agricultural chemical storage, and water storage modules.
- Product placement:
  - Dry bags of fertilizer should be kept off of the floor by the use of shelving or pallets.
- Temperature control: The temperature should be kept between 5 and 30 degrees Celsius with no direct sources of heat, as some fertilizers may be sensitive to high temperatures (UMass Extension, no date).
- Materials:
  - An exhaust fan and louver vent should be utilized to help dissipate heat.

Figure 35. A perspective view of Intermediate Fertilizer Storage.
Fuel Storage & Filling Tank

Purpose and Functions
The fuel storage and filling area is where diesel fuel is stored and may be used to fill trucks, tractors, and other machines. Aboveground tanks are used to store large amounts of fuel on site. It is anticipated that about 500 gallons of diesel fuel storage will be required on a small farm at any given time. There are two types of fuel storage on the agricultural base yard — an aboveground diesel storage tank (i.e., where filling occurs) and other miscellaneous fuel and oil storage. Miscellaneous fuel and oil storage are discussed in the “Pesticide and Agricultural Chemicals” section.

Recommended Area
• Basic: Aboveground fuel tank (capacity of about 500 gallons).
• Intermediate: Aboveground fuel tank (capacity between 500 and 1,320 gallons) (Figure 36).
• Comprehensive: Aboveground fuel tank (capacity of less than 1,320 gallons).

Regulatory Requirements
Aboveground storage tanks used to store petroleum products are regulated under 40 CFR 112. The regulation does not use the term “aboveground storage tank”, but instead uses the term “bulk storage container”, which is defined as “any container used to store oil” that is 55 gallons or greater (FedCenter, 2107). Under the provision, aboveground storage tanks must meet the following design requirements:
• Diked areas must be installed to be sufficiently impervious to contain discharge oil.
• Containment curbs and pits may also be employed for this purpose.
• An alternative system consists of a drainage trench enclosure arranged so that any discharge will terminate and be safely confined in a facility catchment basin or holding pond.

Farm owners must also comply with the Spill Prevention, Control and Countermeasure (SPCC) regulation. The SPCC is a federal regulation created by the U.S. Environmental Protection Agency (EPA) in order to prevent oil from entering surface waters or nearby shorelines of the United States. The SPCC regulation applies to farms that store more than 1,320 gallons of oil or oil products in aboveground storage tanks. Oil or oil products include the following: waste oil, used oil, heating oil, diesel fuel, kerosene, gasoline, crop oil, adjuvant oil, lubricating oil, naphtha, mineral spirits, vegetable oil, animal fat, bio-diesel blends, and synthetic oil.

Components
• Location: Despite any location requirements, to mitigate the risk of water contamination, it is recommended that an aboveground fuel tank should be at least 50 feet from a drinking water well, storm drain, lake, surface water, or designated wetland. The fuel storage and filling tank should be adjacent to the equipment storage and located along the outer perimeter of the base yard to allow for easy refueling.
• Containment: A system that guards against leaks and spills should be developed. Equipment should be fueled on a concrete pad that has a secondary containment structure, such as a curb, to catch spills. Aboveground tanks should be made of high-quality steel and have a secondary containment system (i.e., a double-walled fuel tank) that holds 125% of the total volume stored (CTAHR Cooperative Extension Service, 2000).
Figure 36. A perspective view of Intermediate Fuel Storage and Filling Tanks.
Pesticide & Agricultural Chemical Storage

Purpose and Functions
The pesticide and agricultural chemical storage module will be the dedicated space for storing pesticides, agricultural chemicals, and small amounts of oil products. It should be located near the equipment storage.

Recommended Area
- Basic: Half of a shipping container.
- Intermediate: Half of a shipping container (Figure 37).
- Comprehensive: One whole shipping container.

Components
- Location: Pesticides and fertilizers should be stored in different containers or separated by a physical barrier. Potential contamination should be prevented by storing pesticides in a separate and isolated area, away from grain, fertilizer, and other materials (Sadaka, 1999). The pesticide and agricultural chemical storage should be adjacent to the equipment storage and fertilizer storage and located along the outer perimeter of a base yard.
- Containment: Transfer pumps, pipes, hoses, and valves should be placed above the highest anticipated flood or spill level. The pesticide mixing containment pad should be roofed to help eliminate storm water accumulation. Since the distance between the Post-Harvest Handling areas and the agricultural chemical storage is maximized, a small separate canopy structure will likely be required over the pesticide mixing containment pad. A shallow stainless-steel sump should be placed in the center of the mixing pad. The concrete mixing pad should be sloped towards the sump. A sump should also be placed in the center of the storage container—in case of a spill—and should hold 125 percent of the total volume being stored at any given time (CTAHR Cooperative Extension Service, 2000).
- Safety: An emergency shower and eye flush fountain should be accessible near the pesticide storage and mixing pad. These should only be used in case of emergencies and should trigger an alarm when used (Sadaka, 1999). A fire extinguisher should be accessible near the pesticide storage and mixing pad.
- Security: Pesticides and other chemicals should be stored in a locked container.
- Temperature control: Pesticides and other chemicals should be stored in a cool area. If a temperature control system is used, an optimal temperature would be between 68-and 77-degrees Fahrenheit, unless otherwise indicated.
- Amenities: Pesticides and other chemicals should be kept off of the ground using shelving units. Corrosion-proof metal shelving with a retainer lip at the front of each shelf should be utilized in the storage of pesticides and other chemicals (Sadaka, 1999). Flammable liquids should be kept in a steel safety cabinet specifically for storing flammable liquids.
- Materials: The container floor should be coated with polyurethane for ease of cleaning in case a spill occurs. Adequate lighting should be installed in the storage and handling areas. Pesticides and other chemicals should be stored in a well-ventilated area. Ventilate storage areas using explosion-proof electrical control wiring and an exhaust fan with motors with at least six air exchanges per hour (Sadaka, 1999). A louver vent should be placed at one end of the storage area and an exhaust fan at the other.

The International Safety Equipment Association recommends having a combination emergency shower and eyewash station, modesty curtains, and a drench hose. Combination stations are plumbed and are used when the emergency washing station is to be permanent and when the full body and eyes are at risk of being exposed to corrosive materials. Modesty curtains protect an individual from public display if an emergency occurs where they need to remove their clothing and utilize the emergency shower. Drench hoses are flexible hoses that are used to support, not replace, shower and eyewash units (Baugh, 2016).
All crops have different demands and produce different strains on the design of the base yard. Each crop has unique yields, and varying space requirements for post-harvest processing. The Fertilizer Storage and Pesticide & Agricultural Chemical Storage requirements will need to be tailored to the particular crops that are being farmed. If the base yard is off-grid, the post-harvest water and energy requirements of a particular crop will also need to be taken into account. Therefore, it should be noted that the producer will need to consider his or her crops carefully when determining the module requirements for their base yard.

For the purposes of this manual, recall the diversified crops discussed in Chapter 2. Figure 38 diagrams the varying fertilizer, pesticide, and post-harvest water requirements for these crops with the aim of encouraging producers to be thoughtful about their individual needs when implementing the construction of their base yard.

Figure 37. A perspective view of Intermediate Pesticide and Agricultural Chemical Storage.
Figure 38. Diagram illustrating the varying water, fertilizer, and pesticide requirements of diversified crop portfolio.
Figure 39. View of exterior implement storage area.

Figure 40. Overhead view of storage area.
**Photovoltaic System**

**Background**

Hawaii's per capita electricity consumption is among the lowest in the nation due to the state's generally mild climate, yet because of the state's unique geography and limited resources, Hawaii has the highest electricity prices in the country. In 2015, Hawaii imported 91 percent of the energy it consumed, mostly as petroleum, making it the most petroleum-dependent state in the United States (U.S. EIA, 2017). In 2016, Hawaii generated more solar electricity per capita from distributed facilities than any other state, and solar energy from both utility-scale and distributed facilities resources generated 38 percent of Hawaii's net generation from renewable resources. The use of distributed (consumer-sited, small-scale) renewable sources, like rooftop solar panels, has been rapidly increasing. In 2016, nearly one-third of single-family homes in Oahu had rooftop PV systems (U.S. EIA, 2017). The high cost of electricity – compounded with the readily available solar energy in Hawaii – presents a key challenge and opportunity for farmers to power their base yards with renewable solar energy.

**Purpose and Functions**

The PV system will provide an off-grid power source for the base yard by converting solar irradiation into electricity. Net-metering should be utilized if the opportunity presents itself, however, it should be assumed that grid connection is not available. The PV system must be optimized with the aim of meeting the electricity needs of an agricultural base yard, including lighting, ventilation, HVAC, and refrigeration processes. PV panels could be attached to the roofs of the shipping containers, the roof structure, or elsewhere on a producer's land. About seven panels can be attached to the roof of one container. The PV designs featured in the building plans were created to maximize the potential by utilizing the roof to mount the panels at the optimal angle of tilt for panels in Hawaii, 21 degrees equal to the latitude. The purchase and installation of PV panels and a PV system will have a high initial cost but will save money over time. Moreover, government incentives and various rebates may be available.

The battery requirements for each intensity were found by analyzing the standard peak energy demands required for each intensity (Tables 10.12, and 14). The quantity of batteries required for the Intermediate and Comprehensive intensities reflects the energy difference between the base energy needs of the Base Yard and the energy load for initial cooling of produce within the Climate Controlled Food Storage module. The battery recommended for the Basic intensity is included to accommodate for low sun conditions, such as cloud cover or rainfall, which prevent the solar array from operating at full capacity. It is important to have adequate battery storage in order to properly power each Base Yard, especially in unideal conditions with low levels of sunlight.

The solar panel requirements for each intensity were found utilizing the average weekly energy needs of the Base Yard (Tables 11, 13, and 15). A standard solar panel was assumed with an area of 1.93 square meters and a power production of approximately 7.84 kWh per day per each panel, though these values differ between different available solar panels. A panel efficiency of 20% and an inverter efficiency of 90% was assumed. It should be noted that solar panels experience degradation which reduces the power produced per panel, approximately 0.8% per year, so more panels should be added over time to account for this loss in power production. (Jordan and Kurtz, 2012).

A standard safety factor of 10% was applied in the process of calculating both the number of batteries required and the number of solar panels required, in order to account for imperfect operating conditions.
These calculations were done with average solar radiation values for the island of Oahu, Hawaii, in December. It should be noted that these values differ for different geographic locations and, therefore, the number of solar panels required for each location may be different. It is recommended to find average solar radiation values for your location to determine if your requirements will change or consult an expert for more information.

The usable average weekly power was calculated using the following equation:

$$\text{usable average weekly power (kWh/((m^2)*week))} = \text{average weekly December solar radiation (kWh/((m^2)*week))} * \text{solar panel efficiency} * \text{inverter efficiency} * \frac{1}{1 + \text{safety factor}}$$

The energy storage required to meet peak demand was calculated using the following equation:

$$\text{energy storage required to meet peak demand (kWh)} = \text{peak energy demand (kWh)} - \text{average daily energy produced by solar panels (kWh)}$$

where

$$\text{peak energy demand (kWh)} = \text{peak Climate Controlled Food Storage module energy requirement (kWh)} + \text{daily base energy requirement of Base Yard (kWh)}$$

The peak Climate Controlled Food Storage module energy requirement is a sum of the initial cooling energy, which is assumed to occur over 24 hours once a week, the daily heat conduction through the walls of the container, and the daily heat of respiration of produce within the container, assuming a temperature of 32 °F.

Daily base energy requirement of Base Yard is the energy necessary to power all appliances not associated with the Climate Controlled Food Storage module.
Table 11. Basic intensity base yard battery requirements.

<table>
<thead>
<tr>
<th>Energy use</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscellaneous appliances throughout Base Yard</td>
<td>20.4</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Energy production needed from PV array</td>
<td>20.4</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Assumed battery capacity</td>
<td>5</td>
<td>kWh/battery</td>
</tr>
<tr>
<td>Safety Factor</td>
<td>10</td>
<td>%</td>
</tr>
</tbody>
</table>

Number of batteries recommended\(^1\) 1 battery

\(^1\)To accommodate for cloudy conditions

Table 12. Basic intensity base yard PV panel requirements.

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed solar panel efficiency</td>
<td>20</td>
<td>%</td>
</tr>
<tr>
<td>Assumed inverter efficiency</td>
<td>90</td>
<td>%</td>
</tr>
<tr>
<td>Safety Factor</td>
<td>10</td>
<td>%</td>
</tr>
<tr>
<td>Average weekly December solar radiation(^2)</td>
<td>24.7</td>
<td>kWh/((m(^2))*week)</td>
</tr>
<tr>
<td>Usable average weekly power in December(^2)</td>
<td>4.04</td>
<td>kWh/((m(^2))*week)</td>
</tr>
<tr>
<td>Power Required for Base Yard(^2)</td>
<td>20.4</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Assumed area per PV panel</td>
<td>1.93</td>
<td>m(^2)/panel</td>
</tr>
<tr>
<td>Assumed power produced per panel</td>
<td>7.80</td>
<td>kWh/week/panel</td>
</tr>
</tbody>
</table>

Number of panels required to power Base Yard\(^3\) 4 panels


\(^2\)Value from Table 11

\(^3\)With a standard degradation of 0.8% per year, an additional panel will be required after three years
Table 13. Intermediate intensity base yard battery requirements.

<table>
<thead>
<tr>
<th>Energy use</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Controlled Food Storage module</td>
<td>169.3</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Miscellaneous appliances throughout Base Yard</td>
<td>20.4</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Peak energy demands</td>
<td>98.2</td>
<td>kWh</td>
</tr>
<tr>
<td>Energy production needed from PV array</td>
<td>189.8</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Energy storage required to meet peak demand</td>
<td>82.4</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Assumed battery capacity</td>
<td>5</td>
<td>kWh/battery</td>
</tr>
<tr>
<td>Safety Factor</td>
<td>10</td>
<td>%</td>
</tr>
</tbody>
</table>

**Number of batteries required for Base Yard operation** 16 batteries

Table 14. Intermediate intensity base yard PV panel requirements.

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed PV panel efficiency</td>
<td>20</td>
<td>%</td>
</tr>
<tr>
<td>Assumed inverter efficiency</td>
<td>90</td>
<td>%</td>
</tr>
<tr>
<td>Safety Factor</td>
<td>10</td>
<td>%</td>
</tr>
<tr>
<td>Average weekly December solar radiation¹</td>
<td>24.7</td>
<td>kWh/((m²)*week)</td>
</tr>
<tr>
<td>Usable average weekly power in December²</td>
<td>4.04</td>
<td>kWh/((m²)*week)</td>
</tr>
<tr>
<td>Power Required for Base Yard²</td>
<td>189.8</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Assumed area per PV panel</td>
<td>1.93</td>
<td>m²/panel</td>
</tr>
<tr>
<td>Assumed power produced per panel</td>
<td>7.80</td>
<td>kWh/week/panel</td>
</tr>
</tbody>
</table>

**Number of panels required to power Base Yard³** 27 panels


²Value from Table 11

³With a standard degradation of 0.8% per year, an additional panel will be required after three years.
### Table 15. Comprehensive intensity base yard battery requirements.

<table>
<thead>
<tr>
<th>Energy use</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Controlled Storage Module</td>
<td>244.4</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Miscellaneous appliances throughout Base Yard</td>
<td>33.9</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Peak energy demands</td>
<td>145</td>
<td>kWh</td>
</tr>
<tr>
<td>Energy production needed from solar array</td>
<td>278.3</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Energy storage required to meet peak demand</td>
<td>82.4</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Assumed battery capacity</td>
<td>5</td>
<td>kWh/battery</td>
</tr>
<tr>
<td>Safety Factor</td>
<td>10 %</td>
<td></td>
</tr>
<tr>
<td><strong>Number of batteries required for Base Yard operation</strong></td>
<td><strong>24</strong></td>
<td><strong>batteries</strong></td>
</tr>
</tbody>
</table>

### Table 16. Comprehensive intensity base yard PV panel requirements.

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed PV panel efficiency</td>
<td>20 %</td>
<td></td>
</tr>
<tr>
<td>Assumed inverter efficiency</td>
<td>90 %</td>
<td></td>
</tr>
<tr>
<td>Safety Factor</td>
<td>10 %</td>
<td></td>
</tr>
<tr>
<td>Average weekly December solar radiation²</td>
<td>24.7</td>
<td>kWh/((m²)*week)</td>
</tr>
<tr>
<td>Usable average weekly power in December²</td>
<td>4.04</td>
<td>kWh/((m²)*week)</td>
</tr>
<tr>
<td>Power Required for Base Yard²</td>
<td>278.3</td>
<td>kWh/week</td>
</tr>
<tr>
<td>Assumed area per PV panel</td>
<td>1.93</td>
<td>m²/panel</td>
</tr>
<tr>
<td>Assumed power produced per panel</td>
<td>7.80</td>
<td>kWh/week/panel</td>
</tr>
<tr>
<td><strong>Number of panels required to power Base Yard³</strong></td>
<td><strong>37</strong></td>
<td><strong>Panels</strong></td>
</tr>
</tbody>
</table>


²Value from Table 11

³With a standard degradation of 0.8% per year, an additional panel will be required after three years.
Recommended Area
- Basic: Less than one container roof, or about 22% of one roof covered.
- Intermediate: One and one-third of a container roof covered (Figure 43).
- Comprehensive: Two and one-third of a container roof covered.

Roof structures, covered in the next section, may provide additional area for the growth of PV arrays if the base yard’s energy requirements change.

Components
- Location: The mounting frame should be installed to angle the solar panels 20 degrees South, in order to optimize for solar exposure. The PV panels may be mounted onto the roof structure, container roofs, or stand alone.
- Materials: The main components of a PV system are the solar panels, an inverter to convert direct current (DC) to alternating current (AC), batteries, and a charge regulator (batteries and a charge regulator are added to provide a better security of supply, particularly to off-grid systems).

Figure 42. Illustration of solar difference in approximate PV panel requirements between basic, intermediate, and comprehensive base yard intensities.

Figure 43. A perspective view of PV panels attached to roof.
Roof Structure

Purpose and Functions
Having a roof structure above the container roofing provides more insulation, which helps to maintain interior temperatures and reduce cooling or heating needs. A roof structure with an overhang keeps the rain from running down onto windows and removes the need for a drip bar above the windows (Discover Containers, no date). A roof structure also provides shade and protection from the sun for the base yard operation and can also act as a protective barrier from potential pests.

Recommended Area
- Basic: A roof structure and roof extension should be provided for the break area, any food storage modules, and the PHH area. A roof structure and extension should be an option for the fertilizer storage module.
- Intermediate: A roof structure and appropriate extensions should be provided for the break area, any food storage modules, and the PHH area. A roof structure and extension should be an option for the exterior equipment storage area and the fertilizer storage module.
- Comprehensive: A roof structure and extension should be provided for the break area, any food storage modules, and the PHH area. A roof structure and extension should be an option for the exterior equipment storage area and the fertilizer storage module.

Components
- An overhang of at least three feet is recommended (Walker and Farrell, 2003).
- In areas where a roof extension is needed, beams attached to the containers or posts to extend the roof over applicable area will be required (Discover Containers, no date).

Figure 44. Perspective views of Basic, Intermediate, and Comprehensive Roof Structures.
Figure 45. Overview of an intermediate base yard highlighting a roof structure.

Figure 46. View towards exterior covered area.
Water Storage

Potable Water

To meet FSMA requirements for potable and agricultural water, facilities in off-grid rural areas will require water storage on site. Appropriate plumbing to prevent back-flow, as well as adequate pressure for cleaning activities is required. Shipping containers outfitted with food grade PVC may be used in lieu of traditional water tanks.

Background

To derive estimates for the volume of water to be used and stored, points of water usage in the base yard were identified, which included employee water usage (i.e., showering and hand-washing) and PHH water usage. The water usage per employee is shown in Table 17, while the total employee water usage for each of the three base yard intensities is shown in Table 18. Water usage in the PHH area was estimated by using indicators for water demand for common pieces of equipment found in the PHH area (Table 19).

Table 17. Total water usage from showering and handwashing in one day per employee in gallons (City of Philadelphia, no date; USGS, no date; Pacific Institute, 2018).

<table>
<thead>
<tr>
<th>Water Usage (gal/use)</th>
<th>Number of Uses/Day/Employee</th>
<th>Total Usage per Employee (gal/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Showering</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Handwashing</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Total water usage per employee: 23 gal/day

Note. Shower water usage and number of uses per day data obtained from City of Philadelphia (n.d.); handwashing water usage data obtained from USGS (n.d.); and handwashing number of uses per day per employee obtained from Pacific Institute (2018).

Table 18. Total employee water usage in gallons per day on a three, six, and twelve-acre operations (NASS, 2019).

<table>
<thead>
<tr>
<th>Base Yard Acreage</th>
<th>Number of Employees¹</th>
<th>Total Employee Water Use (gal/day)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>46</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>46</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>69</td>
</tr>
</tbody>
</table>

¹ The number of employees is defined as the number of hired labors and the farm operator/manager. The hired labor for Hawaii was obtained from the 2012 Census of Agriculture by NASS (2019).

² Assuming the total water usage per employee is 23 gallons per day, see Table 17.
Table 18. Total employee water usage in gallons per day on a three, six, and twelve-acre operations (NASS, 2019).

<table>
<thead>
<tr>
<th>PHH Equipment</th>
<th>Water Demands</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dump tank (initial washing)</td>
<td>0.13</td>
<td>gal/lbs.</td>
</tr>
<tr>
<td>Drum/barrel washing</td>
<td>1.11</td>
<td>gal/lbs.</td>
</tr>
<tr>
<td>Low pressure washing</td>
<td>0.13</td>
<td>gal/lbs.</td>
</tr>
<tr>
<td>Sink washing</td>
<td>0.13</td>
<td>gal/lbs.</td>
</tr>
<tr>
<td>Icing</td>
<td>0.04</td>
<td>gal/lbs.</td>
</tr>
<tr>
<td>Storage humidifier</td>
<td>12.00</td>
<td>gal/day</td>
</tr>
<tr>
<td>Dump tank (disinfection washing)</td>
<td>150.00</td>
<td>gal/day</td>
</tr>
</tbody>
</table>

Note. Dump tank (initial washing), low pressure washing, and sink washing water demands were obtained from M. Lehto et al. (2014); drum/barrel washing water demands include wash rate of produce and flow rate of hose and were obtained from Grindstone Farm (2019) and Washington State University (n.d.), respectively; icing water demands were obtained from T. Suslow (n.d.); storage humidifier water demands were obtained from Global Industrial (n.d.); and dump tank (disinfection washing) water demands were obtained from J. Bachmann & R. Earles (2000).

From there, average crop yields were used to find water usage rates for three, six, and twelve-acre operations for the three base yard intensities basic, intermediate, and comprehensive, respectively. From there, a range of rates for water usage per day for each crop were produced. These values were then combined with the daily water usage rate for employees, for a total water usage per day for each base yard intensity (Figure 47).

A range for plausible volumes of water delivered at one time were found, as well as the time that the amounts of water would last. In order to anticipate the frequency of water delivery required, the volume of water used in seven days for each farm size and crop was also calculated to plan for the storage requirements for each scenario (Figure 48).

The farm operator will need to decide what storage volume is best for their needs. It is recommended that the tank be over-sized to contain an extra day’s worth of water than the expected delivery volume. This will allow work to continue while the tank is re-filled on water delivery days.

**Purpose and Functions**

The water contained in the water storage module is meant to be used for employee hygiene needs (e.g., hand-washing and showering) and PHH water requirements. The water storage is not meant to be used as a source of water for irrigation needs.

**Recommended Area**

Many variables influence the volume of water storage required in an agricultural base yard. These include types and amounts of crops harvested, number of employees, and the frequency of water deliveries among others. As a rule of thumb, the minimum storage requirements producers should plan for are:

- Basic: One 7,500-gallon bladder (Figure 49)
- Intermediate: Two 7,500-gallon bladders
- Comprehensive: Three 7,500-gallon bladders
Figure 47. Water usage per crop on three, six, and twelve-acre operations shown in gallons per day. Water usage includes employee and PHH water needs.

Figure 48. Calculated volume of time-based water needs for three, six, and twelve-acre operations, accounting for employee and PHH water requirements.
Figure 49. Exploded view of water storage module (Left).
Figure 50. View towards water storage (Bottom).
Waste Water
About 38 percent of Hawaiian residents are served by an individual wastewater system (Hawaii Department of Health, n.d.). Therefore, the modular agricultural base yard should be designed to accommodate those living in rural areas with a lack of centralized infrastructure, including a centralized wastewater system. Waste water from all handling, processing, chemical mixing, and sanitary facilities must be securely stored on-site prior to being removed by a licensed wastewater treatment operator.

Rinsate Water
Rinsate water is a collection of water in the catchment system of the chemical mixing pad. Wash water is water used to clean crops for consumption and is a mix of dirt, pesticide, fertilizer, and other environmental factors that crops may have been exposed to. Rinsate is a collection of spilled or collected chemicals from the mixing pad that can be applied to crops as a pesticide treatment in accordance with the chemical’s label and intended use. Rinsate can include rainwater in the catchment system and could be a mixture of chemicals. Rinsate cannot be stored due to the mixing of chemicals and the unknown environmental factors. Before using rinsate, direct injection, dedicated application equipment, mixing and loading application equipment in field, and washing application equipment should all be eliminated. Farm staff should actively work to minimize rinsate by working carefully and maintaining Standard Operating Procedure (SOP). Some rinsate cannot be reused based on the EPA laws and regulations on contamination. Even when SOP is followed to a tee, there will still be rinsate to apply. Always before applying rinsate, read labels and follow EPA guidelines on acceptable levels of contamination. The concrete mixing pad should be designed to allow for the best collection of rinsate. The pad should be kept clean and liquid tight so that maximum recovery of rinsate is possible (Kammel et al., 1991).

Wash Water
Wash water is often confused with rinsate water. As discussed in the rinsate water section, these two words are often used in text interchangeably but mean vastly different things. Wash water is a compilation of dirt and debris from harvest, including pesticide and fertilizer residues that the crop may have been exposed to in the field. An important distinction is that wash water cannot be reused. Wash water must meet EPA standards for drinking water (United States Department of Agriculture, 2011). Wash water if used in a dunk tank can be used to wash multiple batches of the same crop given that the turbidity and sanitizer remain at appropriate levels. If various crops need to be washed, cross contamination of wash water should be avoided, and water should be changed before washing different crops. Wash water will need to be properly disposed of between work days, but additional factors might require more frequent disposal of wash water. Wash water cannot be reused and will immediately become waste. For most agricultural base yards, water will need to be stored until it can be picked up and treated by a licensed Waste Water Treatment Plant (Bihn et al., 2014).

Greywater
Greywater is reusable water from sources such as sinks, showers, and laundry if applicable. Greywater cannot be used in food production because of microbial contaminants that are not allowed to come into contact with food according to the FSMA and GAP (United States Department of Agriculture, 2011). Grey water is commonly used in composting toilets (United States Environmental Protection Agency, 1999). In the base yard, grey water can only be re-purposed as a means for composting toilets or it will become waste. Wastewater will be taken and treated off site by a certified treatment plant. Grey water cannot be stored for longer than 24 hours without foul smells being produced. Grey water always has the potential for contamination so it should not come into contact with food or food contact surfaces. Grey water systems are relatively simple to install and require little maintenance (Grey Water Action, no date).
Electrochemical Water Treatment System

Purpose and Functions
The electrochemical water treatment system is designed to treat 100,000 gallons of water per day, providing a decentralized water treatment system on a base yard.

Recommended Area
- Similar to other modules, the electrochemical water treatment system has exterior and interior components. For the interior components (e.g., sand filters and electrochemical treatment cell) about half of a shipping container is required. Immediately outside the container is where the holding tanks or bladders are located (Figure 51).

Components
- Materials: Electrochemical treatment cell, three 50-gallon sand filters, and five 2,500 gallon holding tanks.

Figure 51. A perspective view of the electrochemical water treatment system.
Compost Yard & Rubbish Collection

Purpose and Functions

An area where waste is collected and stored until pickup as well as where composting activities shall occur. Sustainable farm practices reduce food waste when possible. Nonetheless, food waste will be produced during the food supply chain from a variety of sources, such as, produce not being fit for market due to poor size, shape, or quality. The goal is to dispose of waste in the most efficient and productive process by utilizing disposal techniques that yield beneficial products, including anaerobic digestion and composting for fertilizer. Compost and rubbish storage must be stored on site, maintaining FSMA required distances from produce handling areas. These outputs can be stored outside the secure perimeter.

Components

- Location: The risk for potential contamination should be reduced by placing the rubbish collection and turning compost unit or pile away from food handling activities.
- The rubbish collection and composting area should be located a minimum of 50 feet from wells, streams, or other water features (NRCS and NHCP, 2016).

Figure 52. A perspective view of Intermediate Compost Yard.
Secure Perimeter

Purpose and Functions
The base yard should be surrounded by a 10-foot high perimeter fence to protect produce handling and processing areas from cross-contamination and vandalism. The secure perimeter also prevents access to hazardous agricultural chemicals and helps assure the strict separation of animals from produce handling areas. All base yards should consider a 10-foot high perimeter fence. Doors should be locked for security.

Recommended Area
- All base yards should consider a 10-foot high perimeter fence (Figure 53). Doors should be locked for security.

Figure 53. Overhead view of a base yard highlighting the secure perimeter.
Chapter 5: Agricultural Base Yard Spatial Assemblages

A view towards the Storing Assemblage of the base yard which includes the equipment storage, fertilizer storage, and agricultural chemical storage modules.
Introduction
Each producer can tailor his or her Agricultural Base Yard to crop type and scale, off-grid capabilities, and opportunities for change over time. A collaboration between architects and ecological engineers with food science expertise, the planning vocabulary is transferable to the many other places lacking infrastructure for small-scale producers. There are five different spatial assemblages — handling and cleaning, holding and processing, working, storing, and food tourism — as well as infrastructure inputs.

An overview of the spatial assemblages and infrastructure inputs and outputs can be seen in Figure 54. Figures 55, 56, and 57 provide additional elevation views from the street, working and food tourism assemblages, and handling and cleaning and holding and processing assemblages, respectively. Grouping modules under the varying assemblages aid in the conceptual understanding of how these independent modules interact with each other to achieve the routine functions necessary for a thriving farm operation. A module of space for each critical function requires roughly half of a 20-foot shipping container. Base yards of greater intensity may require multiple modules for each critical function.
Figure 54. An overview of assemblages and infrastructure inputs and outputs making up a modular agricultural base yard.

**Assemblage 1 - Handling and Cleaning**
An assemblage devoted to the proper storage and maintenance of tools and equipment that will come in contact with produce per FSMA standards.

**Infrastructure Outputs: Waste Water**
Waste water from all handling, processing, chemical mixing, and sanitary facilities must be securely stored on site prior to being removed by a licensed wastewater treatment operator.

**Assemblage 2 - Holding and Processing**
An assemblage devoted to medium-term holding of product and all processing activities allowable under the FSMA produce rule or FDA ‘very small business’ exceptions to the FSMA HARPC rule.

**Infrastructure Inputs: Power**
Hawaii has the highest electricity rates per KwH in the United States. In 2015, Hawaii imported 91 percent of the energy it consumed, mostly as petroleum, making it the most petroleum-dependent state in the United States. The Base Yard manual urges farmers to consider solar power. PV panel canopies can serve double duty, serving as a FSMA required cover for Post-Harvest handling in exterior areas. Small operations should reserve around 72 square feet of surface area for PV arrays. Very large operations should reserve around 730 square feet for PV arrays.

**Assemblage 3 - Working**
Employee health, hygiene, and training are big components of FSMA. The working assemblage provides employees with appropriate sanitary and break facilities to prevent produce cross-contamination.

**Infrastructure Inputs: Water**
To meet FSMA requirements for potable and agricultural water, facilities in off-grid rural areas will require water storage on site. Appropriate plumbing to prevent back-flow, as well as adequate pressure for cleaning activities is required. Ten foot containers outfitted with food grade PVC may be used in lieu of traditional water tanks. Stacked containers - provided the farmer has access to adequate equipment to do this safely - can generate gravity assisted water pressure for farm activities.

**Secure Perimeter**
The Base Yard should be surrounded by a 10-foot high perimeter fence to protect produce handling and processing areas from cross-contamination and vandalism. The secure perimeter also prevents access to hazardous agricultural chemicals, and helps assure the strict separation of animals from produce handling areas.

**Assemblage 4 - Storing**
An assemblage devoted to the proper storage and maintenance of tools and equipment that will come in contact with produce per FSMA standards.

**Infrastructure Outputs: Waste and Compost**
Compost and rubbish storage must be stored on site, maintaining FSMA required distances from produce handling areas. These outputs can be stored outside the secure perimeter. Compost from sanitary facilities should be appropriately stored to prevent cross-contamination. A licensed wastewater treatment operator should be hired to periodically remove the compost from site.

**Assemblage 5 - Food Tourism**
Value-added systems present small scale farmers with opportunities to enhance and diversify their sources of profit. Capitalizing on one of Hawaii’s primary economic drivers — Tourism — the food tourism assemblage proposes a network of social spaces and facilities for visitors.
Base Yard Elevations

**Figure 55. Street elevation.**

**Figure 56. Working and food tourism assemblages elevation.**

**Figure 57. Handling and cleaning and holding and processing assemblages elevation.**
Assemblage 1 - Handling and Cleaning

Assemblage one, handling and cleaning, is a covered assemblage devoted to the post-harvest handling (PHH) area (Figure 58). Product follows the general flow of receiving, sorting, washing, and preparation for shipping or further on-site holding and processing in this assemblage.

Infrastructure Inputs
PV array to power container module, lighting, and any equipment on handling pad

Infrastructure Inputs
Potable water for first wash, second wash, and hand washing stations

Infrastructure Outputs
Wastewater with organic compounds from produce washing and hand washing stations to be stored on site

Figure 58. PHH area and flows of product, people, and water in assemblage one—handling and cleaning.
FSMA Spotlights and Construction Guidelines
A. FSMA demands that post-harvest handling facilities include measures and employee training to identify covered produce that is reasonably likely to be contaminated. ¹
B. Drains of adequate number and size, appropriately located and designed in such a way that they are cleanable. ²
C. Recommended lighting intensity of 55-65 footcandles in Post-Harvest handling areas. ²
D. Provide adequate exterior lighting as it is related to overall facility security and aids in reduction of microbial contamination.²
E. Floors should be smooth, impervious, non-absorbent, corrosion resistant and cleanable. Floors should also be non-slip. Acceptable materials include sealed concrete, epoxy sealed concrete, quarry tile, and glazed tile. ²
F. Hand-washing facilities must be accessible during post-harvest, packing, or holding activities and furnished with soap, running water, and drying devices.
G. Used produce bins cleaned before they return to field. Equipment and tools (including produce bins) must be designed, installed, and stored to allow for adequate cleaning and maintenance. ¹
H. Potable water to produce washing areas. Under FSMA plumbing must be of adequate size and pressure to avoid being a source of contamination to produce, food contact surfaces, or agricultural water sources. ⁴
I. Waste water piping is especially important for produce with high size-to-waste ratios (such as roots, which have to be cleaned from soil and biological material). Per FSMA requirements, sewage and liquid disposable waste must be properly conveyed. ⁴
J. The FDA defines agricultural water as water used in activities where water is intended or likely to contact covered produce or food contact surfaces. This includes water that is used in growing, harvesting, packing, and holding activities. All agricultural water must be safe and of adequate sanitary quality for its intended use.¹
Assemblage 2 - Holding and Processing

Assemblage two, holding and processing, is devoted to medium-term holding of product and all processing activities allowable under the FSMA produce rule or FDA “very small business” exceptions to the FSMA HARPC rule (Facility Rule) (Figure 59).

Infrastructure Inputs
PV array to power container modules. Three-phase power may be required for climate-controlled storage

Infrastructure Outputs
Waste water from fermenting and pasteurizing processes

Infrastructure Inputs
Potable water for fermenting and pasteurizing, and for ice making at climate-controlled storage

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1 Ice Maker
2 Ice Cooled Table With Undershelf
3 Cooling Unit
4 Steel Shelving
5 Additional Insulation
6 Peeler
7 Oven
8 Slicing Table
9 1 bbl Fermentation Tank
10 Humidifier
11 2000 BTU Heater
12 Drying Racks
13 Exhaust Fan

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3 Fermenting
Small module for fermenting vinegar from fruit.

2 Snack Chip Making
Small module for making snack chips from taro and sweet potato.

1 Climate-Controlled Storage
Produce stored in climate-controlled storage for medium-term holding and processing prior to being shipped.

4 Curing Room
Humidity controlled and heated module activities such as root curing, mango drying and dehydrating, and manipulating fruits for ripening.

5 Shipping
Produce that is held and processed in the Holding and Processing assemblage is shipped once holding times have elapsed.

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Figure 59. PHH area and flows of product, people, and water in assemblage two—holding and processing.
FSMA Spotlights and Construction Guidelines

A. There are only a few Post-Harvest activities allowable under the FSMA Produce Rule, which is the focus of this manual. These include: drying/dehydrating, labeling, packaging, and treating (with ethylene) to manipulate ripening. All other Post-Harvest activities such as baking, boiling, bottling, canning, cooking, cooling, cutting, distilling, evaporating, eviscerating, extracting juice, formulating, freezing, grinding, homogenizing, irradiating, milling, mixing, pasteurizing, peeling, rendering, trimming, and waxing will make the facility subject to the more stringent FSMA Hazard Analysis and Risk-Based Preventive Controls Rule (aka Facility Rule). The purpose of this Base Yard manual is educating and instructing farmers on how to comply with the Produce Rule, and the Facility Rule is outside of the scope of this manual. However, a farmer who desires to engage in value-added processing (such as snack chip making and fermenting vinegar, shown above) can do so, provided that they are a farm-mixed type facility that qualifies as a “very small business” (one that grosses less than $1 million in annual sales of human food) and which engages in processing activities that the FDA has identified as “low-risk” when done on certain foods. Only processing facilities that fall within this category, and which are therefore exempt from the of the Facility Rule, fall within the scope of this manual.

B. Three-phase electrical power will be necessary to operate the refrigeration equipment motors. Hence, Base Yards with climate-controlled storage will require exponentially larger photovoltaic arrays.

C. To guarantee good air flow, the refrigerated storage ceiling should be at least 12-18 inches higher than the produce.

D. Total wall insulation level should be in the range of R20 - R40.

E. The walls of the refrigerated storage module should be painted a light color and shaded from direct sun.

F. Storage facilities require adequate ventilation in order to help extend shelf life and maintain produce quality.
Assemblage 3 - Working

Assemblage three, working, is largely concerned with employee health, hygiene, and training (Figure 60). The working assemblage provides employees with appropriate sanitary and break facilities to prevent produce cross-contamination.

Figure 60. PHH area and flows of product, people, and water in assemblage three—working.
FSMA Spotlights and Construction Guidelines

A. FSMA requires the following toilet facility elements:
   - Employees and visitors must be provided with **adequate readily accessible toilet facilities**.
   - Toilet facilities must be **designed, located and maintained to prevent cross-contamination of covered produce**, food contact surfaces, water sources, and water distribution systems. They must be directly accessible for servicing and cleaning and kept supplied with toilet paper. They must provide for the sanitary disposal of waste and toilet paper.
   - During harvesting, packing, or holding activities, a **hand-washing station must be provided in close proximity to toilet facilities**.4

B. Per FSMA, personnel must be provided with adequate, readily accessible **hand-washing facilities that take place in a fully enclosed building during packing, harvest, or holding activities**. Hand-washing facilities must be furnished with soap, potable running water, adequate drying devices (such as single service towels) and appropriate disposal of waste (wastewater and used single-service towels).4

C. Under FSMA, plumbing must be of an adequate size and design.
   - Plumbing system must **distribute water under pressure as needed**, in sufficient quantities, for sanitary operations, hand-washing facilities, and toilet facilities.
   - Plumbing must properly **convey sewage and liquid disposable waste**.
   - Plumbing must **avoid being a source of contamination** to produce, food contact surfaces, or agricultural water sources.
   - Plumbing system **must not allow back-flow from, or cross connection** between piping systems that discharge waste water or sewage and piping systems that carry water used for sanitary operations or for use in hand-washing facilities.4

D. While there is a lack of guidance from FSMA on the use of compostable toilets, a **farm can use a compostable toilet in Hawaii** as long as it abides by the Hawaii Administrative Rules Chapter 11-62. These rules state that the compost toilet needs to be National Sanitary Foundation (NSF) International certified and designed by a licensed engineer in Hawaii.10

E. Human waste, even after proper composting, is an illegal biological soil amendment in Hawaii, making it illegal to sell or distribute.10 Therefore, after the compost has been properly degraded, it can either be picked up and taken off site by a licensed wastewater treatment operator, buried on site away from crops in a way that provides a reasonably low likelihood of contamination (i.e., should be placed downhill), or stored in a septic tank or seepage pit.

F. Per FSMA, smoking and eating areas for employees should be in designated areas away from food handling areas.11

G. Per FSMA’s record keeping requirements, records should be created at the time an activity is performed or observed; be accurate and legible; and be dated and signed or initialed by the person who performed the documented activity.1
Assemblage 4 - Storing
Assemblage four, storage, is devoted to the proper storage and maintenance of tools and equipment that will come in contact with produce per FSMA standards (Figure 61).
A. FSMA has a section dedicated to biological soil amendments which sets standards for handling, transporting, storing, treating, and applying biological soil amendments of animal origin. The rule prohibits the use of human waste as a biological soil amendment.  

Fertilizers should be stored separate from other chemicals in an enclosed building capable of protecting product from weather and sunlight. There should be no floor drain, and the floor should be impermeable, level, dry, and even. These construction requirements make the modular, prefabricated shipping container an ideal vessel to store Fertilizers. Mechanical ventilation should be used to help dissipate heat, since some fertilizers may be sensitive to high temperatures.

B. Farm operators that use agricultural pesticides and have employees exposed to agricultural pesticides must comply with the EPA’s Worker Protection Standard (WPS). WPS mitigates the risk of pesticide poisoning and injury by requiring decontamination supplies, including an emergency shower and eye flushing fountain. Decontamination supplies must be accessible within ¼ mile of all workers and handlers. Refer to the following guidelines for the provision of decontamination supplies:

- Provide 1 gallon of water per worker and three gallons of water per handler at the beginning of each work period. Water must be safe and cool enough for washing, eye-flushing, and drinking.
- Provide plenty of soap and single-use towels.
- Provide a clean overall (or other change of clothes) for handlers.
- Provide handlers with decontamination supplies where personal protective equipment is removed and at mixing/loading sites.
- When applying a product that requires protective eye-wear, provide one pint of water per handler.

C. Pesticides should be mixed where the risk of pesticides entering any water bodies (e.g., groundwater, surface water bodies, storm drains, streams, etc.) is low if a spill occurs. This risk is mitigated if pesticides are mixed and loaded on a well-constructed concrete pad. The mixing pad should slope to a sump pump that conveys the waste water to a safe storage area, where it can be professionally removed from site.

D. The risk for potential contamination should be reduced by placing the rubbish collection and turning compost unit or pile away from food handling activities. The rubbish collection and composting area should be located a minimum of 50 feet from wells, streams, or other water features.

E. Equipment and Implement Storage depends on specific requirements, crops, and acreage farmed. This manual offers a general equipment list for different scales of farming operations, however, each end-user should verify their own equipment demands:

- **Basic Farms (< 3 acres):** Subcompact Tractor, Tiller, Cultivator 3 Point Carryall, Seeder, Box Blade.
- **Intermediate Farms (3-10 acres):** Compact Tractor, Tiller, Cultivator, Harvest Trailer (10 Ft), Seeder, Mulcher/Irrigation Layer, 3 Point Sprayer, 3 Point Fertilizer Spreader, 3 Point Mower, Box Blade.
- **Comprehensive Farms (10+ acres):** Utility Tractor, Tiller, Cultivator, Harvest Trailer (15 Ft), Seeder, Mulcher/Irrigation Layer, Pull Behind Sprayer, 3 Point Fertilizer Spreader, Liquid Fertilizer Spreader, Hydraulic Pruning Tower, 3 Point Mower, Box Blade.
Assemblage 5 - Food Tourism

Assemblage five, food tourism, is related to value-added systems that present small-scale farmers with opportunities to enhance and diversity their sources of profit (Figure 62). Capitalizing on one of Hawaii’s primary economic drivers—tourism—the fifth assemblage proposes a network of social spaces and facilities for visitors.

1. **Tourist Arrival**
   Food Tourists may arrive on site in individual vehicles or large tour buses. Base Yards who anticipate high volumes of visitors should provide areas for buses to discharge passengers.

2. **Value-Added Art**
   Art acts as a driver for visitor interest. Base Yards that anticipate Food Tourism as part of their value-added business model can take advantage of this with exhibits and mural paintings.

3. **Visitor Entry**
   Provide welcoming exterior areas for visitors to enter the Base Yard.

4. **Appropriately Sized Facilities**
   With the addition of visitors and tourists to the Base Yard, farmers who engage in this value-added model should size bathroom facilities and other amenities to accommodate larger temporal populations on the site.

5. **Expanded Social Spaces**
   Enlarged break areas would improve the day-to-day experience of Base Yard employees, and simultaneously serve as gathering and socializing nodes for larger groups of visitors.

6. **Social Yards**
   Amenable exterior areas for educating tour groups prior to touring the fields, socializing, merchandise sales (shirts, hats, etc), and art and community gatherings are essential for a vibrant food tourism experience.

7. **Outside Interactions**
   Plan for symbiotic relationships with the outside community, such as opportunities for food trucks and vendors to park outside the Base Yard and cater to tourist needs.

Figure 62. PHH area and flows of product, people, and water in assemblage five—food tourism.
FSMA Spotlights and Construction Guidelines

A. **Tourism is the largest economic driver in Hawaii.** In 2012, approximately 8,029,000 tourists in Hawaii spent $14.4 billion dollars. Agriculture was once Hawaii’s dominant economic driver, but has declined massively since the exodus of large scale farming. **Around 96% of farms in Hawaii are small farms, whose operational costs are supplemented by off-farm incomes to keep the operations sustainable.** Food Tourism can help with these problems. Farmers and ranchers with the vision, skills, and commitment can create an enterprise that is able to sustain their agricultural business and lifestyle. 17

B. In terms of value added to the US economy, the arts and cultural sectors contribute a greater share than do mining, agriculture, the energy/utilities sector or industries such as construction and transportation. Meanwhile, rural arts organizations draw nonlocal audiences at higher rates than do urban arts (e.g. 31% or their audience travels “beyond a reasonable distance” to attend events, while the corresponding share that urban organizations report is 19%) 18 Considering these factors, **integrating art and cultural production into the Base Yard design can be a catalyst to draw tourists visiting the state, as well as patrons from local communities.** The value-added business model generates opportunities to expand the small-scale producer’s sources of revenue.

C. Per FSMA, the same bathroom and hand-washing facility requirements that need to be met for employees apply to visitors.4 Therefore, **planning for Food Tourism will most likely involve additional bathroom facilities.** Due to the modular / additive nature of the containers, a farm operator may choose to add additional bathroom modules as their Food Tourism operations grow.

D. Farmers that hope to take advantage of the growing Food Tourism industry to further their business plan should familiarize themselves with Chapter 25 of the Hawaii County Revised Statues. In this chapter, **agricultural tourism is permitted as an accessory use to agricultural activities and agricultural processing** facilities in the agricultural and rural districts, subject to plan approval and in conformance with section 25-4-15(d). Agricultural tourism activities that do not conform with this section may be subject to special use permit requirements. Some of the regulations that agricultural tourism facility operators must comply with include:

- minimums in verifiable gross sales excluding agricultural tourism activities
- hours of operations
- parking, loading/unloading requirements
- maximum areas that the facility can dedicate to tourism related activities
- sales of promotional products
- restrictions on overnight accommodations

In addition to all these, annual events that promote an agricultural industry or area, organized on a not-for-profit basis, are permitted without a need for a special use permit.17 The Base Yard end-user hoping to engage in Food Tourism as a source of value-added revenue, should take advantage of the provisions and heed the guidelines of this section.
Chapter 6: Agricultural Base Yard Intensities & Organizational Schemes

A view towards the covered PHH area from the entrance of a Comprehensive Parallel Bar Modular Agricultural Base Yard.
Operational Intensities

Introduction
This chapter introduces the three varying intensities (e.g., basic, intermediate, and comprehensive) and five organizational schemes (e.g., Parallel Bar, Four Square, Accordion, Constellation, and Fort) for the purposes of accommodating a range of base yard operations. The spatial assemblages from Chapter 4 were used to facilitate the creation of each organizational scheme. The varying intensities will be referenced later in Chapter 6 when area recommendations are given for the different modules.

The modular nature of the base yard makes it adaptable to varying intensities in farming operations. For the purposes of this manual, operational intensities have been divided into three broad categories: basic, intermediate, and comprehensive.

Basic
The basic configuration is intended for very small farms that have a minimal diversity of crops with short holding times and low storage needs (Figure 63). This is meant to include farms with less than three acres of production area and one crop class, with minimal or no washing, sorting, and storage requirements. Critical functions covered within this configuration include basic storage requirements (i.e. equipment storage, fertilizer storage, pesticide and agricultural chemical storage, and fuel storage and filling tank), bathroom facilities, a break area, roofing, an office, a PV system, a post-harvest handling area, and a rubbish collection and composting area. Exterior space for storage of equipment and implements will need to be at least 800 square feet, with a width of at least 45.5 feet and a depth of at least 17.5 feet. A total shipping container footprint space of at least 675 square feet will be required.

Intermediate
The intermediate configuration (e.g., the standard base yard) is intended for small farms with a moderate diversity in crops that may require more intensive processing and washing along with medium to long term storage of produce (Figure 64). This is meant to include farms from three to ten acres of production area that can accommodate multiple crop classes. All critical functions are included in the intermediate configuration, but no functions require more than a single shipping container of space. Exterior space for storage of equipment and implements will need to be at least 1,265 square feet, with a width of at least 72.3 feet and a depth of at least 17.5 feet. A total shipping container footprint space of at least 1,250 square feet will be required.

Comprehensive
The comprehensive configuration is intended for farms with a large diversity of crops that may require more intensive processing and washing along with medium to long term storage of produce (Figure 65). This is meant to include farms greater than ten acres of production area that can accommodate many different crop classes. All critical functions are covered in the comprehensive configuration and multiple twenty-foot shipping containers may be needed for certain critical functions, like equipment storage. Exterior space for storage of equipment and implements will need to be at least 1,590 square feet with a width of at least 83 feet and a depth of at least 19 feet. A total shipping container footprint space of at least 1,575 square feet will be required.
Figure 63. Perspective view of modular agricultural base yard in the basic intensity.

Figure 64. Perspective view of modular agricultural base yard in the intermediate intensity.

Figure 65. Perspective view of modular agricultural base yard in the comprehensive intensity.
Organizational Schemes

Five organizational schemes are proposed in this manual: Parallel Bar, Four Square, Accordion, Constellation, and Fort. Each scheme accommodates a set of assemblages to support site-specific production strategies.

Parallel Bar

Shipping container modules are arranged end-to-end into two parallel bars, with all FSMA mandated adjacencies taken into consideration (for example, keeping pesticide storage containers on the opposite end of Post-Harvest Handling areas to prevent cross-contamination). Handling and visitor areas are located near the bathrooms and lockers, providing easy access to hand-washing facilities. Farm and shipping vehicles can access the facility by traveling through the gravel road between the two bars, allowing produce to be dropped off and picked up at various points. The scheme is optimal for facilities anticipating large numbers of visitors or employees. If the farmer needs to expand his or her operation, additional shipping containers can easily be added at the end of each bar. The linear growth pattern of this scheme also makes it ideal for farmers who forecast large growth in their operation. Figure 66 shows the parallel bar organizational scheme, noting infrastructure inputs and critical/key adjacencies. Figure 67 shows this scheme’s hypothetical growth pattern.
**Four Square**

Shipping container modules are arranged end-to-end into two perpendicular bars, forming an ‘L’ shape. The resulting configuration creates a large exterior yard at the edge which can be used for Post-Harvest Handling, equipment storage, and even additional containers or other modules. The scheme grows by mirroring each bar and the associated yard until you have ‘four squares. This scheme is preferable for larger farms which require extensive handling or equipment storage yards. Figure 68 shows the four-square organizational scheme, noting infrastructure inputs and critical/key adjacencies. Figure 69 shows this scheme’s hypothetical growth pattern.

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** Infrastructure Inputs **

Potable water is stored and distributed from a food grade PVC bladder installed in a ten-foot shipping container. Water to meet FSMA standards for agricultural water. A ten-foot container below contains water heater, and any pumps needed to convey water to all required areas on the site.

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** Power is generated by a PV array, oriented south and angled 20 degrees from horizontal. A battery bank, inverter, and charge converter are stored in the adjacent container, from which power flows to the rest of the site.**

---

** Key Adjacency **

Hazardous storage and waste located away from Handling and Cleaning Assemblage.

---

** Critical Adjacency **

Exterior Post-Harvest handling zones located beneath covered canopy in order to prevent cross-contamination and protect workers from the elements.

---

** Key Adjacency **

The entry is flanked by Working Assemblage modules, facilitating locker use and hand washing upon entering the site.

---

** Key Adjacency **

Handling and Processing Assemblages surround the canopy to create a working node at the receiving area.

---

** Figure 68. Four Square organizational scheme, noting infrastructure inputs and critical key adjacencies. **

** Figure 69. Four Square scheme growth pattern. **

---

For larger schemes that engage in intensive food tourism activities, a second water source may be desired.

---

The entry is flanked by Working Assemblage modules, facilitating locker use and hand washing upon entering the site.

---

Handling and Processing Assemblages surround the canopy to create a working node at the receiving area.

---

Exterior Post-Harvest handling zones located beneath covered canopy in order to prevent cross-contamination and protect workers from the elements.
**Accordion**

Shipping containers are arranged at 45-degree angles in relation to each other, creating a small wedge-shaped yard in between the containers. Every two containers will form a pair with a corresponding wedge-shaped ‘functional yard’ where critical functions can spill out. This scheme favors separation of uses, keeping tourists and visitors separate from storage and handling areas. The small ‘functional yards’ also provide a degree of separation between the various exterior uses of the base yard. This scheme is ideal for small operations that engage in the handling one or two crops in small, separate yards. Similar to the parallel bar, a central circulation spine for farm vehicles is located in the center. Figure 70 shows the accordion organizational scheme, noting infrastructure inputs and critical/key adjacencies. Figure 71 shows this scheme’s hypothetical growth pattern.
**Constellation**

The constellation scheme organizes shipping container modules around a pre-determined boundary. The boundary – a 10-foot high perimeter fence – encompasses enough space for exterior storage requirements, PHH areas, and any social spaces for employees or visitors. Shipping containers are located outside of the 10-foot perimeter – in contrast to previous schemes – and openings in the 10-foot fence correspond with doors in the containers, allowing access to the interior of the modules from inside the 10-foot fence. The constellation scheme allows for container density and keeps farm and shipping vehicle circulation outside of the fenced area. It is ideal for smaller operations that wish to minimize the footprint of the base yard. Ideally, growers with one or two crops and small lots should favor this scheme. Figure 72 shows the constellation organizational scheme, noting infrastructure inputs and critical/key adjacencies. Figure 73 shows this scheme’s hypothetical growth pattern.

---

**Figure 72. Constellation organizational scheme, noting infrastructure inputs and critical/key adjacencies.**

**Figure 73. Constellation scheme growth pattern.**
Fort
The fort scheme uses the shipping container modules to create a large central courtyard. As the base yard grows, the courtyard becomes more defined. In the fort scheme, all container doors face the courtyard, with the exterior of the ‘fort’ acting as a barrier for animals and potential intruders. Any areas of the courtyard perimeter not defined by the containers will require a 10-foot perimeter fence. The courtyard becomes space for PHH areas, social spaces, and exterior implement storage. This scheme is ideal for mid-sized operations which only anticipate modest growth. It will also work for farmers who require ample exterior storage area, and who want to protect their base yards from traffic noise along busier roads. The ‘fort’ will provide additional visual privacy as well. Figure 74 shows the fort organizational scheme, noting infrastructure inputs and critical/key adjacencies. Figure 75 shows this scheme’s hypothetical growth pattern.

Figure 74. Fort organizational scheme, noting infrastructure inputs and critical/key adjacencies.

Figure 75. Fort scheme growth pattern.

Infrastructure Inputs
Power is generated by a PV array, oriented south and angled 20 degrees from horizontal. A battery bank, inverter, and charge converter are stored in the adjacent container, from which power flows to the rest of the site.

Potable water is stored and distributed from a food grade PVC bladder installed in a ten-foot shipping container. Water to meet FSMA standards for agricultural water. A ten-foot container below contains water heater, and any pumps needed to convey water to all required areas on the site.

Critical Adjacency
Handling and Processing Assemblages located beneath covered canopy in order to prevent cross-contamination and protect workers from the elements.

Key Adjacency
Small Food Tourism Assemblage located adjacent to the Handling and Processing Assemblages creating educational and social opportunities.
Appendix
Figure A-1. Diversified crop acreage by Hawaiian island in 2015 (Melrose and Perroy, 2016).

Figure A-2. Types of diversified crops and their acreage harvested in Hawaii (USDA, 2017a).
Figure A-3. Types of vegetables and their acreage harvest in Hawaii (USDA, 2018).

Figure A-4. Types of fruits (expect citrus) and their acreage harvest in Hawaii (USDA, 2017b).
Figure A-5. Types of citrus fruits and their acreage harvested in Hawaii. (USDA, 2017b).
Figure A-6. Post-harvest handling diagram of blackberry from harvest to transport (Kader, 2002).

Figure A-7. Post-harvest handling diagram of strawberry from harvest to transport (Kader, 2002).
Figure A-8. Post-harvest handling diagram of orange from harvest to transport (Kader, 2002).

Figure A-9. Post-harvest handling diagram of banana from harvest to transport (Kader, 2002).
Figure A-10. Post-harvest handling flow for fig (Kader, 2012).

Figure A-11. Post-harvest handling diagram of mango from harvest to transport (Kader, 2002).
Figure A-12. Post-harvest handling diagram of cucumber from harvest to transport (Kader, 2002).

Figure A-13. Post-harvest handling diagram of tomato from harvest to transport (Kader, 2002).
Figure A-14. Post-harvest handling diagram of basil from harvest to transport (Kader, 2002).

Figure A-15. Post-harvest handling diagram of head cabbage from harvest to transport (Campbellh, 2013).
Figure A-16. Post-harvest handling diagram of leaf lettuce from harvest to transport (Smith, 2011; SEMCO, 2014).
Figure A-17. Post-harvest handling diagram of ginger from harvest to transport (Kader, 2002).

Figure A-18. Post-harvest handling diagram of sweet potato from harvest to transport (Kader, 2002).
Figure A-19. Post-harvest handling diagram of taro from harvest to transport (Kader, 2002).
Figure A-20. Post-harvest handling diagram of asparagus from harvest to transport (Thompson, 1942; Aegerter et al., 2011).
Figure A-21. Post-harvest handling diagram of broccoli from harvest to transport (Kime et al., 2005; Le Strange et al., 2010).
Figure A-22. Employment by quarter in Honolulu, HI in 2017 for the fruit and tree nut and vegetable and melon farming industries. Two kinds of employment are identified—employment at the beginning of the quarter and employment stable throughout the quarter. Seasonal productivity is reflective in the quarterly employment indicators (U.S. Census Bureau, 2017). Abbreviations: Emp—Employees at the beginning of the quarter; Emp$—Employees stable throughout the quarter.
Figure A-23. Annual stable employment in Honolulu, HI in the years 2015, 2016, and 2017 for the fruit and tree nut and vegetable and melon farming industries (U.S. Census Bureau, 2017). 1Employment stable throughout the quarter.
Figure A-24. Post-harvest handling area design for food safety (Hadad, no date).

<table>
<thead>
<tr>
<th>Root Vegetables</th>
<th>Insecticides</th>
<th>Herbicides</th>
<th>Fungicides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beets</td>
<td>CHLORPYRIFOS, ESFENVALERATE, METHOMYL</td>
<td>CLETHODIM, GLYPHOSATE, TRIFLURALIN</td>
<td>SULFUR</td>
</tr>
<tr>
<td>Ginger</td>
<td>ACETAMIPRID, FLUPYRADIFURONE, IMIDACLOPRID, PYRETHRINS, THIAMETHOXAM</td>
<td>N/A</td>
<td>CAPTAN, FENAMIDONE, FLUDIOXONIL, MANDIPROPAMIDE TECHN</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>BT KURSTAKI SA-11, BURKHOLDERIA A396 CELLS &amp; MEDIA, CHLORPYRIFOS, GLYPHOSATE POTASSIUM SALT</td>
<td>GLYPHOSATE POT. SALT</td>
<td>AZOXYSTROBIN</td>
</tr>
<tr>
<td>Taro</td>
<td>PYRETHRINS</td>
<td>PARAQUAT, OXYFLUORFEN, CLETHODIM</td>
<td>FLUDIOXONIL, MONO-POTASSIUM SALT</td>
</tr>
</tbody>
</table>

<p>| Stem Vegetables |
|-----------------|-------------|-------------|-------------|
| Asparagus       | ACETAMIPRID, BT KURSTAKI SA-12, CHLORANTRANILIPROLE, CHLORPYRIFOS, MALATHION, METHOMYL, NEEM OIL, SPINETORAM | CLETHODIM, DIURON, FLUMIOXAZIN, GLYPHOSATE, GLYPHOSATE POT. SALT, HALOSULFURON, PARAQUAT, PENDIMETHALIN, SETHOXYDIM, TRIFLURALIN | AZOXYSTROBIN, MANCOZEB, MEFENOXAM |
| Broccoli        | ABAMECTIN, ACETAMIPRID, AZADIRACHTIN, BIFENTHRIN, BT KURSTAKI SA-13, BUPROFEZIN, BURKHOLDERIA A396 CELLS &amp; MEDIA, CARBARYL, CHLORANTRANILIPROLE, CHLORPYRIFOS, CHROMOBAC SUBTSUGAE PRAA4-1 CELLS AND SPENT MEDIA, CYANTRANILIPROLE, CYFLUTHRIN, ESFENVALERATE, FLUPYRADIFURONE, IMIDACLOPRID, MALATHION, METHOMYL, METHOXYFENOZIDE, NEEM OIL, POTASSIUM SALTS, PYRETHRINS, SPINETORAM, SPINOSAD, THIAMETHOXAM, ZETA-CYPERMETHRIN | CLETHODIM, GLYPHOSATE ISO. SALT, GLYPHOSATE POT. SALT, OXYFLUORFEN, PARAQUAT, SETHOXYDIM, TRIFLURALIN | AZOXYSTROBIN, BACILLUS SUBTILIS, BOSCALID, COPPER HYDROXIDE, COPPER OXIDE, CYPRODINIL, DIMETHOMORPH, FENAMIDONE, FLUDIOXONIL, FLUOPYRAM, FLUXAPYROXAD, FOSETYL-AL, IPRODIONE, MANCOZEB, MANDIPROPAMIDE TECHN, MEFENOXAM, MONO-POTASSIUM SALT, PENTHIOPYRAD, PYRACLOSTROBIN, STREPTOMYCES LYDICUS, SULFUR, TRIFLOXYSTROBING |</p>
<table>
<thead>
<tr>
<th>Insecticides</th>
<th>Herbicides</th>
<th>Fungicides</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leafy Greens</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basil</td>
<td>METHOXYFENOZIDE, PYRETHRINS</td>
<td>CLETHODIM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FENAMIDONE, FLUOPICOLIDE, MANDIPROPAMIDE TECHN</td>
</tr>
<tr>
<td>Cabbage</td>
<td>ACETAMIPRID, AZADIRACHTIN, BIFENTHRIN, BT KURSTAKI SA-15, Buprofezin, CHLORANTRANILIPROLE, CHLORPYRIFOS, CYANTRANILIPROLE, CYFLUTHRIN, ESFENVALERATE, FLUPYRADIFURONE, IMIDACLOPRID, MALATHION, METHOMYL, METHOXYFENOZIDE, NEEM OIL, POTASSIUM SALTS, PYRETHRINS, SPINETORAM, SPINOSAD, THIAMETHOXAM, ZETA-CYPERMETHRIN</td>
<td>CLETHODIM, Glyphosate POT. SALT, OXYFLUORFEN, PARAQUAT, SULFENTRAZONE, TRIFLURALIN</td>
</tr>
<tr>
<td>Lettuce leaf</td>
<td>ABAMECTIN, ACETAMIPRID, AZADIRACHTIN, BIFENTHRIN, BT KURSTAKI SA-15, Buprofezin, CHLORANTRANILIPROLE, CHROMOBAC SUBTSUGAE PRAA4-1 CELLS AND SPENT MEDIA, CYANTRANILIPROLE, CYFLUTHRIN, ESFENVALERATE, FLUPYRADIFURONE, IMIDACLOPRID, MALATHION, METHOMYL, METHOXYFENOZIDE, NEEM OIL, PYRETHRINS, SPINETORAM, SPINOSAD, THIAMETHOXAM, ZETA-CYPERMETHRIN</td>
<td>CARFENTRAZONE-ETHYL, CLETHODIM, Glyphosate POT. SALT, OXYFLUORFEN, SETHOXYDIM</td>
</tr>
</tbody>
</table>
### Table A-1 Continued. Diversified crops and their applicable pesticides.

<table>
<thead>
<tr>
<th>Citrus</th>
<th>Insecticides</th>
<th>Herbicides</th>
<th>Fungicides</th>
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<tr>
<td>Orange</td>
<td>ABAMECTIN, ACETAMIPRID, AZADIRACHTIN, BIFENTHRIN, Buprofezin, Carbaryl, Chlorantraniliprole, Chlorpyrifos, Chromobac Subtsugae PRAA4-1 Cells and Spent Media, Cyantraniliprole, Cyfluthrin, Flupyradifurone, Imidacloprid, Kaolin, Malathion, Methomyl, Neem Oil, Pyrethrins, Spinetoram, Spinosad, Thiamethoxam, Zeta-cypermethrin</td>
<td>CARFENTRAZONE-ETHYL, DIuron, Flumioxazin, Glufosinate-Ammonium, Glyphosate ISO. SALT, Glyphosate Pot. SALT, Oxyfluorfen, Paraquat, Pendimethalin, Sethoxydim, Trifluralin</td>
<td>AZOXYSTROBIN, Calcium Polysulfide, Copper Hydroxide, Copper Oxide, Fluxapyroxad, Fosetyl-Al, Mefenoxam, Monopotassium SALT, Pyraclostrobin</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fruit-Vegetables</th>
<th>Insecticides</th>
<th>Herbicides</th>
<th>Fungicides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>ABAMECTIN, AZADIRACHTIN, IMIDACLOPRID, POTASSIUM SALTS, PYRETHRINS, SPINETORAM, SPINOSAD</td>
<td>CARFENTRAZONE-ETHYL, CLETHODIM, GLYPHOSATE ISO. SALT, GLYPHOSATE POT. SALT, HALOSULFURON, OXYFLUORFEN</td>
<td>BOSCALID, COPPER HYDROXIDE, CYPRODINIL, FLUDIOXONIL, MEFENOXAM, MYCLOBUTANIL, PENTHIOPYRAD, PYRACLOSTROBIN, SULFUR</td>
</tr>
<tr>
<td>Tomato</td>
<td>ABAMECTIN, ACETAMIPRID, AZADIRACHTIN, BIFENTHRIN, BT KURSTAKI SA-18, Buprofezin, Carbaryl, Chlorantraniliprole, Chromobac Subtsugae PRAA4-1 Cells and Spent Media, Cyantraniliprole, Cyfluthrin, Esfenvalerate, Imidacloprid, Kaolin, Malathion, Methomyl, Methoxyfenozide, Neem Oil, Potassium SALTS, Pyrethrins, Spinetoram, Spinetoram, Spinosad, Thiamethoxam, Zeta-cypermethrin</td>
<td>CARFENTRAZONE-ETHYL, CLETHODIM, FLUMOXAZIN, Glyphosate ISO. SALT, Glyphosate Pot. SALT, HALOSULFURON, OXYFLUORFEN, PARAQUAT, PENDIMETHALIN, SULFENTRAZONE, TRIFLURALIN</td>
<td>AZOXYSTROBIN, BACILLUS SUBTILIS, BOSCALID, COPPER HYDROXIDE, CYPRODINIL, DIMETHOMORPH, FLUXAPYROXAD, MANCOZEB, MANDIPROPAMIDE TECHN, MEFENOXAM, MONO-POTASSIUM SALT, MYCLOBUTANIL, PENTHIOPYRAD, PYRACLOSTROBIN, STREPTOMYCES LYDICUS, SULFUR, TRIFLOXYSTROBIN</td>
</tr>
<tr>
<td>Berries</td>
<td>Insecticides</td>
<td>Herbicides</td>
<td>Fungicides</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td>Blackberry</td>
<td>BIFENTHRIN, BT KURSTAKI SA-16, CARBARYL, CHLORANTRANILIPROLE, ESFENVALERATE,</td>
<td>CARFENTRAZONE-ETHYL, CLETHODIM, DIURON, GLUFOSINATE-AMMONIUM, GLYPHOSATE</td>
<td>AZOXYSTROBIN, BACILLUS SUBTILIS, BOSCALID, CALCIUM POLYSULFIDE,</td>
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<tr>
<td></td>
<td>IMIDACLOPRID, MALATHION, METHOXYPENOZIDE, PYRETHRINS, SPINETORAM, SPINOSAD,</td>
<td>ISO. SALT, OXYFLUORFEN, PARAQUAT, PENDIMETHALIN, SETHOXYDIM, SULFENTRAZONE</td>
<td>CAPTAN, COPPER HYDROXIDE, CYPRODINIL, FLUDIOXONIL,</td>
</tr>
<tr>
<td></td>
<td>ZETACYPERMETHRIN</td>
<td></td>
<td>FLUOPYRAM, FLUXAPYROXAD, IPRODIONE, MEFENOXAM, MONOPOTASSIUM</td>
</tr>
<tr>
<td>Strawberry</td>
<td>ABAMECTIN, ACETAMIPRID, AZADIRACHTIN, BIFENTHRIN, BT KURSTAKI SA-17, BURKHOLDERIA</td>
<td>FLUMIOXAZIN, PENDIMETHALIN, SULFENTRAZONE</td>
<td>SALT, MYCLOBUTANIL, PYRACLOSTROBIN, SULFUR</td>
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<tr>
<td></td>
<td>A396 CELLS &amp; MEDIA, CARBARYL, CHLORANTRANILIPROLE, CHLORPYRIFOS, CHROMOBAC</td>
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<tr>
<td></td>
<td>SUBTSUGAE PRAA4-1 CELLS AND SPENT MEDIA, FLUPYRADIFURONE, IMIDACLOPRID,</td>
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<td>MALATHION, METHOXYPENOZIDE, NEEM OIL, POTASSIUM SALTS, PYRETHRINS, SPINETORAM,</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>SPINOSAD, THIAMETHOXAM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Banana</td>
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<td>N/A</td>
<td>SULFUR, THIRAM</td>
</tr>
<tr>
<td>Fig</td>
<td>AZADIRACHTIN, CHLORANTRANILIPROLE, MALATHION, PYRETHRINS</td>
<td>CARFENTRAZONE-ETHYL, FLUMIOXAZIN, GLUFOSINATE-AMMONIUM, GLYPHOSATE ISO.</td>
<td>CALCIUM POLYSULFIDE</td>
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<td></td>
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<td>SALT, GLYPHOSATE POT. SALT, OXYFLUORFEN, PARAQUAT, PENDIMETHALIN</td>
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<tr>
<td>Mango</td>
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<td>SULFUR</td>
</tr>
</tbody>
</table>

Table A-2. Pesticides used on diversified crops and their required storage temperatures (EPA, 2016; NCBI, 2019).

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Storage Temperature (°F)</th>
<th>Other Remarks</th>
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<tr>
<td><strong>Insecticides</strong></td>
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</tr>
<tr>
<td>BIFENTHRIN</td>
<td>40-100</td>
<td>Very toxic/hazardous</td>
</tr>
<tr>
<td>BT KURSTAKI SA-11</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>Buprofezin</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>BURKHOLDERIA A396 CELLS &amp; MEDIA</td>
<td>40-100</td>
<td>Avoid freezing</td>
</tr>
<tr>
<td>CARBARYL</td>
<td>40-100</td>
<td>Do not stack over two pallets high</td>
</tr>
<tr>
<td>CHLORANTRANILIPROLE</td>
<td>40-100</td>
<td>Avoid freezing</td>
</tr>
<tr>
<td>CHLORPYRIFOS</td>
<td>36-46</td>
<td>Provision to contain effluent from fire extinguishing</td>
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<tr>
<td>CHROMOBAC SUBTSUGAE PRAA4-1 CELLS AND SPENT MEDIA</td>
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<td>CYFLUTHRIN</td>
<td>40-100</td>
<td>Provision to contain effluent from fire extinguishing</td>
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<tr>
<td>THIAMETHOXAM</td>
<td>40-100</td>
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</tr>
<tr>
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<td>&gt;40</td>
<td>Avoid excess heat</td>
</tr>
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<td>Chemical Name</td>
<td>Storage Temperature (°F)</td>
<td>Other Remarks</td>
</tr>
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<td>-------------------------------------</td>
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<td><strong>Herbicides</strong></td>
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<td>CLETHODIM</td>
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<td>DIURON</td>
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<td>Avoid freezing</td>
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<td>FLUMIOXAZIN</td>
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<tr>
<td>GLUFOSINATE-AMMONIUM</td>
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<td>Avoid freezing</td>
</tr>
<tr>
<td>GLYPHOSATE</td>
<td>40-100</td>
<td>Provision to contain effluent from fire extinguishing</td>
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<tr>
<td>GLYPHOSATE ISO. SALT</td>
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<td>GLYPHOSATE POT. SALT</td>
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<td>HALOSULFURON</td>
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<td>OXYFLUORFEN</td>
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<td>PARAQUAT</td>
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<td>PENDIMETHALIN</td>
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<td>SETHOXYDIM</td>
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<td><strong>Fungicides</strong></td>
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<td>40-100</td>
<td></td>
</tr>
<tr>
<td>BACILLUS SUBTILIS</td>
<td>40-100</td>
<td>Protect from freezing, keep out of direct sunlight, keep away from heat sources</td>
</tr>
<tr>
<td>BOSCALID</td>
<td>40-100</td>
<td>Keep away from places of potential flooding</td>
</tr>
<tr>
<td>CALCIUM POLYSULFIDE</td>
<td>40-100</td>
<td>Keep in shaded area</td>
</tr>
<tr>
<td>CAPTAN</td>
<td>40-100</td>
<td>Provision to contain effluent from fire extinguishing</td>
</tr>
<tr>
<td>COPPER HYDROXIDE</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>COPPER OXIDE</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>CYPRODINIL</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>DIMETHOMORPH</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>FENAMIDONE</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>FLUDIOXONIL</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>FLUOPICOLIDE</td>
<td>40-100</td>
<td>Tightly sealed</td>
</tr>
<tr>
<td>FLUOPYRAM</td>
<td>40-100</td>
<td>Avoid cross contamination with other chemicals</td>
</tr>
<tr>
<td>FLUXAPYROXAD</td>
<td>40-100</td>
<td></td>
</tr>
</tbody>
</table>
### Table A-2 Continued. Pesticides used on diversified crops and their required storage temperatures.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Storage Temperature (°F)</th>
<th>Other Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOSETYL-AL</td>
<td>40-100</td>
<td>Provision to contain effluent from fire extinguishing</td>
</tr>
<tr>
<td>IPRODIONE</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>MANCOZEB</td>
<td>40-100</td>
<td>Provision to contain effluent from fire extinguishing. Keep away from acids.</td>
</tr>
<tr>
<td>MANDIPROPAMIDE TECHN</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>MEFENOXAM</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>MONO-POTASSIUM SALT</td>
<td>40-100</td>
<td>Store separately from fertilizers. Avoid cross contamination.</td>
</tr>
<tr>
<td>MYCLOBUTANIL</td>
<td>40-100</td>
<td>Keep away from open flame.</td>
</tr>
<tr>
<td>PENTHIOPYRAD</td>
<td>40-100</td>
<td>Keep stored in the dark. Protect from direct sunlight.</td>
</tr>
<tr>
<td>PYRACLOSTROBIN</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>STREPTOMYCES LYDICUS</td>
<td>40-85</td>
<td>Out of direct sunlight and heat sources. Keep from overheating and freezing.</td>
</tr>
<tr>
<td>SULFUR</td>
<td>40-100</td>
<td>Fireproof, away from strong oxidants</td>
</tr>
<tr>
<td>TRIFLOXYSTROBIN</td>
<td>40-100</td>
<td></td>
</tr>
<tr>
<td>THIRAM</td>
<td>40-100</td>
<td></td>
</tr>
</tbody>
</table>

Note. Pesticide storage data compiled from EPA (2016) and NCBI (2019).

Disclaimer: Pesticide and chemical labels should always be read for information regarding safe application, storage, and other information relevant to that specific chemical.
References:
City of Philadelphia (no date) Gallons Used Per Person Per Day. Available at: https://www.phila.gov/water/educationoutreach/Documents/Homewateruse_IG5.pdf.
Global Industrial (no date) Aprilaire Manual Control Humidifier, 12 Gallons Per Day. Available at: https://www.globalindustrial.com/p/hvac/humidifiers/humidifiers/aprilaire-whole-house-humidifier-model-500m-built-in-bypass-dampers?presentType=99&trackCatKey=0&trackPrimKey=0&trackType=6&webCatKey=0.


Grey Water Action (no date) About Greywater Reuse. Available at: https://greywateraction.org.greywater-reuse/.


Kader, A. (2012) Postharvest Handling of Some Specialty Fruits (Pitahaya, Fig, Pomegranate, Date, Olive).


