Post-Harvest Handling
Decision Tool

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The Iowa Fruit and Vegetable Working Group operated from 2007 through 2011 as part of the **Value Chain Partnerships** project to address issues limiting the growth of fruit and vegetable growers in the state. Many of the group's activities are now offered by Iowa State University Extension and Outreach, and resources are available from the Leopold Center for Sustainable Agriculture.

Virginia Moore, program assistant at the **Center for Integrated Agricultural Systems (CIAS)**, formatted this publication. CIAS is a research center for sustainable agriculture in the College of Agricultural and Life Sciences, University of Wisconsin-Madison. CIAS fosters multidisciplinary inquiry and supports a range of reseach, curriculum, and program development projects. It brings together university faculty, farmers, policy makers and others to study relationships between farming practices, farm profitability, the environment and rural vitality.

Additional resources
In addition to the content presented in this document, there are additional resources (PDFs, links, etc.) available on the Leopold Center website, including information about branding, equipment, food safety, and additional farm profiles. These resouces are available at:
http://www.leopold.iastate.edu/cool_tools/post_harvest_handling_decision_tool_3

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Iowa Fruit and Vegetable Working Group

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Value Chain Partnerships
An Iowa-Based Network for Food and Agriculture Working Groups

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Introduction

Getting crops planted and harvested at the right time are important for fruit and vegetable production, but the key to a successful operation is how the crop is handled immediately after harvest. Post-harvest handling is the stage of crop production that includes cooling, cleaning, sorting and packing the crop for later stages in the process such as storage, transportation and delivery to the customer. How a product is handled during this crucial period largely determines its quality and safety for consumption.

A farmer's primary concerns during post-harvest handling are to quickly reduce the field temperature of the crop to extend shelf life and retain nutrient value; minimize moisture loss and shrinkage; and avoid physical damage such as bruising to delay spoilage. Sanitation is essential in all steps of the process.

The information in this guide came from case studies of three fruit and vegetable operations: Gardens of Eagan, Farmington, Minnesota; Hog's Back Farm, Arkansaw, Wisconsin; and Spring Hill Community Farm, Prairie Farm, Wisconsin. Post-harvest handling systems used at seven other farms also were summarized and are available on the Post-Harvest Handling Decision Tool website (see http://www.leopold.iastate.edu/cool_tools/post_harvest_handling_decision_tool_3).

Since each crop has an ideal range for storage temperature and humidity, the following discussion of handling systems treats each crop separately, isolating the post-harvest handling aspect of the market farm operation. However, post-harvest handling fits into the larger context of a harvest-wash-pack system on a farm, which fits into the still larger context of food safety, markets, labor availability, delivery schedules, and personal and professional goals.

Speed and Capacity - The speed of any function that requires a human operator is very person-dependent. This person-dependency can be mitigated by mechanization, but, in the end, the speed at which the operator feeds in the product and removes the product at the other end ultimately drives the efficiency of an operation. The fastest worker using a manual system will likely get more done than the slowest worker using a mechanized system.

Likewise, not all improvements to post-harvest handling systems make operations go faster on a per-person basis. Some improvements increase the number of people who can engage in a job, thereby increasing efficiency by allowing for more product to flow through an existing system, while not increasing per-person capacity.

Product Form and Function - When making choices about adding new products to a system with any degree of mechanization, a producer should consider how well the form of the product will fit with the machinery and tools already present, in addition to the market that exists. A grower utilizing a barrel washer to wash carrots may find increased efficiencies when she adds bulk beets, but bunched beets would require an entirely new system of handling.

Evaluating Costs - The costs presented throughout this document are based on delivered cost—but the prices quoted by a dealer or paid at auction only represent the cost of getting the equipment into your farmyard on a pallet. Assembling machinery and installing it in your packing facility almost always takes a significant amount of time and expense. Producers should take into account the time and money it might take to put a new tool into service in their operation.

Baby Salad Greens

For the purpose of this study, salad greens includes the common mixed greens sold as "spring mix" or "mesclun," as well as loose-leaf spinach and arugula. In general, the harvested leaves "fit on a fork," (known at Rock Spring Farm by its acronym, FOAF) and are presented to customers as a ready-to-eat product, whether farms advertise it as such or not.

The primary considerations in the post-harvest handling of salad greens are the rapid cooling of the product and removing water from the surface of the leaves. Handling efficiency seems to be a function of personnel, with the size of washing tanks a minor consideration. The spinners used for drying can present a bottleneck in the operation.

Scale and Costs

Up to 100 pounds per day:
2 100-gallon Rubbermaid-style livestock watering tanks—$150
1 used washing machine—$20
or a 5-gallon Dynamic Salad Spinner (manual)—$240
20 mesh bags—$100

100-250 pounds per day:
1 100-gallon Rubbermaid-style livestock watering tank—$75
1 used washing machine—$20
1 300-gallon Rubbermaid-style stock tank or used stainless-steel tank—$300

Large, commercial operations utilize a wash line and conveyor belt system, moving the leaves through a series of wash tanks to cool the crop and remove grit. During a visual inspection, workers remove contaminants such as weeds or rotten leaves as the produce moves through the line.

On Upper Midwest market farms, the most common method for cooling and cleaning is to submerge the greens in a tank of water using a tray or bag (*see photo below left*), then to mix the different ingredients or do a final rinse in a larger tank. Most operations use a clothes washing machine set to the spin cycle to remove standing water from the leaves. The low level of mechanization means that the speed of the operation and the gentleness of the handling depend heavily on the speed and care of the personnel conducting it.

Many farms have moved away from the production of salad greens because prices have declined or failed to increase with the cost of production. Many Community Supported Agriculture (CSA) operations have limited their offerings of salad greens because of the washing and handling requirements.

Bags and Trays for Initial Rinsing

On the surveyed farms, greens are harvested into a variety of containers, which determine the way in which the initial rinsing is managed.

At Rock Spring Farm, salad greens are harvested into wooden bushel crates lined with a mesh liner. Farmer Chris Blanchard notes that lining the crates isn't very efficient, but he has the red mesh bags on hand and the wooden crates are the only harvest containers currently in use at Rock Spring Farm. After harvesting, the bags of greens are weighed and folded over at the top, then transported to the packing house. At the packing house, bags are dunked in a 100-gallon plastic tank, then palletized and put into the cooler until the packing crew is ready for the final rinse and mixing, which happens in a 300-gallon dairy bulk tank.

At Hog's Back Farm, greens are harvested into ventilated plastic totes (*see top photo on next page*). Greens are poured into 100-gallon tubs of water, then transferred into a second tank using a bulb tray, then removed into a hand-cranked salad spinner. Hog's Back Farm has moved to delivering salad greens only twice over the course of their summer shares.

Featherstone Farm forgoes the initial rinsing step, moving salad greens directly from harvest totes into large tanks of water.

At Driftless Organics, salad greens are washed using black bulb trays. Greens are placed in one tray, with another tray placed on top of that, and the whole thing swished around in the tank to remove any field dirt. In cases of weedy crops or questionable quality, washed greens are sorted at a table by pouring from one tray into another and picking out the cull leaves and plants.

For mixing greens or washing bulk in large tanks, it is essential to handle the greens gently. At Rock Spring Farm, workers slide their hands into the tank of greens and use a circular motion underneath the greens to agitate and blend the leaves. The goal is to use the water instead of the hands to mix and move the product.

Spin Dry

To increase the storage life of baby salad greens, it is essential to remove almost all of the water from the surface of the leaves. All of the surveyed farms accomplish this by means of some sort of spinner.

The most common spinner on Upper Midwest vegetable farms is used clothes washing machines. Only the spin cycle is used, typically for about 45 seconds. The best practice is to monitor the outflow and turn off the spinner when water ceases flowing. With enamel paint on the exterior and an enameled or stainless steel basket, these have food-safe food contact surfaces (*see photo on right*).

Every grower visited uses mesh bags to hold the greens. These bags provide for ease and gentleness of transfer. About six pounds of greens are dried in each batch, usually in two bags to balance the machine.

Hog's Back Farm, which grows only two crops of salad greens each year, uses a five-gallon, hand-cranked Dynamic Salad Spinner. With a removable basket, this spinner can handle about three pounds of greens and takes about one minute to completely dry the greens. Rock Spring Farm used the same machine before upgrading to a washing machine.

Greens removed in mesh bags can be stockpiled to await spinning. According to growers, baby greens should not remain in the water for more than about 20 minutes.

For winter greens production, it is important to note that water frozen in the washing machine takes an extraordinarily long time to dry out. At Rock Spring Farm, the author was always grateful to have the Dynamic Salad Spinner as a backup device.

Overall washing speeds ranged from 20 to 50 pounds per labor hour.

Scale and Costs

The growers surveyed for this project all produced 80 to 100 pounds of salad mix each day that they packed it. The largest farms were packing salad mix up to four times each week, while the smallest packed it just one time each week. None of the growers visited was entirely happy with their handling setup for salad mix.

The author used a hybrid system of Driftless-style bulb tray rinsing and bulk tank mixing on a farm where he worked in the mid-1990s. With this system he washed up to 200 pounds of salad mix in a day using a 400-gallon stainless steel bulk tank. At Rock Spring Farm, in the mid-2000s, 150 pounds of salad mix was washed daily. At larger volumes, speed and equipment remain the same, but greens are processed in multiple batches. Larger final wash tanks allow for more settling of sediment.

Beans and Peas

The overriding consideration for the post-harvest handling of beans and peas is rapid cooling. Excessive moisture can promote rapid breakdown, especially with beans.

On large, commercial operations, hydrocooling is common. However, wetting the pods can promote spoilage unless the water is treated to prevent the growth of fungus. A variety of sorting and grading tables are the most common method for grading, since crops tend to be mechanically harvested. Beans and peas are packed into well-ventilated containers, such as wooden crates or mesh bags.

In the Upper Midwest, none of the visited farms used machinery to grade beans or peas. Because all of the visited farms harvested by hand, there was a feeling that quality was close to adequate when product came into the packing shed. Use of hydrocooling versus forced air cooling was independent of the scale of the operation.

Air Cooling

For air cooling, well-ventilated containers are critical. Regardless of the actual harvest containers used—visited farms used five-gallon buckets or plastic-lined bushel baskets—most farms used well-ventilated plastic totes for initial storage in the cooler. Pallet bags or individual bags were added after the initial removal of field heat to preserve humidity.

Scale and Costs

Because the hydrocooling and air cooling operations do not use any machinery, the labor efficiency of the process is entirely dependent on the speed and motivation of the labor crew.

Up to 20 bushels* (600 pounds):
Folding banquet table— $170-300, depending on quality

**Visited farms picked and packed up to 600 pounds of beans in a day using methods described.*

Hydrocooling

About half of the farms visited hydrocooled beans and peas using a water bath in a bulk tank. Beans and peas were removed from the water bath using mesh bags or ventilated containers. At Rock Spring Farm, a fishing net is used to scoop the last beans out of the tank.

Peracetic acid, as found in the commonly used organically approved water additive Tsunami 100, has been noted to cause peas to turn rusty. This creates a conundrum for organic growers wanting to use hydrocooling, since moisture on the peas promotes breakdown.

Spin Dry

Since all of the farms visited relied on manual harvest for their beans and peas, sorting needs were limited. The farms that used hydrocooling also use that step for quality control.

At Featherstone Fruits and Vegetables, poor harvest conditions occasionally resulted in a need to conduct more rigorous quality control sorting. To do this, butcher paper of the sort available at an office supply store is rolled out on eight-foot plastic banquet tables. Washed peas and beans are poured out on the butcher paper and moved down the paper by hand. The waxy coating provides a food-safe surface and allows the product to slide easily down the table, where it is re-containerized for cooling.

Broccoli, Cauliflower and Cabbage

For the brassica family of crops, rapid cooling and the maintenance of cold and humidity are the primary post-harvest concerns, normally addressed by package icing or hydrocooling. Because it is largely a manual process, handling speed is a function of personnel and equipment capacity. Rapid cooling is not as much of a concern for cabbage.

For large, commercial operations, most broccoli and cauliflower is field packed directly into cartons. Mechanical cutters and banders are used to bundle the broccoli, which is packed immediately. Ice and liquid ice, combined with forced air cooling, are the primary methods for removing field heat and rapidly cooling to the desired temperature.

Most Upper Midwest market farms do not bunch broccoli, although some do. It is more common on truck farms to produce larger heads of broccoli grown on a wider spacing than that used in large-scale commercial production. Broccoli is either hydrocooled or top-iced. Cauliflower is most often air-cooled, unless it has insect frass on it.

Scale and Costs

Up to 300 pounds per week:
1-2 180-gallon Rubbermaid-style livestock watering tanks—$140

Over 300 pounds per week:
Used automatic buncher/cutter—$300*
Ice machine prices depend heavily on the amount of ice needed.

**Only necessary if the market demands bunched broccoli*

Hydrocooling

At Hog's Back, Spring Hill, and Rock Spring Farm, broccoli is brought in from the field in totes or crates and hydrocooled in plastic or stainless steel bulk tanks. David Van Eeckhout notes that at Hog's Back Farm, "We don't dump the broccoli, we transfer it into the tanks." David leaves the broccoli in the tank for a full 15 minutes to remove the field heat. Soaking broccoli has the additional advantage of dislodging cabbage worms if they are present.

Cauliflower is handled more gently. Most of the surveyed growers are not hydrocooling it, because cauliflower bruises more easily than broccoli. A plastic brush can be used with a water bath to remove frass, if necessary.

Cabbage does not get hydrocooled.

Top Icing

At Gardens of Eagan, broccoli is harvested into field totes and placed into a shaded field truck. The truck is backed up to the packing shed and the broccoli is moved directly into labeled boxes. The boxes are set open on a pallet, one layer at a time. Five pounds of ice is scooped into each box, and then the layer of boxes is closed and another placed on top.

Bunching

At Featherstone Fruits and Vegetables, broccoli is harvested into totes and then poured into a bin in the field. The bins get hosed down to rinse and hydrocool when they come in from the field, then six inches of ice nuggets are spread over the top in an ice cap. The broccoli is left in the cooler overnight to chill through, then a crew of four people works to bunch the heads. A crew of two people work to pull the broccoli out of the bins and put it in appropriately sized bunches. Another worker manages the pneumatic broccoli buncher. A rubber band is placed on metal fingers that stretch the rubber band, then two to four stalks of broccoli are placed in the mechanism, and a switch is triggered causing the broccoli stems to be cut to a uniform length and the rubber band to be applied. A fourth worker packs the cases and applies the ice.

For bunching broccoli, Featherstone packs about 20, 20-pound cases each hour with a crew of four people. Bunching broccoli provides some flexibility in harvest timing, since multiple small heads can be combined to meet demand prior to full maturity of the crop (*see photo of broccoli buncher to the right*).

Cabbage

Cabbage was handled manually at all of the visited farms by trimming the stems with a sharp knife and peeling leaves. The speed of this operation is entirely dependent on the efficiency of the workers and the quality of the crop.

Bulk Roots and Tubers

The cleaning methods used by Upper Midwest market farmers resemble those used on very large, commercial operations in their methods, if not their scale. Barrel washers and brush washers, similar to those used by market farmers, predominate on large operations.

On market farms that have not made the investment in mechanization, root washing takes place in a variety of innovative ways, either through pressurized water or agitation in a tank of water.

Manual Root Washing

At a very small scale, most market farmers choose to use a tray and a hose to wash roots. By attaching an inexpensive shut-off valve to the hose, a pressurized spray can be achieved by closing it part way, similar to putting one's thumb over the end of the hose (*see photo below).*

A logical next step might be to substitute an electric pressure washer for the hose and shutoff. Variable pressure is important to adjust for different roots; carrots and beets can withstand higher pressure for faster cleaning than can crops such as daikon radishes. By shortening the wand and twist-tying the trigger into the open position, the wand can be placed over the shoulder, rather than supported in the style of a gun. This technique also increases the distance between the nozzle of the gun and the crop being washed. Using this technique, 100 to 300 pounds of roots may be washed per labor hour. Beets and turnips wash up easily twice as fast as carrots and celeriac. Rock Spring Farm uses a 2000 PSI, 1.5 GPM model with adjustable pressure.

A less expensive and less skill-dependent method involves the use of a mesh bag to vigorously agitate roots in a 100-gallon Rubbermaid-style tub filled with water. Workers hold one top corner of the bag in each hand, submerge the produce, and shake and swish the bag in the water to scrub the vegetables against each other. The entire bag is then removed and dumped onto a sorting table or drying screen. Hog's Back Farm reports rates of about 140 pounds per labor hour using this method (*see top photo on next page*).

Scale and Costs

The removal of soil from bulk roots and tubers provides one of the primary means of quality differentiation for this group of crops. Crops are topped prior to storage and washed using a combination of scrubbing action and pressurized water.

Up to 500 pounds of roots per day:
2 100-gallon Rubbermaid-style livestock watering tanks—$120
5 mesh bags for agitation—$25
- or -
Variable pressure pressure washer—$630

More than 500 pounds of roots per day:
Smooth-walled barrel washer—$2300
Variable pressure pressure washer (optional)—$630

Brush Washer

A brush washer makes a versatile addition to a packing operation for root crops, since it will gently wash beets, turnips, and winter radishes. Carrots and daikon radishes tend to "skate" through without getting rolled around by the brushes. Celeriac does not get adequate soaking and agitation to clean the convoluted roots.

Extra soiling on root crops, as compared to the tender fruit crops discussed previously, may make pre-soaking desirable in certain circumstances. Hosing down bins or totes of produce can improve the performance of the brush washer. In especially muddy conditions, an in-feed belt makes an additional rinsing step easier.

For root crops, a brush washer will clean about 300 pounds of roots per labor hour.

Barrel Washer

When it comes to washing roots, the barrel washer is the king of packing equipment. Made of wood or metal, a motor-driven barrel rotates to agitate roots in a bath or shower of water. Roots work their way through the barrel by the addition of dirty roots at one end and the tendency of the roots to spread out in the barrel.

Two basic barrel designs are found on Upper Midwest market farms. In the one most common at the smaller end of the scale, a copper pipe with small holes in it runs lengthwise through a 30-inch wide, eight-foot long wooden barrel. Water running through this pipe is pressurized through the holes, while the rotation of the barrel causes up to 250 pounds of roots to slide up the walls of the barrel and back down again, creating a scrubbing action between individual roots. The barrel is supported by a frame with casters on the hoops of the barrel. A small electric motor drives the rotation of the barrel by means of a sprocket and chain.

At a slightly larger scale, a second type of barrel is more common. Rather than using pressurized water from a pipe, the barrel sits in a tank of water. Paddles running the length of the barrel lift the roots up and drop them back down into the water. While both types of barrel washer can bruise tender roots such as turnips and winter radishes, the paddle-style washer does much more damage.

Speed of operation is determined by the capacity of the washer. The smaller, smooth-walled barrel washer holds up to about 250 pounds of roots, while the paddle-style barrels can hold much more. The rate at which roots go through, and how clean they get, is determined by how fast roots are added at the in-feed end. With both styles of washer, a gate on the out-feed end keeps a batch of roots tumbling in the washer until they are clean. At Rock Spring Farm, the author uses a smooth-walled barrel washer to clean 500 pounds of roots per labor hour.

Some growers use an additional manually controlled application of pressurized water at the out-feed to further polish the product (*see second photo above of barrel washer and manual rinse*).

With both a brush washer and a barrel washer, Linda Halley of the Gardens of Eagan notes that in her previous experience, carrots, rutabagas, beets, and celeriac were handled with the barrel washer, while turnips and winter radishes were best handled with a brush washer.

Bunched Greens

The primary consideration in the post-harvest handling of bunched greens is rapid cooling and re-hydration of the product, normally accomplished either by hydrocooling alone or in combination with package icing. Handling speed seems to be a function of personnel and size of the tanks, with larger tanks facilitating more rapid packing of crops.

The standard protocol on very large, commercial vegetable operations for rapid cooling and re-hydration of harvested product is a combination of hydrocooling and, where the crops are suited, liquid icing of the product. In large scale hydrocooling, a pump moves chilled water into contact with warm produce. The warmed water is then re-cooled and recycled. Since water removes heat from produce 15 times faster than air, this method provides rapid cooling, although the wetting of some products can promote the growth of decay organisms.

Scale and Costs

Up to 500 bunches per day:
2 100-gallon Rubbermaid-style livestock watering tanks—$150

More than 500 bunches per day:
2 180-gallon Rubbermaid-style livestock watering tanks—$280
2 welded stands—$100
2 homemade PVC drains—$30

Ice machine prices depend heavily on the amount of ice needed

For crops that can tolerate top icing, large, commercial vegetable operations will supplement or replace hydrocooling with the addition of crushed ice or a slurry of crushed ice and water that is pumped into open containers traveling along a conveyor under an injection nozzle. On Upper Midwest market farms, hydrocooling takes place by moving the product through tanks of water. Larger market farms handle enough product to warrant investment in an ice machine for additional cooling and quality maintenance. The low level of mechanization means that the speed of the operation depends heavily on the personnel conducting it.

Water Tanks

Plastic livestock watering tanks, most often those manufactured by Rubbermaid, were used for hydrocooling bunched greens on the three farms included in this study. The plastic tanks, generally rectangular with rounded ends, have rounded edges and corners that facilitate easy rinsing of field dirt. Drains on these tanks are typically located on the long side about one inch above the floor, and open and close by means of a threaded plug.

Most workers can easily move tanks sized up to 100 gallons. Because the drains on these tanks are typically located about one inch above the floor of the tank, workers still need to tip tanks over to completely change the water and clean any soil from the tank (*see photo to the left*).

Fifty-gallon tanks do not provide much depth to keep product away from the settling dirt, but they do empty and fill relatively quickly. One-hundred-gallon tanks have the same footprint as the 50-gallon tank, but provide more depth, as well as additional water to buffer the temperature changes. Tanks up to 100 gallons seem most suitable for a farm handling up to 500 bunches of greens per day, and the tanks facilitate handling up to 150 bunches per labor hour.

With two 180-gallon tanks, Gardens of Eagan reported handling up to 600 bunches of greens per labor hour. Two tanks enable alternate filling and draining, eliminating downtime for the workers. Gardens of Eagan modified their tanks by adding a two-inch PVC drain in the center of the bottom of the tank. The drains open and close by means of a ball valve.

For proper ergonomics, stock tanks of all sizes need to be elevated off of the floor. For tanks up to 100 gallons, plastic totes, wooden crates, sawhorses, and overturned tanks provide adequate support to prevent sagging. For their 180-gallon tanks, Gardens of Eagan welded racks with supporting crosspieces to position the tanks and prevent sagging. The racks also facilitated the location of the drain on the bottom of the tank.

Several Upper Midwest market farms use dairy bulk tanks for hydrocooling. Typically run without refrigeration, these tanks have the advantage of large-size, seamless, stainless steel construction, as well as a drain positioned at the bottom edge in such a way as to facilitate complete drainage of water and solids.

The size and number of tanks to buy will depend on the flexibility needed in an operation, the rate at which tanks can be filled, and the number of units processed through them. In addition to bunched greens, Upper Midwest market farmers use bulk water tanks for handling peppers, cucumbers, bunched roots, and bulk salad greens, as well as pre-soaking bunched roots.

Drainage racks provide an intermediate step between hydrocooling and packing the bunched greens, and are typically constructed of a wood frame with galvanized hardware cloth for a screen. Hog's Back Farm's use of PolyMax panels on their work tables provided an easily cleaned option, although they did not use a drainage step in their process.

Ice Machine

The decision about whether to add ice to bunched greens will depend on the demands of the marketplace, since an ice machine serves to improve the quality and shelf life of produce, not to speed its handling. In addition to bunched greens, many other crops benefit from top icing, including asparagus, broccoli, cantaloupes, carrots, cauliflower, green onions, and sweet corn.

Upper Midwest market farmers use chipped and shaved ice to further cool and rehydrate produce. The cost of liquid or slurry ice would generally prove prohibitive to market growers. Ice provides cooling as well as a moisture shield for produce. It may find an additional use as an aid to displays at roadside stands and farmers' markets.

Ice machines consist of a refrigeration system, an ice-making mechanism, and an insulated bin. They must be hooked up to a water supply system. The insulated bin for collection of the ice may be separate or integral, and additional bins may be purchased or manufactured. Gardens of Eagan scoops ice from their integral bin into two supplemental, wheeled bins for storage in their walk-in cooler, as well as optimal positioning for adding ice to boxes of produce.

Machine capacity is measured in pounds of ice made per day. Flaked ice stores well for several days in insulated bins in a 34°F cooler. Extension publications cite needs of approximately 16 pounds of ice for each 20-pound carton of broccoli. In practice, Gardens of Eagan uses about five pounds of ice per case, probably due to the very local nature of their sales and high turnover in the stores they sell to, since they deliver three times each week. Featherstone Fruits and Vegetables felt that "you can't have too much ice for broccoli." Precise data and calculations for ice requirements can be found here: http://www.bae.ncsu.edu/programs/extension/publicat/postharv/ag-414-5/

Ice machines produce a substantial amount of heat, which may be taken into account when positioning them. Featherstone Fruits and Vegetables has decided to move their ice machines outside of the temperature-controlled packing area, and to use a stainless steel chute to move the ice into that room.

Ice machines require frequent cleaning and sanitizing, and have similar maintenance issues to commercial refrigeration units. These factors should be taken into account when considering an investment in an ice machine (*see photo above*).

Dry-Cured Alliums

Dry-cured alliums include sweet, red, and yellow onions, as well as garlic and shallots. These crops all require a "curing" step after harvest to seal the leaf tissue that makes up the bulb against moisture loss and entrance by pathological organisms. In addition, dirt, loose skin, tops, and roots must be removed prior to sale.

Large, commercial operations use a variety of machines for removing scales from the bulbs, but these are not widely available for farms not operating in major onion-producing areas.

Diversified Upper Midwest market farms use a variety of innovative techniques for accomplishing these tasks using manual labor. Larger, diversified operations frequently invest in a roller topper to achieve the desired result with large table onions. Shallots and garlic are almost all cleaned by hand.

Scale and Costs

The time data was not collected for the different onion-cleaning options, so no specific recommendations are made here. A return on investment analysis should provide reliable information.

For manual cleaning:
Vinyl-dot gloves—$12/10-pack

For mechanical cleaning:
Used roller topper, 2 lines—$1150

Curing

Onion and garlic bulbs are made up of leaf tissue, a part of the plant designed to transpire water obtained from the roots. As onions and garlic reach maturity, the outer leaves senesce, forming a dry layer that prevents this transpiration process. At harvest, growers take steps to fully dry the outer layer and seal the neck of the bulb and the leaf pores against water loss and the invasion of disease-causing bacteria and fungi.

Most diversified Upper Midwest market farmers do not have specialized curing systems, instead putting crates or bins in an unused transplant-production greenhouse, or spreading the onions in a single layer on greenhouse benches. Portable barn fans are used to circulate air and promote drying.

Some farmers have developed specialized systems for curing onions by forcing air through the onions in a manner similar to that used in grain bins. Heating the air can reduce drying time and help to cope with wet periods that are not uncommon during the Upper Midwest onion harvest. At Common Harvest Farm in Osceola, Wisconsin, farmer Dan Guenthner uses a squirrel-cage fan to force air into a plenum under mesh benches in an existing outbuilding. At Rock Spring Farm in Decorah, Iowa, the author, Chris Blanchard, uses a Sunderman Manufacturing greenhouse heater with a squirrel cage fan to force heated air into a plenum under stacked trays of onions and shallots.

Thorough curing greatly eases and speeds the removal of dirt, loose skin, tops, and roots. When removing dried alliums from refrigerated storage, condensation can cause the skins to soften and become difficult to clean.

Manual Cleaning

The most common method for removing the loose skin and roots of onions, shallots, and garlic is for workers to rub the bulbs between their hands. A number of inexpensive aids can facilitate the process and increase speed and effectiveness.

Because direct fresh-market sales, whether to stores, CSAs, or farmers' markets, place a high value on earliness, growers frequently begin to process cured alliums before the curing process is fully complete. At this stage, the loose skins can be quite difficult to remove. A well-wrung kitchen towel can help add friction to slip the skins off at this stage, according to Hog's Back Farm's David Van Eeckhout.

When skins are fully cured, nitrile surgical gloves and cotton gloves with vinyl dots can help to "pop" the skins off by applying pressure while moving the hands across the bulb.

Sharp bypass pruners can cut the tops off of hardneck garlic bulbs without crushing the stem.

Roller Topper

A roller topper consists of multiple pairs of longitudinal rollers that rip the necks and skins from fully cured onions. The rollers have metal ridges that corkscrew down the length of the cylinder. The ridges on alternate rollers corkscrew in opposite directions, and alternate rollers rotate in opposite directions, resulting in a gripping and ripping action that moves the onions down the length of the sloped topping bed.

The rotation of the rollers bounces the onions around quite severely, so only very hard varieties should be cleaned in this way, and only just before sale. This piece of equipment is only suitable for use on round onions. Driftless Organics uses their roller topper to pre-clean yellow and red storage onions, then uses manual cleaning to achieve a finished product.

Market garden roller topper machines can be obtained on the used market and typically consist of two sets of four-foot long rollers. These are undoubtedly the most dangerous piece of packing shed equipment considered here, and their use should be carefully considered on farms with young or unskilled workers.

Tender Crops

As a category, tender crops cover a wide variety of produce. Specifically included here are peppers, winter squash, and cucumbers. Tomatoes, zucchini, and summer squash, as crops that require very gentle and very specialized handling, were specifically excluded.

On large, commercial operations, a water dump seems to be the most common method for removing dirt and dust, and, in the case of cucumbers, any remaining blossoms. In regions where contamination from wet soil does not present a problem for crop quality, field packing is a common practice. Hydrocooling is not normally a consideration for these crops, all of which prefer storage temperatures above 40°F.

Small-scale Upper Midwest market farms will handle these crops using a water dump, although a number of techniques and tools can increase the speed of this operation. Large operations in the Upper Midwest typically invest in a brush washer. The tools surrounding the infeed and outfeed operation of the brush washer typically expand the functionality and capacity of that tool on larger farms.

Removing excess moisture from the surface of these fruiting crops is extremely important to prevent decay. Where fruits touch each other in storage, water will not evaporate and will provide a point for fungal germination and bacterial growth.

Scale and Costs

1 bushel of peppers = 25 lbs
1 bushel of squash = 35 lbs
1 bushel of cucumbers = 48 lbs

Up to 10 bushels per day:
2 100-gallon Rubbermaid-style livestock watering tanks—$150
5 mesh bags for gentle agitation—$25

More than 10 bushels per day:
16-inch brush washer—$1200
Absorber—$745
5-ft rotary packing table—$870
4-ft in-fed belt (optional)—$550

Manual Handling

Manual handling typically relies on some sort of water dump to remove dirt and dust. The most basic tool is a water tank. Workers on various farms use a selection of clean cloths, burlap sacks, and cotton gloves to increase the speed of scrubbing, if necessary.

Mesh bags provide a mechanism on small farms to batch process crops such as peppers and cucumbers. The bags also provide a way to increase agitation for the removal of mud from crops. Workers hold one top corner of the bag in each hand, submerge the produce, and shake and swish the bag in the water to scrub the vegetables against each other. The entire bag is then removed and dumped onto a sorting table or drying screen (*see photo above*).

Submerging peppers provides an opportunity to control for corn borer damage, considered by Upper Midwest market farmers to be the most common blemish that renders the fruit unusable. Damaged peppers take on water and sink to the bottom of the tank.

Winter squash must be handled more gently to avoid damage. At Spring Hill Community Farm workers clean the squash in the field using a burlap sack to remove dried-on dirt. Other manual cleaning methods include dunking individual fruits into a bucket or tank of water, scrubbing with a cloth or cotton glove to remove soil, and then drying with a towel to prevent decay.

The Brush Washer

Linda Halley, Gardens of Eagan, said, "If you have two crops to put through a brush washer, then as soon as you can afford it, buy one, regardless of the scale of your operation." A brush washer, as part of a vegetable wash line, is perhaps the most versatile and most widely used piece of post-harvest handling equipment on small vegetable farms in the Upper Midwest. A series of 10 rotating brushes move produce through a water spray, scrubbing and rinsing dirt away from the product (*see photo of brush washer to the left*).

A vegetable wash line can include multiple components, in addition to the basic washing unit. An in-feed belt provides a space to dump totes or large bins of produce and pre-sort any obvious culls before they are conveyed into the brush washer; neither Gardens of Eagan nor Hog's Back Farm uses this addition, instead feeding produce into the brush washer by hand. Hog's Back Farm has a dedicated table for staging totes of produce, while Gardens of Eagan uses overturned plastic totes. Gardens of Eagan had purchased an in-feed belt when it acquired the brush washer, but no longer uses it.

After product has been cleaned by the washer, it proceeds to the out-feed system. Most commonly, the first step is a series of foam "donut" rollers, referred to as an "absorber," that squeegee water off of the produce, removing surface moisture that can promote fungal and bacterial growth. A kicker brush moves the produce on to the next piece of equipment in the line. Hog's Back Farm did not have an absorber, but planned to make that investment in the near future (*see photo to the left*).

From the donuts, produce may move onto optional sizers. Belt sizers are three feet long and grades one size onto a side packing table or side conveyor for packaging. A punched conveyor belt moves the produce from one sizer to the next, allowing produce that fits through the sizer to fall through to the side packing area. One or more sizers may be in use. Produce not captured by the sizers moves to the main packing table. The packing table may be a homemade tray slanting away from the brush washer. Models sold with the wash line are round and have a rotating table to move produce out of the way of further produce coming off the line, as well as to move product in front of multiple packers. A low rail keeps produce from falling off of the packing table. A single motor normally powers the in-feed belt, the washer, the absorber, and the sizing belts. The round sorting table is powered by its own motor. Mid-sized machines use about one and a half gallons of water per minute.

In addition to tender crops, Upper Midwest market growers use brush washers to clean round root crops, tomatoes, and potatoes. Brush washers can also be used on fruit crops such as apples.

Speed of handling is generally increased by using more people on the line. At Gardens of Eagan, one person feeding the machine can keep up with two workers packing; at Hog's Back Farm, one worker feeds while a single worker packs. While even the smallest machines are rated at 100 bushels per hour, growers in this project reported speeds of around 20 bushels per labor hour with two or three workers operating the machine.

Used machines are available, but not recommended as brush washers tend to show wear quickly.

Tomatoes

The primary considerations in the post-harvest handling of tomatoes are to avoid damage from handling and to control the ripening process of the fruit. Rough handling results in both visible and latent damage. Some dust may need to be removed from the fruit as well.

Large commercial operations harvest fresh market tomatoes at a mature green stage and use controlled atmosphere and ethylene gas to control ripening. Pack lines sort by size and provide a belt for grading and sorting the tomatoes according to ripeness. A slow roller conveyor that slowly turns each tomato provides an opportunity to inspect thoroughly for defects. A brush washer using very soft brushes and a small amount of water may be used to remove dust and foreign material.

Upper Midwest tomato market farms rely on hand sorting and modest temperature control to grade and prepare tomatoes for market. None of the surveyed farms uses a mechanical washer or grader of any kind. All of the farms were using some sort of manual wiping to remove dust and contaminants.

Scale and Costs

The major difference in cost at different scales of production seems to be in handling systems rather than equipment, and the equipment needed does not vary according to scale. At a minimum, food-safe tables should be available for sorting.

Folding banquet table—$170-300, depending on quality

Harvest and Packing Practices

To a large degree, harvest practices determine the necessary post-harvest handling steps. Operations selling primarily through a CSA were more likely to sort tomatoes for ripeness in the field, while operations selling through wholesale markets had developed more sophisticated systems for grading tomatoes by ripeness.

Spring Hill Community Farm harvests all of their tomatoes at the "red" stage (90 percent or more red) and packs them into CSA shares the same day. Stems are popped in the field, and no sorting happens except as the tomatoes are packed into CSA shares.

At Hog's Back Farm, tomatoes are harvested once each week, on Tuesdays for Thursday's delivery, and sorted and graded in the field into oranges, reds, and over-ripes. The tomatoes are allowed to sit for a day to expose any latent problems before packing. Two workers harvest the tomatoes, and David, the farmer, does the sorting. Two thousand tomatoes (600 to 800 pounds) takes three people a little under four hours to harvest and pack.

At Gardens of Eagan, tomatoes are harvested twice a week, still showing a hint of green. This stage is known as "pink" in the tomato industry. Workers harvest using white cotton gloves and remove the calyx in the field. Packing may happen in the field or in the packing shed, depending on quality. A large, laminated table in the packing shed provides space for grading. Tomatoes are graded according to the needs of different buyers.

Featherstone Fruits and Vegetables harvests tomatoes at the breaker stage and brings them into their temperature-controlled packing area to cool them down to 58°F. Tomatoes are harvested in the afternoon and cooled overnight. In the morning, using a packing list, two workers use an ad hoc arrangement of plastic tables in the temperature-controlled room to pack out of harvest totes into boxes. A rag is used to remove dirt. It takes about 90 minutes to grade and pack 800 pounds of tomatoes. Packing in the cool room prevents condensation on the tomatoes and makes it possible to harvest tomatoes before orders are received.

Equipment Considerations

Much of the work that distinguishes market farming happens by hand instead of by machine, and this is even truer of the work at the post-harvest handling stage. The speed at which a farmer can accomplish tractor work can be directly correlated to the size of the tractor and the equipment mounted on it. Mechanical harvesting systems often increase the speed of harvest by orders of magnitude; post-harvest equipment, particularly for the smaller, diverse market farms that are the focus of this document, may increase speed by a factor of only two or four.

With manual labor such as that required to move bunched greens into and out of a crisping tank, skill and motivation can make a much bigger difference than a properly configured setup. In addition, the up-front investment of time and energy that goes into setup and cleanup can make a huge difference in the overall efficiency of an operation handling a diverse range of products.

The combination of diversity of operations, modest efficiency gains, and the manual nature of the work makes investments in new equipment and facilities significantly less concrete than simple number crunching.

The Post-Harvest Handling Decision Web

The following considerations form more of a decision-making web than they do a simple decision-making tree; an investment decision need not pass each consideration to be a good decision for your operation.

Strict (Mostly) Financial Considerations

Reduced Handling - Increasing the speed of post-harvest handling operations can actually reduce the amount of time workers spend moving product around the packing shed.

If operations happen quickly enough, produce can be washed as soon as it comes out of the field, instead of moving it into and out of a cooler. This may require some redistribution of labor, with a distinction between the harvest and packing crews; or, it may be more advantageous with some crops than it is with others. At a larger scale of operations, such as that at Gardens of Eagan, the ability to move crops directly from the harvest vehicle into the packing process avoids an entire step of stacking and un-stacking totes of produce, increasing handling speed and reducing wear and tear on the farmworkers' and farmers' bodies.

In addition, rapid handling of product can increase the effective batch size handled at one time without increasing the time product sits outside of the cooler, resulting in much less effort in the movement of products. A standard handcart can handle five-bushel boxes, while a pallet and pallet jack can move 30-bushel boxes with only a marginal increase in effort.

Product Improvement - In addition to improving the speed at which product is handled, post-harvest handling equipment has the potential to increase product quality. Rapid removal of field heat can significantly improve the shelf life of a product, increasing value to retailers, restaurants, and institutions, as well as final consumers. This increased value can translate into increased sales as well as an increased price.

"Back of the Envelope" Return on Investment Analysis -A return on investment analysis, or ROI, provides an answer to the question, "How long will it take to make a profit from this investment?" For large investments, this analysis can be very complete and thorough; for smaller investments, a back-of-the-envelope analysis can provide the information you need to decide whether to move forward. The main question we want to answer is, "Is this investment going to help my farm be more profitable within an acceptable period of time?"

The basic formula for an ROI is the change in annual net income as a result of the investment, divided by the total investment. The total investment divided by the annual net income gives a more practical figure, the number of years it will take for the investment to provide a return.

Facilities Considerations

Before investing in post-harvest handling equipment, determine if your facilities have or can be modified to have the additional elements required to support the equipment. Changes in water needs, electrical requirements, drainage, and space should be considered.

Weak Link?

Before investing in post-harvest handling equipment, you should first ask if another area of your farm operation should be addressed first.

It doesn't make sense to scale up your handling capacity if you can't consistently produce a crop, or don't have the ability to get it out of the field, or have no place to sell it, or can't store it until it's time to sell it. Sometimes, a weak link can occur because of a large point load, especially for storage crops. At Hog's Back Farm, David van Eeckhout washes all of his storage carrots as soon as they are harvested; with 5,000 pounds of carrots to wash in just a few days, a barrel washer will ease the workload considerably. On the other hand, if Hog's Back was washing 200 pounds of carrots each week for 10 weeks, a barrel washer wouldn't show the same benefits.

Business Structure

The structure of a farm business may point towards or away from the desirability of investing in post-harvest handling equipment. At Spring Hill Community Farm, Mike Racette and Patty Wright have kept their post-harvest equipment at a minimum because CSA members participate in the harvest, washing, and packing process. In this situation, simple systems with few moving parts make the most sense.

Similarly, a farm that relies on high school laborers to complete much of the washing and packing may find that several small crisping tanks make more sense than one larger tank. With several small tanks, one tank can drain and be refilled while others are in use; one large tank can create large pockets of downtime that a motivated and knowledgeable worker could fill with important tasks, but that a minimally supervised crew of high school kids might not use wisely.

Certain pieces of equipment can help to create systems that workers plug in to, with widgets to crank and a machine to dictate the pace. They can also require a lower input of skills, speed, and personal motivation to do the job quickly and well. Bell peppers in a tank can be removed quickly or slowly, and may get scrubbed or may just get swished around, whereas peppers run through a brush washer move at a certain pace, reducing the human factor in how fast or how well the work gets done.

Is This Driving Me Nuts?

Most people get into farming, or stay in farming, for quality of life reasons. If your current systems leave your hands cold, break your back, or take away from the time you should be reading bedtime stories to your children, that alone can be an adequate reason to consider investing in post-harvest handling equipment.

The Ripple Effect

Occasionally, an investment will have far-reaching effects. For a farm that washes all of their fall roots at one time, speeding up the washing and packing process may provide an additional opportunity to finish fall field work. If that field work includes tasks such planting a final cover crop of rye that builds the soil and controls weeds, the effects of the additional time available at a critical moment may be hard to quantify, but it is meaningful nonetheless.

Packing Facility Considerations

A packing facility for fresh produce ideally provides a comfortable, safe, and efficient environment for people and produce alike. Facilities can range from a bare minimum to something that resembles a licensed processing facility.

Minimum Requirements

It doesn't take much to get started with a packing facility, but some basic considerations should be taken into account:

A Roof - Some sort of roof, and preferably side walls in addition, should be used to provide protection from sun, wind, and rain. Small farmers often start with a simple farmers' market awning. At the author's Rock Spring Farm, a 20-foot wide hoophouse with high roll-up sides was used for this purpose; in the summer months, shade cloth provided protection from the sun's heat. Although less than ideal, this setup enabled packing in relative comfort for four seasons every year.

A Walk-In Cooler - Every farm visited for this study had a walk-in cooler. Although many ways exist to chill produce, keeping it cool presents another challenge altogether. A walk-in cooler provides the ability to pre-harvest crops, and deliver them chilled to the customer.

Water - At a minimum, the packing facility needs access to a supply of clean, safe water, and a way to move it away from the workers' boots. A deep gravel bed can provide an inexpensive way to drain water away, as can drainage hoses from the drain plugs of tanks.

Bathrooms and Handwashing Facilities - While none of the farms visited for this study had a bathroom attached to the packing house, all had a bathroom available for use by employees and workers. Hand sanitation in the bathroom and in the packing shed is a must; the absence of a handwashing sink creates an additional burden on management to guarantee the cleanliness of hands that come in contact with the produce.

A simple handwashing area can be created with a small, instant electric water heater, a basin, and a soap dispenser for under $500; while warm water isn't necessary to soap's effectiveness, it does increase the likelihood that workers will scrub their hands for the recommended 20 seconds.

Other Food Safety Considerations - Allowance should be made for sanitizing equipment and facilities, and pests should be excluded. Open-air packing facilities can't exclude pests, but can make the packing area less inviting to rodents, flies, and birds by keeping the area clean of debris, installing bird netting over open rafters, and moving pallets regularly.

Food Safety

While food safety issues are beyond the scope of this document, they are important. With every new health scare, the likelihood that all farmers producing food for humans will be required to meet certain standards for facilities and procedures. Any vegetable farmer intending to stay in business should understand the steps they may need to take in a regulated environment, and make investments that will achieve those steps.

Water

Water may well prove to be the most troublesome element in improving packing operations. Most post-harvest handling equipment uses water to clean and cool the produce, so you need a plentiful, easily accessible supply of clean, safe water. Brush washers and barrel washers rely on a consistent supply of water; although manufacturers can provide more concrete information, a large brush washer can use up to 1.5 gallons of water per minute.

For crisping tanks and tank-type barrel washers the rate at which the tank fills can be a severely limiting factor. With inadequate water supplies, slow tank-filling requires a degree of organization and regimentation that can be difficult to achieve. At a rate of 10 gallons per minute, a 300-gallon tank will take half an hour to fill, so cycling a full tank of dirty water to a full tank of clean water can easily involve 45 minutes of downtime. (Not to mention that at low flow-rates, filling a tank with a hose can make it impossible to have a washing machine operating in the house concurrently!)

Washing vegetables uses a lot of water, and it has to go somewhere. The three-season packing houses visited in this study all drain vegetable wash water out to a pasture or grassy waterway. For a four-season packing facility, deep water line burial to avoid freezing would be an important consideration.

Adequate drainage from the packing area has an importance equal to or greater than an adequate supply of water coming in. The change from washing in a tank to using a barrel washer, for example, changes the ability of the ambient water to remove dirt and mud from the washing area; draining a tank creates a large flow of water all at once, sluicing the mud away with it; at 1.5 gallons of water per minute, a barrel washer allows mud to build up directly underneath it; in addition, without a catch pan, water from a barrel or brush washer can't be directed to particular location, increasing the importance of adequate drainage and slope.

Materials Handling

In many ways, farming is a materials handling game. The more stuff you move the more quickly (while maintaining product quality) the more profitable your farm is likely to be.

Concrete may well be the foremost way to improve the materials handling aspect of the packing shed. Pallet jacks operate most efficiently on concrete, and it can greatly increase the ease of operation for two-wheeled dollies.

Access points should be designed according to product flow, and made flexible enough to accommodate new knowledge and new developments. Even for farms operating on a very small scale, all access points should be designed for the potential use of a pallet jack, with room to steer in and out.

Access for harvest and delivery transport should also be considered. For harvest vehicles, drive-through capability can greatly increase the efficiency with which product can make the transition from field to packing shed.

Coolers for Produce Storage - You can't build a big enough cooler, so packing shed design should accommodate future potential needs for cooler expansion. Coolers should be big enough for palletized product, with enough room to maneuver and organize product as well as to store it.

Additional Storage - Waxed produce boxes, although designed for contact with moisture, are not designed for continual, long-term contact with water. They must be stored in a dry area. Rodents also have an excessive fondness for these expensive items.

Plastic clamshells can deform slightly in extremely cold weather, causing them to close with difficulty or not at all. Accommodation should be made for temperature-controlled storage for these items.

Electricity

Most post-harvest handling equipment utilizes some sort of electrical motor. Electrical outlets should provide adequate access without stringing electrical cords over long distances or through water. Outlets should be protected with a Ground-Fault Interrupter (GFI, or GFCI) switch, and be outfitted with a wet location in use cover

to keep water from contacting outlets that have equipment plugged in. Most equipment runs on a 110-volt supply, although refrigeration and ice machines may require a 220-volt supply.

Seasonal Considerations

In the Upper Midwest, the three-season packing facility seems to be the most prevalent design. All of the facilities visited for this project were open to the elements, and none had made arrangements for permanent heat in their packing facilities. Two had the potential to be sealed up and a unit heater utilized to provide temporary heat.

Growers looking into season extension—either with hoophouses or storage crops—should consider for how many dates each week and for how long into the winter they plan to wash and pack their produce when designing a packing shed.

Water management in an Upper Midwest winter can provide a real challenge, since extreme temperatures can freeze even moving water. At Rock Spring Farm, the author installed perforated drainage tile pipe five feet below the ground to move water from the packing shed to the drainage area, providing an opportunity for water to gradually soak into the groundwater on its way to a possibly frozen outlet.

System Capacity

As a farmer himself, the author is aware that farmers tend to run themselves and their facilities at overcapacity much of the time. Most market farmers can't afford to invest in excess capacity that creates additional overhead, but at the same time, we can't ask our employees to do what we, as entrepreneurs, are willing to do to achieve financial and lifestyle success. Designing a facility that is large enough, but not too large, and comfortable enough, but not too comfortable, is a task very dependent on the experience of the individual grower.

Featured Vegetable Growers

The following descriptions of facilities and handling equipment at three featured farms—Gardens of Eagan, Hog's Back Farm, and Spring Hill Community Farm—can help you develop your own post-harvest handling system.

Gardens of Eagan

Linda Halley, Farmington, MN

"Your kale is so much better and lasts so much longer than kale from the other local producers."

Martin Diffley started Gardens of Eagan in 1973 on five rented acres in Eagan, Minnesota; he was joined in 1985 by Atina as his wife and farming partner. In the mid-1990's, Martin and Atina moved the operation to Farmington as the old land-base succumbed to suburbanization. In the fall of 2007, the farming business was sold to Wedge Community Co-op in Minneapolis.

With over twenty years of experience in organic vegetable production on both large and small farms in Wisconsin and California, Linda Halley took over management of the 65 acres of vegetable production in January of 2008.

Gardens of Eagan has narrowed its focus over the years to selling only to retail stores and wholesale distributors in the Twin Cities, which has a large number of cooperative natural foods stores. Martin and Atina also focused their attention on a limited number of crops: cucumbers, tomatoes, broccoli, cabbage, kale, cauliflower, bell peppers, watermelons, and sweet corn. This has allowed Gardens of Eagan to develop very efficient systems for the production and handling of these crops.

Crops are delivered three days each week during the main part of the season, on Tuesdays, Thursdays, and Saturdays. Most of the harvest, washing, packing take place on Mondays, Wednesdays, and Fridays, with the refrigerated truck loaded on the same night for early-morning departure on delivery mornings. In the peak of the season, Linda may choose to harvest an additional day ahead, making decisions based on how well things keep and the optimal time of day for harvesting; occasionally this is necessary because there is simply too much crop to harvest in a single day.

Gardens of Eagan has a very large crew to conduct and manage the entire operation. On the harvest-wash-and-pack side of the operation, farm manager Linda Halley is assisted by a production and harvest manager as well as a packing coordinator. Additional harvest labor is provided by a crew of five to eight persons. Three more employees work seasonally full time to cover other farm operations.

Facilities

A converted farm shop provides an ample space for washing and packing the produce at Gardens of Eagan. High ceilings and large sliding doors on the south and the west sides make the 40-foot by 40-foot main packing area a pleasant and accessible space, with plenty of room for storage of boxes and harvest totes, a brush washer, a sorting table, and a break and organizational area.

A shed roof over the north side of the building provides a 10-foot wide by 40-foot long space for crisping tanks and pallet jack access to the 16-foot by 20-foot walk-in cooler. Bird netting in the rafters prevents nesting in this open-air portion of the facility. A 12-foot overhead door separates the shed area from the main packing area, leaving ample access for the flow of product and personnel from one space to the other.

The packing facility has a handwashing sink with hot and cold water, and a portable toilet with a handwash station about 100 feet away.

Crops are harvested into a fleet of old U-Haul trucks, which provide easy shade and a convenient height during the harvest. Full trucks back up to the packing facility, and dirty product is washed prior to storage. Often, crops are put directly from the truck into crisping tanks or the brush washer, with no additional stacking or handling. Because of the large scale of the harvest, the harvest crew will frequently bring in half of the harvest, back the truck up to the packing facility, and take another truck out to the field as the packing process begins.

Handling Equipment

Gardens of Eagan uses two 180-gallon Rubbermaid-style stock tanks supported by welded steel frames for crisping their greens. Because of their large size, the tanks have been retrofitted with PVC drains on the bottom of the tank, rather than the standard side plugs positioned an inch above the bottom of a stock tank. Although Linda would prefer a stainless steel milk tank for the ease of cleaning it would provide, the two long, skinny tanks work very well in their location.

An ice machine provides flaked ice that can be added to the top of boxes for additional cooling for the kale, and also a topping for the broccoli, which does not get washed. Two wheeled bins provide storage for ice beyond that available in the machine itself. Crops are topped with ice prior to being moved into storage.

The crisped kale, combined with the ice treatment, lasts much longer than kale that hasn't gone through a dunk tank, but it does have the disadvantage that it needs to be packed into a larger-than-standard box than it would if the ice was allowed to provide the humidity to firm up the leaves. In a smaller box, the kale would get shredded if it wasn't slightly wilted.

A 20-inch wide brush washer provides fast cleaning of peppers and cucumbers. Gardens of Eagan doesn't have an in-feed belt, so overturned totes position a full tote of produce for manual movement into the washer. Drying donuts remove surface moisture at the outlet, and a circular sorting table rotates at the end of the drying donuts to provide easy access for sorting and packing, as well as a place for product to build up without overflowing.

A washable-laminate covered table, approximately four by eight feet, provides ample space for sorting, grading, and packing tomatoes. A shelf under the table stores tomato boxes for quick and easy access.

The extensive use of concrete at Gardens of Eagan makes the use of pallet jacks almost mandatory for moving clean and packed product into the cooler, and from there onto the truck. The scale of the operation makes it practically mandatory.

Hog's Back Farm

David Van Eeckhout, Arkansaw, WI

"Efficiency is more important than diversity of items or markets."

David Van Eeckhout started Hog's Back Farm in 2003 at a farm five miles south of its current location. Prior to starting his own operation, David worked for several leaders in the local and organic foods movement, including New Morning Farm in Pennsylvania; Red Cardinal Farm in Stillwater, Minnesota; and Riverbend Farm in Delano, Minnesota, where he spent three growing seasons. Despite David's ample and broad experience, Hog's Back Farm started small, and grew slowly, using his available capital to finance new investments in equipment and infrastructure.

In 2006, David moved the farm to its current location, where he has five acres in vegetable production at any given time, with about 20 acres in rotation. Almost all of Hog's Back's production goes to its CSA subscription program, which currently sells 165 shares, almost all of them delivered to the Twin Cities. Hog's Back's focus on the CSA allows the farm to excel in that marketing and production model; occasional surpluses are sold through small natural food stores and restaurant connections.

In addition to David, Hog's Back employs one full-time worker from March through November. During the growing season, David adds one additional full-time and two part-time workers.

Hog's Back's Thursday-only delivery schedule dictates the pace of the harvest and packing work on the farm, and requires some additional investment in systems and storage. On Tuesday, the crew harvest time-intensive crops, such as peas, beans, and tomatoes; on Wednesday, they harvest, wash, and pack everything else. On Thursday mornings, CSA shares are packed and rolled directly onto an un-refrigerated delivery truck.

Facilities

In time for the 2007 growing season, David remodeled the 30-foot by 60-foot lower level of a stanchion dairy barn to serve as a packing facility. The stanchions were removed, and the floor and gutters were filled with sand to provide a level surface, then covered with concrete. Circular floor drains provide ample drainage directly to the outdoors. The packing area has a metal ceiling and fiberglass reinforced plastic (FRP, commonly referred to as "dairy board") wall coverings, all of which are washable. Currently, about 40 feet of the barn's 60-foot length is used for washing and packing operations, while the rest of the area houses farm storage and a household summer kitchen.

Raising the floor has presented some challenges due to the newly limited ceiling height, including the need to cut the tops off of the used walk-in coolers David installed. Hog's Back currently runs two coolers: the cold and wet cooler, with a temperature of 34°F, measures eight by 14 feet; the cool and wet cooler, maintained at 55°F, measures eight by 10 feet. Crops that must be kept in a lower humidity environment are stored in the packing shed. The two coolers have doors that are too narrow to accept a standard 40-inch by 48-inch pallet; David has built some narrow pallets, but they are not convenient to use.

Large openings in the northwest and southeast corners, as well as the truck-loading door on the south wall, provide for generous airflow and cooling capacity. David has plans to install doors at these openings. Product enters the packing facility through a ground-height door at the northwest corner; most crops are washed before they go into storage in the walk-in coolers on the east wall. CSA boxes get packed assembly-line fashion on roller track, stacked onto home-made metal carts, and rolled out the south door directly onto Hog's Back's dock-height truck.

Hog's Back washes all of its fall root crops before they go into storage. The silty-loam soil tends to stain the roots, and Hog's Back only delivers up until Thanksgiving, so the minor damage sustained during the washing process is more than offset by the ability to avoid dirt-stains on the roots. This does, however, create a large point load for labor needed at harvest time, making the speed of operations at that time of year extremely important.

Because Hog's Back does not use wax boxes for packing outbound product, a large amount of space in the packing area is devoted to storage of a variety of plastic totes used for harvest, storage, and delivery.

Restroom and hand wash facilities are located in the farmhouse, which is less than 100 feet from the packing facility. In 2009, the hand wash will have moved into the packing facility; in the meantime, the crew uses nitrile surgical gloves for bagging and boxing products.

Handling Equipment

Hog's Back Farm does not have an extensive or expensive array of post-harvest handling equipment. Rubbermaid stock tanks, hoses, a brush washer, and a variety of tables provide the necessary tools to get their work done.

The rinsing tanks at Hog's Back included several 100-gallon tanks, and two 50-gallon tanks. The 100-gallon tanks are the most used, frequently placed on top of an overturned 50-gallon tank to achieve an ergonomic working height (the 50- and 100-gallon tanks have the same footprint). The crew uses these for washing bunched greens, removing the greens, giving them a shake, and packing them directly into plastic totes for storage.

During the harvest season, Hog's Back bunches all root crops to avoid the additional labor of bagging them in the packing facility. Bunched roots are dumped into a tank to soak before washing. To wash the roots, workers use a shut-off valve at the end of a hose to provide a pressurized spray—similar to putting one's thumb over the end of a hose—to wash the roots. "I tell people to count one, two, three, while rotating the bunch in their hand, then set it aside," David notes. Washed bunches are tossed into a rinse tub, then removed, shaken, and packed.

Many farms drain washed greens on a screen table to remove excess water, but Hog's Back doesn't. David notes that bunched greens, and bunched roots with their tops still attached, get packed into CSA boxes and shipped fairly quickly, so the decay that can result from standing water doesn't present the same issues it might for farms selling into a retail store or warehouse.

Hog's Back's packing area has several tall tables, with wooden legs and PolyMax bench panels on top. The PolyMax bench panels are rigid, black plastic designed for greenhouse benches. They have fairly wide ribs, and a one-inch grid for copious drainage. Hog's Back also has several shorter stainless steel tables for weighing and staging product. Some of these stainless steel tables are on wheels to make them easy to move into an optimal position.

The major handling investment that Hog's Back has made is a used brush washer. Theirs is a much pared down model, with no in-feed belt and no absorber to remove water; workers wheel a stainless steel table into position to put a tote of dirty product on, and feed crops such as beets, potatoes, and winter squash through the machine. At the outfeed end is a slanted table covered with a washable, green surface similar to that found in the produce

section of many grocery stores. David is looking at getting a circular sorting table and drying donuts to improve efficiency and storability of crops.

Hog's Back recently invested in a used stainless steel barrel washer for cleaning bulk roots. At the time of my visit, it had not yet arrived.

Spring Hill Community Farm

"'This is driving me nuts,' is the big motivator for upgrading systems."

Patty Wright and Mike Racette, Prairie Farm, WI

For Mike Racette and Patty Wright, 2009 will be the eighteenth year they've grown vegetables for their CSA farm. With no experience in commercial vegetable production, and a farm distinctly lacking in flat ground, Mike and Patty have developed a farm that provides a comfortable living with a minimum of hired help.

With five acres in vegetable production, in addition to cover crops, Spring Hill produces 150 shares each week, which go to the Twin Cities in two separate deliveries. CSA members help with the harvest, washing, and packing operations, and manage all of the deliveries in their own vehicles. Each delivery day, four or five cars, with a total of up to 10 CSA members, come to the farm to participate in the farm work. A single coordinator manages the scheduling through web-based calendar, and Mike and Patty have enough familiarity with their members that they know what sort of work to plan for a given day; for example, if several families are coming with children, Mike and Patty would structure the harvest schedule so that potatoes would be harvested that day for the next several deliveries.

Patty notes that this membership involvement means that Spring Hill needs to provide meaningful work, because people are "smart enough to know when they are just engaged in busy work." Spring Hill also needs to provide work that is appropriate to the available skill level: members don't pick tomatoes because that crop requires too much judgment; they don't pick beans or peas because unskilled workers are just too slow. Typical member tasks would include bunching herbs and greens, digging potatoes, and cleaning dried alliums, all undertakings that involve several people at a time, with a high rate of success.

A crew of five or six people working half time helps Mike and Patty with most of the harvest; work crews don't come in on member days. Greens are harvested ahead of member days so that they have time to pre-chill in Spring Hill's modest walk-in cooler. The efficiency loss that results from having members perform much of the work is offset by members taking deliveries to sites in the Twin Cities, saving not only labor expense but also the need to invest in a delivery vehicle.

On the other hand, Mike notes that new farmers should, "be careful what [they] start with, because it's hard to change." For Spring Hill Community Farm, scaling up would require new land and a change in their delivery and membership systems.

Facilities

The packing facility at Spring Hill Community Farm is the definition of simple, an east-facing 10-foot by 40-foot gravel area covered by a shed roof extending off of a machine shed. A supplemental building provides community space for members, as well as a kitchen and a bathroom. The packing area has antibacterial soap to supplement the handwashing facilities in the community building. The farm has a limited need for storage of boxes and

totes because they pack shares twice each week, reducing the amount of product they have on hand at any given time. Shares are packed into canvas bags for delivery.

Packing of product happens concurrently with the harvest. A four-wheeler with a trailer moves the harvest to the packing shed, and crops are cleaned before going into to the eight-foot by six-foot walk-in cooler inside the machine shed. Because the pole-style space is open to the air, it's easy to access with the trailer. Cleaned product is hand-carried to the walk-in cooler.

Handling Equipment

Because they rely on less-skilled labor, and because the twice-weekly harvest schedule means they manage less product at a time, Mike and Patty have kept their handling equipment to a minimum.

Four 50-gallon Rubbermaid stock tanks are supported on wooden sawhorses to bring them to an appropriate working height. The small tanks refill quickly, requiring less management than a single tank that took longer to fill; members and workers can easily continue washing in one tank while another fills. These tanks are used for bunched greens and peppers. Bunched greens are drained on a screen table before packing.

Spring Hill uses an electric pressure washer to clean their carrots, which are an important signature crop for the farm. The pressure washer has a variable pressure adjustment so crops don't get shredded. Carrots are topped in the field and put into totes for transport to the packing shed, where they are dumped into an empty stock tank and batch-washed with the pressure washer. Rutabagas, parsnips, and bulk turnips are handled in the same way.

Potatoes and topped beets are harvested directly into 25-pound mesh bags, then agitated in a tub of water and sorted on a grading table.

Bunched beets get dunked in a tank and scrubbed with a brush, while bunched turnips are stacked and washed with a pressure washer on a stand.