

Scaling Up for Wholesale Vegetable Production in N.W. Washington



A WSDA Specialty Crop Block Grant Project



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Introduction

Scaling Up for Wholesale Vegetable Production in N.W. Washington

This document is the result of a multi-year effort of working with 12 farms and having conversations with numerous other farming operations in Whatcom and Skagit counties in Washington State. The initial goal of this project was to tease out key post-harvest strategies that could help growers potentially deliver a more consistent product to the marketplace and scale up their individual farming operations.

In the development of this document, we have used an asset-based approach to identify the key operational strategies farmers have developed to produce these crops in Northwest Washington successfully and profitably. As scaling-up conversations with farmers deepened, it was clear that the conversation had to include the scope of the project's key production practices as well.

These practices included identification of peak labor demands in more labor-intensive crops, basic infrastructure needed to broaden a farmer's crop offerings, as well as emphasizing the importance of operating a labor efficient wash/pack operation. We made multiple farm visits to gather strategies, production techniques, challenges in growing their businesses, photo documentation, and information about the operational requirements that are demanded in today's food safety world.

The farm visits also showed how innovative Specialty Crop Producers are. The interviews and on-farm observations showed that there are many successful strategies and approaches to growing a particular crop. There were two components that stood out while observing production practices: the need for mechanization to reduce labor needs in the field and the need for improved/larger facilities for wash/pack operations and longer-term cold storage.

This document is not intended to be a comprehensive crop grower guide, as many excellent publications already exist. The content of this document is intended to enhance the body of knowledge and share the collective experience of growers from our region. Hopefully, it also functions as a resource for Specialty Crop producers looking for new ideas to incorporate into their operation or to see if they are already incorporating best practices into their production.

While the document averages over 10 pages per crop, it only scratches the surface of the complexity involved in today's agricultural operations.

This current document is largely completed; the final expanded document will be posted in September.

SCALING UP CONSIDERATIONS, WHOLESALE BEET PRODUCTION

Level of Difficulty:

Beet production was identified by the cohort of growers involved in this study as an easy crop to grow in relation to other vegetable crops commonly produced in the region. However, several steps were pointed out as critical in producing a profitable crop. Notable comments were that harvest management can be quite challenging if attention isn't paid to variety selection, disease resistance and access to additional labor at harvest time.

Infrastructure Requirements

- Seeding equipment: walk behind seeders, 3-point hitch multi-row seeders
- Field harvest strategy: use of totes or macro bins
- Basic Wash-Pack equipment that can be used for numerous vegetable crops
- Cold Storage if planning to sell bulk beets through the winter

Soils /Fertility

- Beet prefer high organic matter soils with good drainage.
- Beet growth responds best to even moisture and good drainage.
- Beets perform best in light sandy or loamy soils. Growing on clay soils can make harvesting difficult.
- Beets have a higher-than-normal boron requirement. It should be noted that many soils in NW Washington have low boron values. Annual soil testing is important.
- Best quality beets are grown with an adequate moisture supply; irregular soil moisture levels on the dry side can exacerbate boron deficiencies, resulting in Beet Scab.
- Beet fertility requirements are generally considered fairly heavy feeders.
- pH should be maintained over 6.0. A soil test should be done annually, preferably at the same time of year. Many farms in the region pull soil tests anytime between November – February.
- Fertilizer application rate is 600lbs/acre. Feather meal/bone meal, fish meal mix with trace minerals is what several growers like to use. This product can supply a regulated-flow of nutrients all season. “It’s expensive but worth it.”
- Generally, as farms mature and acreage increases, some farms start to purchase certain bulk fertilizers directly with significant cost savings. It has also been the experience with many farms to share or combine orders to get better pricing.

Varieties

- Specific varieties for bulk and storage:
 - Cylindrical Red Ace, Boro (has Cercospora resistance) are the primary varietals grown for bulk and storage beet production.
 - Bunch Beets: Boro along with Subeto F1, a newer variety that is slightly earlier than Boro (has no Cercospora Leaf Spot resistance) but is a more refined beet.
 - Chioggia and Golden beets are widely grown with popular varieties being Touchstone Gold and Guardsmark Chioggia.
- Germination percentage by variety or beet can be much more variable than for other crops.
- To ensure full stands in your fields take the Germination Rate listed on bag/pack into consideration when deciding on plant density in your rows.



Transplant/Direct Seeding

- Most beets are direct seeded by single and multi-row seeders.



Two single Planet Jr. Seeders attached to tool bar and three-point hitch. Versatile planters can be slid to nearly any row width for multiple crops.

- One grower successfully transplants beets due to the challenge and high labor costs in weeding.
- For germination, soil temperature needs to be a minimum of 60 degrees.
- Several growers sow at 4 seeds/ft. in row for bulk beets.
- For bunched beets thin stand to one plant every 2".
- Seed is sown so close to the surface that some growers seed as soon as the ground is workable.
- In most years the first planting is in early April as soon as the ground is dry enough to work.

Seeding Equipment

- One farm uses a Stanhay 4-row seeder along with 4-row cultivators. Use equipment that can plant and cultivate the same number of rows so your cultivation equipment lines up perfectly with your seeding distances.
- One farm uses Planet Jr. seeder with a 4" scatter shoe. This farm is scaling up their production in 2021 to use same 300a Planet Jr. seeder but using four ganged together as a 4-row seeder this coming year.

Pre-emergence

- It is fairly common practice to flame planting prior to germination.
- Rotations need to be planned-out, so that when you start seeding beets and carrots you are seeding on soils that have had proper weed control the year before. This is considered a pretty standard and necessary practice.

Field Production/Cultivation

- Selection and preparation for beet production is important due to the hand-weeding requirement needed most years in the region. Keeping a field weed-free and not allowing any weeds to go to seed the year before a field goes into beets is important. Handing hoeing beets in a field with a high seed bank can prove to be cost prohibitive.
- Initial hand-weeding, tractor cultivation 4-6 times. Cultivation frequency 7-14 days is considered ideal through harvest. This however is very weather dependent.
- You know you've waited too long if you start pulling beets out with your weed roots.
- A second, hand weeding is sometimes needed. This should take place before beets fill in canopy of row.
- In some years, a second-hand weeding with hoes has been required.
- Cultivation implements.
 - Lilliston's on tool bar moving to S tines as crop matures.
 - 4 row cultivator, Skeetee rear mount and belly mount



Walk behind Skeetee 2-row finger weeder. Weeding tools are mostly the same for beet and carrot production.



Versital walk behind cultivation tool. Hybrid Tilmor brand walk behind using Skeetee cultivating heads.

Water Management

- Most growers are using small irrigation reels.
- Irrigation rotation timing was often based on how many acres the water reel was responsible to cover in a rotation.
- Irrigation intervals: 10-14 days depending on weather conditions.
- Keep beets well irrigated to prevent scab from occurring.

Pest Management

- Diseases
 - Beet Scab: keeping moisture levels in your soil consistent will usually prevent occurrence.
 - Cercospora Leaf Spot: use resistant varietals.
 - For Cercospora Leaf Spot management a minimum 2 years of not growing any crop or inadvertent growth of weeds in the Chenopodium family (Goosefoot, nettles) is required.

Succession Strategies for Harvest

- For bunched beets, growers depend on six succession plantings every two to three weeks to fill out seasonal markets. For late fall storage, last sowing is usually by mid-July.



Even stand of Bunched Beets

- Bulk beets often have two sowings, with marketing season starting in August.
- Most farms consider that there is a two-to-three-week window at maturity for harvesting. Fall harvest season widens a bit more than this as the season cools and slows down.
- Growers stressed the importance of keeping a consistent supply and quality available in the marketplace. Learning and understanding the timing for succession planting is paramount in providing a consistent product to the marketplace. Every farm site and piece of land will have unique attributes.
- It's common practice to leave some percentage of your field unharvested as the next succession becomes ready for harvest.
- Keep in mind that different parts of fields and different fields can mature at different rates.

- The first couple of sowings are seeded farther apart since growth and maturity are slower in the early spring. Then sow about every 2 weeks. Last planting depends on variety and how long it will take to mature.
- Last planting will ultimately be based on your experience for the piece of land you are sowing on and will be variety dependent.
- One farm sows six successions every three weeks from April through the end of July. This means the farmer needs to sell one crop every 2-3 weeks.
- Beets in general are considered an easier crop to grow than carrots. The consensus was they can take much more abuse than carrots.
- Last sowing for beets can potentially be a week or two later than for carrots.
- Last planting depends on variety and how long it will take to mature.
- For last sowing of the year, make sure to have size on your beets before it cools down too much in the fall/winter.

Harvest

Farm 1: Second generation farm, mechanized harvest

- Same harvester is used for carrots and beets.
- It should be noted that beets are not as refined as carrots and generally have a wider set of tolerances for irregularities and size to the bulbs in a given pack.
- Beet maturity has a much wider window than carrots, which means potentially multiple harvests through the same part of a field.
- One harvest strategy for machine harvest of beets was to wait until the larger 5% of the crop are too big. They thought it evened out to lose some on the big side to maximize sellable roots towards the small side.
- Carrot/Beet harvester cuts everything at once. Beet tops are not cut as neatly as with carrots and further trimming is necessary.
- Carrot/Beet combine harvester is pulled by an 80-horsepower tractor. See images in Carrot Harvest Machinery section.
- Beets are lifted out of the ground by the tops. Tops are then cut, tubers pulled away into macro bins by conveyor.
- Second tractor 40-60 horsepower “sisters” up to the combine with four bins and paces the combine to fill all bins. Bins ride on a bin filler that has four bin capacity to load and unload bins with conveyer chain.
- Growers like the speed of machine harvest. However, they acknowledge every beet that goes into the bin translates into a lot of time grading on packing line. Pack-out range is 60-90% of the entire yield depending on field success.

Farm 2: First generation farm, semi-mechanized harvest

- 7 years farming, 40-acre farm, Beet production $\frac{1}{2}$ acre
- Beets are harvested by undercutter bar or subsoiler depending on conditions.

- Bunch Beets: are hand harvested and bunched and counted in the field.
- Typically, four beets per/ bunch.
- Beets are run through a basic setup of a short conveyor on each side of an AZS 24" vegetable washer and a 5' circular grading table.
- 1 person loads bunches individually on the conveyor. 1 or 2 people pull off washed bunches and pack directly into waxed boxes.
- Bulk Beets are hand harvested with tops cut and put into bulb flats to be "wagoned" out of the field. Beets will have a longer harvest window than carrots.
- Mid to late summer they will also pack topped #1s in bulk root bags.
- Short-term storage crop is washed and placed in poly root bags.
- For longer term, storage beets can be cut, washed, bagged and stored for up to 6 months if proper storage temperatures and humidity are followed.
- Harvest thru Wash/Pack Labor: Beets are .5 hr per person/ harvest through pack.
- Yield:4- 5 cases/ 24 count, bunched beets per 100' of row.

Farm 3: *Multi-generation farm, hand harvest*

- Grows cylindrical variety called Cylindra, where most of the beet sits above ground.
- Crop is hand harvested and trimmed into plastic stacking crates.
- Totes are weighed in field as per orders.



- Beets are hand harvested, graded, trimmed and weighed in the field before being stacked into large totes and pulled from the field on carts.
- Beets are run through a basic setup of a short conveyor on each side of an AZS 24" vegetable washer and a 5' circular grading table.
- 1 person loads bunches individually on the conveyor. 1 or 2 people pull off washed bunches and pack directly into waxed boxes.



- Bulk beets are placed on conveyor for washing and go directly into 25 lb. root bags.
- Packing time for beets is .5 hour per person per case harvest through wash/pack operations.
- There's interest to expand beet production by lengthening the sales season in late fall and winter through cold storage of product.
- Barrel washers are also a common piece of machinery used for washing product.

Beet grades

- The aesthetic requirements for beets are not as demanding as they are for carrots. Irregularity in shape isn't as important as packing comparable sizes. The USDA #1 grade is "fairly smooth, fairly well shaped" which leaves the grower with a wide range to work in.
- USDA Beet Grades and Standards: <https://www.ams.usda.gov/grades-standards/beets-grades-and-standards>

Wash and Pack Strategies

- The recurrent theme throughout this process with all farms was that labor is one of the major variables in all crops.
- Another point that has been highlighted is to take the time to setup and manage an efficient wash/pack system; it will play a significant role in a farm's profitability.
- Two farms have utilized three different wash and pack strategies for their beet harvest, and both operate successful production programs on their respective farms.

Farm 1: Wash and Pack Strategies (2019 crop was batch washed and packed, 2020 crop was run over a packing line)

- 2019 Batch Wash and Pack
 - Each individual employee grades and washes each bin of product themselves.
 - They stand at bin side with hose, pull beets out, sort, wash and then separate in totes by grade.

- Beets are then run through potato washer with final grading and packing completed on tables.
 - The grower said this process goes smoothly with little cost in machinery. There is a great deal of flexibility with staff allocation in this model.
 - This model takes at least as much floor space as a root crop packing line. One major difference is that when the wash/pack is completed the floor space is not occupied and can be used for other tasks.
- 2020 Automated Packing Line
 - See Carrot section for pictures of automated Beet/Carrot Line
 - Most packing lines move the crop over a series of belts that allow crew members to stand in one place and usually do one task.
 - The real efficiency here is that the crop is being moved on its own and staff spend their time refining the grading, sizing, washing, and rinsing until the final product is bagged and packed.
 - This line needs 10-11 people to run efficiently. These systems allow for 1 person to do one task on the line and have the ability to move a great deal of product in very short period of time.
 - The greatest challenge is to find a packing line that meets the scale of not only your production and floor space, but also a line you can operate utilizing the crew size you can allocate at that time of year.
 - The comparison of batch wash and pack compared to operating an automated packing line was estimated that running an automated packing line improved their output by 100% if not greater, using the same number of workers.
 - Beet Grade and Pack: #1 grade bulk beets- 25 lb. bulk bag.

Post-Harvest/ Cold Storage

- Cooler requirements
 - Optimal storage conditions are 32 degrees and 90-95% humidity. Beets can be stored 6 months at these temperatures after they are topped, cut, and washed.
- Length of marketable storage time
 - No grower was trying to hold product for more than 5-6 weeks.
- Storage life is better for unwashed product but can still hold up for weeks/months once washed and put in bags.
- Limited on farm storage capacity limits existing growers' ability to store beets too far into winter.
- It should be noted that carrots and beets use the same equipment to grow, harvest, wash, and pack.
- Beet Packs used by farms.
 - Bunch beets: average 1.5lbs., 4 beets/bunch, 24 bunches in pack

- Bulk beets: 25 lb. bags washed and topped.

Key Strategies for Beet Production

- Understanding varietal differences of germination variability.
- Timing for first hand-weeding.
- Weekly/bi-weekly cultivation.
- Estimating and understanding the potential labor requirements around harvest intervals.
- Well thought out packing operations.

SCALING UP CONSIDERATIONS, WHOLESALE CARROT PRODUCTION

Carrots are a classic field crop that are direct seeded into rows. Seeding, cultivation, harvest implements and packing line requirements can typically be used interchangeably with beets.

Level of Difficulty:

Carrot production was identified by the cohort of growers as an easy crop to grow in relation to other vegetable crops commonly grown in the region. However, several steps were pointed out as critical in producing a profitable crop. One notable comment was that harvest management can be quite challenging if attention is not paid to variety selection, disease resistance and access to additional labor at harvest time.

Infrastructure Requirements

- Little infrastructure is needed for carrots until harvested product is being brought out of the field and into wash and pack operations.

Soils/ Fertility Management

- Selection and preparation for carrot production is important due to the hand-weeding requirement needed in the region. Keeping a field clean and not allowing any weeds to go to seed the year before the field goes into carrots is required.



Newly weeded field with heavy seed bank

- Forking in carrots can often come from overuse or improper timing of applications of manure/compost and uneven watering.
- Manure/Compost applied in the fall is acceptable, although most growers recommend use of other form of nutrients for carrots. Manure has a long-time requirement for root crops. Pre-harvest rules for raw manure requirement is 120 days (about 4 months).
- Feather meal (slow release) is generally the main pre-plant amendment. Growers' comments were that it is expensive but worth it.
- Carrots are generally considered light feeders, so fertility requirements are comparatively small compared to other crops.
- Good air drainage is best for disease management.
- The market wants long straight, smooth carrots, which is difficult to do in many soils.
- Carrots show best performance in deep topsoil. Lighter textured soils of sandy loams or lighter loam soils with good drainage are best.
- Soil tests should be done annually, preferably at the same time of year. Many farms in the region pull soil tests from November – February.
- Crop Rotations between families of crops
 - Most farms want to keep a 3 to 4-year rotation.
 - This equates to about 25% of the ground potentially not in vegetable production every year.
- Finding cover crops that can generate revenue so the rotations are at least revenue neutral can make a substantial difference in your long-term financial picture.
- One of the many reasons cover crops are so valuable is they have the potential to uptake extra nitrogen as well as other nutrients left in the soil after harvest. Only to be plowed back into the soil in the spring as preparation for the next crop.
- Some growers apply manure solids/compost in the fall, which fulfills the annual nutrient needs for most vegetable crops.
- Special attention needs to be paid to manure applications for carrot production. Most growers recommend not using raw manure.
- Fertilizer applications: 1 only at pre-plant.

Cover Crop Practices

- One participating farm cover crops all fields annually. Fields are planted either in wheat or Fava Beans annually. In both cases, the wheat and beans were harvested as a crop to sell as well.



Fava Bean Cover Crop

Varieties

The varieties listed in this section have been identified as current and commonly used varieties in NW Washington.

- If you plan to machine harvest, it is important that you match carrot varieties suitable for machine harvest, as well as how they handle in your wash and pack and fit into market packing requirements.
- Several growers noted seed availability can be challenging some years.
- It was common on most farms to always have field trials of 6-8 varieties annually.
- Seed costs for the best F1 Hybrid varieties ensures that you have consistency within your plantings, a factor many wholesale growers consider worth it and necessary.
- Popular varieties
 - Mokum F1 (summer), Bolero F1 (fall/storage), Nelson F1, Napoli F1, have been the go-to varieties for many growers in the region.
 - There was general consensus that using F-1 hybrids in carrot production was necessary to meet production and market demands. There was concern for too much variability in open pollinated varieties.
 - Newer varieties finding acceptance in the market are Adana F1, Jerada F1, Naval F1, and Nectar F1.
 - One grower pointed out Yaga's tops were too weak for commercial production and offered Jerada and Naval as a solid replacement.
 - Different colored varieties
 - Gold Nugget (yellow)
 - Purple Haze (although purple shows limited market acceptance).

- *Machine harvest note:* It's important if considering machine harvest varieties to make sure to match your varietal requirements with your harvester. Carrot shape, brittleness, and length are all factors to consider.

Transplant/Direct Seeding

- All farms direct seeded carrots by single and multi-row seeders.
- Germination requirement
 - Soil temperature needs to be a minimum of 60 degrees.
- 20 seed/ft. is typical for growers.
- Seed is sown so close to the surface that some growers seed as soon as the ground is workable.
- Most growers said they don't go by soil temperature. First planting is in early April most years. "We will plant as soon as the ground is dry enough to work".
- The first couple of sowing dates are spaced farther apart since they will mature more slowly in early spring. Then sowing occurs every two weeks. Last planting depends on the variety and how long it will take to mature.
- For last sowing of the year, make sure to have size on your carrots before it cools down too much in the fall/winter. Early July is considered as the latest time period for sowing late fall carrots.
- Carrots rows can be spaced in multiples of 15". Growers use 15"- 30" centers so seeding, and cultivation equipment all line up with various row crops.

Seeding Equipment

- Various equipment is being used depending on the scale of production.
- Various brands of seeders (Stanhay, 300A Planet Jr. and Jimco fare) all used.
- Planting 1 to 4 rows in gangs is used along with multi-row cultivators. Most farms use equipment that can plant and cultivate the same number of rows, so cultivation equipment lines up perfectly with seeding distances.



Gang of 3 three Jang Seeders

Field Production/Cultivation

- A number of farms flame carrot rows pre-plant as well as pre-emergence.
- One farm is experimenting by planting carrot seed close to an inch deep so they can flame post planting without risk of seed damage.
- Most farms will do 1-2 hand weedings the first two or so weeks post-germination.



Handing weeding is a critical step in carrot production.

- Post germination timing for weeding is very important.
- Below are two growers' strategies:

Farm 1

- Want to wait until enough weed plants are germinated and big enough to grab.
- You know you've waited too long if you start pulling carrots out with weed roots.
- A second-hand weeding sometimes is needed. This should take place before carrots fill in the canopy.
- Tractor cultivation 4-6 times per succession was considered ideal.
- Cultivation
 - Use of 4 row cultivators Skeetee rear mount, belly mount Alloway cultivator with Illistons on tool bar, moving to S tines as crop matures.
- Cultivation frequency was 7 -14 days and was considered ideal through harvest. However, this is somewhat weather dependent.
- Carrots are hilled several times through the season.



Right sized carrots for weeding carrots



Upper left: Thoroughly weeded stand

Upper right: 60" wheel base, 3 row bed, recently cultivated using basket weeder field.

Lower right: Allis G with basket weeders

Farm 2

- Carrots weeded post-emergence.
- 3-5 days post emergence: Finger Weeder
- Hand weeding typically takes place 14 days post-emergence.
- 10-14 days followed with Basket Weeder.
- Row spacing 15 inches. 2 row system, planting with 300a-Planet Jr. single row planter.
- Cultivation equipment should match seeder or trans-planter row number. 3 row seeders use 3 row cultivators. In this example row width variability will generally take place every three rows.
- Weeding interval throughout the season is every 7-10 days.



Thorough cultivation of weeds is a critical component for successful carrot production.

Water Management

- Most growers are using small irrigation reels.
- Irrigation rotation timing was often based on how many acres the water reel was responsible to cover in a rotation.

- Irrigation intervals: 10-14 days depending on weather conditions.
- Excess irrigation can cause carrots to split and potentially become stained in heavier soils.
- One grower who grows on heavier soil irrigates to get seed germinated, then backs off on the water.

Crop Succession Strategies

- Good succession planning can extend a harvest throughout the growing year.
- Most growers depend on succession plantings every two to three weeks to fill out seasonal markets. For late fall storage, last sowing is usually by mid-July.
- Most farms consider that there is a two-to-three-week window at maturity for harvesting.
- One grower noted if soil is dry enough, carrot growth will slow considerably, even stop growing, but not die. It was also noted that depending on the time of year, you might be trying to slow down carrot growth. This strategy can lead to the problem of the next planting being ready and coming to saleable size at the same time.
- It's important to maintain a consistent product throughout the course of the year. Learning and understanding succession planting timing is paramount in order to provide a consistent product to the marketplace.
- It's common practice to leave some percentage of your field unharvested as your next succession becomes ready for harvest.
- Keep in mind that different parts of fields and different fields can mature at different rates.
- The first couple of sowings are seeded farther apart since growth and maturity are slower in the early spring.
- Main season sowings tend to be about every two weeks.
- Last planting will ultimately be based on your experience for that piece of land and will be variety dependent.
- Most growers in the study had six succession plantings per growing season

Pest Management

- Field selection and rotation go a long way to manage these pests. Growers said pest damage varies annually.
- Little management other than rotations is the current strategy.
- In bad infestation years, use of remay has been successful at excluding Rust Fly damage at a number of farms.
- PNW Insect Pest Handbook links
 - Carrot Rust Fly: <https://pnwhandbooks.org/insect/vegetable/vegetable-pests/hosts-pests/carrot-carrot-rust-fly>
 - Symphylan: <https://pnwhandbooks.org/insect/vegetable/vegetable-pests/hosts-pests/carrot-garden-symphylan>

- Wireworm: <https://pnwhandbooks.org/insect/vegetable/vegetable-pestshosts-pests/carrot-wireworm>



Rust fly damage

Harvest

General Harvest Notes

- For many farms, harvest usually starts by first pulling carrots to sell as bunched. Size of carrots that are bunched can vary. However, the smaller the carrot the more carrots per bunch.
- Topped carrots are dug when their size and condition meet USDA grades and standards. Two main grades are #1s and #2s.
- Final planting of the year: Some growers increase the last planting so they can harvest well into the late fall, as well as for long-term storage. Carrots will store well in the ground prior to a hard freeze.

Farm 1 (Second generation farm, mechanized harvest)

- Grows 15-20 acres of carrots.
- Carrot/beet harvester, pulled by 80 horsepower tractor.
- Harvesting: Carrots are lifted out of the ground by its tops. Tops are then cut, carrots pulled away into macro bins by conveyor.
- Second tractor 40-60 horsepower “sisters” up to the harvester with empty bins and paces along-side of the combine until all bins are full. Bins ride on a bin filler that has four-bin capacity to load and unload bins with conveyor chain.



L: Carrots dug, topped and conveyed to bin

R: Topped carrots headed for bin



L: Macro bins hold about 700 lbs. of Carrots

R: Bin loader has conveyor can pick up 4 bins and unload 4 bins from tractor



Grading takes place right up until product is in the bag

- Harvest personnel example
 - 3 people, 2 tractor drivers, 1 manages combine.
 - 20 bins (700 lbs.) were harvested in 2.5 hours.
- Growers like the speed of machine harvest. However, they acknowledge that every carrot that goes into the bin translates into a lot of time grading on packing line. Pack-out range is 60-90% of the harvested carrots depending on field success.
- Reasons for low pack-outs.
- Heavy Rust Fly pressure.
 - Significant rain prior to harvest can lead to numerous splits, weird shapes.
 - Uneven sizes with some too small.
 - High weed pressure, which significantly affects the development of roots.
 - In really poor conditions, pack-out could be 40% or less. It's a judgment call as to when it may be better to leave it in the field and put your time into crops that are going to be successful.

Farm 3 (Semi-Mechanized Harvest)

- Carrots are loosened by 3-point undercutter bar, or by using sub-soiler depending on conditions
- Carrots are pulled from soil by hand (*Note: Farm also harvests with an undercutter or sub-soiler depending on conditions*).
- Most of what this farm grows is bunching carrots.
- Mid to late summer they also will pack topped #1s in bulk root bags.

- Short-term storage crop washed placed in poly root bags.
- For longer term storage, store carrots unwashed dirty (stored dirty eliminates second grading if bag sits for several weeks) to preserve quality. Then the carrots are washed as needed.
- High organic matter soils can stain carrot skin if soil is left to dry on the carrots for several days.
- Harvest through Wash/Pack Labor
 - Carrots 1 person/ (24 bu) case/.75 hr
- Yield: 5 cases, bunched carrots per 100'.

Wash and Pack Strategies

- Three farms all operate successful carrot production programs on their respective farms, utilizing three different strategies:
 - Batch grading and packing
 - Basic packing line
 - Automated packing line

Farm 1 (2019)

- Each individual staff grades and washes each bin of product themselves.
- Carrot Packs
 - Three packs are utilized to sell all of their product.
 - Bulk bag 25lbs. and 50-lbs. #1 grade waxed box
 - Bagged cut/ graded #2s- 25- lb bag
 - 10/5- lb. bags per unit (bale)
- Batch wash/pack operations:
 - Stand at bin side with hose, pull carrots out, sort rinsed carrots, beets into separate totes by grade.
 - Carrots are then run through potato washer with final grading and packing completed on tables.
 - The grower said this process goes smoothly with little cost in machinery. A great deal of flexibility with staff allocation in this model.
 - This model takes at least as much floor space as a root crop packing line. One important difference: when wash/pack is completed, the floorspace is not occupied and can be used for other tasks.
- Automated packing line
 - Most packing lines move your crop over a series of belts that allow crew members to stand in one place and usually do one task.
 - The real efficiency here is the crop is being moved on its own and staff spend their time refining grading, sizing, wash, and rinsing, with final product bagged and packed.

- This line needs 10-11 people to run efficiently. These systems have the ability to move a great deal of product in very short periods of time.
- The greatest challenge is to find a line that meets the scale of not only your production and floor space, but also *a line you can operate utilizing the crew size you can allocate* at that time of year.



L: Outside bin dump and wash process for carrot and beet line

R: Use of 4-season greenhouses can be a cost-effective way to house a wash pack facility. Don't forget the shade cloth! Inside Grading and Packing Components of carrot/beet line.



Wash Pack staff, photo taken during Covid

Note: The comparison of batch wash and pack compared to operating an automated packing line was estimated that running an automated packing line improved their output by 100% if not greater using the same number of people.

Farm 2 (second generation vegetable farm, high level of experience and efficiency)

- This farm packs only one grade of product.

- Their line has a simple washer at beginning of line. Then the product travels on a series of belts and workstations to accomplish all tasks through boxing (or baled) and then palletized.
- The carrots are hand harvested with stems attached, hand stacked onto a hay wagon, handfuls placed for ease of off-loading. Wagon is staged immediately at the packing line.



Packing line where each person does one task as carrots move down the belt.

- Packing line operation:
 - 2 people place carrots on belt, run through wash first.
 - 3 people organize carrots into bunch sizes and culls.
 - 2 people apply bunch ties.
 - 2 people pack boxes.
 - 1 person packs pallet. Entire line runs without stopping and no individuals look overly busy.
- This level of efficiency takes years to perfect.

- Crop is harvested and packed for orders only. Carrots are loaded on to delivery truck a few hours later.
- Division of labor on the line made the packing go quickly with little effort.

Farm 3 (First generation farm with seven years of experience.)

- Carrot production on $\frac{1}{2}$ acre
- All bunches are harvested by hand and bunched in the field.
- Soil is a heavy loam.
- Bunches then run through 24" wash line (made by AZS). If carrots sit out too long, dirt will stick and may require an extra blast of water to get them clean enough for market.
- Packing line is run with 2-3 people.
- 1 person places bunches on line.
- 1 or 2 people pull bunches off line and pack into waxed boxes.
- Packing time for Carrots
 - Carrots are sold as fresh untopped bunches.
 - Carrots 1 person/ (24 bu) case/.75 hr/harvest to pack.
- Carrot Packs
 - Bunched fresh carrot packs, 12 or 24 bu., (1 bunch is 1+lbs.) Packed in wax cardboard cases.
 - Bulk Bag 25lbs.

Post-Harvest/ Cold Storage

- Cooler requirements
 - Optimal storage conditions are 32 degrees and 90-95% humidity. Temperatures above 32 degrees result in carrots beginning to sprout if head is too long.
- Length of marketable storage time
 - No grower was trying to hold product for more than 5-10 weeks.
- Limited on farm storage capacity limits their ability to store carrots too far into the winter.
- Optimal storage conditions are required if planning to store carrots for more than a few weeks.
- Carrot and beets grown, washed and packed using same machinery.
 - Packs used by farms:
 - Bunched carrots
 - 12 and 24 ct./ waxed case
 - USDA:<https://www.ams.usda.gov/grades-standards/topped-carrots-grades-and-standards>
 - Topped Carrots
 - 2 grades: #1 and #2 in all packs
 - 25 lb. bulk poly bag
 - 50-pound bulk, wax box
 - 10 count/ 5 lb. bags/ wax box

- 50lbs 1# grade, waxed box

Key Strategies for Carrot Production

- Variety selection/use of F-1 hybrids
- Timing for first hand-weeding
- Weekly/bi-weekly cultivation
- Estimating and understanding the potential labor requirements around harvest intervals was highly stressed.
- Well thought out packing operations.
- Market Driven
- IPM; Integrated Pest Management; Agricultural IPM; Organic; Vegetables; Carrots
- [Organic Farming Practices: Post Harvest](#)
https://vric.ucdavis.edu/pdf/postharvest_organic_handling.pdf

SCALING UP CONSIDERATIONS, WHOLESALE CAULIFLOWER PRODUCTION

Level of Difficulty:

Cauliflower production was identified by the cohort of growers as a challenging crop to grow in relation to other vegetable crops commonly grown in the region. Variety selection, disease, package, and access to additional labor at harvest time are important factors in growing a successful crop. For many growers, their 'main crop' harvest window is late summer into fall harvests.

Infrastructure Requirements

- Seeding assists for transplants: vacuum seeder (100+ flats).
- Greenhouse space to grow starts.
- Mechanical transplanter
- Spacing for head-size
- Overhead irrigation
- Field harvest/pack-ability

Soil type/ Fertility

- To manage successful brassica production over the long term in NW Washington, it will require careful management with a Crop Rotation Plan. Key components include a strong fertility program that manages pH in the upper 6's to 7.
- Cauliflower, like all brassicas, are very susceptible to Club Root. In an ideal world, keep to a crop rotation of minimum of 5+ years. Keeping your fields with a higher pH could also help with reductions in Club Root.
- Having good sanitation protocols to protect soils from Club Root exposure is essential to long-term success in growing all brassicas. Club Root can spread from field to field on tires, implements, hoes, and shoes.
- Soils with high fertility and good water holding capacity will give best results.
- Sandy soils can be successful with thorough fertility and timely irrigations throughout the growing season.
- Clay loam and heavier soils are typically favored for brassica production.
- Cauliflower like other brassicas require a higher pH soil.
- It is important to have an adequate supply of nitrogen and high enough pH for adequate molybdenum to become available. Molybdenum is known to improve curd yield and decrease the incidence of whiptail. Phosphorus levels play a significant role in head quality and yield.
- Stages of cauliflower development should drive your fertility program.
- 4 Stages of Cauliflower Growth
 - Development of leaves and roots

- This is a seedling stage. If transplants are delayed and plants have entered stage two, transplants run the risk of becoming stunted.
- Outer leaf development
- Buildup of nutrients of outer leaves
 - This is an important stage where if you think your nutrient levels are a bit low, a side dress application properly timed could give your plants a needed boost.
- Flower formation.

Varieties:

The varieties listed in this section have been identified as current, commonly used varieties. Listing these is not an endorsement.

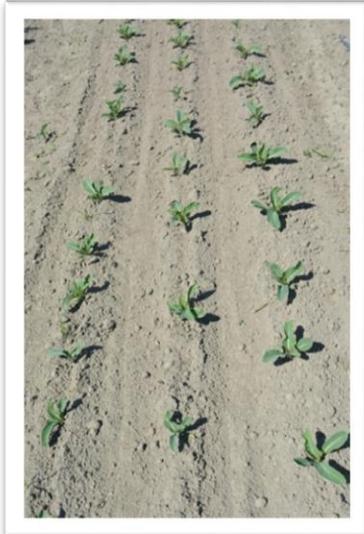
- Early Season: Bishop
- Mid- season: Melrose
- Late season, main crop: Janvel

Seeding/ Transplants

- Three fall sowing of transplants, 1-2 weeks apart
- First sowing date late May to early June. Give transplants 4-5 weeks to get to transplanting size.
- Several growers acknowledge transplants must be in the ground by 7/4.
- Optimal soil temperature at planting is between 65-75 degrees.

Field Production/ Cultivation

- Field Layout and Spacing
 - In row spacing of cauliflower will significantly impact head size.
 - Starting with a spacing trial and an understanding of what size your markets are interested in will be critical information in growing a successful cauliflower crop.
 - Several growers successfully plant cauliflower spaced 12" in row and 40" rows
 - Use of tractor pulled transplanters can provide consistent space in a planting.
 - Irregular spacing in row and inadequate spacing between rows will have major implications on head size at harvest.
 - First weeding is by hand hoe, up to 2 more subsequent weeding's are completed by tractor driven Lilliston/ basket weeder.
 - Several growers successfully plant cauliflower spaced 12" in row and 40" rows
 - Use of tractor pulled transplanters can provide consistent space in a planting.





Rows are hilled multiple times for weed suppression and water conservation.

Water Management

- Consistent irrigation applications are needed to keep soil moisture at even levels for best curd development in producing marketable heads.
- Matching evapotranspiration rates to your irrigation management can play a significant role in head size and yield.
- Overhead irrigation reel and hand lines are both common amongst farms growing brassicas.



Overhead irrigation reel, hand lines both common amongst farms growing brassicas

Pest Management

- Diseases
 - One cannot talk about Cauliflower diseases without mentioning Club Root.
 - PNW Handbook: <https://pnwhandbooks.org/plantdisease/host-disease/cabbage-cauliflower-brassica-sp-clubroot>
 - Cabbage loopers can be intense in fall plantings and destroy a healthy field in days.
 - PNW Handbook: <https://pnwhandbooks.org/insect/vegetable/vegetable-pests/hosts-pests/broccoli-brussels-sprout-cabbage-cauliflower-looper>

Pre-Harvest / Harvest Implementation

- Harvest timing
 - Harvest off each planting 2-3 weeks.
- Yield per 100 linear feet can average 100-125 pounds at 18" spacing/ 75 plants/ 16- 20 oz. heads.
- Good succession planning can extend a harvest run over 2-6 weeks depending to time of year.
- Harvest intervals average every 2 weeks.
- Most growers depend on succession plantings to fill out seasonal markets.
- It is important to estimate and understand the potential labor requirements around harvest intervals.
- 1 person finish packing, weighed and stacked for 4 harvesters.
- All grading/packing and weighing is completed in field.



Harvest with outer leaves to protect delicate head.



Heads packed at 30 lbs./ case. Some markets will accept all sizes of heads if quality is maintained.



L: Hand cut with harvest knives, harvested into totes for easy movement and carrying to the wagon.

R: Some version of packing in the field can be very cost effective with the right sized organization.



L: Field harvesters place totes on packing platform pulled by tractor in the field.

R: Unmarketable heads are slashed in field as seen, to reduce double checking by harvest crews.

Post-Harvest

- Vented cold storage containers and short macro bins (cherry bins) are good cold storage containers to be used in cold storage.
- Growers stress the importance of careful handling of heads during harvest.
- For storage and harvest keep multiple leaves on the harvested head. They provide good protection from bruising.

- In cold storage, cauliflower is sensitive to ethylene gas if held for more than a week. It's important to note that all fruit crops release ethylene gas in their ripening process and will be a significant source of ethylene when fruit and vegetables are stored together.
- Look at packing cost labor if you plan to harvest and repack at wash facility. Heads are fragile and risk damage at every handling step.
- Cauliflower stores best at 32 degrees with humidity at a minimum 80-85%.
- Temperature is the principal factor in harvested produce. Temperature affects the rates of all essential components: respiration, ripening, moisture loss and the ultimate breakdown into decay. Simply put; the higher the temperature, the faster these processes occur.

Labor Comments

- Timely initial hand weeding, well managed bed- two rounds finger weeding, 1 hand weeding.
- Field harvest and packing labor can often be 50% of total labor costs.

SCALING UP CONSIDERATIONS, WHOLESALE SLICING CUCUMBER PRODUCTION

Level of Difficulty:

Slicing Cucumber production was identified by the cohort of growers as an easy crop to grow in relation to other vegetable crops commonly grown in the region. However, when it comes to harvest management it is considered a challenging crop if attention isn't paid to variety selection, disease resistance and access to additional labor at harvest time.

Infrastructure Requirements

- Seeding assists for transplants: vacuum seeder (100+ flats).
- Greenhouse space to grow starts.
- 300'-400' sq. ft. per row = 100' of row @ 3'-4' spacing between rows.
- Basic Wash and Pack equipment. If you are growing a number of vegetable crops that require washing or simply a rinse, consider a basic packing line setup to improve your post-harvest efficiency.
- Chilled water at 34 degrees for washing.
- Greenhouse: four season greenhouses and 3-season tunnels have been, and are still, successfully used for cucumber production in the region.
- For trellis details see: Trellis notes under Supporting Documents for Tomatoes.

Soil type/ Fertility

- Participants have had good success growing cucumbers on many soil types from sandy loam to drainable clay.

- Cucumbers are heavy feeders so good fertility is important.



- Multiple fertilizer applications are recommended by growers starting at first bloom and continue with weekly application through harvest.
- Most grower's fertility management priorities center around the use of Consolidated Organic liquid fertilizer that is applied through drip irrigation 1x/week.
- Two types of fertilizer injector brands are commonly used, Dosatron and Mazzei. See Supporting Links for sources.



Setup to attach Dosatron or other injector for fertigation

- Dosatron fertigators allow you to easily manage dilution of fertilizer applied.
- Some growers side dress with Certified Organic blend based off soil test.
- Micro-nutrients important in producing high quality cucumbers are boron, phosphorus, and calcium. Pay attention to soil test for deficiencies.

Varieties

The varieties listed in this section have been identified as current, commonly used varieties. Listing of these varieties is not an endorsement.

- Most growers grow European varieties like Socrates that technically are thin-skinned varieties, then sell them into slicing markets.
 - *Socrates*: Thin skinned, European type that is commonly grown and sold as a slicing variety. This variety is parthenocarpic (doesn't need pollination), has a good disease package, and a solid performance record in N.W. Washington. Very high yielding, F1 hybrid. Must be grown on trellis.
 - *Paraiso*: Widely grown in this region and again is technically a European variety that is parthenocarpic that needs to be grown on a trellis. It can fit into the slicing market as well. High yielding, F1 Hybrid.
 - *Bristol*: The first commercially available cucumber hybrid with intermediate downy mildew resistance. Trellis is preferred for best production. F1 Hybrid.
- Some growers plant open field plantings of true slicing/thick skinned varieties such as decades old Marketmore76.
- Seed cost for the best F1 Hybrid varieties ensures that you have consistency within your plantings, a factor many wholesale growers consider worth it and necessary.
- Seed cost for the best hybrid varieties and loss of seeds from direct seeded beds to birds was pointed out as reasons why the preference was to transplant starts in most cases, particularly in open field plantings.



F-1 hybrid Socrates



Field Run F-1 Hybrid Consistency

Water Management

- Most slicing cucumbers are grown in tunnels on 6'+ tall trellis.
- Drip irrigation in most soils is used to address the plants' needs for consistent moisture.
- Plantings in heavy clay can add another layer of challenges and must have a sound water management strategy and the ability to control when and how much water is needed.
- Use of soil moisture monitoring tools takes the guess work out of water management. A good Wi-Fi water management system is the Wireless Tag Center: <https://wirelesstag.net/index.html>
- If growing open field varietals, using overhead irrigation early morning to early afternoon was cited as good strategy for minimizing disease conditions (plant and fruit dry out quickly).

Transplants/Direct Seed

- A frequent problem in seeding warm climate crops in Northwest Washington is that soil temperatures can be slow to warm up. Use of a temperature probe or a local Ag Weather-Net Station (see Supporting Links) should be used to verify soil temperature. Make this part of your planting protocol as it only takes a second and is a good defensive practice. Too low soil temperature can be disastrous when seeding/transplanting for seeds to sprout or new roots to develop. Cucumbers are particularly sensitive to soil temperatures.
- Soil temperature needs to be at a minimum of 60 degrees before transplanting or direct seeding.
- Successful seeding examples
 - 98 cell flats transplanted out with 1-2 true leaves.
 - 50 cell flats widely used.
- Some growers seed into 4" pots so when planted out they are more established. The smaller the cell the more precision in timing is required.

- In all cases a granular fertilizer blend was applied before seed or transplants were field planted.
- Cucumber seedlings are sensitive to root disturbance, and rough handling during transplanting can lead to severe stunting of plants and delay harvest. Careful handling of seedlings should be observed.

Pest Management

Diseases

- Downy Mildew is the primary disease that growers face annually. Careful variety selection will allow you to have several successions of plantings before the Downy Mildew becomes a significant challenge.
- <https://pnwhandbooks.org/plantdisease/host-disease/cabbage-cauliflower-brassica-sp-downy-mildew-staghead>

Field Production/Cultivation Methods

- Direct sow, hand transplant, and mechanical transplanters are all used. Cost and risk should be part of your decision-making process when considering direct seeding vs hand or machinery-based transplanting.
- Direct seeding without the use of poly film mulch was not considered a viable program. The concern was weeding labor would be too high.
- Aggressive weed control before canopy fills out was considered critical to the success of this crop. Cucumbers will not compete well with annual Eurasian weeds or grass.
- Where do you want to spend your time? Weekly weeding or would some type of weed barrier allow you to focus more on training and keeping your plants healthy?



One grower plants spring crop of greens that are harvested before cucumbers begin to fill a netted trellis.

Trellis Considerations

- Most Slicing cucumbers are grown in tunnels on 6'+ tall trellis.
- Many growers hang heavy orange bailing twine from 4 season greenhouse trusses. This is a very cost-efficient strategy as long as you know the load abilities of your greenhouse.
- Hanging twine in a 3-season high tunnel will likely cause you problems and isn't recommended.



Leave adequate space on edges.

- Standardized trellis construction allows infrastructure to be reused and to go in quickly: consistent stake distances; annually reusable uniform anchor leashes; consistent anchor distance from stake.
- Reusable weed barrier holds in soil moisture and minimizes areas in tunnels/greenhouses to be weeded.
- Weed Barrier also allows for easy maneuvering of harvest carts.
- Sanitize all parts of greenhouse or tunnel after each growing season.
- Irrigation is timed and scheduled for maintaining even moisture levels.



Stay ahead of growth and cucumber development to ensure cucumbers don't get bound up in your training. This will ensure a development of straight long cucumbers at harvest.

Harvest

- Peak season harvest can demand harvesting daily to keep cucumbers to a marketable size. This means harvesting and discarding fruit if picked too large for market demand.



- Harvest timing was noted to be tied to success with this crop. Grower recommendations range from a target size of 4" to 8" to 10".
- Make sure you understand what your market's target size is.
- Yield per 100 linear feet can average 50 pounds per week.
- Good succession planning can extend a harvest run over 10 weeks.
- Most common harvest interval is every other day, during peak season every-day.
- Minimum harvest intervals 3x/ week up to 7 days/week in warmer than average conditions.
- Harvest experience on 1 farm/ 2 people was 350-400 lb, with a 1 hour harvest and 2 hour wash and pack.
- Most growers depend on succession plantings to fill out seasonal markets. Several growers plant 4 plantings one week apart.



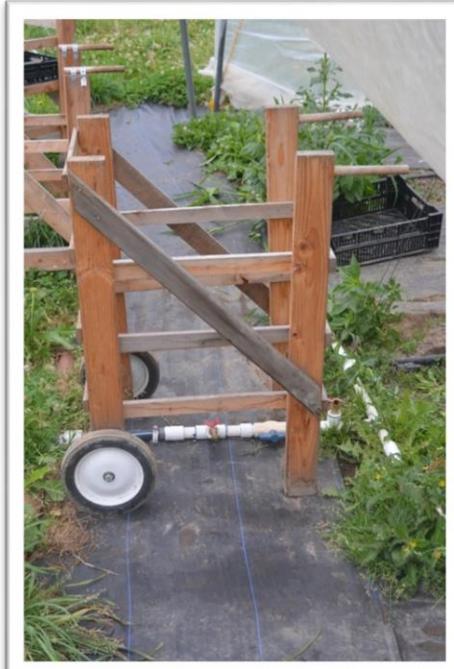
- Harvest is done by hand and with small pruners. Stems are cut short to reduce skin damage inflicted on other cucumbers in the box.

- Cucumber skins are fragile and harvest crews should be trained to avoid significant damage in the harvesting process.
- Estimating and understanding the potential labor requirements around harvest intervals was highly stressed. If the weather demands daily harvest is there enough harvest crew in place without compromising other production responsibilities?



- Consider harvesting into deep flats versus into 5-gallon buckets.
- At this farm cucumbers are harvested and chilled into yellow-topped 20 lb totes, then packed directly into ship case.

- Harvest carts minimize worker fatigue and easy handling of harvest crates.



- Some growers consolidate from harvest buckets into larger 25-40 gallon containers before going back to wash/pack operations.

Post-Harvest

- Vented cold storage containers and black bulb flats are good cold storage containers to be used in cold storage. Cucumbers should be chilled down to pull the heat out of the fruit. If cucumbers are left to sweat in storage containers this has the potential to reduce shelf life.
- Cucumbers are extremely sensitive to ethylene gas and should not be stored in cold storage along with fruit crops for more than a few days bitterness can be a direct result if stored more than a day or two.
- For best shelf life, hold in cooler for 24 hours.
- Length of storage time is 7 days.
- Fruit is rinsed or wiped down before packing if harvested in the field.
- Look at packing cost labor if you plan to wipe down by hand. Providing some automation in the wash and packing can provide significant labor savings. Running cucumbers over a

line to rinse and help pull field heat out of the fruit can significantly improve quality and reduce post-harvest labor time.



This farm chills down cucumbers directly from the field in harvest totes with 36-degree water then packs wet into waxed boxes. Largely eliminates extra step of washing on a line.

- Trellised cucumbers are grown in a protected environment and hang above the ground and are often not washed.
- Keep cooler humidity at a minimum of 80-85%.
- Ideal temperature is 50-54 degrees. Chilling injury can develop if fruit is stored below 50 degrees for more than 2-3 days.
- Cucumbers should not be stored in non-breathable containers (sweating can significantly damage shelf life).

Packaging

- This farm grades for cucumber length to be 8-10".
- Some growers use 20 lb. waxed boxes.
- Standard packing unit is 25 lb. box.
- When cucumbers are dry the use of an enclosed non-wax box/container helps in humidity management even when shipping a short distance.
- Keep cucumbers dry and manage humidity within the box for best shelf life.

Key Labor Areas

- Transplant
- Trellis construction
- Vine training/management- 3-4 hrs., spray zerafol for downy mildew
- Hand harvest management 3-5 x week

- Post-harvest wash/pack.
- % of labor for harvest/wash pack is 50%

Production Links:

2016 Organic and IPM Guide for Cucumbers and Squash

- While this Cornell University document is for pickling cucumbers and winter squash, the production sections are extremely useful and for the most part are applicable to N.W. Washington. The Soil Management/ Crop Rotation and Nutrient management sections will be valuable if you're considering adding either of these crops into your production plan. The overall publication is thorough in its description and evaluation of the steps and considerations for successfully growing Cucumbers and Winter Squash.

Penn State University-Cucumber Production

- Basic grower guide, has good crop calculator for Cucumbers

SCALING UP CONSIDERATIONS, WHOLESALE ROMAINE LETTUCE PROUDCTON

Level of Difficulty:

Romaine is an easy to moderately difficult crop to produce in NW Washington. The market can be very picky, particularly around size and variety. Good communication and a clear understanding of your buyers' interests is important.

Infrastructure Requirements

- This is the equipment needed to maximize labor efficiency in transplanting, cultivation and post-harvest wash and pack:
 - Seeding assists for transplants: vacuum seeder (100+ flats)
 - Greenhouse space to grow starts.
 - Figure 4 sq. ft. of flats equals 100' row of transplants.
 - Basic Wash and Pack equipment. Hand washing romaine heads can be very time consuming. If you are growing a number of vegetable crops that require washing or simply a rinse, consider a basic packing line setup to improve your post-harvest efficiency.
 - Chilled water at 34-36 degrees for washing.

Soil Type/ Fertility

- Romaine is suitable to grow on most soils.
- Clay soils considerations: Early spring and late fall plantings could have additional challenges with drainage and harvest operations in the shoulder seasons.

- Light feeder.
- Pre-transplant blend for all crops. Nutri-rich Organic Blend is commonly used.
- Some growers will grow 2 crops of romaine back-to-back in the same plot and season. One fertilizer application is made pre-plant before the first planting and utilized by both crops.
- Good air drainage is important, leaf dampness increases mildew.
- Early successions are generally more susceptible to sunburn.
- Late successions are generally more susceptible to Mildew.
- Sunburn from overhead irrigation can be a problem.

Varieties

The varieties listed in this section are popular identified varieties currently being used. There are many new varieties released annually. Building relationships with your seed companies can help you find what you're looking for.

- *Salvius*: bolt resistant, Downy Mildew resistance, solid track record in N.W. Washington.
- *Coastal Star*: planted widely in the region, little Downy Mildew resistance.
- Others: *Paris Island Cos, Jericho, Tripleplay*.
- If you have Downy Mildew issues variety selection is paramount.
- Downy Mildew historically has not been a challenge annually in N. W. Washington. Its disease reach continues to move north and should be considered in any plantings of Romaine today. Currently there are no Romaine Downy-Mildew-immune varieties, only resistant varieties.
- Generally, varieties with high leaf count are easier to manage.
- Choose varieties that carry overall good disease resistance package.
- Better plant consistency is usually a defining trait of hybrid varieties and is considered by some growers to be very worthwhile.
- Romaine can be broken down into 2 classes: open heads (more vase shape) or closed heads (more suitable for hearts). Understand what your market wants before you plant.

Water Management

- Successful irrigation delivery systems: small reel overhead is the most common in the region, micro-sprinklers have also been used successfully for several farms in the region.



- One grower is using drip irrigation exclusively for row crops. While drip irrigation has many benefits, such as the ability to fertigate during growing season, it also keeps all irrigation water off of Romaine heads while in the field. Managing logistics of cultivation and the additional cost of implementing a drip program on such a short-lived crop need to be fully addressed before implemented.
- Lettuce is sensitive to inadequate water uptake, has bitterness sensitivity.
- Overhead on clay soils can create fungal issues that can be more prevalent with overhead irrigation.

Transplant/Direct Seed

- Direct seeding is not recommended in our mostly cool growing season.
- Many cell sizes are used successfully. Flat cell counts: 98-72-128-200.



12" spacing between heads, 16"-20" rows

- One grower successfully uses lower count cell trays in spring and then moves to a higher cell count (smaller plug) tray in warmer summer season that allows you to get transplants into the field sooner.
- Most growers in the project hand transplant. One of the larger growers utilizes a tractor pulled mechanical trans-planter (Mechanical Trans-planter MT 500 is one example; there are several similar brands).



Well-used sturdy Mechanical Trans-Planter

- Depending on the weather, transplants need to be watered in the same hour or day of being planted.



L:

Newly transplanted with water wheel (photo is squash not lettuce).

R: Allows for fertilizer to be added at planting time.



Water Wheel 2 row Transplanter dibble allows plant to be watered/fertilized at transplanting.

- Mark rows and in row dibbling to keep even distances for cultivation and crowding.

Pest/Disease

- Plant disease resistant varieties in soils that can handle effective management even in wet shoulder seasons.
- Mid to late season Lygus Bug (creates red lesions and scabs) can be an issue. Elimination of tall grass/weeds nearby will reduce habitat and help with control.
- Slugs are decreased by regular cultivation. OMRI- Slug Bait Sluggo is another option.

Weed Management/Field Cultivation Methods

- Keeping soil loose and weed free will help accelerate growth in spring plantings.



Newly transplanted, first weeding using Tilmor walkbehind.



Tilmor Walkbehind using Skeetee cultivator tines.

- Be aggressive in weed cultivation early in post- transplanted fields.
- Strategize cultivation timings to minimize number of trips through the field.



- Set up cultivators to weed tractor tire rows same time as crop.
- One grower stated, "You need to be pragmatic. Weeds grow alongside and in the middle of the path, but 'weeding for pretty' = more labor and higher costs".

Pre-Harvest setup and implementation

- Water pre-harvest to increase yield. Lettuce is mostly water.

- Harvest Timing: Several growers harvest in the afternoon/evening; plants will have less turgidity, reduced cracking and cullage within the heads at packing.
- Other growers harvest early in the morning before the heat to maximize freshness and durability.
- If you're selling by the pound, you potentially can lose significant weight per head in mid-day harvests.

Harvest

- Most farms hand harvest directly into Macro bins with tractor static or moving.
- Hand harvest into bin.
- Do small amount of trimming in the field.
- Pick at heat of the day when heads are less fragile.
- Pick early in the morning when crop is cool with best hydration.

Post-Harvest

- Use water chilled at 34 degrees to pull heat out of lettuce.
- Grower experience with several OMRI sanitizers SaniDate and Tsunami both approved for organic production. Via carboy, product can be injected into the line; use test strips to check concentration. Check Tsunami for oxidation rate.
- One farm uses Dosatron (see links under Cucumber Production) to drip in sanitizer at a rate that matches the solution outflow to constantly flush solids out of the bottom of wash tank, facilitating a shorter time in the wash process.
- Small, automated Rinse Conveyors are on the market, specifically geared for mid-scale production. AZS Brusher Equipment is one brand and in use at numerous farms in the region.
- Use low pressure/ high speed rinse if using a wash tunnel. Place stem butt up, exterior rinse only.
- The cost to hand wash a crop like Romaine may be difficult to pencil out in your favor if you're thinking about starting to sell into wholesale markets.
- 85% to 95% pack-out is achievable.
- Box count and packaging: Case 24-ct, Case 12-ct

Labor comments

- Several studies, one in Pennsylvania, the other in the Northeast part of the country, suggest a "Total Labor Actuals" for producing Romaine is 46-48% of the cost of production.
- N.W. Washington study by Galinato and C. Miles explain that 64% of labor costs will be harvest and post-harvest activities only.
- Harvest and post-harvest labor are considered the most labor-intensive activities in lettuce production by many growers.

- If you are considering growing romaine compare costs of batch dunking and rinsing of romaine heads to basic conveyor line to rinse exterior of heads.

SCALING UP CONSIDERATIONS, WHOLESALE LEAFY GREENS PRODUCTION

Level of Difficulty:

Growers' comments suggest a moderate level of difficulty in growing Salad mix. Prompt harvests are crucial for marketable size and taste. Proper weed management important for a clean harvest. The product has a short shelf life and does not field hold well.

General Overview

- Small-scale mechanized production of leafy green, salad mix, or hearty greens consists of baby leaf, mixed varieties, and types of lettuce, spinach, kale, and mustards.
- The mechanization of production and seeding through harvest can greatly reduce production costs.
- This system relies on using two pieces of equipment: high-density 3-point seeder and a walk behind push 28" harvester. This system provides significant labor savings when executed well.
- The total labor percentage breaks down into 50% production and 50% wash/pack.

Below we outline two examples of successful models that are being used, one using ***direct seeding*** and the other utilizing ***transplanted plugs***.

Direct Seeding Model

Infrastructure Requirements

- 3-point High Density seeder
- Walk behind and 3 pt. harvesters are available. Both units are battery powered harvesters that use a ban sawblade for the cutter, greens fall onto a 30" conveyer that pulls greens away from the cutter blade and moves them into a 25 lb. tote at the back of the harvester. (Manufacturer Suttons Ag in Salinas, CA.) Irrigation system set up with electronic valves for multiple irrigations daily during germination if needed.
- Cold Storage for immediate post-harvest processing and storage of finished product
- Wash/Pack licensed facility

- Wash bubblers
- Automated Salad Spinners
- Vacuum Sealer

Soils/ Fertility

- Well drained, dense bottom ground soils with good water holding capacity.
- To fully benefit from using a mechanical harvester, the production system must start the season with “clean”, low seed bank levels of weed seed. This is extremely important.
- Fertility amendments
 - 5 tons per acre of manure solid/ compost split into first application October, second application February 1 on cover crop.
- Soil test annually
- General pre-plant amendments
 - Lime/pH adjustment
 - 50 lbs. of Perfect Blend 4-2-2 applied per 80"x200' bed 1-2 weeks before seeding.
- Utilization of cover crops, stale bed flaming, maintaining clean cultivated soils are all practices utilized to produce successful crops of leafy greens.



High-density Seeder rolls out flat seed bed

- Direct seeding will require soils to be worked-up reasonably well with few clods left on the top of the bed.
- Trashy soil surface can plug up the seeder and can drag clods or other organic debris creating deep grooves that can bury seed too deep.



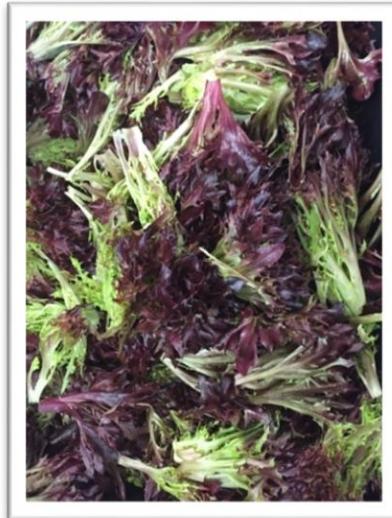
*Even stands of seedlings rapidly create an environment
less favorable for weed competition*

- Seeding nearly on top of bed can give seed a quick push to stay ahead of weed seed germination, but will require closer/shorter irrigation intervals.
- Seeding deeper allows for easing off of water and waiting longer for germination.

Varieties

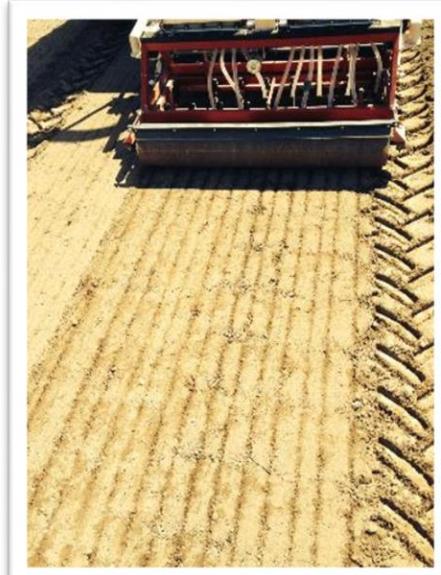
- Grower comments on varieties: Look for color, lots of loft in mix, the bolder the better, crunchy/crisp.

- These varieties change fast and are always getting better. Work with your seed supplies as there are many good mixes available.



Seeding

- Succession direct seeding every 1-2 weeks.
- Spring/Fall plantings can take place during chickweed germination season (62 degrees is optimal germination temperature). Chickweed has demonstrated it can out compete any of the brassicas, spinach or lettuce we planted in our fall plantings if bed preparation isn't done properly.
- Flaming two times before planting is highly recommended by growers utilizing this type of production system. All grading/packing and weighing is completed in field.
- Fall plantings beds are flamed 2x/ in the same day and flamed 2x at 7-10 days apart with successful results.
- Sutton Seeder is designed for this specific high-density seeding application. This seeder is a drop seeder with rotating brushes to help seed find the hole. The seed drops into a poly tube connected to a shoe that makes a furrow in the soil. You must have enough seed in the hoppers to facilitate thorough consistent delivery of seed.
- Fall planting, this farm flamed 2x in the same day and flamed 2x at 1 week apart. Both reduced nearly all weed competition that produced impressive stands of kale and spring mix.



High density drop seeder creates flat seeding surface and presses seed in using one roller on front and rear of seeder.

- This farm used:
 - 80" bed with a 69" planting surface
 - 32 rows per bed
 - 2300 seeds per running foot
- Closed canopy crop by 2.5 – 3 weeks
- Use varieties with same vigor
- Target seeding rate is 3-7 seeds per inch/per row with 16 rows in a 60' bed top.
- Lettuce seeding rate was 50-100 grams of seed depending on variety per 80"x 200' bed.
- To minimize plugging of seeder delivery tubes the soil will need to have clods smaller than $\frac{1}{2}$ ".
- Seeding hoppers run at constant rpms, so it is extremely important to calibrate your seeding density. This farm has been able to make necessary corrections by going up or down a gear or increasing rpms within the same gear.
- Sutton Seeder sizes:
 - Lettuce: Plate #8
 - Spinach, Beets, Chard: Plate#18
 - Mustards, Brassicas: Plate 6# to #8 depending on seed size and density goals.



*Walk behind seeders like this do a good job for putting down the amount of seed required.
Grower notes it's a lot of passes.*

Post-Planting Through Germination

- Seed needs to be watered in immediately and soil surface should not be allowed to dry out until germination is complete. In trials at multiple farms significant negative impacts on germination percentage and early growth has been observed if soil had been allowed to develop a crust on the surface.
- In sunny warm summer weather (80-90's temperatures), irrigation was run multiple times in a day until complete germination was achieved.



- Crusting of the soil can affect your stand at maturity. In this farm's experience and observations there can be a delay of up to 10 days.
- Delay in germination will increase weed pressure and can give you irregular germination that will cause significant reduction in yield with leaves being of different lengths and maturity.



Harvest of healthy stand of Flashy Trout Back

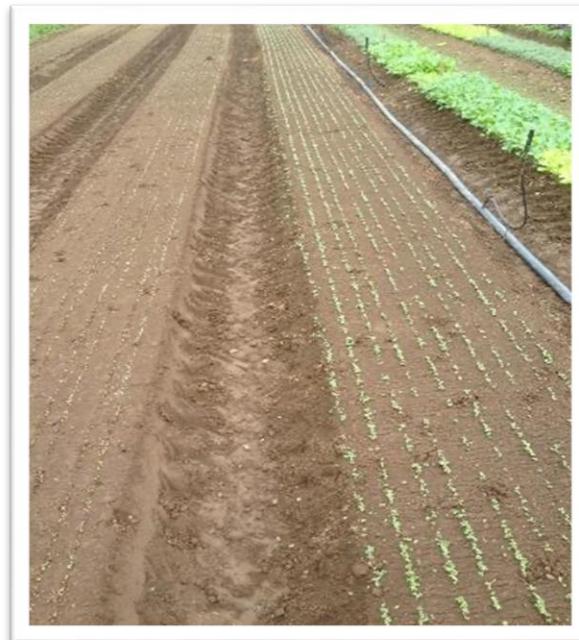
Weed Management/ Field Cultivation Methods

- The only cultivation done was sweeps behind tractor tires post-germination to prevent weeds from seeding.
- Beds were weeded by hand one or two days before harvesting if needed.
-

Water Management

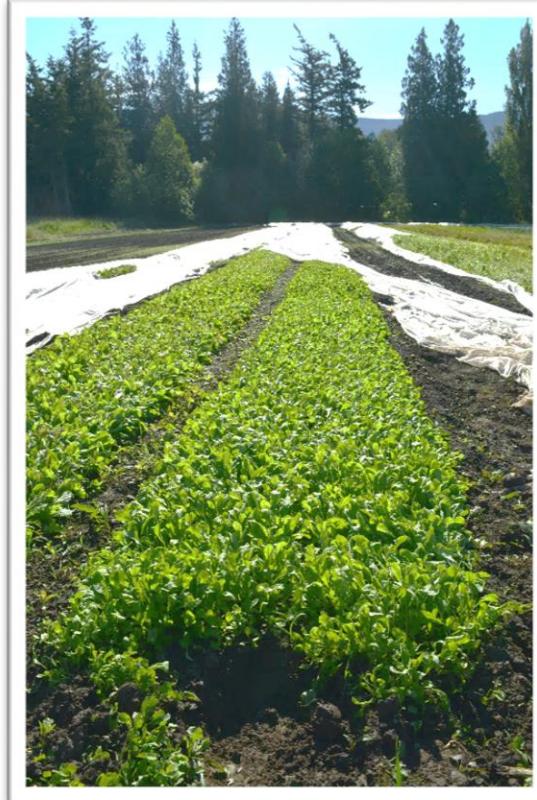
- One of the most important steps for success with this crop is keeping soils moist until complete germination takes place.
- Using micro sprinklers, electronic valves and an Electronic Controller, this farm was able to germinate solid, consistent stands through weeks of 90+ degrees.

- Multiple irrigation start times during germination helps to keep the soil cool and improve germination.
- Using overhead hand lines running 1x set per day did not produce marketable stands of salad greens. Stands that were produced on 1 irrigation/day can rapidly become bitter on hot temperature days. High-density plantings such as these have too much competition for water and nutrients in conjunction with high respiration levels.
- Building experience with Soil Moisture sensors will take the guesswork out of how much water is required.



Pest Management

- No diseases challenges have been identified to date.
- Slugs in finished product have been a challenge.
- Good management strategy for Flea Beetles in the spring and fall with brassicas or mustards is required.



Spring plantings of brassicas can run into flea beetle problems. Use of remay post-seeding to harvest has been very effective.

Pre-Harvest

- Weeding in the field is less expensive than sorting out weeds in the processing phase.
- One hand weeding 1-2 days before harvest is recommended.
- Confidence in the processing room that your harvested greens are weed free and can just be washed and bagged has shown a savings of over \$1.00/lb. in this processing step. If you have to sort through the entire harvest in the wash/pack step, it's very expensive and time consuming on a harvest day.
- In late summer weeding, Amaranth, Potato Vine, and Lambs Quarter must be pulled when under 6" tall. Their root systems destroy salad green leaves, causing more culling at harvest.

- Irrigation the night before harvest will increase turgidity and weight in greens. Weight increases have been as high as 20% with irrigation application the night before.
- The last week of growth can be 50% of the volume harvested.



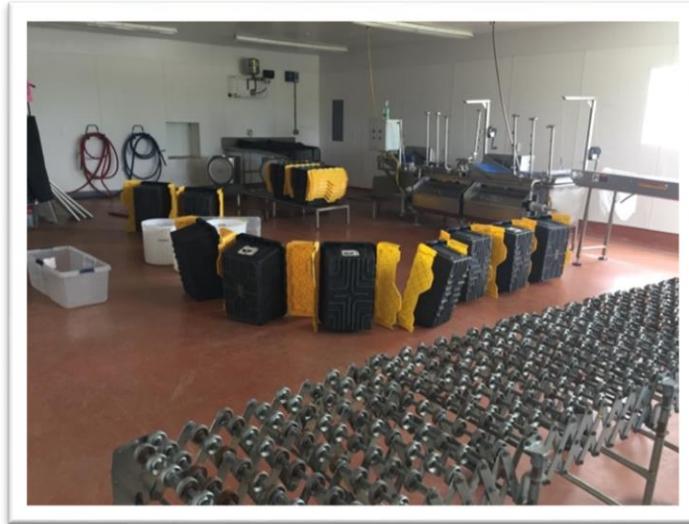
- Harvester and field containers sanitized before every harvest.
- Harvest a minimum of 2 harvests (cuts) per bed. About half the time, a third harvest was possible.
- Mid-summer growth cycle for lettuce:
 - Seeding to 1st cut: 28-35 days
 - 1st cut to 2nd cut: 5-6 days on most lettuce varieties
 - 1st cut to 2nd cut on short frilly types (Lolla Rossa types): 7-8 days
 - 2nd cut to 3rd cut 5-7 days.
- Crop duration for 3 cuts is 45-55 days (harvests).
- Walk behind harvesters can cut $\frac{1}{2}$ to 1lb. per second sustained harvest with three people. These consist of a ban saw blade for cutting and a conveyor to pulled harvested greens away for the cutting edge and deliver them to a harvest 25 lb. tote.



- The duration between cuts was only 5-7 days. This farm found that if production got ahead of sales, they could cut a bed, time the regrowth to harvest, and not lose the crop. In multiple trials to cut and dump was 1 hour per bed. In 5-7 days, another full bed was ready to harvest.

Harvest/Post-Harvest

- Harvest should be completed in the early hours of the morning before heat can begin to accumulate in the beds. Filled harvest totes should be kept out of the sun as they can accumulate heat very rapidly.
- Greens are transported immediately to the cooler.
- Greens need to be washed over a line or in a batch washer using 34-degree water. In both cases they are spun dry.
- The drier you can get the finished product, the longer the shelf life you will have.
- Providing a mixture of texture and leaf sizes will help reduce culls in the processing line. Greens that are straight and smooth show significant increase in culls on the processing line.
- Utilizing at least one frilly variety in a mix will give the mix loft, and therefore air, in and around the mix. Flat greens tend to cake, particularly in the washing process, and can produce over 30% culls.
- Product is packed in 3-5-pound lined non-waxed boxes.



Certified Vegetable Processing facility for Salad Mix Wash and Pack.

Labor Breakdown

- Growers' experiences have been that the only additional labor cost associated with harvest is the time it takes to make 2 additional cuts 5-7 days apart. When these costs are added to total labor cost per pound the price per pound goes down.

Infrastructure

- Greenhouse/propagation house used to seed transplants.
- Mechanical transplanter
- Cold storage for immediate post-harvest processing.
- Salad greens spinner used for appropriately drying greens for a longer shelf life.

Field Transplant

- This farm does no direct seeding.
- Pelleted seeds are seeded into 220 cell flats.
- The seedlings prefer shade and not excessive heat. Shade cloth can be used in the propagation house to ensure proper germination in the hotter months.
- The seedlings go through a hardening off period outside of the propagation house for at least a week prior to transplanting in the field.
- Plants are transplanted about 4 weeks after germination.
- Stale beds can be utilized to get a head start on killing back weeds.
- Flame weeding before transplanting has proven to be effective. After the transplants are in the field, a basket weeder and finger weeder can effectively reduce weed pressure.

- Weekly cultivation is necessary until plants form canopy and weeds are shaded out. The use of a tine weeder is also effective in killing thread stage weeds.

Irrigation

- Overhead water with micro sprinklers for an even application of water.
- Excessive overhead watering can lead to disease pressure into fall.

Harvest

- Equipment
 - There are several models/styles of mechanical harvesters for salad mix. Those tools can harvest hundreds of pounds in an hour.
 - Farmer's Friend, Johnny's Seeds and Sutton Ag all have great options depending on what scale the crop is grown.
 - Harvest totes are used to collect the greens in the field. Each tote holds 8-15lbs of product.
- Product should be kept out of direct sunlight to prevent wilting.
- Harvest two or three times per week depending on markets.
- Harvest intervals are important as this is a very fast-growing crop, especially in July and August.
- Salad greens may be mechanically harvested or harvested by hand with sharp knives.
- Product is harvested into harvest totes in the field and weighed in the field to ensure the correct final weight is processed.
- Salad mix should not have long stems or tough texture and should not exceed 2-3 inches in length.
- With machine harvest, 2 farms have experimented and made a cut and dumped extra greens. Then 5 days later they recut the bed when crop was needed for needed for markets.

Post-Harvest

- Product needs to be cooled right away and kept dry but held at high humidity to ensure proper shelf life.
- When harvest greens are brought back to process area, they are immediately dunked into a tub of cold water, collected with a perforated 1 ¼ bushel basket with handles, and allowed to drain before being placed into a salad spinner for 3 minutes to properly dry.
- The product is then placed into sanitized totes lined with a plastic bag that holds five pounds.
- The finished product can be sold in a cardboard box if the plastic liners are used or in a waxed box otherwise.

- Units can be sold as 10 pounds cases (two, 5-pound bags in an IP-8 sized box) or 5 pounds in an IP-4.

Labor Estimates

- 70% of the costs for total labor for salad greens goes to harvest and post-harvest handling of salad greens.
- 75% of the total cost of salad greens is attributed to the labor of harvest and processing. This total would go down substantially if hand weeding is required.
- Labor is necessary to make stale bed.
- Transplants take around four weeks in propagation house, which includes seeding trays, daily watering, and moving trays around to harden off and get to the field.
- Labor is necessary for transplanting, weeding, and as well as irrigation needs, which can include setting up hoses, water reels, troubleshooting leaks, or moving around hoses during harvest or cultivation.
- Labor is needed for harvesting greens, cleaning and packaging product, and deliveries.
- It is also needed for fieldwork post-harvest.

Key Practices

- Low seed bank soils
- Utilize stale bed practices
- Ability for multiple irrigation start times during germination
- Well-thought-out Wash and Pack
- Solid marketing plan

SCALING UP CONSIDERATIONS, WHOLESALE CHERRY TOMATO PROUDCTON

Level of Difficulty:

Grower consensus is that this is a complicated crop to grow in NW Washington. It is fairly difficult, more of a technical crop than lettuce or cucumbers. Successful production requires a systems approach. There are many established precautionary strategies involved in tomato production. These strategies are straightforward, but you must *do them all in a timely manner* to be profitable. In NW Washington, Early/ Late Blight and Fulvia are persistent pathogens that only allow for this crop to be grown successfully in greenhouses and/or 3-season tunnels. Commercial variety selection of Cherry tomato varieties doesn't offer much blight resistance

when grown in the open field. Keep plants close enough to maximize production but far enough apart to maintain airflow.

Infrastructure Required

- Greenhouses and 3-season tunnels are most commonly used. Roll-up sides and the ability to open significant parts of both ends for ventilation is necessary. Excess humidity and temperature will need to be monitored daily.
- Trellis system: several growers utilize their 4-season greenhouses to support trellis system/plant support.
- 3-season High Tunnels with good production can very rapidly compromise your hoop structure. Using a freestanding trellis is best in these lighter tunnels.
- With a free-standing trellis structure, use stakes: 8'/steel; 12-gauge HTF wire; short stakes for anchors at trellis ends to support the crop load.
- 1-wire trellis with a minimum height of 6' or however high you can harvest by hand without a step. Loosely wrap the string around the plant and use tomato clips at base to secure. This method is quick and easy to train. It is also quick for end of season tear down.
- Multi-wire trellis: clip around plant/ attach to trellis wires.
- Interior of greenhouse/tunnel, all surfaces, and trellis parts must be sanitized pre-plant. This is your best shot to eliminate or slow the transmission of numerous diseases.
- Some growers re-wind the nylon and reuse the following year. This isn't worth it for others.
- Install trellis and transplant late April early May in warmest sites. In cooler sites growers suggest late May.
- Plant training: use adjustable tomato strings and clips. Plants will grow about 8-15'.
- Drip irrigation should be considered a given and is necessary to protect against development of blight and other tomato diseases.

Soil Type/ Fertility

- Tomatoes can grow in a wide variety of soils. The heavier the soil type, the longer the delay in the spring to work soil up.
- Heavy feeder, especially of nitrogen, potassium. Utilize agronomist recommendations.
- Several farms broadcast Skagit Farmer's Granular- 10-9-14, tied to a soil test.
- Several farms use compost.
- One farm uses a cover crop program for their fertility.
- One farm applies fertigation once a week through mid-to-late August.
 - Fertigation material: converted organics- 2.5 gal./appl. Covers 250'x20'.
- Foliar feeding (calcium products) has been successful to discourage blossom end rot. Sometimes calcium deficiencies in plants can be an uptake issue in the plant vs. a soil deficiency.

- Inadequate fertility will significantly reduce production. Side dressing multiple times or weekly fertigation through peak harvest has demonstrated major differences in productivity/profitability with little extra time involved.
- Plants need to be vigorous to provide the high production needed in a wholesale model.

Varieties

The varieties listed in this section are popular identified varieties currently being used. Listing these is not an endorsement.

- Look for varieties with good disease resistant packages and newer genetics.
- *Reds:* Secura-early, Bartelli- mid through late
- *Golds:* Sungold, Toronijina (newer genetics means that training and growth habit are more predictable; less suckering; fruit trusses no suckering)
- *Yellow:* Esterina
- There are many excellent varieties suitable for this region. It was generally agreed that any variety with “Sweet,” “Gold” or “Sun” in the names is probably a good bet.
- Most catalogs identify a variety’s resistance to common pathogens. Compare disease resistant packages. With cherry tomatoes, growers agreed to put flavor as a top priority and disease resistance secondary.

Water Management



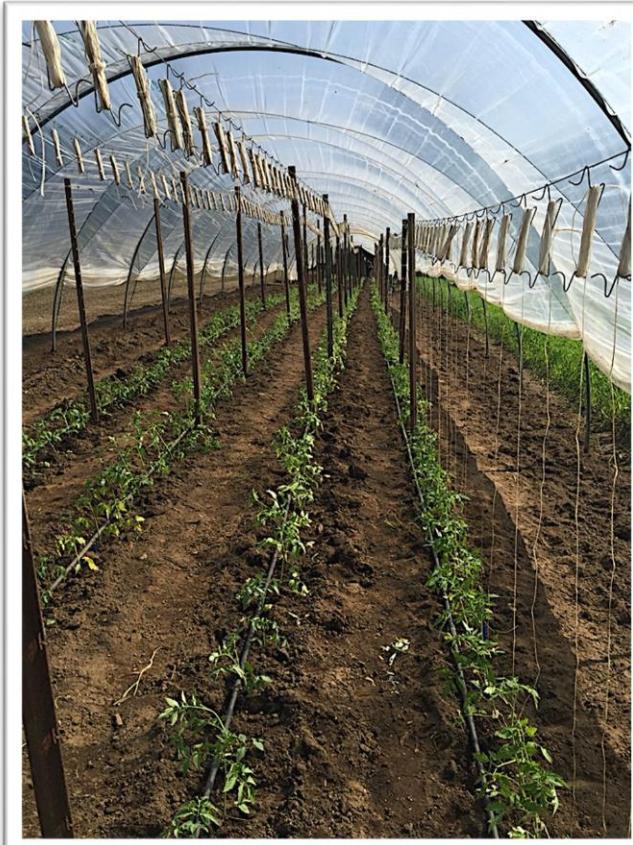
Targeted drip irrigation for consistent, adequate moisture levels is a cornerstone of a successful tomato program.

- One grower stated, “More water pushes towards more vegetative growth and splitting, less water, and more fruit ripening.”

- At the end of the season, cut off water 2 weeks before last harvest. Cut or turn water way down after you set all the fruit you want to ripen.
- Utilizing technology to monitor soil moisture is important. Several soil monitoring devices are available.
- Monitor evapotranspiration rates in your greenhouse or tunnels as humidity plays a major role in irrigation requirements.
- You can find good, comprehensive up to date weather information on the Washington Ag Weathernet with over 25 weather stations housed in the agricultural areas throughout Western Washington. <https://weather.wsu.edu>

Seeding/ Transplant

- Many growers start plants in 50 or 98 cell trays.



New transplants from 4" pots

- Plants then are bumped into 4" pots and typically hand planted.

- Watch soil temperature! Transplanting into cold soil will stunt plants and significantly slow your first harvest. This is where patience pays off. Close up greenhouse/tunnels and allow daytime heat to collect and warm up the soil pre-plant and post plant until the weather warms up.
- Caution – don't cook your tomatoes. Remember a cool day outside will carry a very different temperature inside the tunnel.
- There can be a 15 degree increase in temperature in an open tunnel compared with outdoor ambient air temperature on a sunny day.
- There are many successful strategies and opinions on plant spacing. All comments were within the following parameters: 3'-4' between rows, and 1'-2' in-row.



Air flow is critical component in Western Washington conditions. Fans, Side rollups, ends that open fully play a significant role annually in tunnel production.

- Some growers are splitting the plant and developing 2 split leaders; this should help reduce the vigor and increase the harvestable area of the plant later into the season. For cherry tomatoes in particular this strategy is a practical way to manage the plants' well-known excessive vigor.
- Consider mixing varieties that produce assorted colors for good marketing.

Disease Management

- Do not follow potatoes or peppers in your rotation with a tomato crop! These crops are all the same family with many of the same diseases.
- Annually it is important to sanitize all stakes, string, poly, weed mat, used drip irrigation, and anything that you plan to use inside the tunnel that's not brand new. If you don't sanitize, you are likely going to inoculate your crop with undesirable pathogens.

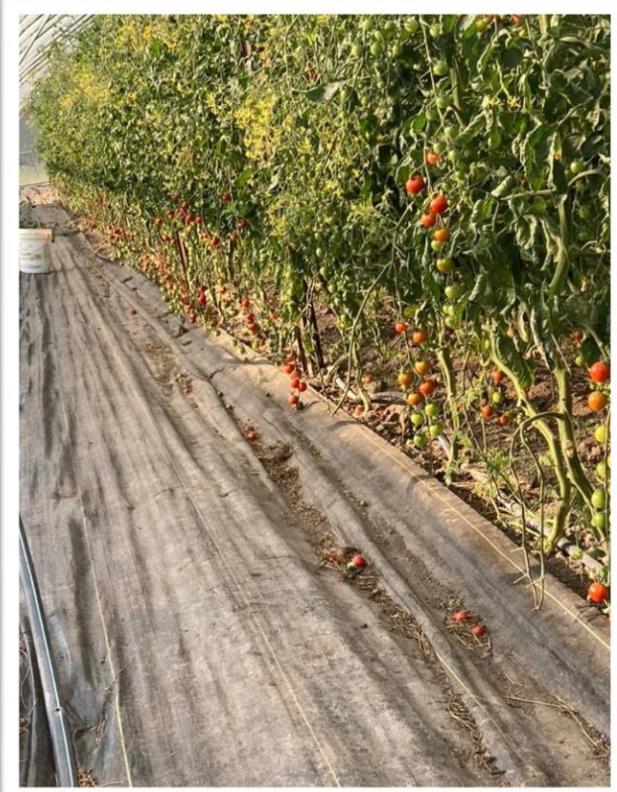


Some growers begin spray programs within a week of transplanting. Foggers like this are an efficient way to get thorough coverage with low volume on all parts of the plant.

- There are numerous diseases that frequent tunnel production. Familiarize your staff with what these diseases look like. PNW Pest Handbook is an excellent source for this region.
 - Late Blight: <https://pnwhandbooks.org/plantdisease/host-disease/tomato-solanum-lycopersicum-late-blight>
 - Passalora fulva (very common): This Cornell document has a disease resistance variety chart: <https://ecommons.cornell.edu/handle/1813/70183>.
- The lower, older leaves on plants are often the place disease takes hold. Prune out older leaves, remove away from proximity of planting. This step will also provide better air movement at the base of plants.
- Watch for moisture issues. When the inside of the tunnel hits dew point, tall plants have free moisture on leaves and fruit. Blights and Fulva need this moisture to flourish.
- Sanitize tools, especially when pruning/ cutting. Sanitize between plants. Use bleach solution or alcohol.
- Pay attention to any discoloration of foliage; take the time to recognize what the different diseases look like. Walking through 2x a week scouting and pulling any suspect leaves will pay big dividends later in the season. Don't be afraid to cull the plant and clean up the area; the less disease incubators you have, the better.
- This is one of the most expensive crops to produce in N.W. Washington and if done right it can produce one of the largest revenues. ***Protect your investment with bi-weekly monitoring and pruning out any suspect leaves or plants of these diseases!***

Weed Management/ Field Cultivation Methods

- Hand Cultivation/ Alleyway Management
 - Since tomatoes are grown in greenhouses or tunnels, hand cultivation tools are typically employed. Use of woven landscape fabric that can be used for many years is very common to roll down the alley ways after being sanitized.



The landscape fabric offers another benefit. After pruning is completed in the day, you can sweep all the prunings to one end of your greenhouse in minutes and save a lot of time.

- Some growers use a rototiller between rows. The potential disadvantage of tillage is that it creates soft alleyways during harvest.
- One grower built narrow harvest carts that roll along on the landscape fabric to reduce the constant lifting of harvest flats as you move down the row. (See Cucumber Production)

Plant Growth/Training Season

- Plant training and pruning needs to happen at regular intervals to keep unwanted growth in check so nutrients and growth go into the part of the plant you want to keep.



L: Training, pruning and harvest make significant demands on your production crew at peak season.

R: In greenhouse and tunnels, use fans to disperse dew point moisture

- Crack rollups in early morning to help disperse moisture on plants.
- Plant training
 - Use adjustable tomato strings with manufactured clips.
 - Consistent pruning of inner suckers is important to maximize plant growth.
 - Most growers grow to a single stem. This means taking all other growing points off each vine.
- Temperature management is important all through the season. Tomato flowers have a temperature threshold of 91 degrees, when they start to drop blossoms. Attention to venting during sunny warm days can't be overstated.
- Grower experience shows 5-8 clusters of tomatoes is the potential target in the region. If you lose 2 of those clusters to excessive heat, your profit ability is greatly challenged.



Cherry tomato plants will grow 8'-15' in a season.

Pre-Harvest

- Sanitize harvest flats between each harvest.
- Develop inventory rotation process so oldest fruit is shipped first.



Sanitized flats palletized and covered ready for use.

Harvest



L: Mixed colors are popular in many markets.

R: Bucket on a string option.



Cherry picking buckets offer a lot of advantages.

- Growers: Pick into pints; pick in bulk then put into pints; use tomato cartons to pick; use sweet cherry harvest buckets with shoulder straps (see supporting resources.) They are an excellent hands-free harvest assist.
- Temperature can be hot for workers in the greenhouse. Harvesting in early morning is a widespread practice.
- Learn to dial in the ripeness of your varieties. Color counts, but flavor is king. Don't pick too early as you'll lose weight. Don't pick fruit past prime, as you'll see more splitting.
- Harvest intervals vary by grower: 2 x week, every other day; every 3rd day. This probably has to do with your daily heat unit accumulations.
- Crop is most commonly sold by the flat (pints) or in bulk flats by the pound.

Post-Harvest

- Tomatoes to be graded either during harvest or soon after. Don't allow splits to go into harvest flats. Some growers keep a pint or quart container in harvest flat to pre-sort out culls.
- For storage, harvested flats need ventilated, cool space out of the sun. Fruit flies will be a problem as season progresses. Running a small fan constantly over flats can keep flies from getting established.
- Good storage conditions can safely hold cherry tomatoes for 7-10 days.
- Packaging
 - 10 lbs./bulk/flat
 - 12/ct pints/flat

Labor Considerations and Concentrations

- Because of the high demand for labor and the difficulty finding labor today, tomatoes are a hard crop to scale even with higher market demand than farmers want to produce.
- Set up of tunnel, trellis and strings.
- Transplanting
- Pruning/training multiple times
- Hand labor intensive crop with main harvest at peak vegetable harvest season
- In one NW Washington study, labor was 64% of all expenses.
- See Resources for Growing Tomatoes at the end of this document.

SCALING UP CONSIDERATIONS, WHOLESALE WINTER SQUASH PRODUCTION

Winter squash is a classic field crop that is typically transplanted into rows or into single row poly-film covered beds. Cultivation, harvest implements and packing line requirements for this crop are common implements and equipment that can be used interchangeably with other common NW field crops.

Level of Difficulty:

Winter squash production was identified by the cohort of growers as an easy/moderate difficulty crop to grow in relation to other vegetable crops commonly grown in the region. However, several steps were pointed out as critical in producing a profitable crop. Proper fertility and irrigation management were identified as key to producing a high quality/yielding crop. Depending on the size of winter squash field, ample harvest labor is important for an efficient and thorough harvest. Plan for adequate curing and storage space so you have time to market and sell your crop.

Infrastructure requirements

- Greenhouse for transplant production
- Seeding assists for transplants: Vacuum seeder (100+ flats).
- 3-point transplanter
- Bed shaper with poly-mulch layer, most shapers require 40 horsepower tractor or larger.
- Waterwheel transplanter: into plastic mulch beds.
- Macro bins for harvest and storage of winter squash
- Basic Wash/Pack equipment required.
- Adequate temperature-controlled curing space

Soil type/fertility, Management

- The farmers involved in this project had good success growing Winter Squash on many soil types, from sandy loam to clay-loam.
- Winter Squash are heavy feeders and can grow successfully on a wide range of soil types from sandy loams to clay-loams. Sound fertility practices are typically necessary to bring in the tonnage and size needed to produce a crop that buyers want.
- Applications of raw manure are commonly applied to cover crop, pre-field work. Raw manure applications need to be made 180 days before harvesting of any product.
- Micro-nutrients play an important role in producing high quality, productive plants. Key micro-nutrients in cucurbit production are boron, phosphorus, and calcium.
- In all cases a pre-plant granular fertilizer blend was applied before transplants were field planted.
- It was pointed out multiple times that irrigation management is key in optimizing yields, while backing off or completely shutting off the water will play a major role in increasing storage viability.
- Pre-plant broadcast fertilizer based on soil test results is common practice.
- Some grower's fertility management priorities center around the use of Consolidated Organic liquid fertilizer that is applied through drip irrigation 1x/week.
- Two types of fertilizer injector are commonly used: Dosatron, Mazzei.

- Several farms consider well-drained soil to be ideal and use black plastic mulch beds for added warmth and aid in early plant establishment.
- Many farms plant utilizing black poly film beds and fertigation through drip irrigation systems. Green spool on top of mulch layer lays drip lines under poly.
- Depending on the size of winter squash field, it was stressed that ample harvest labor is important for an efficient and thorough harvest.

Varieties:

- When making variety selection chose varieties that have good disease packages for this region.
 - Delicata - Honey boat, Bush type
 - Butternut -Shorter day maturity clones Granite, Butterfly
 - Acorn - Carnival
 - Red Kuri - Summer Tops
 - Black Futsu
 - Sweet meat
 - Spaghetti



Red Kuri, Carnival and Sugar Pie Pumpkins curing on wire racks in greenhouse.

Seeding/Transplants

- Winter squash (all Cucurbits) are particularly sensitive to cool soil temperatures. [A frequent problem](#) in seeding warm climate crops in Northwest Washington is that soil temperature can be slow to warm up in the spring. Consider use of a temperature probe or use local [Washington](#) Ag Weather-Net <https://weather.wsu.edu> to verify local soil temperatures. Make this part of your planting protocol as it only takes a second and is a good defensive practice.
- Too low of soil temperature can be disastrous to the out-come of seeding/transplanting into soil that isn't up to the desired temperature for seed to sprout or new roots to develop. Ideally soil temperatures needs to be at a minimum of 60 degrees before transplanting or direct seeding.
- Planting typically occurs as soon as soil is workable and at temperature.
- Cost and risk should be part of your decision-making process when considering direct seeding vs hand or machinery-based transplanting.
- Direct seeding without the use of poly film mulch was not considered a viable program for any farms in the project. The concerns are two-fold: weeding labor would be too high and grower experience of losing significant seed to mice and birds.
- Buckeye bed shaper/poly film mulch layer: green spool on top holds and lays down dripline under the poly.
- Tractor size generally needs to be 40 horsepower or larger.



- Successful seeding/cell size examples:
 - 50, 72, 98 cell flats are all widely used.
 - Some growers seed into 4" pots so when planted out they are more established.
 - Non-mulched field row planting: Mechanical and Planet Junior transplanter are used.
 - Some growers seed into 4" pots so when planted out they are more established.



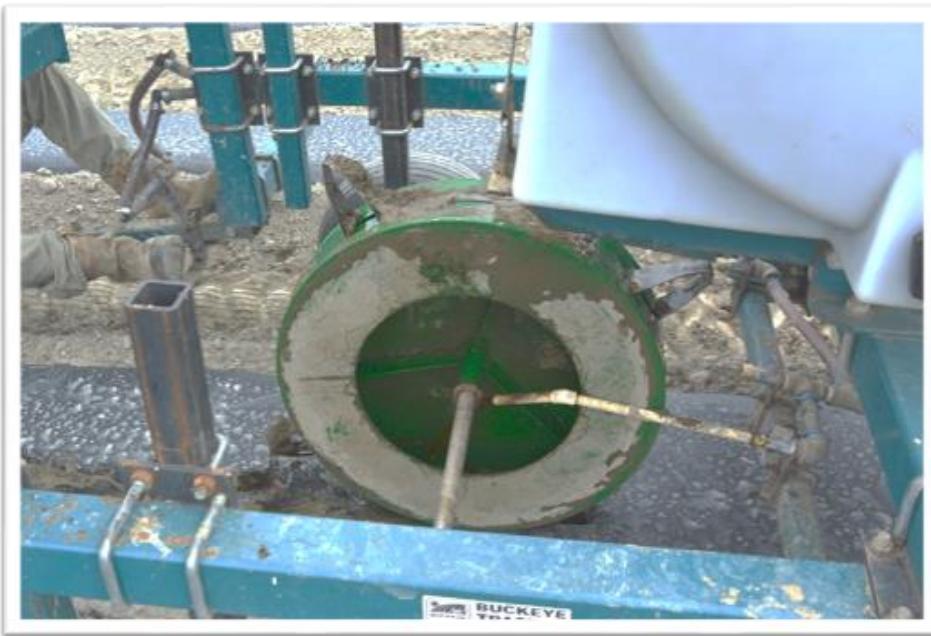
- **The smaller the cell size flat the more precision in timing is required.**
 - Remay is used in propagation space to protect seedlings from bird/critter damage.



Transplants are grown until they develop 1 to 2 true leaves.



Poly-mulched beds: Water Wheel transplanter punches whole in poly depositing water and fertilizer at the same time.



- Seedlings are transplanted into plastic mulch beds using a Water Wheel transplanter. The water tank, in this case, uses the opportunity to mix 50/50 blend of water with liquid fertilizers of Consolidated Organics, Kelp and Humic acid. White PVC pipe delivers a steady stream of water and nutrients to each planting hole.



Making sure plants are placed deep enough into the muddy mix is a critical detail.

- Flat holders hold 4 flats per planter. Forks on front hold dozens of flats to reduce restocking to a minimum. Water tank depletion is often the stopping point in transplanting. Crew members here trade positions to reduce fatigue.



- To put a rented field into production, this grower has done an excellent job organizing and executing a lot of extra steps, expenses, and additional labor to plant 7+ acres of crops.
 - All equipment, water, fertilizer, needs to be trucked to the site.
 - Meet all requirements that are mandatory for farm workers protection: potable water, hand washing/sanitizer, and portapotty.
 - Purchasing of gasoline-run water pump
 - Find and rent 800' irrigation hand long enough to act as mainline that delivers water to irrigation zones that attach to a single dripline.



Farm owner and farm manager get pump and mainline setup while transplanting takes place.

Field Production/Cultivation Methods

- Field layout and spacing ranges widely from 1'-3' in row and 5'-14' between rows. Field layout is typically determined by use of poly film and or cultivation machinery.
- Spacing ranges for participating farms were 5' between beds and 16"-22" in rows for bush types and winter squash, and 22"-24" for vining types of winter squash.



Farmall setup for alleyway/ poly film edge cultivation

- Mechanical cultivator sweeps are used to cultivate shoulders of beds and alley ways. Multivator is also used to manage center alleyway cultivation. Hand weeding with a stirrup hoe is also used to ensure a clean, weed-free field.
- There are several research trials that demonstrated the impacts of plant density in the field. These trials showed that plant density had no significant impact on yield across the varieties in the project. The trials did show there was significant impact on squash size, number of squash per acre, and significant differences in number of squash per plant. See Cornell Curcubit Grower Guide in resources at end of section.
- The information above is supported backed up by farms in this project saying they base their fertility plan and plant spacing on what their size/weight target is at harvest.
- While most growers felt there were significant improvements utilizing black poly film with Summer Squash, some growers thought it made things too difficult for growing Winter Squash.
- Moisture retention and the reduction of weeding hours were big reasons listed for poly use.
- Water Wheel transplanter, Mechanical, and Planet Jr trans-planters are all used.
- Aggressive weed control before canopy fills out was considered critical to the success of this crop. Cucurbits will not compete well with annual Eurasian weeds or grass.
- Use of poly films or woven weed fabric is widely used. Covering of entire soil surface eliminates just about all weeding and gives you time to focus on the crop.
- When growing trailing varieties of winter squash, training plants to run parallel to rows help to ease tractor cultivation between beds.

Pollination Requirements

- Use of pollinator bees can play significant role in fruit set and yield tonnage.

- Several growers made the recommendation of 4-6 hives per acre to provide sufficient pollination for fruit development. Many growers rely on hives they know are housed within a mile of their farms.

Water Management

- Winter Squash require uniform irrigation for optimum growth and yield.
- Plantings in heavy clay can add another layer of challenges and must have a sound water management strategy and the ability to control when and how much water is needed.
- If using overhead irrigation, early morning to early afternoon was cited as good strategy for minimizing disease conditions - not to mention the significant percentage of evaporation that can happen.
- Unlike with Cucumbers and Zucchini, reduction of irrigation is important as fruits begin reach harvest stage. This will improve quality and storage life.
- **ASHS, Yield Response of Winter Squash to Irrigation Regime and Plant Density** Thorough demonstration and discussion of impacts from irrigation and plant spacing/density: <https://journals.ashs.org/hortsci/view/journals/hortsci/54/7/article-p1190.xml>

Pest Management

- Diseases: Careful variety selection for good disease package, particularly for powdery mildew is a significant challenge. <https://pnwhandbooks.org/plantdisease/host-disease/squash-cucurbita-spp-powdery-mildew>

Pre-Harvest/Harvest Implementation

- Know accepted harvest Indices/ stage of ripeness for winter squash can be the difference between good tasting squash and great tasting squash. (See resource documents listed at end of section.)



Currently most growers harvest don't start until vines have completely died down.



Use of harvest wagon with macro-bins, crew harvests into totes, designated worker on wagon weighs/empties totes into Macro bin. Pickers leave full totes and grab empty totes to keep pace.

- Harvesting squash on days where the soil is reasonably dry will minimize how much soil is carried inside to your pack area.
- Macro Bin 54's can hold 700-1000+-pounds.
- Yield ranges are five to seven tons per acre for small-fruited squash or 2000-4000 fruit per acre.
- For medium and larger sized squash, yields can range from 5-10 tons/acre.

- Tracking percentage of culls by variety is important and demonstrates the value of choosing regionally suitable varieties.
- Depending on the size of winter squash field, it was stressed that ample harvest labor is important for an efficient and thorough harvest.

Post-harvest

- There was a wide variety of ways growers cleaned their crop.
- One grower utilizes their wash-line to clean and polish fruits.
- Other growers dry cleaned fruits with soft cloth to polish off any dirt and packed into cardboard case sizes.
- Winter squash fruits require a curing space with ample airflow at 80-85 degrees and 70% relative humidity for ideal curing for about one week.
- Post cure: Ideal conditions for long-term storage are 55% humidity @ 55 degrees.
- Long-term storage is considered 2-5 months.
- Winter squash needs significant space for late fall/winter storage.
- All growers acknowledged the challenges of suitable winter storage space in Northwestern Washington.
- Macro Bin 54's can hold 700-1000+-pounds and have a footprint of 48x48" (4'x4'x 24"). If you harvest 10,000 lbs. of squash @ 800lbs/bin and don't have vertical storage ability (no forklift) you would need 200 sq./ft of floor space. If you could stack bins 5 high you would only need 32 sq. Ft.
- General pack-size is 35 pounds per case.

Labor breakdown estimates for Winter Squash

Growers were asked to estimate what they thought was the labor breakdown for this crop.

- General consensus is 75% of labor is for harvest, wash/ pack.
- They also estimated about 50% of their annual production costs were for labor during harvest and wash/pack operations.
- Major hired labor categories for Winter Squash:
 - Seeding/ propagation
 - Water management for the life of the seedling
 - Field irrigation management
 - Machinery operators for transplanter, cultivation and hand harvest.

Trials done at Cornell University have posted these storage recommendations:

- Acorn-type squashes, such as Table Queen, should keep 5 to 8 weeks at 50 F.
- Butternut squash should keep at least 2 to 3 months at 50 F, generally will keep longer but with cullage starting to develop.

- Hubbard squash, if in good condition initially, can be successfully stored for 6 months at 50 to 55 F with 70% relative humidity. A 15% loss in weight from shrinkage for 6 months storage would be average.
- Trials in New York curing for mechanical injury and to help ripen unripe squash was not necessary.

Squash Resources

Cornell Organic Production and IPM Guide for Cucumbers and Squash Cucurbit

Grower Guide offers significant information on soil nutrient budgeting for these crops.

<https://ecommons.cornell.edu/bitstream/handle/1813/42894/2016-org-cuke-squash-NYSIPM.pdf?sequence=2&isAllowed=y>

Oregon State University: Growing Winter Squash and Pumpkin

While this document is a decade old it provides excellent information on production recommendations as well as harvest considerations, techniques, yield potentials.

<https://horticulture.oregonstate.edu/oregon-vegetables/squash-pumpkin-and-winter>

ASHS Yield Response of Winter Squash to irrigation regime and Plant Density Thorough demonstration and discussion of impacts from irrigation and Plant spacing/density.

<https://journals.ashs.org/hortsci/view/journals/hortsci/54/7/article-p1190.xml>

Uspest.org: This site has excellent pest models for both fruit and vegetables. The site is also starting to post degree day models of vegetable phenology (development) that could be helpful to farmers looking to dial in their succession plantings. This is new ground breaking work that has the potential to offer growers a better way to track plant development through the growing season. <https://uspest.org/wea/weaexp.html>

SCALING UP CONSIDERATIONS, WHOLESALE ZUCCHINI PRODUCTION

Zucchini is a classic field crop that is typically transplanted. Cultivation, harvest, implements and packing line requirements can be used interchangeably with many other common field crops. Short-term cold storage is needed.

Level of Difficulty

Zucchini production was identified by the cohort of growers as an easy/moderate difficulty crop to grow in relation to other vegetable crops commonly grown in the region. However, several steps were pointed out as critical in producing a profitable

crop. One notable point was Zucchini harvest management, where it can be quite challenging if attention isn't paid to variety selection, disease resistance and access to additional labor at harvest time.

Infrastructure Requirements

- Greenhouse for transplant production
- Seeding assists for transplants: Vacuum seeder (100+ flats)
- 3-point transplanter
- Beds shaper with Poly mulch layer, most shapers require 40 horsepower or larger
- Waterwheel transplanter: for plastic mulched beds
- Harvest totes
- Basic Wash and Pack equipment

Soil type/fertility, Management

- The farmers involved in this project had good success growing Zucchini on many soil types, from sandy loam to drainable clay.
- Zucchini is a heavy feeder crop and requires good fertility to be profitable.
- Applications of raw manure or compost are commonly applied to cover crop/pre-field work. Raw manure applications need to be made 180 days before harvesting any product.
- Pre-plant broadcast of granular fertilizer based on soil test results is common practice.
- Some grower's fertility management priorities center around the use of Consolidated Organic liquid fertilizer that is applied through drip irrigation 1x/week.
- Two types of fertilizer injector brands are commonly used: Dostron, Mazzei. See Supporting Links for sources.
- It was noted several times that micro-nutrients are important in producing high quality, productive plants. Key micro-nutrients: boron; phosphorus; calcium. Pay attention to soil tests for deficiencies.
- Zucchini can handle a wide range of soil tolerances. Growers prefer fields with good tilth and high organic matter with good drainage.
- Several farms consider well-drained soil to be ideal. Plastic mulch beds add warmth and aid in early plant establishment. Common practice is pre-plant broadcast fertilizer based on soil test results as well as fertigation through drip irrigation.
- Cornell's Organic Production and IPM Guide for Cucumbers and Squash Cucurbits Grower Guide offer significant information on accessing soil nutrient budgeting for these crops. <https://ecommons.cornell.edu/bitstream/handle/1813/42894/2016-org-cuke-squash-NYSIPM.pdf?sequence=2&isAllowed=y>

Varieties:

- Several growers noted that most western Washington markets are looking for green varieties of Zucchini.
- Green Varieties: Noche and Trooper

- Yellow Variety: Golden Delight

Direct Seeding/Transplanting

- Successful seeding/cell size examples:
 - 98 cell flats transplanted out with 1-2 true leaves
 - 72 and 50 cell flats are widely used.
- Some growers seed into 4" pots so when planted out transplants are more established.
- **The smaller the cell the more precision in transplant timing is required.**
- Seeding assists for transplants: Vacuum seeder (100+ flats).
- Several farms plant single row beds covered in black plastic mulch
- Beds shaper with Poly mulch layer, tractor size 40 horsepower or larger.
- Poly-mulched beds; Seedlings are transplanted into plastic mulch beds using Water Wheel Transplanter. (See Winter Squash sections for Photos of transplanting.)
- Zucchini (Cucurbits) are particularly sensitive to cool soil-temperatures. A common problem in seeding warm climate crops in Northwest Washington is that soil temperatures can be slow to warm up in the spring.
- Consider use of a temperature probe or use local Ag Weather-Net station (see Supporting Links) to verify local soil temperatures. Make this part of your planting protocol as it only takes a second and is a good defensive practice.
- It can be disastrous to seed/transplant into soil that isn't up to desired temperature for seeds to sprout or new roots to develop. Ideally soil temperatures need to be at a minimum of 60 degrees before transplanting or direct seeding.
- Planting typically occurs as soon as soil is workable.
- Cost and risk should be part of your decision-making process when considering direct seeding vs hand or machinery-based transplanting.
- Direct seeding without the use of poly film mulch was not considered a viable program. The concerns are two-fold: weeding labor would be too high and growers experienced losing significant seed to mice and birds.



Some growers don't use plastic and keep rows clean cultivated.

- Other transplanters used: Mechanical brand transplanter.
- In row plant spacing is 2'-5'; between rows is 4'-5'.
- Remay is used in propagation space to protect seedlings from bird/rodent damage.

Open Field Production/Cultivation Methods

- Most growers felt there were significant improvements when black poly film or woven weed fabric was used. Moisture retention and the reduction of weeding hours were big reasons listed poly use.
- Transplanting can be done by hand.
- Mechanical trans-planters and Water Wheel transplanters are also used. Cost and risk should be part of your decision-making process when considering direct seeding vs hand or machinery-based transplanting.
- Direct seeding without the use of poly-film mulch was not considered a viable program. The concerns are two-fold: weeding labor is too high and growers experienced losing significant seed to mice and birds.

- Aggressive weed control before canopy fills out was considered critical to the success of this crop. Cucurbits will not compete well with annual Eurasian weeds or grass.



Tillage to manage weeds along poly film edges.



- Seedlings are transplanted into black poly-mulched raised beds. Mechanical cultivator sweeps are used to cultivate shoulders of beds and alley ways. A Multivator is also used to manage center alleyway cultivation. Hand weeding with a stirrup hoes is also used to ensure clean, weed seed-free field.

Pollination Requirements

- Use of pollinator bees can play significant role in fruit set and yield tonnage.
- Several growers made the recommendation of 4-6 hives per acre to provide sufficient pollination for fruit development.

Water Management

- Most farms utilize overhead sprinkler irrigation for un-mulched plantings and drip is primarily used under poly film plantings.
- Plantings in heavy clay can add another layer of challenges and must have a sound water management strategy and the ability to control when and how much water is applied.
- If using overhead irrigation, early morning to early afternoon water applications was cited as a good strategy for minimizing disease conditions.
- Sound irrigation management post fruit set is important in Zucchini production. Consider use of local evapo-transpiration data to help you manage your soil hydration levels. (Washington Agweathernet has over 15 weather stations in NW Washington)
- Depending on soil and weather conditions, irrigation needs can be up to 1-2 inches of water per week.

Pest Management

- Diseases
 - Careful variety selection of downy mildew resistant varieties will allow you to have several successions of plantings before downy mildew becomes a significant challenge.



Downy Mildew in Zucchini

- Downy Mildew isn't a true fungus. It's a water mold that thrives in wet or humid conditions. It can affect members of the cucurbit family including cucumbers, summer squash and winter squash.
- PNW Vegetable Extension Group is a great online source for cucurbit ID and explanation of diseases. https://mtvernon.wsu.edu/path_team/cucurbit.htm
- Most common diseases found in Northwest curcubit production: Angular Leaf Spot/Black Root rot, Curly Top, Downy Mildew, Scab, White Mold.

Harvest Requirements/Implementation



Zucchini is typically harvested between 6 to 9 inches in length.



Harvest is typically into 5-gallon buckets that are transferred in the field into waxed boxes

- At peak season the harvest window is 2-to-3-day harvest intervals.
- Some growers direct pack zucchini in the fields, while at other farms zucchini is harvested into reusable totes to get out of the field, graded and repacked.

Post-Harvest

- Getting harvested zucchini into cold storage post-harvest certainly will help with shelf life for the end user.
- Use of a wash line can also be used to cool down, wash, and polish fruits. Use of cool wash line water will aid in pulling heat of your crop.
- General pack-size is 35 pounds per case.

Labor Notes/Breakdown

- General consensus is 75% of labor is for harvest/wash and pack. About 50% of total costs are for labor and packaging during harvest and wash/pack as it compares to the total annual operation cost for the crop.
- Major labor categories:
 - Hired labor was used for seeding in the propagation house
 - Water management for the life of the seedling
 - Field irrigation management
 - Cultivating tractor operator

- Transplanters
- Hand harvesting

RESOURCES

High Production Cucumber and Tomato Trellis

- **Materials**
 - 8' Rib back steel posts
 - End posts pound in on angle
 - 15' Spacing in row post
 - Trellis Anchors- Screw in 2'/3" disc
 - High Tensile wire- 12 ga.
- **Installation**
 - Make fixed loops on each end of your anchor wires so you can reuse every year and they are fast to install. You will need to standardize the distance from anchor to end stake.
 - Trellis const.- 2x 1 day 4 rows 100' 1 tunnel.



Trellis and Harvesting Supplies

Sources for Tomato/Cucumber trellis strings and clips:

- Johnny's Selected Seeds
 - <https://www.johnnyseeds.com/tools-supplies/trellising-crop-supports/clips>
 - <https://www.johnnyseeds.com/tools-supplies/trellising-crop-supports/rollerhook>

- A.M. Leonard
 - <https://www.amleo.com/tomato-clips-25-mm-250-count/p/TOMCLIP25>

Trellis Supplies

- OVS/Wilson Irrigation- <https://ovs.com/catalog/growers-supplies/trellis-supplies>
- Full line of trellis supplies production.
- User friendly website, has office in Lynden.

Harvesting Buckets for Cherry Tomatoes

- Superior Fruit Equipment- https://www.sfequip.com/cherry-bucket-18-qt/?sku=89000&gclid=EAIaIQobChMIs8euv-XY7wIVkyCtBh1dZwraEAQYCCABEgJdCvD_BwE
- Gemplers- <https://gemplers.com/products/18-qt-plastic-cherry-bucket>

Irrigation/Fertigation Management

- Wireless Tag Sensor:
<https://www.google.com/search?client=safari&rls=en&q=wireless+tag+sensor&ie=UTF-8&oe=UTF-8>
 - Good, relatively inexpensive wireless moisture and temperature sensors that can be managed by your home computer or phone. In use by numerous local growers.

Fertigation Applicators

- [Dosatron](#)
 - Widely used in the nursery industry, small farm community. Fertilizer rates can be easily calibrated for solution.
- [Mazzei PVDF Venturi](#)
 - Basic set up for Fertigation

Pest Resources

[Pacific Northwest Pest Handbook](#)

- Annually published for up-to-date information of management of insects and diseases.

US Pest: <http://uspest.org/wea>

- Serves numerous phenology or degree-day (DD) models and maps, plant disease risk and other hourly-data driven models to the USA and particularly Western states. Decision support systems (DSSs) depend on having weather data and forecasts of known provenance and quality assurance. Also, real-time decision support must rely on always changing, continuously updated methods and data types with multiple options in particular with regard to weather and climate forecasts.

Weather Data

- [Washington Ag Weather Net](#)
 - Comprehensive site with weather stations across Washington State. Some crop disease/insect models, heat unit charting, evapotranspiration and more.

Irrigation Management

- [Wireless Tag Sensor](#)
 - Good, relatively inexpensive wireless moisture and temperature sensors, in use by numerous NW growers.

Production Links

- [Rinse Conveyor- AZS Brusher Equipment](#)
 - 821 Crooked Ln, Ephrata, PA 17522
 - Phone: (717) 733-2584
 - Sturdy basic wash and rinse with belt
- [Rotating Sorting Table](#)
 - Tew Manufacturing NY. Added here as an add on to Rinse Conveyor. Will enable wash and packing in a production line system versus a batch packing process
 - Can wash effectively, root crops, lettuce, loose spinach and other multiple crops
- [Economic Profitability of Growing Lettuce and Tomato in Western Washington under High Tunnel and open-field Production Systems](#)
 - Suzette P. Galinato, Carol A. Miles