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BABY-LEAF SALAD GREEN PRODUCTION GUIDE FOR WESTERN WASHINGTON

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BABY-LEAF SALAD GREEN PRODUCTION GUIDE FOR WESTERN WASHINGTON

By
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Abstract

Lettuce is the top-grossing fresh market vegetable crop in the United States, and salad mixes featuring baby-leaf greens are becoming increasingly popular among consumers who desire to eat healthy, convenient food. Growers in western Washington may produce salad greens throughout the year, using season-extension techniques such as row covers, low tunnels, and high tunnels during the winter. This production guide is for growers in western Washington who want to produce baby-leaf salad greens. This guide discusses the selection, growing, harvesting, and processing of baby-leaf greens, as well as related food safety concerns, all of which can present unique challenges. This guide also describes specific crops commonly grown for baby-leaf salads, and the pros and cons of each.

Baby-Leaf Salad Green Production Guide for Western Washington

Introduction

Lettuce is the top-grossing fresh market vegetable crop in the United States and is grown on more acres than any other fresh market vegetable crop excluding potato (USDA 2013). Ready-to-eat bagged salad was first available in the late 1980s, and was originally just shredded head lettuce that could not be marketed as whole heads due to cosmetic imperfections (Kerns et al. 1999). Today, salad mixes include a mix of six to eight baby-leaf greens that are flavorful, nutritious, and visually interesting. As a result, baby-leaf salad is increasingly popular among consumers who desire to eat healthy, convenient food, while head lettuce consumption has decreased (Cook 2011; Glaser et al. 2001).

While sales of ready-to-eat salad are highest in the summer, sales are strong year-round (Thompson and Wilson 1999). California and Arizona produce 96% of all salad mix because these regions have relatively mild year-round climates (Cook 2011; Smith et al. 2011). Growers in western Washington are in a good position to produce salad greens throughout the year, as the maritime climate is relatively temperate year-round. While the main growing season for salad greens is May to September in western Washington, season-extension techniques, such as row cover, low tunnels, and high tunnels, can be used to produce salad greens during the winter (Miles et al. 2004).

Baby-leaf salad mixes are comprised of several types of leafy greens harvested when leaves are 4 inches long so they are bite-sized. There is no strict requirement regarding the composition of baby-leaf salad mix, and growers have the flexibility to alter the composition of their mix based on what is available at each harvest to achieve a balance of color, texture, and flavor.

Crop Selection

The main crop types grown for baby-leaf salad mix are arugula, beet, kale, lettuce, mustard, pak choi, and spinach. Select crop types and cultivars for baby-leaf production with the end product in mind.

A salad mix should include an aesthetically pleasing mix with good texture and flavor. Many cultivars used for baby-leaf salad green production were bred for full head maturity, and only recently have seed companies begun to release cultivars bred specifically for baby-leaf salad production. Cultivars developed for baby-leaf production have good leaf shape, color, and texture at approximately 30 days after planting, as well as thicker leaves for extended shelf life (increased leaf thickness reduces leaf damage in processing and post-harvest water loss).

Crop growth rates vary among crop types, cultivars, seasons, and locations. Some cultivars may be more productive at different times of year.

Figure 1. Lettuce cultivar with a flat leaf structure tends to clog processing equipment (left), whereas cultivars with loft pass through the equipment more easily (right).

The best way to ensure a good mix at each harvest date is to plant two to three more crop types than is needed for each harvest and select the best ones at each harvest date. Experiment in your area and plan to harvest six to eight different crop types for baby-leaf salad mix at any given time.

Harvesting, washing, packaging, and shipping baby-leaf salad can present unique challenges (Clarkson et al. 2003). Flat leaves can clump together during the processing such that they catch under the roller bars during washing (Figure 1), causing young leaves to bruise and tear (Figure 2). This leads to larger discard rates (up to 30%).

Reduce postharvest damage and loss by choosing cultivars with an upright growth habit, thicker leaves, good midrib strength, and textured leaves. Upright cultivars are a requirement if using a machine harvester.

Utilizing at least one textured or frilly cultivar will facilitate grading and mechanical washing, and will provide “loft” in the final mix. Loft refers to the air space between leaves, which helps to extend shelf life of the salad mix. Cultivars that have smooth leaves, such as many spinach and lettuce cultivars, require particular care in washing and drying.

The following list of crops commonly grown for baby-leaf salad production is in alphabetical order and not according to importance. Importance can vary based on market demand, season, weather, and pest issues in your area. This guide does not include recommended cultivars for each crop type as cultivars perform differently based on season, location, and management, but it does include a general description of characters and traits for successful cultivar selection.

Figure 2. Bruising on baby-leaf lettuce (left) caused when leaves catch in processing equipment (right). Also, note that smooth-textured leaves stick together in the processing equipment, causing higher production costs and shorter shelf life.

Arugula

Arugula (*Eruca sativa*), also known as rocket salad or roquette, has a spicy, peppery flavor. Heirloom cultivars tend to have a stronger flavor than newer cultivars. Newer cultivars have a lobed leaf margin, whereas heirloom cultivars have a heavily incised leaf (Figure 3). Due to its strong flavor, arugula is usually mixed with milder greens such as lettuce.

Arugula seed is quick to germinate under a diversity of weather and soil conditions and has vigorous seedlings.

Arugula bolts (premature flowering) in response to high temperatures and long day lengths. Tendency to bolt in response to these environmental changes will vary between cultivars but, in general, temperatures above 80°F and day lengths exceeding 12 hours will trigger bolting in arugula (Morales et al. 2006). Risk of bolting is highest in early summer.

Figure 3. Newer arugula cultivars have a slightly lobed leaf margin (left), whereas heirloom wild-type cultivars have a heavily incised leaf (right).

Flea beetle is the primary problem affecting arugula in western Washington; however, the leaf type can mask minor damage. If flea beetle pressure is high in your area, place row cover over the crop soon after seeding for protection (Parker et al. 2012a, 2012b).

Beet greens

Plant breeders have developed some beet (*Beta vulgaris*) cultivars specifically for their greens or tops, though these cultivars will still form an edible taproot if grown to maturity. Beet greens are very similar to Swiss chard in texture, but they have a sweeter flavor. Leaves and stems are red, for traditional cultivars, and green or yellow for golden beets (Figure 4). Beets tend to be slow to become established, similar to lettuce, and may take 2 to 3 weeks to emerge.

Beets are biennial (takes 2 years to complete its reproductive cycle), so they will very rarely bolt when grown as baby-leaf salad greens unless they are subjected to overwintering or a very long cold spell (temperatures below 35°F for more than 2 weeks) in early spring or late fall.

Kale

Kale (*Brassica oleracea* var. *acephala*) leaves and stems range in color from green to purplish red, and leaves vary in structure from smooth to savoy to curly (Figure 5). All kale leaf types are suitable for baby-green production, and the serrated leaf structure prevents leaves from sticking together.

Figure 5. Red Russian kale at time of harvest for baby-leaf salad mix.

Kale is quick to germinate and establish a stand in a wide range of soil types, temperatures, and moisture levels. Kale is highly cold tolerant once established and therefore is well suited for production in the fall in western Washington.

Similar to beets, kale is a biennial crop so bolting is rare unless it has been overwintered or experiences a severe cold spell in spring or fall. This makes kale a good candidate for “shoulder-seasons” (plantings earlier or later than the main May-through-September production season), since it will seldom bolt in response to day length and temperature shifts that occur in late spring and late summer as arugula, mustard greens, and spinach often do.

Figure 4. Red leaves and stems of traditional cultivars (left) and green leaves and yellow stems of golden beets (right).

Flea beetle is the primary problem affecting kale in western Washington; however, the leaf type tends to mask minor damage. If flea beetle pressure is high in your area, place row cover over the crop soon after seeding, for protection.

Lettuce

There are five types of lettuce (*Lactuca sativa*): crisphead, butterhead, romaine, Batavian, and leaf. Lettuce is a very desirable crop in baby-leaf salad mix, and Romaine and leaf lettuces are the most commonly used types for baby-leaf production.

Lettuce leaf color ranges from red to green, and varies in leaf shape and structure (Figure 6). Mixes of baby-leaf salad that include contrasting colors are very appealing to consumers. Leaf structure is particularly important as flat leaves have no "blistering" or loft; they can clog processing equipment, and they create a very dense, compacted salad mix with a relatively short postharvest shelf life. Furthermore, lettuce types with flat leaves are problematic in dryers that use centrifugal force to remove water after washing because leaves stick together, potentially requiring further handling during packaging.

Lettuce is quick to germinate and grow from June through August in western Washington, and will be ready for harvest in 30–35 days, whereas lettuce seedlings are very slow to germinate and establish stands in cool spring and fall temperatures. Lettuce rarely bolts in western Washington, particularly when harvested at a young growth stage as in baby-lettuce production.

Figure 6. There are a diversity of lettuce cultivars with different leaf colors and types (left); cultivars with flat leaves are less suitable for processing than cultivars with textured leaves (right).

Mustard

Mustard green crops (*Brassica sp.*) come in a wide range of colors, leaf shape, leaf texture (savoy and smooth), growth habit, and flavor (mild to spicy). Tatsoi (*Brassica rapa* var. *rosularis*; spinach mustard, spoon mustard) and mizuna (*Brassica juncea* var. *japonica;* Japanese mustard) are the most common types of mustard greens used in baby-leaf salad mixes (Figure 7).

Mustard crops tend to germinate at low soil temperatures and can quickly establish in the spring and fall.

Figure 7. Tatsoi, also known as spinach mustard or spoon mustard (cultivar Yukina Savoy pictured on left) and mizuna, also known as Japanese mustard (cultivar Mizspoona pictured on right) at time of harvest for baby-leaf salad mix.

Mustard greens bolt in response to high temperatures and long day lengths. Tendency to bolt in response to these environmental changes will vary between cultivars but, in general, temperatures above 80°F and day lengths exceeding 12 hours will trigger bolting (Nishioka et al. 2005).

Flea beetle is the primary problem affecting mustard green crops in western Washington. Depending on the mustard crop's leaf shape, damage can be very visible. There is no cultivar resistance to flea beetles in any mustard green. Many growers place row covers over the crop soon after seeding to protect it from the flea beetle.

Pak choi

Pak choi (*Brassica rapa* ssp. *chinensis*) cultivars are primarily green-leafed; however, there are a handful of red-leafed cultivars available (Figure 8). Pak choi has a large stem that forms early in its development. This large stem adds crunch to baby-leaf salad mix, and adds weight to the crop. The postharvest shelf life of pak choi tends to be longer than for most other baby-leaf salad crops.

Pak choi is quick to germinate and become established in the field.

Pak choi bolts in response to high temperatures and long day lengths. Tendency to bolt in response to these environmental changes will vary between cultivars but, in general, temperatures above 80°F and day lengths exceeding 12 hours will trigger bolting (Nishioka et al. 2005).

Flea beetle is the primary production problem affecting pak choi in western Washington, and damage is readily apparent on the pak choi leaf type, making management critical. Place row cover over the crop shortly after seeding, for protection.

Spinach

Spinach (*Spinacia oleracea*) cultivars have either smooth or savoyed (curly, crinkly) leaves; baby-leaf spinach producers use smooth-leaved cultivars almost exclusively (Koike et al. 2011). Savoyed cultivars do not develop full savoy at 30 days after planting, the time of baby-leaf harvest, so it is not worth planting these cultivars for this trait.

Spinach cultivars well-suited for baby-leaf production will have an upright growth habit that minimizes exposure to soil and increases ease of harvesting (Figure 9). Spinach leaf angle is affected by day length, and a cultivar that performs well in spring might perform very differently in fall. Leaf area and thickness of spinach leaves are influenced by day length as well, such that spinach grown under long-day conditions have increased leaf area but decreased leaf thickness relative to spinach grown under short-day conditions (7 hours) (Rogers 2008).

Spinach tends to establish quickly under spring, summer, and fall growing conditions in western Washington. Most cultivars of spinach will also be prone to bolting once days exceed 14 hours in length.

Figure 8. Green-leafed pak choi cultivar Joi Choi, at time of harvest.

Figure 9. Spinach plants grown for baby-leaf production, at time of harvest.

Almost all commercially grown spinach cultivars are hybrids with resistance to bolting and many common diseases. Downy mildew is the most economically significant problem affecting spinach in western Washington.

There are 13 races of downy mildew identified to date for spinach. Cultivar resistance for downy mildew is race-specific, so most spinach cultivars will be resistant to some races but not others. There are very few spinach cultivars with resistance to all 13 races of downy mildew, and it is very difficult to predict which races will be present each growing season. Minimize the likelihood of downy mildew affecting your crop by choosing cultivars with resistance to a range of races. Information on downy mildew resistance for spinach cultivars is available from most seed suppliers.

Field Selection

Baby-leaf salad-green crops grow best in light-textured soils such as silt loam and sandy loam. Light, loose soil provides better drainage during the cold, wet weather that frequently occurs during spring, fall, and winter in western Washington. Light, loose soil also warms up more readily in the early spring and is less likely to become compacted after planting.

Soil compaction can inhibit emergence in direct-seeded leafy greens crops. Leafy green crops will grow in heavy clay soils as long as the soil has good structure, but raised beds and row covers or low tunnels can help to increase soil temperature and prevent flooding.

The optimal pH range for leafy greens crops is from 6.2 to 6.8. Good yields can still be achieved in soils with a pH higher than this, but lettuce and spinach in particular are very sensitive to a pH lower than 6.0. Apply lime in the recommended amount for soils with pH lower than 6.2.

Most leafy green crops have a low degree of salt tolerance. Measure soil salinity by determining the electrical conductivity of the soil, either through a soil-testing lab or using a portable electrical conductivity (EC) meter (Sonon et al. 2012). Research has shown the soil salinity threshold for yield loss to be 1.3 deciseimens per meter for lettuce and 2.0 deciseimens/m for spinach at 72°F (Shannon and Grieve 1999). In the mustard family, there is quite a bit of diversity among cultivars grown as salad crops, but most have a soil salinity threshold in the range of 1.8 to 3.2 deciseimens/m; below this, yield loss will occur.

Soil Cultivation and Field Preparation

Baby-leaf salad greens are small-seeded crops that require a fine, firm seedbed for good germination. Prepare soil such that crop residues are incorporated and soil clods are broken up as these can plug the seeder and reduce seed-to-soil contact, negatively affecting germination.

Raised beds with finely tilled soil, firmed with a roller bar are well suited for baby-leaf salad production (Figure 10), and will provide even moisture distribution during irrigation. Do not compact the soil, as this will prevent seed germination and emergence.

Field preparation in western Washington can be difficult in early spring and late fall, even in well-drained soils, due to heavy rainfall. If soil has a drainage problem or is very compacted, chisel plow to loosen soil.

Use raised beds in fields with poor drainage or in areas that receive high rainfall to increase drainage and prevent flood damage (Figure 10). Raised beds also increase soil temperature, reduce soil compaction, and prevent mud contamination of the crop at harvest.

Fertilizer

Baby-leaf salad greens are short-season crops harvested about 30 days after planting, thus nutrient uptake is relatively low. Collect a soil sample for analysis following instructions given in the WSU publication *Soil Testing: A Guide for Farms with Diverse Vegetable Crops* (Collins 2012). Apply fertilizer based on recommendations for salad crop production provided by the commercial laboratory.

If using compost or manure, apply in the fall prior to seeding baby-leaf salad greens. If using an organic commercial fertilizer, apply 2 to 3 weeks before planting. If using a conventional commercial fertilizer, apply just before or at planting. This will improve the availability of the fertilizers to the crop. Do not apply an excess of nitrogen or phosphorus, as this will shorten shelf life of baby-leaf crops (Hoque et al. 2010).

Seed

Fungicide-treated seed is available for most leafy green crops and may be beneficial under conditions where damping-off and low germination have a history of reducing stand establishment.

Pelletized seed allows for precision planting by increasing the size of the seed for easier handling and better compatibility with tools such as precision push-style row seeders. Pelleted seed is especially beneficial for planting lettuce seed, which has a pointed, oblong shape and is very small and light. If using non-pelleted seed, high-density drop seeders provide good seeding accuracy.

Non-treated, conventional, as well as organic seed is also readily available. Regardless of which type of seed you choose, it is always important to ensure that the seed germination rate has been recently tested and is adequate for good stand establishment (90% or greater is advisable). The germination rate on the package of seed purchased in previous years may not be accurate; either test germination or discard the seed.

If you are farming organically, check with your certifier to ensure approval of any seed treatments or coatings for use in certified organic production. Only purchase seed from a reputable supplier who tests seed regularly for seed-borne pathogens.

Figure 10. Raised beds with fine-tilled soil (left) firmed with a roller bar (center) to ensure adequate seed-to-soil contact for germination of direct-seeded crops. Raised beds can prevent the crop from being flooded in the spring, fall, and winter (right).

Seeding

Seed crops in the spring when soil temperature reaches 50°F. In the fall, do not seed after October 15 unless you will cover the crop with row cover or a tunnel.

Baby-leaf salad greens are seeded at a very high density to achieve economic yields and discourage weed growth.

Determine bed width based on your equipment: measure the inside space between the tires of your tractor, subtract 12 inches (6 inches on either side), and this will be the width of your beds (Figure 11).

Figure 11. Base bed width on the inside space between the tires of your tractor. Subtract 12 inches and this will be the bed-planting surface. (Adapted with permission from Sahar Dabirian, WSU)

For example, for a tractor with 50 inches of space between the tires, the bed width would be 38 inches. Space rows 2 ½–3 inches apart on the bed with in-row seeding densities of 1 to 4 seeds per inch (Table 1). This planting density is equivalent to 104,544,000 to 557,568,000 seeds per acre (assuming 6 feet, center-to-center, for beds).

Optimal density will vary from location to location due to environmental conditions. For example, decreased airflow within beds due to excess seeding density can lead to high disease incidence and lower yield at locations with high precipitation and humidity.

Table 2 lists the approximate number of seeds per pound for crops commonly grown for baby-leaf salad. Use this information to calculate how much seed you will need to purchase and plant for your baby-leaf salad mix production.

Table 1. Number of baby-leaf greens seeds per 100-foot bed[a]

	Seeds per Inch	
Number of rows	1	4
12	14,400	57,600
16	19,200	76,800

[a] In 12 or 16 rows with 1 to 4 seeds per inch.

Table 2. Average number of seeds per pound for baby-leaf salad-green crops[a]

Crop	Seeds per Pound
Arugula	302,400
Beet	28,550
Kale	122,600
Lettuce	378,000
Mustard green cv. Bekana	151,200
Mustard green cv. Komatsuna	162,000
Mustard green cv. Yukina Savoy	226,800
Pac Choi	174,450
Spinach	48,250

[a] Based on 100-seed weights measured at WSU Mount Vernon NWREC.

By hand, direct-seed baby-leaf salad crops by drilling with a push-seeder. By tractor, use a high-density mechanical drop seeder (Figure 12). Select seed plate sizes that best fit the size of the seed. Mechanical seeders suitable for salad green seed include a drop mechanism with brushes.

Fill the seed hopper with a sufficient volume of seed in order to assure even seed distribution. If a tractor-driven seeder is used, adjust tractor speed up or down as needed to ensure the correct seeding density.

Planting Schedule

Each type of crop has a different growth rate and it can be challenging to create a planting schedule that permits each crop to reach harvestable size for baby-leaf salad on the same day. In general, Brassica crops, which include arugula, mustard, pak choi, and kale, have the fastest growth rate; chenopod crops, which include spinach and beets, have a medium growth rate; and lettuce has the slowest growth rate (Figure 13).

For a summer planting of lettuce in western Washington, the time from seeding to the first harvest is 28–35 days (based on a 4-inch leaf length). The time from the first harvest to the second harvest is 5–6 days for most lettuce cultivars, while the time to second harvest of short frilly cultivars (i.e., Lolla Rossa types) is 7–8 days.

Figure 12. A 16-row mechanical seeder (left and center). Arugula (10 rows) mechanically seeded (right).

Figure 13. Staggered plantings of baby-leaf salad greens in separate beds (left), so that fast-growing crops do not shade out slower-growing crops (right) and all crops can be harvested on the same day.

The time from the second harvest to the third harvest for most cultivars is 5–7 days. You may achieve a fourth harvest from a single planting in some instances, and this will likely be 5–7 days after the third harvest. Thus, for lettuce, the time from seeding to the third harvest is 38–50 days. Table 3 provides days-to-harvest information for common baby-leaf salad crops during spring and fall at two locations in western Washington.

Another consideration for scheduling planting dates for brassica and spinach crops is that both are likely to bolt if planted too late in the spring or too early in the fall. Bolting results in a rapid decline in crop quality, and crops can be unmarketable.

Brassica crops and spinach are long-day crops, thus they begin to flower when day length exceeds their critical day length (12 hours for brassicas and 14 hours for spinach) and temperatures are above 80°F. In western Washington, day length exceeds 12 hours from approximately March 15 to September 25, and exceeds 14 hours from April 25 to August 15.

Table 3. Average number of days to harvest for spring and fall for baby-leaf salad crops[a]

Crop	Spring		Fall	
	Mount Vernon	Everson	Mount Vernon	Everson
Arugula	32	38	31	58
Beet	54	45	48	44
Bekana	29	35	29	48
Kale	30	37	30	43
Komatsuna	29	35	29	29
Lettuce	45	42	49	58
Pac Choi	29	35	30	42
Spinach	36	36	53	48
Yukina Savoy	33	39	35	51
Average	35	35	37	42

[a] As measured (for 2 years) at Mount Vernon and Everson in western WA; based on a research study by Washington State University.

In contrast, lettuce is also a long day plant, but it seldom bolts in western Washington regardless of day length. This is likely because many cultivars are bolting resistant, and temperatures are not high enough in the region to induce bolting.

Irrigation

Even soil moisture is essential for good germination of baby-leaf salad crops. If soil moisture is low after planting, lightly irrigate immediately after planting until the soil surface is wet, and keep the soil surface wet by irrigating daily until germination is complete.

In sunny, warm weather, it may be necessary to irrigate up to five times per day to maintain adequate soil moisture.

For up to 10 days after seeding, do not allow soil to dry, otherwise a crust can form on the soil surface and delay seed emergence. Delayed emergence will not only increase weed pressure due to exposed soil surface, it will also reduce yield, as leaves will be different lengths.

Keeping the soil moist until complete crop emergence is one of the most important steps to success for baby-leaf salad green production.

If using drip irrigation, place two drip tapes per 3-foot-wide bed (Figure 14), with emitter spacing no more than 12 inches apart. If using micro sprinklers (Figure 15), arrange the sprinkler heads such that the entire planting area receives irrigation.

After emergence, maintain consistent soil moisture. In many parts of western Washington, precipitation will provide sufficient irrigation in the spring, fall, and winter if crops are not covered.

Figure 14. Drip irrigation for baby-leaf salad crops.

Figure 15. Micro sprinkler irrigation in baby-leaf salad greens.

Food Safety Considerations for Irrigation Water

Good Agricultural Practices (GAP) recommend only using potable water for irrigating crops that are consumed raw (WSDA 2009). New proposed Food and Drug Administration (FDA) legislation called the Food Safety Modernization Act (FSMA) targets leafy green crops due to their association with outbreaks of foodborne illness (Blanchard 2013; FDA 2014).

Regulations classify surface-water irrigation as a higher contamination risk than ground-water irrigation, and consider irrigating with potable water the lowest contamination risk.

Water used for overhead irrigation, such as that applied by micro sprinklers, is considered a more likely source of contamination than drip or furrow irrigation, as micro sprinklers bring water into contact with the edible portion of the crop.

Surface- and ground-water used for irrigation and/or pesticide applications must be tested regularly to show that they meet safety standards for foodborne pathogens. Refer to the FDA FSMA for specific guidelines regarding water testing.

Irrigation can prevent bitter flavors from developing in salad-green crops during hot weather. In the week before the first harvest, adequate irrigation can double crop yield.

The evening before harvest, irrigate baby-leaf salad greens to maximize yield, increase leaf turgidity and shelf life, and minimize postharvest loss.

Season Extension Techniques

Several season extension techniques are compatible with baby-leaf salad crop production. Use raised beds to provide good soil drainage and avoid mud contaminating the crop at harvest.

Row cover is a simple tool to protect the crop from heavy rain and requires low capital investment (Figure 16). Low tunnels are simple structures easily moved from bed to bed each season (Figure 17). Row cover and low tunnel covers may be spun bonded polyester fabric or clear agricultural plastic.

Place row cover or a low tunnel over the crop when the temperature falls below 50°F or when rains become heavy. If using plastic covering for row covers or low tunnels, be sure to use pre-slit plastics or vent throughout the day as needed.

If the sun is out and the air temperature is greater than 60°F, temperature under non-ventilated plastic can reach 20°F higher than outside temperatures, which can damage the crop.

A high tunnel is a larger structure that, depending on model and size, may remain in the field for several years, or may be moved around the field from year to year (Figure 18).

Figure 16. Row cover is placed directly over the crop and is removed here to observe crop growth and to remove weeds as needed.

A high tunnel provides the most protection and improved growing conditions for the crop, but also is the most costly method and may require the greatest degree of day-to-day management depending on levels of wind, rain, and snow in your area.

Weed Management

Weed management is one of the most challenging aspects of growing baby-leaf salad greens, particularly in western Washington where weed pressure is year-round.

Plant baby-leaf salad greens in a very clean field, as weed management after the crop has emerged is extremely difficult and not economically viable.

Figure 17. A low tunnel made with agricultural plastic over wire hoops and placed over one raised bed of baby-leaf salad greens (left); low tunnel vented to prevent crop damage when the temperature is above 60°F and the sun is out (right).

Figure 18. A high tunnel design, which remains in the same location each year and the crop is rotated (left), and a high tunnel design, which is easily dismantled and moved around the field (right).

Weed pressure in a field can be reduced over time by utilizing cover crops and/or herbicides regularly, and cultivating or hand-removing weeds before they to go seed. Planting in clean fields with very low weed pressure is another key to success for growing baby-leaf salad greens.

Stale Seedbed Technique

The "stale seedbed" technique involves preparing the seedbed several weeks prior to seeding, and just prior to seeding, removing all the weeds that have germinated. This technique is very effective for baby-leaf salad crops, and is particularly effective for the control of annual weeds.

Prepare and irrigate the seedbeds, and leave fallow for one to 3 weeks to allow all weed seeds at the soil surface to germinate. Kill these weed seedlings using flaming (Figure 19) or pre-plant herbicides labeled for the crops you intend to plant. You can apply a propane flaming treatment either immediately before or after seeding.

Plant the crop into the bed using minimal soil disturbance so as not to bring any new weed seeds to the surface.

False Seedbed Technique

An alternative method to the stale seedbed technique is the "false-seedbed" technique. Here, beds are prepared as previously described in the stale seedbed technique, then a shallow (< 2 in.) cultivation is performed just prior to seeding. The goal for both of these methods is to avoid redistributing weed seeds vertically within the soil profile after killing weed seedlings at the surface.

Figure 19. Flame a bed for weed control either immediately before or after seeding baby-leaf salad crops (left); flaming desiccates (completely dries out) newly emerged weeds (right).

If weeds become established, remove them before they exceed 6 inches in height, otherwise they will compete with the salad green crop and can severely impact crop quality.

Chickweed is a very common weed in the fall in western Washington and can out-compete most baby-leaf salad crops in fall plantings. Weeding beds where chickweed is established is labor intensive, costly, and generally unsuccessful, leading to beds unsuitable for harvest. Flaming can provide good control for chickweed, but you may need to apply two flaming applications, one week apart, before seeding, to manage it effectively.

After the crop has emerged, control grasses with herbicides approved for use on the specific crop (spinach, lettuce, mustard greens, etc.). Refer to the *Pacific Northwest Weed Management Handbook* (Peachey et al. 2014) for current herbicide recommendations, and check herbicide product labels to meet pre-harvest intervals for baby-leaf salad greens.

Mechanical cultivation techniques, such as tilling or finger weeding between rows within a bed, are not recommended for dense baby-leaf crop plantings. Hand weeding is effective, and can take three to four person-hours to weed a 100- to 250-foot bed depending on weed density.

Weed beds 1 to 2 days before harvest to minimize the number of weeds picked with the crop. Weeding the field requires significantly less labor than removing weeds during processing; therefore, field weeding is more cost effective.

Abiotic Disorders

Baby-leaf salad crops are affected by numerous abiotic disorders (problems caused by environmental conditions), which result in a wide range of symptoms such as discoloration and tissue damage. Growers often misdiagnose them as a sign of disease or insect damage.

It is important to recognize these symptoms to address the true cause of the problem and avoid unnecessary use of pesticides. Below are the abiotic disorders most likely to affect baby-leaf salad crops in western Washington.

Nutrient Deficiency

A shortage of any essential macro- or micronutrient will affect the health of all crops grown for baby-leaf salad (Hosier and Bradley 1999). However, deficiencies of the macronutrients nitrogen (Figure 20), phosphorus (Figure 21), and potassium (Figure 22) are the most common deficiencies affecting the health and marketability of baby-leaf salad crops.

Figure 20. Nitrogen deficiency symptoms include chlorotic (yellowed) leaves and/or stunted plant growth.

Figure 21. Phosphorus deficiency symptoms include stunted growth, purple stem and leaf veins, and yellowing of the most mature leaves.

Figure 22. Potassium deficiency symptoms include yellowed leaf margins progressing to desiccation.

Salt Injury

In contrast to nutrient deficiencies, salt injury can occur when an excess of fertilizer is applied to a field. Salt injury also occurs when soils have naturally high salt content, such as soils near saline bodies of water. A soil test will determine the salinity of a field, and if salt levels are too high they can be lowered by leeching salt from the root zone with irrigation.

High soil salinity can negatively affect the germination of direct-seeded crops, and most crops grown for baby-leaf salads are not salt tolerant.

Signs of salt injury include slow and inconsistent rate of seed germination, yellow leaves and brown leaf margins, wilting, poor root development, and plant death (Figure 23; Lilly and Averre 1999).

Figure 23. Salt injury on leaves after overhead fertigation.

Edema

Edema affects spinach, beet greens, pak choi, mustards, and arugula and is recognizable by irregular bumps on the surface of leaves (Figure 24). These bumps form when air is cooler than soil, soil moisture is high, and relative humidity is high. Under these conditions, plant transpiration slows down while soil moisture uptake by the roots increases. This causes an increase in turgor pressure that bursts the epidermal cells of the leaves, causing protrusion, discoloration, and eventually cell death. Bumps develop into yellow lesions that can be easily misidentified as disease.

Edema bumps will sometimes also lead to cracking in the leaf surface (Johnson 2013). Edema is most common from late fall to early spring in western Washington.

Figure 24. Edema manifests as irregular bumps on the surface of leaves. (Open source image, Pop Vriend Seed Co., Holland, via the Pacific Northwest Vegetable Extension Group)

Frost Damage

Many baby-leaf salad crops, such as kale and lettuce, are cold-tolerant and can survive moderate frost, but it is possible for frost damage to occur on all baby-leaf salad crops. It should be noted that crops such as kale that are extremely frost-tolerant at a mature growth stage will be less tolerant of frost at an immature growth stage, as in baby-leaf salad production.

When baby-leaf salad crops do not succumb completely to a frost, they may be left with pale lesions that can resemble disease and render the crop unmarketable (Figure 25). These lesions appear when frost causes the leaf cuticle to separate from the underlying epidermal cells.

Mitigate frost damage to crops by planting only frost-tolerant cultivars from fall to spring and utilizing row cover, low tunnels, or high tunnels to protect the crops.

Figure 25. Frost damage on a leaf of baby kale.

Guttation

High soil moisture and high relative humidity in spring, fall, and winter cause spinach to excrete water droplets through the leaves, primarily through the stomata on the underside of the leaf (Figure 26). These water droplets dry during the day as sunlight hits the leaf and air temperature increases, leaving behind tiny white granules of salts and other solutes (dissolved substances) that were dissolved in the water. These granules do not harm the plant but can be mistaken for insect eggs or disease. They must be washed off harvested leaves during processing as they are unsightly.

It is very difficult to avoid guttation in the colder months, but reducing irrigation, if applicable, can reduce the severity of guttation (Ernst et al. 2012).

Figure 26. Guttation on the underside of a spinach leaf harvested in early spring.

Common Diseases and Insect Pests

Many of the same diseases and insect pests that affect mature vegetable crops in your area also affect baby-leaf salad green crops. Below are photos of the most common problems that affect baby-leaf salad crops in western Washington: damping off (Figure 27), downy mildew (Figure 28), grey mold (Figure 29), schlerotinia rot (Figure 30), cabbage looper (Figure 31), flea beetle (Figure 32), and green peach aphid (Figure 33).

For a complete list of diseases and insect pests that affect baby-leaf salad crops and management recommendations, refer to the *Pacific Northwest Plant Disease Management Handbook* (Pscheidt and Ocamb 2014) and the *Pacific Northwest Insect Management Handbook* (Hollingsworth et al. 2014).

Figure 27. Damping off in arugula seedlings, which is caused by many different soilborne fungi (*Pythium spp., Phytophthora spp., Rhizoctonia spp.,* and others).

Harvesting and Processing

Harvest baby-leaf salad crops in the early morning when temperatures are as low as possible, and cool them immediately after harvest to remove any field heat to maximize crop quality and yield, particularly when daytime temperatures are high and humidity is low.

Spinach, under 70°F day and 54°F night conditions, that is harvested at 6 a.m. has been shown to have a shelf life 3 days longer than spinach harvested at 9 a.m. or noon. (Rogers 2008). Additionally, baby-leaf greens harvested at dawn weigh more than those harvested later in the day. The relatively low temperatures and high humidity in the early morning prevent water loss.

Figure 28. Downy mildew on lettuce (*Bremia lactucae*; left) and spinach (*Peronospora farinosa*; right; image by Dr. Lindsey du Toit).

Figure 29. Grey mold (*Botrytis cinerea*) on lettuce.

Figure 30. Sclerotinia rot (*Sclerotinium sclerotiorum*) on baby-leaf romaine lettuce.

Figure 31. Cabbage looper (*Trichoplusia ni*) found on arugula.

Figure 32. Flea beetle (*Phyllotreta cruciferae*, circled) and flea beetle damage on baby-leaf mizuna.

Figure 33. Green peach aphid (*Myzus persicae*) on baby-leaf lettuce.

The lower amount of accumulated carbohydrates present in the leaves in the early morning (before the day's photosynthesis begins) may also slow respiration during postharvest handling, thus slowing degradation during handling and storage (Able et al. 2005).

Baby-leaf salad greens can be harvested manually or mechanically. Manually harvest baby-leaf salad with clippers or a blade (Figure 34). Manual harvesting is labor-intensive and time-consuming; therefore, only use this method for small-scale production.

Mechanical harvesters for baby-leaf salad greens are available in different sizes, from one to six beds wide, and can be hand-pushed or tractor-driven (Figure 35). Even hand-pushed mechanical harvesting is very labor efficient.

Figure 35. One-bed-wide hand-push mechanical harvester for baby-leaf salad greens.

For example, in a research experiment in western Washington, two people operating a one-bed-wide, hand-push mechanical harvester harvested approximately 180–200 lb per hour of baby-leaf salad greens.

Cutting blades and conveyor belts on mechanical harvesters are electrically driven, and most are adjustable to accommodate a range of crop heights. Due to food safety considerations, sanitize the mechanical harvester before every harvest.

Many baby-leaf salad growers will harvest a bed three or four times. To do this, it is critical not to damage the plant meristem (point of new vegetative growth) during harvest or no regrowth will occur.

Figure 34. Hand harvesting baby-leaf salad greens with clippers (left); a blade commonly used for harvesting baby-leaf salad crops (right).

For the first harvest, cut the crop approximately 1 inch above the soil line (adjust as needed based on the height of the plant meristem in your field). For the following harvests, raise the blade about 1 inch each time to avoid harvesting leaves cut in previous harvests. Yield and crop quality will be comparable for all crop harvests.

If a crop is a few inches taller than ideal at time of harvest, harvest only the top 4 inches of the leaves; then mow the crop to approximately 2 inches and allow it to regrow for the next harvest. Alternatively, market crops such as kale, mustard greens, chard, and spinach that have exceeded a suitable size for baby-leaf salad as braising mix. Lettuce and pak choi that are too large for baby-leaf salad may be marketed as mini-heads. Any leaves that were cut in the previous harvest can easily be removed after harvest.

Stricter food safety regulations apply to salad green crops harvested two or more times, because the cuts created on a plant during the first harvest are believed to be a potential point of entry for foodborne pathogens. Salad greens from the second harvest are therefore considered to be *processed* and must be handled, sanitized, and stored as is required for processed products under state and federal food safety regulations. Contact your county and state health departments for more information regarding safe-handling procedures for processed salad crops.

The following are general guidelines:

- Rinse salad greens in a second tank with the same concentration of water to sodium hypochlorite. Small-scale growers often use stainless steel tubs, while large-scale growers use processing equipment designed specifically for salad greens (Figure 36).
- Wash and sanitize baby-leaf salad greens in a dunk tank full of a cold water and sodium hypochlorite solution (150–200 ppm, or 3/4 to 1 tablespoon per gallon of water; McGlynn 2013).
- Dry salad greens using a spinner to remove excess moisture from leaves before packing into cold storage (Figure 37). Excess moisture on leaves rapidly accelerates postharvest decay.
- Store baby-leaf salad greens at 32°F and 95%–100% humidity for a shelf life of approximately 2 weeks (Wright 2004). A cold room can be constructed by insulating a small room and installing an air conditioner and temperature-control unit (Figure 38).

The main cause of postharvest quality loss in lettuce crops is tissue breakdown and subsequent rot, while the main cause of postharvest quality loss in brassica and chenopod crops is yellowing (Wagstaff et al. 2007). Cut salad greens do not produce much ethylene, and they should not be stored with crops that do produce ethylene during storage, as this will result in rapid loss of quality of salad green crops through discoloration (Wright 2004).

Figure 36. Multipurpose wash and rinse tubs on medium-scale farms (left), and a processing line designed especially for salad greens (right).

Food Safety Considerations

Postharvest sanitization reduces the potential number of human pathogens on the surface of leafy greens, such as *Escherichia coli* O157: H7, *Listeria monocytogenes, Clostridium botulinum, Salmonella* spp., and *Staphylococcus aureus.*

Sanitization controls organisms that contribute to spoilage and shorten postharvest shelf life of salad greens, such as the bacteria *Pseudomonas marginalis*.

A sodium hypochlorite wash water solution with 150 ppm of chlorine is the most commonly used sanitizing agent, but UV light, gamma irradiation, and ozone are also effective at reducing the number of pathogens on the surface of produce. Sodium hypochlorite is not approved for organic production, but wash water sanitizers with a peracetic acid base that meet organic standards are available (Carella 2014).

The water used in processing baby-leaf salad greens must meet the same safety standards as potable water.

Figure 37. A commercial salad spinner used to remove excess moisture from leaves.


Figure 38. A homemade cold room for salad crops, maintained at 32°F and 95–100% humidity, using an air conditioner and temperature-control unit.

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