

# Hydroponic Lettuce Production in Controlled Environments

*Arundathi Sharma, Kim Leonberger, Nicole Gauthier  
and Qinglu Ying*

## Introduction

Lettuce (*Lactuca sativa*) is one of the most common vegetables of hydroponic systems. Hydroponics is a method of growing plants without soil. Plants can be grown in soilless medium (drip or ebb-and-flow benches) or in nutrient solution with or without the support of an inert medium (deep water culture and nutrient film technique). In all hydroponic systems, all plant nutritional needs are supplied through the irrigation water.

Hydroponics is a highly exacting and demanding system that requires a greater amount of production knowledge, experience, technical skill, and financial investment than many other production systems. A grower must be committed to meeting the daily demands of production to be successful.

While there are a number of different hydroponic systems that have been commercially successful for lettuce production, this guide will focus on the nutrient film technique (NFT), deep water culture (DWC), and drip irrigation system. Prospective growers should obtain as much information as they can about hydroponic production before starting this type of enterprise.

## Marketing Considerations

Hydroponic production costs, which tend to be higher than typical field production, require growers to either identify consistent markets willing to pay a premium price or produce at a great enough scale to realize scale economies while shipping large amounts of produce. Such market niches may take some time to develop to maximize returns. Growers with superior crops and off-season or year-round availability will have a marketing edge with many buyers. Potential hydroponic growers should talk to local grocers or specialty food retailers interested in locally grown produce to explore expectations around quality, packaging, price, and other buyer expectations from vendors.

The quantity and variety of leafy greens and herbs demanded by Americans has increased as consumers desire more health and diversity in their diets. Per capita consumption of fresh lettuce (romaine and leaf) has increased over the years, reaching 31.5 pounds in 2023 (Davis et al., 2024). In 2022, lettuce contributed nearly 20% of the \$21.8 billion in cash receipts earned by U.S. growers from the sale of vegetables and melons (Weber, 2023). Greens and herbs may be grown and marketed on a variety of scales for different markets, from farmers markets to large-scale commercial wholesale accounts. Wholesale lettuce production is dominated by large scale growers in the western US. While relatively large Kentucky producers could investigate smaller-scale wholesale production, opportunities for hydroponic greens will most likely come from direct marketing to local, small-scale buyers, rather than wholesale distributors. Proper handling practices and other food safety considerations are crucial components for successfully marketing lettuce and other greens and herbs.

## Production Considerations

### Facility requirement and equipment

Hydroponic lettuce production requires well-ventilated greenhouses or similar structures, oriented to optimize environmental conditions. The structure should provide shading or cooling during the summer months, while maximizing light and heat capture in the winter. Consistent access to water is essential and water quality is critical for hydroponic production, as plants rely entirely on water for nutrient delivery and root health. Well or municipal water is recommended due to its stability and lower pathogen risk, while surface water from ponds or rivers may increase the likelihood of introducing plant pathogens. In addition, the facility should have reliable access to electricity, which is necessary to operate water and air pumps and irrigation controllers.

A variety of handheld tools and portable sensors can be used to greatly support daily management in hydroponic lettuce production. Essential devices include calibrated electrical conductivity (EC) and pH meters, which allow growers to quickly assess nutrient strength and solution acidity to maintain stable root-zone environments. For solution-based systems, a dissolved oxygen (DO) meter is also highly valuable for ensuring oxygen availability in the root zone, which supports healthy root development and reduces the risk of root diseases. A light meter or a quantum sensor enable growers to verify adequate daily light levels. Portable climate sensors that measure air temperature, relative humidity, and vapor pressure deficit offer quick spot-checks across the greenhouse to maintain a stable growing environment. Handheld infrared thermometers help monitor leaf and nutrient solution temperatures, providing early warning of heat stress or suboptimal conditions.

With proper environmental and crop management, lettuce yields typically range from approximately 0.4 to 1.2 lb/ft<sup>2</sup> (2-6 kg/m<sup>2</sup>) of growing space per crop cycle. Before starting production, growers should evaluate greenhouse size and usable production area in relation to expected market demand to ensure adequate and efficient output.

## Growing environment

Lettuce is a cool season crop and the air temperature for hydroponic lettuce production should not exceed 75 °F (24 °C) during the day and 65 °F (18 °C) at night, with an optimal daily light integral (DLI) of 12-17 mol/m<sup>2</sup>/day. Lettuce becomes prone to bolting when exposed to prolonged heat and/or high temperature fluctuations. When active cooling is not feasible in production systems, fluctuating temperatures can be more detrimental to lettuce growth and quality than sustained high temperatures. Bolting is a process in which the plant produces a flower stalk and seeds, often due to environment stress like heat. Lettuce bolting leads to a shorter harvest window, bitter taste, and an unmarketable crop. Selecting heat-resistant cultivars and implementing shading, evaporative cooling, and ventilation are strategies to alleviate heat stress.

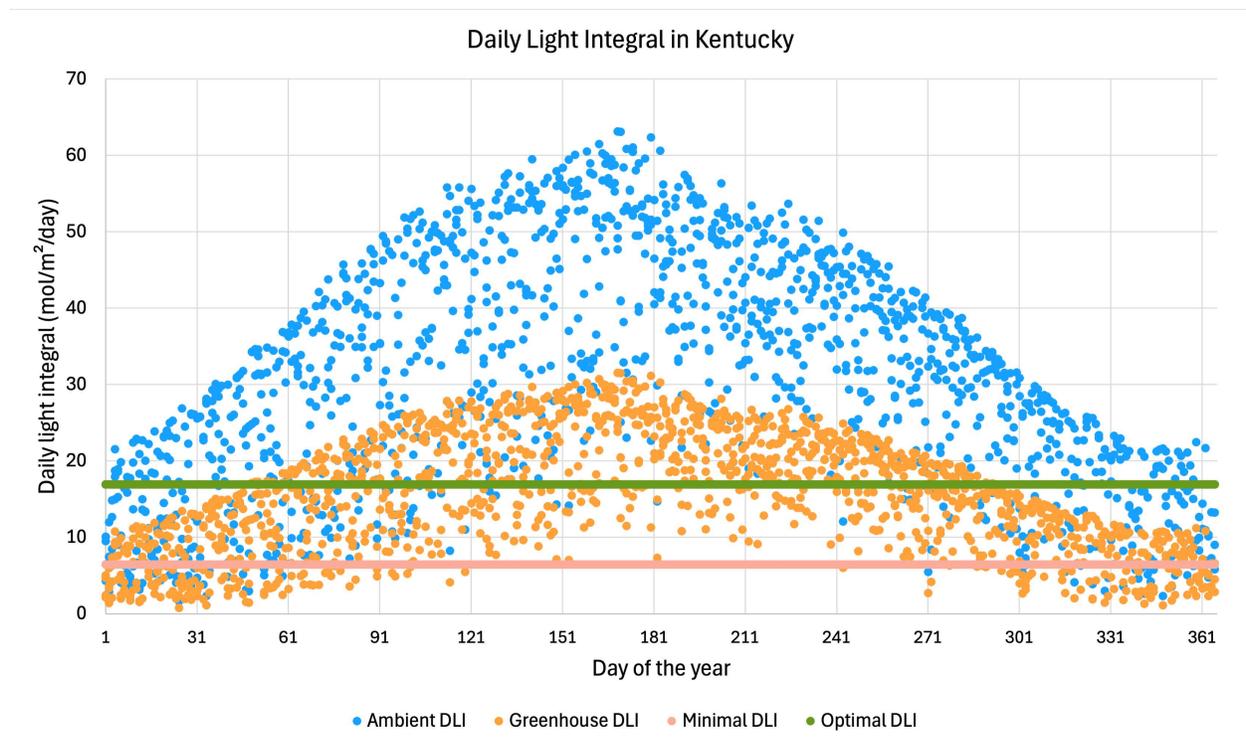


Figure 1. Daily light integral (DLI) of ambient (outside) and inside the greenhouse in Kentucky, based on average ambient measurements from 2021 to 2024 across Mesonet climate stations in 80 counties. Greenhouse DLI was estimated assuming a 50% light transmission rate. Minimum and optimal DLI for lettuce production are indicated – for many Kentucky farms, winter lettuce production is possible with little to no supplemental lighting.

As a cool-season crop, lettuce can be cultivated under suboptimal conditions when growers face resource limitations, such as restricted heating or lack of supplemental lighting. Lettuce can tolerate nighttime temperatures as low as 50 °F (10 °C) and daytime temperatures of 59 °F (15 °C), particularly during the winter months when ambient light levels are low. The minimum DLI requirement for lettuce ranges from approximately 6.5 to 9.7 mol/m<sup>2</sup>/day. However, growing lettuce under low light and temperature conditions will extend the time from planting to harvest. Contact your Extension agent or greenhouse specialist for instantaneous light measurements in your production area to estimate the resultant DLI. Alternatively, lower-cost light sensors (usually measured in W/m<sup>2</sup> or lux) can be used with spectral conversion factors to estimate light availability. Fig. 1 offers an idea of how much light you may have to supplement, should you choose to do so. See Additional Resources for more information about light measurement units.



Figure 2. Tipburn of green leaf (left) and red leaf (right) lettuce

Relative humidity should be maintained at 50 to 70%. Lettuce also requires consistent airflow to maintain transpiration and nutrient uptake, particularly calcium. Calcium is essential for cell wall development in rapidly growing tissues, and calcium deficiency can result in a physiological disorder known as tipburn. Tipburn is characterized by necrosis at the edges of the growing tip and young growing leaves (Fig. 2). Tipburn can be mitigated by reducing growing light and/or temperature, shortening the production cycle, improving air flow to 0.7 - 2.2 miles/hour (0.3 -1.0 m/s) and transpiration rate. Selecting tipburn-resistant varieties is another effective strategy; growers can refer to the additional resources for screening results on lettuce tipburn sensitivity.

## Fertigation

Regardless of the type of hydroponic system used, a complete fertilizer solution containing all 14 essential mineral elements required for plant growth is necessary. Prior to developing a nutrient management plan, it is strongly recommended that growers submit a water sample to a reputable analytical laboratory for a comprehensive analysis. This analysis should assess pH, EC, alkalinity, hardness, macronutrients and micronutrients, and the presence of potentially harmful ions. In Kentucky, source water is typically alkaline and exhibits a high pH over 7.0, which can interfere with nutrient availability. Therefore, acidification, most commonly with phosphoric, nitric, or sulfuric acid, is often necessary to lower the pH of the irrigation water to the optimal range of 5.5 to 6.0 for nutrient uptake in hydroponic systems for lettuce. While pH reflects how acidic or basic the solution is, alkalinity measures the water's buffering capacity, or its resistance to pH change, and the two should not be confused. Maintaining an alkalinity around 80 ppm (as calcium carbonate) is generally recommended because it provides enough buffering to keep the nutrient solution stable while still allowing growers to adjust pH effectively. UK Extension Publication HO-111 elaborates on Kentucky water's alkalinity and how it can be understood from test results reported by Regulatory Services (see references). EC of the fertilizer solution is controlled by the dilution rate of fertilizers.

| Nutrient | N   | P  | K   | Ca  | Mg | Fe  | Mn   | Zn   | B    | Cu   | Mo   |
|----------|-----|----|-----|-----|----|-----|------|------|------|------|------|
| ppm      | 150 | 39 | 162 | 139 | 47 | 1.3 | 0.38 | 0.11 | 0.38 | 0.11 | 0.08 |

Table 1. An example fertigation recipe with electrical conductivity around 1.5 mS/cm for hydroponic lettuce production. Growers may submit a treated (fertilizer-amended) water sample to Regulatory Services to confirm what nutrients their crop is receiving.

Fertigation recipes should be adjusted based on crop varieties and cultivars, growth stages, environmental conditions, and the availability of fertilizer sources. Table 1 provides an example of a balanced fertilizer formulation. Custom nutrient solutions are often prepared using more than 10 individual fertilizer salts, typically dissolved into two or three concentrated stock tanks (commonly labeled Tank A, B, and occasionally C). While this "made-from-scratch" approach offers precision, it can be complex and labor-intensive, particularly for small-scale or beginning hydroponic growers.

As a simpler alternative, growers can use either a single complete fertilizer (e.g., 17-5-17) or a two-part system. A common two-part method involves dissolving calcium nitrate (e.g., 15.5-0-0) in Tank A and a complete fertilizer (e.g., 5-11-26 Hydroponic Special) in Tank B. An acid (e.g., sulfuric, phosphoric, or citric acid) can be added to Tank B to

reduce the pH of alkaline source water and improve nutrient availability, or it can be placed in a standalone Tank C to allow pH adjustment after all fertilizers have been injected into the solution. When using sulfuric or phosphoric acid, growers should remember that these acids also contribute additional sulfate ( $\text{SO}_4^{2-}$ ) or phosphate ( $\text{PO}_4^{3-}$ ) ions to the nutrient solution, and fertilizer recipes may need to be adjusted to avoid unintended increases in these nutrients. An exact fertilizer recipe must be developed based on the specific test results of the source water. Contact your county Extension agent or greenhouse specialist for help formulating customized recipes.

## Varieties and cultivars

Butterhead, romaine, and leaf types are varieties of lettuce that are commonly grown in hydroponic systems, with seed companies offering a wide catalog of cultivars bred specifically for controlled environments and/or hydroponic systems. Generally, romaine type lettuce is more challenging to produce in controlled environments compared with leaf and butterhead types. Growers should consider factors including growth rate, head size, and disease resistance when choosing a cultivar to grow. Additionally, selecting for seasonal conditions—such as heat-tolerance for summer or faster growth for low-light winter months—can optimize yield and quality year-round.

## Production Timeline and Practices

The greenhouse lettuce production timeline (Fig. 3) begins with planting and germination, which typically lasts about 3 days. This is followed by a seedling growth phase of approximately 10 days. Once the seedlings are robust enough, they are transplanted into the main hydroponic system. After transplant, lettuce enters a growth-to-harvest phase lasting approximately 30 to 40 days, depending on species and growing environments.

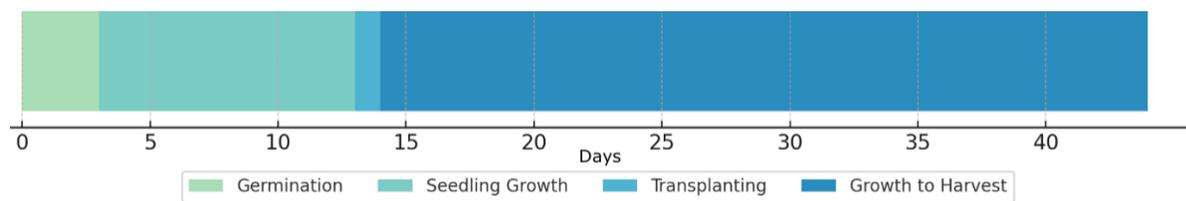


Figure 3. Lettuce production timeline in greenhouses.

## Propagation

Lettuce can be propagated using a variety of soilless substrates, including bonded plugs such as Rockwool, coco coir-based, or peat-based plugs, as well as loose substrates filled in high density seedling trays (e.g., 128-cell tray). Sow one seed per plug or cell.

The choice of propagation substrate should align with the specific hydroponic production system being used. For water-based systems like deep water culture (DWC) or nutrient film technique (NFT), bonded 1-inch plugs are strongly recommended. These plugs are designed to retain their structure and will not fall apart when submerged in water, providing better stability, uniform moisture retention, and ease of transplanting into these systems.

Substrates, particularly rockwool, should be pre-charged with a nutrient solution using a balanced complete fertilizer with an EC of 1.0 mS/cm and a pH of 5.5-6.0 before seeding. Place one seed per plug/cell. Lettuce seeds germinate best at a temperature of 68 °F (20 °C) and high relative humidity over 88%. If ambient air temperatures are below optimal, a heat mat can be used to maintain consistent warmth and promote uniform germination. A germination dome can also be used to maintain high relative humidity during this stage but should be removed as soon as the seeds have emerged, about two days after seeding. Lettuce seeds require only minimal light at around 50  $\mu\text{mol}/\text{m}^2/\text{s}$  to initiate germination, but light intensity should gradually increase to 200 - 300  $\mu\text{mol}/\text{m}^2/\text{s}$  as seedlings develop. Providing higher light levels after emergence supports stronger growth, reduces stretch, and encourages compact, healthy seedlings. Seedlings should be watered at least once per day with a nutrient solution using a balanced complete fertilizer with an EC of 1.0 mS/cm and a pH of 5.5-6.0, depending on plant sizes and growing environments.



Figure 4. Float bed (left) and nutrient film technique (right) lettuce production at a commercial farm in Kentucky.

## Transplant

Seedlings are typically ready for transplanting into the final production system once they have developed 3 to 4 true leaves and roots have visibly emerged from the bottom of

the propagation substrate, usually 14 to 21 days after seeding. Table 2 describes common hydroponic systems, their key components, considerations, advantages, and disadvantages. To ensure successful transplanting, thoroughly water the seedlings beforehand. This helps prevent root desiccation and keeps the substrate intact during handling. In liquid-based hydroponic systems such as DWC or NFT, it is essential to ensure that seedling roots are in contact with the nutrient solution at the time of transplanting. Because the substrate volume is minimal, seedlings can quickly dry out if their roots are not touching the water. For substrate-based systems like drip irrigation or ebb-and-flow, it is important to determine irrigation volume and frequency based on substrate properties and crop stages.

## Post-transplant production

In liquid-based hydroponic systems such as DWC and NFT (Fig. 4), continuous monitoring of nutrient solution pH and EC is essential because plants steadily absorb water and nutrients from the recirculating reservoir, leading to gradual shifts in solution balance. To maintain optimal nutrient availability, growers should adjust the solution as needed by adding fertilizers, acid, or fresh water to correct pH or EC drift. The reservoir should be topped up every few days to replace lost volume and stabilize nutrient concentration, and a full or partial solution replacement is generally recommended every 3 to 4 weeks to prevent nutrient imbalance and the buildup of unwanted ions. Respacing strategies, i.e., gradually increasing the distance between plants as they grow, can also be applied by liquid-based systems to optimize space use efficiency and improve airflow while improving overall yield. Growers should plan to align respacing schedules with available labor and anticipated market demand.

In substrate-based systems, leachate can be collected by placing a saucer beneath pots in a drip irrigation setup, or by using the pour-through method in an ebb-and-flow system. Analyzing the leachate's pH and EC provides a snapshot of the root zone environment and helps guide nutrient and irrigation adjustments. Leachate pH dropping below 5.5 or rising above 7.0, and EC falling below 0.8 mS/cm or exceeding about 2.5 mS/cm, should raise concern and prompt nutrient or irrigation adjustments.

Plants can typically be harvested 21 to 35 days after transplanting and a fully grown lettuce can be 100 to 210 g/head (3.5 to 7.5 oz/head), depending on the species, cultivar, and growing environment. In summer, earlier harvests may help prevent tipburn, while in winter, slower growth due to suboptimal light and temperature may necessitate later harvests.

Table 2: Overview of main hydroponic systems for lettuce production.

|                                     | <b>Deep Water Culture (DWC)/Float Bed</b>   | <b>Nutrient Film Technique (NFT)</b>  | <b>Drip Irrigation</b>  | <b>Ebb-and-Flow (Flood and Drain)</b>  |
|-------------------------------------|---|---|---|--|
| <b>System Description</b>           | Floating rafts on nutrient solution contained in a framed bed lined with waterproof liner   | Sloped troughs or channels with shallow nutrient flow driven by a pump in the reservoir           | Plant containers/trays filled with media; drip lines and emitters deliver water and nutrients through main irrigation line                | Shallow flood tables on a bench; water and nutrients are delivered to flood and may or may not drain back to the reservoir |
| <b>Key Components</b>               | Frame (wood or metal) at least 12in depth, liner (EPDM or HDPE), foam rafts, air pump, air stones                                   | Troughs/channels (PVC or food-safe plastic), pump, reservoir, return lines                        | Containers, drip emitters, dripper stakes and tubing, main irrigation lines, timer, switch/solenoid valve, reservoir, fertilizer injector | Flood trays, timer, switch/solenoid valve, drain system, reservoir, fertilizer injector                                    |
| <b>Substrates</b>                   | Bonded plugs (generally 1x1 in) inserted in raft holes  | Bonded plugs (generally 1x1 in) inserted in NFT channels  | Loose media (like peat-based substrates)  | Loose media (like peat-based substrates)   |
| <b>Oxygenation</b>                  | Need air pump and air stones, 6-8 ppm dissolved oxygen  | None – continuous thin film provides oxygen   | None - rely on air space in substrates  | None - rely on air space in substrates   |
| <b>Water Use</b>                    | High volume (>4 L/plant) (>1 gal/plant)   | Low volume with the thin film   | Moderate  | Moderate   |
| <b>Planting density<sup>1</sup></b> | 3 to 4 plants/ft <sup>2</sup> or 35 to 40 plants/m <sup>2</sup>   | ~2 plants/ft <sup>2</sup> or 30 plants/m <sup>2</sup>   | 1 to 2 plants/ft <sup>2</sup> or 20 to 25 plants/m <sup>2</sup>   | ~2 plants/ft <sup>2</sup> or 25 plants/m <sup>2</sup>  |
| <b>Nutrient Delivery</b>            | Constant –roots submerged in nutrient-rich water. Single, complete fertilizer required  | Constant – thin stream of nutrient water flows past roots. Single, complete fertilizer required.  | Constant – thin stream of nutrient water flows past roots. Single, complete fertilizer required.  | Periodic – nutrient solution delivered on timed intervals. Precise, multi-part fertilizer recipes possible                 |
| <b>Advantages</b>                   | Simple system set up, low labor needs, low risk of plants drying out, possibility of plant spacing to maximize space use efficiency | Low water and nutrient consumption, possibility of plant spacing to maximize space use efficiency | Precise water and nutrient delivery to individual plants, may sell containerized live plant   | Flexible layout, Works for plants of all sizes, simple automation; more uniform growth, may sell containerized live plant  |
| <b>Disadvantages</b>                | Large volume of water, waterborne pathogens can spread through shared solution  | System failure will cause rapid dry out; waterborne pathogens can spread through shared solution  | Doesn't work for propagation, emitter clogging, labor intensive for installation  | Doesn't work for propagation, emitter clogging, labor intensive for installation   |

## Disease Management

Lettuce is susceptible to several diseases that can result in reduced yield. The most common diseases are included here, but growers may encounter additional diseases not included in this publication. Contact a county Extension agent for assistance with disease confirmation.

Table 3: Major diseases and management strategies for greenhouse hydroponic lettuce production.

| Major diseases  | Management   |
|---|--|
| <p><b>Botrytis gray mold</b> (<i>Botrytis cinerea</i>) is a fungal disease that begins as a soft rot of lower leaves. Symptoms appear brownish-gray to orange. Infection occurs as leaves age or become damaged. Fuzzy, gray fungal growth is often visible as disease becomes severe. Infection can spread to surrounding, healthy leaves and crowns. <i>Botrytis</i> sp. proliferates when humidity reaches 85% and senescent tissue or debris is readily available. Gray mold usually occurs under cool conditions (65 to 75°F or 18 to 24°C) such as in shaded areas or within dense canopies.</p>  | <p>Remove dead, dying, and diseased leaves as soon as they appear.</p> <p>Maintain humidity below 85% by exchanging indoor air.</p> <p>Preventative fungicides are effective when conditions are conducive for disease.</p>  |
| <p><b>Pythium root rot</b> (<i>Pythium</i> spp., <i>Phytophthium</i> spp., <i>Globosporangium</i> spp.) is caused by a group of soilborne, fungus-like pathogens known as water molds. Symptoms include overall stunting or wilting, with marginal leaf scorch or yellowing of outer leaves that becomes more severe as root rot progresses. Roots become soft, mushy, and grayish-brown, and the cortex sloughs off leaving the stele intact (known as “rat tails”). These pathogens can also cause damping off in which seeds are infected before or after emergence. These water mold species favor wet conditions, and optimal temperatures are dependent upon species. Water mold pathogens can also become established in irrigation lines and hydroponic systems. Fungus gnats are known to transmit <i>Pythium</i> spp.</p> | <p>Do not introduce diseased plugs into production systems.</p> <p>Remove dead, dying, and diseased plants as soon as they appear.</p> <p>Fallow and sanitize greenhouses and hydroponic systems between crops.</p> <p>Fungicides can help suppress disease or prevent new infections.</p> |
| <p><b>Minor diseases</b></p>  | <p><b>Management</b></p>   |

|  |   |
|--|---|
| <p><b>Bacterial soft rot</b> <i>Pectobacterium carotovorum</i> [formerly <i>Erwinia carotovora</i>,) other secondary bacteria is caused by secondary infections of vascular tissue that often lead to slimy decay. Infections begin as wilting with pinkish brown discoloration of lower leaves. As infections spread, leaf and crown tissue becomes water-soaked and slimy (known as “jelly butt”). Plants eventually collapse. Vascular discoloration can be observed in cut stems. Lettuce is most susceptible as it matures. Bacterial soft rot is most common as a postharvest disease. <i>Pectobacterium</i> sp. favors wet conditions and warm temperatures (above 77°F or 25°C).</p> | <p>Remove dead, dying, and diseased plants as soon as they appear.</p> <p>Clean harvest tools regularly.</p> <p>Avoid wounding or bruising leaves during harvest.</p> <p>Bactericides such as copper can help suppress disease or prevent new infections.</p> |
| <p><b>Bottom rot</b> (<i>Rhizoctonia solani</i>) is a soilborne, fungal disease that causes rot on lower leaves. Initial symptoms include brown to orange lesions on lower leaves, expanding to midribs. If disease becomes severe, rot expands to inner leaves and heads. The crown is often the last part of the plant to decay. Bottom rot occurs under warm (77 to 95°F or 25 to 35°C), wet conditions. The fungus can infect healthy leaves or colonize dead or dying tissue.</p>   | <p>Fallow and sanitize greenhouses between crops.</p> <p>Fungicides can help prevent or reduce disease.</p> <p>Mildly affected lettuce heads can often be marketed by removing infected lower leaves.</p>   |
| <p><b>Powdery mildew</b> (<i>Golovinomyces</i> spp.) is a fungal disease that causes powdery growth on all lettuce tissue. Early infections appear as small patches of white fungal growth on upper and lower sides of older leaves. The causal fungus has a wide host range, including other vegetable crops, weeds, and ornamentals. Disease can establish under a wide range of conditions, but it is most severe at moderate temperatures (65 to 70°F or 18 to 21°C).</p>  | <p>Increase air circulation and exchanging humid air.</p> <p>Preventative fungicides are effective when conditions are conducive for disease.</p>   |

## References/Resources:

Davis, W., Weber, C., Wechsler, S., Wakefield, H., and Lucier, G. (2024). Vegetables and pulses outlook: April 2024. U.S. Department of Agriculture. Economic Research Service.

Gauthier, N., Leonberger, K., and Ying, Q. Common lettuce diseases in Kentucky. (<https://plantpathology.mgcafe.uky.edu/sites/plantpathology.ca.uky.edu/files/PPFS-VG-53.pdf>).

Ingram, D. (2014). Understanding irrigation water test results and their implications on nursery and greenhouse crop management. ([https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=1160&context=anr\\_reports](https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=1160&context=anr_reports)).

Kubota, C., and Ertle J. (2023). Lettuce tipburn sensitivity trial – preliminary results. E-Gro Alert. (<https://e-gro.org/pdf/E810.pdf>).

Mattson, N.S. (2015). Tipburn of hydroponic lettuce. E-Gro Alert.

Paz, M., Fisher, P. R., and Gómez, C. (2019). Minimum light requirements for indoor gardening of lettuce. *Urban Agriculture & Regional Food Systems*, 4(1), 1-10.

Sharma, A., and Knight, J. (2023). Irrigation in hydroponic systems: An illustrated overview. (<https://ccd.uky.edu/sites/default/files/2024-12/ccd-sp-20-irrigation-in-hydroponic-systems.pdf>).

Weber, C. (2023). U.S. lettuce production shifts regionally by season. U.S. Department of Agriculture. Economic Research Service.

## Suggested Citation:

Sharma, A. et al (2025). *Hydroponic lettuce production in controlled environments*. CCD-CP-63. Lexington, KY: Center for Crop Diversification, University of Kentucky Martin Gatton College of Agriculture, Food and Environment. Available: <https://ccd.uky.edu/resources/crops/vegetables/lettuce>

**Reviewed by:** Petrus Langenhoven, Vegetable Specialist, Purdue University and Tim Woods, Ag Economist, University of Kentucky. Original publication written by Cheryl Kaiser and Matt Ernst 2016.

---

## Cooperative Extension Service

Agriculture and Natural Resources  
Family and Consumer Sciences  
4-H Youth Development  
Community and Economic Development

## MARTIN-GATTON COLLEGE OF AGRICULTURE, FOOD AND ENVIRONMENT

Educational programs of Kentucky Cooperative Extension serve all people regardless of economic or social status and will not discriminate on the basis of race, color, ethnic origin, national origin, creed, religion, political belief, sex, sexual orientation, gender identity, gender expression, pregnancy, marital status, genetic information, age, veteran status, physical or mental disability or reprisal or retaliation for prior civil rights activity. Reasonable accommodation of disability may be available with prior notice. Program information may be made available in languages other than English. University of Kentucky, Kentucky State University, U.S. Department of Agriculture, and Kentucky Counties, Cooperating. Lexington, KY 40506



Disabilities  
accommodated  
with prior notification.