Virginia Cooperative Extension
Virginia Tech • Virginia State University
www.ext.vt.edu

Hydroponic Production of Edible Crops: Management Basics

Authored by Joyce Latimer, Professor and Extension Specialist, School of Plant and Environmental Sciences, Virginia Tech; Amber Vallotton, Extension Specialist, School of Plant and Environmental Sciences, Virginia Tech; Toni Sperry, Research Assistant, School of Plant and Environmental Sciences, Virginia Tech; Chris Mullins, Extension Specialist, Virginia State University; Holly Scoggins, Associate Professor Emeritus, School of Plant and Environmental Sciences, Virginia Tech

Introduction

With the increasing number of controlled environment agriculture (CEA) farms, Virginia Cooperative Extension (VCE) is working closely with specialty crop growers to address the challenges of establishing and managing hydroponic greenhouse operations. Growers interested in producing food crops in controlled environments can use several different types of hydroponic systems.

Regardless of the hydroponic system you select for producing your crop, you have to start with proper management of the greenhouse to meet the production requirements for that crop. The goal in greenhouse production is to optimize the environment and growing conditions for the selected crop(s).

Managing Environmental Conditions

Greenhouse production is considered "protected agriculture". We control the temperature, air flow and composition, and the light levels in our greenhouse. To optimize plant growth, we maintain the temperature in the greenhouse within the optimum range for growth of the selected crop (Figure 1). For example, tomato production requires higher temperatures (80°F day/60°F night) than does lettuce production (70°F day/60°F night). In addition, the optimum temperatures may change with the growth stage of the crop. Educate yourself on the specifics of your crop to optimize production. Venting the greenhouse is used to cool the crops but it also brings in fresh air that replenishes the carbon dioxide which enhances photosynthesis and growth (Figure 2). This fresh air also lowers the relative humidity in the greenhouse which reduces plant disease by keeping leaves dry and reducing infections by many of our common plant pathogens like Botrytis and powdery mildew.

Figure 1. Using an aspirated thermostat, hung near canopy level, helps to accurately control greenhouse temperature. (Joyce Latimer, Virginia Cooperative Extension)

Figure 2. Venting the greenhouse can be via natural airflow using dropdown sides and ridge vents (left) or mechanical by pulling outside air through cellulose water walls (right). (Joyce Latimer, Virginia Cooperative Extension)

When we are not venting, constant circulation of the air in greenhouse promotes uniform growth and reduces disease by providing a more consistent growing environment — reducing cool, high humidity spots that foster disease (Figure 3).

Figure 3. Horizontal airflow fans (HAF) should run whenever the greenhouse is not venting to ensure good air circulation around the plants. (Joyce Latimer, Virginia Cooperative Extension)

Good air circulation improves plant transpiration which improves nutrient uptake and distribution. This is especially important with calcium, the lack of which causes blossom end rot in tomatoes and peppers as well as tip burn in head lettuces (Figure 4).

Figure 4. Poor air circulation reduces plant transpiration leading to calcium deficiencies that cause blossom end rot in tomatoes and peppers (left) or tip burn in head lettuces (right). (Joyce Latimer, Virginia Cooperative Extension)

Specialized fans to increase air circulation in key areas can reduce the incidences of calcium deficiency (Figure 5 and 6). Proper spacing of the crop within the hydroponic system will also improve air movement in and around the plants thus increasing plant transpiration.

Figure 5. For very tall and dense crops like tomatoes, peppers and cucumbers, vertical air flow tubes can improve air circulation throughout the crop. (Joyce Latimer, Virginia Cooperative Extension)

Figure 6. For head lettuce production, paddle fans direct more air into the centers of the heads, improving transpiration to reduce tip burn. (Joyce Latimer, Virginia Cooperative Extension)

As with temperature, crops have optimum light requirements which are measured as daily light integrals (DLI), defined as the total moles of light accumulated in a 24-hour period. Faust and Logan (2018) developed a map of montly DLI values for the United States (Figure 7). It has subsequently been adapted to interactively provide details for more local DLI accumulations.

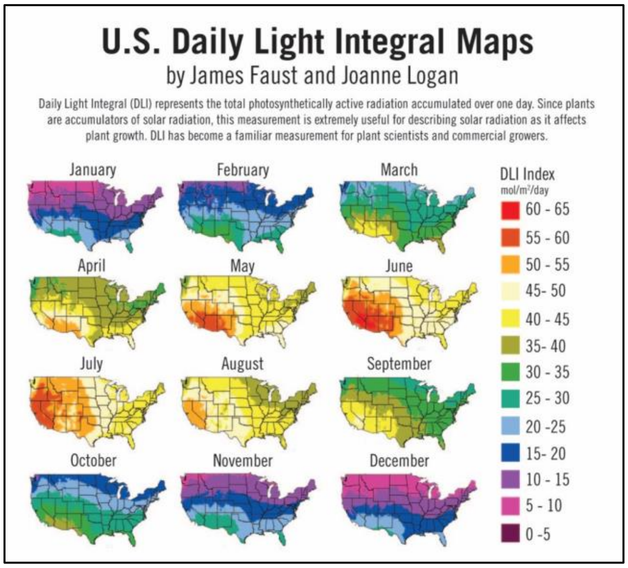

Figure 7. Daily light integral (DLI) maps estimate the average photosynthetically active light accumulated during each month of the year. (Faust and Logan, 2018)

For example, the optimum DLI for lettuces is about 17 mol/m^2/day. To put that in perspective, the DLI of a clear day in the summer in Virginia is about 40 to 44 mol/m^2/day whereas winter light levels range from 15 to 20 mol/m^2/day (American Floral Endowment n.d.). And, remember the greenhouse structure and glazing can reduce the light received by the crop by 30% to 50%. Therefore, without supplemental lighting, a lettuce crop that finishes in 35 days in the summer will require twice that time to finish in the winter. The rule of thumb is that a 1% increase in light level will provide a 1% increase in yield of leafy green biomass.

Providing supplemental lighting during winter months will provide the light necessary to enhance growth and shorten crop production time (Figure 8). Increasing the number of turns — that's how many times we grow a crop in the same place — increases profitability as long as you have a market for the crop.

Figure 8. Supplementing the light during months of low DLI will increase plant growth and reduce production time. (Joyce Latimer, Virginia Cooperative Extension)

Note: excessive light levels during production increases the incidence of leaf tip burn and other growth disorders. Identify the optimums for your crop and meet them as well as possible.

Growing Conditions - Nutrition

The nutrient solution in our hydroponic systems is critical to optimum plant growth. First, the irrigation water used to create the nutrient solution must be of high quality. Have a certified lab provide you with an irrigation water quality test before you start production and at least yearly after that. This analysis will alert you to any contaminants or excessive levels of minerals in your source water as well as give you the alkalinity and pH of the water (Figure 9). Knowing the alkalinity will aid in decisions regarding pH management for optimum nutrient availability to the crop.

Add the nutrient mix designed for your crop (Figure 10), then use the appropriate meters and tools to maintain the proper balance of nutrients and water pH (see Mullins et al. 2023a for details). If the pH is not managed properly, the nutrients in the solution will not be available for uptake by the plants (Sanchez et al. 2020).

Sample Description **Irrigation Water**

PARAMETERS	CHEMICAL SYMBOL	UNITS	RESULT	OPTIMUM
Soluble Salts	EC	ms/cm	0.28	<1.5
pH	pH		7.75	5.4 - 6.8
Alkalinity		ppm	68.92	<150
Total Nitrogen	Total N	ppm	4.16	<10
Nitrate	NO3-N	ppm	2.82	<10
Ammonium	NH4-N	ppm	1.34	<10
Phosphorus	P	ppm	0.03	<1
Soluble	P205	ppm	0.08	<1
Potassium	K	ppm	3.34	<10
Calcium	Ca	ppm	38.26	<120
Magnesium	Mg	ppm	8.01	<24

Figure 9. An irrigation water test provides information on the quality of water for crop production which is essential to planning a good nutrient management plan. (Joyce Latimer, Virginia Cooperative Extension)

Figure 10. Nutrient components and rates vary with the crop being grown and its growth stage. For optimum plant production, follow a good nutrient management plan using high quality fertilizers. (Joyce Latimer, Virginia Cooperative Extension)

Selecting the Production System Based on the Crop

Identifying the crop(s) you will produce also will guide you in the selection of the production system and the space required for production. For more details on individual hydroponic systems, see those publications in the rest of the *Hydroponic Production of Edibe Crops* series.

Nutrient Film Technique (NFT)

Leafy greens and herbs are very popular crops in hydroponic production. They are great for local markets. One of the most common production systems for leafy greens and herbs or head lettuces is the Nutrient Film Technique or NFT systems.

This system consists of closed loop, recirculating nutrient solution running through covered troughs in which the plants grow. The system requires a reservoir for the nutrient solution and a submersible pump that continually circulates solution through the troughs. The nutrient solution flowing through the troughs is generally sufficiently oxygenated for good root growth (Figure 11).

Figure 11. Nutrient film technique (NFT) systems can be purchased as prefabricated channels (top) or constructed with PVC pipe (bottom). Channels with removable tops are easier to clean between crops. (Joyce Latimer, Virginia Cooperative Extension)

Deep Water Culture (DWC)

A system that has been developed from the tobacco transplant float bed system – a vinyl pond liner, supported by 2x10" boards or cinder blocks, and filled with nutrient solution – is now called deep water culture (DWC).

This system consists of styrofoam or plastic trays or insulation boards that float on the top of the nutrient solution (Figure 12). Plant density is very flexible depending on how the holes are cut. DWC systems can be very inexpensive to build and use. The nutrient solution should be aerated and circulated to optimize uniformity. The better the aeration of the nutrient solution, the better the plant growth.

Figure 12. Deep water culture systems are relatively inexpensive to construct and can utilize insulation board with holes drilled at different densities to accommodate different crops. (Joyce Latimer, Virginia Cooperative Extension)

The nutrient solution in DWC systems is more stable than in NFT due to the larger volume of water. You are also less likely to lose your crop in the event of a power outage using the DWC system as compared to the NFT which requires constant solution circulation to bathe the root system.

Media Systems

Stacker systems are a vertical growing system used in some commercial operations for head lettuces and herbs (Figure 13). These stacked styrofoam or plastic forms are filled with an inert substrate, commonly perlite. The plants are transplanted into these pockets. These are typically non-recirculating systems. The nutrient solution is added at the top of the stack and drains away at the bottom of the stack. LED strip lights between the stackers or regular rotation of the stackers can ameliorate the reduced light availability at the bottom of the stacker. Be aware that the perlite can only be used a few times before you must dispose of it. Identify the means of doing so in your community before investing here.

Figure 13. Stacker systems can optimize production space but may show gradients in plant size and quality from the top to bottom, based on reduced light or nutrient availability. (Joyce Latimer, Virginia Cooperative Extension)

Tall crops like tomatoes and peppers, or vining crops like cucumbers, require a substantial root support system in addition to trellis system to support shoot growth. Typically, these are buckets (European hard plastic buckets called Bato buckets) or large plastic nursery containers filled with coarse pine bark or perlite substrate, or slabs of rockwool (Figure 14).

Figure 14. Large commercial producers tend to use rockwool slabs resting on the greenhouse floor (peppers) (left), or hanging in a supported trough (tomatoes) (right). (Joyce Latimer, Virginia Cooperative Extension)

Bag-type systems may include actual 3 cubic feet bags of pine bark/peat substrates laid flat on the floor or bench or plastic covered beds of this type of substrate (Figure 15).

Figure 15. Bag culture used for herb production. Spacing is flexible as holes can be placed as necessary. (Joyce Latimer, Virginia Cooperative Extension)

All of these arrangements allow the addition of the nutrient solution through a drip system as necessary for plant growth. These systems may be recirculating or not depending on the substrate.

Good air circulation is critical to good plant growth in these crops. Foliage density and plant height can be very high. Typically, the plants are supported on a wire system and older leaves are removed to reduce foliage density to improve airflow. Vertical air circulation fans are common to get good air circulation through the entire crop canopy.

Conclusion

This has been a quick overview of using hydroponic growing systems in the greenhouse. Selection of the growing system will depend on the greenhouse facilities and crop being grown. However, the principles of good greenhouse management are critical to production of healthy and salable produce.

Be aware that fully enclosed structures can be used to grow crops hydroponically. These facilities are typically called *indoor* controlled environment agriculture (CEA). Being indoors requires the use of lights. However, the production systems can be stacked in horizontal rows that can maximize the use of the indoor space. Generally, start-up costs are much higher for indoor CEA than for greenhouse production, primarily due to the lighting costs. The lights typically create a significant heat load in the building as well. So, good air conditioning and dehumidification systems are critical to creating an optimized growing environment.

References

American Floral Endowment. n.d. *DLI Interactive Map*. https://endowment.org/dlimaps/. Accessed September 27, 2022.

Faust, J. and J. Logan. 2018. "New National Light Maps Help Greenhouse Growers Manage Plant Growth". *Clemson News*, November 14, 2018.

Mattson, N. 2016. "Growing Hydroponic Leafy Greens". *Greenhouse Product News Magazine*, October 2016.

Mullins, C. A. Vallotton, J. Latimer, T. Sperry, and H. Scoggins. 2023a. *Greenhouse Production of Edible Crops: Nutrient Film Technique (NFT) Systems*. Virginia Cooperative Extension Publication. SPES-463NP

Sanchez, E., R. Berghage, T. Ford, F. Di Gioia and N. Flax. 2020. *Hydroponics systems and principles of plant nutrition: Essential nutrients, function, deficiency, and excess*. PennState Extension Publications. ART-6556.

Additional Resources

Pena, J.G. 2005. *Hydroponic Vegetable Production*. Texas A&M Agrilife Extension. Texas A&M University, College Station, Texas.

Pickens, J. and D. Wells, 2022. *Controlling the Greenhouse Environment for Vegetable Crops*. Alabama Cooperative Extension System Publication. ANR-29256.

Pfeufer, E., N.Ward Gauthier and P. Konopka. 2016. *Managing Greenhouse & High Tunnel Environments to Reduce Plant Diseases*. University of Kentucky Cooperative Extension Service Plant Pathology Fact Sheet PPFS-GH-01.

Acknowledgements

This work was supported by the Virginia Department of Agriculture and Consumer Services (VDACS) Specialty Crop Block Grant Program, Award Number 2020-548, from the U.S. Department of Agriculture's (USDA) Agricultural Marketing Service. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the US. Department of Agriculture.

2023 SPES-462NP