Martin-Gatton College of Agriculture, Food and Environment
University of Kentucky

Center for Crop Diversification System Profile
CCD-SP-20

Irrigation in Hydroponic Systems: An Illustrated Overview

Arundathi Sharma[1] and Joshua Knight[2]

Introduction

Hydroponics is defined by soilless cultivation of plants. In plant production systems, soil provides two critical functions: it provides physical support for plant roots and it is a source of fertility accessible to the roots. In hydroponic systems, a soilless medium or substrate provides root support, while most nutrients are supplied through the water directly as it passes through and is absorbed into the medium. Additionally, the substrate can provide some plant nutrients directly or indirectly by providing a habitat for microbial activity.

One of the most noticeable differences an experienced field grower will find when experimenting with soilless cultivation will be in the crop's day-to-day water/irrigation and nutrient management. Closed-system hydroponics systems store and reuse nutrient solution. These systems offer growers control to avoid abiotic crop diseases associated with nutrient deficiency or excess (toxicity). Closed systems also present opportunities for recycling irrigation water, which can reduce costs associated with fertilizer losses due to leaching, reduce water losses to evaporation and runoff, and reduce environmental pollution by reducing discharges of excess fertilizer into waterways.

This article will present three common closed-system hydroponic "irrigation" methods for growing leafy greens: deep water culture (DWC), nutrient film technique (NFT), and ebb-and-flow (also known as flood-and-drain). These methods can also be used for a variety of crops, and it is possible to build any of these systems using common equipment from hardware stores. One can also purchase whole systems or custom solutions that use these methods if ready to scale up the operation. Commercial growers may be able to get financial assistance for purchasing more specialized and critical components and management equipment, such as pH and EC meters. Treat the included diagrams as conceptual guides, rather than construction schematics.

Irrigation and Nutrient Management

Before choosing what type of hydroponics set-up to start with, a grower should have a management plan for conditioning irrigation water, as this is necessary in all soilless growing systems. Within closed system hydroponics, conditioning irrigation water is a continuous process of preparing, monitoring and managing a desirable nutrient solution made from a combination of water soluble fertilizer and irrigation water. The fertilizer solution will be the crop's primary source of nutrients, making this aspect of system management critical for production. **Reusing nutrient solution requires careful and constant monitoring of fertility (as measured by pH and EC), as well as periodic "refreshing" to avoid excess salinity in the nutrient solution.** In this context, refreshing means to discharge the existing solution and begin with new irrigation water and a new batch of fertilizer.

The resources section at the end of this publication provides links to helpful information getting started with active nutrient control for hydroponics. Once you have a system for preparing and monitoring the nutrient solution, you're ready to start feeding your crops using one of the following methods.

CENTER FOR CROP DIVERSIFICATION
www.uky.edu/CCD

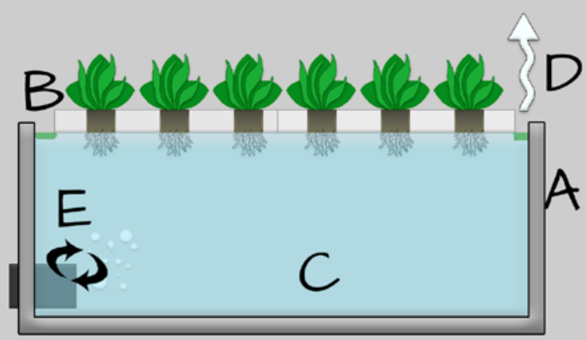
[1]Arundathi Sharma is an Extension Associate for Controlled-Environment Horticulture.
[2]Joshua Knight is a Senior Extension Associate with the Center for Crop Diversification.

Hydroponic Irrigation Systems

Deep Water Culture (DWC aka "Float Bed")

In Deep Water Culture, the crop is direct seeded or transplanted into soilless media-filled individual cells in a tray, which is floated atop a deep pool-like structure filled with nutrient solution (see Figure 1). Similar float bed systems are commonly used for growing tobacco transplants. In this system, water is not pumped or stored, instead it resides in the open tank. This can lead to algae buildup and increased evaporation losses of water compared to other hydroponic methods with an enclosed source tank. Once the salinity becomes too high, the entire nutrient bath must be dumped and refreshed. It may be beneficial to keep a small air pump or water circulation pump in the bath to ensure that roots have access to (dissolved) oxygen.

Figure 1 - Deep Water Culture (DWC)
Also called a "Float Bed", this system may be familiar to growers who have raised tobacco transplants.

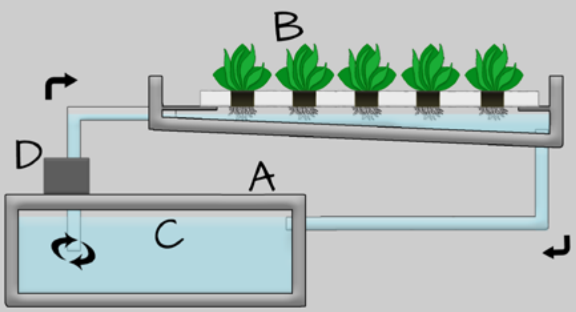


A. Water tank can be a simple frame lined with suitable plastic sheet.
B. Trays hold the growing medium (and plants) in place and can be made of low-cost buoyant insulation board.
C. Nutrient solution should be monitored regularly and periodically refreshed.
D. Evaporation and algal buildup tends to occur wherever the water surface is exposed.
E. Air pump may be added for increasing dissolved oxygen in the nutrient solution.

Nutrient Film Technique (NFT)

In this method of hydroponic growing, trays sit in a shallow channel through which nutrient solution is continually pumped. This ensures a constant thin layer of nutrient solution for the roots to access – hence the name "Nutrient Film Technique." As shown in Figure 2, a downward slope in the channel reduces stress on the pump and ensures water is always moving; this technique requires a robust water pump and management. Without a proper mitigation strategy, a broken pump can leave plants without water and lead to plant tissue damage and crop loss.

Figure 2 - Nutrient Film Technique (NFT)
A continuously running pump in these systems keeps a thin layer of nutrient solution moving constantly over the roots, allowing them constant access to air, water, and nutrients.



A. Nutrient solution is stored in a central tank.
B. Trays that hold the growing medium (and plants) are supported above a channel where the nutrient solution flows through. Trays must be positioned such that the growing medium/roots can access the solution in the channel. The gutter itself has a downward slope, ensuring water is always able to drain from the channel.
C. Stored/reused nutrient solution should be monitored and refreshed periodically.
D. A pump keeps the nutrient solution flowing to the plants. It is wise to invest in robust pump hardware and management for an NFT system.

Ebb & Flow (Flood & Drain)

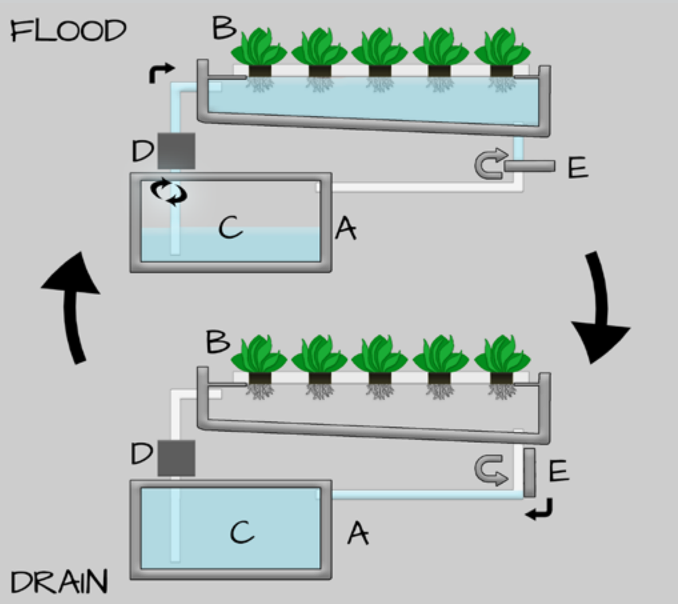
In this method of hydroponic growing, the roots and growing medium are flooded with the nutrient solution, they are allowed to soak for some time, and then the nutrient solution is drained back into the catchment tank. This can be achieved in several ways. One method is shown in Figure 3, where all the crops sit in the same irrigation channel. Other methods (e.g., Bato/Dutch Bucket or container/bag cultivation, shown in Figure 4) may use a drip line to irrigate individual containers or sacks, which all share a common drain. The soak time and frequency of the flood-and-drain cycle are variables a grower can adjust with crop size and growing conditions.

Comparing Systems

It is important to understand no system is "better" without consideration of the larger production system or what resources a grower has available.

Figure 3 - Flood & Drain

This system uses a similar setup to the one shown for NFT. However, instead of running continuously, the pump only periodically floods the roots with nutrient solution. Afterwards, the roots and growing medium soak for some time to absorb the solution before the channel is drained to allow the roots to access air again. This sequence is repeated with each irrigation cycle. A grower can control the flood duration and the frequency of this cycle.

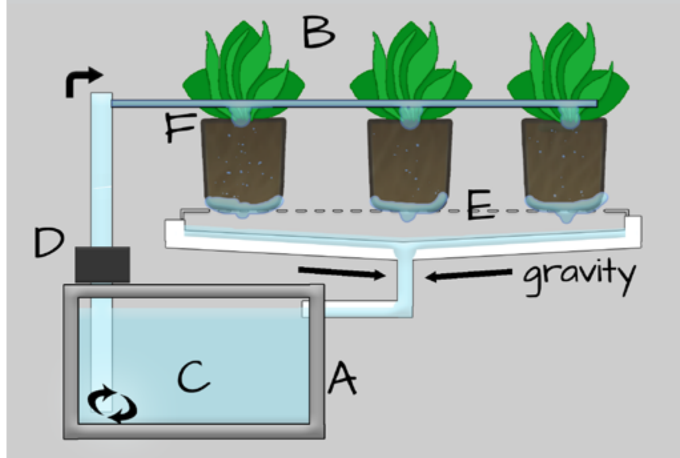


A. Nutrient solution is stored in a central tank.
B. Trays of plants in growing media are supported above a channel that floods with nutrient solution. The trays should be positioned such that the growing medium can soak in the nutrient solution when the channel is filled.
C. Stored/reused nutrient solution should be monitored and refreshed periodically.
D. At the start of an irrigation cycle, the pump should run until the channel is filled with water.
E. When an irrigation cycle starts, the drain valve is closed to allow the channel to fill as the pump runs. Once the channel is filled, the pump should stop running. The valve remains closed to allow the growing medium and roots to soak. At the end of the soaking period, the valve opens again to allow the nutrient solution in the channel to flow back into the tank. It remains open until the beginning of the next irrigation cycle.

A grower with an existing tobacco float bed and limited capital for investment may consider starting with a Deep Water Culture system to explore soilless food crop production. On the other hand, a grower experienced in or already using drip irrigation with in-ground or containerized production may find the flood and drain system a more straightforward method for improving their water and fertilizer efficiency.

Figure 4 - Flood & Drain Dutch (Bato) Bucket

In this system, plants and soilless media are grown within individual containers (e.g., bags, buckets), rather than aggregated in trays. Nutrient solution is transported through a line and irrigates each container individually. The containers are placed on a shared gutter with holes at the bottom, allowing the excess nutrient solution to drain back into a stock tank for future irrigation cycles.



A. Nutrient solution is stored in a common tank.
B. Plants grow in individual containers filled with soilless media, which allow free flow of nutrient solution through holes in the bottom.
C. Stored/reused nutrient solution should be monitored and refreshed periodically.
D. At the start of an irrigation cycle, the pump pushes water from the tank through the irrigation line, then stops once the media should be allowed to drain.
E. The containers share a common gutter and can sit atop a drain cover.
F. Irrigation hardware (drip line, emitters) can be similar to what might be used in traditional field cultivation.

Conclusions

This article is not an exhaustive list of hydroponic irrigation systems. Instead, it is meant to help a commercial grower interested in hydroponics better visualize what their first irrigation system might look like and how it would be managed. For further information, please see the Selected Resources section of this publication.

Selected Resources

Water Quality Tools and Reference Materials

• Grower Tools – www.cleanwater3.org

• The WaterQual tool interprets water quality tests for sources used in irrigation in greenhouses and nurseries. http://cleanwater3.org/wqi.asp?id=3 (Video guide - https://youtu.be/lkSiSmDwIqw)

• The Waterborne solutions tool summarizes published research on control of plant pathogens and algae. https://www.cleanwater3.org/gsearch.asp

• Use the Irrigation Volume Tool to determine how much water you are applying at each irrigation cycle for part or all of your operation https://occviz.com/CW3/IV/IV.html (Video guide - https://youtu.be/RVX2h5_VSjo)

• The Chlorine Contact Time Calculators will help you determine if you have adequate contact time for your chlorine-based disinfectants for proper sanitization of your irrigation lines. https://occviz.com/CW3/CT/CT.html (Video guide - https://youtu.be/IaywP9nphjo)

• Use the Chloride Dilution Calculator to ensure that you are correctly diluting your chlorine for a stock tank and other applications. https://occviz.com/CW3/Cl/cl.html (Video guide - https://youtu.be/vlzmbwwsqnk)

• Parts per million to recipe (https://www.backpocketgrower.org/ppmtorecipe.asp) and recipe to parts per million (http://backpocketgrower.com/recipetoppm.asp) calculators help calculate dosage for sanitizing chemicals and water-soluble fertilizers.

• Alkcalc estimates the amount of acid to add to neutralize alkalinity of your irrigation water. http://e-gro.org/alkcalc/

• This pipe volume calculator helps you calculate the volume of your pipe or mixing tanks. http://www.handymath.com/cgi-bin/cylinder.cgi?submit=Entry

Nutrient Solution Management, Monitoring and Sampling

• Introductory overview of managing pH and EC in hydroponic systems (Oklahoma State Extension - https://extension.okstate.edu/fact-sheets/electrical-conductivity-and-ph-guide-for-hydroponics.html)

• University of Missouri Extension video guide to selecting a pH and EC meter . https://www.youtube.com/watch?v=NTv3cjIh7W0

• MSU Extension: Calibrate your pH and EC meter in your greenhouse, resource guide for pH/EC meter calibration. https://www.canr.msu.edu/news/calibrate_your_ph_and_ec_meter_in_your_greenhouse

• HO-111: Understanding Irrigation Water Test Results and Their Implications on Nursery and Greenhouse Crop Management (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/HO111.pdf)

• HO-112: Understanding Soilless Media Test Results and Their Implications on Nursery and Greenhouse Crop Management (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/HO112.pdf)

• E-GRO article: PourThruMethod for Large Containerized Crops explains how to assess pH and EC in containerized crops (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/eGRO%20Pour%20Thru.pdf)

• CEH-1-IG: Irrigation Water Sampling explains how to collect samples for testing (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/Water%20Sampling_CEH%20Infographic-1.pdf)

• AGR-164: Water Quality Guidelines for Tobacco Float Systems provides some guidelines for base water quality required for growing tobacco transplants in float beds; this can be a helpful starting point for growers looking to grow other crops as well (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/agr164.pdf)

• E-GRO article: Test & Adjust Nutrients in Hydroponics explains best practices for testing and adjusting nutrients in hydroponics (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/Test%20and%20Adjust%20Nutrient%20in%20Hydroponics-1.pdf)

• E-GRO article: Fertilizer Calculation Basics for Hydroponics provides an indepth explanation of how to calculate hydroponic fertilizer inputs (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/Fertilizer%20Calculation%20Basics%20for%20Hydroponics.pdf)

• E-GRO article: Jar Test: Determining Fertilizer Solubility and Compability explains how growers interested in mixing their own fertilizer can check for solubility and compatibility of their custom blends using a simple test. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/Jar%20Test%20-%20Determining%20Fertilizer%20

Solubility%20and%20Compatibility-1.pdf)

• AGR-174: Using Conductivity Meters for Nitrogen Management in Float Systems explains how to use conductivity meters to estimate nitrogen content in a nutrient solution. While this content was originally geared towards tobacco, the methods can be applied in any soilless system. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/agr174.pdf)

Disease

• E-GRO article: Root Disease Management in Hydroponic Systems highlights waterborne root disease common to hydroponic crops; it focuses on deep water culture systems. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/E706.pdf)

System Management/Hydroponics Overview

• UK CCD has compiled materials specific to high-tunnel and greenhouse growers: https://www.uky.edu/ccd/production/system-resources/gh-ht

• NMSU Extension Guide H-180: Hydroponics: Water-saving Farming for New Mexico's Arid Desert, an overview of hydroponics and crop production in regions with water and arable land limitations. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/H180.pdf)

• The section starting on page 11 of ID-160: Burley and Dark Tobacco Production Guide goes into detail about proper management of tobacco float systems; much of this is applicable to deep water culture for other crops. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/ID160.pdf)

• HO-122: Simple Calculations for Small Drip Irrigation Systems explains how to design a drip irrigation system. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/HO122.pdf)

• HO-120: Off the Grid: Ultra-low Pressure Drip Irrigation and Rainwater Catchment outlines the design of a low-pressure drip irrigation system with rainwater catchment – this is particularly interesting for growers looking to reduce their water footprint (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/HO120.pdf)

Crop Variety Selection

• Purdue Extension HO-310-W: Performance of Lettuce Varieties in Greenhouse Hydroponic Production compares the performance of a few lettuce varieties in hydroponic greenhouse production. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/HO-310-W.pdf)

• UT and IFAS Extension W 844-C: Tomatoes, Peppers and Cucumbers in Small-Scale Soilless and Hydroponics Systems, a general handbook for small-scale soilless production of tomatoes, cucumbers, and peppers. These are three of the most common greenhouse crops, but among the most challenging and cost-intensive to manage. This handbook is particularly helpful for inexperienced growers who need to start small. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/W844-C.pdf)

• UT & IFAS Extension W 844-B: Leafy Crop Production in Small-Scale Soilless and Hydroponic Systems is a general handbook for small-scale leafy greens production. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/W844-B.pdf)

• UK Research Article (page 23-24): Evaluate and Determine Fresh Yield of Approximately 15 Species and Cultivars of Lettuces, Greens, and Herbs for Seasonal Production in Kentucky Tobacco Greenhouses features research investigating the performance of Mei Qing Choi, tatsoi, lettuces, greens, herbs in greenhouse and/or float bed (DWC) cultivation (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/horticultural.pdf)

Grant Programs

Reach out to Kentucky Center for Agriculture and Rural Development (KCARD) and your local county agent for guidance when submitting these applications! https://www.kcard.info/active-grants

• Kentucky Horticulture Council has prepared a helpful guide and can help you test your agricultural water for compliance with the Food Safety and Modernization Act (FSMA) - https://kyhortcouncil.org/ag-water-sampling-testing/

• UK Division of Regulatory Services provides water testing services; contact your county agent for more information. (https://www.rs.uky.edu/soil/water.php)

• Kentucky Agriculture Development Fund (KADF)'s On-Farm Water Management Program (OFWM) 2023 Guidelines has information on KADF funding of on-farm water-saving initiatives, including development/transition to hydroponic growing to reduce fertilizer runoff and conserve water. (https://greenhousehort.ca.uky.edu/sites/greenhousehort.ca.uky.edu/files/ADF_APP_project-guidelines_water-1.pdf)

Suggested Citation:

Sharma, A. and J. Knight. (2023). *Irrigation in Hydroponic Systems: An Illustrated Overview*. CCD-SP-20. Lexington, KY: Center for Crop Diversification, University of Kentucky College of Agriculture, Food and Environment. Available: http://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/CCD-SP-20 Irrigation in Hydroponic Systems

Reviewed by Christy Cassady, Extension Specialist; Casey Byrd, Extension Associate

Illustrations by Joshua Knight, University of Kentucky

October 2023