Plans for Converting a Chicken House into a Greenhouse and Systems and Crops for Production*

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*This conversion plan is based on the chicken houses at a farm in Peachland, North Carolina, but the concepts can be applied to or modified for other chicken houses.

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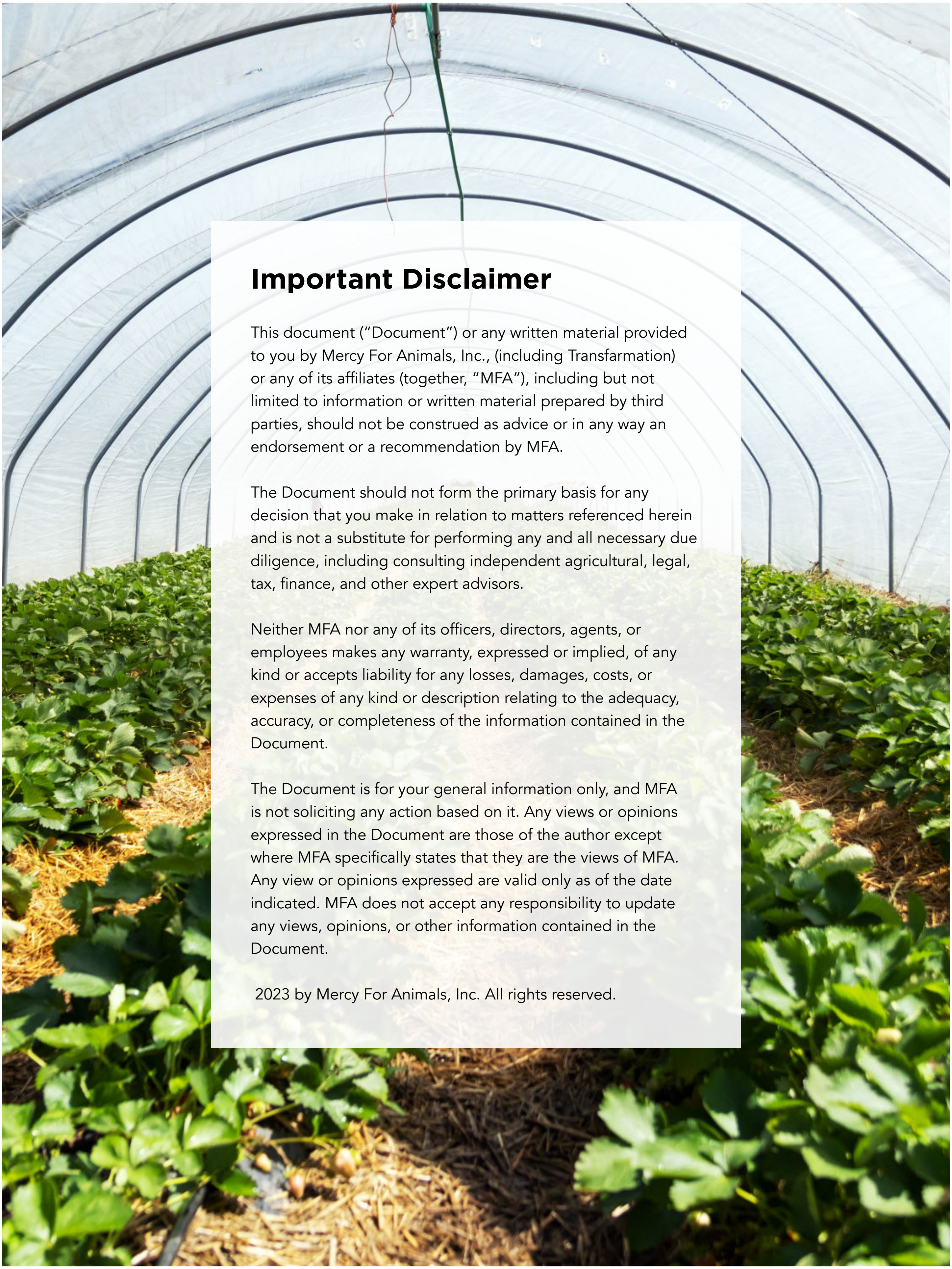

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I. Description of Current Facilities

- The farm consists of three chicken houses that are currently not in production.
- One house is 40' x 300', and the other two are 40' x 500'.
- The houses have metal roofs, evaporative cooling pads on the sides, exhaust fans at the ends, and propane-fueled forced air heaters.
- The houses have plastic-lined, insulated ceilings, most likely with wood framing.
- The floor appears to be a combination of dirt, sawdust or wood chips, and poultry litter.
- The water source is well and municipal water.
- The houses have been out of production since around fall 2021. They are in overall good condition and have potential for conversion to horticultural use.

II. Steps to Convert the Structure to a Greenhouse

Although a greenhouse is typically constructed with a metal frame, a wood-framed chicken house can be converted to a greenhouse through the process below.

Remove the ceiling, any insulation material, the metal roof, and the wall material, leaving only the framework of the structure in place. The metal from the roof and sides could be repurposed or sold to offset the cost of conversion to a greenhouse. Leaving the roof in place and installing sole-source lighting inside is another option. We recommend this only for the production of leafy green crops in hydroponic systems. Even in such cases, the costs and benefits of sole-source lighting over sunlight must be carefully considered.

Clean the framework, pressure wash to remove dirt, disinfect, and paint white to reflect light and protect wood from moisture. A variety of disinfectants are available.[1]

Clean and disinfect the evaporative cooling system and ensure it is in proper working order.

Clean and disinfect the heaters and ensure they are in proper working order. Duct the heat into perforated poly tubes hung from the rafters to distribute heat evenly throughout the structure.[2]

Recover the structure with the following:

- Polycarbonate panels
  - Most expensive but longest lasting.
  - Single-wall panels are less expensive but also less energy efficient than double-wall panels.[3]
- Double layer of clear polyethylene film
  - Moderately expensive and energy efficient.
  - Must include an inflation fan for air insulation between the layers.
  - Must be replaced every three to five years depending on thickness and quality of film.[4]
- Single layer of clear polyethylene film
  - Least expensive option to install.
  - Shortest life span.
  - Least energy efficient (most expensive to heat).
- Glass is also an option, but we feel it would be cost prohibitive and without significant benefits in this application. The choice of covering material may be influenced by the crops grown and the production season. For crops produced through the winter, a double layer of inflated polyethylene film or double-wall polycarbonate panels will retain the most heat and reduce energy consumption compared with a single layer of polyethylene film. If crops will be produced only spring through fall, then minimal heat will be required, and a single layer of polyethylene film would be sufficient.[5]

Install horizontal airflow fans (HAFs) to circulate air, which will help control humidity and minimize temperature differences throughout the structure.[6]

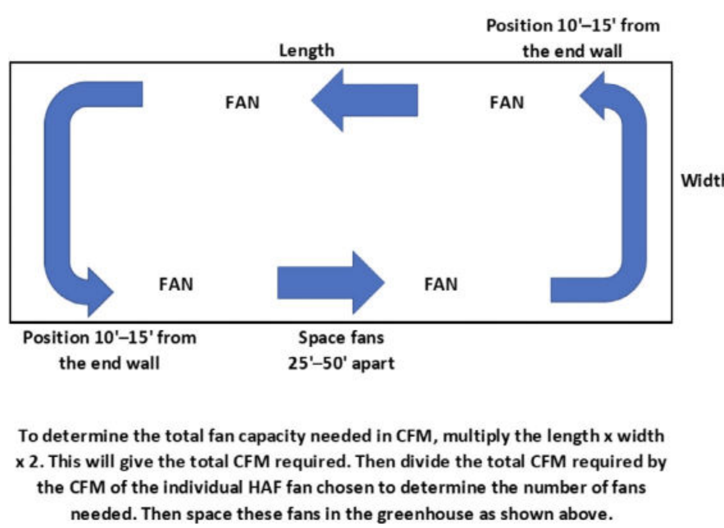


Figure 1. HAF fan positioning and direction of airflow.

Consider removing some of the poultry litter from the floor to reduce the potential for ammonia toxicity to plants. Treat what remains with aluminum sulfate or an acid such as sodium bisulfate or phosphoric acid to convert the ammonia to ammonium to reduce any potential negative effects on plants.[7]

Cover the ground with gravel or ground-cover fabric or plastic, depending on which growing system will be used. Ground-cover fabric is preferable to plastic since the fabric is woven and will allow water to drain through and prevent puddling, which can lead to algae growth, fungus gnats, and plant diseases.[8]

The following are optional points to consider, which may be referenced in the specific crop sections below:

Supplemental Lighting

Although the sun is the primary source of light for plants in a greenhouse, supplemental light can help by providing consistent light from day to day and increasing plant growth when sunlight is limited. LED and HPS are the best options for supplemental lights. LED fixtures are typically more expensive, but they have a longer life span, are more energy efficient, and come in a variety of spectrums for a variety of crops and applications. HPS fixtures are typically less expensive, but they have a shorter life span, are less energy efficient, and have a fixed spectrum. HPS lights do produce heat, which can be beneficial when running lights during the winter. The type of light, specific fixtures, and layout will be based on the crops and growing system chosen. We recommend consulting a greenhouse lighting manufacturer or supplier.[9]

Integrated Greenhouse Control System

Growers have several options when it comes to climate control. The simplest option is to have two thermostats. One controls the heating system, and the other controls the cooling-ventilation system. This is a basic but moderately effective method of controlling the greenhouse climate. But this method presents potential problems, such as wide temperature fluctuations, running the heating and cooling-ventilation systems at the same time, and excessive energy consumption. A solution to these problems is to install an integrated greenhouse control system. Such a system provides the grower with more control over the greenhouse environment by integrating the heating and cooling-ventilation controls and often includes outside weather monitoring to inform the system, since the outside environment significantly impacts the greenhouse environment.[10]

Shade Cloth

While greenhouses are normally designed to permit maximum light penetration, some crops and production stages can benefit from limiting light or reducing temperature during periods of high light. Shade cloth can be installed externally over the top of the house or internally above the plants. Ideally shade cloth is installed in a way that allows for easy removal or retraction when it is not needed.[11]

Partitions

Since the chicken houses are large (300'–500' in length), installing a partition may be desirable in order to section off part of a house for conversion to a greenhouse or other uses. This would also allow for a house to be converted into sections over time as money permits. A partition would reduce the volume of air to be conditioned, which would reduce the associated energy costs. If a partition is installed, all the required environmental systems and controls (heating and cooling-ventilation) must be contained within the space used as a greenhouse.

III. Crop Production in Raised Beds

Introduction

A wide variety of crops can be grown in raised beds, including a range of cut flowers and a number of vegetables, herbs, and fruiting crops. Adjustments to infrastructure and the width of raised beds will be noted as needed.

When choosing a crop, the time from seeding or transplanting to harvesting and the seasonal needs or availability of crops are important considerations. Growing in a greenhouse can facilitate production of crops outside their normal field-production season. Some vegetable crops to consider are leafy greens, such as lettuce varieties or chard; tomatoes; cucumbers; peppers; root vegetables; and squash.

Many cut flowers can be grown in raised beds in a greenhouse. Growing cut flowers in a greenhouse enables you to have a variety of flowers available all year. The space within the greenhouse is limited, so growing perennial flowers would result in long seasons of only foliage instead of flowers; therefore, it is better to frequently rotate annual varieties after the final harvest of the preceding flower crop.

Steps Involved

Flooring

Before installing the raised beds in the basic converted greenhouse structure (see page 2), the entire floor should be graded to provide proper drainage and then covered with UV-resistant ground-cover fabric. Another option is installing the raised beds, lining with ground-cover fabric or black plastic, and mulching or putting gravel in the pathways between them. Any of the “waste” soil or poultry litter removed during this process could be composted and used to fertilize or amend the soil.

Constructing Raised Beds

The raised beds can be constructed using wood, composite materials, concrete blocks, or even the metal roofing material that was removed from the houses. Which wood to choose is important to consider. Treated wood will last a long time, but most of the chemicals used in the treatment process cannot be used in certified organic farming, so looking into policies regarding treated wood prior to selection is important.[12] Some varieties of wood, such as cedar, black locust, redwood, Douglas fir, and cypress, are naturally resistant to rot and insect damage. Location will determine the availability of wood. Depending on the type of wood chosen and whether or not the beds are lined, the wood may need to be replaced every seven to 15 years.

Raised Bed Layout

In a 40' x 300' chicken house, a suggested dimension for the beds is 2' x 25' with a crossbar for support at the halfway point to prevent bowing of the wood. If the raised beds are constructed horizontally facing south, this would allow for 27 beds about 8' from each other lengthwise and around 8.5' apart widthwise. Bed spacing can be adjusted as desired, but be sure to leave enough space between beds to prevent shading, allow room to work, and maneuver equipment. Since the existing ground will be covered, it is important to consider the height of the beds so that the crop has sufficient room to grow. It is suggested that the beds be a minimum of 8" deep for crops such as leafy greens, beans, and cucumbers and 12"–24" deep for crops such as peppers, tomato, or squash with a deeper root system.[13]

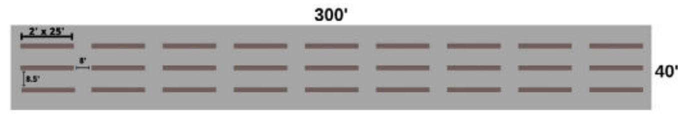


Figure 2. Raised-bed greenhouse layout.

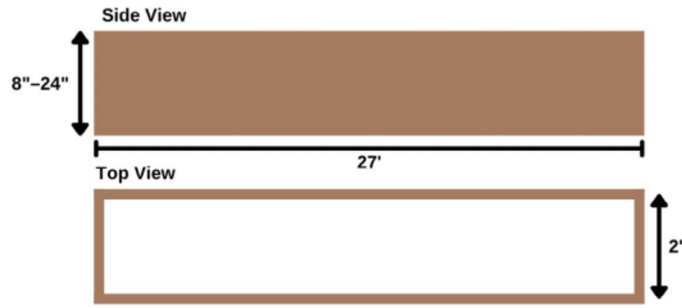


Figure 3. Raised-bed dimensions.

Growing Media

The raised beds should be lined with black, woven ground-cover fabric.[14] Then the beds can be filled with soil or media. The soil or media can be topsoil or a mixture of topsoil and soilless mixes, such as peat moss, compost, coconut coir, vermiculite, or rice hulls.[15] An advantage to using composted or soilless mixes is reduced need for weed control. The Organic Materials Review Institute has published a list of USDA-approved potting soils for organic production.[16]

Irrigation System

Once the beds are installed, an irrigation system should be installed. Options include the following:

- **Drip Irrigation:**[17] Drip tubes have thin walls and drip emitters that are evenly spaced and built into the irrigation pipe. Drip tape[18] lies flat when water flow is stopped, but when swelled with water it allows for low-flow and low-pressure watering of individual plants directly at the roots. Drip tape can be laid in the rows within the raised beds, and the individual plants can be planted next to the emitters on the tape. Another option is to buy drip tubing and install emitters as needed.
    - **Pros:** is relatively inexpensive, allows for precise watering of individual plants, helps prevent foliar diseases, uses water efficiently (reduces waste).
    - **Cons:** emitters may clog easily, system may need to be replaced more often than others,

nutrient buildup and pH rise may result from low volumes of water applied.

- **Overhead Sprinklers:**[19] Overhead sprinklers supply water to the media surface and plant foliage. Such a system can be as simple as fixed sprinkler heads spaced evenly, hanging from a pipe running the length of the structure, running along the ground and mounted on risers, or automated using an overhead boom[20] with many sprinkler heads that run on a track or rail above the crops. We recommend that you consult an irrigation company once the crop and farm layout are chosen so the company can specify the best sprinkler-system type and layout.
  - Pros: can be automated, may last longer than other systems.
  - **Cons:** are expensive to replace, may encourage foliar diseases, could lead to overwatering and weed growth, may require zoning or installation of a larger pump for high-pressure systems.

Additional Infrastructure and Systems

Once the crop has been chosen, the addition of supplemental lighting, shade cloth, or a greenhouse control system should be considered. These decisions will be based on the needs of the crop, the season(s) of production, the level of control required, and the available capital. See Section II above ("Steps to Convert the Structure to a Greenhouse") for an explanation of these options.

Pros and Cons of Crop Production in Raised Beds

Pros:

- Relatively inexpensive to construct and will last for many years.
- Requires less frequent monitoring and adjusting than hydroponic systems.
- The farmer may already have experience with this type of production.

Cons:

- Materials used to construct the beds may need to be replaced periodically.
- The soil will require regular amendments.
- Compared with hydroponic systems, more manual labor and bending over are required.

Important Considerations:

- Grading to ensure proper water drainage.
- Labor needs.
- Amending the beds before, after, and between crop rotations.

IV. Crop Production in Containers

Introduction

This option is similar to raised beds and involves growing in containers directly on the ground. Containers could be plastic pots or flats/trays of small propagules. Crops commonly grown in pots are ornamental trees, shrubs, and herbaceous plants. Cut flowers and even many vegetable crops can also be grown in containers. Crops that are grown in flats are typically transplants of a variety of plants, such as vegetables and flowers. This method is relatively inexpensive because it does not require infrastructure like raised beds or hydroponic systems.

Steps Involved

Flooring

After prepping and sanitizing the initial floor as discussed in Section II above ("Steps to Convert the Structure to a Greenhouse"), the floor can be lined with a black ground cloth,[21] with or without gravel. Since the pots or trays will sit directly on the ground, the ground must be graded to provide sufficient water drainage and prevent puddling.

Pots or Trays

Various options exist for trays and pots, but the choice largely depends on the crop chosen. Examples below:

- Vegetable transplant trays[22] will vary in size and material depending on the specific crop and its size.
- Pots for shrubs or ornamental plants[23] will vary in size and material depending on the specific crop and its size.

Growing Media

The pots or trays are typically filled with a mix of soilless media, such as peat moss, wood fiber, compost, coconut coir, vermiculite, perlite, and rice hulls.[24] The specific mixture of these components will vary depending on the crop and its particular needs, as well as the size of the container. An advantage to using composted or soilless mixes is reduced need for weed control. The Organic Materials Review Institute has published a list of USDA-approved potting soils for organic production.[25]

Irrigation System

Once the crop, layout, and method of growing are established, the choice of irrigation system should be made.

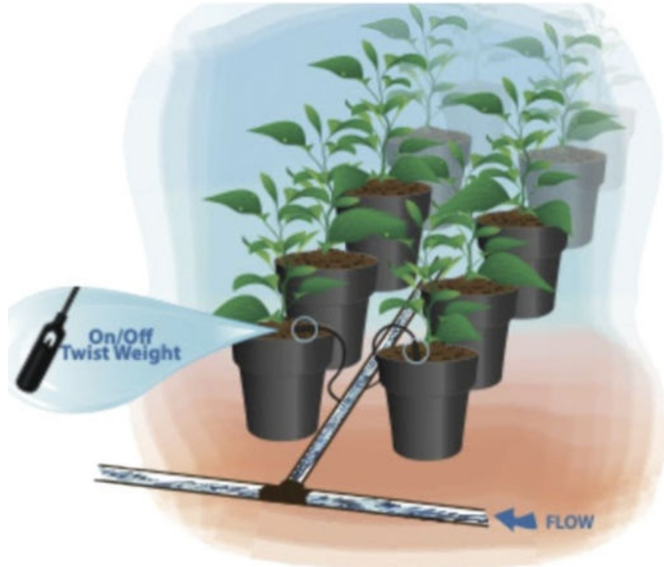
- **Overhead Sprinklers:** Ideal for trays of small plants and transplants, overhead sprinklers supply water to the media surface and plant foliage. Such a system can be as simple as fixed sprinkler heads spaced evenly, hanging from a pipe running the length of the structure, running along the ground and mounted on risers, or automated using an overhead boom[26] with many sprinkler heads that run on a track or rail above the crops. We recommend that you consult an irrigation company once the crop and layout are chosen so the company can specify the best sprinkler-system type and layout.
    - **Pros:** can be automated, may last longer than other systems.
    - **Cons**: are expensive to replace, can encourage foliar diseases, could lead to overwatering and weed growth, may require zoning or installation of a larger pump for high-pressure systems.

- **Drip Irrigation:**[27] Ideal for larger containers of shrubs or ornamental plants, this method involves delivering water directly to the surface of each container, which minimizes foliar disease pressure and maximizes water-use efficiency.
    - **Pros:** is relatively inexpensive, allows for precise watering of individual plants, helps prevent foliar diseases, uses water efficiently (reduces waste).
    - **Cons:** emitters may clog easily, system may need to be replaced more often than others, nutrient buildup and pH rise may result from low volumes of water applied.

Pros and Cons of Crop Production in Containers

Pros:

- Least expensive method for crop production.
- Can easily be transitioned to the production of other crops or growing systems.



Source: "Nursery and Greenhouse Irrigation Guide," Drip Depot.

Figure 4. Irrigation system for container crop production.

Cons:

- Can be labor intensive to move large numbers of trays or pots.
- Containers restrict the types of crops that can be grown.

Important Considerations:

- Grading to ensure proper water drainage.
- Labor needs.
- Container choice, as not all container sizes are suitable for all crops.

V. Crop Production in Hydroponic Float Systems

Introduction

The floating raft system or deep-water culture is a method of hydroponic production where the crops are suspended on rafts in troughs filled with a nutrient solution.

The nutrient solution is aerated and circulated with pumps, and the roots of the plants grow from a soilless medium, such as rockwool or coconut coir, directly into the nutrient solution.

The crops take up nutrients directly from the solution, which is closely monitored and adjusted on the basis of pH and electrical conductivity.

Since this system relies on the plants to float on the surface of the water, the crop chosen must be relatively lightweight and lack an extensive and vigorous root system. Leafy greens, such as lettuce and herbs, are the best crops to grow using this system, since they are lightweight, have a short growth period, have a more compact growth habit, and are easily harvested.

Figure 5. Lettuce growing on a hydroponic float raft.

Steps Involved

Flooring

Start by prepping and sanitizing the initial floor as discussed in Section II above ("Steps to Convert the Structure to a Greenhouse"). Flooring options include pouring concrete, adding gravel, or covering with black plastic or ground-cloth material. Concrete ensures a sanitary, level base that can easily be cleaned, but it is the most expensive option. Covering the ground with black ground-cloth fabric,[28] with or without gravel, is a moderately priced option. Ensuring that the hydroponic systems are properly leveled may be more difficult with this option.

Installing the Systems

Float systems can be constructed[29] using a wooden frame and thick poly liner, or they can be purchased[30] to fit specific dimensions. The basic elements of a float system are as follows:

- The frame, which can be constructed from wood or purchased in various forms, such as square steel pipes, and lined with poly liner. These frames/ troughs can be set directly on the ground, or they can be elevated on benches. Their placement depends on the specific system, the overall weight, and ergonomics.
- The float or raft, which is commonly made from Styrofoam,[31] rigid foam-board insulation,[32] or plastic.[33] The floating rafts support the plants and insulate the nutrient solution from temperature swings. The rafts are often white to aid in reflection

of the incoming light to maintain a more consistent temperature within the nutrient solution. Plastic rafts are more easily cleaned and disinfected and may last longer than Styrofoam. An advantage to rigid foam-board insulation is that it can be custom cut to fit nearly any size system.

Substrate

The growing substrate should drain well, allow for aeration, retain some nutrients, and help structure the crop. The ideal growing substrate may be dependent on the type of raft chosen/constructed, since it needs to fit precisely into the holes of the raft. The most common substrates are rockwool[34] and Oasis,[35] but they have limitations in organic growing operations. Substrates such as rockwool and Oasis allow for easy seeding and harvesting.

Nutrient Solution

The choice of specific nutrient solution should be based on the crop produced. Blends are available—for example, a blend for leafy greens.[36] The availability of nutrients in the solution depends on the solution's pH and electrical conductivity (EC). The solution should be checked daily using a pH and EC meter[37] and adjusted as required.[38]

Pros and Cons of Crop Production in Hydroponic Float Systems

Pros:

- Faster production and lower water use than soil-based systems.
- Least expensive hydroponic system to install.
- Systems and rafts can easily be reused.
- Consistent and stable plant growth since roots have constant contact with the nutrient solution.
- Does not require much electricity except for the pumps.
- Can withstand short power outages since the plants float on the nutrient solution.
- Nutrient solution does not require recirculating but could be sanitized and reused if needed.

Cons:

- Requires daily monitoring and adjustment of the nutrient solution.
- Can be difficult to adjust and calibrate nutrient levels if they get outside an acceptable range.
- Systems built on the ground require bending over.
- Longer power outages would require a back-up generator to prevent crop harm or failure.

VI. Crop Production in Hydroponic NFT Systems

Introduction

Nutrient film technique (NFT) is a method of hydroponics used primarily in growing leafy greens with low mass and short growth cycles (lettuce, spinach, herbs, etc.).

Fruiting vegetables or other crops that take longer to grow, are heavier, or have larger root systems are not suitable for NFT systems.

In this hydroponic system, a thin stream (film) of nutrient solution flows through a channel 3–10 inches wide and containing the plant's roots. The plants are inserted through a cover in the channel, and the roots grow directly into the stream of nutrients.

The system's channels are sloped slightly to enable the nutrient film to flow easily.

The nutrient solution is contained in a reservoir where it can be adjusted and aerated before it is pumped through a small-diameter line to the top of the channels.[39]

Source: "Controlled Environment Agriculture Innovation Center," The Institute for Advanced Learning and Research

Figure 6. Hydroponic NFT system for growing lettuce.

Steps Involved

Flooring

Start by prepping and sanitizing the initial floor as discussed in Section II above ("Steps to Convert the Structure to a Greenhouse"). Flooring options include pouring concrete, adding gravel, or covering with black plastic or ground-cloth material. Concrete ensures a sanitary, level base that can easily be cleaned, but it is the most expensive option. Covering the ground with black ground-cloth fabric,[40] with or without gravel, is a moderately priced option. Ensuring the hydroponic systems are properly leveled may be more difficult with this option.

Installing the Systems

NFT systems can be purchased in various sizes and styles to meet the needs of the layout and the crop.[41] Some companies will custom build NFT systems to fit the specific needs of the greenhouse structure.[42] These systems are usually glued and bolted together. They must slope slightly from the top to the bottom of the channels so that the nutrient film will flow properly.

Substrate

The growing substrate should drain well, allow for aeration, retain some nutrients, and help structure the crop. The ideal growing substrate may be dependent on the specific NFT system chosen, since the substrate must fit precisely into the holes in the channel covers. The most common substrates are rockwool[43] and Oasis,[44] but they have limitations in organic growing operations. Substrates such as rockwool and Oasis allow for easy seeding and harvesting.

Nutrient Solution

Choice of specific nutrient solution should be based on the crop produced. Blends are available—for example, a blend for leafy greens.[45] The availability of nutrients in the solution depends on the solution's pH and electrical conductivity (EC). The solution should be checked daily using a pH and EC meter[46] and adjusted as required.[47]

Pros and Cons of Crop Production in Hydroponic NFT Systems

Pros:

- Faster production and lower water use than soil-based systems.
- Nutrient solution is recirculated and reused throughout the crop cycle.
- Channels and covers have a long life and are easily cleaned, disinfected, and reused.
- The systems are elevated, making for more comfortable, ergonomically sound working conditions than float systems.

Cons:

- More expensive to purchase initially and slightly more costly to maintain than float systems.
- More complex than float systems.
- Clogged supply lines or channels can lead to crop harm or failure.
- Can be difficult to adjust and calibrate nutrient levels if they get outside an acceptable range.
- Requires daily monitoring and adjustment of the nutrient solution.
- A back-up generator would be required in the event of a power outage (even a short outage), as the systems rely on pumps to supply the nutrient solution to the plants.

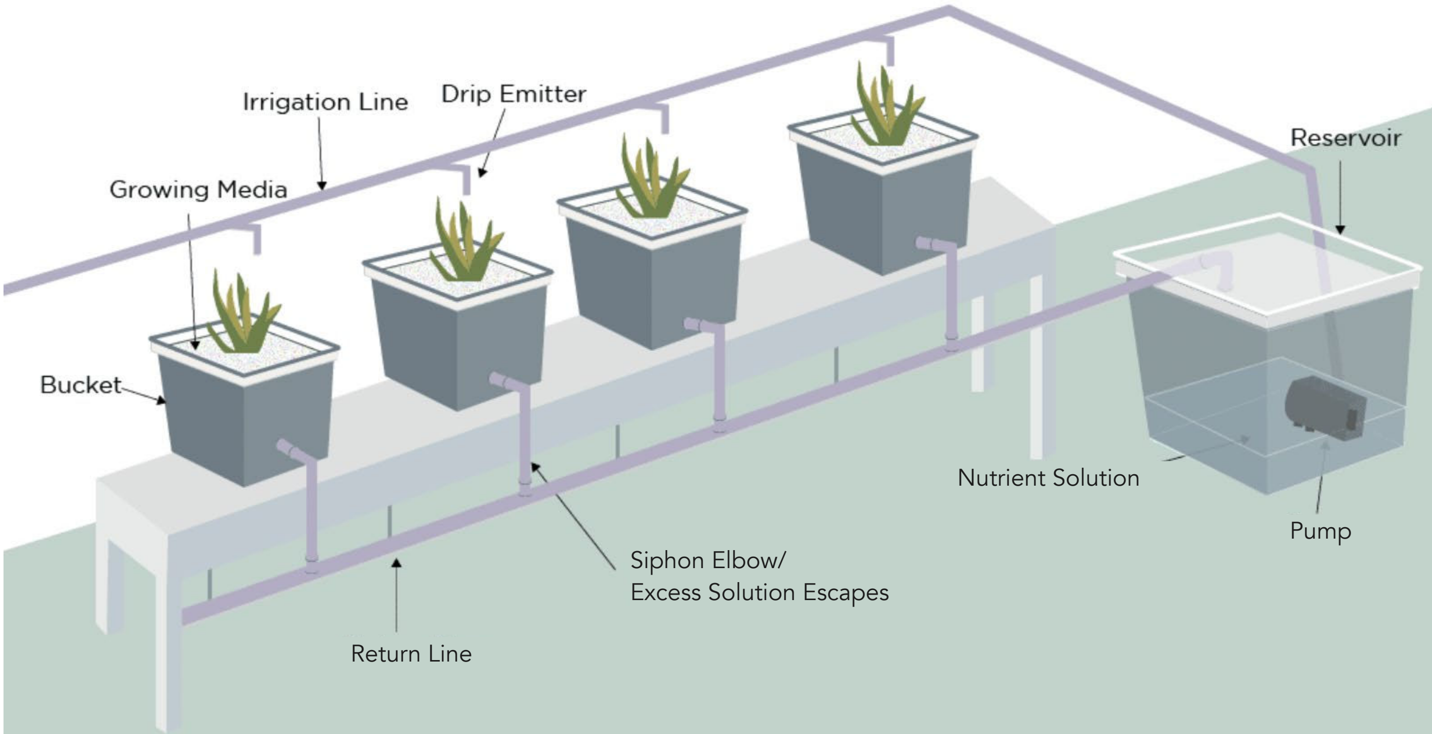
VII. Crop Production in Dutch Bucket Systems

Introduction

The Dutch bucket, also called "Bato bucket," system is somewhat of a hybrid between container production and hydroponic growing systems.

The individual buckets are connected via common irrigation and drainage lines that deliver the nutrient solution to the plants and collect unused solution and carry it back to the reservoir.

Fruiting crops, including vining crops, are typically grown in these systems. Commonly grown in Dutch buckets on commercial scales are tomatoes, cucumbers, peppers, squash, beans, peas, and eggplants.[48] These are heavy nutrient feeders, meaning they require large quantities of nutrients to produce high yields. Another crop that grows well in Dutch buckets is strawberries.[49] Strawberries have a lower, bushier growth habit and different requirements than vining crops.



Source: "Dutch Bucket/Bato Bucket System," Trees.com.

Figure 7. Elements of a hydroponic Dutch bucket system.

Steps Involved

Flooring

Start by prepping and sanitizing the initial floor as discussed in Section II above ("Steps to Convert the Structure to a Greenhouse"). Flooring options include pouring concrete, adding gravel, or covering with black plastic or ground-cloth material. Concrete ensures a sanitary, level base that can easily be cleaned, but it is the most expensive option. Covering the ground with black ground-cloth fabric,[50] with or without gravel, is a moderately priced option. Ensuring the hydroponic systems are properly leveled may be more difficult with this option.

Installing the Systems

Dutch bucket systems are most commonly purchased as a complete kit,[51] although they can also be made from scratch.[52] The basic elements of a Dutch bucket system are as follows:

- Buckets that hold the substrate and roots.
- Drainage line that connects to each bucket through a hole on the base and drains back to the reservoir.
- Irrigation line that distributes the nutrient solution from the reservoir to the buckets.
- Reservoir that contains the nutrient solution and a pump to deliver the solution to each bucket through the irrigation line.
- Buckets can be placed directly on the ground. More commonly they are elevated using a frame or table.
- The system requires a small degree of slope to enable the nutrient solution to drain out of the buckets and flow back to the reservoir by gravity.
- Vining plants[53] require a support system for the above-ground growth. Wire or cables can be attached to the ceiling and secured on the buckets to create the support system. The crops are attached to the wire with twine and hand tying or with small plastic rings that hold the stems on the main wire. This will force the plants to grow upward and ensure the crops do not crowd one another while allowing for maximum growth and production.
- Strawberries[54] do not grow as tall as vining plants do; thus, strawberries do not need a wire support system. But their bushy growth means wider space is needed between plants. A smaller support system could also be installed, but it is not critical.

Source: "Hydroponic Bucket System" (page 3), Hydroponic Answers.

Figure 8. Hydroponic Dutch bucket system.

Substrate

Perlite is the most commonly used growing substrate. Other substrate options include clay pebbles, coco coir, peat, and vermiculite.[55] The substrate must drain well to allow for root aeration while also holding on to some of the nutrient solution to enable the roots to absorb necessary water and nutrients. The substrate may be used for more than one crop cycle, but many growers replace the substrate with each cycle due to plant disease concerns.

Nutrient Solution

Choice of specific nutrient solution should be based on the crop produced. Blends are available—for example, a blend for vining crops.[56] The availability of nutrients in the solution depends on the solution's pH and electrical conductivity (EC). The solution should be checked daily using a pH and EC meter[57] and adjusted as required.[58] As the solution circulates through the bucket system, the plants will absorb the nutrients, meaning these nutrients will need to be replenished in the reservoir over time.

Pros and Cons of Crop Production in Dutch Bucket Systems

Pros:

- Faster production and lower water use than soil-based systems.
- Can be used for fruiting and vining vegetables.
- Nutrient solution is recirculated and reused throughout the crop cycle.
- The buckets have a long life and are easily cleaned, disinfected, and reused.
- The systems can be elevated, making for more comfortable, ergonomically sound working conditions than float systems.
- Small quantities of nutrient solution contained at the bottoms of the buckets may enable the plants to survive a short power outage.

Cons:

- More expensive to purchase and slightly more costly to maintain than float systems.
- More complex than float systems.
- Vining crops require extra labor for tying/training and may be harder to reach as they grow taller.
- Clogged supply lines or drain lines can lead to crop harm or failure.
- Requires daily monitoring and adjustment of the nutrient solution.
- Growing substrate typically must be replaced with each crop cycle.
- A back-up generator would be required in the event of most power outages, as the systems rely on pumps to supply the nutrient solution to the plants.

Important Considerations for all Hydroponic Systems

The source water should be tested to determine the pH, the EC, and the presence of minerals or chemicals. Water treatment should be based on the results of this source water test. The water quality will also impact the choice of nutrient solution.

Nutrient solution may be reused from one crop cycle to another, but it should be tested to determine the quality and quantity of nutrients present and treated to prevent the spread of disease from one crop to the next.

Hydroponic systems need either level ground (float systems) or a slight slope (NFT and Dutch bucket systems). Accordingly, care must be taken before setting up the systems to ensure optimal performance.

Power outages can be devastating for hydroponic production. A generator capable of powering the pumps is a good investment.

Supplemental lighting is beneficial for the production of fruiting crops, especially during the winter months. Hydroponic systems require daily monitoring and adjustment to prevent losses due to leaks, clogs, or nutrient solution problems.

Plants should be transplanted, not directly seeded, into hydroponic systems.

See the following resources for further descriptions of hydroponic systems and production:

- A Recipe for Hydroponic Success
- Hydroponic Leafy Greens
- Hydroponic Lettuce Handbook
- Hydroponic Systems & What's Right for You
- Hydroponic Systems Overview

Endnotes

[1] UMass Extension Greenhouse Crops and Floriculture Program, "Cleaning and Disinfecting the Greenhouse," University of Massachusetts Amherst, last modified 2015, https://ag.umass.edu/greenhouse-floriculture/fact-sheets/cleaning-disinfecting-greenhouse.

[2] "Poly Convection Tubing 4 mil 18 in Diameter (per Linear Ft)," Agriculture Solutions, accessed August 19, 2022, https://www.agriculturesolutions.com/poly-convection-tubing-4-mil-18-in-diameter-per-linear-ft.

[3] "Polycarbonate Panels," Growers Supply, accessed August 19, 2022, https://www.growerssupply.com/farm/supplies/cat1a%3Bgs_greenhouse_polycarbonate.html.

[4] "Plastic Film: Durable Polyethylene, Greenhouse Film, Overwintering Film, Poly Film," Greenhouse Megastore, accessed August 19, 2022, https://www.greenhousemegastore.com/coverings/plastic-film/; "Inflation Blower, 60 CFM," Greenhouse Megastore, n.d., https://bit.ly/inflationblower.

[5] "Choosing the Right Greenhouse Covering for Your Operation," Grow Span, April 26, 2018, https://www.growspan.com/news/choosing-the-right-greenhouse-covering/.

[6] "Horizontal Air Flow Is Best for Greenhouse Air Circulation," Farm Energy, April 3, 2019, https://bit.ly/horizontalairflowbest; "Schaefer HAF Fan," Greenhouse Megastore, accessed August 23, 2022, https://www.greenhousemegastore.com/equip/cooling/fans/schaefer-haf-fan?returnurl=%2fequip%2fcooling%2ffans%2f.

[7] Philip Moore, USDA-ARS, *Treating Poultry Litter with Aluminum Sulfate (Alum)* (Washington, DC: USDA Agricultural Research Service, n.d.), https://www.ars.usda.gov/ARSUserFiles/np212/LivestockGRACEnet/AlumPoultryLitter.pdf.

[8] "Heavy Duty Ground Cover," Growers Supply, accessed August 19, 2022, https://www.growerssupply.com/farm/supplies/prod1;gs_greenhouse_covering-gs_ground_cover_fabrics_1-gs_covers_2;pg108196.htm.

[9] Neil Mattson, *Greenhouse Lighting* (Ithaca, NY: Cornell University, 2015), 1–6, https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/b/5759/files/2015/03/Greenhouse-Lighting-27mfc6l.pdf.

[10] Chris Manning, "How Large Greenhouses Can Utilize Environmental Controls," Greenhouse Management, March 1, 2021, https://www.greenhousemag.com/article/production-how-large-greenhouses-can-utilize-environmental-controls/; "Cultivation Control," Greenhouse Management, September 18, 2019, https://www.greenhousemag.com/article/time-to-upgrade-cultivation-control/.

[11] Nathan Eylands, Charles Gagne, and Neil S. Mattson, "Transitioning Your Greenhouse from Spring to Summer," Greenhouse Grower, June 2, 2021, https://www.greenhousegrower.com/production/transitioning-your-greenhouse-from-spring-to-summer/.

[12] "Raised Garden Beds: How to Build & Where to Buy," Earth Easy, accessed August 19, 2022, https://bit.ly/buildandbuybeds.

[13] "Filling Raised Beds," University of Maryland Extension, last modified August 11, 2022, https://extension.umd.edu/resource/soil-fill-raised-beds.

[14] "Heavy-Duty Ground Cover—12' x 300'," Growers Supply, accessed August 19, 2022, https://www.growerssupply.com/farm/supplies/ProductDisplay?mfPartNumber=10820.

[15] Lewis W. Jett, "Raised Bed Gardening," University of West Virginia Extension, last modified July 28, 2022, https://bit.ly/wvirginiauniversity.

[16] Organic Materials Review Institute, *OMRI Products List: A Directory of Products for Organic Use* (Eugene, OR: OMRI, 2022), 69, https://www.omri.org/omri-lists.

[17] "Featured Products," Berry Hill Drip Irrigation Specialists, accessed August 19, 2022, https://www.berryhilldrip.com/.

[18] "Drip Tape Irrigation," Berry Hill Drip Irrigation Specialists, accessed August 19, 2022, https://www.berryhilldrip.com/Drip-Tape-Irrigation/.

[19] "Sprinklers (Stakes, Stands, Micro, etc.)," Blueberry Hill Drip Irrigation Specialists, accessed August 22, 2022, https://www.berryhilldrip.com/Sprinklers/.

[20] "Boom Irrigation Systems," University of Massachusetts Amherst, https://bit.ly/boomirrigation.

[21] "Heavy Duty Ground Cover."

[22] "Plug Trays," Growers Supply, accessed August 22, 2022, https://www.growerssupply.com/farm/supplies/prod1;gs_pots_trays_containers_1;pg109044.html.

[23] "Nursery and Greenhouse Pots," Growers Supply, accessed August 22, 2022, https://www.growerssupply.com/farm/supplies/prod1;gs_pots_trays_containers_1;pg109632.html.

[24] W. Garrett Owen and Roberto G. Lopez, *Commercial Greenhouse and Nursery Production* (West Lafayette, IN: Purdue University Extension, 2015), 2–6, https://www.extension.purdue.edu/extmedia/HO/HO-255-W.pdf.

[25] Organic Materials Review Institute, *OMRI Products List*.

[26] "Boom Irrigation Systems."

[27] "Nursery and Greenhouse Irrigation Guide," Drip Depot, last modified April 15, 2022, https://help.dripdepot.com/support/solutions/articles/11000097617-nursery-and-greenhouse-irrigation.

[28] "Heavy Duty Ground Cover."

[29] Michael Sweat, Richard Tyson, and Robert Hochmuth, *Building a Floating Hydroponic Garden* (Gainesville, FL: University of Florida, n.d.), 1, https://edis.ifas.ufl.edu/pdf/HS/HS184/HS184-7880270.pdf.

[30] "HydroCycle Raft Beds," Growers Supply, accessed August 22, 2022, https://www.growerssupply.com/farm/supplies/prod1;gs_hydroponics;pg115330.html.

[31] "Lettuce Rafts," Beaver Plastics, accessed August 22, 2022, https://bpgrower.com/lettucerafts.

[32] "Foam Board Insulation," The Home Depot, accessed August 22, 2022, https://www.homedepot.com/b/Building-Materials-Insulation-Foam-Board-Insulation/N-5yc1vZbaxx.

[33] "Leafy Greens and Herbs," Meteor Systems, accessed August 22, 2022, https://www.meteorsystems.nl/en/leaf-greetings-and-herbs.

[34] "1"x 1"x 1.5" Pad of 200 AO25/40 Cubes," Crop King, accessed August 22, 2022, https://cropking.com/catalog/rockwool-growing-media-bato-growing-accessories-nft-growing-accessories/1x-1x-15-pad-200.

[35] "Oasis Horticubes Thincut," Crop King, accessed August 22, 2022, https://cropking.com/catalog/oasis-growing-media/oasis-horticubes-thincut-276ct-single-dibble-case-20-sheets.

[36] "Hydro-Gro Leafy," Crop King, accessed August 22, 2022, https://cropking.com/catalog/nutrients-nutrients-and-additives-nft-growing-accessories/hydro-gro-leafy-greens.

[37] "Bluelab Combo Meter," Crop King, accessed August 22, 2022, https://cropking.com/catalog/ph-and-ec-testing-equipment/bluelab-combo-meter.

[38] "Maintenance," General Hydroponics, accessed August 22, 2022, https://generalhydroponics.com/products/categories/maintenance/.

[39] "NFT Hydroponics," Crop King (blog), accessed August 22, 2022, https://cropking.com/blog/nft-hydroponics.

[40] "Heavy Duty Ground Cover."

[41] "NFT Systems, Commercial," Crop King, accessed August 22, 2022, https://cropking.com/catalog/products/commercial.

[42] "Custom Hydroponic Systems," Grow Span, accessed August 22, 2022, https://www.growspan.com/growspan-industries/hydrocycle-growing-systems/hydroponics-systems/.

[43] "1"x 1"x 1.5" Pad of 200 AO25/40 Cubes."

[44] "Oasis Horticubes Thincut."

[45] "Hydro-Gro Leafy."

[46] "Bluelab Combo Meter."

[47] "Maintenance."

[48] "Dutch Bucket Hydroponics," Crop King, accessed August 22, 2022, https://cropking.com/blog/dutch-bucket-hydroponics.

[49] "How to Grow Hydroponic Strawberries," Hydrobuilder, accessed August 22, 2022, https://hydrobuilder.com/learn/hydroponic-strawberries/.

[50] "Heavy Duty Ground Cover."

[51] "Bato Bucket Systems," Crop King, accessed August 22, 2022, https://cropking.com/catalog/products/bato-bucket-systems; "PolyMax Dutch Buckets & Systems," Growers Supply, accessed August 22, 2022, https://www.growerssupply.com/farm/supplies/cat1;gs_hydroponics;gs_dutch_buckets_systems.html.

[52] "How to Build a 5 Gallon Hydroponic Bucket," No Soil Solutions, accessed August 22, 2022, https://www.nosoilsolutions.com/build-gallon-hydroponic-bucket/.

[53] "Dutch Bucket Hydroponics."

[54] "Dutch Bucket (Bato Pot) Hydroponic System for Indoor Growing of Strawberries," StrawberryPlants.org, last modified February 14, 2022, https://bit.ly/batodutchbucket.

[55] Deidre Hughes and Karla Garcia, "Designing and Building a Dutch Bucket System," Hort Americas, accessed August 22, 2022, https://hortamericas.com/grower-resources/designing-and-building-a-dutch-bucket-system/.

[56] "Hydro-Gro Vine," Crop King, accessed August 22, 2022, https://cropking.com/catalog/nutrients-nutrients-and-additives/hydro-gro-vine-crops.

[57] "Bluelab Combo Meter."

[58] "Maintenance."