# Harvesting the Future: Your Guide to Growing Fresh, Year-Round Produce with Small-scale Hydroponic Production Systems

**Vaughn Reints,** SDSU Extension Horticulture Assistant
**Kristine Lang,** Assistant Professor & SDSU Extension Consumer Horticulture Specialist
**Rhoda Burrows,** Professor & SDSU Extension Horticulture Specialist

**June 2025**

*Special thanks to SDSU Extension Master Gardener Trainee, Max Peterson, for editorial review of this fact sheet.*

Imagine a fresh salad harvested at home, even though snow is piled high outside. Welcome to hydroponics, the soil-free, season-proof way to grow food at home! Think of it as gardening's tech-savvy cousin: With hydroponics, plants get VIP treatment by being fed directly through nutrient-rich water, skipping the soil entirely, and speeding up growth. No backyard or greenhouse? No problem! One may even set up a hydroponic system on a windowsill, on a small balcony, or in any nook that has light. Even light can be provided with special grow-lights.

Hydroponics is more than just a modern twist on gardening. It's an efficient, sustainable way to grow produce year-round. By circulating water directly to plant roots, hydroponic systems use up to 90% less water than traditional soil-based gardening. Because the environment is controlled, there's less stress from weeds, pests, and weather changes, which leads to faster, healthier growth. For anyone curious about safety, hydroponic crops can be grown in controlled environments, reducing the risk of soil- and air-borne contaminants. Some hydroponically grown foods qualify for organic certification under the USDA's NOP and OFPA standards.

Starting seeds in a hydroponic system is straightforward. Using inert growing mediums like rockwool, seeds are kept moist until they germinate, and shortly after they will draw nutrients directly from the water. (It is possible, however, to grow seedlings to transplant stage without nutrients.) This setup allows crops like lettuce, herbs, tomatoes, and even strawberries, to flourish indoors. With a simple container, nutrient solution, and grow-lights, anyone can start a hydroponic garden and grow fresh produce year-round (Figure 1).


**Figure 1.** A few herbs and 2 different varieties of lettuce growing in a small-scale hydroponics system. Photo courtesy of David Graper.

## Choosing Your Growing Media

In hydroponics, the growing media act as a soil replacement by supporting plant roots, and ensuring they have access to water and nutrients. It's important to choose a neutral medium that won't alter the pH of your nutrient solution, as pH changes can affect nutrient

availability. Certain media are best suited for seed starting, others for plant support, and some work well for both:

- **Rockwool:** Made from volcanic rock, limestone, and coke, rockwool is a sterile medium popular for hydroponics. It holds moisture well, provides excellent air flow, and can be reused if rinsed thoroughly. Often used for both seed starting and plant support, rockwool provides a stable environment for young roots to establish themselves.
- **Clay Pellets:** Lightweight and porous, clay pellets offer good aeration, but they don't retain water as well as some media. They're ideal for supporting established plants, rather than seed starting. Clay pellets are easy to reuse, making them a go-to for many hydroponic setups.
- **Gravel:** A cost-effective option that's easy to find, gravel offers stability for larger plants but holds very little water. It's useful as a supportive layer in systems where water circulates frequently, although it's not ideal for moisture retention.
- **Pumice:** This lightweight, porous stone holds both water and air, making it suitable for supporting established plants. It's also pH-neutral, which keeps the nutrient solution stable. Pumice can be reused and works well in hydroponic systems where moisture control is essential.
- **Perlite:** A lightweight, expanded volcanic glass known for its excellent drainage and aeration properties. Unlike pumice, perlite holds little water, making it ideal for improving air circulation around roots and preventing waterlogging. Its lightweight nature, however, might provide less stability for larger plants.
- **Rice Hulls:** A sustainable choice that decomposes very slowly, rice hulls provide moderate water retention and aeration. They're a good eco-friendly option for plant support, though not typically used for seed starting.
- **Vermiculite:** Known for its excellent water-holding capacity, vermiculite provides better moisture retention than perlite, though it has limited aeration. It works well for starting seeds or rooting cuttings, ensuring young plants have a steady supply of water.

## Choosing your Growing Containers

Choosing the right container is key to supporting plant roots and maintaining a stable water environment. The container holds both the nutrient solution and the growing media, so it's important to select one that fits available space, plant type, and system setup. For beginners, simple containers can work well, while advanced setups may call for specialized containers.

Smaller, less expensive systems, like the Kratky or Deep-Water Culture (DWC), can be created with recycled containers or jars—perfect for herbs or leafy greens. For larger or more complex systems, tubs or buckets provide the necessary depth to support larger plants, and allow for more water volume, which stabilizes the system. As a rule of thumb, for greens one gallon of volume per head of lettuce suffices but use at least four gallons of volume for tomatoes or peppers. Remember, "As above, so below," which implies that the larger the mass of the plant above the container, the larger the root mass below.

Regardless of the size, it's essential to keep containers clean to prevent algae and bacteria buildup. Opaque, food-safe containers with non-porous surfaces are ideal, as they block out light and discourage algae growth. If re-using containers, thoroughly clean and sanitize them between uses to ensure your hydroponic environment remains sanitary and optimal for plant health.

### Net Cups and Their Purpose

Net cups are important components in many hydroponic systems, as they securely hold the growing media and plants, yet allow roots to grow freely into the nutrient solution below. These slotted cups promote aeration and ensure that the roots can access water and nutrients efficiently. Net cups are typically made of durable plastic, which can withstand constant moisture and provide long-term use (Figure 2).

**Figure 2.** Roots are trimmed back to allow transplant to fit into plastic inserts used with the system. Photo courtesy of David Graper.

For those who don't have net cups readily available, various household items can be re-purposed to serve a similar function:

- **Plastic or Styrofoam Cups:** By cutting slits or holes into the sides and bottom, these cups can mimic the aeration and drainage properties of net cups.
- **Reusable Mesh Containers:** Small mesh baskets or containers used for organizing items can be adapted to hold plants and allow root growth.
- **Perforated Yogurt or Other Food Safe Containers:** With a few strategic cuts, yogurt containers can be converted into make-shift net cups.
- **Small Garden Pots:** With added holes or slits in the sides and bottom, small, plastic flower or garden pots can be re-purposed to allow root access to the nutrient solution.

## Managing Your Water Source

Water quality is a major factor in hydroponics, as it directly impacts how well plants absorb nutrients. Ideally, the water should be free from contaminants and minerals that might interrupt the balance and interfere with nutrient uptake. Many hydroponic growers prefer distilled, reverse osmosis, or filtered water to prevent mineral buildup, but tap water can also work if it's tested and treated if needed.

Maintaining a proper pH is essential for nutrient absorption. Most plants thrive in a slightly acidic environment, with a pH of 5.5-6.5. Regular pH testing is recommended, as certain growing media or nutrient solutions can shift the water's pH over time. If adjustments are necessary, pH adjusters, available in hydroponic supply stores and possibly in your home in the form of acids and bases, can bring the pH to optimal levels.

Keeping the water clean and well-oxygenated also prevents root rot and other problems. Aerating the water, either with an air pump or by ensuring good circulation, promotes healthier root growth. Regularly change the water according to your system's needs to maintain a fresh nutrient supply, and to prevent algae or bacteria growth.

## Adding Nutrients to the Mix

Hydroponic plants rely entirely on a nutrient solution to receive the essential minerals they need. Overall, plants require approximately 17 essential nutrients to thrive. These nutrients are divided into macronutrients and micronutrients. Macronutrients include nitrogen, phosphorus, and potassium, which are required in larger amounts to support growth and flowering. Secondary macronutrients—calcium, magnesium, and sulfur—also play key roles in plant health and development.

Micronutrients (sometimes called trace elements) include iron, manganese, zinc, copper, boron, and molybdenum. Although required in smaller amounts, micronutrients are vital for various metabolic processes that ensure plants remain healthy and productive.

Pre-mixed nutrient solutions designed for hydroponics generally include a balanced, full spectrum of macro and micronutrients for optimal plant growth. When mixing the solution, follow the manufacturer's instructions to avoid nutrient imbalances, also known as nutrient lockout, that could affect plant health.

To keep plants thriving, change the nutrient solution every one to two weeks. Fresh solutions help maintain balanced nutrient levels, and prevent pH fluctuations, which can occur as plants absorb nutrients. For smaller systems or high-demand plants like fruiting tomatoes, weekly solution changes may be best. In larger recirculating systems, a two-to-three-week interval may be sufficient, as the larger water volume stabilizes nutrient levels for longer.

Refreshing the nutrient solution regularly and monitoring the pH creates a stable, nutrient-rich environment that supports healthy, vigorous plant growth.

## Choosing and Installing Grow Lights

Providing adequate lighting for plants is essential for success in hydroponics, especially if the plants are not grown outside or in a greenhouse. In addition to basic brightness, understanding Photosynthetically Active Radiation (PAR) values can help provide the best light for plant growth. PAR measures the amount of light in the wavelengths plants use most for photosynthesis, specifically, 400-700 nanometers. The higher the PAR value, the more usable light the plants receive.

For effective growth, leafy greens usually thrive with PAR values around 200-400 $\mu mol/m^2/s$, while fruiting plants like tomatoes and peppers benefit from higher PAR, often in the 400-600 $\mu mol/m^2/s$ range. Light-Emitting Diode (LED) grow-lights are a popular choice because of their energy efficiency and their ability to produce these specific wavelengths without generating excessive heat.

Proper light-placement is necessary for ensuring plants receive optimal PAR. Keep lights close enough to give plants ample energy without causing heat stress. For

most leafy greens, 12-16 hours of light daily is ideal, while fruiting plants may need up to 18 hours to support flowering and fruit development. Adjustable light setups allow moving the lights as the plants grow, maintaining optimal distance and light intensity.

Many gardeners choose full-spectrum LED lights, which mimic natural sunlight, and provide a balanced range of wavelengths. LEDs that offer a blend of blue and red wavelengths can also be beneficial, with blue promoting vegetative growth, and red supporting flowering and fruiting.

## Starting Your Seeds

Starting seeds in a hydroponic system ensures plants have a healthy foundation before relocation into the main setup. Most growers begin with inert growing media like rockwool, coco coir, or sponges, to give seeds a stable base and to allow roots to establish, while remaining neutral pH. Simply place the seeds in the medium, keep it moist, and provide a warm environment to encourage germination. Using a humidity dome can help maintain moisture and warmth, speeding up germination.

Some cultivars are better suited to hydroponics than others, particularly those bred for compact growth or quick maturation. While almost any variety can work, selecting cultivars labeled for hydroponic or container growth can yield better results.

Once the seeds sprout, they'll need light to continue growing strong. For seedlings, placing them under grow-lights or near a bright window for 12-16 hours daily is ideal. When seedlings have developed two to three true leaves and have visible roots, they are ready to be transferred into the hydroponic system (Figures 3 & 4).

**Figure 3.** A typical nursery supplied transplant with outer decayed leaves and petioles removed after washing sand from the transplants. Photo courtesy of David Graper.

**Figure 4.** Transplant inserted into growing system tube. Photo courtesy of David Graper.

## The Role of Air Pumps and Dissolved Oxygen (DO)

Maintaining adequate oxygen levels in the nutrient solution is an important step for healthy root development. Roots submerged in water without sufficient oxygen can suffer from root rot and other problems. Air pumps and dissolved oxygen (DO) management help to prevent those problems.

Air pumps add oxygen to the nutrient solution by creating bubbles, which increase the water's surface exposure and agitation, and allow more oxygen to dissolve into the water. Air pumps are particularly beneficial in systems like Deep Water Culture (DWC), where plant roots are fully submerged for extended periods. An air pump helps prevent the roots from suffocating and supports optimal nutrient uptake by aerating the nutrient solution.

DO refers to the amount of oxygen available in the water for plant roots. While plants need oxygen from the atmosphere, submerged roots rely on DO in the nutrient solution. Maintaining DO levels above 5-8 mg/L is generally recommended for most hydroponic systems. Low oxygen levels can slow plant growth and can increase susceptibility to diseases.

### When to Use an Air Pump

As noted, air pumps ensure that the nutrient solution remains well-oxygenated and are particularly beneficial in systems where roots are submerged for extended periods, such as DWC or certain Nutrient Film Technique (NFT) setups. These systems depend on constant oxygenation to prevent root suffocation and to maintain optimal growth. Signs that an air pump might be needed include root stress indicators, like browning, a foul odor, or slowed plant growth. All those symptoms

might result from low oxygen levels.

Maintaining high DO levels has numerous benefits. Well-oxygenated roots are less prone to rot, and they absorb nutrients more effectively, promoting healthier and more vigorous growth. Adequate oxygen also accelerates metabolic processes, allowing plants to grow faster. Additionally, maintaining a high-oxygen environment can reduce the likelihood of root pathogens developing, and can create a more resilient system overall.

To further boost oxygen levels in the nutrient solution, some growers use diluted hydrogen peroxide. Diluted hydrogen peroxide can increase the oxygen content but can also act as a disinfectant to keep the system clean and to prevent microbial buildup.

To monitor and maintain optimal DO levels, a dissolved-oxygen meter can be used. This tool measures the concentration of oxygen in the nutrient solution.

## A Simple, Effective Home Hydroponic System

Assemble the right tools and materials before setting up a hydroponic system to ensure smooth operation and plant health.

### Essential Equipment

- **Growing containers:** Suitable for holding the nutrient solution and supporting plants.
- **Growing Media:** Options include oasis cubes, rockwool, or coco coir for seed starting. For larger plants, use expanded clay pellets, perlite, gravel, etc. for root support.
- **pH Meter:** For accurately measuring the pH of the nutrient solution and keeping it in the optimal range (5.5-6.5). Meters that can be calibrated are preferable.
- **Electrical Conductivity (EC) Meter:** To monitor nutrient concentration and maintain the right balance for plant growth. Meters that can be calibrated for accuracy are preferable.
- **Grow-Lights:** LED lights are preferred for at-home, indoor setups to provide full-spectrum lighting with adequate PAR.

### Optional Tools

- **Light Meter:** To measure PAR to ensure plants receive sufficient light.
- **DO Meter:** Helps maintain adequate oxygen levels in water for healthy root growth.
- **Ambient Thermometer and Hygrometer, or Psychrometer:** For monitoring room temperature and humidity levels to optimize the growth environment.
- **Humidity Dome:** Used during seed germination to retain moisture and warmth.
- **Air Pump:** Provides aeration in the nutrient solution to promote healthy roots and to prevent stagnation.
- **Thermometer for Nutrient Solution:** Helps to keep the nutrient solution at an optimal temperature (65-75°F or 18-24°C).

## References and Resources


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P-00337