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SEED STARTING IN HYDROPONIC SYSTEMS & PRIMARY ENVIRONMENTAL VARIABLES

955 Benton Ave., Winslow, ME 04901 • Phone: 1-877-564-6697 • Fax: 1-800-738-6314
Email: service@johnnyseeds.com • Web Site: Johnnyseeds.com

This document describes the basic steps of seed-starting in hydroponic systems and introduces some of the primary variables that affect plant health and productivity in hydroponic systems. We do not currently conduct hydroponic trials on our research farm; however, we have compiled this information based on the information we receive from independent hydroponic growers, as well as academic and industry resources.

GROWING IN HYDROPONIC SYSTEMS

Hydroponic systems can produce a higher yield per square foot than traditional in-soil farming. Unlike some field crops that can grow with little attention for extended periods of time, hydroponic systems require daily management.

SEED-STARTING IN HYDROPONIC SYSTEMS

1. **Choose your medium.** You might seed into flats filled with soilless potting mix, or seed directly into germination plugs. See our "Hydroponic Media" tech sheet for more information on different media.
2. **Ensure the medium is thoroughly moist before you seed.** Water or soak the medium until it is thoroughly moist and contains no dry pockets.[11]
3. **Place seeds in the medium.** Follow variety-specific instructions for seeding depth and spacing.
4. **Water regularly with plain water.** It is important to keep the seeds moist during the germination period. You can water gently by hand, with an overhead mister, or use sub-irrigation. Although some growers use full-strength hydroponic nutrients during the germination period, this is not recommended, as the salts in the nutrients can make it difficult for the seeds to take up water and begin growing, and make the root growth less vigorous.[3,10,13,14]
5. **Cover seeds to keep them moist during germination.** To retain moisture during the germination period, cover the seeds with a fine layer of vermiculite and/or a plastic humidity dome. Be aware that a humidity dome will increase the temperature; use care to ensure the temperature does not rise too high. Remove the humidity dome as soon as seeds germinate.
6. **Maintain optimal temperature for germination.** Adjust temperatures up or down as necessary; use a heat mat, if necessary.
7. **Fertilize appropriately.** Once the plants have emerged, water with a dilute hydroponic nutrient solution according to the directions on the product label.
8. **Add supplemental lighting**, as necessary, once seeds have germinated.
9. **Transplant.** Plants are generally ready to be transplanted when they have developed true leaves and, if using propagation plugs, the roots are visible on the outside of the plug. Because hydroponic plants don't need to compete for nutrients, you can generally space your plants more closely together than when growing in soil.[14]

PRIMARY ENVIRONMENTAL VARIABLES OF HYDROPONIC SYSTEMS

Table 1. Growing Hydroponic Crops: Basic Requirements

Temperature	Light[11]	Daily Light Integral[1]	pH [6,7,8,11]	Carbon Dioxide[11]
Varies by crop; follow growing instructions.	At least 14 hours per day	At least 12 mol per m^2 per day	5.8–6.2 (Slightly Higher in aquaponic and organic systems)	300–1,500 ppm

MONITORING TOOLS
You may want to have a few monitoring tools on hand. Most of these devices are reasonably affordable and readily available from hydroponic growing suppliers:

- Thermometer
- EC (electroconductivity) meter
- Light meter
- pH strips or test kit

TEMPERATURE
Temperatures that are too high or too low will result in poor germination and increase the risk of disease. The optimum temperature will vary by crop and lifecycle stage; follow individual growing instructions for each crop you are growing.

Once established, plants need approximately a 10°F (12°C) drop in nighttime temperatures to grow properly. For example, an ideal temperature range for many crops is 75°F (24°C) in the daytime and 60–65°F (16–18°C) at night. Most plants (except tropical varieties) cannot photosynthesize efficiently at temperatures higher than 85–90°F (29–32°C). If you are growing indoors, remember that supplemental lighting can increase the temperature significantly. Also note that to avoid root damage, temperature of the nutrient solution should be maintained no warmer than ambient temperatures.[3,5,6,14]

pH
The pH of the nutrient solution can significantly affect the plant's ability to take up nutrients. For most crops and hydroponic systems, the ideal pH range is 5.8–6.2 (slightly higher for organic and aquaponic systems).[6,7,8,11]

You can measure pH with a pH meter, litmus paper test strips, or an indicator solution. Plain water normally has a pH of 7.0–8.2. Most nutrient solutions are acidic and once you add them to the water, the pH will drop. To understand how pH fluctuates in your specific growing environment, you may want to take several pH measurements:

- water
- water/nutrient solution
- growing medium with nutrient solution added

If the pH is off, you can use a commercially available pH adjustment solution (called "pH Up" or "pH Down") to adjust your pH.

If you monitor pH regularly, you will see that the pH slowly rises as the plants take up nutrients. When you replenish the nutrient solution, you will see the pH fall again. If you notice more dramatic changes in pH, it can be indicative of disease: root rot can cause the pH to drop to 3.0-5.0 while algae growth can raise pH levels above optimal levels.[7,14]

LIGHT
Once germinated, seedlings need proper light levels for healthy growth. Too much light can cause sunscald or plant stress while too little light will limit growth and reduce plant health. Natural light, of course, varies based seasonal changes in day length and sun angle.

Growers measure light levels as Daily Light Integral (DLI). DLI is the amount of photosynthetic active radiation (also known as PAR) that plants receive each day. Just as you may use a rain gauge to measure rainfall, you can use a light meter to measure DLI. DLI is expressed as moles of light (mol) per square meter (m^2) per day.[16]

Vegetables typically need 14 hours of sunlight per day and at least 12 mol per m^2 per day. Greenhouses typically cause a 25%-50% loss of DLI due to glazing and shading from the structure, so supplemental lighting may be needed at certain times of the year.[1,11]

If you are using supplemental lighting, note that light color is an additional factor to consider. Plants use light within the visible wavelength range of 400–700 nm. Herbs and leafy greens do best with lights that have a higher proportion of blue light (450–496 nm), which encourages vegetative growth. Vegetables like tomatoes prefer lights that have more red (620–750 nm), which encourages flowering and fruiting. LED lights are the most energy-efficient option and some LED lights allow you to adjust the light color to suit your needs.[3,13]

NUTRIENT SOLUTIONS & CONCENTRATIONS
The home gardener or beginning grower will want to start with one of the many pre-made solutions on the market. Each comes with its own instructions for mixing and application.

To monitor nutrient concentrations in your system over time, you can measure the electroconductivity (EC) of the solution. Using an electrical conductivity meter, you can detect the level of total dissolved nutrients in the hydroponic solution expressed on a scale of milliSiemens per cm^2 (mS). The package directions will tell you what your EC level should be.

Note, however, that EC is not a reliable indicator if you are using organic fertilizer solutions.[2,15]

Record the EC when you mix up your solution and then monitor it daily. You will see the EC drop as plants take up the nutrients. Once it falls below an acceptable range, you will want to add more nutrient solution; you can determine the amount you need to add based on the percentage drop you have seen in the EC.

You may want to take measurements both from the nutrient solution itself and from sample points in your growing medium; this will allow you to get a sense for whether your growing medium is accumulating a build-up of nutrients.[3]

Optimum EC levels vary by crop. Plants will require less EC in warmer months and will require more EC in cooler months and when fruiting. A suggested range is provided in table 2, however, you will need to experiment to find the optimal range for your crop, season, and growing system.[9]

Table 2: Nutrient Requirement Ranges[9,12,15]

Crop	Electro Conductivity (EC) mS
Lettuce	0.8–1.4
Tomatoes	2–3.5
Cucumbers	1.6–2.4
Basil	1.0–1.4
Peppers	2.0–3.0

The drawback of EC is that it does not tell you about the specific chemical makeup of the nutrients in the water, only the overall nutrient levels. Plants take up individual nutrients at different rates, and therefore, it is possible for the solution to become unbalanced over time, even if the EC is still within an acceptable range. For this reason, you should change your nutrient solution completely on a regular basis. Recommendations on how frequently you should change your solution vary; you may want to start by replacing your solution every 3-4 weeks or whenever you see symptoms of deficiency or toxicity in your plants.[3,10,11]

ORGANIC FERTILIZERS

It can be a bit more challenging to use organic fertilizers than synthetic fertilizers. Organic fertilizer mixtures are less precise than their synthetic counterparts and it is, therefore, easier to run into nutrient deficiencies. They can also contain high levels of carbon, which can contribute to fungal and bacterial growth. Finally, EC is not a reliable indicator of nutrient concentrations for organic fertilizers, so it can be hard to monitor fertilizer levels. If you would like to use organic fertilizers, be sure to use a product specifically designed for hydroponic systems.[8]

WATER

You may want to test your water to understand how naturally occurring elements in the water will affect plant growth. If you have hard water (high concentrations of calcium and magnesium in the water), you may want to use a nutrient solution designed for hard water. Water treated with sodium or other water softening chemicals can be detrimental to plants. High levels of salt in the water can limit calcium uptake and lead to disease (research suggests that water with salt levels of 3,000ppm can reduce yields by 10-25%).[11,14]

CARBON DIOXIDE

Plants need adequate levels of carbon dioxide (CO_2) to photosynthesize; low CO_2 levels reduce growth and can cause flower and fruit drop, reducing overall yields. However, indoor growing environments can become CO_2 deficient. This is most likely to happen in a closed greenhouse on sunny, cold winter mornings—because of the cold, ventilation fans are not running, but because the sun is out, plants are photosynthesizing and using up available CO_2. Plants can deplete available CO_2 in as little as just one hour in a closed greenhouse. You can ensure adequate CO_2 with appropriate ventilation.[11,13]

AIR CIRCULATION

Good air circulation helps reduce disease pressure, helps dissipate pockets of air that are too high or low in temperature, and, as we discussed above, helps ensure plants receive adequate CO_2. Air movement can also help seedlings develop a thicker stem, producing a shorter, stalkier, less leggy plant.[11,13]

OXYGEN LEVELS

Oxygen is imperative for plant growth. Over-watering or compaction of the growing medium can limit oxygen to the roots, leading to root death. Using a medium that supports good aeration is important for maintaining healthy oxygen levels.[6]

Oxygen levels in the nutrient solution are a function of temperature; when the nutrient solution is too warm, plants' access to oxygen becomes compromised. Some growers use an air pump (to aerate the nutrient solution) and a water chiller (to cool the nutrient solution down to optimal temperature).[4]

RECOMMENDED RESOURCES

- Helweg, Rick. *How to Grow Fruits, Vegetables & Houseplants without Soil*. Ocala, FL: Atlantic Publishing Group, Inc., 2014.
- Resh, Howard M. *Hydroponic Food Production: A Definitive Guidebook for the Advanced Home Gardener and the Commercial Hydroponic Grower.* 7th ed. New York: CRC Press, 2013.
- Maximum Yield Magazine
  https://www.maximumyield.com
- Small Farms & Alternative Enterprises: Hydroponic Production
  http://smallfarms.ifas.ufl.edu/crops/hydroponics/hydroponic_production.html

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16. Torres, Ariana P., and Roberto G. Lopez. "Commercial Greenhouse Production: Measuring Daily Light Integral in a Greenhouse." Accessed October 27, 2017. https://www.extension.purdue.edu/extmedia/ho/ho-238-w.pdf.

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