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SEED-STARTING IN HYDROPONIC SYSTEMS
& PRIMARY ENVIRONMENTAL VARIABLES

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GROWING IN HYDROPONIC SYSTEMS

Hydroponics is a type of controlled environment agriculture (CEA) where yields per square foot can be higher than those of than traditional in-soil farming. Crops grown in hydroponic systems require daily management, however, in contrast to some field crops that can be grown with little attention for extended periods of time.

Here are some recommendations for successful hydroponic seed-starting and an overview of the environmental variables that need to be closely monitored to produce healthy hydroponic seedlings.

This tech sheet describes 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 at Johnny's research farm, but have compiled this information from our hydroponic trial cooperators, academic and industry resources, and independent hydroponic growers.

10 STEPS for SUCCESSFUL HYDROPONIC SEED-STARTING

1. **Choose varieties bred, selected and trialed in hydroponic systems.** See our list of Hydroponic Performers, or call us for assistance.
2. **Choose your medium.** You can seed into flats filled with soilless potting mix or seed directly into germination plugs or another type of medium. For more information, see Hydroponic Media: Options, Care & Additional Considerations.
3. **Ensure the medium is thoroughly moistened before you seed.** Water or soak the medium until it is homogeneously moist, with no dry pockets.[11]
4. **Place seeds in the medium.** Follow variety-specific instructions for seeding depth and spacing.
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 using a humidity dome will increase the temperature within, so use care to ensure the temperature does not rise too high. Remove the humidity dome as soon as seeds germinate.
6. **Water regularly with plain water.** It is important to keep the seeds moist during the germination period. You can water gently by hand or with an overhead mister, or use subirrigation, also known as seepage irrigation. We do not recommend full-strength hydroponic nutrients be used during the germination period, because 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.[3,13]
7. **Maintain optimal temperature for germination.** Adjust temperatures up or down as necessary; use a heat mat, if necessary.
8. **Fertilize appropriately.** Once the plants have emerged, water with a dilute hydroponic nutrient solution according to the directions on the product label.
9. **Add supplemental lighting**, as necessary, once seeds have germinated.
10. **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 do not need to compete for nutrients, the plants can generally be spaced more closely together than when growing in soil.[14]

WHAT TO MONITOR & WHY: THE PRIMARY ENVIRONMENTAL VARIABLES OF HYDROPONIC SYSTEMS

Table 1. Basic Requirements of Hydroponic Crops

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)	300–1500 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 range will vary by crop and lifecycle stage; follow individual growing instructions for each crop you are growing.

Once established, plants need an approximately 10°F (12°C) drop between daytime and 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 crops (other than tropical varieties) cannot efficiently photosynthesize at temperatures exceeding 85–90°F (29–32°C).

Supplemental lighting in the protected culture setting can significantly increase the ambient temperature. 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
Plain water normally has a pH of 7.0–8.2. Most nutrient solutions are acidic, and once added to the water source, will decrease the 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.

To understand how pH fluctuates in your specific growing environment, you may want to take routine pH measurements of the following:
- water source
- water/nutrient solution
- growing medium with nutrient solution added

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

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. More dramatic changes in pH can be indicative of disease; for example, root rot can cause the pH to drop to 3.0–5.0, while algal 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 will limit growth and compromise plant health. Natural light varies on the basis of seasonal changes in day length and sun angle.

DAILY LIGHT INTEGRAL (DLI)
Growers, particularly in the protected-culture setting, find it useful to quantify light levels as daily light integral (DLI). The DLI is the amount of photosynthetically active radiation (*photons*) that plants receive each day. Just as you can use a rain gauge to measure rainfall, you can use a light meter to measure DLI, typically expressed as *moles of light* (mol) *per square meter* (m^2) per day.[15]

RECOMMENDED LIGHT LEVELS

Most vegetables need 14 hours of sunlight per day and at least 12 mol per m^2 per day. Strawberries grown hydroponically require 15–25 mols of DLI with a minimum of 12, measured at the canopy level, in the greenhouse.[9] Plants in greenhouses with conventional glazing typically experience a 25%–50% reduction in DLI below that of outdoor levels due to the glazing and shading from the structure. Depending upon the crop and a host of variables that influence natural light levels, supplemental lighting may thus be needed at certain times of the year or year-round.[1,11]

LIGHT COLOR

If you are using supplemental lighting, light color is an additional factor to consider. Plants use light within the visible wavelength range of 400–700 nanometers (nm). Herbs and leafy greens fare best with lights emitting a higher proportion at the blue end of the spectrum (450–496 nm), which encourages vegetative growth. Crops like tomatoes prefer lights that emit a higher proportion at the red end of the spectrum (620–750 nm), which encourages flowering and fruiting. Ultraviolet light (UV) aids development of fruit color in crops such as strawberries.[9] LED lights are the most energy-efficient option, and some are adjustable for color to suit crop needs.[3,13]

HYDROPONIC NUTRIENT SOLUTIONS & CONCENTRATIONS

The home gardener or beginning grower will want to start with one of the many preformulated solutions on the market. Each comes with its own instructions for mixing and application.

To monitor nutrient concentrations, measure the electroconductivity (EC) of the solution in your system over time. Use an electrical conductivity meter to detect the level of total dissolved nutrients in the hydroponic solution expressed on a scale of *milliSiemens per centimeter* (mS/cm). The package directions will indicate the desired EC levels. *Note, however, that EC is not a reliable indicator if you are using organic fertilizer solutions.*[2]

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; determine the amount 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]

RECOMMENDED NUTRIENT LEVELS

Optimum EC levels vary by crop. Plants will require lower EC in warmer months and higher 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.[10]

Table 2: Nutrient Requirement Ranges for Common Hydroponic Crops[11,12,15]

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

REPLACING THE NUTRIENT SOLUTION

A shortcoming of EC is that it does not reveal the specific chemical makeup of nutrients in the water, only the overall nutrient levels. Plants take up individual nutrients at different rates, and thus it is possible for the solution to become imbalanced over time, even if the EC is still within an acceptable range.

For this reason, the nutrient solution should be completely changed on a regular basis. Recommendations on how frequently to change the solution vary; start by replacing your solution every 3–4 weeks, or whenever you see symptoms of deficiency or toxicity in your plants.[3,11]

ORGANIC FERTILIZERS IN HYDROPONICS

Using organic fertilizers can present more of a challenge than using synthetic ones.

- The composition of organic fertilizer mixtures is less precise than that of their synthetic counterparts, and nutrient deficiencies can be encountered more readily as a result.
- Organic fertilizers can also contain high levels of carbon, which in excess can contribute to fungal and bacterial growth.
- Finally, EC is not a reliable indicator of actual nutrient concentrations, which can also make it harder to monitor and ensure adequate levels with organic fertilizers.

If you elect to use organic fertilizers, we recommend you choose a product specifically designed for hydroponic systems.[8]

WATER

Testing your water source will help you to understand how naturally occurring elements in the water may affect plant growth. If you have hard water (ie, 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 3000ppm 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.

Indoor growing environments can be prone to becoming CO_2 deficient. This is most likely to happen in a closed greenhouse system on sunny, cold winter mornings when ventilation fans are not running and plants are actively photosynthesizing, 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, dissipate pockets of air that are too high or low in temperature, and as discussed above, ensure plants receive adequate CO_2. Air movement can also help seedlings develop a thicker stem, producing a shorter, stockier, less leggy plant.[11,13]

OXYGEN LEVELS

Oxygen is imperative for plant growth. Overwatering and compaction of the growing medium can both 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, the plants' access to oxygen is compromised. Some growers use an air pump to aerate the nutrient solution and a water chiller to cool the nutrient solution down to an optimal temperature.[4]

REFERENCES & FURTHER READING

RESOURCES FROM JOHNNY'S

- Hydroponic Seed Starting for Healthy Hydroponic Seedlings: How to Begin, What to Monitor & Why *Article (HTML) version of this Tech Sheet*
- Introduction to Hydroponic Growing • Types of Systems; How Hydroponics Differs from Growing in Soil; Scheduling Plantings; Specialty Techniques; How to Choose Varieties for Hydroponic Production *Article*
- Hydroponic Growing Media • Common Options & Selecting a Medium, Using Plugs vs Soilless Medium, Monitoring Salt Build-up & Maintaining Medium Hygiene *Tech Sheet (PDF)*
- Hydroponics Information Guide *4-pp Brochure (PDF)*
- Hydroponics Variety Listing *Insert (PDF)*
- Pests & Diseases of Greenhouses & Hydroponic Systems *Tech Sheet (PDF)*

GENERAL HYDROPONIC GROWING RESOURCES

- Hydroponic Society of America
- Hydroponics. University of Florida: IFAS Extension
- Cornell Controlled Environmental Agriculture

PLANT NUTRITION

- Guide to Symptoms of Plant Nutrient Deficiencies. University of Arizona Cooperative Extension.

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