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Hydroponics for Home Gardeners

For centuries, civilizations throughout the world have experimented with soilless gardening, from the ancient Babylonians to the Aztec Indians. Marco Polo spoke of China's magnificent floating gardens, and there is documentation that the Egyptians practiced primitive hydroponics. It was not until the 1930s, however, that this "new" form of gardening began to receive notice due to the notable experimentation of Dr. W.E. Gericke of the University of California. Gericke, often called the "father of modern hydroponics," coined the term *hydroponics,* which literally means "working with water." Since that time, many developments have been made, and hydroponic gardening continues to grow and thrive in popularity and usage.

Hydroponics is, simply put, growing plants without soil. The discovery was made years ago that it was not the actual soil that plants need to grow—is the mineral nutrients held by soil particles or those unleashed through the action of bacteria and worms. The nutrients slowly dissolve in the surrounding soil-water solution, and the roots then absorb the nutrients from the soil-water. All plants have the same basic needs whether they are grown in soil or not. When the plant's nutritional needs are met, soil is no longer necessary. In fact, the soil may harbor pathogens and other organisms that could harm the plant. In hydroponics, all the nutrients are supplied in a water solution that passes over the roots or floods around them at regular intervals. Plants often grow faster in a hydroponic system because nutrients are immediately available and therefore can be assimilated faster.

When experimenting with hydroponics, as with all other gardening techniques, it is important that the gardener know the basic physiology of the plant—that is, how the plant works. Plants use their roots to draw in water and minerals that are transported upward into the leaves. They also take in oxygen and release carbon dioxide in respiration. The leaves absorb energy during the day from sunlight and take up carbon dioxide from the air. The water from the roots, the carbon dioxide, and the light energy combine to form carbohydrates such as sugar. The plant then releases oxygen back into the atmosphere. These actions, aided by the nutrients gleaned from absorbed minerals, complete the process of photosynthesis, providing the energy and raw materials for growth. At night, the process reverses in the leaves. Carbohydrates break down, releasing the energy needed to create new leaves, stems, and roots, and carbon dioxide is released. Plants, much like human beings and animals, require water, air, food, light, and warmth in order to perform these essential physiological processes and, as a result, to grow and reproduce.

The basic hydroponic system should fill the needs of the plant's roots just as the earth would by providing support, oxygen and carbon dioxide exchange (via the substrate), and water and nutrients (via the nutrient solution). Adequate light and warmth complete the minimal requirements for successful hydroponic plant growth.

Substrate

In order to serve as a suitable replacement for soil, the substrate must be capable of supporting the root system and holding moisture and nutrients. It should be inert, free of insects and diseases, and not easily broken down. Also, the substrate should allow adequate aeration of the roots and have good drainage qualities. Plants need sufficient access to oxygen in the air in order to grow and take up water and nutrients. Poor drainage can lead to decreased growth, stunting, wilting, and discoloration of the leaves and, in the worst cases, "drowning." Several commonly used substrates are coarse sand (ask for washed river sand), gravel, perlite, coarse vermiculite, and rock wool. Perlite and coarse vermiculite are good choices because they are sterile, uniform, and readily available in garden centers. Sand and gravel also work well but should be washed thoroughly before planting to remove lime or other impurities.

Water

Mature plants process a surprisingly large amount of water. For instance, a fully grown tomato plant may use up to ⅔ gallon of water a day. An inadequate water supply is the most limiting factor to plant growth. Water deficiencies can cause the plant to spend all its available energy on developing an extensive root system, the result being a small, stunted shoot. For this reason, it is important that the media be flooded, and subsequently drained, one to three times daily or as often as necessary to keep the roots moist.

Light

The amount of light required varies from plant to plant. Most fruiting plants such as corn, tomatoes, and peppers need 8 to 10 hours of sunlight a day. If these plants are grown indoors, an artificial light must be used to provide high light intensity without causing the temperature to rise above acceptable levels. This situation may be difficult to achieve. On the other hand, many ornamental and foliage plants require less sunlight than fruiting plants do and therefore perform very well indoors. One common error in applying hydroponics is trying to grow plants in reduced light when full sun is required.

Temperature

Warm-season plants perform best when the temperature is between 70 and 80 degrees F during the day and 60 to 70 degrees F at night. Cool-season plants generally require temperatures approximately 10 degrees lower than those suitable for warm-season plants. Above or below this range, plant growth will slow dramatically. Therefore, it is important that these temperatures be maintained whenever possible.

Nutrients

The key ingredient in the recipe for successful hydroponic gardening is the nutrient solution. In traditional soil-based gardening, the plant receives fertilizer from the slow breakdown of organic materials and the release of mineral nutrients in the soil. Hydroponic systems provide readily available, water-soluble minerals directly to the roots in a complete and balanced solution, thus eliminating the need for soil.

There are sixteen elements needed for plant growth. Plants extract several of these elements, such as oxygen, carbon, and hydrogen, from water and air. The rest of the elements must be supplied through the nutrient solution.

The primary macronutrients are nitrogen (N), phosphorus (P), and potassium (K). The secondary macronutrients are calcium (Ca), magnesium (Mg), and sulfur (S). These distinctions are made based on how much of each nutrient plants need. Micronutrients, or trace elements, such as iron (Fe), manganese (Mn), boron (B), molybdenum (Mo), zinc (Zn), copper (Cu), and chlorine (Cl) are used in very small amounts by plants, hence the name *micronutrients.* Micronutrients are sometimes present as impurities in the water and in the solid substrate.

Nitrogen

Nitrogen is central to the development of new leaves and stems as well as to overall growth and performance. An overabundance of nitrogen causes soft, weak growth and possible delay of fruit and flower production. Symptoms of nitrogen deficiency are yellowing leaves and weak, spindly growth.

Phosphorus

Phosphorus is used by the plant in photosynthesis and in the production of flowers and seeds. It also encourages strong root growth. When phosphorus levels are low, the older leaves begin to turn deep green and develop brown or purple discoloration. Other symptoms may be stunted growth and chlorosis, or yellowing, of the lower leaves.

Potassium

Potassium is necessary during all stages of growth, particularly during fruit development. It is involved in the manufacture of sugars, starches, and chlorophyll. Potassium helps the plant make good use of air and water by regulating stomatal openings in the leaves and also helps build strong roots. Deficiency symptoms are mottling and yellowing of older leaves, generally along the margins, and flower and fruit drop.

Calcium

Calcium is used by the plant in the manufacture and growth of cells. It also acts as a buffer for excess nutrients in soil. Calcium deficiency is recognizable by the curling and stunting of young leaves and dieback of the shoot tip. Too much calcium can stunt the growth of a young plant.

Magnesium

Magnesium is fundamental in the absorption of light energy and is central to the structure of the chlorophyll molecule. Symptoms of magnesium deficiency include curled leaf margins, yellowing of older leaves (veins remain green), and, eventually, bright green coloration of the growing tips.

Nutrient Solutions

The elements needed for successful hydroponic growth are widely available in premixed form from gardening catalogs, garden centers, fertilizer companies, and hydroponic supply companies. Most hydroponics amateurs will rely on these commercially available mixes rather than preparing their own solutions at home. However, for those enthusiasts who are willing to mix their own, the extra time and effort may offer more precise nutrient combinations for specific plants, as well as provide an opportunity for experimentation.

Many nutrient solution recipes have been developed, some for general use and others for specific plants, and no one recipe is better for all plants than another. Hydroponic nutrient solutions contain several water-soluble, nutritive salts that can be purchased at fertilizer companies, greenhouse supply companies, and chemical companies. The primary and secondary macronutrient salts are usually mixed in a large volume of water at a concentration ready to use on plants. The micronutrients are mixed as separate concentrated solutions that are then added in a measured amount to the macronutrient solution.

Table 1. Nutrient Solution No. 1

	Amount of chemical to add to 10 gallons of water		Parts per million in nutrient solution
Chemical compound	Grams	Level teaspoons	
Potassium phosphate (KN_2PO_4)	10.1	2	78 K 62 P
Potassium nitrate (KNO_3)	11.5	2½	117 K 42 N
Calcium nitrate ($Ca(NO_3)_2 \bullet 4H_2O$)	22.3	4½	100 Ca 70 N
Magnesium sulfate (Epsom salts) ($MgSO_4 \bullet 7H_2O$)	18.6	4	48 Mg 64 S

Table 2. Nutrient Solution No. 2

	Amount of chemical to add to 10 gallons of water		Parts per million in nutrient solution
Chemical compound	Grams	Level teaspoons	
Ammonium phosphate ($NH_4H_2PO_4$)	8.7	2	28 N 63 P
Potassium nitrate (KNO_3)	19.0	4	195 K 70 N
Calcium nitrate ($Ca(NO_3)_2 \bullet 4H_2O$)	22.3	4½	100 Ca 70 N
Magnesium sulfate (Epsom salts) ($MgSO_4 \bullet 7H_2O$)	18.6	4	48 Mg 64 S

To make your own solution, mix 10 gallons of macronutrient solution according to the recipe in either Table 1 or Table 2. Nutrient solution No. 1 is more appropriate for slow-growing plants and plants growing under low light intensity, such as foliage plants. Nutrient solution No. 2 is more appropriate for rapidly growing plants and plants under high light intensity, especially vegetables.

Next, mix the following two micronutrient solutions, and add each to the macronutrient solution.

- Mix 7.6 grams (1¼ level teaspoons) of boric acid (H_3BO_4) and 0.6 grams (1⁄10 teaspoon) of manganese chloride ($MnCl_2 \cdot 4H_2O$) in 1 quart of water. Use ½ cup of this solution for 10 gallons of macronutrient solution.
- Mix 3 grams (½ level teaspoon) of chelated iron (NaFe EDTA) in 1 quart of water. Use 1⅗ cup of this solution for 10 gallons of macronutrient solution.

After mixing the nutrient solutions together, check the pH. (Meters for measuring pH can be purchased from garden and hydroponic supply companies.) Most plants grow well in a slightly acidic solution with a pH of 5.5 to 6.5. If the solution is too alkaline (pH greater than 7.0), add a few drops of white vinegar per gallon, stir, and recheck the pH. If the solution is to acidic, add a small amount of baking soda per gallon to increase the pH. Continue rechecking and making adjustments until the desired pH level is reached.

The nutrient solution can be reused for 10 to 14 days when applied one to three times a day. At the end of this period, flood the substrate with clean water and drain it several times to wash out any accumulated materials. Mix and add a new solution.

Simple Hydroponic Systems

The simplest hydroponic system for beginners is a nonrecycling system consisting of a well-drained container filled with an acceptable substrate (see the section on substrates). The nutrient solution is mixed, and then it is applied one to three times daily, using a simple watering can. The excess solution drains away and is lost (Figure 1).

A more economical technique is the recycling method, which involves collecting and reusing excess solution. The simplest version of this technique involves placing a large dish under the plant container to catch the solution and then pouring the solution back over the plant at regular intervals.

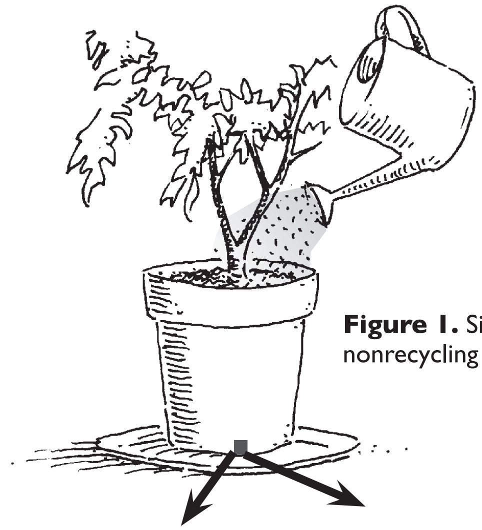

Figure 1. Simple nonrecycling system

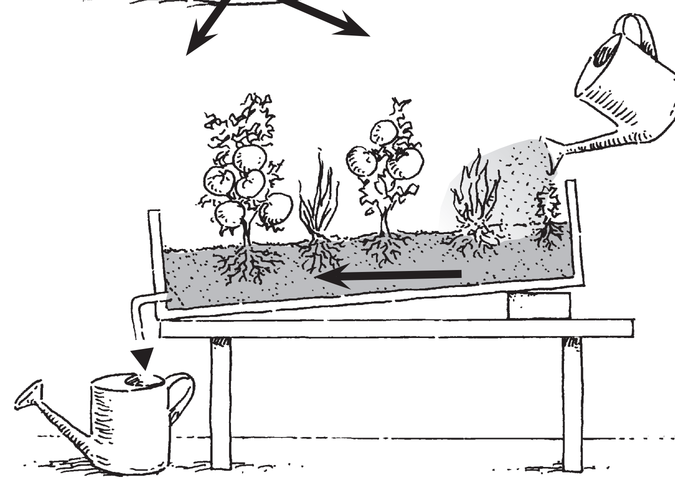

Figure 2. Container with outlet and hose

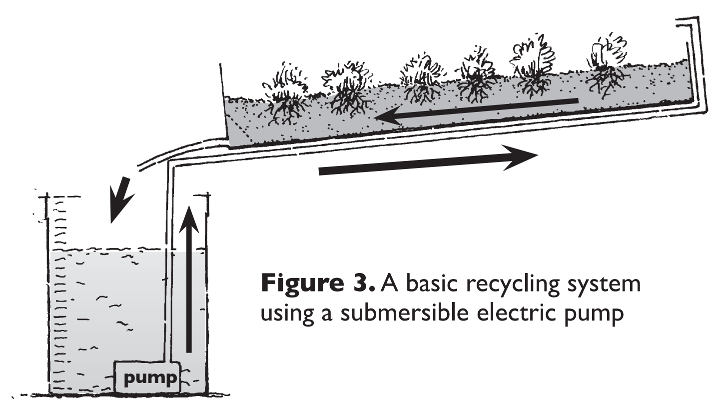

Figure 3. A basic recycling system using a submersible electric pump

A larger-scale version of the recycling method involves using a container that has a hose and an outlet an inch or two from its base. The container must be raised off the floor and tilted so that the nutrient solution drains through the outlet into a receptacle (Figure 2). These simple hand-fed methods work best with small-scale systems. For larger systems, a submersible pump can be used to pump the solution back into the container from the receptacle (Figure 3).

In addition to the systems that require a substrate, there are nonaggregate methods such as water culture and aeroponics. In water culture, the plant's roots are kept submerged in the nutrient solution. The plants are supported by a grid of wire, rope, or string or by coarse screening. This method, however, introduces aeration problems and requires an aquarium pump to bubble oxygen into the nutrient solution.

One simple version of water culture for a single plant consists of using a pint- to quart-sized glass or plastic bottle or jar that has a stopper or lid with two holes in it. The stem of a young plant is passed through one hole so that the plant is held above the nutrient solution and the roots are in the nutrient solution. The plant's stem is surrounded with cotton for support. The nutrient solution is aerated by an aquarium pump. The plastic tube from the pump is passed through the second hole in the lid and into the nutrient solution. The container is covered with aluminum foil to keep light off the root system (Figure 4).

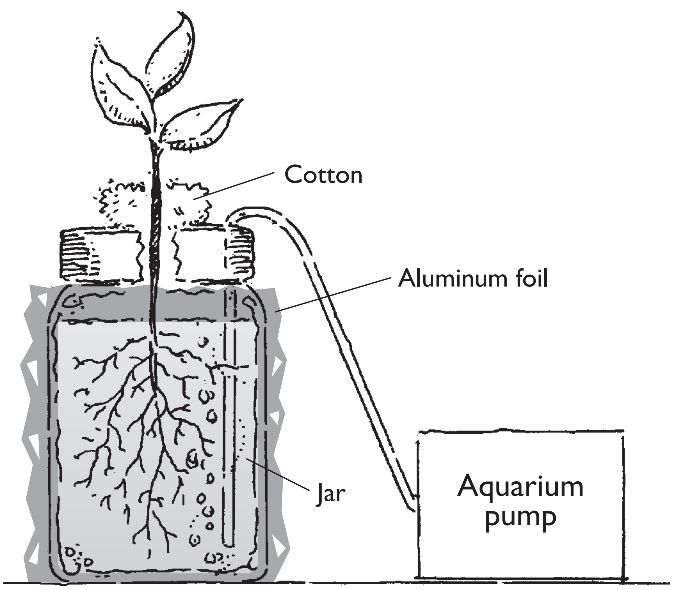

Figure 4. Simple nonaggregate hydroponics system

In aeroponics, the plant's roots are suspended in air and are regularly misted with a fine spray of nutrient solution. Misting must occur often enough to cover the roots with a constant film of nutrient solution at all times. The misting chamber must be kept dark so algae does not grow and compete with the roots. This method requires more mechanical and electrical sophistication than the previous methods do. The methods that use a substrate are generally less expensive, are easier to transplant from, and have fewer difficulties than the water or aeroponics methods do.

Getting Started

It is important that the beginner keep in mind that hydroponics is not the perfect solution to all gardening woes. There are pros and cons to both traditional soil-based gardening and hydroponics. One major disadvantage of hydroponics is the commitment of time and energy necessary for success. Soilless gardening is much more exacting than traditional gardening and may overwhelm the novice gardener if too complex a system is implemented. Begin with a small project such as an herb garden to get a feel for hydroponics, and, as your knowledge and comfort increase, move on to a more elaborate system.

Additional Reading

J. Benton Jones, Jr. 1997. *Hydroponics, a Practical Guide for the Soilless Grower.* St. Lucie Press, Boca Raton, FL.

Howard M. Resh. 1997. *Hydroponics Home Food Gardens*. Woodbridge Press Publishing Company, Santa Barbara, CA.

Howard M. Resh. 1995. *Hydroponic Food Production*. Woodbridge Press Publishing Company, Santa Barbara, CA.

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