BACKYARD HYDROPONICS by Clyde Berndsen, Master Gardener, January 2014

I. BACKGROUND

Hydroponics is a method of growing plants in a water solution without soil. It is also known as aquaculture, water culture or soil-less culture. It is applied to any technique of growing plants without soil.

The actual practice of hydroponics dates back to the Aztec Indians who grew crops on floating rafts covered with soil on shallow lakes where cultivation in soil was not possible. The plant roots grew through the soil and raft down into the water of the lake. A few of these "floating gardens" still exist near Mexico City.

In the late 1600s in England, John Woodward conducted formal experiments using water solutions to find out how plants obtained their food. He and others who followed his experiments were not successful until the mid 1800s when advances in the field of chemistry made it possible to define the list of nutrients used by plants. Botanists in France and Germany conducted experiments that added known quantities of minerals to water and found they could grow plants without soil.

Around 1930 Dr. William F. Gericke of UCLA, coined the word hydroponics to describe the growing of plants with their roots suspended in water containing fertilizer. The word comes from two Greek words, "hydro" (water) and "ponos" (to work or labor), which literally means "water works." Professor Gericke set up a growing lab and successfully grew hydroponic tomatoes that were 25 feet tall. He went on to raise a wide variety of vegetables as well as flowers, grains, root crops and fruits. After publishing his results around 1936, many universities and scientific institutions in the U.S. and Europe started their own trial growing laboratories.

During World War II, the Royal Air Force was the first to establish hydroponic facilities at many of their military bases which provided fresh vegetables for their personnel. In 1940, Purdue University developed the "Nutriculture" system of growing plants in gravel. This technique was used by the U.S. Army to supply fresh vegetables to troops during WW II. In 1946 the Army built a 220 by 24-foot hydroponic garden in Japan which was used to feed troops during the Korean Conflict. It was used until 1970 (I probably ate some of these vegetables while serving with the Air Force in Korea in 1952-53).

Today the commercial hydroponic production of vegetables and cut flowers is widely practiced throughout the world. Nearly all are done in greenhouses where growing conditions and yields can be optimized. Thousands of amateur gardeners, worldwide, have also taken up the hobby of hydroponics and are enjoying the benefits of soil-less gardening in their homes. Locally in San Diego County, there are several hydroponic cut flower growers.

II. ADVANTAGES

Some advantages are:

- Nutrients are not wasted or leached away
- Nutrients supplied to the plants can be controlled
- Crop yields and plant growth are consistent
- Conserves water
- No weeds
- No soil borne diseases or pests
- No crop rotation
- More plants can be grown in a smaller area

III. DISADVANTAGES

Some disadvantages are:

- Initial high cost of setting up the system
- Requires regular monitoring of nutrient solutions
- Specially trained personnel required

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IV. HYDROPONIC SYSTEM

A hydroponic system consists of four basic elements:

- Growing media
- Nutrient solution
- Equipment
- Light

V. GROWING MEDIA

The growing media is inert material or substitute “soil” that provides good root structure support and holds moisture. There is no plant food value in it. Its function is to support the plant so that it can be

nourished several times a day with the nutrient solution. It must be sterile with no disease producing organisms.

Common gardening materials that may be used as growing media are:

- Coarse sand
- Gravel
- Perlite
- Vermiculite

Coarse Sand-- The best sand for hydroponics is coarse sand, especially river or beach sand, particle size 1/16 to a 1/8 of an inch. Fine sands may become waterlogged, which prevents good root aeration. It is inexpensive if you gather it yourself. Be sure to rinse it well before using.

Gravel -- Gravel was the preferred media for many years. Small rounded broken stones, pebbles, pea gravel or crushed rocks of various types measuring 1/4-3/8 inch size are ideal. Gravel provides good root aeration and good moisture retention.

Perlite – Perlite, an expanded volcanic rock is a natural material. It is lightweight, inert, absorbs moisture well, and provides good root aeration. It is also fairly inexpensive and available at many gardening stores. The medium particle size is preferred (used extensively at Disney's Epcot Park).

Vermiculite -- Vermiculite is obtained from naturally occurring deposits of hydrated magnesium aluminum silicate. When heated the water is converted to steam which expands the material twelve to fifteen times. The resulting product is sterile, lightweight, highly absorbent and holds water and air. It is available in many gardening stores. Vermiculite has given very good results in hydroponics but it is best to mix it with coarse sand because its high water retaining properties may hold too much water and not enough air for the roots.

Three specialized products also have been developed for hydroponic gardening and are available in hydroponic supply stores. There may be other materials used for hydroponics but these are the most common:

- Shredded coconut fiber
- Expanded clay pellets
- Rockwool

Shredded coconut fiber -- Shredded coconut fiber is used widely in commercial hydroponic systems. It is the husks of coconuts, commercially called "coir" that is ground and formed into many specialized products. It is available in compressed bricks, slabs, cubes and compressed pots. In commercial quantities it is cheap. It is used once and normally discarded.

Expanded clay pellets -- Expanded clay pellets, trade named "Hydroton", was developed specifically as a growing media for hydroponic gardening. It absorbs moisture and provides good aeration for roots. It is rather expensive but may be reused. Because the plant roots will grow into the pellets it needs to be cleaned and sterilized between crops. This can be accomplished by spreading the Hydroton pellets on a cookie sheet on the backyard grill and roasting them for about 15 minutes. This burns the root hairs and at the same time sterilizes the pellets. The pellets need to be rinsed well after sterilizing to remove salts and carbon residue.

Rockwool -- Rockwool products were developed in Denmark and Holland and sold commercially as "Grodan". It is highly absorbent and provides good root aeration. It is moderately expensive and is available formed into 1/2-inch cubes, blocks and slabs for starting cuttings and seeds. Normally it is not reused. Rockwool used for building insulation should not be used for hydroponics as it is treated with water repellent.

Some hydroponic systems do not use a growing medium. In this case, the roots are periodically immersed or sprayed with the nutrient solution. In other systems, a large number of small plants such as lettuce or strawberries are grown in styrofoam or plastic trays that are floating on tanks of nutrient solution. This technique is used by large-scale commercial growers and is not easily adapted to the backyard.

Plants that are intended for hydroponic gardening should be started in inert growing medium and not in soil. Washing the soil from the roots of small plants for hydroponic use is difficult and may damage the roots to the point that the plant may not survive. Most seeds may be started directly in the growing media just as one would do with soil. Plain water can be used until the seed germinates and the first true leaves develop.

VI. NUTRIENT SOLUTION

Hydroponic culture uses water with added plant nutrients to make up a solution to feed the plants. This is the most important element of the hydroponic system. The nutrient solution provides the 16 essential mineral elements necessary for optimum plant development. These elements occur normally

in the soil and are made available as they are dissolved by soil moisture and absorbed by the roots. The lack of any one or several of the essential elements will affect plant growth and development. In the hydroponic system all essential elements are put into the nutrient solution. The absorption of the elements by plants is the same whether the nutrients originate in the soil or a soil-less medium. When all of the essential elements are present in the nutrient solution and the proper pH of the solution is maintained, the plants will absorb their nutrients at optimum levels. Combined with proper light and temperature, these elements will enable the plants to thrive and produce high yields.

The pH of the nutrient solution must be tested when it is first made up and then tested at about weekly intervals. Most plants like soils that are slightly acidic, a pH of 6.0 to 6.5. In Poway where I garden the water has a pH of 7.6. After adding one teaspoon of nutrient solution concentrate to a gallon of water the pH is about 6.4. To bring it down to 6.0, one teaspoon of regular white vinegar is added. As the plant removes nutrients from the solution the pH will increase. In four or five days it will be close to 7.0 or above. Then additional water is added with two teaspoons of vinegar. Test kits to measure water pH are available from hydroponic suppliers for $15-$20. The kit I use from PETCO is used to measure the pH of fresh water aquariums and costs about $5.00.

The nutrient solution can be modified as the plant develops. A higher nitrogen formula 7-4-10 may be used to promote early aggressive growth of the plant's structure and foliar development (the three numbers on a fertilizer product are the percent Nitrogen, Phosphorus and Potassium in this order). As the plant matures, the nutrient solution is changed to reduce the nitrogen and increase the potassium (relative to nitrogen) 4-8-7 for flowering and fruiting. Some formulas called bloom busters with a ratio of 2-45-28 are sold to help produce larger blooms and heavier fruit. It is mostly used at the very end of the plant life cycle. Do not try to be too good to the plant and increase the strength of the solution (a mistake I made with my first attempt at hydroponics). Three tablespoons of Rapidgrow 15-15-15 per gallon of water are not better than one tablespoon.

For the backyard gardener, I suggest nutrient materials be purchased as pre-mixed nutrient formula from a hydroponic supplier. Many concentrated dry and liquid formulas are available in pound and pint sizes. A pint or pound of concentrated nutrient will last a long time. One or two level teaspoons of nutrient formula are all that is needed for a gallon of water.

Some gardeners may choose to prepare their own nutrient solutions from basic chemicals. Separate nutrient ingredients for custom formulas are available from hydroponic suppliers. Many formulas for nutrient solutions can be found in hydroponic books and pamphlets.

Here is a sample formula for inorganic nutrients:

11.5 ounces ammonium sulfate
8 ounces ammonium phosphate
4 ounces. potassium chloride
3 ounces. calcium sulfate
5.5 ounces magnesium sulfate

In a separate container mix the listed trace elements. The chemicals should be ground to a fine powder. Mix:

½ ounce iron sulfate
½ teaspoon manganese sulfate
¼ teaspoon boric acid powder
¼ teaspoon zinc sulfate
¼ teaspoon copper sulfate

Mix all the chemicals well and use 1 to 2 teaspoons of the mix per gallon of water to make up the nutrient solution.

For those who wish to use organic nutrients mix:

1.5 teaspoons fish emulsion
1.5 teaspoons liquid seaweed
1 teaspoon blood meal
1 gallon water

Both formulas work equally well according to one reference. The organic formula was discontinued because of an unpleasant odor it creates (dead fish, ripe seaweed, and blood meal).

VII. EQUIPMENT

Only a few basic garden items are necessary for a simple hydroponic system: a couple of pots, trays, and some perlite. More complex systems will use plastic pipes, hoses, valves and a storage tank for the nutrient solution. For an automatic system, a small water pump and a timer are necessary. Different kinds of hydroponic systems with instructions are available for purchase as a kit or may be

bought piece by piece from hydroponic equipment suppliers. A creative gardener should be able to build a system using readily available plastic trays, tubs, and irrigation PVC pipes and fittings.

Pot and wick system:

In the simplest form of hydroponic gardening, you only need two containers; one with drain holes and one without holes, growing medium and a wick. With a large plant, such as a tomato vine, a pot that measures at least 5-8 inches in diameter by 10 inches deep or larger is required. The tray, two or three inches deep which serves as a nutrient reservoir, is placed under the pot. A fibrous wick with both ends frayed is placed through the drainage hole in the pot. Growing medium is placed in the pot with the wick oriented vertically in the center of the pot. This will uniformly distribute the nutrient growing medium as capillary action moves the solution up the wick and throughout the medium. The growing medium should be initially soaked with water. The pot should sit on small blocks or pieces of PVC plastic pipe so that the bottom of the pot is just at the solution level with the wick in the solution.

Several pots can be placed in a single tray. Periodically water should be added to the nutrient solution to keep the level at the bottom of the pots. Every ten days to two weeks the nutrient solution should be changed. The pot and reservoir should be flushed out several times with plain water to remove fertilizer salts from the growing media. New nutrient solution is then placed in the tray. The old nutrient solution is excellent for watering plants grown in soil, in regular pots or distributed to plants in the garden. Don't dump it down the drain as it will only add to the pollution problems.

How to grow lettuce with a pot and wick system:

Materials needed:

1 pot with drainage holes 5-8 inches in diameter
1 pot without drainage holes slightly larger
I fibrous wick about 10 inches long made of nylon, polyester or rayon
Perlite to fill the pot with the drainage holes
A 10 inch square piece of plastic wrap
Piece of string about 20 inches long
Lettuce seeds
Any water soluble fertilizer powder

Procedure:

1. Tie a knot in the wick about 3 inches from the end and wet the wick with water.
2. Thread the wick through the hole in the pot with the knot on the outside.
3. Fill the pot with perlite to ¼ inch of the top making sure the wick is in the center of the pot.
4. Soak the perlite with water until it runs out the bottom.

5. Place the perlite pot inside the pot without holes. Several small stones or blocks should be placed under the perlite pot so it is raised slightly above the water. The wick should be long enough to touch the bottom of the outer pot.
6. Sprinkle a few leaf lettuce seeds on top of the perlite.
7. Water in the seeds gently. Remove excess water but leave enough water in bottom pot for the wick to be in the water.
8. Place plastic wrap over the pot with the perlite and secure with string.
9. Place in warm location and check every few days to see if seeds are germinating.
10. Add water to keep level in bottom pot just at the bottom of the upper pot.
11. After seeds have germinated and true leaves form, discard the water in the bottom pot and remove the plastic wrap cover and discard.
12. Make up fertilizer solution using ½ the suggested amount of fertilizer powder. **Caution: Do not add more than ½ the recommended amount.**
13. Place perlite pot in larger pot and gently pour about 1/2 cup fertilizer solution over the perlite.
14. Place pot in sunny location and ensure sufficient nutrient solution is in the bottom pot.
15. Check every few days on the level of the fertilizer solution in bottom pot. Make sure it just touches the upper pot.
16. When lettuce leaves are about 3 inches long, carefully cut outer leaves with scissors and enjoy.
17. Do not pull off leaves as it may dislodge the plant. New leaves will continue to form and grow if the center of the lettuce plant is allowed to grow.

Plastic bag system:

A plastic garbage bag, about eight-gallon size, may be used in place of a pot. The growing medium is placed in the bag and several ¼ inch drainage holes are punched in the bottom around the base. The bag is placed in a plastic tray to collect surplus nutrient solution. Small blocks should be placed under the bag to keep it from being submerged in the nutrient solution. Make sure the holes are at the bottom of the bag so that complete drainage will occur when nutrient is poured in the top of the bag. After the plant is planted in the medium, nutrient solution should be poured in the top of the bag once a day. If you have a large plant like a cucumber or tomato, the solution should be added several times a day and more frequently if the plant shows signs of wilting during hot weather. Excess watering with the solution or letting the bag stand in the solution may cause root rot and wilting of the plant. Use your finger to test the dryness of the medium. With a little experience you will know how moist the medium is and when to water. Overwatering is the most common problem in hydroponic gardening.

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Local hydroponic suppliers

City Farmers Nursery, 4823 Home Ave., San Diego 619-284-6358

Innovative Growing Solutions (IGS) 7922-B Miramar Rd. San Diego 858-578-0466

Foothill Hydroponics 10705 Burbank Blvd., North Hollywood, CA 91601, 818- 760-4025

http://sdhydroponics.com/ retail locations throughout San Diego county.

References

Hydroponic Gardening, Raymond Bridwell, Woodbridge Press Publishing Co. 1972

Hydroponic Tomatoes for the Home Gardener, Howard M. Resh, Woodbridge Press, 1997

Beginners Guide to Hydroponics, James Sholo Douglas, Sterling Publishing Co., 1972

Easy Gardening with Hydroponics, Mohsen Dala, Foothill Hydroponics, 1999

Gardening Indoors with Rockwool, George F. Patten and Alyssa F. Bust, 1997, Van Patten Publishing

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Biography

Clyde began fooling around with hydroponics shortly after visiting "The Land" exhibit at Epcot in Disney World, Florida while living in Virginia in 1983. The exhibit has a "Disney style" boat ride through real greenhouses where fruits and vegetables are grown using many different hydroponic techniques. The harvested crops are served to customers in the restaurant in “The Land” exhibit. Clyde had been a backyard vegetable gardener for many years and thought this type of gardening looked easy. He bought a book on the subject and made a hydroponic system out of PVC pipe, a plastic container, some hoses and a small pump. This experiment turned out to be a disaster. A couple of years after becoming a Master Gardener, he tried hydroponics again. The Master Gardener training by Vincent Lazaneo, Urban Horticulture Advisor, UC Cooperative Extension paid off. Clyde had a better understanding about growing plants and their needs -- and he bought a better book.