HowTo Hydroponics

By Keith Roberto

The complete guide to building and operating your own indoor and outdoor hydroponic gardens. Includes detailed instructions and step-by-step plans.

3rd Edition

How-To Hydroponics

third edition

A How-To Guide To Soilfree Gardening
text, art and photography by Keith Roberto

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Contents

Give a man a meal,
feed him once.

Teach a man to fish,
feed him for life...

Foreword

How To Hydroponics was written to provide you with a basic education in the science of hydroponics while giving you the hands on experience that makes learning fun and effective. It covers all the information you should need to gain a basic understanding of the science and develop a working knowledge of the technology. You will learn, step-by-step, to build the hydroponic system of your choice from the plans included within. Whether you grow for food, fun or profit, we'll show you how to start growing your favorite flowers, herbs and veggies with this exciting technology.

How-To Hydroponics is the result of nearly a decade of research and development in the exciting field of hydroponics. We have spared no expense to provide you with all the knowledge you'll need to get growing with hydroponics successfully. We have made every effort to ensure that all questions and discrepancies brought to our attention from the original publication have been answered and corrected in this newly revised edition. Of course, there may be some things that we've overlooked - so please bring anything you find to our attention for future corrections. Email me at: kr@futuregarden.com

It is recommended that you read this book in the order it has been assembled so you will not miss out on important information that could jeopardize your efforts. Take the time to read the book entirely before you begin any type of construction, as there is a wealth of important information within that may effect your choice of which garden to build and ultimately affect your garden's success.

For those new to gardening, we begin with a brief introduction to Hydroponics and then move right into a basic review on the biology and chemistry principles that will help you understand how to grow perfect plants - don't worry - it's all real basic stuff!. From there, we move on to planning your hydroponic garden so that you get the most out of your available space and build the system that is right for you. At the end of each set of plans there is a "Get Growing" page that will outline the proper use of the system and how to start your favorite crops in it.

Since the Hydroponic industry is still rather small and there aren't many local shops at which to purchase supplies, we've established an online garden store that specializes in hydroponic garden supplies and even prefabricated gardens for those of you who can't wait to get started! In cooperation with some of the best companies in the industry, we are constantly striving to include a complete selection of components, nutrients and accessories that you may require to build and maintain the gardens featured in this publication. If you can't find it locally, try: http://futuregarden.com/store.html

Good Luck and Happy growing!

Keith Roberto

Thank you for purchasing How-To Hydroponics

Water - the basis of life

Known as the universal solvent, without water life on Earth would not exist. Right now, deep space probes are searching the far reaches of our solar system for water while three quarters of our own planet is bathed in it. Every living cell contains water. Every living plant depends on it to thrive. This book is about water. How to manage it, infuse it with the nutrition vital to plants and deliver it to their thirsty roots.

In nature, fire and water act together to recharge the soil with nutrients. When forests burn, wood is turned to ash. Wood ash is rich in Potassium, one of the plant kingdom's fundamental foods. When the rains come, lifeless leaves and fallen branches are helped along their path to decay. Animals and insects hasten this process by their consumption of plants and excretion of organic wastes.

Organic matter in the soil is biologically decomposed into the basic nutrient salts that plants feed on. Falling rains once again help in dissolving these salts and making them available for plants to absorb through their roots. For a plant to receive a well balanced diet, everything in nature must be in perfect harmony. Forests must burn, animals must eat, rains must come, wood must rot, microbes in the soil must work. Rarely, if ever, can you find such ideal conditions occurring on a regular basis. In fact, Earth's rainforests may be the only examples left of near perfect botanical conditions. Visit one if you ever get the chance.

Hydroponics is about enriching water with the very same nutrient salts as found in nature. It is about creating and maintaining a "nutrient solution" that is perfectly balanced for your plants. Most hydroponic systems contain the nutrient solution and protect it from evaporating and from discharging into our environment unlike the runoff from exposed, fertilized soil. This conservative approach to water management is what makes hydroponics the method of choice in drought stricken area worldwide and as a result is rapidly becoming known as "Earth Friendly Gardening."

Since you will be practicing the art of "water gardening", it is a wise idea to know what your local water contains. This can be done by calling your water company and asking for an analysis. If your water comes from a well, you will most likely have to send it out to a lab for analysis. The most important factor affesting water quality is the "hardness" or "softness" of the water. Hard water means that there is alot of dissolved mineral content, primarily calcium carbonate which usually shows up as scale on hot water pipes. Soft water is generally very pure or low in dissolved solids. Distilled or water that has been through a reverse osmosis filter would be considered soft. There exists on the market a number of nutrient formulations that are specific for hard or soft water applications. It is a good idea to keep this in mind when purchasing or mixing up your own nutrients.

Hydroponics - a quick overview

Truly a wonder of modern science - hydroponic gardens produce bountiful harvests of fruit, vegetables, grains, herbs and flowers in places never before able to sustain growth. Hydroponic gardens produce the healthiest crops with the highest yields and vitamin content thanks to their perfectly balanced nutrient solutions. Modern hydroponic methods provide food for millions of people worldwide and supply you, me and the food service industry with superior produce. In fact, hydroponic cultivation is so effective, NASA has devised an advanced method of hydroponics for use in outer space. The science of hydroponics began with experimentation into determining the elementary composition of plants. These experiments have been dated as early as 1600 A.D., however, records show that plants have been cultivated in soilfree mixtures of sand and gravel even earlier. The hanging gardens of Babylon and the floating gardens of the Mexican Aztecs are perfect examples of early hydroponic gardening. Egyptian hieroglyphics have even been found depicting the cultivation of plants in water as far back as several hundred years BC.

The word "Hydroponics" was coined by Dr. W.F. Gericke in 1936 to describe the cultivation of both edible and ornamental plants in a solution of water and dissolved nutrients. The simple meaning is derived from the Greek "Hydro"- meaning water, and "Ponos"- meaning labor. In this method of cultivation, plants are provided with the nutrients required for growth by a “nutrient” solution which is basically nutrient enriched mineral water. This nutrient solution can be circulated around the roots by either the passive force of gravity or the active force of an electromechanical pump. Some systems simply bath the roots in nutrient solution and use an air pump to oxygenate the solution from below to prevent stagnation and provide the roots with important oxygen.

Plants grown hydroponically are healthier than their soil grown counterparts since they receive a perfectly balanced diet and do not come in contact with soilborne pests and diseases. Super efficient hydroponic systems like the ones we show you how to build conserve water and nutrients by preventing evaporation and runoff. Arid regions where water is scarce can now grow crops with hydroponics. Since hydroponic systems deliver water and nutrients directly to the plant, crops can be grown closer together without starving each other and healthier plants add to a higher yield. By growing crops in a sterile environment, under ideal conditions, hydroponics saves the costs of soil preparation, insecticides, fungicides and losses due to drought and ground flooding.

NASA space agriculture display at Epcot Center™ Orlando, Florida.

In soil, plants waste a tremendous amount of energy developing a large root system to search for moisture and nutrients. When grown hydroponically, the roots are bathed or sprayed with nutrients dissolved in water. This way their energy can be redirected into the production of more foliage, flowers, fruits and vegetables.

Aeroponic Squash at Epcot Center

Plants grown hydroponically are healthier because they receive a well balanced 'diet'. They are more vigorous because little energy is wasted searching for water and nutrients. As a result, hydroponically grown produce is generally larger, tastier, and more nutritious than the same produce grown in soil. In order to give the physical support soil would normally provide, a sterile medium such as sand, gravel, rocks, cocofiber or rockwool (or combination of each) may be used. In the case of aeroponics, no medium is used and the plants receive physical support from baskets and in this case, wires suspended from the roof. These plants are rotated through a chamber that supplies their roots with a fine spray of water and hydroponic nutrients. Oxygen to the roots increases a plant's metabolism substantially.

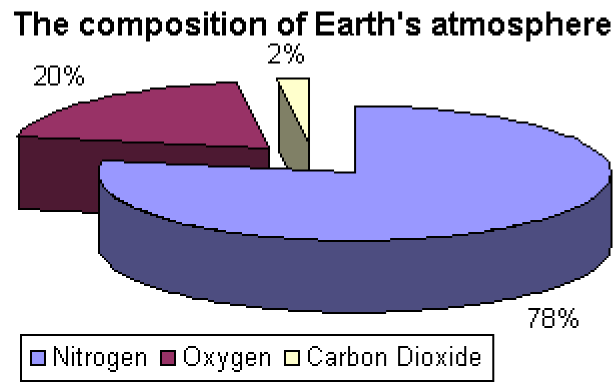
Some advantages of replacing soil with a sterile medium are:
1. Elimination of soil borne pests, funguses and diseases.
2. Elimination of troublesome weeds and stray seedlings.
3. Reduction of health risks and labor costs associated with pest management and soil care.

At the Environmental Research Laboratory (ERL) at the University of Arizona in Tucson, Dr. Carl Hodges and Dr. Merle Jensen in conjunction with Walt Disney Productions, have developed new concepts for presenting hydroponic technologies to the public in an entertaining way. The ERL helped create two attractions called "Listen to The Land" and "Tomorrow's Harvest" - both major facilities at Epcot Center near Orlando, Florida.

Hydroponics is NASA's solution to provide a self sufficient food source for future space stations and proposed visitors to mars. The administration has sponsored a research program titled Controlled Ecological Life Support System (CELSS) in order to further develop the technology and carry it into the future. The picture below is of Epcot/NASA's Space Agriculture expo as seen from a tour of the Epcot Center attraction. The lighting used in these examples is high pressure sodium or HPS, which delivers an excellent spectrum of color and output in lumens. High Intensity Discharge (H.I.D.) lighting, which includes the HPS and metal halide type lamps, is the best lighting to use when gardening indoors or supplementing natural lighting outdoors due to its efficiency and close representation of the sun's natural light color and intensity.

The organic composition of plants

To develop a strong understanding of hydroponics, we must first review the organic composition of plants. The molecule is the smallest recognizable assembly of atoms that can be identified as being a specific element. Common elements are: Hydrogen - Oxygen - Gold - Silver etc... All *organic* matter on Earth is comprised of at least four basic elements. In fact, the scientific qualification for labelling matter organic is that it must be comprised of the following elements; Carbon, Hydrogen, Oxygen and Nitrogen. Over 90% of a plant's dry weight is comprised of these four organic elements. The interesting thing is that while many claim that plants grown hydroponically are not "organic", ANYTHING THAT CAN GROW IS ORGANIC!



The atmosphere of our planet is comprised of approximately 78% Nitrogen, 20% Oxygen and 2% Carbon dioxide, in addition to a small percentage of inert gases. Carbon dioxide is known as a compound since it is a combination of one Carbon molecule and two Oxygen molecules. Most elements exist as compounds in nature because they are chemically unstable when pure in form, reacting with other other elements until stabilized into compounds. This is an important issue when choosing nutrients to use with your hydroponic system - keep this in mind when you read about a *single* part nutrient that contains "everything" - if this were the case, the nutrient would become useless in a short amount of time as the elemental salts within would rapidly combine into compounds your plants simply cannot absorb. The compound H2O (water) is made of two parts Hydrogen and one part Oxygen. H20 is formed when Hydrogen, an unstable gas, is burned or oxidized (combined with Oxygen). Since C, H, and O are readily available in both the air and water, plants possess the ability to extract these elements from either and use them to create food. Light provides the energy to make this possible.

(C) Carbon

Occurs in the cell walls, sugars manufactured by chlorophyll, as well as chlorophyll itself. Carbon constitutes approximately 50% of a plant's dry weight.

(H) Hydrogen

Important in nutrient cation exchange (the chemical reaction which causes roots to uptake nutrients) and in plant-soil relations. Hydrogen is also essential for the formation of sugars and starches and is easily obtained from water. Water also keeps the plants structure rigid through what is known as turgor pressure, notice when a plant is lacking water it will begin to lose turgor pressure and wilt.

(O) Oxygen

Required to form sugars, starches and cellulose. Oxygen is essential for the process of respiration which provides energy plants utilize to grow.

(N) Nitrogen

Necessary for the formation of amino acids, co-enzymes and chlorophyll.

For a plant to develop properly, it must have access to all the necessary elements. Because these four elements occur naturally, most people rarely consider them when discussing plant nutrition. It should be stressed that the exclusion or depletion of any one of these elements would cause death of the organism. Just as you are what you eat, so are your plants so feed them a well balanced diet.

Plant nutrition

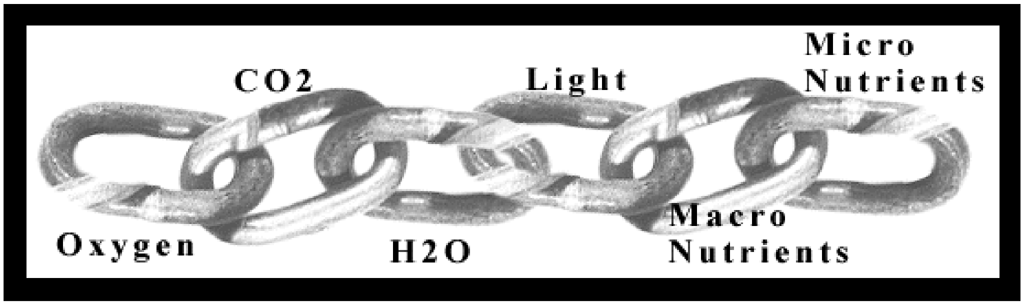
Macro nutrients are absorbed in large quantities
They serve the following purposes once ingested:
(N) Nitrogen
Necessary for the formation of amino acids, co enzymes, and chlorophyll.
(P) Phosphorus
Sugar, phosphate and ATP (energy) production-flower and fruit production-root growth.
(K) Potassium
Protein synthesis requires high potassium levels. Hardiness, root growth, and the manufacture of sugar and starch also require potassium.

Micro nutrients are absorbed in smaller quantities
They serve these purposes:
(B) Boron
Necessary for the formation of cell walls when combined with calcium.
(Ca) Calcium
Required for cell wall formation.
(Cu) Copper
Activates enzymes, necessary for photosynthesis and respiration.
(Fe) Iron
Chlorophyll formation, respiration of sugars to provide growth energy.
(Mg) Magnesium
Chlorophyll production, enzyme manufacture.
(Mn) Manganese
A catalyst in the growth process, formation of oxygen in photosynthesis.
(Mo) Molybdenum
Nitrogen metabolism and fixation.
(S) Sulfur
Protein synthesis, water uptake , fruiting and seeding, natural fungicide.
(Zn) Zinc
Chlorophyll formation, respiration and nitrogen metabolism.

Most nutrients are listed with the amounts of N-P-K represented in percentages. For instance, a 10-10-10 solution would contain 10% Nitrogen 10% phosphorus and 10% potassium by weight. If you do the math, you will find this concentration adds up to only 30% - this is because the remaining percentage usually consists of a filler of chelating materials used to assist the nutritional process. Use only nutrients specifically designed for hydroponics, as conventional formulas prepared for plants grown in soil do not contain the proper balances. I personally favor the two and three part nutrient formulas as they always outperform the general purpose nutrients. The two and three part formulas allow you to custom blend for each crop and stage of growth.

The nutrient solution

Compare the measure of a plants health to the strength of a chain, it too is only as strong as its weakest link. To insure that your 'chain' is strong, it is very important to make sure all the links are in place, and in good supply. Proper concentration of nutrients within the solution is critical, as hydroponically grown plants are completely dependant upon it for food and different plants have varying nutrient requirements. Most commercially available hydroponic nutrients now come with instructions for mixing solutions specific to plant types, stages of growth and growing conditions. There is a great number of commercially available nutrients on the market which makes getting started in hydroponics easy for the beginner not looking to make their own nutrients. When selecting a nutrient to use with your garden, there are a few things you need to look for. The most important factor is that the nutrient be designed SPECIFICALLY FOR HYDROPONIC application. Using a supplemental fertilizer like Miracle Grow or Peter's is not advised as these formulas are designed for use as a supplement to soil based gardens and do not contain the trace and micro-nutrients essential to the plant. the second consideration in choosing a nutrient is that of using a powder or liquid formula. Multi-purpose, single part powdered nutrients are o.k. for growing plants hydroponically under low to moderate lighting conditions.



If you plan to grow under High Intensity Discharge lighting or in strong, direct sunlight, you will find using a two-part powdered or liquid nutrient gives you better performance. The reason for this is simple, one part, multipurpose nutrients are designed to satisfy the widest range of plants, lighting conditions and stages of growth. They are not custom-blendable according to your specific crop or conditions. I prefer the two and three part liquids for exactly this reason - you can blend them in different concentrations and combinations to target the specific growth requirements of your crops at each stage of growth. A very powerful technique in optimizing the growth of your garden. The picture below is of the Above & Beyond line of liquid nutrients from FutureGarden.

It has come to my attention over the years that there are many interested in making their own nutrients so I have provided a few recipes. If you are reading the Acrobat version, you will find a nutrient calculator spreadsheet included with your download. Otherwise, consult the table on the next page which details the salts required to make three hydroponic nutrient solutions for use with vegetative, fruiting and flowering crops.

The weights shown are all based upon making 1 gallon of nutrient. To make more than a gallon, multiply the gram weights by the total gallons of nutrient solution required, ie: 20, 40 etc... These formulas have been tested with a wide variety of plants all in the same system and have performed quite well, however, results will depend upon the quality of raw materials and precision with which you prepare these solutions.

Hydroponic nutrient recipes

					N - P - K
To make	**1.00**	**gallon(s) of**	**VEGETATIVE NUTRIENT**		**9.5 - 5.67 - 11.3**

Use	6.00	grams of	Calcium Nitrate	Ca(NO3)2	
	2.09	grams of	Potassium Nitrate	KNO3	
	0.46	grams of	Sulfate of Potash	K2SO4	
	1.39	grams of	Monopotassium Phosphate	KH2PO4	
	2.42	grams of	Magnesium Sulfate	MgSO4 * 7H2O	
	0.40	grams of	7% Fe Chelated Trace Elements		See Trace Box

To make	**1.00**	**gallon(s) of**	**FRUITING NUTRIENT**	**8.2 - 5.9 - 13.6**

Use	8.00	grams of	Calcium Nitrate	Ca(NO3)2	
	2.80	grams of	Potassium Nitrate	KNO3	
	1.70	grams of	Sulfate of Potash	K2SO4	
	1.39	grams of	Monopotassium Phosphate	KH2PO4	
	2.40	grams of	Magnesium Sulfate	MgSO4 * 7H2O	
	0.40	grams of	7% Fe Chelated Trace Elements		See Trace Box

To make	**1.00**	**gallon(s) of**	**FLOWERING NUTRIENT**	**5.5 - 7.97 - 18.4**

Use	4.10	grams of	Calcium Nitrate	Ca(NO3)2	
	2.80	grams of	Potassium Nitrate	KNO3	
	0.46	grams of	Sulfate of Potash	K2SO4	
	1.39	grams of	Monopotassium Phosphate	KH2PO4	
	2.40	grams of	Magnesium Sulfate	MgSO4 * 7H2O	
	0.40	grams of	7% Fe Chelated Trace Elements		See Trace Box

Chelated Trace Element Mix

Iron	Fe	7.00%
Manganese	Mn	2.00%
Zinc	Zn	0.40%
Copper	Cu	0.10%
Boron	B	1.30%
Molybdenum	Mo	0.06%

Please follow these directions carefully:

Fill your empty reservoir 75% full with clean, hot water. Multiply the above gram weigths of each specific salt by however many gallons your reservoir holds as these ratios are based upon making only one gallon of nutrient solution. Dissolve each salt, one at a time - make sure each salt dissolves entirely before adding the next.

WARNING:

These elemental salts are extremely reactive in their native states - use eye protection when handling them and avoid contact with skin. Follow the directions given to you by the supplier. Avoid using inaccurate “kitchen” type scales - your crop is worth it.

Measuring nutrient concentration and pH

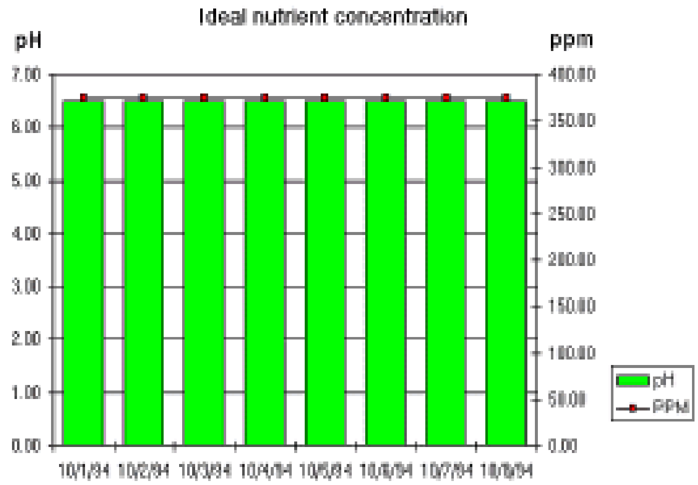
In order to measure the amount of nutrients in solution, a measurement of PPM or TDS (Parts Per Million and Total Dissolved Solids) is performed. This measurement is also commonly referred to as the EC or 'Electrical Conductivity' of a solution as that is actually what you are measuring. There are a number of methods of measuring PPM, my favorite is the digital PPM gauge which is simply submerged in the nutrient solution for a reading to be taken. Digital PPM meters are calibrated with a solution that has a PPM of 1000 - you do need to calibrate them every so often but nothing beats the convenience. Frequent changes of your nutrient solution will generally keep the concentrations where they need to be. My best advice is to follow the directions that come with the nutrient you plan to use. In any case, plan to replace nutrient solution on a bi-weekly basis for best results.

All the nutrients in the world will do a plant no good if it cannot absorb them easily. A major factor in determining a plants ability to uptake nutrients is the relative acidity, or pH (potential Hydrogen) of the soil or solution from which they feed. pH is measured on a scale of 1-14 and represents the concentration of hydrogen ions in solution. Generally, it is used to determine whether a solution is acidic or basic. A 1 on the scale represents a low ion concentration (an acid), pure water is considered neutral at a pH of 7. A 14 on the scale represents the highest concentration of ions (basic, alkaline). Some nutrients may become unavailable to the plant if the solution pH drifts from an optimal reading, which for most plants is between 5.5 and 6.5. This condition is called "nutrient lockout". pH can be tested with litmus paper and adjusted with an inexpensive pH control kit as shown below. Follow directions on product packaging.

Replacing your nutrient solution every 2 weeks is the best insurance against crop damage as frequent changes will provide your crop with all the nutrients it needs. Under ideal conditions, pH and PPM will drift only slightly as the nutrient solution is used by the crop. Another great way to keep your nutrients in the "green" is by using a larger reservoir - the extra capacity helps act as a buffer and maintains pH and concentration better than a "just enough to do the job" approach to reservoir capacity. Nutritional requirements vary throughout a plant's life cycle; light intensity, stage of growth (vegetative or flowering) and the general size of plant all play a role in determining its nutritional requirements. By regularly monitoring pH and PPM, you will have the ability to make corrections to your nutrient solution before your crop suffers. There are certain signs to look for when testing the PPM and pH of your nutrient solution. The opposite page outlines them for you. An unusually high pH will decrease the availability of Iron, Manganese, Boron, Copper, Zinc and Phosphorous. A pH that is too low will reduce availability of Potassium, Sulphur, Calcium, Magnesium and Phosphorous. The pH of common solutions are as follows;

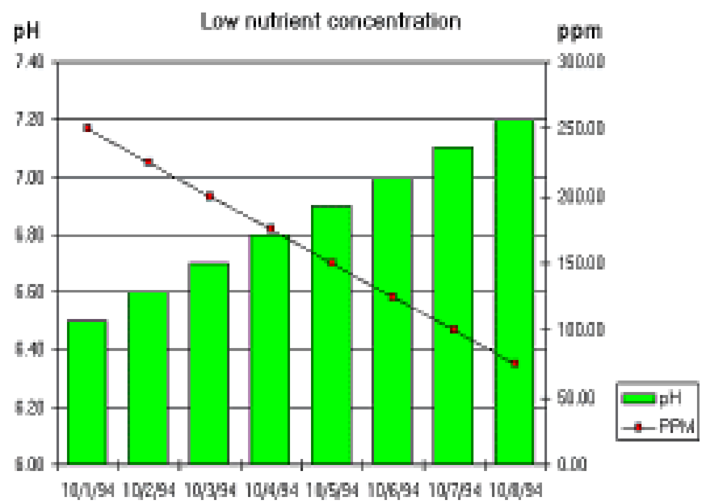
Battery Acid = 1	Vinegar = 2.75
Orange juice = 4.25	Boric Acid = 5
Milk = 6.75	Pure Water = 7.0
Blood = 7.5	Sea Water = 7.75
Borax = 9.25	Ammonia = 11.25
Bleach = 12.5	Lye (caustic soda) = 13.5

Since pH and PPM generally share an inversely proportional relationship, by measuring pH, you can sometimes infer what is happening to the concentration of your nutrient solution. The charts below are over exaggerated for illustration of these principles.



Proper Balance:

In this example a perfect balance exists between plant requirements, solution pH and nutrient concentration. This is exemplified by steady readings in both PPM and pH over time. Naturally the volume of nutrient solution decreases over time, however, that is not indicated here... Your goal is to deliver exactly what the plant requires - no more - no less - temperature and light intensity play a major role in determining this balance.

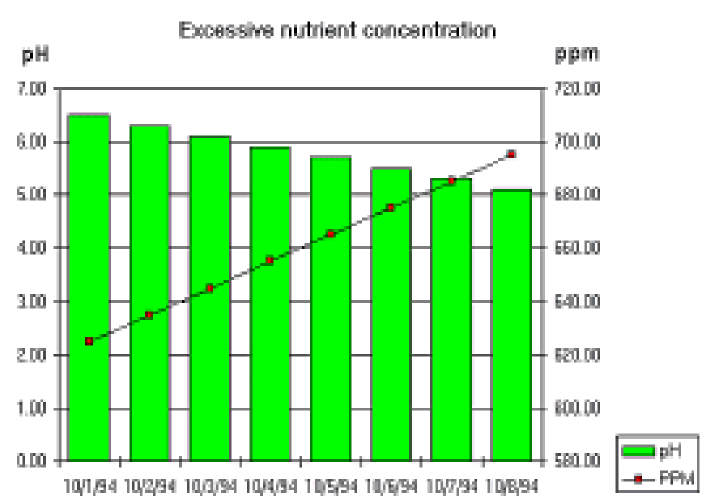


Insufficient Nutrient:

The crop is consuming more nutrient than water, note the PPM decrease. Since most nutrient solutions have a pH buffer which tends to pull down the pH, the decrease in concentration results in the rise of pH.

NOTE:

Many times what you may observe to be a nutrient deficiency i.e.: yellowing older leaves, red petioles and stems, may actually be caused by an excess of nutrient or unhappy pH - be sure to use that pH and PPM test kit and meter!



Excessive Nutrient:

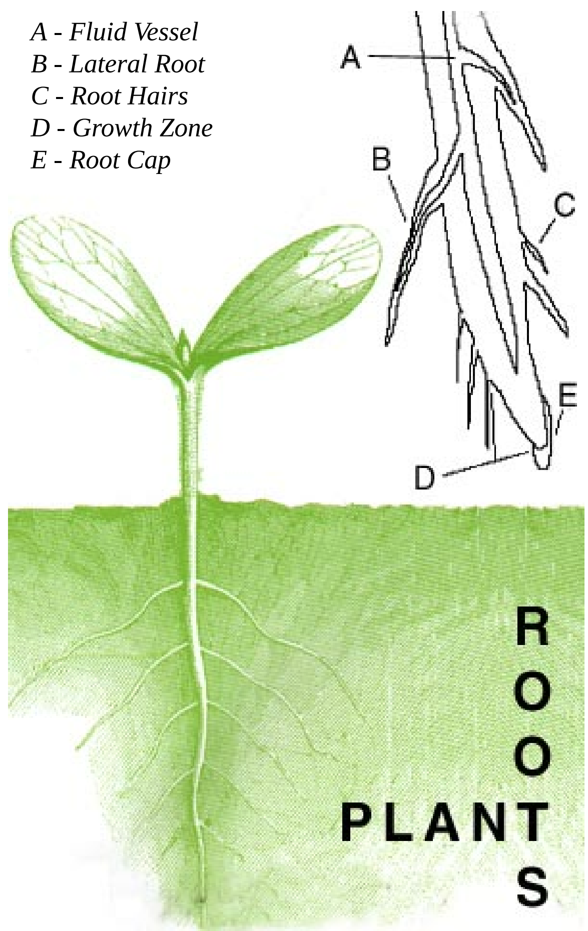
Here the plants leave excess nutrient behind. This imbalance causes PPM to increase, effectively decreasing pH, causing nutrient lockout.   Possible causes are high heat/intense light which will increase the plant's transpiration of water as the plants "sweat".

Diagnosis of these problems is important. Once you get into a routine with a particular crop and growing environment, you will develop a knack for what should and should not be, making this seemingly complex process simple. Keep a log and LEARN!

It's all about the roots!

Root systems vary in size from those of a seedling, perhaps a few inches long, to those of a 300' redwood (pictured at right holding up the author) which can grow larger in size than the visible tree itself! Regardless of physical size, roots serve the plant three essential functions; the uptake of water and nutrients, storage for manufactured materials and providing physical support for the plant above ground. Hydroponics is all about the roots - healthy roots!

The absorption of water and nutrients take place just behind the root tip through tiny root hairs. These root hairs are extremely delicate and usually die off as the root tip grows further into the medium. The method in which the roots absorb water and nutrients is called diffusion. In this process water and oxygen pass into the root structure through membranes in the cell walls. An interesting point is that diffusion actually takes place at the ionic level which in laymen's terms means that nutritional elements are passed by the electrical exchange of charged particles. This is always my first line of defense against those who claim that hydroponics is unnatural and isn't "organic" because plants grown that way aren't fed "organic" nutrients. Foolish to say the least - the bottom line is that roots can ONLY uptake PURE ELEMENTS and a hydroponic system is a much cleaner environment than their compost pile.



Oxygen is absorbed and then utilized for growth, in return the roots give off carbon dioxide. Absence of oxygen in the root zone causes asphyxiation, damaging the roots and adversely affecting the tops of the plant as well. Stagnation of water in the root zone can also cause asphyxiation in addition to root rot. Once a plants roots die, or become dehydrated, death of the organism is usually imminent. Many studies have proven that oxygenation to the root zone is a major factor in determining a plant's growth potential - so much so that the practice of "Aeroponics" has developed to maximize growth one step beyond that conventionally believed to be possible with hydroponics. Plants grown aeroponically have their roots suspended in thin air!

Plants can function normally with their roots exposed to light provided they are always at 100% relative humidity. However, exposure to light will promote the growth of green algae. Algae appears as a green or brown slime on roots, plumbing, and containers. Some studies have suggested that plants suffer when their roots are exposed to light, this is probably due to the resulting algae growth on the surface of the root. Algae will compete for both water and nutrients, as well as oxygen. To be on the safe side, I recommend using opaque containers and avoid using transparent materials for tubing and reservoirs - dark green, blue and black work best at blocking stray light. Plant roots are extremely delicate and should not be handled. You will, at some point, need to transplant seedlings or cuttings to your hydroponic garden - just be gentle and keep roots wet. In the event that roots begin to obstruct proper flow and drainage in your system, you may have no choice but to adjust their position which may cause damage if you're not careful. For optimal nutrient uptake the nutrient solution should be a perfect environment for the developing roots. Three simple indications will reveal if the roots are healthy or not:

1. Visual indications
Healthy roots appear full and white in color. As plants mature, a slight yellowing is normal to a degree.

2. pH measurement
If the pH is off - your roots will not be happy. A pH of between 5.5 and 6.5 is generally the ideal range for most plants. Remember that 7.0 is neutral.

3. PPM measurement
Too much or too little food is no good either. The PPM of your nutrient solution can range from around 800 for a crop like lettuce under low light/low heat to 1600 for tomatoes under intense light and supplemental CO2.

It is of utmost importance to maintain sufficient humidity around the roots at all times, low humidity will cause dehydration and root dieback. However, you do NOT want to leave your roots soaking in STAGNANT water as this will also cause the roots to die from lack of oxygen. Dieback is visible in the form of dry, browned, and sometimes decaying roots. Once roots are dead there is no reviving them. If the damage is serious, your crop stands a slim chance of surviving.

Measuring pH is easy utilizing inexpensive test kits. There are currently two kinds, the first consists of pretreated paper strips (litmus paper) that react to different pH levels by turning color. Simply dip a test strip into the solution and compare the resulting color change on the strip to a corresponding value on the included chart. The second method utilizes a small tube which is filled with solution to which a few drops of indicator chemical are added. The results of this test are indicated the same as the paper strip test, with a corresponding color change. I prefer the later as it is more accurate. Digital pH meters are great to have as they provide instant readings but they must be handled carefully. Since extremely acidic or alkaline solutions are not only bad for your roots but also highly corrosive, care must be taken to avoid these situations. Check pH regularly when first starting out so as to familiarize yourself with the process, your crop and the system. It is important that any water used for refills or new batches of nutrient be pH balanced to +/- 6.0 (depending on crop) before mixing with your concentrated nutrient powders or liquids.

Soilfree hydroponic mediums

In most hydroponic gardens, soilfree mediums are used primarily for starting seeds and when rooting cuttings. The less medium a system requires, the easier and less expensive it is to operate. This is a major consideration for those who wish to make a profit from their hydroponic gardens. Modern day soilfree mediums have come a long way since the use of river gravel and sand. A perfect medium is one that is able to hold a nearly equal concentration of air and water. As you have leaned, your plants need both oxygen and nutrients to reach their roots. The determining factor in water/air holding capacity of a medium are the small spaces between each granule or fiber. The name for these “holes” in the medium is “interstitial spaces”. Fine sand features very small interstitial spaces which cannot hold much air and water. On the other hand, coarse gravel has large interstitial spaces which can hold lots of both. The next factor we must concern ourselves with is that water has weight and always seeks the lowest ground. In the case of coarse gravel, this means that water will run right through leaving behind only a moist trace. If you constantly recirculate your nutrient solution, this medium would be o.k., however, because of this fact coarse gravel really doesn’t make a good medium for systems that do not constantly circulate nutrient solution to the plants.

UltraPeat^{tm} a.k.a. Coco Peat/ Coco Coir:

Our favorite loose growing medium is Coconut Fiber or Cocopeat. It represents a major step forward in organic soilfree potting mediums. It has the water retention of vermiculite and the air retention of perlite, however, it is a completely organic medium made from ground up coconut husks! Why coconut husks? The coconut husk serves its seed two purposes; 1. Protection from the sun and salt while floating around the oceans and 2. A hormone rich, fungus free medium to solicit germination and rooting upon landfall. Ground up and sterilized, cocopeat offers plants the perfect rooting medium and protection against root diseases and fungus infestation. Cocopeat is a completely renewable resource, unlike peat moss which is rapidly becoming depleted from overuse.

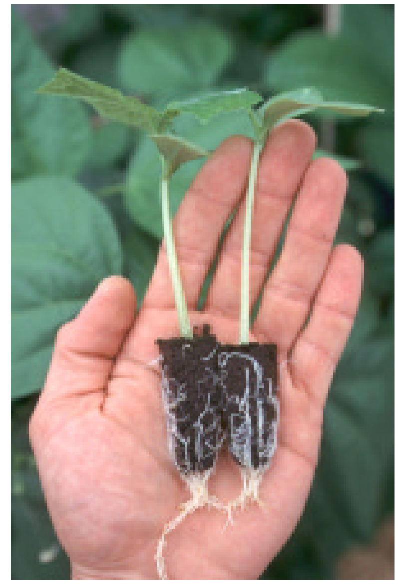
Perlite

Perlite has been around for the longest time of all these soilfree mediums. Made from air-puffed glass pellets, and literally as light as air, Perlite has excellent oxygen retention which is the main reason it is used as a supplement in soil and soilfree mixes. The main drawback of Perlite is that becuse it is so lightweight, it is easily washed away and makes a lousy medium in flood and flush type systems.

Grorox /Hydroton - Expanded Clay Pellets:

A relatively new development in coarse mediums is Geolite/ Grorox/Hydroton, which is made of expanded clay pellets that maintain water by virtue of their porosity and surface area. These mediums are are pH neutral and reusable, making them ideal for hydroponic systems. Do not use Lava rocks as they alter the pH.

Perfect Starts[tm] soil free starting sponges.



The latest breakthrough in hydroponic mediums are these “molded” starter sponges made from organic compost and a flexible, biodegradable binder. Available in many shapes and sizes, they solve the problem growers face when wanting to use an organic medium in a hydroponic system. Namely, they do not fall apart as does rockwool and vermiculite when used to start seeds. The starting sponges exhibit perfect air to water holding capacity and when used in conjunction with their high density foam startingtrays, force roots to grow directly downwards instead of spiraling around as do many other types of starting trays.

GroDan Rockwool

Rockwool is made from molten rock which is spun into long, glass-like fibers. These fibers are available compressed into bricks and cubes or as loose material called flock. Rockwool has a good water to air capacity and is widely used as a starting medium for seeds and a rooting medium for cuttings. Some of the world’s largest hydroponic greenhouses use rockwool slabs to raise all sorts of fully mature plants.

The mixed green seedlings at right were planted in cocopeat in easy to handle flats. When these seedlings harden off, they will be transplated to their new homes in soilfree gardens. The transplantation process for seedlings raised in cocopeat is as simple as shaking or rinsing the loose cocopeat from the plant and inserting them into whatever will support them in their new home.

This hydroponic system is truly soilfree. The Aeroflo series by General Hydroponics can accept seedlings or starts grown in any of the mediums featured in this chapter. You’ll learn how to make these systems yourself in the back of this book.

Let there be light

In nature, plants depend upon the energy of the sun. Through a process called photosynthesis, sunlight is converted to sugars to provide fuel for growth. These sugars are utilized as necessary in a process called respiration, excess sugar can then be stored for later use. Photosynthesis is made possible by chlorophyll which is contained within the leaf cells. It is this chlorophyll which gives vegetation its characteristic green color. Light is trapped by the chlorophyll, activating the process of photosynthesis. Inside the chlorophyll, light energy is combined with carbon dioxide and water to produce oxygen and sugar. The sugar is then oxidized (or metabolized) through the process of respiration, producing carbon dioxide, water, and energy for growth. Excess oxygen and water are transpired by the leaf into the air. Plant growth, therefore, is directly affected by the amount and quality of light it receives.

The quality of light refers to the intensity and spectrum of colors contained within the light, as different colors of light affect the plant in different ways as described above. Different plants require varied lengths of daylight hours, this duration of daylight is called the photoperiod. Photoperiod affects flowering (reproduction), and in many cases must be precise to induce the flowering of certain species. In addition, different plant types require different light intensities, be sure to research the natural environments of the plants you intend to grow in order to reproduce their favored climes as closely as possible.

White light

Is actually a combination of all colors of light. Red + Green + Blue (and all colors in between) = White...

Blue light

Photosynthesis occurs, tips grow toward light (phototropism), hormones trigger growth, dormancy is inhibited. Metal Halide lamps are high in blue light making them good for leafy plants.

Green light

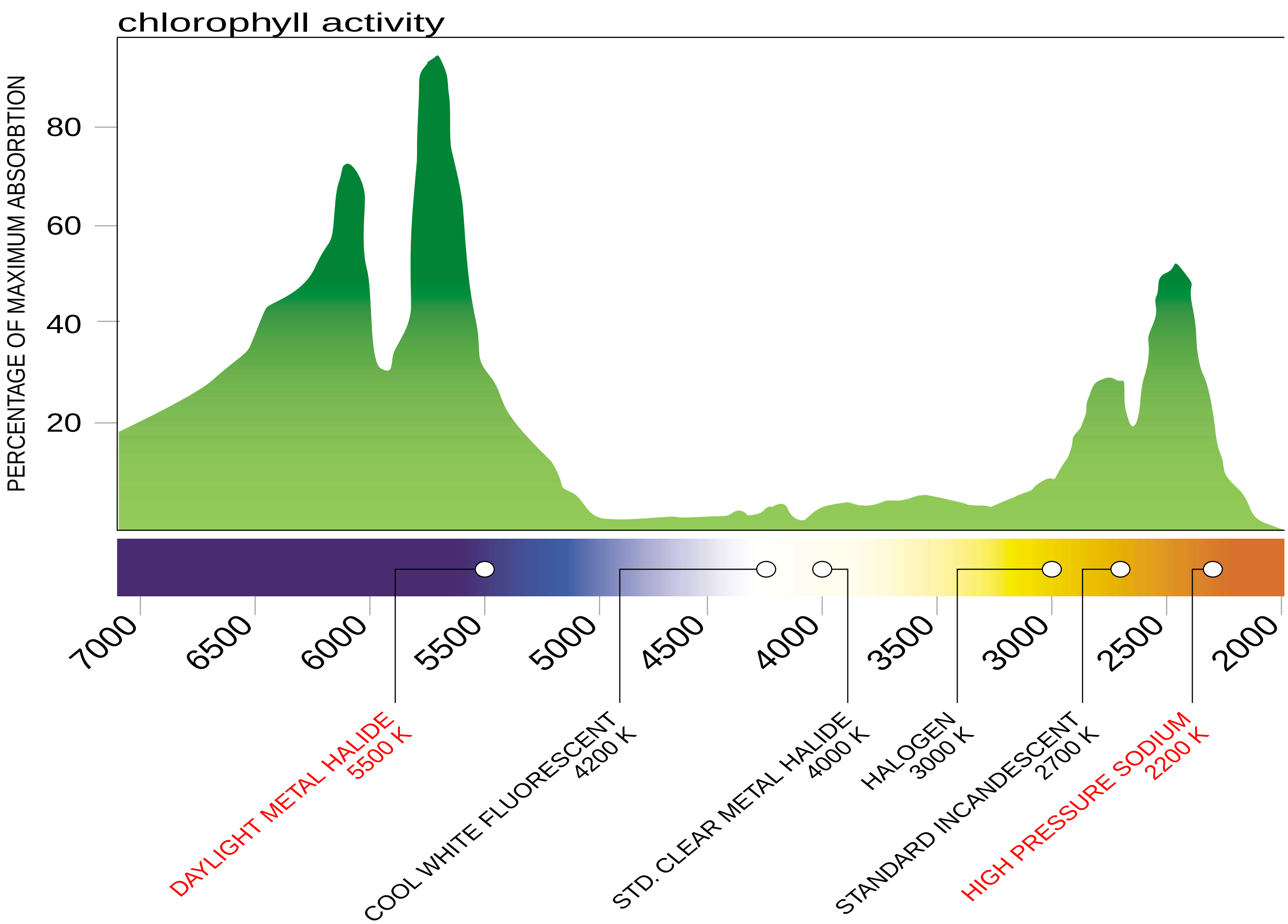
Most of this color light is reflected, that is why plants appear green, however some green light is required for growth.   Most HID lamps do not emit much green light.

Red light

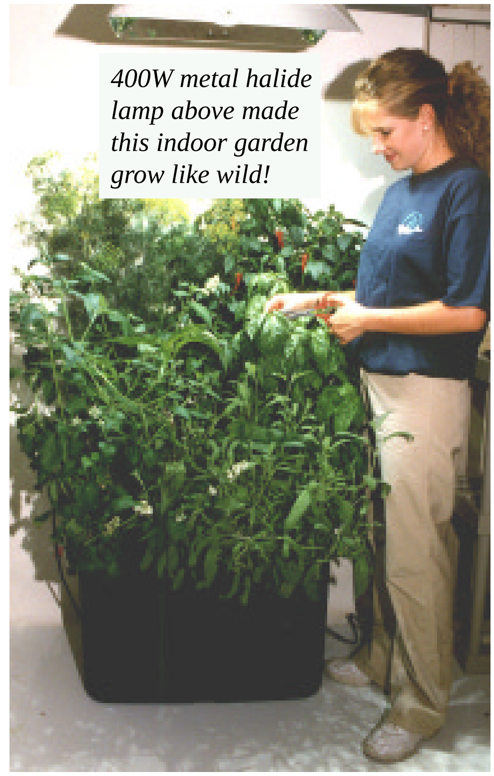
Photosynthesis occurs, seed germination aided, pigments formed, flowering aided, dormancy induced. High Pressure Sodium bulbs emit red light and are generally better for flowering and fruiting plants.

Far-Red light

Speeds up some full sun plants, reverses some red light effects. HID lighting usually doesn't emit far-red except in the case of some High and low pressure sodium bulbs, more so in the form of heat rather than photosynthetic light.



Indoor lighting for horticulture



Nothing beats the Sun when it comes to growing, however, new types of High Intensity Discharge lighting have made growing indoors a viable alternative. Many of you are familiar with fluorescent "grow" lights designed to grow plants indoors. These products are fine for low-light plants where limited results are expected. But what if you want to achieve the ultimate growth potential of your favorite plants indoors or supplement sunlight in your greenhouse? Your answer is to use Horticultural High Intensity Discharge lighting, or HID for short. These lighting systems consist of a lamp, reflector and power supply and are designed to provide the maximum output of photosynthetic light for the amount of power consumed. HID lighting systems can illuminate your garden with the right quality and quantity of light to make for impressive results.

Horticultural HID lighting is used by the world's premier growers to provide many benefits simply unattainable with conventional fluorescent and incandescent lamps. HID lighting allows commercial growers to increase crop yields, bring crops to market on schedule and produce crops when out of season, making them even more valuable to the consumer market. HID lighting is so efficient and powerful that many indoor growers turn a healthy profits even after the initial investment and the monthly electric bills have been paid. Until recently, HID lighting for horticulture has been prohibitively expensive for everyday gardeners due to a limited market and the costs of production. But thanks to the ingenious lighting products by new manufacturers such as Sunlight Supply and Diamond Lights, lighting costs have been reduced to the point where everyone can enjoy their benefits.

In choosing an HID lighting system, blue and red are the two primary colors of light you need to be concerned with for HID lighting. Blue light is most pronounced during the summer months when the sun is highest in the sky. It is responsible for keeping plant growth compact and shapely. Red light, such as when the sun is lower in the sky during the fall harvest months, is responsible for triggering reproduction in plants in the form of flowers and fruits. Metal Halide (MH) lamps emit primarily blue light making them ideal for the vegetative growth stage. High Pressure Sodium (HPS) lamps emit primarily red light which causes exaggerated flowering and fruiting during the plant reproductive stage. Thus, if you plan to grow mostly leafy crops such as lettuce and vegetative herbs, your best bet is an MH lighting system. If you want to grow flowering plants, the Son Agro HPS lamp is your best bet since it adds about 30% more to the blue spectrum than does a standard HPS bulb. As a matter of fact, there are conversion bulbs which allow you to buy one type of system and use both types of lamps. These bulbs cost more but give you the added benefit of being able to start your plants with the MH bulb, ensuring tight, compact growth, and then switching over to the HPS lamp when the plants are ready to flower and fruit for higher yield. Remember, lights emit heat which needs to be vented to keep indoor gardens within 65-80 degrees and 50-75% humidity.

The primary benefit to employing a High Intensity Discharge (HID) horticultural lighting system is the control it gives you over your plants' growing environment. In many areas, once fall arrives the growing season is over, and if you're a hard-core gardener like me, you'll miss it dearly! Horticultural lighting systems allow us all to extend the growing season by providing our favorite plants with an indoor most closely equivalent to sunlight. This is a great advantage for those of us who appreciate having a year-round supply of fresh flowers, veggies and herbs! HID lighting is also great way to jump-start spring by starting your seedlings months ahead of last frost. Another great advantage of indoor horticultural lighting is your ability to control the length of daylight thus empowering you with the ability to force flower your favorite strain even when completely out of season. Vegetative growth photoperiods are 16 to 18 hours/day, more then 18 hrs. is minimally advantageous and not worth the cost in electricity. Flowering photoperiods are usually between 10 and 14 hours per day. Remember, to grow perfect plants, the secret to the right light is Color, Intensity and Duration!

Color (Photosynthetic spectrum)

Photosynthesis is most pronounced in the red (600-680nm) and blue (380-480nm) wavelengths of light. Horticultural lighting, also know as High Intensity Discharge (HID) lighting is designed to cover these specific wavelengths. There are two types of HID lamps which emit different color spectrums. Metal Halide lamps emit a white/blue spectrum. MH lamps are best used as a primary light source (if no or little natural sunlight is available). This type of lamp promotes compact vegetative growth. There are also MH to HPS conversion bulbs available which allow you to provide MH light during vegetative growth and then switch over to the HPS for fruiting/flowering stages of growth. High pressure sodium lamps emit a yellow/orange spectrum. They are the best lamps available for secondary or supplementary lighting (used in conjunction with natural sunlight). This type of light promotes flowering/budding in plants. HPS lamps are ideal for greenhouses and commercial growing applications. The Son Agro HPS lamps add an additional 30% blue factor to their spectrum, making them a better choice than straight HPS lamps for solo use. There are also HPS to MH conversion bulbs available which allow you to provide MH light during vegetative growth and then switch over to the HPS for fruiting/flowering stages of growth.

Intensity

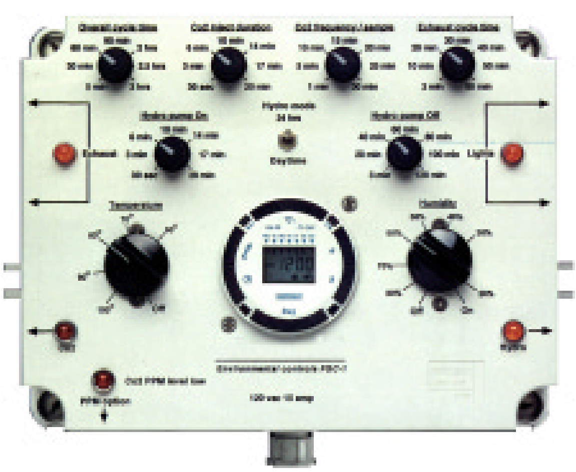
Light intensity is commonly measured in power (watts) per square foot. For optimal photosynthesis to occur a general rule of thumb is 20-40 watts per square foot, with 20 being best for low-light plants and 40 best for light loving plants. Keep 400W HID lamps a minimum of 16" from plants and 1000W lamps 24" from plants. To increase light effectiveness, paint room with flat white paint. You may also want to use reflective mylar sheeting which is 90-95% reflective whereby flat white 75-80% reflective. - Gloss white 70-75% reflectivity
Yellow paint 65-70% reflectivity - Aluminum foil 60-65% reflectivity - Black <10% reflective.

Duration (Photoperiod):

Most plants grow best when exposed to 16-18 hrs of light per day. Additional hours of light during the day have not been found to increase growth by any significant amount. Plants that exhibit photoperiodism, the trait that causes daylength to trigger flowering, should be exposed to 12-14 hours of light once flowering is desired. Total darkness is required during the darkness cycle for flowers and fruit to form correctly. Select a timer to control the duration of HID light. Some popular plants that are frequently grown indoors and exhibit "photoperiodism are Chrysanthemums, Poinsettias, Bromeliads, Pansies, Gibsofilia, Fuschi, Petunia, Gladiolia and Roses. These plants will flower when their photoperiod is 12hrs. of light and 12hrs. of darkness. Using indoor lights and a timer, you can force flower them during market peaks to increase yields and provide on-time delivery to market.

Environmental control and automation

When gardening indoors or in a greenhouse, you will certainly want to take advantage of the benefits a controlled environment can deliver. By maintaining your crops favorite growing conditions, you will realize larger harvests, faster growth and ultimately, better quality produce whether it be tomatoes, flowers or herbs and spices. Assuming that you have either natural sunlight in a greenhouse or HID light available indoors, the remaining considerations are temperature, humidity and air quality. In order to control temperature in a greenhouse, you will need to install circulation fans which will vent hot air outside the greenhouse while drawing in cooler air from close to the ground. This exchange of air is usually controlled with a thermostat connected directly to a vent fan. Indoors, you would perform the same function in a similar manner. Some indoor gardeners prefer to leave a vent fan running continously as the heat build-up under HID lights can happen very rapidly and usually warrants continuous ventilation. A temperature of 65-75 degrees F. is usually accepted as best for most popular crops. Too high a temperature willl force your plants to transpire a disproportionate amount of water to nutrient, resulting in rising nutrient concentrations and possible problems with pH and nutrient lock-out. Too low a temperature will slow growth significantly as many plants will become dormant. There are many commercially available temperature controllers on the market such as the NFT and ART series shown at top right. This adjustable cycle timer allows the user to preset a particular length of time for the switch to provide power and then a particular length of time for the switch to turn off. The “cycle” can be adjusted to operate ventilation fans, CO2 generators and pumps.



Humidity

The next factor you will want to control in your greenhouse or indoor garden. If the humidity is too high, your crop will suffer from rot and mold problems, as well as a tendency to “overheat” due to its inability to transpire moisture into the already saturated atmosphere. Humidistats control humidity in much the same manner as a thermostat controls temperature. A humidistat can be set to operate a ventilation fan once a particular level of moisture in the air is breached. Rarely when growing hydroponically in an enclosed area will you run into problems of too little humidity, however, if this is the case, you will either need to lower the temperature or the intensity of light so as not to dehydrate your crops. A level of 60-70% humidity is generally accepted as best for most crops. Too dry an atmosphere will cause excessive water transpiration and leave a high concentration of nutrients in your reservoir - very similar to what too high an ambient temperature or too strong a light intensity would cause. There are also a number of Thermostat/Humidistats on the market which combine both functions into the control of a single ventilation fan. The fan is programmed to operate when either the preset temperature or humidity levels are exceeded.

Unless you plan to keep a constant watch over your garden’s temperature and humidity, it is a good idea to invest in automating these environmental controls to do the watching over for you. Some people have even gone to such lengths as to connect temperature and humidity sensors to their computers and integrate environmental controls through software programs and custom charting applications. This is pretty high-tech stuff but I’m sure NASA is all over it, as every last ounce counts when you’re on your way to Mars.

Supercharging your garden with CO_2

As your plants "breathe" CO_2 and "exhale" O_2, the balance of these two critical gases begins to shift. In nature, this uneven exchange fits in perfectly as animals "breath" in O_2 and "exhale" CO_2. Of course a perfect world it is not and modern industry and the burning of fossil fuels has somewhat "unbalanced" this effect. However, in your greenhouse or growroom, you will need to help your plants breathe by supplying a constant exchange of fresh air which by nature contains about 2% CO_2. If you have already employed a thermostat and humidistat in combination with a vent fan, there is a good possibility that these two mechanisms will provide a good exchange of fresh air. However, if your fan is not operating frequently enough, you may be starving your plants of their most favorite flavors of gas, CO_2.

Generally speaking, it is best to exchange the entire contents of your growing area about once an hour during daylight hours. To do this efficiently, you can use a fan which either runs continuously at a slow speed, or a fan that runs at high speed in short bursts. To determine the size of the fan that is necessary, simply multiply the length of your growing area by its height and then by its width. This number (use feet as a measurement unit) will be the Cubic Feet of your area. When buying a fan, you will notice that they are sold according to "Cubic Feet per Minute" or CFM ratings. What this means is that the particular fan will move the particular amount of air in one minute. So - if your greenhouse is 10ft x 10ft x 8ft. That's 800 CuFt. - you would need an 800CFM fan to exchange the air in the entire greenhouse in one minute. That's a big fan and you certainly don't need to move it all out in just a minute's time. I would suggest using a 100 CFM fan and running it for 4 minutes every half hour. You can do this easily with a programmable cycle timer like the one we discussed on the previous page.

CO_2 and you

CO_2 is known as the "greenhouse gas" which traps the sun's heat in Earth's atmosphere. It is responsible for global warming and a host of environmental changes that include altered weather patterns and rising tides. CO_2 causes these problems by insulating the Earth from heat loss and reflecting some of the suns heating rays back onto the earth. Many of you already know that plants require CO_2 to manufacture food within their leaves. Many of you have also heard that adding CO_2 to the growing environement can significantly increase the growth rates of most plants. This is 100% true. However, managing CO_2 is tricky because of the factors preceeding this topic. For example, if you are constantly exhuasting the air from your greenhouse or growroom, how would you supply a never ending supply of CO_2??? - You could perhaps add a CO_2 cylinder with a regulator as shown below. The regulator can be set to slowly "leak" CO_2 into the air flow of a reciprocating fan in order to evenly distribute it across the growing environment. You could hook the regulator up to an electrical valve called a "solenoid" which is then controlled by either a timer - to go on when the exhaust fans are off, or to release every X minutes for X minutes (another use for the cycle timer). You could hook the solenoid valve up to a CO_2 measurement and

delivery system that would deliver CO_2 once the levels dropped below those you set as minimum. There are many crafty ways to add CO_2 to your garden, the trick is to make it cost effective and safe. CO_2 is not a gas you want to be inhaling in high concentrations. Your garden will only benefit from so much before you wind up choking it up with too much. For these reasons I suggest using either a metering system or a mathematical formula to detemine exactly how much to add and at what intervals.

CO_2 is measured much the same way as nutrient in solution - PPM (Parts Per Million). Most gardens and crops will benenfit significantly when the concentration of available CO_2 is kept between 1000 and 1600 PPM. You will need a CO_2 test kit or meter to accurately monitor this value, however, you can use the charts that come with CO_2 injection systems to determine exactly how to achieve these levels using their equipment. Without using an integrated measurement/injection system, you will basically need to determine the size of your room in cubic feet, using this volume, the manufacturer will specify something along the lines of "set the regulator to "X" PSI and open the valve for "X" minutes every "X" minutes between exhaust cycles. Since every CO_2 system is inherently different, you will have to rely on the manufacturers recommendations to insure accuracy and proper delivery of this growth boosting gas to your growing area. CO_2 can also be generated by using propane and natural gas burners as these gases when burned result in the dsischarge of CO_2 and water vapor. Of course keeping an open flame in any unsupervised area is dangerous so these CO_2 generation systems are designed for safety and must be operated with extreme caution. The advantages to using a natural gas CO_2 generator are that they are generally cheaper to operate and can double as heaters for colder area applications. Indoors, the heat generated by these units is usually a problem that neutralizes their effectiveness since to exhaust the aditional heat you will also wind up exhausting the additional CO_2. If you are a beginner I strongly advise leaving CO_2 for once you gain experience and have your garden completely under control. There are a number of excellent books on CO_2 - pick one up!

One of my readers wrote in explaining a simple way to create and distribute CO2 indoors using just a few inexpensive parts.

You'll need a 1 gallon milk jug, a pound of sugar, enough water to dissolve all the sugar, a packet of yeast, and some tubing. Begin by drilling a small tight hole in the cap of your 1 gallon jug, pass a length of 1/4" air tubing through it just enough so that it hangs inside the bottle. The other end should be placed near your plants, preferably behind a fan that will evenly distribute the CO2 throughout your garden.

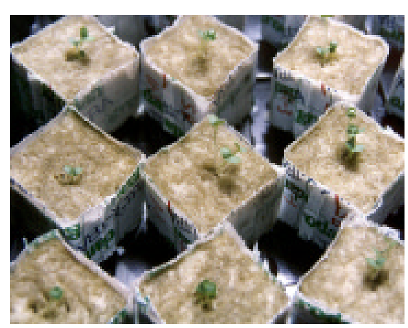
Fill your container with 1 lb. of sugar, add warm water and stir until completely dissolved. Add 1 packet of yeast, replace cap and stir. CO2 will be released gradually as the Yeast begins to digest the sugar.

Getting started with seeds

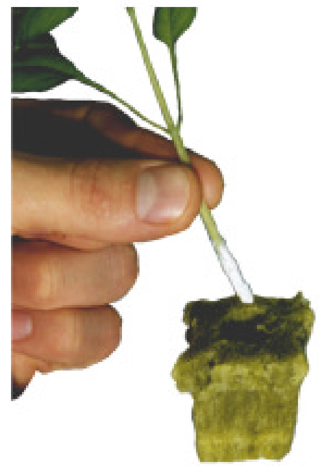
Most plants primary means for reproduction is the seed. The seed is formed inside the female flower after pollination by the male plant. All seeds begin as an egg within the carpel of a female flower. After male pollen is introduced to the female flower by wind or insect, the egg becomes an embryo and forms a hard coating around itself. When development finally stops, the seed is released and carried by wind, rain, bird or bug to its final resting place and if all conditions are right, it will become a new plant and repeat the process. If you plan to grow indoors, you will need to “play bee” and manually pollinate your flowers for them to bear fruit or seed. With peppers and tomatoes I simply “tickle” the open flowers with a soft artists brush to spread the pollen.

To start your seeds and/or cuttings, we recommend using a 10” x 10” or 10” x 20” flat with insert trays to seperate each plant. Keep the humidity high by using a 6” Clear Dome Cover - (not shown). A little ingenuity, some tupperware and clear plastic wrap will work too. You’ll also need to select a starting medium and a growing medium. The starting medium is what you will plant your seeds or cuttings in until they grow large enough to transplant into the system. The growing medium is what you will transplant them into. The systems in this book all use GroRox as a growing medium and only the hydroponic planter design uses a significant quantity. We have had excellent results with both 1” rockwool cubes and loose cocofiber as a starting medium, vermiculite and pearlite work very well too. Just recently, a new starting medium was introduced that is being called soil free sponges (I’m sure a neato trade name will be soon to follow!) - we’ve been testing them here for FutureGarden.com and have found them to be a real winner. The sponges are made from organic compost that is molded into small squares and cone shapes using a biodegradable binder. The advantage to using these sponges are that they allow the hydroponic grower to utilize an organic medium for starting seeds and rooting cuttings without the risk of it breaking apart and falling into the reservoir like cocopeat and perlite will do. See the chapeter on hydroponic mediums for more info. Avoid using soil as it is not sterile and may contain diseases and/or pests that will infect your system. Water your medium with a 1/2 strength nutrient solution (see instructions that come with your choice of nutrient) and keep it moist but not soaked while your seeds or cuttings root. If you are using cocopeat, it comes in dehydrated bricks that will have to be soaked for a while in the 1/2 strength nutrient solution for them to re-hydrate and loosen up. One brick usually makes about two gallons of loose cocopeat, so you may not want to use the entire brick at once. Through my experience, I have developed a simple and very successful method of germination. First, mix up a batch of 1/2 strength nutrient solution with a pH of 6.5 and soak the rockwool cubes, or water your loose medium until thoroughly moistened. This provides the seedling with a little extra food for once it germinates - until it is transplanted into your system.

Next, lay the seeded cubes into a 10"x20" flat with a clear dome cover. A 20 watt overhead fluorescent bulb will provide sufficient light - be sure to maintain 68-78 degrees. After germination, wait about a week or two until roots appear at the bottom of the cubes or loose medium and the first set of true leaves are open before transplanting to the baskets which will fit into your system.



Making clones of your favorite plant



A second method of starting and restocking your garden is cloning. In this procedure, a small growing tip is taken from a mature healthy plant and made to grow its own roots. This method is independent of the plants reproductive system and thus eliminates the possibility that future generations will continue to evolve, as cloning results in plants which are exactly alike in all aspects. Cloning is very popular with indoor growers - *and sheep :*>) - that wish to preserve the characteristics of a particularly favorite strain. In order for cuttings to root properly, the following must be observed:

1. Root zone temperature 72-76 degrees.
2. Air temperature 70-78 degrees and 90-100% humidity.
3. Indirect, low intensity light (20 watt florescent).
4. Root feeding with dilute solution. Rooting hormone may be used as it will help your cuttings significantly.
5. Foliar feeding with dilute 20% strength nutrient spray.

Procedure:

1. Select a healthy growing tip from a plant you wish to clone. The tip should be approximately 3-6" long and include no more than three sets of leaves including the tip. Using a sterile razor, sever the tip and immediately place into a room temperature bath of dilute nutrient solution or prepared cloning solution such as Olivia’s. Saturate a rockwool cube, some cocofiber/vermiculite or one of the new soil free sponges with the cloning solution or 1/2 strength nutrient if you are using a cloning gel or powder (powder shown at right).

2. Make a fresh cut at a 45 degree angle just above the last cut (end) - keeping the cutting immersed in solution. This will assure that no air bubbles form in the stem which would impede the uptake of nutrient solution. Insert the cut end into the cloning gel or powder and quickly but gently insert the cutting about 1/2 to 3/4" into the moistened medium. The cutting is now ready to be enclosed in a flat with humidity dome under a soft light source. See bottom of previous page.

3. Maintain a bottom temperature of 72-76 degrees Fahrenheit, humidity of 95-100% and soft lighting (20 watt fluorescent) until roots develop in 7-14 days.

When your seedlings or cuttings are ready to be transplanted, you will need to use a large diameter (8-16mm) gravel-like medium to support them in their respective growing cups. We recommend using the expanded clay pellets (GroRox) as they are reusable and do not alter the pH of your nutrient solution. You can substitute clean gravel or lava rock for this purpose.

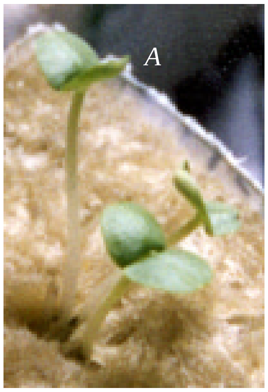
Stocking your hydroponic garden

Once your seedlings or clones have established a root system and hardened off, they can be transplanted into your system. If you used rockwool as a starting medium, this process involves nothing more than placing them into your system and turning it on. If you used a loose starting medium like perlite or cocopeat, you will need to gently remove the medium from the young roots by either rinsing or soaking them in a pail of warm water OR use a porous open-weave mesh to keep the cocopeat from falling into your system and clogging it. I have experimented with aquarium filter cloth - just a very fine layer between the cocopeat plug and the mesh baskets seems to work best. To transplant into the hydroponic planter described later in this book, dig out a small hole in the GroRox, place then into the system and gently backfill around the roots. To place your plants into grow cups for any of the other systems in this book, you would follow the same procedure except you would be backfilling around the roots as they sit inside the cups. Try to get the roots as close to the bottom of the baskets as possible. See photo.

When you first place the plants into your system, give them a week of lower than normal lighting so that they can recover from the move and re-establish their vigorous growth. Keep a watch-ful eye on your new plants - sometimes they may look a little wilted - this is normal transplant shock which can be avoided by lowering the light and maintaining the roots in your starting medium by employing the fabric method as described above. It is also a good idea to water your plants from above with the nutrient solution for a few days. This will ensure that their roots are kept moist while they are adjusting to their new home. The picture at left shows some salad greens and basil seedlings after they were transplanted to grow cups in preparation for placement in my pvc system. I usually keep them in the cups for about three days under soft fluorescent light and top water them before placing them into the system and under HID lights. If you are growing indoors under an HID light or if you are growing outdoors in the good 'ole sunshine, it is a good idea to condition your seedlings/rooted cuttings by placing them near a sunny window but out of direct light or by lifting your grow lamp to about twice its normal distance from the plants - two to four days with reduced light and they should be fine to gradually start increasing their exposure. Once their roots find your nutrient solution, watch out! They will grow like crazy!

(Basil seedling started in a Perfect Starts™ plug)

Stages of growth



A plant's life cycle begins with germination, recognized by the above-ground appearance of a growing shoot. Mated to this shoot are two small, round leaves known as cotyledons (A). Once these leaves begin manufacturing food, the plant begins to grow and enters the seedling stage. During this time the plant develops it first set of true leaves, resembling those of a mature plant. The primary formation of a root system begins. The root development that takes place at this time is key to the rate at which the plant will continue to grow. Providing the proper environment for the roots will ensure that your crop will have a chance to flourish.

Basil sprouts two days after germination.

Once the root system can support further growth, the vegetative stage begins. Nutritional requirements at this time call for large amounts of nitrogen, required for the production of chlorophyll, as growth during this period is primarily stem, branch and leaf. The most substantial growth over the lifecycle of the plant occurs in the vegetative stage and will continue unless interrupted by a change in environment or lack of water/nutrients.

The final stage of the organisms lifecycle is the reproductive stage. Because the objective is now to reproduce, and thus carry on evolution, energies are directed to the manufacture of flowers, seeds, and fruit. The primary nutritional requirements begin to shift at this time from a high-N diet to a low N, high P-K diet. This is due to a considerable slow down in vegetative growth while reproduction takes place. This change prompts a switch in nutrient solutions from a vegetative formula to a flowering, or 'bloom' formula. Many hydroponic nutrients now come as a two part system for exactly this reason. In some plants, reproduction is triggered by a change in the length of daylight, this characteristic is called photoperiodism. It is this characteristic which governs when these plants may be sown and harvested if growing outdoors. Indoors, be sure to provide the proper photoperiod for your crop or they may never fully develop. Changing the length of artificial daylight can trick the plant into flowering early. Commercial growers use this trick to deliver flowers to markets out of season and at a premium to vendors and customers alike.

If you are growing indoors, for lack of natural insects, you must play "bee" by pollinating the flowers on your plants manually. For tomatoes and peppers a delicate touch with a brush on each flower will help the plant pollinate itself to produce fruit. There are commercially available plant "shakers" that vibrate the flowering plants every so often to accomplish the same. I have found that the breeze from a strong circulating fan is usually sufficient to cause pollination indoors.

Growers guide to popular plants

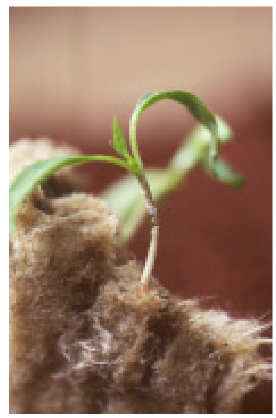
The following table outlines the favorite conditions for these plants to thrive in your hydroponic garden. Adhere closely to these parameters and you will be happily surprised by the results. Always use a high quality hydroponic nutrient and maintain a healthy growing area by allowing plenty of light, air and moisture to reach your plants. Seed packets will contain more information on the particular strain you wish to grow.

Plant name	**Lighting conditions**	**HID Lamp type**	**Favorable temp.**	**pH**	**PPM/TDS**
African Violet	*Bright but filtered*	*250/400/1000W HPS*	*warm*	*6.0-7.0*	*840-1050*
Basil	*high light.*	*250/400/1000W MH*	*warm*	*5.5-6.5*	*700-1120*
Beans	*high light.*	*400/1000W*	*warm*	*6*	*1400-2800*
Broccoli	*medium to high light.*	*400W*	*cool*	*6.0-6.8*	*1900-2450*
Chilies - Capsicum	*high light.*	*400/1000W MH*	*warm to hot*	*6*	*1260-1540*
Cucumber	*medium light.*	*1000W*	*hot*	*5.5-6.0*	*1100-1750*
Eggplant	*high light.*	*1000W*	*hot*	*6*	*1200-2450*
Endive - Chicory - Radicchio	*medium light.*	*400/1000W*	*cool*	*5.5*	*1100-1680*
Lettuce	*medium light.*	*250/400/1000W MH*	*cool*	*6.0-7.0*	*560-840*
Marjoram	*high light.*	*400/1000W*	*warm*	*6.9*	*1120-1400*
Melon	*high light.*	*400/1000W*	*hot*	*5.5-6.0*	*1400-1750*
Mint	*medium to high light.*	*250/400/1000W MH*	*warm*	*5.5-6.5*	*1400-1680*
Okra	*medium light.*	*400/1000W*	*warm*	*6.5*	*1400-1680*
Orchid - Cattleya	*bright (2000-3000 Fc) light.*	*400/1000W MH*	*Day 90 - Night 55F*	*7.0-7.5*	*300-500*
Orchid - Cymbidium	*bright shady light.*	*400/1000W MH*	*Day 80 - Night 60F*	*5.5-6.0*	*300-500*
Orchid - Denrobium	*1800-2500Fc of light.*	*400/1000W MH*	*Day 90 - Night 55F*	*7.0-7.5*	*300-500*
Orchid - Oncidium	*2000-6000Fc of light.*	*400/1000W MH*	*Day 85 - Night 60F*	*7.0-7.5*	*300-500*
Orchid - Paphiopedilum	*bright shady light.*	*400/1000W MH*	*Day 75 - Night 55F*	*7.0-7.5*	*300-500*
Orchid - Paphiopedilum	*bright shady light.*	*400/1000W MH*	*Day 75 - Night 65F*	*7.0-7.5*	*300-500*
Orchid - Phalaenopsis	*bright shady light.*	*400/1000W MH*	*Day 85 - Night 65F*	*7.0-7.5*	*300-500*
Oregano	*high light.*	*250/400/1000W MH*	*warm*	*6.0-7.0*	*1120-1400*
Parsley	*high light.*	*250/400/1000W MH*	*warm*	*5.5-7.0*	*560-1260*
Pea (Snow, Snap)	*medium light.*	*400/1000W*	*cool*	*6.0-7.0*	*980-1260*
Peppers - Chillies	*bright shady light.*	*400/1000W MH*	*warm to hot*	*5.5-6.0*	*300-500*
Rosemary	*high light.*	*400/1000W*	*warm*	*5.5-6.0*	*700-1120*
Roses	*1000-3000fC*	*400/1000W HPS*	*warm*	*5.5-6.0*	*1050-1750*
Sage	*high light.*	*250/400/1000W MH*	*warm to hot*	*5.5-6.5*	*700-1120*
Scallion - Green Onions	*medium to high light.*	*250/400/1000W MH*	*warm to hot*	*6.0-7.0*	*980-1260*
Spinach	*medium light.*	*400/1000W*	*cool to warm*	*6.0-7.0*	*1260-1610*
Squash - Pumpkins	*high light.*	*400/1000W*	*hot*	*5.5-7.5*	*1260-1680*
Strawberry	*high light.*	*400/1000W HPS*	*warm*	*6*	*1260-1540*
Sweet Corn	*high light.*	*400/1000W*	*hot*	*6*	*840-1680*
Swiss Chard	*medium to high light.*	*400/1000W*	*warm to hot*	*6.0-7.0*	*1260-1610*
Thyme	*high light.*	*400/1000W*	*warm*	*5.5-7.0*	*560-1120*
Tomato	*high light.*	*400/1000W HPS*	*hot*	*5.5-6.5*	*1400-3500*
Watermelon	*high light.*	*400/1000W*	*hot*	*5.8*	*1260-1680*
Zucchini - Summer Squash	*high light.*	*400/1000W*	*warm to hot*	*6*	*1260-1680*

Problems with your plants?

Just as your garden faces infiltration by bugs, so it does from disease. However, the wonderful thing about soilfree garedening is that there is no soil to harbor disease. Instead, you have only to contend with the nutrient solution. To avoid the growth of algae and disease causing organisms that may propagate within your nutrient tank, there are a few precautions you can take to avoid this scenario. First off, keep you nutrient temperature below 80 degrees F. Better yet would be to keep it from 68-72 degrees F., but in many cases this is difficult due to extreme ambient temperatures and strong sunlight heating up your reservoir. You can insulate your reservoir by keeping it out oif direct sunlight and covering it with reflective insulation such as Celotex board or foil-backed fiberglass. In extreme conditions, burying the lower part of the reservoir, or even the entire reservoir can keep it perfectly in check as the temperature of the earth remains much cooler and more constant. There is also the option of burying a coil of polyethylene tubing through which you pass your nutrient solution kind of like a chilling coil. Experimentation and discussion with growers in your area will yield many solutions. Keep your nutrient solution aerated and Oxygen rich by plumbing your system so that there is plenty of spray and/or bubbling water being generated by your pump. The nutrient returns should create a good splashing action inside your reservoir to maintain aeration and avoid nutrient stagnation.

Algae is only a problem when your nutrient is exposed to light. Be sure to use only opaque materials and tubing to construct your hydroponic garden. It is always a good idea to completely flush your system between crops with a 10% solution of hot water and bleach. Make sure you rinse it well after doing so. The best prevention against all plant problems as caused by external organisms is to keep your growing area sanitary. Remove any dead leaves, dust and dirt to avoid giving critters a place to grow and food to eat. Rarely will bugs attack a perfectly healthy plant as nature has devised for each its own line of natural defenses. Overwatering seedlings and cuttings will cause damping off - this is basically the growth of a fungus which attacks the plant tissue and eventually destroys the plant. See picture.



Biological control of bugs

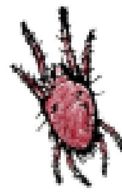
Yuck - I hate bugs - especially when they infest my indoor garden. I never had a problem with Whiteflies until I brought a pepper plant from outside into my indoor garden. What a mistake that was! I broke every rule of indoor gardening when I did that - I guess sometimes you ignore the warnings cause you assume “it won’t happen to me” - I even inspected the plant outdoors and found it to be “apparently” free from critters. well I think you’ve already guessed the lesson here - KEEP YOUR INDOOR GARDEN FREE FROM OUTDOOR INVADERS!

Outside, the bugs most likely to infest your plants are controlled by natural predators. Inside, you have no such luck and without any natural enemies Whiteflies and spider mites can really get out of control quickly. The leaf at right is infested with Whitefly larvae - which will molt and become annoying little pests inside of seven days. Once the Whitefly larvae molts and gains wings, it will spread the infestation by laying eggs within just days and start the process all over again. The eggs only lie dormant for about ten days before hatching.

To take care of infestations, you need to be aware of the biological control options. I do not advocate the use of pesticides, even pyrethrin, which is made from flower extract, since they are number one toxic and number two - well - let's just say that pests actually build up a tolerance to them which only helps to breed stronger strains of pests. Biological control of pests means simply that we are limiting the negative impact of the pest population by introducing predator insects. It may sound like adding fire to the fire to introduce another insect to your garden but the predator insect population is controlled by the amount of food available, in this case say Whiteflies. So as the predator insects eat up the enemy, their population naturally decreases as the food goes with them. A perfect solution if you as me - nature at its finest!

There are a number of non-toxic methods you can employ to help limit pests both indoors and out, the best is to use yellow sticky traps which attract flies and keep them sticking around for a little longer than they'd of liked. You can make these with some yellow paint, cardboard strips and a jar of vaseline. Paint the strips, let 'em dry and then gob on the vaseline which will stick 'em just as well as glue.

Problem pest	**Predator solution**	**Qty/sq. ft.**
Whitefly	Encarsia formosa	Use 1-2
Two spotted spider mite	Phytoseiulus persimilis	Use 1-2
Aphids (pink, black & green)	Lady bugs, Lacewings	Use 1-2



spider mite

Nutritional problems:

Nutritional problems can be diagnosed and corrected by using the following chart. If you determine there is a problem with your nutrient, it is best to flush your system and begin with a fresh batch of corrected formulation.

Nutrient	**Deficiency of nutrient results in:**	**Excess nutrient results in**
Nitrogen	Plants are slow growing, weak and stunted Leaves are yellowing - older leaves first and maturity is reached early with low yield.	Plants are dark green, soft and succulent Fruit and seed crops may not produce.
Phosphorous	Slow growing, stunted and dark green. Older leaves may turn purple and show signs first.	Results in Iron and zinc deficiency.
Potassium	Older leaf margins appear burned out.	Results in Magnesium deficiency.
Calcium	Tips of shoots and roots die off.	Results in Mg and/or K deficiency symptoms.
Magnesium	Older leaves turn yellow between viens.	N/A
Molybdenum	Similar to Nitrogen deficiency.	Hard to spot.
Sulfur	Young leaves yellow, stems become woody.	Premature leaf death.
Iron	Yellowing between viens (interveinal chlorosis)	N/A
Manganese	Stunted growth, interveinal chlorosis of young leaves.	Older leaves exhibit small brown spots with yellow rings around them.
Boron	Leaves and stems grow brittle and stunt growth.	Leaves die from tips inward.
Zinc	Interveinal chlorosis - young leaves, growth stunted.	N/A
Copper	Stunted growth, distorted young leaves. Shoots die.	Causes Iron deficiency.

Integrated Pest Management Web Sites

Web Sites - Biological Control and Integrated Pest Management

An electronic database on suppliers of beneficial organisms in North America with additional information on biological control and integrated pest management is also available. Both can be accessed through the Department of Pesticide Regulation's Home Page at **http://www.cdpr.ca.gov**

The following is a brief listing of university and government **Web sites** on biological control and integrated pest management:

APHIS National Biological Control Institute (NBCI) - USDA Animal and Plant Health Service
http://www.aphis.usda.gov/nbci/nbci.html

APHIS Plant Protection Centers - USDA Animal and Plant Health Service
http://www.aphis.usda.gov/PPQ/bco/

Auburn's Biological Control Institute (BCI) - Auburn University
http://www.ag.auburn.edu/bci/bci.html

Cornell's Biological Control Home Page - Cornell University
http://www.nysaes.cornell.edu:80/ent/biocontrol/index.html

Florida Agricultural Information Retrieval System - University of Florida
http://hammock.ifas.ufl.edu/

Florida's National IPM Network - University of Florida
http://hammock.ifas.ufl.edu/tmp/en.html

NEB Guide - Biological Control of Insect and Mite Pests - University of Nebraska Cooperative Ext.
http://ianrwww.unl.edu/ianr/pubs/extnpubs/insects/g1251.HTM#SOURCES

North Carolina's National IPM Network (North Carolina State University)
http://ipmwww.ncsu.edu/

North Carolina State BioControl Contents - North Carolina State University
http://ipmwww.ncsu.edu/biocontrol/biocontrol.html

Purdue's Biological Control Laboratory - University of Purdue Cooperative Extension
http://www.entm.purdue.edu/entomology/bclab/biocontrol.html

University of California IPM Home Page - University of California at Davis
http://www.ipm.ucdavis.edu/

Making a market for your garden

Many gourmet restaurants and markets will purchase high quality hydroponic produce, provided it is available in good supply and on a regular basis. If you are interested in making a profit from your garden, you should first investigate the local marketplace and determine just what it is that you should grow. Don't try to compete with everyone else, identify a unique opportunity for a high profit plant by interviewing the owners and operators of these establishments. I have found that growing culinary herbs is the best way to make extra income from your garden. Of course there's always the tomato and pepper plants which are a staple food for most, but both require much more space and considerably more time to harvest. Growing fresh cut flowers can also be very profitable, however, it is a harder market to penetrate and flowers take longer to grow than herbs. The reason herbs make such a great product to produce and market is simple; the most popular culinary herbs are all leafy plants that will grow like wild in your hydroponic garden. before getting started, you should contact your local county clerk's office to determine what legal requirements you'll need to meet to start your own business. So let's take a look at how we can get started in making a market for your garden.

Investigate your local market

The most important thing you can do before planting any herbs to sell is to visit your local markets and determine what they sell and where the opportunity exists. Take a look at the fresh herb fridge and see what they have and how fresh it is. Nine times out of ten you will be amazed at how ragged their "fresh" herbs really are! Have a look at the prices and jot them down. Also, take notes of the quantities being sold in each package. Usually fresh herbs are sold by the "bunch" which in most cases is about as much as you could grab in your hand. Study the packaging and labels as you will need to create a unique identity for your own. Visit as many small markets as you can in your immediate area. Compile your information and organize it so you can determine what is selling and for how much. Below is a list of what I have determined to be the best selling herbs in order of importance. Assign a retail price to each from the research you have conducted.

Most popular culinary herbs in order of marketability:

Basil: Ocimum basilicum
Dill: Anethum graveolens
French Tarragon: Artemesia dracunculus
Mint: Mentha
Oregano: Origanum
Sweet Marjoram: Marjorana hortensis
French Sorrel: Rumex scutatus
Rosemary: Rosemary officinalis
Chive: Allium schoenoprasum
Parsley: Petroselinum crispum
Thyme: Thymus
Sage: Salvia officinalis

Product quality considerations

Quality is by far the most important consideration that will determine your success. If you are growing hydroponically, you are already ahead of the game. However, you will certainly want to perfect your method before considering commercial success. If you are totally new to hydroponics and gardening, take a few months getting your green thumb cause once you go commercial, you will be counted upon to deliver quality produce on time.

Another important factor in your success is product packaging. Assuming you have perfected your crop and production techniques, you should concentrate a good amount of energy on packaging. You will certainly want to use a visually appealing package for your herbs. Many commercial herbs are packaged in screen printed plastic bags with colorful logos. Since you are just starting out, and certainly shouldn't go throught that added expense, you should try using a clear zip lock type of plastic bag to which you can apply a simple self-adhesive label. It is a good idea to use a hole punch to make a couple of "breathing" holes in your bags to maintain product freshness. Give your herbs just a slight misting with some water before sealing the bags. Use a small kitchen scale to weigh your herbs to ensure uniformity from package to package.

Many patrons of gourmet markets will identify with a wholesome looking label that is indicative of the local origin of the produce. An excellent method of building and growing your herb business is to invest some time and money in creating a visually appealing label and "brand" name for your produce. By creating your own brand of fresh herbs, people will recognize your products and have a handy "name" to refer to when telling their friends how fresh and wonderful your produce is. Creating your own brand will also allow you to enter into larger markets because your following will already be familiar with the quality of your product and attribute it to your "brand". This is exactly how the Mega-brands are created and although you might not be thinking in terms of nationwide branding and becoming a "Mega" sized operation, it is nice to know that your hard work is building your reputation and at the same time positioning yourself for future growth.

Once you have some sample product available, even if it is only from your first round of crops, package a few bunches, apply your labels and hit the streets. It's a great idea to bring a cooler along with you, packed with ice and with your samples inside. This way when you introduce your local merchant to your product it will be fresh and appealing. This is especially important if you live in a very hot area and you plan to spend the whole day on the road visiting merchants. It is also a good idea to print yourself up some simple business cards that match the labelling on your product. Take advantage of the software available today that helps you design materials for starting a small business. There are literally hundreds of titles on the shelf that include templates and royalty free artwork you can use to get started. Remember, position yourself as a wholesome grower that only uses the finest nutrients, purest water and NO insecticides, fungicides or herbicides in the production of your herbs. This alone will sway people to trying your herbs over the ones that are field grown and contain who knows what.

dill, oregano and sage grown in our aerospring aeroponic system.

Approaching your prospective customers

Now that you have a great product, nice package and an idea of what is important, here is what to do and say. Start off with the smallest store you can find, the smaller the better since the chances that the person you encounter will be an owner or someone who is in charge is much higher and if they express a sincere interest, you can realistically supply a smaller operation alot easier than a large market. Start small but always think big. You will want to speak to the owner or buyer so identify who they are and approach them by simply introducing yourself with your name and telling them that you would like just a moment of their time to discuss your gourmet produce. You will certainly have a sample with you (freshly chilled from your cooler!) so have it in hand and get it into his/hers as soon as you introduce yourself. by putting the product directly in front of the customer, you can let your product do most of the talking, especially if you are a little nervous at first. Explain how your herbs are grown in a soilfree environment that completely devoid of chemical pesticides, herbacides and fungicides. Your crop is so healthy because it is fed the finest hydroponic nutrients and purest water. Explain how since you are (most likely) “just down the road”, you can deliver herbs that are literally only hours old.

Your goal with this first customer contact is to get them to agree to showcase your herbs in their market. Tell them right off the bat that you would love a chance to leave them there on consignment to eliminate any financial commitment from the vendor except once they are sold. You will need to be competitive with their current suppliers but if your herbs are significantly of better quality, you have the upper hand here. Assume that every vendor is looking to double their money so if a bunch of basil sells for $3.99 you can bet they are paying about $1.50 - Since you are leaving them there on consignment and your costs (due to the higher quality farming techniques you use) are considerably higher than those grown out in the field, explain that upon sale of the produce, they will pay you 50% of the sale price. Now remember - I told you to start small - this is so you can get some experience and confidence. Once they agree and you work out a delivery and payment schedule, you are now in business. The next step is to meet your expectations and deliver on time.

It is a great idea that once you establish an account you visit the store a few times a week to see how your herbs are selling and determine which are the hot sellers. Of course you will want to concentrate on growing the hottest sellers. I can tell you from experience that Basil will most likely be your best seller and most profitable crop. However, each market differs and you will have to learn on your own what to grow. Keep your vendors supply going strong, people will tend to buy produce that is in abundant supply. If there is only one bundle left, they may have the preconception that it has been sitting around for a while and isn’t fresh. On the other hand, once word gets out about how great your herbs are - they may start disappearing alot quicker than you can supply them. The next step is to scale your business by expanding your production and signing on new vendors to distribute your herbs.

Herb seeds are available in many garden centers so finding them is not problem. Follow the direction on the seed packets for proper germination and growing techniques. Remember, the most valuable information on the subject of making a market for your garden is to visit your local markets and see what is selling. Talk to your local merchants and listen to what they will gladly tell you about their requirements. After all, they are looking to make money selling herbs too!

Types of hydroponic systems

A hydroponic system should be designed to fulfill the specific requirements of plants with the most reliable and efficient method(s) of nutrient delivery. The three major plant-requirements that a hydroponic system must satisfy are:

1) Provide roots with a fresh supply of water and nutrients while avoiding stagnation.
2) Maintain aeration to the root zone to refresh the supply of oxygen and remove built-up CO_2.
3) Prevent dehydration of the roots by maintaining close to 100% relative humidity.

Hydroponic systems can be either active or passive. An active system includes a mechanical means for recirculating the nutrient solution while a passive system relies on capillary action/absorption and/or the force of gravity to replenish roots with nutrient. Besides being generally more efficient, and thus more productive, a nice feature of active systems is the ease at which they may be implemented within an automated greenhouse. Just as a simple fan can be connected to a thermostat to control exhaust, a timer may be connected to the pump(s) of an active system to cycle on and off as necessary. If this system was designed properly, a large nutrient reservoir could feed the crop for a couple of weeks before needing a refill. In this scenario, as long as the system is reliable, the garden will continue to thrive indefinitely and unsupervised.

For a hydroponic system to be considered reliable, we must insure that the three major plant requirements are met on a consistent basis. Efficiency is just as important because it will define your operating expenses and in some cases prevent disrupting the environment. The best way to build a reliable, efficient system is through intelligent engineering combined with practical experience. Although the feats of modern engineers are quite incredible these days, sometimes complex problems are solved with even more complex solutions. I believe that the most fundamental solutions are the most reliable. KISS - Keep It Simple Stupid - (US military dictum). Live by the KISS rule and rest easy at night!

Now let's take a look at some of the active hydroponic techniques currently in use today. One of the earliest records of people using hydroponics describes the floating gardens of the Mexican Aztecs. These gardens were crafted similar to naturally occurring ponds, complete with water lilies and hyacinths. In nature, these plants obtain water and nutrition directly from the pond in a bioponic environment. Waste products from fish, birds and other animals provide a rich blend of organic nutrients for the plants to thrive upon and fresh water falls from the sky in the form of precipitation to replenish that transpired by plants and lost to evaporation. In the ancient water garden, aeration and circulation was provided by the action of falling rain or running water. When the rain stopped falling or the stream ran dry, these gardens would become stagnated and eventually dry up without human intervention. For this reason, people built sophisticated irrigation systems consisting of troughs.

A second ancient method of hydroponics is sand or gravel culture. This method is still used today in the middle east where sand is quite abundant, and the lack of arable land leaves few alternatives. Although sand can be used as a growing medium with great success, it has poor aeration qualities due to the small interstitial spaces between the grains. Remember when choosing a soilfree medium for hydroponics to look for good water holding capacity and good drainage qualities as well. This combination will ensure that your choice of mediums will allow the roots to feed, exhaust CO_2 and ingest Oxygen properly. Provided proper nutrient and water circulation is met, you'd be surprised at what mediums plants can grow in. I once grew a plant in the styrofoam peanuts used to protect shipments and we've all seen weeds growing from the cracks in cement sidewalks.

More recent research has shown the importance oxygen plays in the root zone. Oxygen is necessary for the plant to perform respiration, which provides the energy needed for the uptake of water and nutrient ions. Studies have proven that increased absorption of oxygen by the roots results in healthier, faster growing, and larger crops. With the results of this research being released to the industry, new methods have been designed to exploit this phenomenon.

The rockwool slab drip system

The simplest and probably most common method is using drip irrigation to deliver nutrient enriched water to plants grown in rockwool slabs. Many commercial tomato and pepper growers use this technique since it is relatively low-maintenance and pretty fool-proof. the picture at right depicts a rockwool slab, drip fed garden as photographed at Epcot Center's "Tomorrow's Harvest" tour.

The nutrient film technique

Work on the Nutrient Film Technique, or NFT for short, was pioneered by Allen Cooper at the Glasshouse Crops Research Institute in Littlehampton, England. Plants are placed atop an inverted 'V' shaped channel, sealed on all sides, through which a thin film of nutrient solution passes along the bottom. Roots grow down along the channel, receiving oxygen directly from the inside of the trough, while receiving water and nutrients from the thin film of nutrient below. The enclosed chamber maintains 100% humidity to protect against dehydration. Excellent results can be obtained with this system, however, maintaining the 'film' becomes difficult once the roots form large mats at the bottom of the trough. Puddling results in stagnation, depleting the roots of oxygen and fresh nutrient. Efficiency, on the other hand, is excellent because the closed trough prevents limits evaporation, while a pump/reservoir combination below collects and recycles excess nutrient.

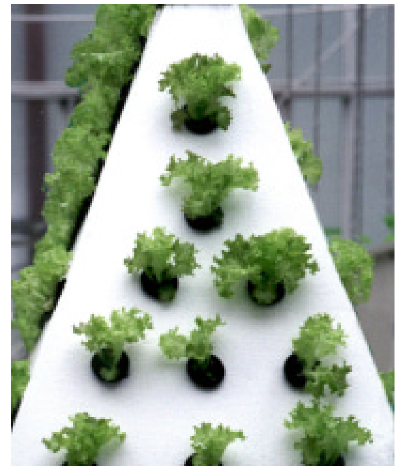
The raft system

An interesting technique of growing lettuce and other short crops that require no vertical support is the raft system. In this method, plants are supported in baskets that fit into styrofoam sheets and float upon a bath of nutrient solution. The nutrient solution is circulated and aerated from below to maintain a high level of oxygenation and avoid stagnation. The raft system is a very economic means of producing large quantities of lettuce and mixed greens in a short amount of time.

Ein Gedi system

First developed in Ein Gedi Israel, hence the name, the Ein Gedi System (EGS) introduced a revolutionary new method to hydroponics. The system is comprised of fully enclosed rectangular growth chambers, inside of which, nutrient solution is circulated 1-6 inches below evenly spaced mesh baskets that contain the plants. The air gap between the baskets and solution is misted by sprayers residing along the upper inside of the chamber. Roots growing into the mist zone are subjected to intense oxygenation, resulting in vigorous development. Once the roots grow through the mist zone, they are greeted by a circulating bath of oxygenated nutrient solution which eliminates the problem of stagnation commonly associated with NFT. The EGS provides a quick and efficient method for developing seedlings and cuttings into large and healthy plants. The PVC systems you can build from our plans employ this technique.

Aeroponics

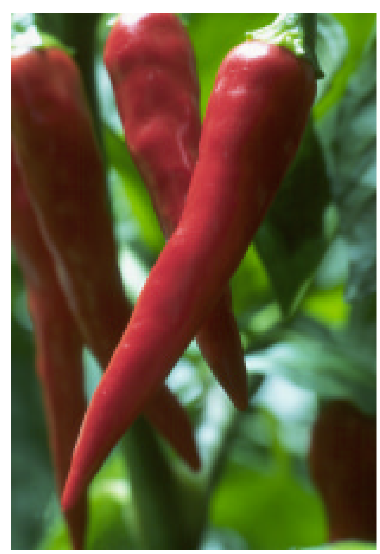


The most recent technology to be developed in agriculture is Aeroponics, a method in which a plant's roots are grown suspended mid-air. The plants are generally suspended from baskets (similar to those in which strawberries are packaged) at the top of a closed trough or cylinder. With the plants suspended in this manner, all essential nourishment can be provided to the roots by spraying them with a nutrient solution. Since the roots are suspended in mid-air, they receive the maximum amount of Oxygen possible. This method is also the most nutrient-efficient because you need only provide what the plants require, and any nutrient that is not absorbed is drained and recycled much like the in previous methods. Pictured at right is an interesting aeroponic application whereby plants are grown in styrofoam sheets that form an enclosed "A" frame. Inside the "A" are misters that spray the roots as described above.

It is of utmost importance that the atmosphere in which the roots grow is maintained at 100% relative humidity to prevent root dehydration. A drawback to current aeroponic systems is that in the event of pump malfunction or loss of power, the root systems will not remain healthy for long without the spray of nutrient enriched water - they will quickly dry up and die. However, the increased oxygenation that is received by the plant's root structure benefits growth at an unprecedented level and has been scientifically proven to increase crop yields by as much as 10 times over soil. Our AeroSpring[tm] design that is featured for construction later on, combines a deep, oxygenated reservoir to protect against root dehydration in the event of pump failure.

Vertical Gardening

This is another interesting application of aeroponics. It is manufactured by Vertigro and represents a great way of saving greenhouse space. The system functions much in the same fashion as the system above except it shares a drain pipe with as many units as required. See the black hoses below growing cylinders. Vertigro is located in Florida near Epcot Center where these photos were taken. As you can see, hydroponic system design represents equal opportunity for a challenge and progress. If you can master the basic skills of plumbing, which can be picked up best by DOING, you can have lots of fun experimenting and improving upon the hydroponic systems in use today. In the next section of this book You will learn how to build your own hydroponic and aeroponic systems that employ these advanced techniques.



A tip for hot pepper lovers

If you're a lover of super spicy foods like me, try growing your favorite strain of chile or habanero peppers in the aeroponic Aerospring you'll learn to build later on. Peppers have the unique characteristic of increasing their "kick" when they become water stressed. When grown aeroponically, you can control the level of water stress by using an adjustable cycle timer like Diamond's NFT-2 and setting the "off" cycle so that the roots *almost* dry out between feedings.

Planning your hydroponic garden

The First Step To A Great Garden Is Planning.

Consider the space you have available for your intended garden. Don't forget that if you plan to grow indoors in a tight space you will also need room to access your garden and perform routine maintenance such as pruning and nutrient changes. For this purpose, leave yourself ample space to work. Too many people try to fit too much garden into too small a space. Remember - a hydroponic garden will give you a significantly higher yield than a soil garden of equal size. If you plan to grow indoors, consider the location for its access to direct sunlight. Most plants need a minimum of 4-6 hours direct sunlight and a total of at least 12-14 hours of light daily. Your garden will not benefit from more than 18 hours of light daily however. A south facing window is a great place to start (assuming you live in the northern hemisphere) and to provide supplemental lighting, or in the case of providing exclusive lighting indoors, consider purchasing a High Intensity Discharge lighting system. HID lighting systems are available in either High Pressure Sodium (HPS) or Metal Halide (MH) configurations. HID lighting systems for horticulture provide maximum efficiency in converting electricity to light and will provide your garden with sufficient intensity of light to thrive.

Outdoors you can take advantage of the natural sunlight to supercharge your garden. Outside you will have to consider the effects of the weather including temperature and heat/cold. Direct sunlight will heat up the nutrient solution in your garden. Maintain the nutrient temperature between 65 and 75 degrees for best results - temperatures outside this band will slow the growth of your crop. Rainwater will cause the pH and concentration of your nutrient solution to drift if it gets into the system. Make provisions to keep rainwater out of your hydroponic system - This is more of a problem with the hydroponic planter design as it has a large exposed area to receive precipitation. Plastic skirts can be cut from plastic bags which when placed around the stems and over the grow sites will keep rainwater out of the other two hydroponic garden designs. To protect your nutrient solution from excessive heat and strong direct sunlight, consider using celotex or another type of reflective insulation commonly available at building supply stores. Make sure all electrical connections are kept dry as per manufacturer's instructions. Most timers ARE NOT WATERPROOF!

You'll Want To Have The Proper Tools Too!

To construct the hydroponic planter you'll need a magic marker, scissors and a some aquarium safe silicone sealant. Add a sharp razor and hacksaw to the list to build the AeroSpring - you'll also be happy to have an electric drill with a 2 7/8" holesaw attachment to make cutting the grow sites easier. The hybrid PVC systems are pretty much going to necessitate the electric drill and holesaw - especially if you plan to build the heavy duty design that utilizes 6" PVC pipe for grow chambers. While PVC is easy to cut with a hacksaw, cutting perfectly circular holes into the tubing is going to be next to impossible without this tool. If you don't own a heavy duty 3/8" or 1/2" drive electric drill, you can most likely borrow or rent one. You will most likely need to buy the 2 7/8" holesaw - at this size they usually consist of two parts - an arbor which holds the drill bit (for drilling the pilot hole) and the actual holesaw which looks like a half a beer can with a saw toothed edge for cutting circles. Get directions on using this equipment BEFORE you even pick it up as it can be dangerous without exercising the proper care and cautions. If you haven't any power tools or experience using them, you may consider hiring an experienced handyman or carpenter to cut the holes for you. The best way I've found to cut these holes is by using a drill press and shop clamps to steady the pipes while cutting the holes. I've built several 4" and 6" systems using nothing more than a 12V cordless drill and steady hand though so don't be discouraged!

Three inexpensive hydroponic gardens you can build

Before we get started though, there are a number of important considerations. The first would be in deciding upon a suitable location for your garden. Outdoors is great because the sun is free and there's plenty of space, however, you may not be able to grow outdoors if you are in an apartment building or congested urban area. In this case you have the option of growing indoors using High Intensity Discharge lighting. Whicheverway you go - if you pay close attention to the guidelines discussed in this publication, you should undoubtedly achieve success.

If you plan to grow indoors

Invest in an HID light! (Metal Halide for leafy plants - HPS for flowering & fruiting plants). I use a 400 watt metal halide lamp with reflective hood to light nearly four gardens simultaneously and with excellent results. Since HID lights aren't exactly cheap, you may choose to substitute high output fluorescents instead, but in the long run, you'll get more light output and certainly more yield with an HID lamp. Either way you grow, try to get at least 20 watts per square foot of garden for best results. I prefer 30-40 watts per square foot of garden as the extra light makes a BIG difference. On the following page I briefly describe each system you can build. I recommended the lamp sizes based on the growing area of each respective garden. If you were to illuminate more than one garden at a time, you can use this simple formula to determine your lighting requirements. Multiply your growing area width by its length and the result by 20-40 watts (depending on crop) - the result is your required lighting wattage. Standard indoor HID grow lights come in 100, 150, 175, 250, 400, 1000 and 1500 Watt sizes. Most high output fluorescents deliver about 10 watts per running foot of bulb. To achieve proper illumination with fluorescent lighting, use an array of 3 bulbs for every foot your garden is wide. For example, if your garden is 3' x 4' - use (3) 4' bulbs per foot of width - (9) 4' bulbs total. This will give you 30 watts per square foot - perfect! - keep them close to the plants too - 6-12" max. Remember, water and electricity are hazardous to your health! Follow safety precautions on product packaging and inserts. Keep lights and ballasts away from moisture! Use a fan to circulate air throughout your garden.

When growing outdoors

Protect the reservoir from heat and direct sunlight. Maintain solution temperatures between 68 and 75 degrees F. You may want to bury the reservoir to take advantage of the cool and consistent soil temperatures. You can use aluminum foil to reflect sunlight and keep the reservoir from getting too hot. In really hot climates, you can create a cooling loop, buried in the soil to dissipate heat by having the nutrient pass through it on its way to the injectors (not applicable for the hydroponic planter design). You may need to use a larger pump to overcome the extra resistance inside the additional tubing. Keep any electrical equipment protected from the rain - use only equipment suitable for outdoor use. Hire a licensed electrician to install the proper wiring and outlets to power your outdoor garden.

Notes

All hydroponic systems subject parts to a slightly corrosive solution - pH's of 5.5>7.5.
Part(s) availability may require substituting an item, please keep in mind that only nontoxic and nonmetallic parts should be used. Clean all parts thouroughly with a 10% solution of bleach to remove mold release compounds and contaminants. Avoid using automotive hoses and tubing.

About these plans

Years of studying the science of hydroponics and countless hours tinkering with the latest and greatest techniques have contributed to the design of the systems in this publication. I've combined the best features, advantages and benefits of all the most current technology into these systems which you can now build for yourself from inexpensive and easy to find parts.

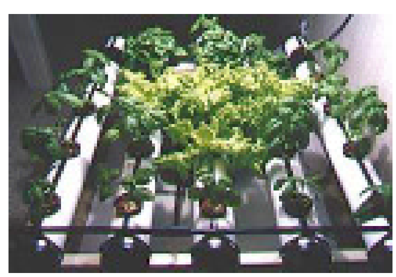
The Basic Hydroponic Planter

Inexpensive and easy to build, this hydroponic garden can be built in under an hour. Perfect for science projects and windowsills, this garden builds quickly and will get you growing in no time. Ideal for growing short culinary herbs, smaller leafy green vegetables and flowers. Indoors use with a 100-175W MH or HPS light for best results when sunlight isn't available.

The Aeroponic AeroSpring[tm] Garden

An excellent way to discover the added benefits and increased growth rates of Aeroponics. This garden will amaze you with how quickly your favorite plants grow with their roots suspended midair! Inexpensive design and simple construction also make this garden ideal for the advanced project and hobby gardener. Ideal for growing both culinary and medicinal herbs, smaller vegetables and flowers. Indoors use with a 250W MH or HPS light for best results when sunlight isn't available.

The PVC Pipe Gardens

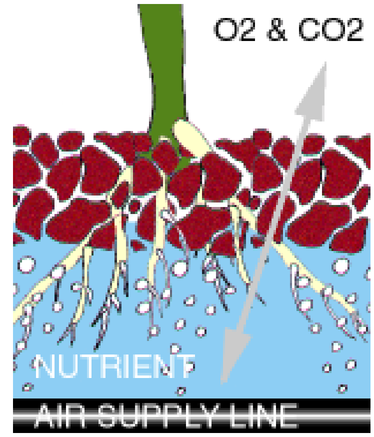


These designs were inspired by the many commercially available hydroponic gardens that utilize PVC pipe as a main design component. PVC pipe is relatively inexpensive, easy to work with and extremely durable. These designs allow easy expansion owing to their popularity among commercial growers and family farmers. Perfect for producing large harvests of rapidly growing crops such as salad greens, culinary and medicinal herbs and decorative flowers. This garden requires a bit more skill and some power tools to complete. There is the option to build it with either four inch or six inch diameter PVC according to intended use. Indoors use with 250-1500W MH or HPS light for best results when sunlight isn't available.

Build a hydroponic planter

Theory of operation.

This is a simple hydroponic garden that allows your plants to grow directly in the nutrient solution by providing physical support with GroRox and oxygenation to the roots with a common aquarium air pump and air curtain.



The diagram at right details how the roots grow down through the GroRox into the nutrient solution which is aerated by the release of bubbles from the slowly leaking supply line (aquarium air curtain).

To get started building this garden, you'll need only the most basic parts which you shouldn't have trouble finding locally in stores that sell garden and pet products. If you run into problems sourcing the parts, visit the FutureGarden store online at http://futuregarden.com/store.html

Hydroponic Planter Parts List.

(1) Plastic deck planter with a sealed bottom.
We used a Dynamic Designs 27" x 12" x 10" deck planter with a sealed bottom. You can use a round or square design too - you'll just have to improvise the plans but the theory is the same. Use a container that is free from holes and made of a rugged, opaque plastic.

(1) Roll of 1/4" Air Tubing
Connects the pump outlet to the air curtain.

(1) 2500cc minimum Aquarium Air Pump
We used a single output air pump with a "T" fitting to split the air line into two feeds. You can use a dual outlet for better performance without the "t" fitting. These types of pumps are commonly available in pet stores throughout the country.

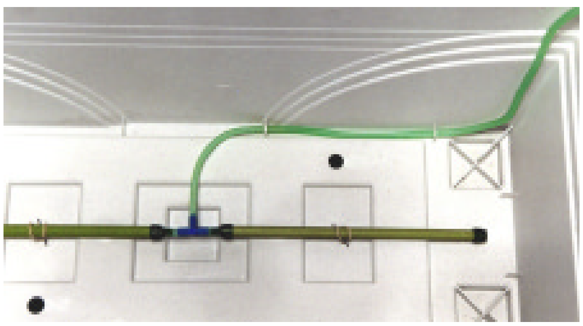
(1) 1/8" Airline "T" fitting
To split the output of a single outlet air pump - not necessary if using a dual outlet air pump or if you use a single air curtain that runs the entire length of the planter.

(2) 2" Air Curtains or (1) 24" air curtain
Provide a full length stream of air bubbles to oxygenate nutrient bath.

(7) Gal. of GroRox or expanded clay pellets, Lava rocks or 3/8" gravel.
Used as a growing medium to fill the planter. You need to make sure that the medium is clean from grit and dust as they will drastically alter the pH and sacrifice your crop. The quantity required is based upon planter size.

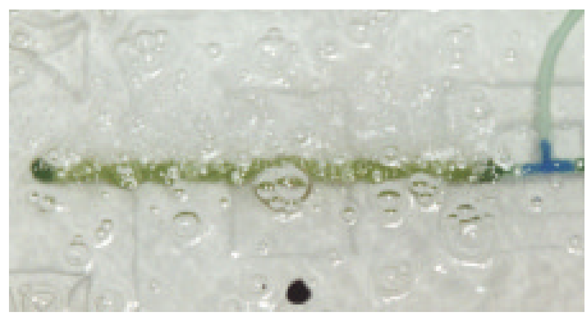
Step 1.
If you are utilizing a non-weighted air curtains as in the picture at right, you should secure it/them to the bottom of your hydroponic planter so they do not move around. I took advantage of small tabs molded into the bottom of our planter to hold the air curtains down with some stainless steel wire and rubber bands. Make sure you don't use anything that will rust inside the planter.

Step 2.
The layout is real simple... Using the "t" fitting as shown, connect both air curtains to the supply line and route it along the bottom and up the side of the planter. You may also use a single air curtain of 24" or so in length and feed it from just one end. I drilled holes in some tabs that were molded into the planter to secure the airline.

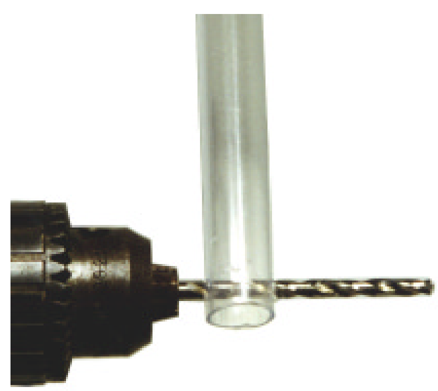


After securing the air curtain(s) and attaching the supply lines, fill your system with water and run the pump to check for even distribution of air bubbles and absence of leaks!

If your system is bubbling away like the one at right, you can drain the water and continue on to the next step. If you do not have a steady stream of bubbles, make sure your air line is not kinked or clogged. If all else fails, you may try using a more powerful air pump.



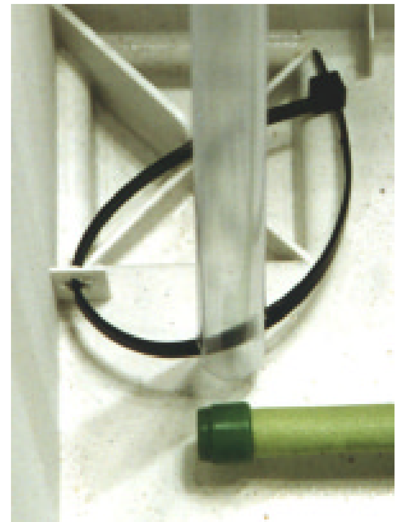
Step 3.
You may choose to install a nutrient level indicator. To do this, simply drill a hole through the bottom of a section of 1/2" clear rigid tubing as shown at left. This will allow you to secure the bottom of the tube to the inside of the planter with a plastic tie.



I highly recommend adding this feature as there is no other means of determining the level of nutrient inside the planter and you certainly don't want to risk drying out your crop!

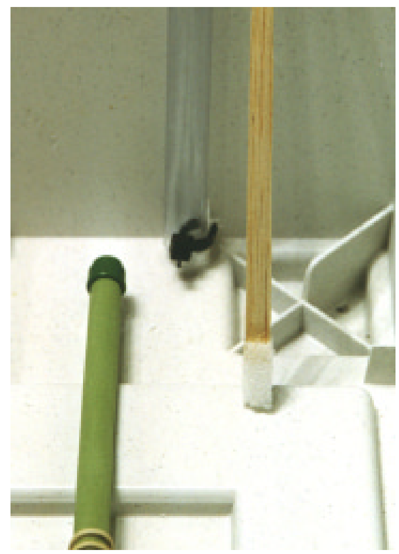
Step 4.

Attach the bottom of the level indicator to a tab through which you drilled another equal size hole - using a plastic zip-tie. We chose the Dynamic Design deck planter because of the many molded in tabs which allow easy connection to the planter.



Step 5.

To make the level indicator float - simply cut a piece of 1/16 inch balsa wood into a large "match stick" shape so that it can easily side up and down inside the indicator tube. Now all you have to do is either glue on a small piece of styrofoam to add buoyancy or use it without as a dipstick. Either way, apply a coat of clear wood sealer to the stick to keep it from getting waterlogged. You can use a plastic drinking straw in place of the balsa wood stick if you can find one long enough. Try your local convenience store as sometimes they have extra-long straws for their Super-Sized fountain drinks.



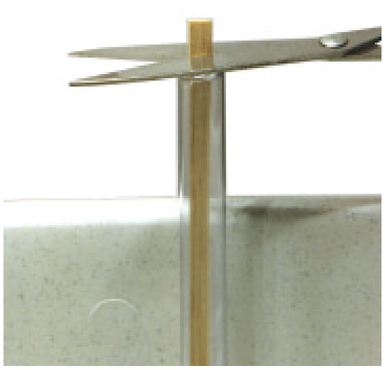
Step 6.

If you do in fact use a float - insert the dipstick into the tube and cut it flush with the top of the indicator tube. If you want to use it as a dipstick without the float, you can leave it a bit longer so you will have plenty to hold onto when checking levels.

Step 7.

Now you are ready to fill your garden with GroRox or clean pea sized gravel. Fill it up to within two inches of the top. Fill the system with nutrient solution according to the directions that came with your nutrients. Try to add one gallon at a time and mark off the level on the dipstick so at a glance you will know how much remains in the system.

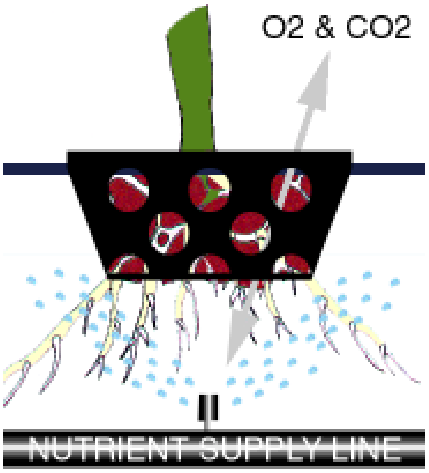
To insert your plants, simply dig a hole as deep as the seedlings roots have grown and carefully backfill around them. Make sure you get their roots down deep enough so they are getting wet. Water from above for a few days till they adjust. Once your seedlings or rooted cuttings have been planted, you should run the air pump for one hour every four hours or so - or just leave it on constantly.



ALWAYS MAKE SURE THE NUTRIENT LEVEL IS SUFFICIENT! - Growing outdoors in high heat and direct sunlight will cause your plants to go through a lot of nutrient and since this system is not a closed cyclic type, you will lose some to evaporation.

Build the aeroponic Aerospring™ garden

Theory of operation.



Aeroponics is the most advanced means of cultivating plants. It has been show to outperform soil based cultivation by up to a factor of ten! The reason it is so effective is that since the roots are suspended midair, they receive the maximum amount of oxygenation possible while maintaining 100% humidity for exceptional growth potential.

The diagram at right details how the roots grow down through suspended baskets containing GroRox and into the misting chamber where they are gently sprayed with nutrient solution every few minutes.

To get started building this garden, you'll need mostly common parts which should be available in local garden and housewares stores. If you run into problems sourcing the parts, visit the FutureGarden store online at: http://futuregarden.com/store.html There should a kit available by the time you read this which includes many of the harder to find items needed to build this garden.

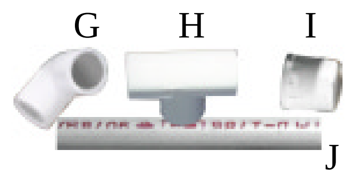
A glimpse at the picture below quickly reveals how healthy roots should look. Full, white in color and just loving that Aeroponic chamber! These tomato plants grew so quickly under a 250W HPS lamp that we had to cut them down because they took over our office!

AeroSpring parts list

A. (1) 30-50 Gallon Plastic Container With Lid
We used a “Tucker” 42 Gallon Storage Container With Hinged Lid from Caldor, a local housewares store. You should have no problem finding these containers on sale in just about every type of store from home improvement/hardware to bed and bath. You want to use a container that is free from holes and made of a rugged, opaque plastic - preferably dark blue, black, green or red in color to keep light from passing through its walls and causing algae growth within the system. The container needs to have a lid that fits securely as you will be cutting holes in it through which your plants will be suspended in plastic cups, allowing the roots to grow down within.

B. (1) 100-150 GPH Submersible Pump
We used a Beckett 150 GPH Submersible Pump from Home Depot, a home improvement store. These types of pumps are commonly available as fountain and pool/spa cover drainage pumps. I found 150-300 GPH pumps to work best.

C. (1) 1/4” > 1/2” Threaded Coupler
Connects the pump outlet to the 1/2” PVC pipe
D. (2) 1/2” PVC Male Threaded Couplers
To connect 1/2” PVC pipe to pump and valve
E. (1) 1/2” PVC Ball Valve
F. (1) 1/2” > 3/4” Garden Hose Adapter
G. (1) 1/2” PVC “L” Fitting
H. (1) 1/2” PVC “T” Fitting
I. (1) 1/2” PVC end cap
J. (1) 10’ PVC Pipe 1/2” Inside Diameter
The above parts can be purchased at a plumbing supply store.



K. (4-8) 16 Oz. “Solo” Plastic Cups
Final quantity depending on how many grow sites you choose - you will also need some smooth, clean gravel or GroRox to fill these cups with and provide an anchor for your plant’s roots. You’ll need about 2 cups per grow site.
L. (1) Cycle Timer +/- 20% Duty Cycle
A cycle timer is one that turns on for “x” minutes and off for “x” minutes and then repeats this “cycle” as long as it is plugged in. We used an NFT-1 cycle timer that is specifically manufactured for hydroponic applications. It turns on for 1 minute and then off for four minutes. This is effectively a 20% duty cycle which keeps the roots wet and the pump from running continuously which would heat up the nutrient solution quickly.

M. (6-8) Micro Sprayers - 180 or 360 Degree pattern
Pictured at right are actually three different types of micro sprayers - be sure to use those designed for low pressure applications or else they will not “spray”
1) Stocking or Filter Bag - not shown

Step 1.
Measure the diameter of your selected growing baskets at the shoulder or at approximately 3/4 its height. Record this width as it will be the width of the holes you will need to cut to accept the cups.

For Solo brand 16 Oz. cups, the diameter is 3”

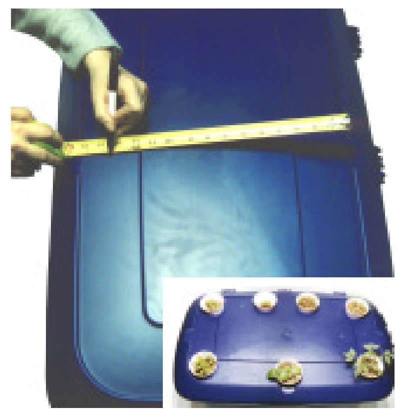
Step 2.
Measure the depth of the cups from where you have measured the diameter - This distance or depth is how far into the misting chamber your cups will sit and is important in determining at what height to mount the spray manifold.

For Solo brand 16 Oz. cups, the depth is 3 1/4”

Step 3.
The Sprayer manifold will run lengthwise inside the misting chamber (Parallel to top and bottom in picture on right). You need to determine the spacing and quantity of grow sites for your system now.

We chose to have seven grow sites with three in front and four in back - see inset photo...

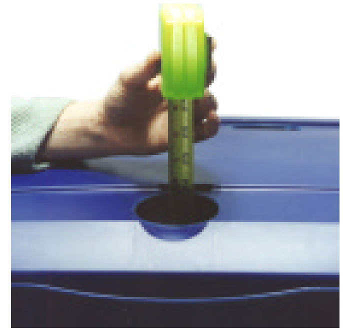
Basically all you need to do is to mark off the centers of the holes you will cut in the next step - USE A RULER!



Step 4.
Using a holesaw - size determined from Step 1. - and the marks you just made in the previous step, cut out the grow sites. Use CAUTION with the holesaw - You can also use a sharp razor knife to cut them or a pen-type soldering iron to melt them. Whatever you use BE CAREFUL!!! Sand the edges to make them uniform.

Step 5.

Now you will need to measure the distance from the lid down to the bottom of he misting chamber. Simply use a tape measure and record this measurement as it will be used in the following step.



Step 6.

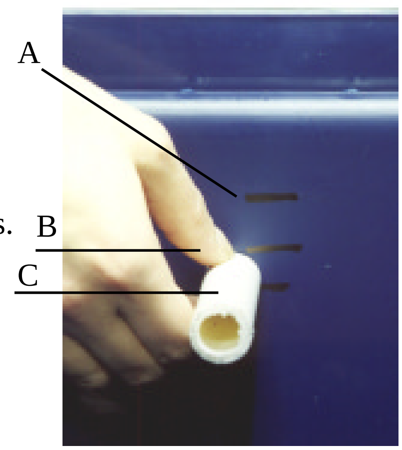
Now subtract the cup depth from Step 2 from the distance measured in step 5. Make a mark on the inside of the chamber at this height - this is where the bottoms of the cups will be situated once placed into the system. You will use this mark to determine the proper height to mount the misting manifold.

NOTE: This picture depicts marking the front of the misting chamber when in fact it should depict marking either side (behind model's elbow). Don't get confused here cause it could mess you up on Steps 7 and 8.

Step 7.

From the mark you made in Step 6 (A), mark off two more lines, the first (B) at one inch below and the second (C) at 1 1/2" below. This is so that the tops of the sprayers are at the same level as the bottoms of the cups. Some sprayers will aim the spray upwards at a slight angle - you may wish to try them out first to determine if this is the case. Your goal is to get the spray to hit the bottoms of the cups.

Look at the drawing of the completed injection manifold in Step 16. It will give you a better idea of what you will be creating in these next few steps...



Step 8.

At the height of the last mark you made (#2 from above), drill a 7/8" hole at the horizontal center of each end of the misting chamber. Remember - the misting manifold runs lengthwise (left to right) inside the chamber and it runs parallel to the top and bottom of your chamber. These holes need to be perfectly aligned so use care in judgement.

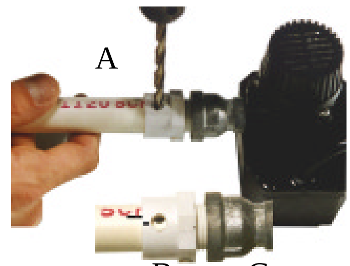
Step 9.

Cut a 6” piece of 1/2” PVC and insert it through one of the holes you just drilled. This will be the drain side of the chamber so if it is to be placed in a tight space - you should consider which side you want the drain fitting to be on...

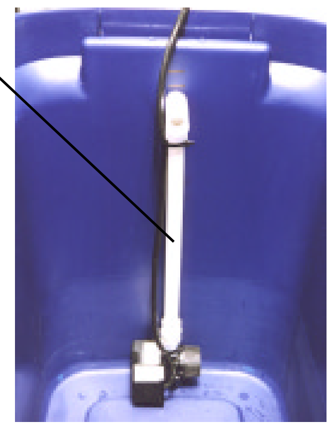
On the inside of the chamber and on the end of the 6” pipe, insert the 1/2” PVC “T” fitting so that the extra opening points downward into the chamber and the opposite end opening faces the opposite side of the chamber (Step 11. Photo)

Step 10 - 11.

Get out your pump and screw on the 1/2” threaded PVC adapter (C) and one 1/2” PVC threaded coupler (B).



Now lay the pump down on the bottom of the chamber with the outlet facing up towards the “T” fitting and measure out a length of pipe (D), to connect them. You want the pipe to be long enough to fit snugly and maintain proper alignment.



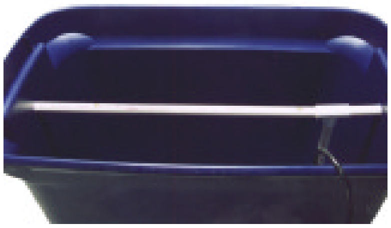
Now you may remove the pump and vertical pipe and drill a pressure relief valve into the fitting as shown in the picture above (A). The hole should be drilled through only one side of the fitting and pipe with a 3/8” drill. The purpose of this hole is to allow excess pump pressure to bleed off inside the chamber, causing a gentle circulation inside the reservoir. By keeping this joint free from glue, you can rotate the pipe inside the fitting to vary the amount of relief (pic. B shows a 50% setting.)

Step 12.

Now you can glue on the “L” fitting on the outside of the chamber and attach the ball valve with the remaining 1/2” PVC threaded fitting. To this you will screw in the garden hose adapter which will serve as your drain system. A simple twist of the valve will allow you to pump out old nutrient solution instead of having to upset the plants to drain it manually with a bucket.

Step 13.

You can now place the pump and its vertical manifold back into the chamber, connect the vertical manifold to the “T” fitting and then cut a piece of 1/2” PVC pipe to connect to the open end and pass at least 4” through the opposite side of the chamber. This horizontal structure is the misting manifold.



Step 14.

Cap off the open end of the misting manifold as it exits the chamber on the opposite side of the drain using the 1/2” PVC end cap. Most of these PVC fittings will fit snugly - use glue when necessary and to prevent leaks.

Step 15.

Our particular container had two small holes in the handles at either end of the chamber. We used a hot melt glue gun to seal them up. Make sure you inspect your chamber for any holes and plug them up with hot melt glue or aquarium safe silicone.

Step 16.

Using the diagram at right as a general guide - mark off locations for the sprayers at even intervals along the top of the misting manifold.

We found that the 150 GPH pump we chose had enough power to run eight sprayers so we put five across the top and three upside down between them to provide even more spray to the roots. (not shown)

Step 17.
Drill the holes to accept your sprayers. Make sure you don't drill them too big otherwise you will not get a good seal and the sprayers may pop out due to pressure. Antelco make a line of small garden sprayers perfect for this application - we have them on our site if you can't find any locally.

Step 18.
Screw or glue in your sprayers with silicone sealant. The ones we use screw in using their included wrench. You'll probably want to remove and clean the sprayers between crops as even the finest filter may pass small root hairs that will eventually clog your system.

Step 19.
Get your grow cups together for this step. Here we used a small pen-type soldering iron to melt the root holes into the bottoms of the Solo brand cups. You could use a razor blade or drill to cut them out too.

Make sure you don't make the holes bigger than your growing medium otherwise it will all fall out!

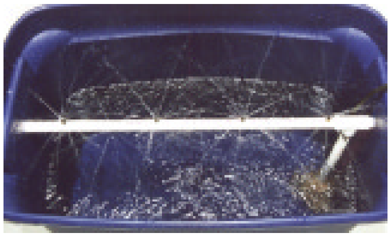
Step 20.
The more holes the better - again - make sure they are not big enough to allow loss of your growing medium (gravel , expanded clay pellets or lava rock). The holes only need to go about 1/2 way up the cup.

Step 21.

Our lid required the use of a plastic skirt, duct taped to the inside of it to prevent water from spraying outside of the chamber. Here you see the lid, upside down with the finished cups in place and the plastic skirt (cut from a garbage bag) securely taped in place around the perimeter of the lid. When the lid is in place, the skirt hangs down between the inside of the chamber and the outside of the cups to prevent over-spray from causing a leaky mess....

Step 22.

Time to Test - Fill ‘er up - I made marks on the vertical manifold to indicate the water level in gallons - to do this, simply fill it up a given amount at a time and mark it off accordingly. Spray should reach all walls of the chamber - you can adjust their strength by rotating the vertical manifold and adjusting the relief valve.



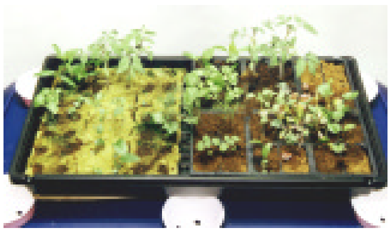
Step 23.

Put the lid on, making sure that the plastic skirt (if required) falls into place. Insert the cups and fill them with a layer or two of your growing medium. Run the pump and make sure that the medium is getting moistened through the holes in the cups.

You can pull out the cups as the pump runs and check for water droplets on their outside too. The medium only needs to get slightly moistened so that until the roots grow down and out of the cups, they can feed. You can adjust the relief valve to increase/decrease spray.

After your system is complete and checked out, you can prepare your seedlings for transplanting into the system. We planted this array of salad greens, tomatoes, basil, oregano, dill and sage about three weeks before transplanting.

You will see that our seedlings sprouted in both rockwool cubes (on left) and in the Cocofiber (on right). Cocofiber needs to be rinsed off the roots before transplanting into the cups. All in all we have determined the Cocofiber to be better for sprouting seeds than rockwool but it is much messier than the rockwool cubes!



Step 24

To transplant your seedlings or cuttings, make sure they have at least a set of true leaves and have developed a small root system. Simply line the bottoms of your cups with a layer or two of medium and then backfill around your plants to offer them support in their new home. You should pre-moisten the medium with nutrient solution first to avoid drying out the roots.

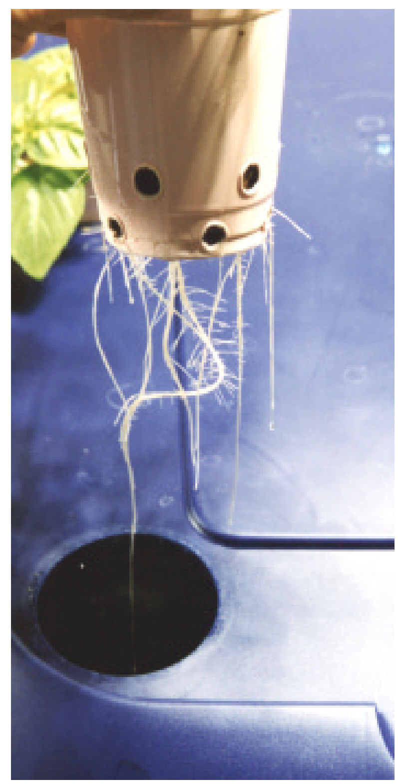
Step 25

Here are two sweet basil plants that we just transplanted. Notice that we backfilled the medium all the way up to the growing tops. We did this so that the roots had plenty of support and moist medium available until they mature and grow out beyond the confines of their cup.

Step 26

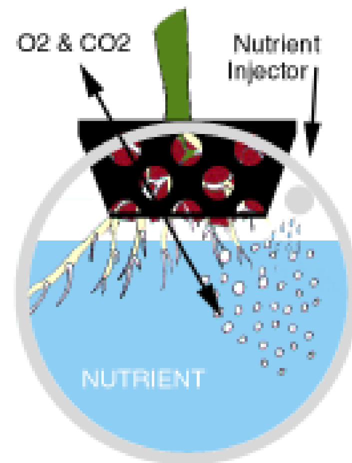
After about a week, you will see the roots beginning to poke through the holes in the cups and down and into the misting chamber - once this happens plant growth really takes off since the benefit of Aeroponics is realized.

I have found that the best spray cycle is a 1 minute on / 4 minutes off routine. It seems to be just the right ratio of on/off to allow the plants enough nutrient in high heat/strong lighting conditions. The NFT-1 cycle timer is a perfect match.



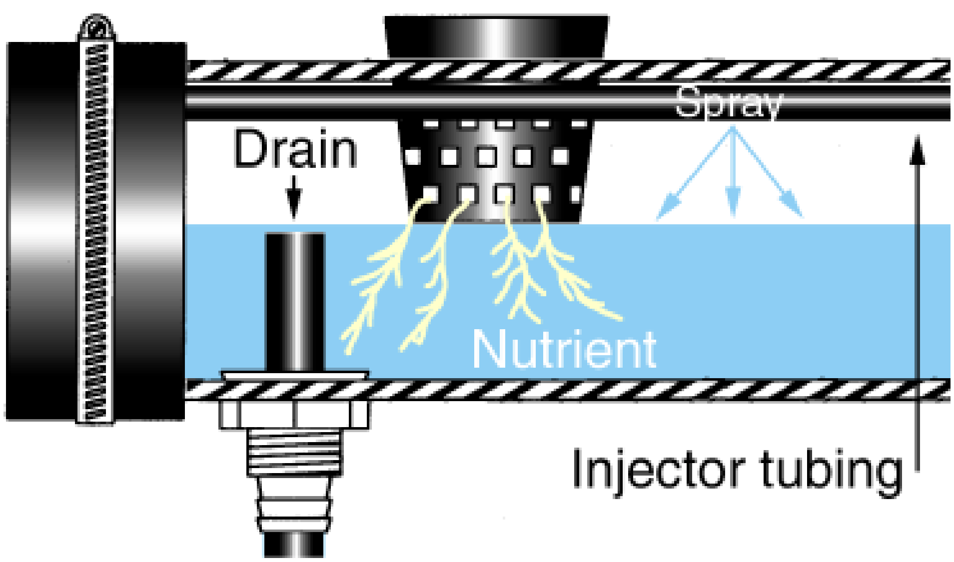
Build the pvc pipe hydroponic systems

Theory of operation.



The rapid cropping systems that have evolved from simple PVC piping are truly unique and exceptional hydroponic gardens. Extremely cost effective and durable, they are the leading means of high yield rapid cropping using hydroponics. The systems operate by circulating a deep flow of nutrient solution within the PVC pipes whereby the plants are suspended in baskets which protrude into the PVC pipes at specific spacing (depending upon crop type) and the roots grow down into the circulating nutrient below. Either four or six inch diameter PVC pipe can be used depending upon crop type and budgetary constraints.

The only fundamental difference between four and six inch piped systems is the nutrient injection technique. Since the four inch systems tend to be shorter in overall length, they employ a single source injector at the end opposite the drain fitting. This is to ensure that the nutrient solution within the grow pipes is fully circulated and does not stagnate. The six inch piped systems generally employ an internal length of piping (usually 1/2 to 3/4" dia.) that runs the entire length of the pipe (grow chambers). This additional piece of pipe in attached on the inside of the growth chambers and is pictured in such a fashion that at each occurrence of a grow site a stream of fresh nutrient sprays down into the circulating flow to create an extremely oxygenated nutrient solution. Both systems are drained by a standard sink or "thru hull" type fitting (a different size fitting applies to either the four or six inch system) and are fed by means of an external pump.



Planning your PVC pipe system

The beauty of a system based upon PVC pipe is that it can easily be customized for your particular application. You may choose to utilize either four or six inch diameter PVC pipe for the growth chambers. If you are planning to grow indoors, four inch PVC is generally the way to go as most of the plants grown indoors are of the smaller variety and do not form large root systems. Outdoors is another story since you can grow just about anything - including tomatoes and peppers that can eventually reach ten feet in height! Plants this large develop root systems that can clog a four inch chamber so consider using six inch chambers. These plans will cover constructing both types and the differences in each so that you can build either. You can even build a hybrid system which uses both - this would make sense if you plan to grow one row of large tomatoes and/or peppers and many smaller rows of leafy greens and/or herbs and spices. Very few people grow large tomatoes and peppers indoors since they require much more light and space than is usually available. Consult the chart below to determine what size chambers best fit your needs.

PVC Size	For Plants	Lifecycle	Location	Budget for 40 plant system*
4”	< 36” tall	< 4 months	indoors	< $150
6”	> 36” tall	> 4 months	in & outdoors	$150 - $300

* based upon your choice of components

We are currently working to offer completion kits for these designs which include all the specialized hardware you’ll need. Visit the FutureGarden online store at: http://futuregarden.com/store.html and look for them if you need to.

The following notes may be useful in planning construction of these systems:

1. Each foot of 4" PVC pipe when horizontally oriented holds roughly .33 gallons of water when filled 50% or 2" deep (the average level the growth chambers operate at) a 3ft. section will hold eight lbs. of water.
2. Each foot of 6” pipe holds about 1 gallon (eight lbs.) at the level required to reach the bottoms of 3” baskets. Use this measurement in place of .33 for 4” pipe.
3. Reservoir size - the bigger the better - try to have about 1 gallon per plant available in the reservoir in addition to what’s inside the chambers. To determine the liquid capacity of a given sized container, use the following formula: **Length x Width x Height (all in inches) / 144 X 7.4 = Capacity in Gallons**
4. Nutrient circulation - you’ll want a pump with a high enough “GPH” (gallons per hour) to circulate the entire contents of your reservoir and growth chambers (add line #’s 1 or 2 and 3) within 30 minutes and with enough pressure to create a strong spray and maximum aeration within the chambers. When selecting a pump, measure the distance (in feet) from the bottom of your reservoir to the top of your growth chambers, this is the pump "head", it will generally be between 2 and 3 feet for most systems so make sure the pump you buy can provide the required GPH at the proper “head”.
5. Use a timer that will cycle the pump on and off in 30 to 60 minute increments or an adjustable cycle timer

IMPORTANT! - All supply tubing should be of an opaque (dark) plastic material such as polyethylene, PVC, or similar to avoid the penetration of bright light which will cause the growth of green algae. Avoid using rubber tubing designed for gasoline/oil transfer, it is usually treated with a compound which may contaminate your system.

System overview

These next two pages depict different views of the completed system which you should study to familiarize yourself with the design and operation of the system BEFORE you start building.

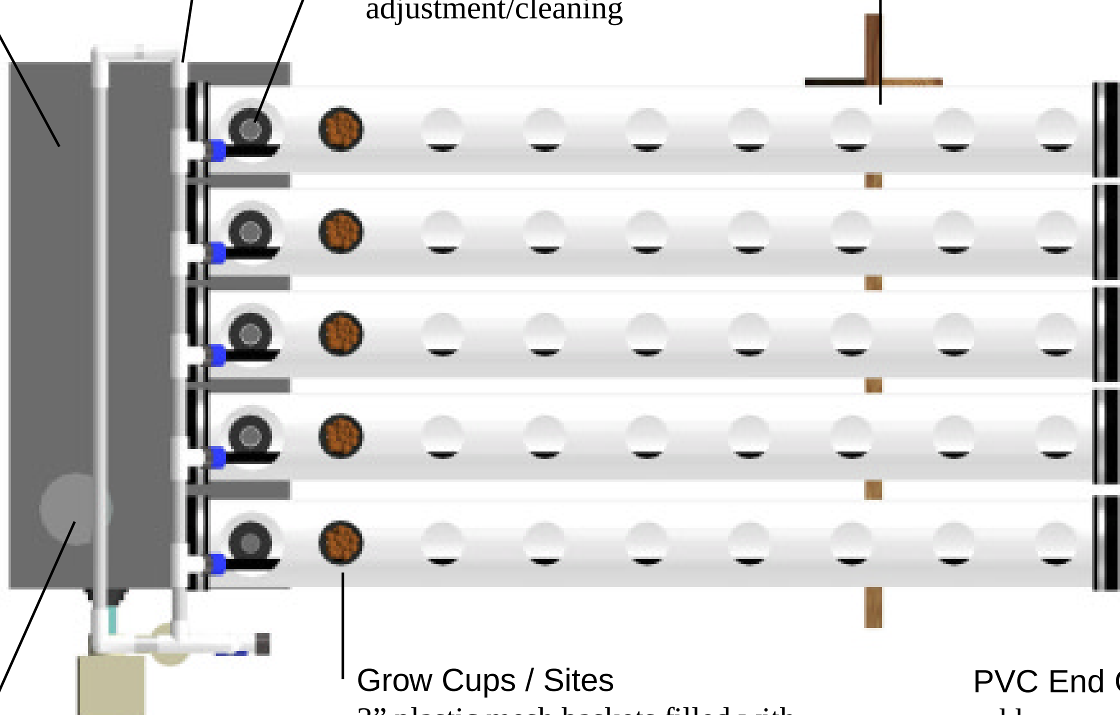
The spacing between growth chambers and the grow sites on each chamber is completely customizeable - we used 7” center to center spacing for the grow sites as when the six inch chambers are next to each other they are about 7” centerline to centerline. Again - consider what you plan to grow and plan your plant spacing and chamber arrangement accordingly.

Reservoir
made from a heavy duty 44 gallon plastic storage container.

Injection Manifold
made from common PVC pipe - balances pump pressure across chambers and delivers fresh nutrient.

Growth Chambers
made from (3) 10’ sections of 6” dia. PVC pipe. Each cut in half.

Drains/Access Holes
level adjusting drain fittings return nutrient to reservoir - holes allow adjustment/cleaning



Reservoir Access Hole
allows access to pump filter and easy refill of reservoir.

Grow Cups / Sites
3” plastic mesh baskets filled with clean GroRox, Lava rocks or large gravel - support plants and allow roots to grow down into chambers containing the circulating nutrient solution. (only fiveshown). Spacing is dependant upon type of crops.

PVC End Caps
rubber caps can be removed easily for cleaning chambers also know as Gem caps - come in 4” and 6” diameters.

System overview

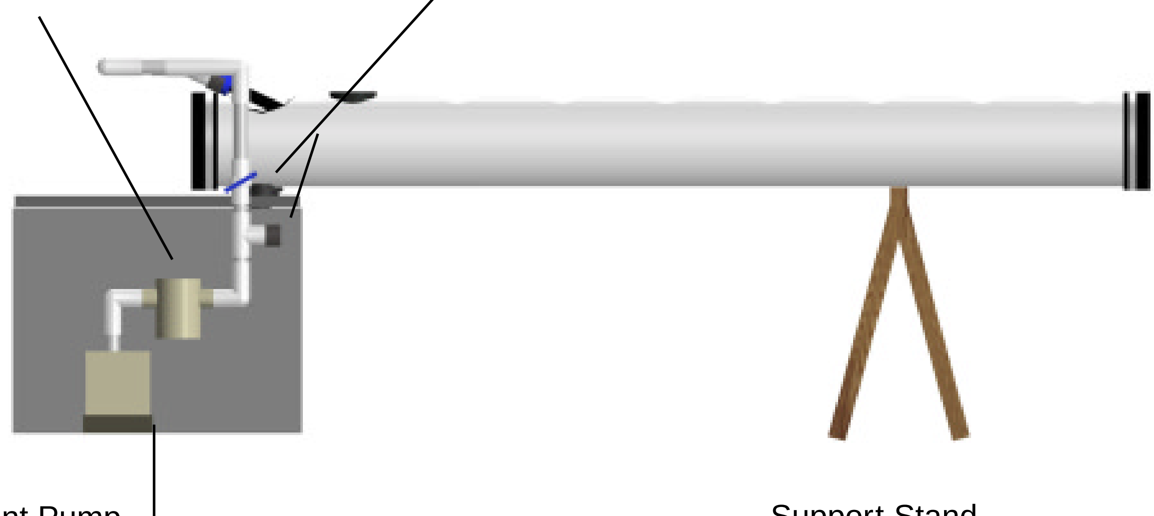
Although there is a wide selection of submersible pumps which can be used inside the reservoir, we prefer to use them externally as this way they do not heat up the nutrient solution and are easier to service (clean their intake filters) The view below shows a non-submersible pump manufactured by General Hydroponics specifically for this type of system.

In-line Filter

Traps any fine particles that get past the strainers inside the reservoir and pump intake before they clog the sprayers. Two piece screw off design makes for easy cleaning.

Bypass Valve/Waste Fitting

By closing this valve and attaching a garden hose to the fitting directly below, the flow is diverted so you can easily pump out the system and refresh the nutrient solution.



Nutrient Pump

A 300-1200 GPH pump is used to circulate nutrient throughout the system - needs to have enough pressure to create a strong enough spray inside the chambers to cause aeration of the solution within.

Support Stand

made from a common saw horse kit - can be made with 2” diameter PVC pipes as well - Use one for a 5’ chamber and two for a ten foot chamber spaced evenly to distribute the weight of the pipes full of nutrient solution.

Plumbing system parts list - injection manifold

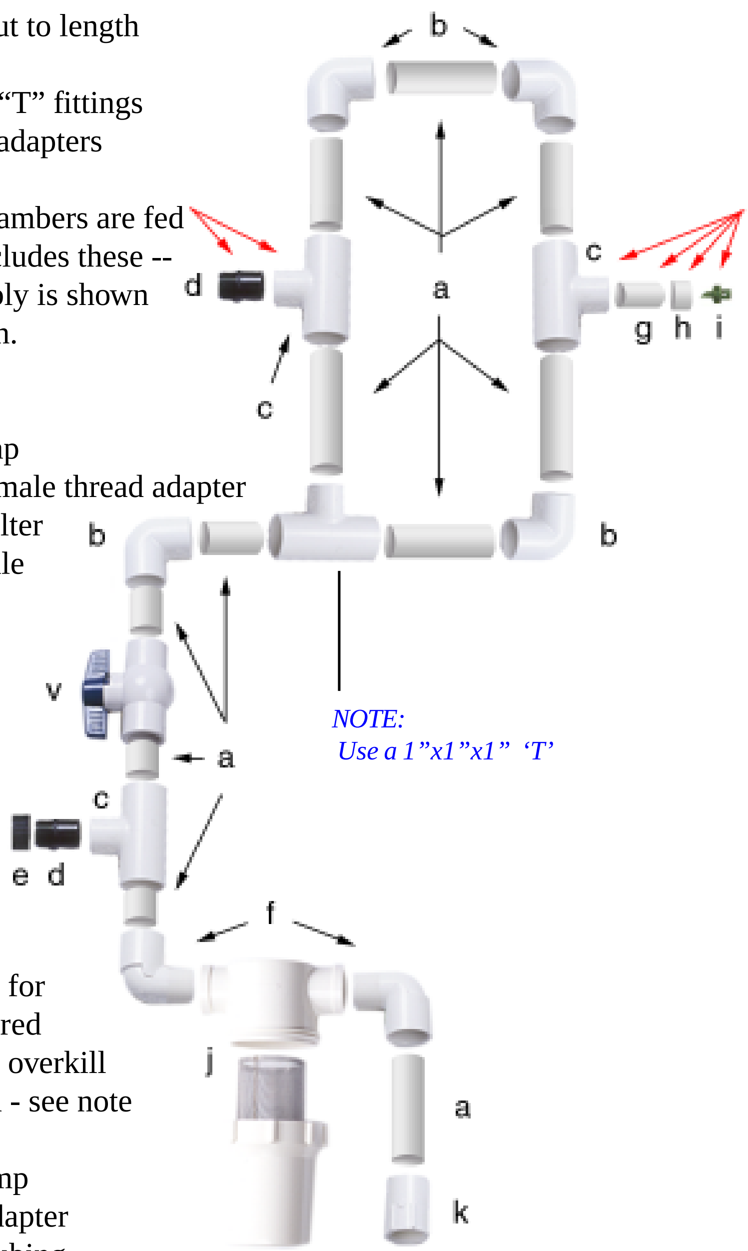
Study this page to understand and familiarize yourself with the plumbing system and determine what parts you will need. These parts are also available at the FutureGarden.com store.

a. 1” dia. PVC pipes cut to length
b. 1” dia. PVC elbows
c. 1” x 1” x 3/4” PVC “T” fittings
d. 3/4” PVC to thread adapters

Each of the 6” grow chambers are fed by an assembly that includes these -- parts - only one assembly is shown for clarity of illustration.

e. 3/4” threaded end cap
f. 1” x 1” PVC slip to male thread adapter
j. 1” inlet/outlet Teel filter
k. 1” PVC slip to female threaded adapter

v. 1” PVC ball valve



These four parts are specific to constructing the 4” chamber system only. Each chamber is fed by a group of these four parts, only one group is shown for clarity of illustration.

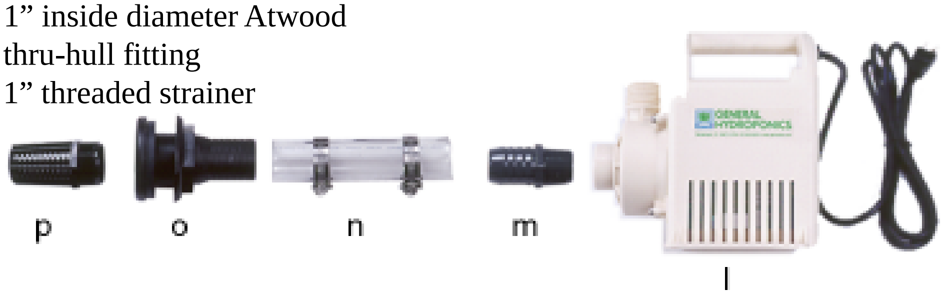
c. 1” x 1” x 3/4” PVC “T”
g. 3/4” dia. PVC pipe nipple
h. 3/4 “ PVC end cap
i. 1/4” microjet sprayer

NOTE:
If you are building a smaller garden (<15 ft. of total grow chamber length) you may utilize a lower volume, submersible pump shown below as part “q.” You will need to determine the proper fitting to connect it to the feeder manifold at the part labeled “k”

The following parts are for building the 6” chambered system only as they are overkill for the four inch design - see note across page.

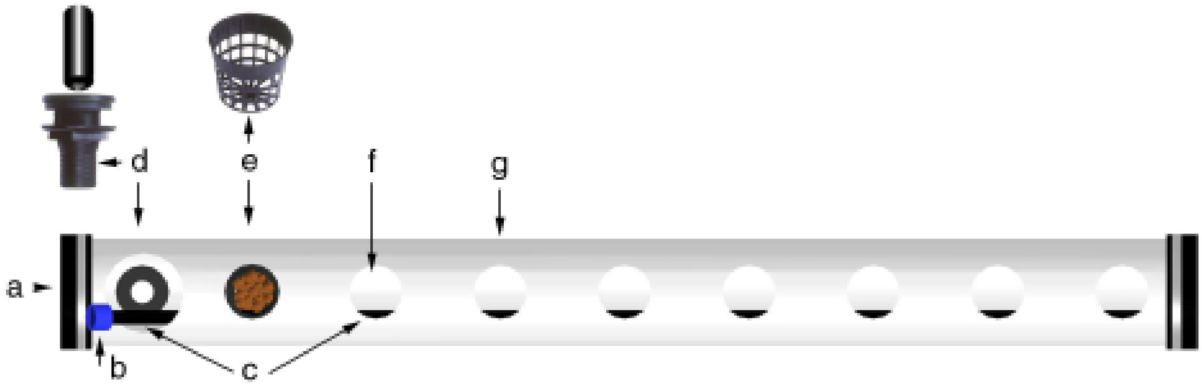
l. 1/4 HP non. sub. pump
m. 1” thread to barb adapter
n. 1” inside diameter tubing
o. 1” inside diameter Atwood thru-hull fitting
p. 1” threaded strainer

q. 300-500 GPH submersible pump with intake filter. May be used in place of parts “l” through “p.”



Parts list - grow chambers & reservoir

Study these last few diagrams to determine what parts you will need. Most of these parts are also available at the FutureGarden.com store. They also have prefabricated grow chambers in the event you do not wish to make your own.



a. Rubber inspection caps - available in both 4” and 6” depending upon which size chamber you build - also known as “Gem Caps” or “Cleanout Caps” You’ll need two per chamber.
b. 3/4” thread to 1/2” or 3/8” inside diameter barbed adapters - 6” system only.
c. 1/2” or 3/8” inside diameter polyethylene or PVC sprayline - not used on the 4” system - drilled with one 3/32” hole at each occurrence of a grow site (“f”) to provide a spray of nutrient solution to each plant. See the previous page to view the fittings necessary for the 4” system. You’ll need one assembly per chamber.
d. Drain fitting - the 6” system requires the use of Atwood (or similar) 1” ID thru-hull fittings - the 4” system requires the use of a smaller fitting made by Forespar (or similar) that measure XX” inside diameter - you can find these at boating stores sold as sink and bilge fittings. They both require a length of snug fitting tubing to be inserted inside them which acts to control the level of nutrient inside the chambers - pictured above fitting.
e. 3” plastic mesh baskets - these fit snugly into the 2 7/8” holes that represent the grow sites. They are filled with GroRox or similar expanded clay, lava rock or clean large gravel. Your seedlings will be inserted into these cups and backfilled with the GroRox in preparation for planting in the system.
f. Grow site - a 2 7/8” hole spaced according to the types of crop you plan to grow.
g. Grow Chamber - can be either 4” or 6” diameter PVC pipe. Six inch is pictured

These last two items are the stand and reservoir. For a reservoir you can use an opaque, heavy duty plastic storage container - the type commonly found in housewares and home improvement stores. The heavier duty, the better, as the weight of one end of the chambers will be resting on it. If you are building the 6” system, try to use the type that are made for storing tools in work trucks and at job sites. Home Depot sells them for about $45 - They’re called “Tuff Boxes” - Make sure you remove all metal hardware from this type as it will rust in the acidic nutrient solution.

Grow chamber construction

You should now be familiar with the design and function of each part of your system. Refer back to the preceding pages to refresh your memory as we go along. We will now illustrate the step-by-step construction of your rapid cropping hydroponic system. We will point out the differences between the 4” and 6” systems as we go along.

Step 1.

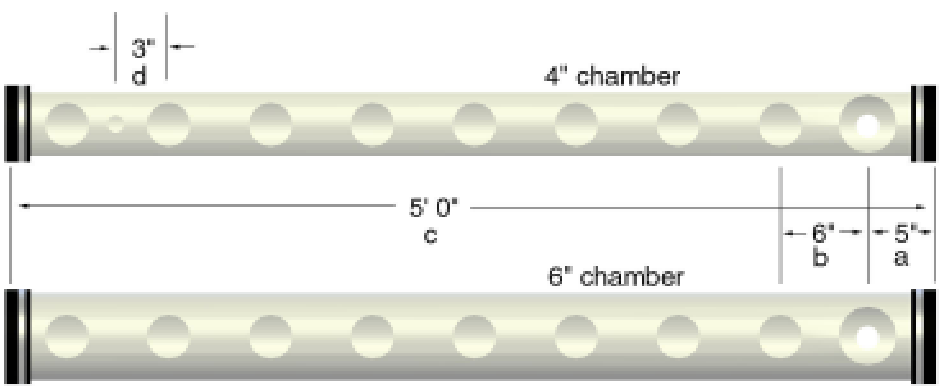
The objective of this step is to cut down the store bought foot lengths of PVC into the sizes required for your system. Since PVC usually comes in ten foot lengths, we will make the most of each by cutting them exactly in half to yield two five foot chambers. Use a good quality saw with many teeth per inch, a metal hacksaw works great and they even make a serrated wire saw with handles on at each end as a cheap means of cutting PVC pipe.

> Secure pipes from rolling or moving before you cut.
> Make cuts as straight as possible or rubber end caps may leak.
> Remove all excess shavings from cuts and holes drilled in PVC with 100 grit sandpaper. Wear a pair of gloves when working with PVC as it is sharp.

Step 2.

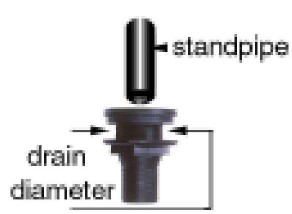
Now mark the locations for the grow sites, drain holes and injector holes. Use the diagram below for reference: a. Is the distance between the drain end of pipe and the center of the drain hole which is on the bottom of the chamber. Directly opposite the drain hole on the top of the chamber is an access hole which allows you to adjust the drain standpipe to control nutrient solution level. b. Is the distance between the centers of each grow site. c. Is the overall length of t

On each side of PVC pipe their is a line of print that details the manufacturer’s specs for that pipe, use it as a guide to keep your holes centered.



Step 3.

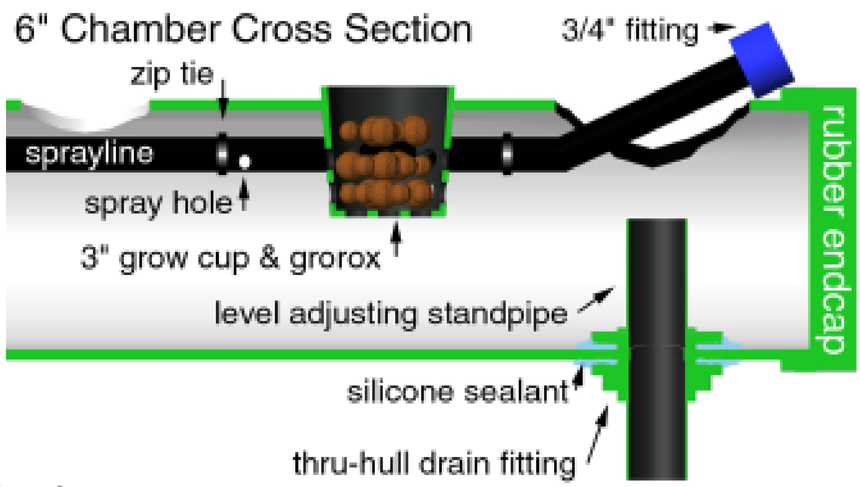
Secure the chambers with your grow site marks facing up. Using a 2 7/8" holesaw, slowly cut the holes for each grow site as marked. Afterwards, use a holesaw with the same diameter as your drain fitting’s external diameter, cut hole on BOTTOM of tube at location a. For 4” chambers only, drill a 1” hole at location d. For the pipe nipples and sprayers to enter the chambers.



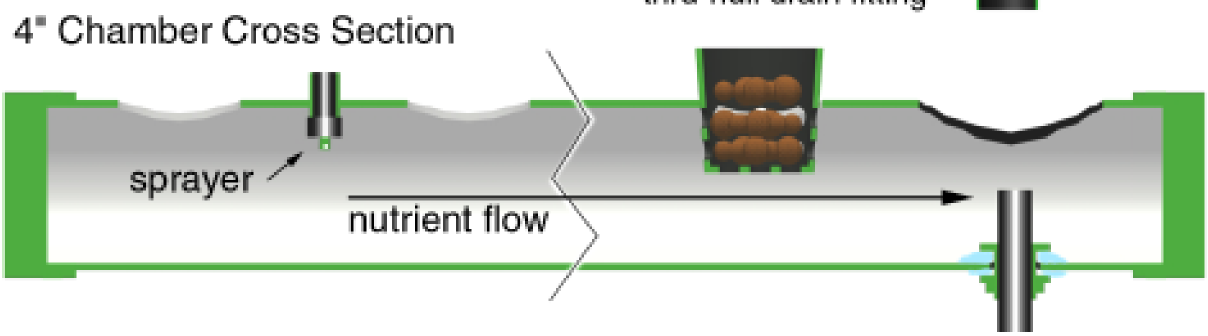
Step 4.

If you are building the 6” system, you will need to fit the chambers with internal spraylines. For this you can use 1/2” inside diameter flexible, polyethylene tubing or 1/2” PVC, if you use the PVC, you will need to add a 45 degree elbow at the access hole end - see diagram below. The spraylines are attached to the inside of the chambers with plastic “Zip Ties” which are fed through a small hole drilled into the chamber and then wrapped around the spraylines and passed back out through the same hole - see diagram. You will want to secure them as high up as possible but not so that they interfere with the placement of the grow cups.

You will need to run the spraylines the entire length of the chambers and at each grow site, drill a 1/16” hole so that they will spray down directly under the grow cups. Plug the opposite ends of the spraylines with either a PVC end cap or silicone sealant. See picture below of sprayers in action.

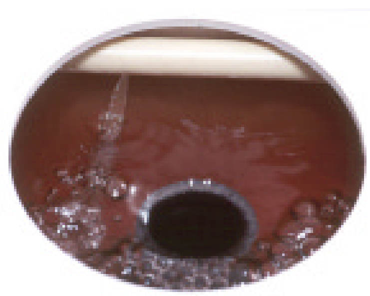


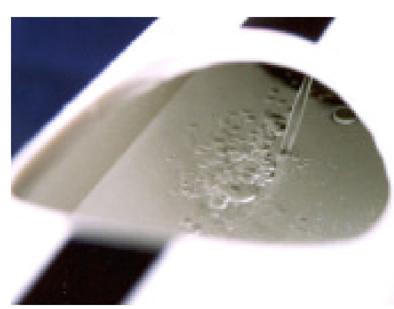
If you are building the 4” system, you will see by the diagram at right that the sprayer is located on the opposite end of the chamber from the drain. This is because you want the nutrient to flow from the sprayer to the drain. Since the 6” system has a spray hole at each grow site, the drain and supply end of the sprayline can be at the same end of the chamber.



You will want to use plenty of silicone when installing the drain fittings - see diagrams. You will need to find a piece of tubing to use as a level adjusting standpipe within the drain fittings. It should fit snugly inside the drain fittings and maintain the nutrient level for at least a couple of hours in the event your pump stops working for any extended period.

The pictures at right depict the proper workings of the spraylines in the 6” chamber and the sprayer in the 4” chamber (far right). Notice the strong spray is creating significant aeration of the solution. This is key to the system’s operation.



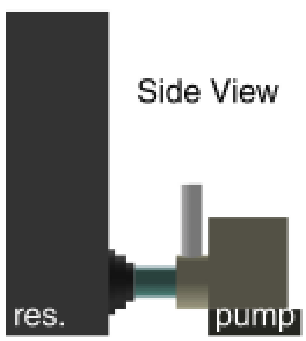


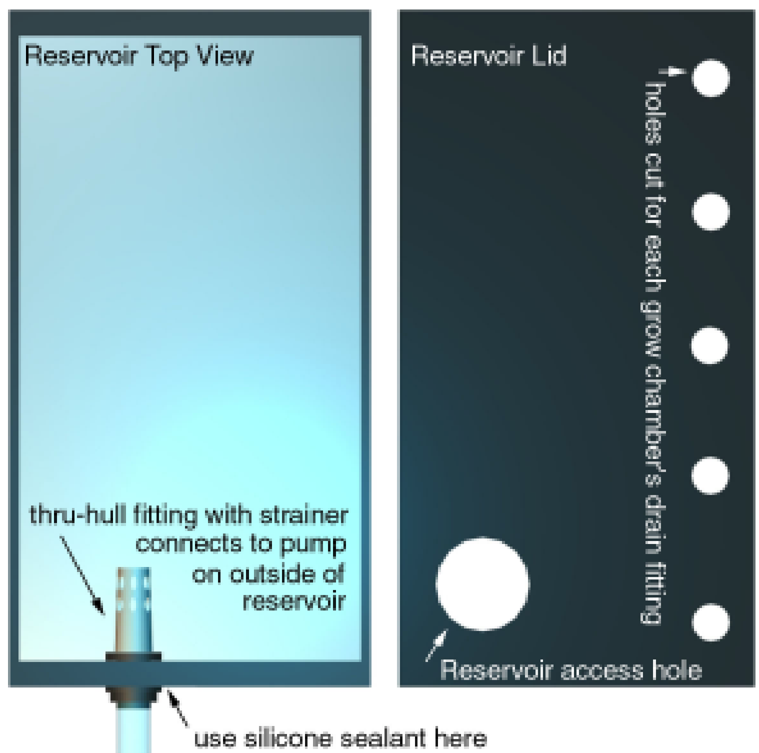
Reservoir construction

These diagrams detail the layout of the reservoir for use with an external pump. Many larger submersible pumps can be used externally by removing the detachable intake grates - beneath which you will usually find a threaded intake fitting. If you are building the 4” system or plan to use a submersible pump, you will not need 6” system. The only difference would be that you no longer need to drill the hole for the thru-hull fitting as you will no longer be using it. In this case, you may elect to pass the pump line through a hole you can drill above the water line or in the lid of the reservoir. I strongly recommend using an external pump as it will keep the nutrient temperatures cooler since its heat will be dissipated outside the reservoir. Use lots of silicone sealant where the thru-hull fitting passes through the reservoir.

When cutting the holes in the lid for the chamber’s drain fittings to drain back into the reservoir, you will need to space them at least 7” apart if you are using 6” chambers. The spacing you choose ultimately depends upon the configu-ration of your garden and the number of cham-bers you plan to use. You’ll be cutting the same size holes in the lid and in the reservoir as you did for the drain fitting on the chambers. (see step 3.)

See diagram on page 67 to see how the chambers and reservoir fit together.....



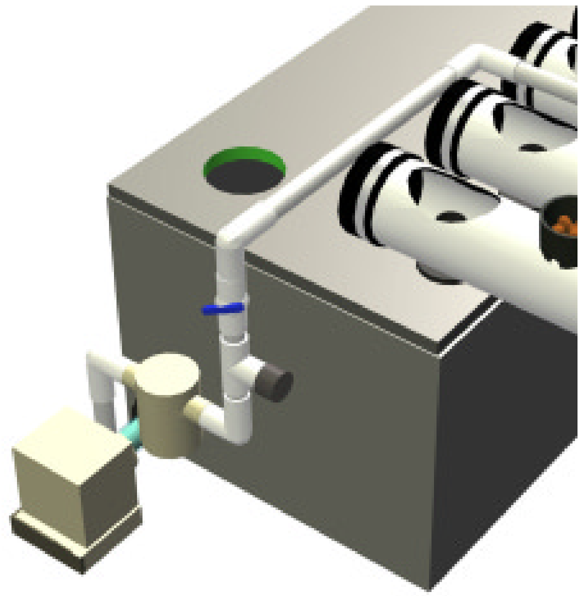


Step 5.

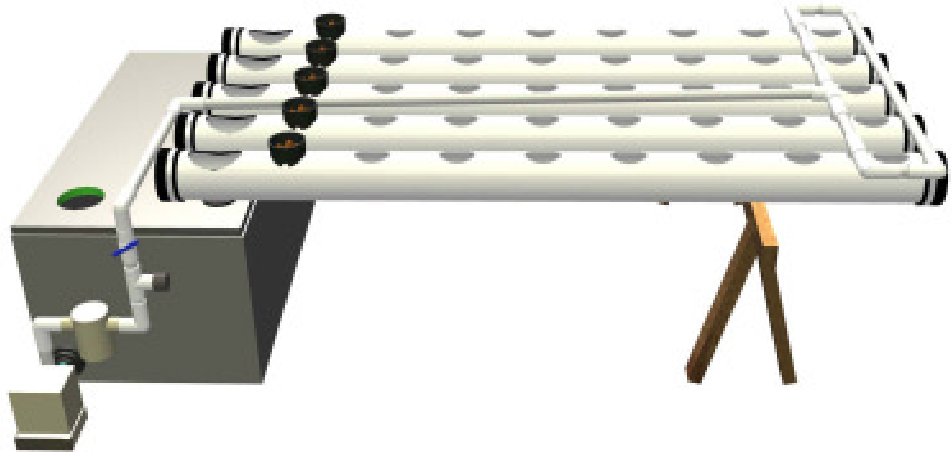
Build your support structure from a sawhorse kit and some 2x4's. Although saw horses make a simple and inexpensive support structure, there are many alternatives available including using 2” PVC pipes in the same fashion as outdoor furniture. Screw 2" drywall screws into the stand as shown to keep the chambers from rolling adjust their heights for proper drainage. Use drywall screws which have a very coarse thread, this will allow quick adjustment. It is important if there is a very slight decline from the spray end of the 4” chambered system to the reservoir/drain end. This is not necessary on the 6” system.

Manifold construction

The final step in completing your system is to assemble the manifold. The 4" and 6" systems differ here as the injection manifold for the larger system is located at the same end as the drains whereby the smaller manifold is located at the opposite end. Shown at right is the 4" system's manifold which is assembled from the parts on page 19. It is a good idea to dry fit these parts together before you cement them with PVC glue. Many people opt to modify these parts slightly to accommodate differing layouts and pump selections.

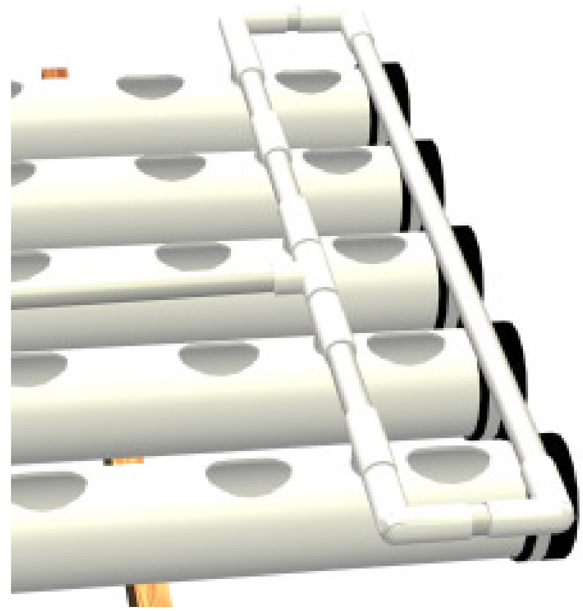


The diagram below depicts the entire 4" system to illustrate how the manifold and plumbing is assembled.

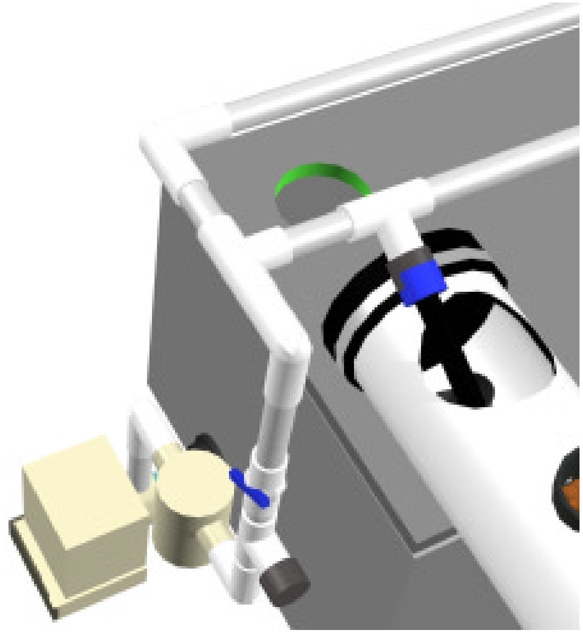


4" System

The manifold simply rests on top of the grow chambers and directs the sprayers downward into the chambers with PVC "T" fittings as show at right. Each "T" fitting is connected to a short piece of tubing with an end cap glued in place. A hole is then drilled into the end cap and a sprayer nozzle installed. The size of the hole is dependant upon the sprayer you choose - however, you may opt to leave out the sprayer and simply use a smaller hole in the end cap as a nozzle - similar to the way the larger system's spraylines rely on holes to create a spray. If this is the case, start off with a hole no larger than 3/32" - this way you can increase the size of the hole to increase the flow of nutrient without running the risk of drilling too large a hole which would turn the spray into a trickle. With five chambers and a 300 GPH pump, I've found a 1/8" hole works best.



Assembly of the larger manifold is basically the same except it is located at the same end as the drain fittings. See diagram at right for details. Each chamber is then connected to the manifold with a 3/4” threaded adapter, this way they can be individually removed from the system and the empty fitting can be plugged with a 3/4” screw-in cap. When it is time to drain the system all you need to do is turn off the pump, close the blue valve and connect a garden hose to the fitting directly below it on the manifold. Turning the pump back on will then divert the flow out the garden hose until the reservoir is empty. When finished, remove the garden hose and replace the screw-in cap on the fitting, open the valve and refill your reservoir. The access hole just behind the chamber on the reservoir lid allows easy addition of water and nutrients and access to the intake screen on the pump.



You will probably want to provide some additional support for the manifold just behind the chambers - this extra section can be connected to another set of grow chambers in the event you would like to expand your system. Realize that adding another set of chambers will lower the pressure in your plumbing system and require a larger pump. I recommend a 1/4HP pump for this purpose as it will support up to (10) five foot chambers - I use the 1/4HP pump even for systems with only five chambers since it preforms really well and delivers a high pressure spray and plenty of aeration to the nutrient inside the chambers.

To complete your system, use PVC cement on all non-threaded PVC fittings to eliminate the possibility of leaks and separation. Fill the system with clean water and pressure test its operation - you’ll probably want to remove the level-adjusting standpipes for the first test just to make sure there are no leaks in the plumbing before you allow the chambers to fill up.

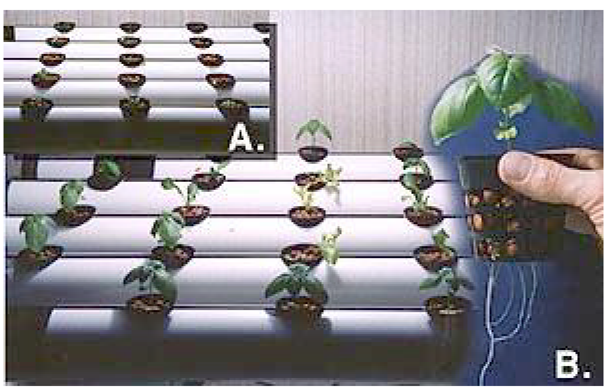
6” System

Final assembly and system operation

Now that your system is complete, you will want to run a quick test before committing a crop to it. There is another slight difference in operation between the 4” and 6” systems in that the smaller system requires that the nutrient level actually touch the bottoms of the grow cups - see picture at right - you’ll notice the water level just touches the bottom of the basket so that the GroRox will wick up enough moisture to get seedling started without flooding them out. As the plants mature and their roots grow down into the chamber, you can lower the standpipes to about 1” below the cups.

The larger system, since it has an internal sprayers at each grow site, doesn’t require that the nutrient level be run so high. Make sure though that you adjust the nutrient level so that if the spray isn’t at least splashing nutrient up into the cups, the nutrient level touches the bottom of the cups until the roots grow down into the chamber.

Operation of the system is rather simple, I like to use a cycling timer that is adjustable like Diamond’s NFT-2- this allows me to vary the amount of time that the pump is on for and the amount of time that it is off for as well. For example, when I first start seedlings in the system, I like to run the pump on for ten minutes and then off for twenty. As the plants mature, I cut back to a five minute on time and a thirty minute off time. This cycle continues until you unplug the timer. This is because seedlings need the extra watering time to help them develop roots. Once their roots grow down into the chamber, they are bathed in the nutrient solution and the sprayers are acting more as a means of aeration that a source for nutrient.



Inset A - seedlings just moved to the system.
Foreground - after an adjustment period during which time roots begin to grow...
Inset B - close-up of basil plant after 7 days in system, notice roots below grow cup.

During the first week in the system you must pay close attention to your plants and constantly check that the GroRox inside each basket are getting moistened with nutrient.

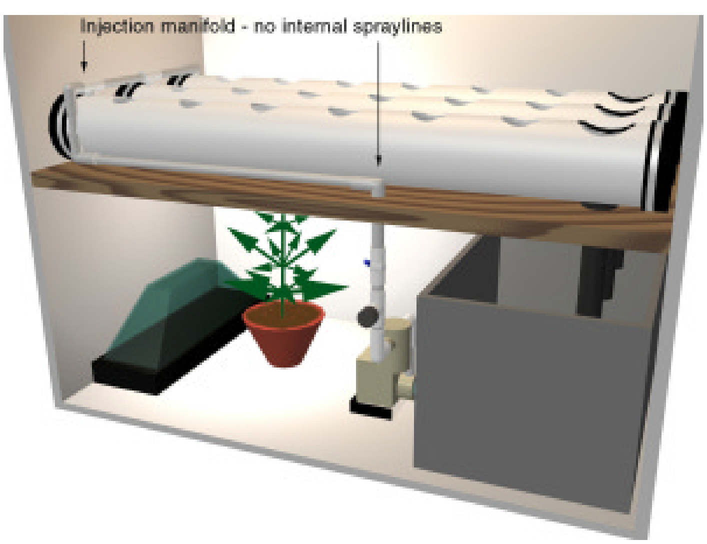
Once all of the plants roots extend below the baskets and into the nutrient solution, your crop will really take off! After the roots reach the bottom of the chambers, you may lower the standpipes so the nutrient level is just below the baskets. After the roots get real strong, you can even remove the standpipes entirely and run the system as a hybrid Aeroponic/Nutrient Film Technique system. Access holes in the chambers and on the reservoir should be covered with an opaque plastic sheeting to keep light from causing algae growth - REMEMBER - keep light and heat away from your nutrient solution!

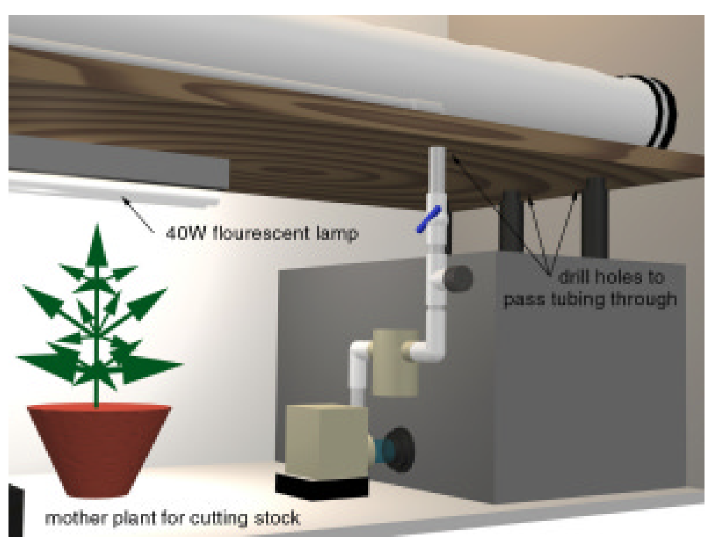
The spare closet garden

If you live in an area where space outdoors is tough to come by, here are some ideas for creating a closet garden. In the example shown below, the six inch PVC system is custom fit inside this available space. You will find that this configuration works well for maintaining a steady supply of salad greens, herbs and flowers by virtue of the two-level arrangement. On the lower level, a fluorescent light of 40Watts is used to start seedlings and root cuttings hat are kept inside the 10"x20" humidity domed flat in the lower left. If you wish to take cuttings for speedier growth and solid stock, you can use the remaining area for growing a "mother" plant which is used for the sole purpose of taking cuttings. Once the cuttings are rooted or seedlings ready, you can easily transplant them to the upper part of your closet for placement into your modified PVC system and exposure to the High Intensity Discharge lamp. Be very careful to keep your lamp at least 24" from all surfaces, walls and ceiling. Installing a small vent fan in the ceiling is also a necessity as heat will build up quickly. Use the type commonly found in bathrooms - 100-150 CFM should be fine for most small areas.

Flower power!

If you do a careful job of blocking light between the upper and lower halves, you can force flower your favorites by reducing the daylight hours of operation to 12-14 hours per day. While your flowers are blooming on top, your next crop can be rooting below. On a system this small, you can save alot of hassles by leaving out the internal spraylines and using the same method of injection that the four inch PVC system uses. That is simply a direct spray down and into the chamber. Use a strong chain secured to your ceiling to raise and lower the light according to the height of your crop.



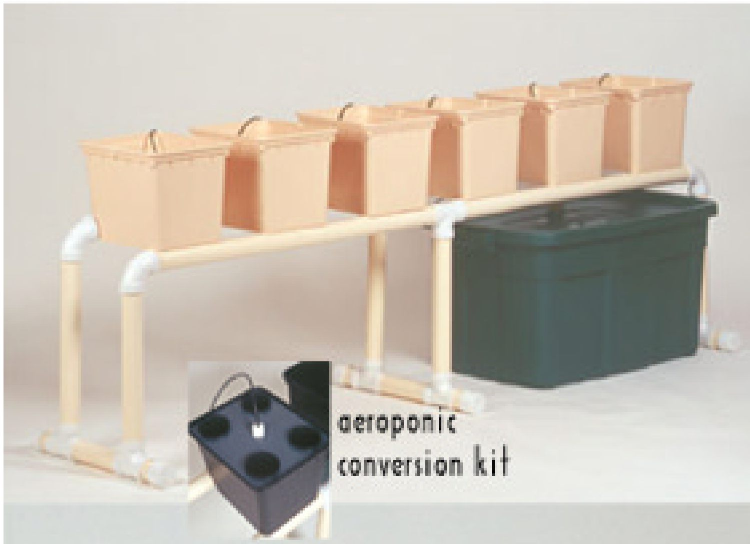


Conclusion

Hydroponics is rapidly gaining momentum and popularity as the best way to cultivate everything from flowers and food to medicine. In Europe, hydroponics is now widely accepted by consumers and is quickly catching on in other countries abroad. By now you should be well on your way to harvesting your first crop of hydroponic produce. I hope that I have answered all of your questions and provided you with a strong understanding of the hydroponic method. Please feel free to email me with any comments/suggestions and mistake I may have missed so I can make the proper corrections to this manual for future editions.

I may be contacted at kr@futuregarden.com and am always happy to answer your questions.

How-To Hydroponics garden completion kits



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