Lesson Five -Nutrient Requirements and Testing

Many hydroponic formulas have been developed over the past 40 years with some designed for specific plants while others are designed for general hydroponic gardening. For plant growth, the concentration of individual elements must stay within certain ranges that have been determined through scientific experimentation.

The average concentration of these elements should fall within these parameters:
Nitrogen (nitrate form) 70 -300 PPM
Nitrogen (ammonium form) 0 -31 PPM
Potassium 200 -400 PPM
Phosphorous 30 -90 PPM
Calcium 150 -400 PPM
Sulfur 60 -330 PPM
Magnesium 25 -75 PPM
Iron .5 -5.0 PPM
Boron .1 -1.0 PPM
Manganese .1 -1.0 PPM
Zinc .02 -.2 PPM
Molybdenum .01 -.1 PPM
Copper .02 -.2 PPM

*PPM = parts per million

Plant Uses of Individual Elements:

Careful experiments using hydroponics have shown that each of the elements a plant needs has a very specific function in plant growth.

Nitrogen:
Nitrogen is a component of proteins, which form an essential part of protoplasm and also occur as stored foods in plant cells. Nitrogen is also a part of other organic compounds in plants such as chlorophyll, amino acids, alkaloids and some plant hormones.

Sulfur:
Sulfur forms a part of the protein molecule. Plant proteins may have from .5- 1.5% of this element. The sulfhydryl group is a very important group essential for the action of certain enzymes and coenzymes. In additional sulfur is a constituent of ferredoxin and of some lipids.

Phosphorous:
This element is also a component of some plant proteins, phospholipids, sugar phosphates, nucleic acids, A TP and NADP. The highest percentages of phosphorous occur in the parts of the plant that are growing rapidly.

Potassium:

Potassium accumulates in tissues that are growing rapidly. It will migrate from older tissues to merestematic regions. For example, during the maturing of the crop there is movement of potassium from leaves into the fruit.

Calcium:
All ordinary green plants require calcium. It is one of the constituents of the middle lamella of the cell wall, where it occurs in the form of calcium pectate. Calcium affects the permeability of cytoplasmic membranes and the hydration of colloids. Calcium may be found in combination with organic acids in the plant.

Magnesium:
Magnesium is a constituent of chlorophyll. It occupies a central position in the molecule. Chlorophylls are the only major compounds of plants that contain magnesium as a stable component. Many enzyme reactions, particularly those involving a transfer of phosphate, are activated by magnesium ions.

Iron:
A number of essential compounds in plants contain iron in a form that is bound firmly into the molecule. Iron plays a role in being the site on some electron carriers where electrons are absorbed and then given off during electron transport. The iron atom is alternately reduced and then oxidized. Iron plays a very important role in energy conversion reactions of both photo synthesis and transpiration.

Boron:
Although the exact function of boron in plant metabolism is unclear, boron does playa regular role in carbohydrate breakdown. Symptoms of boron deficiency include stunted roots and shoot elongation, lack of flowering, darkening of tissues and growth abnormalities.

Zinc:
Zinc is essential to the normal development of a variety of plants. Large quantities of zinc are toxic to plants.

Manganese:
The importance of manganese as an activator of several enzymes of aerobic respiration explains some of the disruptive effects of a manganese deficiency on metabolism. The most obvious sign of a manganese deficiency is chlorosis. Manganese chlorosis results in the leaf taking on a mottled appearance.

Copper:
Copper is a constituent of certain enzyme systems, such as ascorbic acid oxidize and cyto chrome oxidize. In addition" copper is found in plastocyanin, part of the electron-transport chain in photosynthesis.

Molybdenum:
Molybdenum is important in enzyme systems involved in nitrogen fixation and nitrate reduction. Plants suffering molybdenum deficiency can absorb nitrate ions but are unable to use this form of nitrogen.

Hydroponic Nutrient Mixes

A gardener can purchase all of these minerals separately and mix their own hydroponic fertilizer. Unfortunately, the fertilizers that make up a hydroponic formula aren't sold as pure nitrogen or pure potassium, so it gets more complex. They are sold as chemical compounds, such as calcium nitrate, potassium nitrate, magnesium sulfate, potassium sulfate and mono potassium phosphate.

Since there are many dependable pre-mix hydroponic formulas available, it is generally more efficient and more economical to use a proven formula that contains all of the above mentioned nutrients in the correct quantities for plant growth. one that you simply add to water.

Whether you are using a pre-mixed formula or creating your own" it is important to follow these guidelines:

1. Weigh or measure the nutrients carefully.
2. Place the nutrients in separate piles or containers to be sure the proportions make sense.
3. Be sure no components are left out or measured twice.
4. Accuracy should be within 5 %.
5. When you are sure the proportions are correct, pour your nutrients into the water in the mixing containers and stir vigorously. Nutrients will dissolve best in warm water.
6. Measure the nutrient concentration level and record it.

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Nutrient Disorders

Nutrient	Deficiency	Excess
Nitrogen	Older leaves turn chlorotic and may eventually die. Plant is stunted Foliage is light green.	Plant becomes over vigorous, leaves become very dark green. Fruit clusters have excessive growth and fruit ripening is delayed.
Potassium	Older leaves appear chlorotic between veins, but veins remain green. Leaf edges may burn or roll.	Uncommon to show toxicity. Secondary manganese deficiency may occur.
Phosphorous	Stem, leaf veins, petioles turn yellow, followed by reddish-purplish as phosphorous is drawn from them into the new growth. Seedlings may develop slowly. Fruiting is poor.	No direct toxicity. Copper and zinc availability may be reduced.
Calcium	Plant is stunted. Young leaves turn yellow. Blossoms die and fall off. Tomatoes may develop brown spots on the fruit.	No direct toxicity.
Sulfur	Younger leaves become yellow with purpling at base. Older leaves turn light green.	Small leaves.
Iron	New growth pales, veins stay green. Blossoms drop off. Yellowing occurs between veins.	Very uncommon.
Magnesium	Older leaves curl and yellow areas appear between veins. Young leaves curl and become brittle.	No direct toxicity.
Zinc	Leaves become chlorotic between veins and often develop necrotic spots.	Reduces availability of iron.
Molybdenum	Older leaves turn yellow and leaf margins curl.	Rare. Tomato leaves may turn bright yellow.
Copper	Pale yellow. Leaves become spotted. Plant is stunted.	May reduce availability of iron.

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Deficiencies and Excesses
Since there is no soil to act as a buffer, your hydroponic crops will quickly respond to a nutrient deficiency or toxicity. Nutrient deficiencies are more common than excesses, with the most common deficiencies being nitrogen, iron and magnesium.

Deficiencies and excesses can be avoided by following a routine mixing procedure and schedule, daily monitoring of your nutrient solution and adequate feeding of the plants. If you have an extreme deficiency or toxicity, the plants will respond quickly and symptoms such as discoloration of foliage will occur. A minor deficiency or toxicity may not initially show symptoms but eventually will affect plant growth, vigor and/or fruiting.

Measuring Conductivity
Conductivity is a measure of the rate at which a small electric current flows through a solution. When the concentration of nutrients is greater, the current will flow faster. When the concentration of the nutrients is lower, the current will flow slower.

You can measure your nutrient solution to determine how strong or weak it is with an EC (electrical conductivity) or TDS (total dissolved solids) meter. An EC meter usually shows the reading in either micromhs per centimeter (uMho/cm) or microsiemens per centimeter (uS/cm). 1.0 uMho/cm is equivalent to 1.0 uS/cm. A TDS meter usually shows the reading in milli-grams per liter(mg/l) or parts per million (ppm).


EC Meter

EC is generally measured at 77 F (25 C). If the temperature of the solution is raised, the EC will read higher, even though no nutrients have been added. If the temperature drops below 77 F (25 C), the EC will decrease.
Therefore, it is important to always measure your EC at a consistent temperature of 77 F (25 C). Some EC and TDS meters compensate for varying temperatures.

Another measurement in conductivity is CF (conductivity factor) which is expressed on a scale of I -100. Pure water containing no nutrients is rated at 0 and maximum strength nutrients would rate 100.

Some general guidelines for EC levels are as follows:

	Fruiting Plants **(such as tomatoes, cucumbers)**	**Leafy Plants** **(such as lettuce, basil)**
Initial Growth (seedling stage)	1600 -1800 mMho/cm 1120 -1260 ppm	1400 -1600 mMho/cm 980 -1120 ppm
Average EC	2500 mMho/cm 1750 ppm	1800 mMho/cm 1260 ppm
Fruiting	2400 -2600 mMho/cm 1680 -1820 ppm	xxx
Low light conditions (winter)	2800 -3000 mMho/cm 2000 ppm	2000 mMho/cm 1320 ppm
High light conditions (summer)	2200 -2400 mMho/cm 1700 ppm	1600 mMho/cm 1120 ppm

In low light conditions (winter), a hydroponic grower should increase the concentration of nutrients in solution in a hydroponic garden. In high light conditions (summer), a hydroponic grower should decrease the concentration of nutrients in solution in a hydroponic garden.

Salt Build-Ups

When a plant uses a nutrient from a chemical "salt" molecule supplied in a nutrient solution, it is actually using only one part of that molecule. The remaining part of that molecule generally stays in the hydroponic system and eventually can reach damaging levels of concentration.

This process, which often happens in traditional agriculture where heavy fertilizer concentrations are applied to soil crops, is referred to as salt-build up. By testing our nutrient solution daily. we can monitor the salt levels. If the salt levels are rising. the concentration will be higher and therefore our EC reading will be higher. In our hydroponic system, it is quite easy to resolve the problems associated with salt build-up by flushing the growing medium or replacing our nutrient solution with a fresh mix.

In the soil, once salt concentrations reach toxic levels, it is difficult to correct and often makes what was once excellent farm soil unusable. The problem is exacerbated by the salts being washed and flushed into our waterways, rivers and streams where they are also toxic to fish, birds and other wildlife.

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Hydroponic Garden Nutrient Monitoring:
-To ensure that your plants are being fed the proper nutrients and nutrient concentrations, it is important to monitor your nutrient solution.

On a daily basis you should test the nutrient solution and record the results

- EC (Nutrient concentrations)
- PH (acidity / alkalinity...see Lesson 4 for more information on PH)
- Temperature of nutrient solution
- Daytime room temperature
- Nighttime room temperature

It is also important to record when you replace your nutrient solution so you can easily determine when it should again be replaced.

In addition to these tests, you may also want to record the stage of plant growth, the size of your plants and any problems or significant changes.

Recording this information gives you an accurate accounting of what is happening with your plants. This data is an excellent tool for diagnosing problems, should they arise.

Advanced Nutrient Testing
Neither an EC or TDS meter can indicate precisely what nutrients make up the fertilizer solution. More complete test kits are available for this purpose. Many commercial growers test their nutrient solutions on a regular basis to ensure they are feeding exactly the mix that is intended. Regular leaf analysis is an excellent tool for determining the health of your plants. Leaf tissue samples are dried, crushed and analyzed to determine the exact nutrient content.
Most of the more complex kits will test nitrogen, potassium, phosphorous and sulfur. Commercial labs offer more precise results. In the event of a combination of nutrient deficiencies, the symptoms of one problem may mask the symptoms of another. A leaf tissue analysis may be the only way to determine what is wrong with your plants.

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Month: *July*

Example of Data for Hydroponic Tomato Garden

Date	EC	pH	Sol. Temp	Day Temp	Night Temp	Growth Stage	Size	Comments
1	*1800*	*6.0*	*74 F*	*76 F*	*70 F*	*Seed*	-	*Planted seeds*
2	*1800*	*6.0*	*74 F*	*76 F*	*70 F*	*Seed*	-	
3	*1800*	*6.0*	*74 F*	*78 F*	*70 F*	*Seed*	-	
4	*1800*	*6.0*	*74 F*	*78 F*	*70 F*	*Seed*	*0.0"*	*Seeds Germinated*
5	*2000*	*6.0*	*70 F*	*78 F*	*68 F*	*Seedling*	*0.5"*	*Leaves emerge*
6	*2050*	*6.0*	*70 F*	*78 F*	*68 F*	*Seedling*	*0.9"*	
7	*2100*	*6.0*	*70 F*	*79 F*	*67 F*	*Seedling*	*1.0"*	
8	*2150*	*6.0*	*70 F*	*78 F*	*68 F*	*Seedling*	*1.5"*	
9	*2200*	*6.0*	*70 F*	*79 F*	*69 F*	*Seedling*	*2.0"*	*2nd leaves appear*
10	*2400*	*6.0*	*70 F*	*77 F*	*68 F*	*Seedling*	*2.3"*	*Replace nutrient solution*
11	*2400*	*6.0*	*70 F*	*80 F*	*67 F*	*Seedling*	*2.6"*	
12	*2450*	*6.0*	*70 F*	*79 F*	*66 F*	*Seedling*	*3.0"*	
13	*2450*	*6.0*	*70 F*	*80 F*	*68 F*	*Seedling*	*3.5"*	
14	*2500*	*6.0*	*70 F*	*80 F*	*69 F*	*Seedling*	*4.0"*	*Rapid growth*
15	*2500*	*6.0*	*70 F*	*80 F*	*67 F*	*Seedling*	*4.5"*	
16	*2500*	*6.0*	*70 F*	*79 F*	*68 F*	*Seedling*	*5.0"*	*Yellowing leaves*
17	*2500*	*6.0*	*70 F*	*77 F*	*70 F*	*Seedling*	*5.5"*	
18	*2400*	*6.0*	*70 F*	*80 F*	*69 F*	*Vegetative*	*6.0"*	*Replace nutrient solution*
19	*2400*	*6.0*	*70 F*	*78 F*	*69 F*	*Vegetative*	*6.8"*	*Yellowing gone*
20	*2450*	*6.0*	*70 F*	*80 F*	*68 F*	*Vegetative*	*7.6"*	
21	*2450*	*6.0*	*70 F*	*79 F*	*69 F*	*Vegetative*	*8.0"*	
22	*2500*	*6.0*	*70 F*	*77 F*	*67 F*	*Vegetative*	*8.8"*	*Rapid growth*
23	*2500*	*6.1*	*70 F*	*80 F*	*68 F*	*Vegetative*	*9.6"*	
24	*2500*	*6.1*	*70 F*	*79 F*	*70 F*	*Vegetative*	*10.2"*	
25	*2500*	*6.1*	*70 F*	*80 F*	*69 F*	*Vegetative*	*11.0"*	
26	*2500*	*6.0*	*70 F*	*79 F*	*69 F*	*Vegetative*	*11.6"*	
27	*2600*	*6.0*	*70 F*	*77 F*	*68 F*	*Vegetative*	*12.0"*	*Replace nutrient solution*
28	*2600*	*6.0*	*70 F*	*80 F*	*69 F*	*Fruiting*	*12.5"*	*buds appear*
29	*2600*	*6.1*	*70 F*	*79 F*	*67 F*	*Fruiting*	*13.0"*	
30	*2650*	*6.1*	*70 F*	*80 F*	*68 F*	*Fruiting*	*13.5"*	
31	*2700*	*6.1*	*70 F*	*79 F*	*70 F*	*Fruiting*	*14.0"*	*First flower opens*

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Record of Data for Hydroponic Garden

Date	**EC**	**p H**	Temperature	Growth Stage	**Size**	**Comments**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
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31						

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Lesson Six -Seed Germination
Planting Your Garden

When your hydroponic system is built, your pumps and timers have been tested and are functioning properly and the nutrient solutions are mixed and tested, you are ready to plant your garden.

Plants that have been raised in soil can be transplanted in a hydroponic garden if the roots are thoroughly rinsed of all soil and organic material but there is always a risk of introducing pests and disease from the nursery where the plants were propagated. There is also a strong possibility that the plants have been overcrowded, over or under watered and generally stressed.

Growrocks

By starting your plants from seed, you have the most control over the initial development of your crop. As a general rule, seeds are free of pests and disease. If you start your seeds in a hydroponic system, there is no transplant stress or shock and minimal chance of disease.

A seed needs moisture and warm temperatures to germinate, which can be provided in your hydroponic garden, or in a system designed for propagation.

Direct seeding into the hydroponic garden is a common method of propagation. Direct seeding works well in perlite, rockwool or any other medium that is fine enough not to loose the seed in. It is important to thoroughly moisten your growing medium prior to seeding.

To seed directly into perlite (or a similar medium) sprinkle the seeds on the moistened perlite and cover with a thin layer of perlite to keep the seeds from drying out. Follow the directions on the seed packet for planting depth.

Rockwool is most often used in the form of cubes for seed propagation. To plant seeds in rockwool, soak the cube in water or nutrient solution and drop the seed into the hole in the center of the rockwool cube. Many growers seed into rockwool cubes and, when the seedling develops, move the whole cube with the plant in it, into the hydroponic garden. A seedling in a rockwool cube can easily be transplanted into an NFT, ebb and flow or drip system.

Lettuce plant emerging from a rockwool cube.

Once seeded the growing medium will need to be flushed on a regular basis to keep it moist. You can initially use water for germination, right up to the point that the seed coat cracks open and the radical root is exposed. At that point you have a seedling rather than a seed, which will need water, nutrients, light and warmth. The frequency of flushing your growing medium depends on the type of medium you choose. If you are using perlite or rockwool, it will probably need to be flushed every 2 or 3 hours. The medium and the seeds need to be moist.

Controlling temperature is important for good seed germination. Some growers will start their seeds in an incubator, propagation table or similar device to maintain the ideal temperature throughout the germination process. If proper temperatures are not maintained, germination will be delayed or may not happen at all. If you are using an incubator or propagation table, you can seed directly into the growing medium.

When you plant seed for your hydroponic garden, you should over seed by 25 % -50 %. Once your seeds have developed into seedlings, you can select the strongest plants and keep them. The weaker plants can be removed by pinching the plant off at the base. Pulling the plant out will disturb the roots of the plant that you are keeping.

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The Germination Process:
(see diagram on page 6-3)

The initial stages of plant growth happen within the seed coat.
As the seed absorbs water, growth begins with cell enlargement. In the presence of water, the stored reserves within the seed are converted chemically to substances that can be readily used in the growing process.

Once the seed coat breaks and the radical root comes out, the seedling will need to draw moisture and nutrition from the medium surrounding it.

Several days after the root has emerged, the shoot begins to grow. In the presence of light, the seed leaves (cotyledons) open. The opening of the first foliage leaves will follow.

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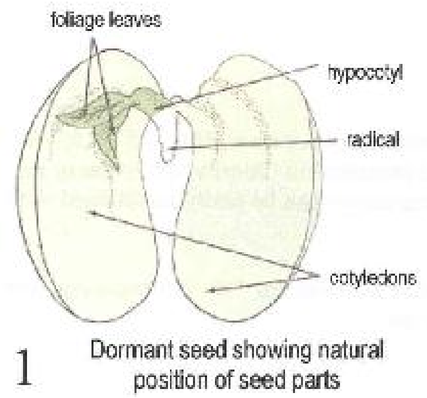
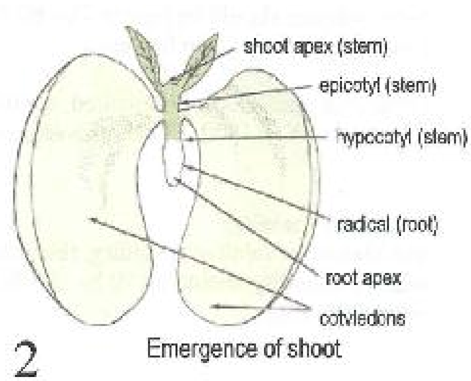
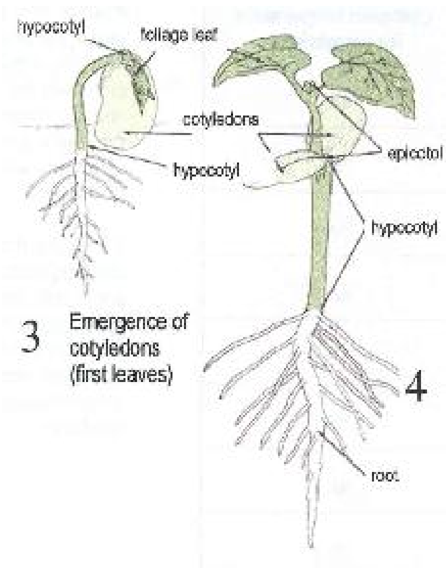
LESSON SIX
Seed Germination 6 -3

Germination Process

Sample of a Bean Seed







Seeding with first foliage leaves

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Germination Requirements:

Moisture:
Saturate your growing medium with water or nutrient solution with a pH of 5.5 - 6.5. Be sure to keep the growing medium moist throughout germination. Ideally, the water or nutrient solution should be kept at 75 -80 F. This temperature can be easily maintained with a submersible aquarium heater.
Once your plants have germinated, a nutrient solution with a pH of 5.5 - 6.5 and a nutrient concentration of 1800 - 2000 umhos/cm should be fed.

Relative humidity:
The higher the relative humidity, the greater the absorption of water by the seed. Ideally , relative humidity should be 70 % -80 % in the air around the media and near 100 % right around the seed.

Ideal temperatures: Bottom heat is advantageous for propagation. Heated propagation mats are made for this purpose and are often incorporated into incubation chambers and propagation tables.

Providing the ideal ambient temperature for your seeds will encourage quick germination. The chart below shows optimum germination temperatures for a variety of plants.

Crop	Optimum temperature for germination
Carrots	86 F
Cucumbers	76 F
Lettuce	76F
Melons	90F
Parsley	77 F
Peas	76 F
Radishes	86 F
Tomatoes	78

Light
(see Lesson 7 for more information on lighting):
The first few days of seed germination (the time prior to the radical root emerging) can take place in the dark. After that time, light must be provided. If proper light is not provided, a plant will grow tall and spindly as it reaches for the light. This is often referred to as "stretching." Young plants will quickly do this. For seedling growth, having at least 500 foot candles of light is required. This can be either natural or artificial light. If artificial light is used, set a timer that turns the light on for 16 hours and off for 8 hours of each day. Plants do need darkness as part of their daily cycle, so do not leave the light on all of the time.

Choosing What Plants To Grow
When choosing the plants you will grow in your hydroponic garden, you should choose plants that have similar needs to grow together. For instance, a tomato and cucumber plant have similar needs in temperature, light and nutrient requirements. Lettuce and basil also have like needs.
Since your garden can hold a limited number of plants, be sure to plan what you will grow prior to planting. Schedule regular seeding for plants like lettuce and radishes for a continuous harvest.

Basil:
Basil is a fast growing, hardy herb that is an excellent choice for a hydroponic garden. Once a basil plant is 12 -18 inches tall, cuttings can be taken. Remove any flowers or buds to encourage continuous leaf production. A basil plant will produce fresh growth for 3 -4 months and then should be removed from the system and replaced with a new plant.

Like needs: lettuce, spinach
Days to germinate: 6 -10

Beans:
Beans do well in a hydroponic garden. They grow rapidly and produce high yields. Beans will grow well in an Ebb and Flow system with a loose growing medium such as perlite or expanded clay pebbles.

If climbing beans are planted, you will need a trellis for support. Beans will generally produce in about 6-8 weeks, with total time in the garden about 3-4 months.

Like needs: peas
Days to germinate: 3 -8

Broccoli
Broccoli, like cabbage or cauliflower, likes cooler temperatures. If these are crops you want to grow, they should be grown together in an area where cooler temperatures can be maintained. Broccoli is slow to germinate and develop. Time from seed to harvest is about 4 months.

Like Needs: cabbage, cauliflower

Carrots:
Carrots, and other root crops will do well in a hydroponic garden as long as they have a large enough grow bed to mature and fully develop. A loose growing medium, like perlite, works best for root crops.

Carrots will be ready to harvest in about 2-1/2 -3 months.

Like needs: radishes, beets, leeks
Days to germinate: 6 -10

Cucumbers:
Their rapid growth and high productivity make cucumbers an excellent choice for a hydroponic garden. The European seedless varieties are great tasting and easy to grow. These varieties will produce cucumbers at about 6 weeks and continue to grow up to 6 months. Being along term crop, cucumbers will do best in a drip system with perlite or rockwool as the growing medium.

Pick the cucumbers regularly to encourage continuous production.

Plant support will be needed for cucumber plants. The cucumber plant will be quite large so provide adequate space if you choose to grow them.

Like needs: tomatoes, peppers
Days to germinate: 3 -5

Lettuce:
Lettuce and leaf crops do very well in a hydroponic garden. Leaf lettuce generally will do better than head lettuce. Lettuce will grow best in an NFT system, but will also grow in an ebb and flow or drip system.

Most lettuce varieties will be ready for harvest in 35- 45 days.

When harvesting, you can remove just the leaves you need or you can harvest the whole plant. If you are harvesting the whole plant, remove the root ball with the plant and refrigerate to store.

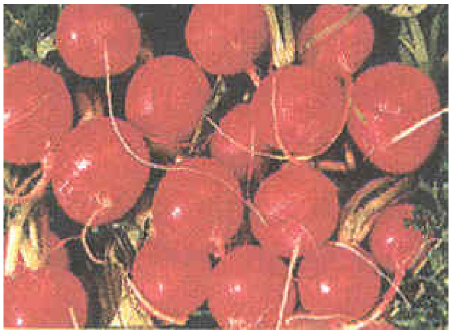
Seed lettuce every few days for a continuous supply.

Like needs: basil, leaf crops, spinach
Days to germinate: 4 -8

Peppers
Any kind of pepper, hot or sweet, will do well in hydroponics. The only draw back is that it may take up to 4 months to harvest. The best growing system for peppers is a drip system. They will also do well in an ebb and flow system.

There are many varieties of peppers available in a wide range of colors and flavors.

Like needs: tomatoes, cucumbers
Days to germinate: 10 -14



Radishes:
Radishes will do well in hydroponics as long as they have a grow bed deep enough to accommodate their growth. Radishes germi- nate and grow very quickly. Most radish varieties will mature in 30 -40 days. Continuous planting will give you a steady supply.
Radishes will do well in an ebb and flow or drip system with perlite or expanded clay pebbles as the growing medium.

Like needs: carrots, beets, leeks
Days to germinate: 2 -5

Spinach:
Spinach grows well in a hydroponic garden. An NFT or ebb and flow system will both produce good results.

Spinach is slower to germinate and grow than lettuce, with harvest at approximately 50 -60 days.

Spinach leaves can be harvested as you need them or, like lettuce, the whole plant with the root ball intact can be harvested. Seed often for a continuous supply.

Like needs: lettuce, basil
Days to germinate: 6 -12

Strawberries:
Strawberries will grow quite well in a hydroponic garden. Most of- ten, you will find strawberry shoots rather than seeds. These shoots can be transplanted into your garden but be sure they are free of pests and disease and then wash the roots thoroughly to remove all soil and organic debris.

Tomatoes:
Tomatoes are the most popular commercial hydroponic crop.
Most commercial growers grow full size, indeterminate varieties. These varieties will bear fruit in about 100 days and continue to produce up to a year. There are miniature tomato varieties available that are perfect for a smaller hydroponic garden.

A drip system is the best method of growing tomatoes in a hy- droponic garden but they will also grow in other systems.

If you are growing tomatoes indoors, you may need to pollinate the individual flowers for fruit set to occur. This can be achieved by vibrating the flower or flower truss. As a tomato plant develops, plant support will be needed.

Like needs: cucumbers, peppers
Days to germinate: 3 -6

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Lesson Seven -Light

Transpiration and Photosynthesis

Plants require a constant supply of energy to grow and this energy comes from light. In nature, plants receive light from the sun. In a classroom, you may need to add artificial light so your plants have an adequate amount of light to grow.

There are various types of artificial lights that provide differing light spectrums. Before learning about these artificial lights, it is important to understand how plants use light in the growth process.

Transpiration and photosynthesis are the two major processes that are carried out by green plants that use energy from the sun. Both of these processes use large amounts of light energy but. only in photosynthesis is a significant amount of energy from light actually stored for future use. Light influences other processes such as flowering, seed germination, certain growth stages and pigment production but, in these cases, only very small amounts of energy from light are used.

During the transpiration process, plants draw in carbon dioxide from the air through their pores and water from their roots and give off oxygen and water vapor. Energy from the sun evaporates water from the plant cell walls. Although this results in a movement of water in the plant tissue (xylem). this energy is neither stored nor used to bring about vital reactions involved in the synthesis of foods, in assimilation, growth or reproduction.

In photosynthesis, which literally means "putting together (synthesis) by means of light (photo)," water is drawn up through the stem from the roots and into the leaf tissue where the chloroplasts, containing chlorophyll (a green pigment) can be found. There the water encounters carbon dioxide which entered the leaf from the air through minute breathing pores (stomata) located abundantly on the underside of the leaves. The stomata also permits the outflow of water vapor and oxygen. The light, carbon dioxide and water produce carbohydrates which are stored in the plant and later released as energy for other vital plant functions.

Energy stored as chemical energy in foods (carbohydrates, fats, proteins) is continually released in living cells during the process of respiration. Basica1ly, photosynthesis stores energy and respiration releases it. enabling cells to perform the work of living. By releasing energy, respiration provides the energy needed for all other plant functions.
All animals ultimately depend on photosynthesis because it is the method by which all basic food is created.

Light Spectrums

White light, as it comes from the sun, is composed of waves of red light, through successively shorter waves to violet light. The band of colors that compose the visible spectrum of light (that which we can see) include, starting with the longest rays, red, orange, yellow, green, blue, indigo and violet. The visible spectrum represents only a part of the radiant energy that comes from the sun and only a part of the visible spectrum is effective in photosynthesis.

Wavelengths exist that we our unable to perceive with our eyes. Beyond the red rays are still longer rays called infrared and beyond the violet rays are even shorter rays called the ultraviolet.
The fact that chlorophyll is green to the eye is evidence that some of the blue and red wavelengths of white light are absorbed, leaving proportionally more green to be transmitted, reflected and seen.

Much of the red, blue, indigo and violet wavelengths are absorbed and used in photosynthesis while part of the red and most of the yellow, orange and green are barely used in photosynthesis.

Signs of Light Deficiencies:

- plants will stretch and reach toward the light source
- stem elongation
- plant deformities
- no fruit set

Artificial Lighting
If your hydroponic garden is in direct sunlight, the plants should receive adequate amounts of light and absorb the spectrums they need.

In a greenhouse setting, supplemental light is sometimes used to extend the hours of light a plant receives during low light conditions (cloudy weather or short days), and to extend the growing season of a plant. If you are growing in an area with some, but limited sunlight, such as a windowsill, supplemental lighting will be needed.

Any supplemental light is beneficial to increase plant growth and production. The higher the intensity and the broader the spectrum, the greater the benefit.

You can grow in a completely enclosed space with no natural light if you provide all artificial light but there are several drawbacks including the cost of the lights and the energy to run them is high, there may be a compromise of the plants needs if the artificial lighting does not provide the complete light spectrum the plant needs and artificial lighting will not exactly duplicate the spectrum of light the sun provides.

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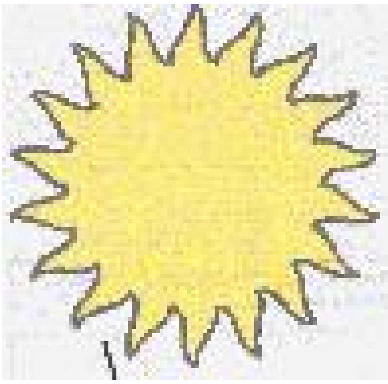

Photosynthesis and Transpiration

Energy (light) comes from the sun

Photosynthesis:
Leaves make food (carbohydrates), water and oxygen from sunlight, carbon dioxide and water.

Transpiration:
Leaves draw in carbon dioxide from air through pores and give off water vapor and oxygen.

Plants draw water from the soil or growing medium.

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Light Spectrums

Wavelength	Visible to the human eye	Used in pho-tosynthesis	Used in flowering
Infrared (longest rays)			
Red	X	X	X
Orange	X		X
Yellow	X		X
Green	X		X
Blue	X	X	
Indigo	X	X	
Violet	X	X	
Ultraviolet (shortest rays)			

Plant Light Needs:
Plants have differing needs for light and, as a general rule, most fruiting crops need more light when they are in a fruiting stage than when they are in a vegetative stage.

The chart below shows a variety of crops and their individual light needs.

Crop	Light Needs
Beans	Medium - High
Beets	Low
Broccoli	Medium - High
Cabbage	Low -Medium
Carrots	Low
Cauliflower	Medium -High
Cucumber	High
Lettuce	Low
Melons	High
Peas	Medium - High
Peppers	High
Radishes	Low
Onions	Medium - High
Spinach	Low
Tomatoes	High

Various crop Light Needs

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Lamp Placement:
When lighting your plants, the proximity of the lamp to your plants is directly related to the intensity of the light provided. The closer the lamp, the more intense the light. When you raise your lamp, the intensity is lessened. It is important not to have your lamp so close that it burns the plant leaves.

Increased light coverage can be achieved by installing a light mover that will rotate your light. You can also use reflective paint or reflective surfaces (aluminum foil, for instance) surrounding the growing area to increase light.

Types of Lights for Plant Growth
HID (High Intensity Discharge) lights are the common choice for supplemental lighting in a large space such as a greenhouse. They are the most efficient and very intense. Metal halide, mercury vapor and high pressure sodium lights are examples of high intensity discharge lights.

If you are growing in an area that has some natural light, such as in a windowsill, you can probably light it with a less intense light. Fluorescent tubes will likely provide the additional light that you need.

Fluorescent lights will also be adequate for propagation of seedlings, plant cuttings and some low-light house plants.

In a grow room without noticeable natural light, HID's are necessary to provide ample light for plant production. High Intensity Discharge lights can create an excessive amount of heat.
When using HID's, ventilation and cooling may be necessary. Vented reflector hoods are available for this purpose. Also keep in mind that HID's require high amounts of electricity and are more costly to run than most other types of lights.

Incandescent Light:
Although some supplemental light is better than none, incandescent light offers the lowest level of intensity and is generally better used as a room light than a plant light.

Specialty incandescent grow bulbs are available and will provide a better light spectrum than a standard incandescent bulb but the intensity is still limited.

Standard incandescent bulbs are high in the red spectrum but low in the blue spectrum which most plants need for vegetative growth.

Incandescent bulbs are inexpensive to initially buy but they are generally not efficient or effective for plant growth.

Fluorescent Light:
Fluorescent tubes offer a broader color spectrum and are available in a variety of kinds including

bright white. cool white. warm white. plant bulbs. daylight and full spectrum. The combination of warm and cool white offer a broad light spectrum.

Fluorescent bulbs are relatively inexpensive, long-lasting and provide even, cool lighting.

The down-side to fluorescent lights is that they are low in intensity and need to be very close to the plants to be effective. Seedlings, cuttings and most house plants will benefit from fluorescent lighting.

Metal Halide Light:
Metal halide lights offer a broad spectrum with ample blue light for vegetative growth. The metal halides are more efficient than Mercury Vapor lights. which at one time. were the primary source of HID light.

Metal halides are one of the best light sources for plant growth and, if you were using only one type of light, metal halide would be the best choice.

High Pressure Sodium Light:
High pressure sodium lights are very efficient. They are long lasting and strong in the yellow- red spectrums. Their only disadvantage is that they aren't quite strong enough in the blue spectrum for vegetative development.

The high pressure sodium lights are a good choice for flowering plants. The combination of metal halide and high pressure sodium offers the broadest light spectrum and must be used in situations where no natural light is found.

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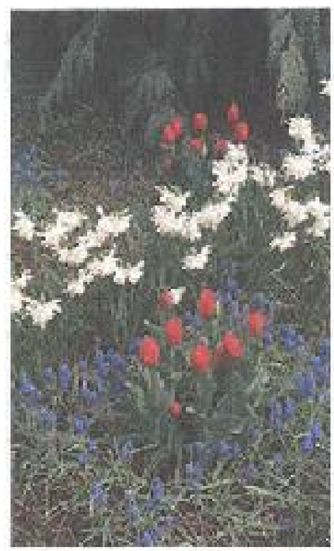
What is Botany?

Botany is the study of plants. It is divided into many areas including:

- *plant taxonomy* (identifying, describing and classifying plants)
- *plant geography* (the location of certain plants)
- *ecology* (studies the relationship between plants and the environment)
- *paleobotany* (the study of ancient plants)
- *phytopathology* (the study of plant disease)
- *economic botany* (how plants can be used as products)
- *plant morphology* (the structure of plants)
- *plant physiology* (the function of plant parts)
- *plant crytology* (the study of plant cells and their parts)
- *plant anatomy and histology* (the internal structure of plants)

As you can see, botany is a very broad subject and one that we can only scratch the surface of in this lesson where our focus will be on an introduction to *plant morphology* and *plant physiology*. In Lesson Ten you are introduced to *economic botany*.

What makes a Plant "a Plant"?
In the five-kingdom classification system, plants are considered multi-cellular (having multiple cells) and eukaryotic (having a membrane around the nucleus of each cell). In addition, plants have light-absorbing molecules (chlorophyll) and a number of cartenoid pigments. Plants store food in the form of carbohydrates and their cell walls are made mostly of cellulose.
Plants are necessary for the continuation of life on Earth because they are an integral part of the food chain, supplying both energy and oxygen for more complex life forms. Plants are found everywhere except the polar zones, the highest mountains, the deepest oceans and the driest parts of the deserts.
It is estimated that up to 90% of the living mass on Earth is made up of plants. There are an estimated 400,000 species of plants with Columbia, Equador and Peru having more plant species than any other collection of countries in the world.


A *variety* of *plants*

The parts of a flowering plant include:

The Stem
The stem produces and supports new leaves, branches and flowers and keeps these parts in effective positions to receive light, water and warmth. The stem's main function is to transport water and nutrients to and from the roots. In some cases it may also contribute to the reproduction of the plant, store food or help in photosynthesis.

The Root
The root of a plant is what anchors the plant in the soil and absorbs nutrients and water. In hydroponics, the root mainly serves only to absorb the nutrients and water we feed them. Roots range from a single large root, the tap root, to a mass of smaller, similar sized roots. The roots penetrate the soil or growing medium by cell division and elongation of the cells just behind the tip.
In a hydroponic growing system, the plant's root system will be much smaller than if it were grown in soil. Since the purpose of the roots are to seek out and absorb the nutrients and water and a hydroponic solution provides exactly what the roots are looking for, they do not need to develop an extensive root system.

The Leaf
As we learned in Lesson Seven, leaves are the plant's means of intercepting light, obtaining and storing water and food, exchanging gases and providing a site for photosynthesis.

The Flower
The flower of a flowering plant is the sexual reproduction unit that produces and houses the sex cells (gametes). Flowers also attract pollinators (e.g. insects and birds) that carry pollen from the stamen and fertilize other plants.

The Fruit
The fruit aids in the dispersion of the plant's seeds. After fertilization, the ovary begins to develop into a fruit, the ovules into seeds. The seeds are carried off and will, if conditions are right, eventually germinate and start a new plant. Seeds are dispersed in several different ways: Light seeds, such as dandelions, can be carried by the wind. Birds are attracted to some fruits and, after eating the fruit, leave seeds in their droppings. Some seeds are barbed and easily stick to unsuspecting passersby (usually animals). Eventually, the seed is scratched off or falls off. Some seeds will drop from the plant in a high wind or when shaken.


Fruit

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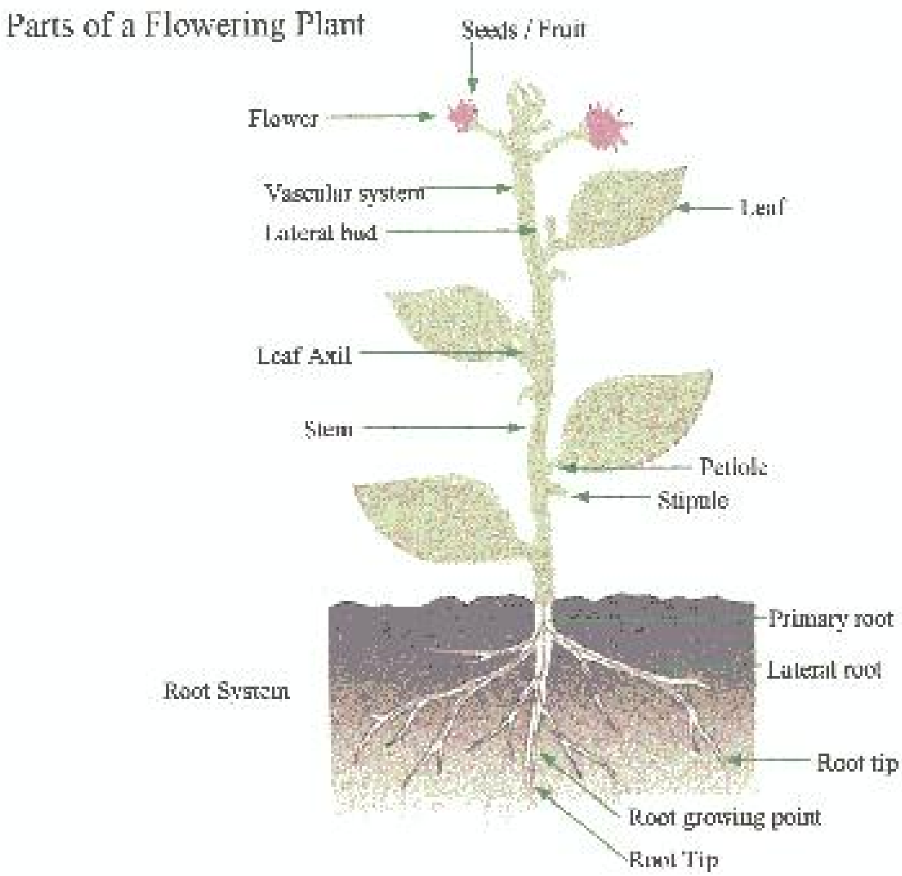
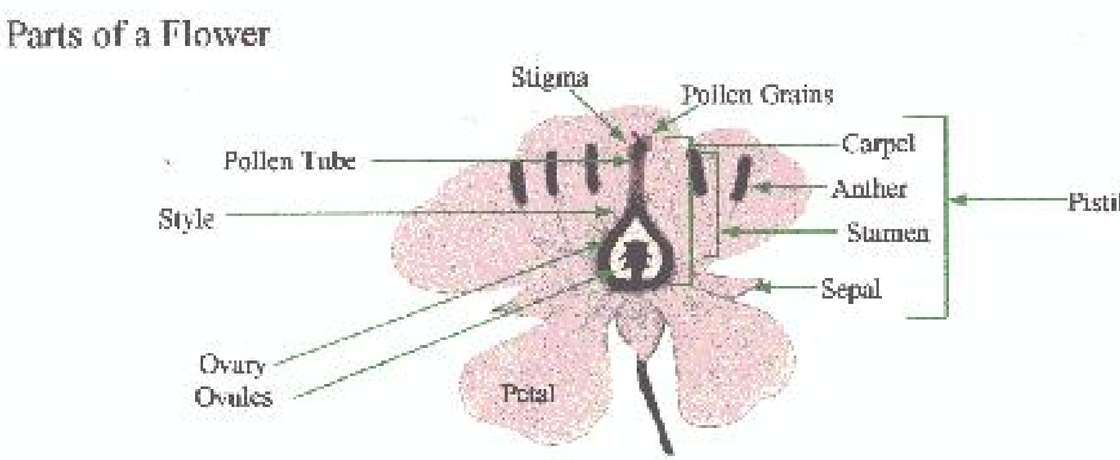

Parts of a Flowering Plant
Seeds / Fruit
Flower
Vascular system
Lateral bud
Leaf
Leaf Axil
Stem
Petiole
Stipule
Primary root
Lateral root
Root System
Root tip
Root growing point
Root Tip


Parts of a Flower
Stigma
Pollen Grains
Carpel
Pollen Tube
Anther
Pistil
Style
Stamen
Sepal
Ovary
Ovules
Petal

Categories of Plants

Plants fall into different categories, determined by the plant's life cycle in the environment.

Type	Life Cycle
Annual	An annual plant (also known as "determinate") completes its life cycle within one growing season-from germination of a seed through growth, flowering, production of seeds and death.
Biennial	A biennial plant has a natural life cycle of two growing seasons. The seed is sown in the first year and the plant grows, usually with vegetative growth. The second year, it flowers and dies.
Perennial	A perennial plant (also known as "indeterminate") lives for a number of years and flowers each year.

There are other divisions of plants based on their hardiness.

Type	Characteristic
Tender	Sensitive to the cold (can be annual, biennial or perennial)
Hardy	Able to withstand frosts (can be annual, biennial or perennial)

Plant Reproduction:

Plants reproduce by sexual or asexual reproduction or both depending on the species. One of the most important factors that aid in plant growth and reproduction is the availability of nitrogen (N_2).

Sexual Reproduction
Seeds are the focus of sexual reproduction in plants. As a seeded plant grows, it holds an egg within and when the plant matures, the egg is fertilized by pollen from itself or another plant. Fertilization from other plants usually takes place by the transfer of pollen grains which can be carried by the wind, insects, bees, birds or animals. The fertilized egg (zygote) remains in the plant and eventually becomes a seed ready to produce another plant.

Asexual Reproduction
Asexual plant reproduction requires only one organism. There is no change in the chromosome number if a new plant is separated from the parent plant. Single cell division in asexual reproduction does not change the chromosome number. The new plants have the same genetic structure as the parents.

Asexual reproduction includes plants that grow from bulbs (such as tulips), feelers (such as crabgrass) and rhizomes (underground stems). Branches grafted to trees (such as certain types of oranges and grapes) can also be classified as asexual reproduction. Single celled plants (such as algae) also reproduce asexually by ordinary cell division.

Plant Growth Stages for Fruiting Plants:

All flowering plants go through the basic growth stages: seedling, vegetative, early fruiting and mature fruiting. As the plant passes from one phase to another, there are not clear demarcations between the phases. In fact, there is usually overlapping from one to the next.

Seedling

When a seed has germinated and the cotyledons (first leaves) emerge, the shoot begins to grow and the plant enters the seedling stage. During this time, providing exactly the right environ- mental conditions and nutrient diet is critical to the well-being of your plant. A healthy seed- ling will be deep in color and will quickly develop new leaves. The stem will grow strong to support the weight of the plant.

An unhealthy seedling will be pale in color and, often, the stem will be weak or break off all together.

The growing conditions under which seedlings are grown affects the fruiting and health of the crop for its entire life.

In a hydroponic system, the seedlings are usually fed a weaker nutrient solution than a mature plant.

Vegetative

The vegetative stage begins when your plants are quickly developing their leafy mass and often continues throughout the plant's life. In fruiting plants, it is important to build a strong plant prior to the development of the first flowers.

The nutrient solution that is being fed to the plants is usually increased to a stronger solution with a higher percentage of nitrogen in the vegetative stage. The vegetative stage is quite demanding of Nitrogen.

Early Fruiting

The early fruiting stage begins when the first buds appear on a plant. At this point, specifically with tomato plants, the nutrient concentration is again increased to a stronger solution but the percentage of Nitrogen is decreased.

Mature Fruiting

The mature fruiting stage begins when your fruit begins to ripen. Depending upon the variety of plant and whether or not it is determinate or indeterminate, this stage can last from one month to several years. With an indeterminate variety (which is what most commercial hydroponic tomato growers grow) it is important to balance the vegetative growth with the fruiting. Too much vegetative growth will halt fruiting and produce an unruly plant. Too heavy of a fruit load will result in the plant halting new flower production until the fruit load in lessened resulting in uneven harvesting.

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Lesson Nine - Biological Pest Control

Many gardeners and consumers are concerned with the quality, purity and safety of the food they eat. With soils becoming tainted and water sources polluted, it is a valid concern. In the farming industry, use of pesticides and herbicides has grown for years as farmers have attempted to control the pests and weeds that challenge their crops.

With consumers demanding safer produce, there has recently been an active movement away from excessive pesticide use. One way to achieve this is by the use of Biological pest controls rather than chemical pest controls. Biological controls consist of insects, mites and micro-organisms which, as natural enemies, keep pests under control.

Many commercial hydroponic growers who produce their crops within a controlled environment greenhouse exclusively use biological controls for problem pests. When bringing biological controls or beneficial insects into the greenhouse a natural balance can be achieved. It is possible to control pests in an open field with biological means but it is not as effective as within a greenhouse or other closed environment.

Virtually all insects have a predator or enemy and that is what makes biological control work. There are insectaries (facilities that raise insects) throughout the US and Worldwide that breed and sell beneficial insects. Beneficials are shipped as eggs, larvae or adults and are usually sent overnight to the user who quickly distributes them to the problem areas.

In the world of beneficial insects, there are predators and parasites. Predators will actually consume the pest insect. A lacewing is a good example of a predator. Lacewings are welcomed in most gardens because they are know for their voracious appetite and broad diet of various insects.

Leaf Miner
Pest Insect

A parasite is an insect that lays its eggs within the egg sack of another insect, displacing or consuming the eggs that were there. The Larvae that emerge from the egg sack are those of the parasite, not it's victim.

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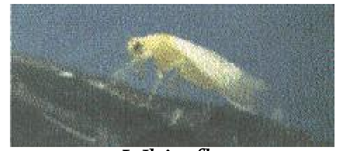
Garden Pests and Their Biological Controls

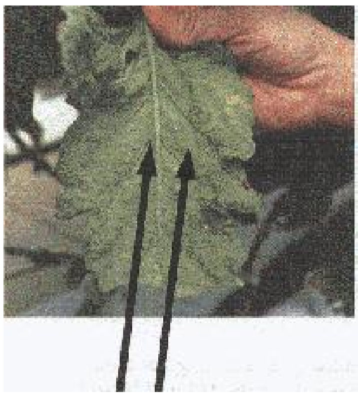
Pest:

Whitefly:

Whitefly are an extreme problem for greenhouse growers, field and orchard crop farmers and home gardeners. The *whitefly* sucks large quantities of sap from the plant and secretes the sugars as honeydew. This makes the leaves sticky and susceptible to fungal growth and rot. In a serious infestation, the fungus and rot associated with the honeydew can kill an entire crop in a matter of weeks. In addition, whitefly can pose a great threat to plant health because they are able to transmit many plant viruses.



Whitefly



Whitefly eggs on the underside of a *tomato leaf*

A *whitefly* looks like a small white moth, 1/8" in length. They rest on plant leaves and will quickly fly away when disturbed.

Whitefly lie their eggs on the under side of a leaf. Shiny, sticky leaves are signs of *whitefly* presence.

Biological Control:

Encarcia Formosa.

This tiny parasitic wasp lays its eggs in the larvae of the whitefly. Parasitized larvae turn black and are easily recognized. Adult *EncarsiaFormosa* also feed on honeydew and the body fluids of whitefly larvae.

Encarcia Formosa

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Pest:

Thrips:

Thrip

Thrips are found in crops all over the world. Crops are attacked by a number of species of these small winged insects. Larvae and adult insects feed on all above-ground parts of the plant and, as a result, the tissue dies. Loss of chlorophyll reduces yield. Serious attacks may result in desiccation of leaves and damage to flowers and fruits. *Thrips* can also transmit plant diseases.

Thrip damage on plant leaf

Due to their small size, the damage *thrips* do is usually spotted before the *thrips* are noticed. Damage appears as small yellow speckles on the leaves later followed by a silvery sheen on leaf surfaces. The *thrips* feed by scraping at tender leaves, with most damage occurring on new growth. They are only 1/12" long, but can move very quickly. Adults look similar to a small worm with wings. *Thrips* can also carry and transmit plant disease.

Biological Control:

Amblyseius cucumeris and *Orius laevigatus*
Amblyseius cucumeris is an effective predator of young thrip larvae. *Orius laevigatus,* another predator, is often applied in conjunction with *Amblyseius* because they kill adults and larger larval stages of *thrips.*

Amblyseius cucumeris

Onus laevigatus

Pest:

Aphids

Aphids inflict serious damage in various crops and their reproductive capacity is enormous. The damage they cause is due to secreted honeydew resulting in contamination of fruit. *Aphids* are also notorious for carrymg vlruses.

Green aphids

Aphids are slow moving insects, inhabiting the undersides of leaves. They establish dense colonies of tiny (1/32" -1/8"), soft bodied, pear shaped insects that are light green, pink, yel-low, brown or black in color.

Biological Control:

Aphidius colemani and Aphidoletes aphidimyza

The parasitic wasp *Aphidius colemani* is particularly effective against some species of aphids. Parasitised *aphids* form characteristic white "mummies." *Aphidoletes aphidimyza is* effective on a wide range of *aphid* species and lays its eggs in aphid colonies. The orange larvae that hatch from these eggs feed voraciously on *aphids.*

Aphidius colemani

Aphidoletes aphidimyza

Pest:

Red Spider Mites


Spider Mites

Red Spider Mites are a pest of nearly all horticultural crops, both in greenhouses and outdoors. Their tremendous reproductive capacity means that these mites are capable of rapidly destroying plants. The larvae, nymphs and adult mites all cause damage to the plant by feeding on plant tissue.

Red Spider Mites are about the size of a pin head, inhabit the undersides of plant leaves and can be seen scurrying around. Their eggs can be seen with a magnifier, scattered at random and ranging in color from clear to tan. With large infestations, a fine webbing can be seen covering the plant top. *Red Spider Mites* prefer lower humidity levels and normally go dormant in winter.

Biological Control:

Phytoseiulus persimilis

This predatory mite feeds on eggs, nymphs and adults of a number of species of red spider mite. *Phytoseiulus persimilis* responds to specific chemical cues when locating it's prey" This makes it effective in locating new *Red Spider Mite* colonies.


Phytoseiulus persimilis

Pest:

Leaf Miners

Damage by Leaf Miners

Leaf Miners are a major problem for many crops. The larvae form tunnels in the leaves of the plant. This may lead to desiccation and early leaf loss. The loss of chlorophyll may result in severe reductions in yields.

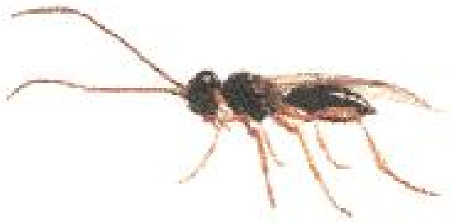
Leaf Miner

Leaf Miner adults are small black and yellow flies. *Leaf Miners* eggs are inserted in leaves and larvae feed between leaf surfaces, creating a meandering track or "mine." At high population levels, entire leaves may be covered with these tracks. Mature larvae leave the tracks, dropping to the ground to pupate. This life cycle takes only 2 weeks in warm weather.

Biological Control

Dacnusa sibirica and *Diglyphus isaea*

These parasitic wasps lay their eggs in or near leaf miner larvae. The young parasite larvae hatch from these eggs and begin to feed on their host, internally if *Dacnusa* and externally if *Diglyphus*. Eventually a new parasite adult emerges to continue the work of its predecessors.



Dacnusa sibirica

Diglyphus isaea

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Pest:

Beet Armyworm

The *beet armyworm* is a major pest of fresh market tomatoes. Each larvae may damage several fruit, leaving shallow gouges that make the fruit unmarketable. Newly hatched larvae feed together near the egg cluster and gradually disperse as they grow. They skeletonize leaves and may leave a webbing on the feeding site. Older larvae chew irregular pieces from leaves and feed on green fruit.

Beet Annyworm

Beet armyworm eggs are laid in clusters covered with hair-like scales left by the female moth. There may be 100 or more per cluster. Larvae are usually dull green with many fine, wavy, light colored stripes down the back and a broader stripe along each side. The adult beet armyworms are smooth skinned, without any obvious hairs.

Biological control

Hyposoter exiguae

This parasitic wasp is a natural enemy of *beet armyworms*. It also attacks tomato fruit worms and cabbage loppers. The *hyposoter exiguae* usually kills the larvae in the third instars and generally has its greatest impact early in the season.

Hyposoter exiguae

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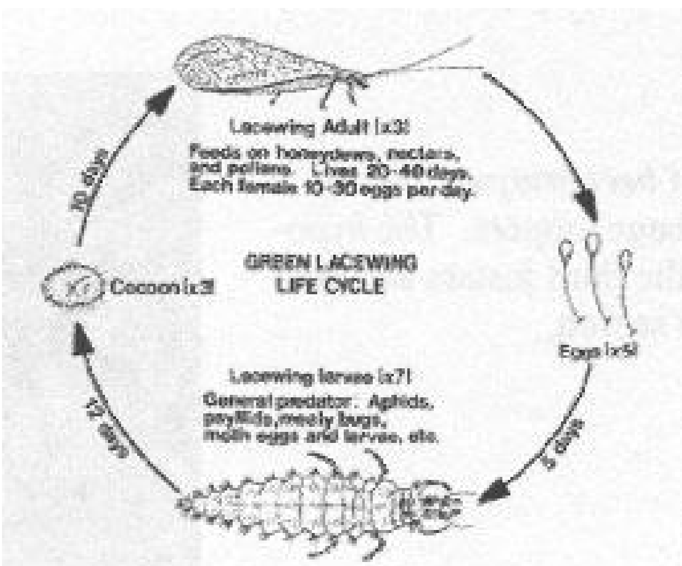
Other Beneficial Insects

Ladybug consuming aphids

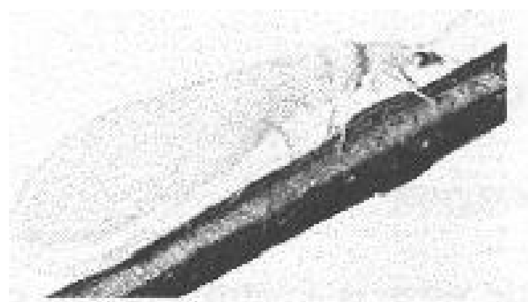
Two other insects that are always considered beneficial are ladybugs and lacewings. Both are predators, known for their voracious appetites and broad diet of insects. Both of these predators will help control almost every pest insect that we have discussed with the exclusion of the beet armyworm.

Both the ladybug and lacewing actively feed and consume problem pests in the larval stage as well as the adult stage.

Ladybugs and lacewings are a welcome addition to any garden, farm or greenhouse.



Lacewing Life Cycle



Adult Lacewing

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Other Safe Options for Pest Control

Occasionally, additional means of control will be necessary and, fortunately, there are other safe options for pest control.

Insecticidal Soap

Insecticidal soap is an environmentally sound method of getting rid of pest insects. It is basically a soap solution that, when sprayed directly on the insect, will smother them. It does not leave a residue and crops sprayed with insecticidal soap can be harvested the same day. As a general rule, insecticidal soap will not harm most beneficial insects.

Insecticidal soap is available as a spray or in a concentrate form to be mixed with water. For best results, use softened or purified water if you are mixing it from the concentrate.

Sticky Strips

Sticky strips provide a safe method of trapping insects. The insects are attracted to the bright color of the sticky strip and, once they land, they are stuck. When the strips are full, simply discard and replace with a new ones.

Many commercial growers use sticky strips for monitoring what insects are in the greenhouse. By checking the sticky strips on a regular basis, the grower knows what insects are present and whether or not the population is growing.

Botanical Sprays

Botanical sprays are made from plants that have insecticidal qualities. These products are generally safer than chemical insecticides but, even though the are natural, they are insecticides and should only be used as a last resort.

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The demand for premium, healthful produce has risen dramatically over the past ten years. Consumers today want and will pay a premium price for produce that is known to be safe and free of harmful pesticides and herbicides.


Commercial hydroponic greenhouse

The combination of hydroponic technology and a controlled environment greenhouse is an ideal solution to filling this demand. With this combination, known as Soilless/Controlled Environment Agriculture (S/CEA), a grower can produce extremely high quality produce close to the marketplace. This eliminates the cost and damage that occurs in commercial trucking of field produce.

A commercial hydroponic operation uses up to 1/20 of the water and a fraction of the space needed to produce an equivalent amount of produce in traditional agriculture.

There are hydroponic farms throughout the United States and worldwide. Most hydroponic farms in the US are family or small business operations. Several large hydroponic facilities, covering as much as 80 acres, are spread throughout the United States.

The smaller hydroponic farms usually have 1/8 -1 acre in hydroponic production while the larger facilities average 20 - 40 acres. The smaller operations generally have the advantage of offering vine ripened produce and being near the marketplace.

The premium quality of hydroponic produce is due to the controlled environment, greenhouse grade, pure nutrients and the lack of herbicides and pesticides.

The most popular hydroponic crop in the US is tomatoes, with second being cucumbers, third, leaf crops and fourth, herbs, peppers and flowers. Ironically, there is more hydroponic produce flown into the United States from Holland, Canada, Europe and Mexico than is grown here. As more and more hydroponic farms are established in the United States, this will change.


Hydroponic tomato crop

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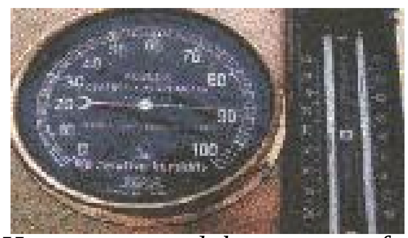
The productivity of commercial systems has improved greatly and the cost has dropped in the past few years. Commercial tomato growers who once hoped to annually pick 20 pounds per plant are now picking as much as 35- 40 pounds per plant annually. The cost of establishing a commercial hydroponic greenhouse operation is quite reasonable when considering the potential profits.

With proper training, hard work and good business sense, a grower can make their hydroponic greenhouse business a profitable venture.

The Daily Operation of a Hydroponic Greenhouse

On a day-to-day basis, most commercial hydroponic growers do testing and monitoring similar to what you have done in your hydroponic garden in the classroom. The pH and nutrient concentrations of the feed solution and that of the reservoir need to be tested and the temperature and humidity levels monitored.

An efficient grower will record all of this information. This data is helpful when assessing the overall health of the crop, diagnosing problems and ascertaining what factors may have positively or negatively affected their crop.



Hygrometer *and thermometer for monitoring temperature and humidity*

A grower must also ensure that the plants are getting fed properly and on time. Depending on the stage of growth of the crop and the amount of light available, a grower alters the concentration of the feed solution.

The most important job of a commercial grower is to be observant, meticulous and organized. When a grower is in the greenhouse, they must closely look at the plants to see if there are any changes, pests or disease that could threaten their crop. Daily observation is crucial in the prevention of large problems in the greenhouse.

Plant Culturing

In addition to the daily monitoring of a crop, there are many culturing chores that a grower performs to ensure the highest quality fruit and the highest quantity harvest. With along term fruiting crop, such as tomatoes or cucumbers, there is more daily culturing chores than with a short term crop, such as lettuce. With a lettuce operation, more emphasis is placed on continuous seeding and harvesting of the crop rather than plant culturing.

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Most commercial tomato growers plant an indeterminate variety from seed. They replant their greenhouse once a year. The seeds can be propagated in a small space and, when the seedlings are several weeks old, they are moved into the greenhouse. With most varieties, the grower will begin harvesting in about 100 days and continue harvesting for 8-9 months.

In fruiting crops, there are five primary culturing jobs that need to be done every week. These jobs include:

Clipping

When the tomato plants are set out in the greenhouse, they will need to be supported. The type of support system used varies from grower to grower but most are some variation of the following. Main support wires are strung above the plant rows. From the main wires a string is hung down to each plant and then the plant is clipped to it. The tomato plants can grow as much as one foot per week so the clipping process needs to be done every week.


Plant clip and support string on a tomato plant

Sucker Pruning


Removing a sucker

When the tomato plants are four or five weeks old, suckers (also called side branches) begin to grow at every leaf axial. In the greenhouse, you groom the plant to one main stem, removing each of the side branches and leaving only the main stem and leaves. From this point on, sucker pruning will need to be done once a week.

A sucker is removed by firmly grasping the sucker and bending it one way and then back.

Cluster Pruning

To ensure an even fruit load on the plant and larger tomatoes overall, a hydroponic grower cluster prune. Cluster pruning begins when your first tomatoes have set and are approximately the size of a pea. When cluster pruning, you remove the misshapen, smallest and weakest fruit, leaving the largest to develop. Depending on the season and the current fruit load, most of beef-steak-type tomato growers prune the clusters to 3 or 4 tomatoes and most cluster-type tomato growers prune the clusters to 5-6 tomatoes per cluster. Most growers will cluster prune their tomato plants once a week.


Cluster pruning

Leaf Pruning

As a tomato plant matures, the lower leaves can be removed to encourage fresh new growth at the top of the plant. The lower leaves easily break off when pressure is applied at the base of the leaf.

Leaning and Lowering
An indeterminate tomato variety can grow to lengths of25 feet or more. To keep the growing part of the plant within reach, growers lean and lower the whole plant. When the plants are leaned and lowered, the top 6 feet, which is the producing part of the plant, is left vertical and the remaining stem is laid horizontally.

Other Greenhouse Jobs
In addition to the weekly jobs a hydroponic farmer does, there are several other processes that need to be accomplished on a regular basis.

Pollination
In an outdoor environment, the tomato flowers would be pollinated by insects and wind but, since there are limited amounts of both in the greenhouse, the grower needs to pollinate the flowers. There are pollinating wands that a grower can use. Touching this vibrating wand to every open flower cluster will give adequate pollination.


Pollinating


Bumble bee

Most l arge hydroponic operations bring a specialized bumble bee hive into the greenhouse and allow the bees to do the pollinating. The bees are labor saving and more efficient than a person. Bees have virtually no tolerance for pesticides so, if bees are used for pollination in a greenhouse, biological control must be the only means of insect control employed.

Most hydroponic cucumber varieties are self-pollinating so growers of cucumbers do not need to pollinate the flowers.

Harvesting and Packing
Most hydroponic greenhouse growers who are close to the marketplace will allow their tomatoes to vine-ripen. They harvest them every two or three days. Many growers of premium produce will label their product with a the brand name and brief description or the benefits of how it was grown.

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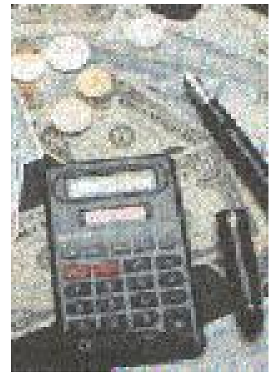
Marketing



So a hydroponic grower has completed their daily testing, weekly culturing chores and grown a premium product. ..what do they do with it? Sell it!

In most cases, the cost of growing a crop in a controlled environment is higher than a field-grown crop. The farmer growing in a controlled environment has maintained the ideal temperatures, humidity, light and feed to the plants. In return, their produce should be of the highest quality and, if marketed properly, should bring a premium price.

A hydroponic grower should be sure to emphasize what makes their produce special and what makes it taste so good.

Points that a hydroponic farmer might promote are:

- vine ripened
- tastes, looks and smells great
- grown in a controlled environment
- hand picked and packed
- herbicide free
- pesticide free
- available most of the year
- higher nutritional value

Growers can sell their fresh produce in a number of ways, some of which include:

Direct to grocery stores
When you sell directly to grocery stores, you have the most control over how your produce is transported and handled. The disadvantage is that you need the expertise and time to effectively establish markets and then deliver your produce on a timely basis.

Sell to a **produce broker**
If you do not have the expertise or time to market your produce you may consider having a produce broker or distributor market your produce for you. A broker will usually charge 15 -20 % of the gross sales for their service. Broker marketing is convenient, but you will earn less and lose control over the handling and transportation of your produce.

Market through a **co-op or grower network**
A co-op is a compromise between you doing the marketing and having someone else do it for you. If there are several growers in an area, they may be able to share the responsibilities of marketing and delivery.

Roadside stand or farmer's market

A farmer's market or roadside stand allows you to sell directly to the customer. Since you are selling retail with this means of marketing, you will probably have the highest profits. The disadvantage is that you not only have to bring your produce to the market, you have to stand there and sell it. For some growers this is an ideal means of selling their produce. For others, it isn't worth the extra time involved.

A commercial grower of hydroponic produce must always remember that they are selling a premium product and, as long as the quality is there, the market will follow.

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Introduction

The skills used by students during this unit on hydroponics include observation, measuring, testing, experimenting, recording data, problem solving and critical thinking.

The activities and lessons in this guide are aimed at students in grades 7 -10 but they can be easily adapted for advanced sixth grade students or used as the basis of a more extensive unit for high school science.

Hydroponics is simply growing plants in a solution of water and fertilizer without soil.
Many home gardeners and commercial hydroponic farmers use this method because it is
very pure, precise and allows the grower more control over the plant's growth and development.

As a general rule, plants grown in a hydroponic system will grow more quickly and vigorously than plants grown in soil. Altering what a plant is fed and the way in which it is grown can have varying results. In a classroom, this allows students to develop test theories on plant growth. In commercial applications, this allows growers to grow superior quality produce to what is grown in the fields.

Hydroponics is an ideal means for teaching students plant science, plant nutrition, plant physiology, plant care, nutrient and pH testing, entomology and agriculture. A unit in hydroponics also enforces practical uses of chemistry, mathematics. physics. economics and engineering. The monitoring of the hydroponic garden helps instill a sense of responsibility while enforcing skills in testing, analysis, experimenting, recording data and critical thinking. A unit on hydroponics can be started at the beginning of a semester and run through the entire semester, allowing the educator to present the individual concepts and lessons as the plants develop.

Although one hydroponic system is adequate for teaching this unit, having a hydroponic garden for every group of 4-6 students will create the most dynamic learning environment and provide the opportunity for students to hypothesize, experiment, interpret and explore various theories on plant growth and development. The students lessons will be published free for down loading and the Educator's Guide can be ordered for a small fee or is included free with any gardens ordered.

Groups may experiment with differing light levels and different types of lighting, with varying pH levels or varying nutrient concentrations, with comparisons between the different growing methods and different growing mediums. Experimenting with the nutrient formulas, pH, light and other environmental factors, helps students to develop a clearer understanding of the scientific process.

What you will will need to teach this unit:

- hydroponic growing system (or what you need to build one...see lesson three)
- growing medium
- hydroponic fertilizer mix
- pH tester
- EC meter (optional)
- seeds or bedding plants
- plant light (optional)

Suggested Teaching Aids:

11 Plant Garden or similar hydroponic garden.
This Educator's Guide contains the information needed to teach this unit. Each lesson includes a lesson overview,