LESSON 3: NUTRIENTS

In a traditionally grown plant, It gets its nutrients from the soil. The soil holds nutrients that are leached from rocks and minerals in the soil, as well as minerals from animal waste, and decomposed plant and animal matter. These minerals are then transferred into water in the soil, and the water is absorbed by the plant roots. For hydroponics this concept is the same, only the execution is different. Rather than soil holding nutrient-rich moisture, a Nutrient-rich solution is applied to the roots either directly, or by means of a growing medium.

A drawback to this type of system is that there is no buffer to the plants, so if there is something wrong with the nutrient solution, the plants will be affected. Also in a system where no growing medium is used, if the nutrient solution is interrupted (power outage, pump failure, clogged lines etc) the roots of the plant can dry out very quickly causing damage to the plant.

In the last few decades different nutrient solutions for different types of plants have been developed. Some focus on the needs of a specific type of plant, while others are a more general purpose solution. A gardener can purchase 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.

Some hydroponics systems use what is known as "Aquaculture" where a fish tank is attached to the hydroponics system. The fish are fed normally, and the water from the fish tank circulates through the hydroponics system, where the fish waste is absorbed by the plants and used for food, and at the same time cleaning the water making it suitable for the fish.

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.

DIAGNOSING DEFICIENCY

On the following pages you will find information on nutrient deficiency. This information is also available as a stand-alone application on Hydroponics Dictionary.

BORON

Deficiencies show up first in younger leaves; they turn yellow. Boron deficiencies resemble calcium deficiencies. Symptoms include stunting, discoloration, death of growing tips, and floral abortion.Boron deficiencies stunt roots, mutate leaves, and create brittle leaves that appear bronzed or scorched.

Boron deficiency symptoms first appear at growing points. This results in a stunted appearance and short internodes (rosetting). Both the pith and epidermis of stems may develop hollow, roughened or cracked stems.

Leaf margins discolor and die backs. Necrotic spots develop between leaf veins. Deficient leaves become thick and they may wilt with necrotic and chlorotic spotting.

If you have a potassium deficiency, plants have a hard time absorbing boron.

Excessive boron can cause the same kinds of problems as calcium deficiency cause. To complicate matters, the symptoms of excess boron can resemble the symptoms of deficient boron.

Boron is used for sugar transport within the plant. It helps with cell replication, production of amino acids, pollination, seed production, carbohydrate synthesis and transport, cell division, differentiation, maturation, respiration and growth, and water uptake.

Boron is essential for plant growth but its mode of action is poorly understood. Boron is taken in by roots and transported via xylem to other parts of the plant. In the cell membrane it is mainly present as a borate ester. Boron is involved in lignification of cell walls and in differentiation of xylem.

Boron plays a regulating role in synthesis of cell walls. as well as in stabilization of constituents of the cell wall and cell membranes. Boron deficiency immediately results in inhibition of primary and secondary root growth.

Boron regulates phenol metabolism and synthesis of lignins by forming a stable borate ester with phenolic acids.

CALCIUM

Deficiencies show first in new, young growth. Calcium moves slowly within plants and concentrated in roots and older growth. That's why young growth shows deficiency signs first.

Calcium deficiency symptoms include: leaf tips, leaf edges and new growth turn brown and die; chlorosis, necrosis, & distorted leaf margins; leaf tips hooking, turning brown and black, and dieing off.

Deficiency is not the only problem associated with calcium. If too much calcium is present early in a plant's life cycle, growth is stunted. In other phases of growth, calcium excess interferes with magnesium and potassium uptake.Calcium is transported via water to plant tissues, but if calcium levels in root zone media are too low, calcium deficiency can occur regardless of what levels are in the plant aboveground.

Because calcium is immobile, it cannot be easily translocated to the region of active growth in the shoot tip. Thus, calcium deficiency can cause severe reduction in new growth.

Although calcium may be adequate in the lowest leaves, levels in the meristematic upper plant region can still be low, causing defective upper leaf growth followed by necrotic patches in young leaves.During early blooming phase, calcium deficiency can affect shoot growth, resulting in abortion of flower and bud structures.

Moderate calcium deficiency results in bended or twisted leaves, along with white streaks or white leaf margins in new leaf growth.
Calcium deficiencies make roots stubby and twisted and can cause root death.

Severe calcium deficiency can destroy all new growth and cause leaf mutations.

Calcium is crucial to cell elongation and is an important component in cell walls. It acts as a binding agent between cells and enhances uptake of negatively charged ions such as nitrate, sulfate, borate and molybdate. Calcium is important for uptake of most macro and micro nutrients. Calcium is responsible for strong growth and very important in bud set and water uptake.

Calcium is a major constituent of cell walls, is critical to root and leaf development, seed production, pollen germination, cell mitosis, cell division and floral maturity.

Calcium binds primarily to cell walls and cell membranes. The high concentration of calcium in the cell wall and cell membranes provides rigidity to the plant cell wall structure. The absence of calcium causes degradation of the cell wall and lead to a softening of the plant tissue.

Adequate calcium helps plants resist fungal infections, which are often a big problem in hydroponics grow rooms.

Calcium plays a vital role in cell and root replication.

CHLORINE

Believe it or not, chlorine is essential for plant growth. It's needed for photosynthesis. It's an enzyme activator that assists production of oxygen from water and in water transport regulation.

Plants use chlorine as chloride ion. Chlorine is useful as a charge balancing ion and for turgidity regulation, keeping plant cells free of infection by disease. It helps open and close stomata by increasing osmotic pressure in cells.

Excess chlorine causes burnt tips and margins on young leaves. If chlorine levels are too high, cuttings will not root well, and seeds may not germinate.

High chlorine levels also cause leaves to take on a yellowish bronze color, and they are slow to develop. Chlorine is commonly used to treat drinking water, so you are far more likely to see an excess of chlorine in your garden rather than a deficiency.

If you determine that chlorine is at toxic levels in your garden, get a reverse osmosis unit or distiller to remove chlorine from the water you use for your plants.

COBALT

Deficiencies are rare, but express themselves as chlorosis of younger leaves.

Cobalt is a chelation “bridge” that assists uptake of other metals and nitrogen fixation. It assists enzymes related to manufacture of aromatic compounds. It is also required for a few bacteria and algae.

Cobalt is essential to proper use of nitrogen Three enzyme systems of Rhizobium bacteria are known to contain cobalamin. There’s correlation between cobalt concentration, nitrogen fixation and root nodule development.

Cobalt is required for methionine synthesis, ribonucleotide synthesis and synthesis of methylmalonyl-coenzyme A mutase. The latter is necessary for the synthesis of leghemoglobin, which plays a major role in protection of nitrogenase against oxygen, which is able to irreversibly damage the enzyme.

COPPER

Deficiencies show up first on youngest leaves, young tips, buds and shoots. Older leaves develop chlorosis, growing tips die and bud development is small. Copper deficiencies cause irregular growth and pale green leaves that wither at leaf margins.

Leaves at top of the plant wilt first, followed by chlorotic and necrotic areas on leaves, and necrosis of the apical meristem (the center stem of the plant).

Leaves on top half of plant show unusual puckering with veinal chlorosis. Copper deficiencies also show on the leaf, where the petiole joins the main stem of the plant beginning about 10 or more leaves below the growing point.

Excess copper is extremely dangerous to plants. Plants can develop iron chlorosis, stunted growth and stunted root development. Toxic buildup of copper occurs quicker in acidic soils.

Copper activates several enzymes, is needed for photosynthesis, and assists metabolism of carbohydrates and proteins. It intensifies color and flavor. It is essential in several enzyme systems and in plant respiration.

Copper is a divalent cation and is taken up by the plant as Cu^+ or as a copper chelate complex and transported via xylem and phloem.

Copper deficiency immediately harms activity of copper-containing enzymes, but remember, an excess of copper is toxic to plant cells.

IRON

Iron deficiency is common in many plants, especially those grown indoors.

Deficiencies initially show as interveinal chlorosis in young leaves, with leaf veins green in color and older leaves unaffected. Leaves are smaller than normal.
Iron deficiency is especially a problem in alkaline conditions, or in wet, poorly root zone media. Iron becomes more bioavailable when root zone and nutrient water becomes more acidic, or when the proper chelates are bound with the iron.

Iron deficiency also reveals itself as interveinal chlorotic mottling of immature leaves. In severe cases, new leaves lack chlorophyll but show little or no necrotic spots. Chlorotic mottling of immature leaves starts first near bases of leaflets so that the middle of the leaf appears to have a yellow streak. Cool temperatures, high humidity and wet root zone conditions create Fe deficiencies, especially if Fe is already in short supply.Plant uptake of Fe decreases with increased soil pH, and is adversely affected by high levels of available P, Mn and Zn in soils. Excessive iron causes bronzing of leaves with tiny brown spots.

Plants use iron for protein and nucleic acid metabolism, chlorophyll formation and electron transport. Enzymes (catalase, peroxidase, cytochromes) and photosynthesis components require iron. The ratio of iron and sulfur available to plants directly affects their ability to take in nitrogen.

Iron in plants and root zones are mostly found bound to chelates; that's why free iron levels are extremely low (10mM). Iron has to be reduced to Fe^{+} at the root surface before being transported to the cytoplasm (only grasses can absorb iron in the form of Fe^{3+}). In the xylem iron is transported in the form of a iron-carbohydrate complex.

MAGNESIUM

Magnesium deficiencies show first in older, lower leaves. The symptoms start from the margin inwards. The leaf mid-rib and veins remain green while leaf margins are yellow or whitish, sometimes leaving a green arrowhead shape in the centre of the blade.

Interveinal chlorotic mottling or marbling of older leaves proceeds toward younger leaves as magnesium deficiency becomes more severe. This is sometimes accompanied by leaf tips curling upwards.
Chlorotic interveinal yellow patches can occur near leaf centers. In these cases, leaf margins are the last to turn yellow. Interveinal yellow patches then progress to necrotic spots or patches and scorching of the leaf margins. In some cases, leaves die and drop off.

Magnesium shortages result in defective bud production and inadequate bud development.Excess magnesium interferes with calcium and potassium uptake.

Plants use magnesium to: produce chlorophyll; regulate enzymes for transport of nutrients and carbohydrates in the plant; cell replication; seed production.

Magnesium is an important co-factor in production of ATP, the compound that helps plants transfer energy. It is also a bridge between ATP and enzyme activity.

Flowering and fruiting plants use more and more magnesium as they progress towards maturation and harvest. Magnesium helps plants generate energy through photosynthesis and is also crucial to protein synthesis.

MOLYBDENUM

Deficiencies show up in older and middle-aged leaves first, and then show up in younger leaves.

Molybdenum is rarely deficient in most plants, but chlorosis symptoms similar to nitrogen deficiency are typical of molybdenum deficiency, along with scorching and strapping of leaf margins.
Molybdenum deficiency often occurs when sulfur and phosphorus are deficient. It can reveal itself as interveinal yellow spotting and mottling of older leaves. Deficiency also shows as pale leaves (similar to nitrogen deficiency), with some marginal leaf chlorosis. New leaves may twist and leaves may cup and thicken.

Excessive molybdenum looks like iron or copper deficiency.

Molybdenum is needed for the reduction of absorbed nitrates into ammonia prior to incorporation into amino acids. It performs this function as part of the enzyme nitrate reductase.

In addition to direct plant functions, molybdenum is used for nitrogen fixation by nitrogen-fixing bacteria.

Molybdenum is primarily present in the form of MoO_4. Depending on the environmental conditions a molybdate ion can accept one or two protons. Polyanions such as tri- and hexamolybdate can be formed under certain physiological conditions. Molybdenum (Mo) has limited mobility in plants and is apparently transported through the xylem and phloem.

Several enzymes are known to use Mo as a co-factor. The two most important molybdenum-containing enzymes are nitrogenase and nitrate reductase.

Molybdenum is directly involved in the reduction of nitrogen. Nitrogen molecules bind to molybdenum atoms in the nitrogenase complex. After activation of the nitrogenase complex, the iron-molybdenum complex changes its structure and as a result reduction of nitrogen occurs. The electrons required for this reduction are supplied by an iron-sulfur protein which is part of the nitrogenase complex. This is an energy-intensive reaction.

Nitrate reductase reduces nitrate into nitrite in the nitrogen assimilation process of the plant. Nitrate reductase contains a heme-iron molecule and two molybdenum atoms. FAD, cytochromes [Fe2/Fe3] and molybdenum [Mo(V)/(VI)] are functional parts of the nitrate reductase complex and the electron transport chain. Electrons derived from NADPH are used to reduce nitrate to nitrite. The activity of nitrate reductase is reduced during molybdenum deficiency but can be restored by adding molybdenum.

As you can see, this hard to pronounce micronutrient is important to plant functions.

NITROGEN

Nitrogen deficiencies often appear first in older leaves, and will manifest as a light green overall appearance.

As symptoms progress, the leaves turn a yellow color and stems become weak and lower leaves drop off. Necrosis develops in older leaves. New growth becomes weak and spindly. Tops and roots grow poorly.

When plants are in the mid to later growth or flowering stages, older growth and large fan leaves may show nitrogen deficiency.

This is normal during the late stage of floral development because plants near the end of their lives are using up their nutrient and carbohydrate reserves. As leaves turn completely yellow, remove them from the plant.

Nitrogen excess turns foliage very dark green and can make plants susceptible to drought, disease and insect predation.

Nitrogen is crucial to photosynthesis and reproductive function. Nitrogen makes proteins and is essential to new cell growth. Nitrogen is mainly utilized for leaf and stem growth, as well as overall plant size and vigor.

Nitrogen moves easily to active young shoots and leaves and moves more slowly to older leaves. Nitrogen is involved in the structuring of amino acids, enzymes (specialized proteins that perform duties inside plants), proteins and nucleic acids. All of these are essential for cell division and most other plant functions. Obviously, nitrogen is essential to plant growth.

The "salts" commonly used as a source of nitrogen are: potassium nitrate (KNO_3), ammonium nitrate (NH_4No_3) and calcium nitrate ($Ca (No_3)_2.4H_2O$).

Nitrate is transported via xylem to all parts of the plant, where it participates in nitrogen assimilation. Nitrate is stored in cell vacuoles and fulfills important functions in the osmo-regulation and anion-cation balance in plant cells.

Inorganic nitrogen is reduced to ammonia and incorporated in organic molecules. Ammonium in the roots is most commonly stored as organic nitrogen. This reaction is carried out by two enzymes, nitrate and nitrite reductases. Nitrate is first converted into nitrite by nitrate reductase; then, nitrite is reduced into ammonia by nitrite reductase.

Conversion of nitrate into nitrite occurs in the cytoplasm. Nitrate reductase consists of FAD, cytochromes [Fe2/Fe3] and molybdenum [Mo(V)/(VI)].

These components form integral parts of the electron transport chain through which electrons are used to reduce nitrate to nitrite. If high nitrate concentrations are present it can also be transported to the leaves where it is then reduced.
Glutamine synthetase and glutamate synthase are key enzymes in conversion of ammonium into glutamine. It is then converted into asparagine, arginine and allantoin act as basic sources of nitrogen for all macromolecules biosynthesis.

You should daily monitor your plants, focusing on their leaves. If you see pale leaves with a yellow tinge like the picture, you may have a nitrogen deficiency.
Such deficiency can slow growth, decrease harvest size and damage the overall health of your plants. The best ways to avoid nitrogen deficiency are to use quality products, and to keep your root zone pH in the ideal 5.8 to 6.3 range.

PHOSPHORUS

Phosphorus deficiencies show up in older growth first. You will see leaf tips curling downwards. When phosphorus is deficient, slow and spindly plants with reduced growth will result.

Phosphorus deficiency leaf damage often shows itself as patches that are dull dark green to bluish green. In severe cases, older leaf and petioles turn reddish purple.

Younger leaves appear yellowish green with purplish veins when nitrogen is deficient, but will have dark green veins when phosphorus is deficient.Necrotic spots occur on leaf margins in advanced stages of phosphorus deficiency. Leaf tips look like they have been burnt.

Phosphorus deficiency is most common when ph is above 7 or below 5.5. Phosphorus will bind with soil very easily and this can cause excess phosphorus. Excess phosphorus can create deficiencies of zinc and iron.

Plants use phosphorus for photosynthesis, respiration, storing carbohydrates, cell division, energy transport (ATP, ADP), nucleic acids, enzymes and phospholipids.
Phosphorus builds strong roots and is vital for seed and flower production. Highest levels of phosphorus are needed during germination, early seedling growth and flowering.

Some crops require lots of phosphorus, but most require more potassium and nitrogen and magnesium than phosphorus. Several types of hydroponics plants need far more phosphorus during flowering than during vegetative growth phase.

Excess phosphorus causes decrease in the uptake of zinc, iron and copper- which starts a chain reaction of other macro and micro nutrient deficiencies.

When temperatures drop below 55 degrees Fahrenheit (12 degrees Celsius), plants have a hard time uptaking phosphorus.

Phosphorus is present in the plant as inorganic phosphate (Pi), or bound to a carbon atom. Phospholipids in bio-membranes contain a large amount of phosphorus. In these molecules phosphorus makes a connection between a diglyceride and an amino acid, amine or alcohol via a phosphate- ester bond.

Phospholipids consist of a hydrophobic tail, the diglyceride, and a hydrophilic head containing PO_4. Membranes consist of two monolayers of phospholipids known as a lipid bilayer. The hydrophilic end of the phospholipids are oriented towards water (outward) while the hydrophobic ends are orientated inwards.

Phosphorous plays a very central role in determining the total energy metabolism of the plant because it forms energy-rich phosphate esters (C-P) such as glucose-6-phosphate. Energy released during the glycolysis, oxidative phosphorylation or photosynthesis is used to synthesize ATP and this energy is liberated during the hydrolysis of ATP in ADP and inorganic phosphate. ATP is unstable and therefore turns over rapidly.

With non-metabolic storage, phosphate is stored as inorganic phosphate (Pi) in vacuoles.Phosphorus regulates starch production in chloroplasts. ADP-glucose-pyrophosphorylase, an enzyme involved in the synthesis of starch, is inhibited by Pi and stimulated by triose-phosphates.

Phosphorus deficiency can cause reduction in growth rate and show up as dark-green coloration of leaves, caused by accumulation of chlorophyll in leaves.

POTASSIUM

Potassium deficiencies show first in older leaves and are displayed as: yellowing; singed or scorching of leaf margins with small necrotic areas that start small and get bigger; brittle stems accompanied by withering leaf tips; interveinal chlorosis starting at the base of young leaves; reddening and upwards leaf curl in older leaves. In vegetative stage, plants develop too slow and are stunted. In bloom phase, flowers develop slowly and fail to achieve normal size. Deficiencies of potassium are a major cause of small harvests.

Excess potassium interferes with calcium and magnesium uptake.

Potassium is essential in function and formation of enzymes and proteins. It is also essential in regulation of osmotic pressure and in most metabolic cellular processes.

SILICON

Silicon is a very important plant nutrient. It is a vital component of epidermal cell walls. It strengthens plants so they can fight off diseases and resist insects, drought, heat and stress.

The performance-enhancing benefits of potassium silicate are most easily provided by using a packaged potassium silicate product purchased at a hydroponics retail store. Potassium Silicate substantially strengthens plants' ability to transport nutrients and other substances in roots and internal plant cells.

Potassium Silicate increases cell wall stability, speeds up root cell replication, builds stronger and more extensive root systems, increases nutrient absorption and resistance to stress/drought, and enhances plants' ability to resist pathogens and insects.

Silica is a buffering and balancing substance that helps plants deal with potentially-toxic levels of salts, minerals and pollutants.

Potassium Silicate will help give your plant a larger, stronger, more vigorous living infrastructure.

SULFER

Deficiencies show up on older leaves first. Then they show up on younger leaves, turning them light green, then yellow. These symptoms are accompanied by slow growth. Leaves lose color, but veins remain green.

Sulfur deficiency symptoms are easily recognizable and are frequently confused with the nitrogen deficiency symptoms. Sulfur deficiency causes small and spindly plants with short, slender stalks and reduced growth rate with delayed maturity.

An overdose of sulfur can cause premature dropping of leaves.
Some plants require as much sulfur as they do phosphorus. Sulfur is a component of cystine and methionine (amino acids that make up plant proteins). Sulfur is therefore a component of plant proteins.

It also has a major role in root growth and chlorophyll production. Sulfur is essential to seed production and overall plant hardiness. It is an enzyme activator and coenzyme compound. Sulfur enhances flavor and odor; it also is a formative part of chloroplasts and nucleic acid proteins. Sulfur deficiency decreases protein synthesis and causes significant reduction in leaf chlorophyll levels.

Please note that augmentation of sulfur is NOT achieved by the use of sulfur burners.

ZINC

Zinc deficiencies are among the more serious of micronutrient deficiencies and should be corrected as soon as they are diagnosed.

Deficiency first shows itself as pronounced interveinal chlorosis in young leaves and mid-shoot leaves. You might also see interveinal yellowish areas starting at leaf tip and margins and eventually affecting all growing points of the plant.

Interveinal chlorotic mottling may be mimic iron and manganese deficiencies except for that it is accompanied

by tiny leaves, and rosetting (short internodes).
Other signs of zinc deficiencies include grayish brown spots that form on leaves halfway up the plant and then spread. When zinc deficiency onset is sudden the chlorosis can appear to be identical to that of iron and manganese deficiency.

Excess zinc toxicity often looks like copper deficiency because it interferes with uptake of copper. Excess zinc can cause iron deficiencies and in extreme cases it can cause plant death, but it is uncommon to have excess zinc.
Zinc is essential for growth regulation and regulating carbohydrate consumption. Zinc improves chlorophyll function. It's a component in many enzymes and is important in enzyme systems, particularly for water absorption and usage. It's essential for plant hormone balance, especially auxin (IAA) activity and electron transport.

Zinc is absorbed through roots. After it reaches the xylem it is transported as a free Zn^+ ion. Plants depend on several zinc-containing enzymes, including alcohol dehydrogenase. In Super Oxide Dismutase (SOD), zinc is complexed with copper by means of a nitrogen atom from histidine. Carbonic anhydrase binds carbon dioxide, which makes it possible to reversibly store CO_2 as HCO_3^-.

Zinc is a critical miconutrient and must be properly provided to plants in a form that is bioavailable to them.

MIXING AND TESTING SOLUTIONS

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.

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 milligrams per liter(mg/l) or parts per million (ppm).

The temperature the nutrient solution should be tested at 25° C/ 77°F for consistency. For the sake of clarity, all measurements in this guide will be done using a TDS meter and the ppm measurement.

PPM GUIDES

Use the following guide to check the optimal ppm for the plant your growing and its' growth stage.

	Fruiting Plants	Leafy Plants
Initial Growth	1120-1260 ppm	980-1120 ppm
Average EC	1750 ppm	1260 ppm
Fruiting	1680 -1820 ppm	N/A
Low light (winter)	2000 ppm	1320 ppm
high light (summer)	1700 ppm	1120 ppm

You should closely monitor the PPM of your nutrient solution, and record your results. You should also record how often you change the nutrient solution. If left unchanged for too long, or the nutrient solution is just topped up, then the leftover “salts” in the nutrient solution may be allowed to reach toxic levels.

You should also measure the growth of the plant daily. This information in combination with the PPM data will help you to diagnose problems should they arise. It is also a great way for students to observe the effects, both positive and negative ppm has on plant growth.

When mixing nutrient solutions, dilute them to the concentration recommended by the manufacturer, which is usually 1 or 2 teaspoons per gallon of water. Nutrients are more available to plants when the temperature is around 24° C / 75° F. Tap water may contain significant concentrations of chlorine, which can adversely affect plant growth. If your water has a lot of chlorine, you can use distilled water or simply let water stand uncovered for a couple of days before using it. Your students may want to explore this themselves by comparing plants grown with distilled- versus tap water-based nutrient solutions.

The amount of nutrient solution you use depends on the type of system, temperature, light, and concentration of the solution. If you are going to grow leafy plants like lettuce or basil, or flowers, on a floating raft system 2 liters per plant should cover it. If you are going to be using a more sophisticated system and growing a larger, fruiting plant like tomato plants, you'll need closer to 7 liters per plant. After a few days consider topping off your solution with water to prevent the leftover salts from building up.

At some point you'll need to change the nutrient solution in the system, for most systems 15 days should be adequate. Be careful in how you dispose of these nutrient solutions, consider putting them into household plants. Do not dispose of these nutrients outside if there is a lake, stream, or other water source nearby. If you are isolated from water sources you should be able to put the nutrients in your outdoor garden without worry.