PLANTED TANKS—

# THE BASICS

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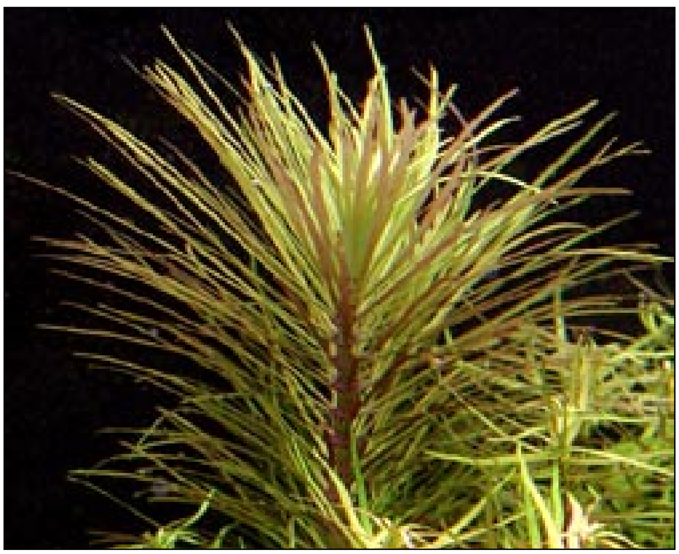
## Introduction

It has been as recently as the early nineties that aquatic gardening in the United States began to significantly gain popularity. We all learned in grade school that plants need light, carbon dioxide, and water; however, using them in our aquariums never seemed to connect. While commonplace now and even though it had been done in Europe for years, there was actually a time when the idea of adding carbon dioxide and more light to aquariums was a hard sell and revolutionary in America.

Most people making their first try at growing aquatic plants begin as fish keepers who want to add a little beauty and a natural presence to their tanks. However, much like the Baby Boomer generation trying to program a VCR, there is a mysterious and insurmountable barrier blocking their success. With meticulous accuracy, they overcome the most demanding and unreasonably specific water requirements to reproduce a fish so rare and delicate that most of us have never heard of it. Yet keeping the simplest of plants is impossible. With each new plant purchase comes a new failure. The unfortunate victims (plants) usually die and are replaced again and again until the beginning hobbyist just gives up and resorts to plastic alternatives.



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Since there are so many different methods of growing plants, sometimes successful aquatic gardeners aren't any help because they often don't seem to be able to agree amongst themselves. In fact they regularly disagree. A fish keeper getting over the shock that we actually add deadly carbon dioxide to our aquariums is further overwhelmed by five different opinions on how best to do it.

As the title says, the following information is very basic. It is oriented to that person who is just starting to cross over from fish keeper to aquatic gardener. If you have successfully grown a plant or two, you're probably ahead of what comes next. As a disclaimer, I'll say that there is no point discussed here that could not be or has not been debated by experienced aquatic plant gardeners. There are dozens of methods and opinions on how best to grow plants. Many of them are correct and very successful. There is no one way to do it. It will be up to the reader to take the information here and move on to the broader discussion of each subject.

## Water

Everyone knows that water involves more factors than just filling your tank from the tap. Tap water often contains chlorine and/or chloramines that must be removed. Sometimes there are other toxins in water as well, but generally, if your fish live in it, your plants will too.

Some people add salt to their water for the health of the fish, however, some aquatic plants will not tolerate salinity.

Frequent large water changes are encouraged by many successful aquatic plant growers. The rationale is that it helps to prevent the buildup of excessive nutrients and keeps algae from becoming complacent. There is by no means any one standard of practice. Many people do it differently.

For plant-growing purposes, water has three main parameters that you need to be familiar with: pH, GH, and KH. pH measures how acidic or basic the water is. A pH of less than 7 is acidic, a pH of greater than 7 is basic, and a pH of 7 is neutral. General hardness or GH is a measure of certain dissolved minerals, usually calcium, magnesium, iron, and manganese. Carbonate hardness or KH is a measure of dissolved bicarbonate ions. Bicarbonate has two effects on your water. It makes the water more basic, and it acts as a buffer, which helps your water resist rapid pH changes from acidic compounds.

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If your fish live in your water, likely your plants will too.

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This Discus tank has aquatic plants that are growing well in higher temperatures. Tank by Jeff Senske (AGA Member) of Aquarium Design Group www.aquariumdesigngroup.com.

If you are asked how hard your water is, a plant person would probably be referring to KH. Fish people are usually referring to GH. This topic is much more complicated and scientific than I have described here, but after all, this is "The Basics." For the remainder of this article, references to water hardness will always refer to KH.

Many plants are classified as preferring acidic or basic water and as preferring hard or soft water. This is not exactly true. Plants do not "prefer," they are just adapted to surviving in the extremes of one or the other more easily. Most plants will flourish in a wide variety of conditions regardless of what your plant book tells you they "prefer." For example, *Vallisneria* is considered a hard water plant. True, it will probably not grow in very soft water, but will do fine after some acclimation in somewhat soft water. This is okay because almost no one keeps **very** soft water anyway. pH and KH control are discussed more in the carbon dioxide section.

In nature, fish and plants are found growing together in the same rivers and streams. Therefore, obviously, they like the same temperatures. So pick a temperature that is best for the fish and the plants should do fine. The question always comes up about what to do with Discus. No doubt you have seen beautifully planted tanks with Discus. Some plants might not do well with these higher temperatures, but there are plenty that do. As with later discussions on light, pH, and hardness, even if a plant is not well adapted to the extreme temperature that it is forced to survive in, it will usually grow satisfactorily anyway.

## Filtration

Filtration in a healthy planted aquarium involves different considerations than fish-only tanks. We have all been taught that an aquarium filter provides three different functions: mechanical, chemical, and biological conditioning of the water. In a densely planted aquarium, large debris that would normally be removed by the mechanical filtration process often gets trapped in the plant mass, never reaching the filter. If you are doing regular water changes, molecules normally removed by chemical filtration may never build up to levels that would be harmful anyway. Also, many plants act as chemical filters by absorbing various dangerous compounds. Lastly, in a heavily planted tank, most if not all ammonia, nitrite, and nitrates are absorbed by the plants for nutrition, which practically eliminates the need for biological filtration. In fact, you will read later that many aquatic gardeners actually add nitrate to their tanks for fertilizer. As you can imagine, this completely alters the cycling process customary in fish-only tanks. It is reasonable to say that in a planted aquarium, your plants are your filter.

I will propose to you that there is a fourth function of filters that is not normally considered. The reason is that fish don't require it as much, and the function is water circulation. This is more my opinion than convention, but many people share my belief. Circulation helps distribute nutrients to the plants and the water movement stimulates healthy growth. If you are familiar with reef aquariums, you know that water movement is important for the same function in various corals and anemones.

You can use any of the filters with planted aquariums that you use with fish-only ones. Considerable debate exists on the usefulness of undergravel and wet/dry filters. However, there are just as many people who claim that they are inappropriate for planted aquariums as claim they can grow great plants with them. Most people use canister filters. $CO_2$ reactors and UV filters can be plumbed into their intakes/returns, they are quiet, low maintenance, and turn over a large volume of water. Box filters to me are basically canister filters that hang on the back of your aquarium and have a lid. They can be great for pH probes, withdrawing water for testing, and as a convenient place to add fertilizers. On the down side, they can cause some loss of $CO_2$.

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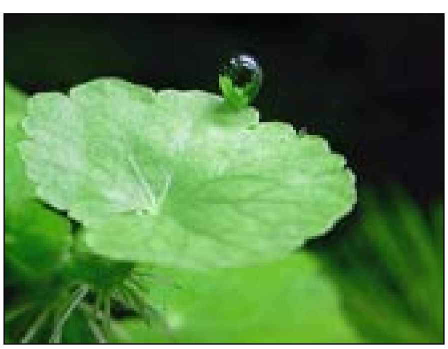
In a heavily planted tank, most if not all ammonia, nitrite, and nitrates are absorbed by the plants for nutrition, which practically eliminates the need for biological filtration.

## Carbon Dioxide

Carbon is the molecular backbone of all living things, and plants are roughly 90% carbon and oxygen. This fact alone should impress upon you the importance of providing these molecules, which you do in the form of carbon dioxide or $CO_2$.

Many beginning aquatic plant growers believe that insufficient light is the cause of poor plant growth. Actually plants receiving low light and good levels of $CO_2$ will do better than plants receiving good light and low levels of $CO_2$. If you don't learn anything else from this article, learn that it is more important to invest time, effort, and money into making sure your plants are receiving a good supply of $CO_2$ before anything else.

Another error beginners make is believing that the fish will give off enough $CO_2$ for their plants. It doesn't matter how many fish you have, they probably don't give off enough. The exception is in some very slow growth, low light tanks. In those tanks, the $CO_2$ from fish and that which is being absorbed into the water from air stone agitation may be minimally adequate. This exception is exactly that, an exception. For most people aspiring to grow aquatic plants, you must add $CO_2$.



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It is very important to invest time, effort, and money into making sure your plants are receiving a good supply of $CO_2$.

A final mistake is using an air stone. Surface agitation causes $CO_2$ to be driven out of the water when it needs to be conserved. This might seem contradictory to the statement in the previous paragraph, but there is a difference. In a tank with no supplemental $CO_2$, the tank becomes so severely depleted that the small amount percolated into the water with the air stone is at least providing a nominal addition. In a tank **with** supplemental $CO_2$, the air stone drives out what you have added, causing a loss. This starves the plants in addition to wasting money from repeated $CO_2$ tank refills.

Thoughts on the amount of $CO_2$ needed vary from just a little to around 30ppm. Early on people were mostly using 15ppm, but in the last few years 30ppm has become more common. You can determine how much you have by testing for $CO_2$ directly or by using the KH/pH table. A $CO_2$ test kit can be expensive and using the table is fairly accurate. Therefore, most people don't spend money on a $CO_2$ test kit.

Carbon dioxide added to water causes it to become more acidic. As previously discussed, bicarbonate added to water creates a buffer and causes it to become more basic. Therefore, since KH is roughly a measurement of bicarbonate, if you know what your KH and pH are, you can mathematically estimate the $CO_2$ level using the KH/pH table. This method is not without error. There are chemicals other than bicarbonate and $CO_2$ that can alter your water's pH, but it's a good estimate nonetheless.

Using the table on page 7, you can see that if you have a KH of 4 and a corresponding pH of 6.8, you have an estimated $CO_2$ level of 18.7ppm. In this case, to get the $CO_2$ level to 30ppm the hobbyist would increase the $CO_2$ flow to decrease the pH down to about 6.6. Occasionally a beginner is confused and wants to add some chemical to decrease the pH. This doesn't make sense. The purpose is to get the optimal amount of $CO_2$, which is not increased by adding chemicals but only by adding more $CO_2$.

I will mention several times in this article how it is important to maintain appropriate levels of $CO_2$, regardless of how much light you have. I want to clarify that statement now. If after additional research you decide you need 30ppm of $CO_2$, then you should work to maintain 30ppm $CO_2$. No matter how much light you have or fertilizer you add, you need 30ppm $CO_2$. Yes, in high light $CO_2$ is used up faster, but you don't want to add more as this will decrease your pH. In low light, the plants use less $CO_2$, but if you add less, the plants won't have enough and your pH will increase. As long as you maintain 30ppm there will be plenty to go around and your pH will remain stable. Therefore, maintain appropriate levels of $CO_2$ regardless of all other factors.

There are many ways to get $CO_2$ into the water. Thankfully, these days it is much cheaper than in the past. Four methods will be briefly covered here. They are yeast fermentation, also referred to as DIY (Do-It-

Yourself), organic carbon, carbon electrolysis, and compressed $CO_2$.

| pH | 6.0 | 6.2 | 6.4 | 6.6 | 6.8 | 7.0 | 7.2 | 7.4 | 7.6 | 7.8 | 8.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| KHº | | | | | | | | | | | |
| 0.5 | 15 | 9.3 | 5.9 | 3.7 | 2.4 | 1.5 | 0.9 | 0.6 | 0.4 | 0.2 | 0.1 |
| 1.0 | 30 | 18.6 | 11.8 | 7.4 | 4.7 | 3.0 | 1.9 | 1.2 | 0.7 | 0.47 | 0.3 |
| 1.5 | 44 | 28 | 17.6 | 11.1 | 7.0 | 4.4 | 2.8 | 1.8 | 1.1 | 0.7 | 0.4 |
| 2.0 | 59 | 37 | 24 | 14.8 | 9.4 | 5.9 | 3.7 | 2.4 | 1.5 | 0.9 | 0.6 |
| 2.5 | 73 | 46 | 30 | 18.5 | 11.8 | 7.3 | 4.6 | 3.0 | 1.9 | 1.2 | 0.7 |
| 3.0 | 87 | 56 | 35 | 22 | 14 | 8.7 | 5.6 | 3.5 | 2.2 | 1.4 | 0.9 |
| 3.5 | 103 | 65 | 41 | 26 | 16.4 | 10.3 | 6.5 | 4.1 | 2.6 | 1.6 | 1 |
| 4.0 | 118 | 75 | 47 | 30 | 18.7 | 11.8 | 7.5 | 4.7 | 3.0 | 1.9 | 1.2 |
| 5.0 | 147 | 93 | 59 | 37 | 23 | 14.7 | 9.3 | 5.9 | 3.7 | 2.3 | 1.5 |
| 6.0 | 177 | 112 | 71 | 45 | 28 | 17.7 | 11.2 | 7.1 | 4.5 | 2.8 | 1.8 |
| 8.0 | 240 | 149 | 94 | 59 | 37 | 24 | 14.9 | 9.4 | 5.9 | 3.7 | 2.3 |
| 10 | 300 | 186 | 118 | 74 | 47 | 30 | 18.6 | 11.8 | 7.4 | 4.7 | 3.0 |
| 15 | 440 | 280 | 176 | 111 | 70 | 44 | 28 | 17.6 | 11.1 | 7.0 | 4.4 |
| 20 | 590 | 370 | 240 | 148 | 94 | 59 | 37 | 24 | 14.8 | 9.4 | 5.9 |

## Do-It-Yourself $CO_2$

DIY $CO_2$ involves adding yeast, sugar, and water to a bottle that is sealed and has a tube leading from the bottle to your tank. The yeast uses the sugar as food and gives off $CO_2$ as a waste by-product. The output end of the tubing is usually placed into the intake of a filter, which helps dissolve the exiting $CO_2$ into the water as it passes through. As you can imagine, yeast in a bottle doesn't give off a great amount of $CO_2$, so this method is usually used for small tanks or medium size tanks with lower light and slower growing plants. Its advantages are that it's very cheap, easy, and works well. A brew of DIY yeast culture will last about two weeks. A caveat to this method is suspending the sugar in gelatin. The yeast does not have access to all the sugar at once. Therefore, it is digested at a constant rate, which provides a slower and more consistent $CO_2$ output. The advantage of doing it this way is that it will last 2 – 3 months. The disadvantage is that the output of $CO_2$ is much less, so you are limited to very small aquariums, or you must add additional bottles of yeast. Other disadvantages to the DIY method in general are that it is fairly labor intensive and can be quite messy.

## Organic $CO_2$

Many plants are able to extract carbon from some small organic compounds. This ability is taken advantage of with the Seachem product Flourish Excel (www.seachem.com). This is usually a good choice for smaller tanks because of cost prohibitions and because it is just not feasible in large tanks where so much $CO_2$ is needed. Five milliliters of Flourish Excel is added per 10 gallons of water 2 – 3 times a week. People have complained of this product killing fish, but it only happens when you use more than the recommended amount. Also, it is safer if you dilute it in a little water before adding it or if you pour it in near your filter output. I believe that the only people who have killed fish with this product are people who used it incorrectly. I have used in excess of the recommended amount and poured it directly on top of gathering fish who thought they were about to be fed with no deaths. (As a side note, Flourish Excel is the best thing there is for killing black brush algae in my opinion.) Tanks with organic matter in the substrate can also benefit from this method. As the organic molecules decompose and float up into the water, some plants are able to extract $CO_2$ from them. For more in-depth information on this topic read *Ecology of the Planted Aquarium* by Diana Walstad. Autographed editions are available through the Aquatic Gardeners Association bookstore at www.aquatic-gardeners.org.

## Carbon Electrolysis

Carbon electrolysis involves a carbon block that is connected to electrodes. Electricity generates a reaction between the aquarium water and the carbon that causes $CO_2$ to be released. This is another method that is best for smaller tanks or medium-sized tanks with lower light and slower growing plants. The device gives off small amounts of $CO_2$, so in large tanks or brightly lit medium-sized tanks, the cost of replacing the blocks may more than justify the purchase of a compressed gas system. Advantages of this system are that it is very easy to use and works great. Its disadvantage is that it can be expensive. Carbo-Plus is the brand name of one of several devices that act similarly.

## Compressed $CO_2$

A compressed (or pressurized) $CO_2$ gas system is best for most situations. It is less time-consuming, less messy, and in the long run usually cheaper. The only situation for which it might not be the best choice is in small- or medium-sized tanks with low light and slow-growing plants. In those instances, it is a good choice, but it is probably more than is needed. A compressed $CO_2$ system consists usually of a bottle of $CO_2$ gas, a regulator, a needle valve, and something to help dissolve the $CO_2$ into the water. The system can also contain a solenoid valve and pH controller. $CO_2$ is allowed into the system via the regulator. The needle valve reduces the large volume of $CO_2$ from the regulator into a smaller controlled release of gas. Sometimes at this point a bubble counter is added to help gauge the rate $CO_2$ is flowing. Finally it all runs into a diffuser or reactor. A diffuser turns the stream of $CO_2$ into tiny bubbles, which are released directly into the tank. The bubbles dissolve into the water as they rise to the surface. A reactor is plumbed into the tubing from your filter or connected to a small pump. $CO_2$ is bubbled into the reactor and dissolves as water passes through. Reactors are much more efficient, but they are also more expensive. Some people run the outflow of $CO_2$ bubbles into their filter intake, which dissolves them as they pass through. Sometimes, however, $CO_2$ can build up and stall the filter and/or cause "burps" of $CO_2$ to be released.

With a compressed gas system, you can easily add too much $CO_2$, bottom out your pH, and suffocate your fish. Therefore, you must control its flow into your aquarium.

There are two processes for maintaining safe $CO_2$ levels: the manual and the automatic system.

With the manual system, $CO_2$ is slowly and constantly diffused into the water. This is the system employed by most aquarists. It is reliable, and the equipment needed is cheaper. Here are some factors to consider with this method. First, during the day, so much $CO_2$ is absorbed by the plants that the water can become deficient if not absent of $CO_2$ after a few hours with the lights on. Second, the opposite situation is a problem at night. Since the $CO_2$ is always going, it can build up, and levels can become too high. To remedy this, many people use an electric solenoid valve and timer to turn off the $CO_2$ flow at night. Alternately some use an air stone at night with a timer to drive excess $CO_2$ out of the water. Still again, since the water usually becomes so severely depleted of $CO_2$ during the day, many people leave the $CO_2$ on 24 hours because if the flow is small enough, it doesn't build up to critical levels anyway. I repeat that the manual system is the method used by most aquarists. While it seems to be fraught with hazards, it obviously works well. In recent times, single unit regulator, solenoid, and needle valve combinations have been available at a reasonable price. This has made option number one above almost a no-brainer. I personally don't recommend leaving the $CO_2$ on 24 hours a day.

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Oxygen "pearls" are formed when plants receive optimal growing conditions that include adequate $CO_2$.

The automatic system adds a pH meter/controller and an electric solenoid valve to the manual method. Remember when $CO_2$ is added to water, it makes it more acidic. The pH meter is set to a certain level, and when the pH goes slightly above that level, the controller (meter) opens the solenoid valve, and $CO_2$ is added to the aquarium. When the pH goes back below the set level, the controller (meter) will shut off the solenoid valve and $CO_2$ injection is stopped. Many people like this method, but the additional cost of the meter/controller and solenoid is prohibitive. Since the manual system is reliable, it is often argued that the automatic system is a waste of money. However, there are those that enjoy the accuracy, reliability, and gadget fun provided with automation. Also the price of pH controllers has come down in recent years.

Basically you will test your KH. Then with the manual system, you will test your pH very often over the first few days and correspondingly adjust the needle valve to increase or decrease the flow of $CO_2$ until you get the pH in the range you need. With the automatic system, you set the pH controller to the pH you want and it monitors the water and adds $CO_2$ only when you need it.

You should be concerned with the safety of compressed gas containers in the home. Should the bottle be tipped over and the regulator broken, a $CO_2$ cylinder can become a dangerous missile. This is particularly an issue when children or pets are involved. Use extra caution with bottles of compressed $CO_2$ gas.

There is a last method by which plants can obtain carbon, that will not be discussed in this article, called biogenic decalcification. In this process plants break down bicarbonate to utilize the carbon and oxygen within that molecule. Plants that originate from hard water take best advantage of this process. This makes sense because it is bicarbonate that makes the water hard. The application of biogenic decalcification to the home aquarium is limited. An excellent discussion of this topic can be found in *Ecology of the Planted Aquarium* by Diana Walstad.

So what are these pretty little bubbles that are coming from your leaves now? No, it's not excess $CO_2$. It is oxygen. In a healthy planted aquarium with supplemented $CO_2$, the plants put off so much oxygen that the water becomes unable to absorb any more. The oxygen collects underneath the leaves until it coalesces into bubbles, which float to the top of the water. The effect is rewarding and beautiful. It makes all the trouble of setting up $CO_2$ worth the effort.

## Light

Light is the energy that drives your plant's metabolisms. Without light, your plants don't have the energy to take up nutrients, grow, and survive. You won't get far without gas in your car, and plants will die very quickly without sufficient lighting.

When I first started learning to grow plants, all we knew to use for lighting was the bulb that came with the aquarium. At some point, someone made the observation that the sun is much brighter than that one lonely bulb in our hoods. Therefore, since plants grow in sunlight (and not in our tanks), maybe what was missing was sufficient light. Thus, the aquatic plant revolution started in the United States. People began adding more light to their tanks, and the plants started to grow. Finally, some success!

Soon after people increased their light, they decided maybe it wasn't such intense light that was needed but the proper spectrum of light. Immediately, special color rendition Vita-Lite and Triton bulbs became must-haves for everyone trying to grow aquatic plants. The plants looked better, but those bulbs were very expensive. Over time, the consensus turned back to intensity being the main factor in successful plant growth.

Today, it is generally recognized that plants will grow in a variety of spectrums as long as there is enough

A moderate light level can successfully and beautifully grow just about every common plant in the hobby today.

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light present. The taste of the observer is what mostly determines the appropriate color of light needed. Plants use light in the blue and red areas of the spectrum, but blue and red don't make for a pretty aquarium. Various broad spectrum "daylight" bulbs are the choice of most aquatic gardeners.

The color of light is usually expressed in degrees Kelvin. A light with a rating of 5500 Kelvin or K most approximates natural sunlight. Lights with a lower temperature such as a 4300K are more yellow and orange. Higher Kelvin rated lights, such as a 10,000K are more blue. Plants will grow in the extremes, but again, what matters is how the aquarium looks to you. For people who only have one bulb, they usually pick one somewhere in the mid range such as 6700K. People who have multiple bulbs often mix several different temperatures to bring out the various colors in their plants. As a side note, Kelvin is not the only method of qualifying light spectra, but it is the more commonly employed system by aquatic bulb manufacturers.

The amount of light you have is usually measured in watts per gallon. Simply add up the wattage from each of your bulbs, and divide it by the number of gallons of water that your tank holds. While this system is presently the standard, it is generally considered a poor method of quantifying the light you have. Some good alternatives have been proposed, however at this time no better system is recognized or universally accepted.

Actually, how much light you need is a subject of intense and sometimes livid debate. For years people have used the measurement of 2 – 4 watts/gallon. These days people grow plants with less and many people have much more. Generally about 3 watts/gallon or less is a low light tank and more than 3 watts/gallon is a high light tank. There is definitely no broad consensus here.

Other things that factor into the amount of light you need are how deep your tank is and what plants you want to grow. Very deep aquariums may need more light so that the illumination will penetrate down to the gravel. Also, different plants have different light requirements (discussed later).

How long you should leave your lights on (or photoperiod) usually depends on the amount of light you have and algae. For most people it is about 8 – 12 hours daily. If you have low light, you may need a longer photoperiod, and if you are getting algae, you can reduce your photoperiod to see if that helps.

Often plants are classified as low or high light plants when in truth most are neither. Many "low light" plants will grow and flourish in very high light. The error is that these plants don't usually prefer the lower light, they just tolerate it better than high light plants. Correspondingly, "high light" plants won't always die in lower light. They usually just grow slower and more subdued. For example, you might try to create a foreground from the plant *Glossostigma elantinoides* or "Glosso." In high light it grows as a runner with small leaves that tightly hug the gravel creating a lush lawn effect. Glosso is considered a high to very high light plant, but nothing could be more from the truth. It will grow great in mid to lower light. It will probably just grow straight up like a stem plant. *Cryptocoryne* species are known as low light plants, when in nature, many grow in direct sunlight. So in summary, the light needed to simply keep a plant alive may be different from that which is necessary for it to flourish and reproduce. Again, plants will survive and grow under a variety of lighting conditions. It is only when you get into the extremes where concerns about high- and low-light loving plants come into consideration. For the beginner's sake, here in the real world, if you stick to a moderate light level you will be able to successfully and beautifully grow about every common plant in the hobby today.

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*Cryptocoryne* are known as low light plants, but in nature many grow in direct sunlight.

There are three types of lighting commonly used in planted tanks. They are normal output fluorescent (NO), compact fluorescent (CF), and metal halide (MH). They are all good choices for lighting with each having its own advantages and disadvantages. Some factors to consider when looking at lighting are cost, spectra, and how quickly a bulb loses its intensity. Cost and loss of intensity are related because one bulb may be cheaper, but if you have to replace it three times more often than one that is twice as expensive, you are not saving money.

Normal output fluorescent lights come in the best selection of colors and have cheaper options available. However, some tend to lose their intensity relatively quickly and may not be bright enough for deeper tanks. Compact fluorescents have a strong intensity that is mostly retained throughout the life of the bulb. They can be expensive, but this is offset by their long life. The pins that connect the bulb to the socket are sometimes different in bulbs from different manufacturers. This can be a pain, but it has improved in recent times. Lastly, compact fluorescent lights can get very hot. Metal halides fairly quickly lose their intensity, are expensive, can get dangerously hot, and do not have as wide a selection of colors to choose from. However, the beautiful pinpoint beam they project causes a tank to sparkle and makes you forget about their negative attributes. Many people chose MH lighting solely on the look and ignore the negatives. In a visual hobby, what other reason do you need?

High output (HO), very high output (VHO), mercury vapor, and high pressure sodium lights are also used in planted tanks but not as often. T-5 bulbs are the newest type available, but so far there is only limited experience with their use. Lastly, LED lighting is being discussed for the future, but so far I know of no available fixtures using this technology. Stay tuned.

The best lighting is only as good as its reflector. Reflectors range from the useless white piece of plastic in the top of the hood, to super shiny polished aluminum. Obviously, the more mirror-like the reflector is, the better. Reflector evaluation also needs to involve the shape of the light beam reflected. A very tight beam will only illuminate a small area of the tank while the corners are in the dark. Some reflectors scatter light everywhere making them almost as useless as that white plastic piece. The ideal reflector would be very shiny and bent several times as to look like an upside down "U" with the ends spread a bit wide. Confused? Think of an arch under a very large expansion bridge.

**I definitely don't want to leave you with the impression that you must have high light to successfully grow aquatic plants.** The truth is quite the opposite. There is at least a minimum of light required for plants to grow and survive. You don't have to have 6 watts/gallon, but usually you need more than that which came in the hood supplied with your tank. Success can be achieved with many levels of lighting.

Again, light is the energy that drives the life processes of your plants. The amount of illumination you have will determine how much fertilizer your plants take up, how much you need to add, and how often you must add it. This is aside from $CO_2$, which will be absorbed faster in high light, but should be maintained at appropriate levels regardless of how much light you have. The amount of light you have is often the great equalizer that, apart from $CO_2$, determines how you carry out all the other aspects of growing plants.

## Substrate

Your substrate is not merely the stuff that holds plants down. It is a dynamic part of their health. Many think it's the simplest component of the aquatic garden, but it's a very complex part and often the most intensely debated.

One often-overlooked component of a substrate is its bacterial biofilm. After you place your substrate into the aquarium, it almost immediately begins to be colonized by bacteria. It can take several months for the bacteria to establish, but once they do, they help break down various materials and make nutrients available to the roots. Also plant roots secrete chemicals and enzymes that break down substances around them making additional nutrients available.

Cation exchange capacity, or CEC, is occasionally used to measure the merit of substrates. CEC is the sum total of the exchangeable cations that a soil (substrate) can adsorb. Cations are positively charged particles. Basically a substrate with a high CEC will have more positive charged particles for your plants to absorb. Since many nutrients used by plants fit this description, this is good.

In the old days, the only substrates available were colored quartz gravel, sand, or soil. Now things are considerably more complex. Substrates are hard to classify into groups, but for this article I have tried to create some organization by dividing them into inert, soil-based, laterite-based, nutritive substrates, and other.

The inert group includes the colored quartz gravels and sands sold in most pet shops. Plants can derive no nutrients from these substrates. After a long time in your tank, once a bacterial biofilm has had time to develop, the plants establish a little, and the gravel becomes filled with decaying organic matter, these substrates become viable. This usually takes many months and again, the nutrients don't actually come from the gravel or sand itself but from the material accumulated in it.

Soil is actually a good substrate. It has a high CEC, it probably already has a biofilm, and usually has lots of nutrients. Among its detractors are that it's messy, and anaerobic areas can develop. Anaerobic processes can give off gasses that are harmful to plants and fish. Also you can't really know what toxins, fertilizers, or parasites might be present in soil. Many people feel strongly about soil as a substrate, and its use has increased in recent times. A possible way around the risks of having potentially harmful soil is to use commercial potting soil. For more information on soil substrates I recommend you read *Ecology of the Planted Aquarium* by Diana Walstad.

Laterite is a gravel additive. It is clay or soil that is placed in the bottom layer of your aquarium's substrate. It is usually used with the inert substrates to make them fertile. Its good points are that it works great, is inex-

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A section of a planted aquarium with some of the Seachem Flourite substrate exposed.

pensive, has readily available nutrients, and has a high CEC. Its negatives are that it can be messy like soil, and some claim that it gives out over time unless you use substrate heating cables. There are several other gravel additives as well, but a discussion of them and a discussion of the substrate heating cables mentioned above goes beyond the scope of this article. Like most everything else in this hobby, some people love 'em. Some people think they are useless.

The nutritive substrates are various gravel type products that, unlike plain quartz, actually have some fertilizing capacity—some more than others. Compared to the other groups, these products are relatively new to the market. A few of these are Flourite, Onyx, Eco-Complete, Flora Base, and the ADA products. The debate is fierce regarding their merits or lack thereof. A detractor to these is their high price, but their advocates remind us that this is only a one-time expense for most of them. Individually they all have their various pros and cons. Overall they are good substrates for your tank.

A couple of substrates used that were not originally intended for the aquarium are Turface, which is used on baseball fields, and kitty litter (clay-based and containing no added chemicals). Some complain that Turface is too light weight and that kitty litter can get soft. However, many people have had success with both of these.

A good study on some of the above substrates and a few others can be found on Jamie Johnson's web page at home.earthlink.net/~kaydeejay/substrates.html.

## Nutrients

In the past, people added nothing to their tanks to fertilize the plants. Then at some point, someone said that plants needed iron to grow, and everyone had to have a bottle of Ferroplant, the only commonly available iron supplement at the time. In the nineties, Dupla additives were introduced and became popular with the addition of laterite to the substrate and Dupla drops to the water. The rationale was (and still is partially) that plants receive most nutrients through their roots. Fertilizer added to the water was transported to the roots via convection currents. During this time the idea of adding nitrogen and phosphorus to your water was heresy, as everyone knew they caused terrible algae outbreaks. A few years later Paul Sears and Kevin Conlin presented an informal study called appropriately enough the Sears-Conlin Paper (www.thekrib.com/Plants/Fertilizer/sears-conlin.html), where they used a mixture of trace elements, potassium, magnesium, and the previously forbidden nitrogen to fertilize their tanks. The results were that plants flourished and algae retreated in this phosphorus-limited environment. Ultimately a few years later, Tom Barr barbarically shattered the final sacrilege of aquatic gardening. With abandon he added phosphorus to his water, watched his plants grow, and the algae die.

So, which is the winner today? Well, as you might have guessed, despite years of successes with each of these methods and several others, there is still no consensus and the debate continues. If I were to guess, I would say that most people use a hybrid of several approaches. Most plants benefit from the addition of nutrients to the substrate as well as the water column. Additionally whether you limit them or supply them in abundance, plants must have all the basic nutrients to survive. The best thing to do is to get out on the Internet, do some reading, and pick a place to start.

In addition to carbon and oxygen, plants need an array of nutrients. These are usually divided into two groups, macronutrients and micronutrients. Macronutrients are those elements for which plants require significant amounts, and micronutrients or trace elements are those in which only minute amounts are needed. Personally I think of there being a third or "intermediate" class, which are those that fall somewhere in between.

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Most plants benefit from the addition of nutrients to the substrate and the water column.

The macronutrients are nitrogen, potassium, and phosphorus. The intermediate nutrients are calcium, magnesium, sulfur, and iron. The micronutrients are manganese, molybdenum, zinc, copper, boron, and others.

Most aquatic gardeners will agree on the above. The controversy in this area relates to how best to supply nutrients and how much if any need to be added. I will leave the "how much" to your future investigation and will briefly discuss the "how" below.

Depending on your tank's fish load, light, and $CO_2$ levels, enough macronutrients may be supplied by tap water, fish waste and other decaying matter. However in high light/high $CO_2$ conditions, these may need to be supplemented. There are now commercial products that supply nitrogen, phosphorus, and potassium in addition to bulk chemicals that can be purchased from garden centers and hydroponics supply businesses.

Note that the elements that make up your tank's GH are about the same elements that make up the intermediate nutrients. Therefore, if you have a few degrees of GH, you usually have enough of the intermediate nutrients. If your GH is low, then there are commercial products available to increase it. If you are creative, you can probably find the bulk chemicals to do this as well. The only exception here is iron. Most aquatic gardeners supplement their tanks with iron. Again, commercial products and bulk chemicals are available.

Micronutrients are also available in commercial preparations and bulk chemical trace mixtures. Because so little of the trace elements are needed, many people do not give them as much attention as they need. However, many enzymes require these elements to function. Even if only an infinitesimal amount is needed, it makes them no less important. Without them, the plants will languish or die. I personally believe that most people do not dose enough traces.

Once you decide how much of these you want to add from reading more advanced writings, there are two great online tools to help you with your calculations. Chuck Gadd's Fertilizer Calculator (www.csd.net/~cgadd/aqua/art_plant_dosage_calc.htm) and the "Fertilator" on Aquatic Plant Central (www.aquaticplantcentral.com/forumapc/fertilator.php?). The Fertilator is somewhat advanced and many of us used Chuck Gadd's Calculator for years before the Fertilator came along. I suggest you start with the Calculator and move on to the "Fertilator" when you are more comfortable with what you are doing.

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Members of the AGA, DFWAPC, and GWAPA after a successful day collecting aquatic plants.

## Computer

Maybe you don't think about it, but these days you need a computer to help you grow plants. The latest information is not in the books, and magazine articles are sometimes written by fish hobbyists who know little about aquatic plant keeping. (Some magazines though are better than others.)

Some of the most up-to-date information is available on any of several online aquatic plant mailing lists and bulletin boards. The box below contains some of the more popular ones.

The APD is the premier of all the lists, but it tends to be more oriented to the advanced hobbyist. Most beginner type questions have been answered on the APD multiple times, and a search of the archives might yield better results than making a post. Some of the other forums have commercial interests, but that usually doesn't keep you from getting great information and tips. I think they are usually better for the beginner. The forums also offer the advantage of being able to add pictures, which the APD does not.

For the chemistry challenged, there is good information on The Krib. Much of it is copies of old posts to the APD, but even though it is dated, the chemistry basics never change. The best place for aquascaping topics will be one of the forums. At this writing, Aquatic Plant Central (APC) is the most popular. Not only does it have great discussion groups, but has some excellent tools such as the "Fertilator" and algae identifier. I encourage you to spend some time in all the online communities to start with. Each often has different people and overall personality. A beginner may become a bit overwhelmed by the APD or the larger forums and prefer to start with a smaller group.

### Online Mailing Lists, Web Sites, and Forums

- Aquatic Plants Digest (APD) Mailing List fins.actwin.com/aquatic-plants/
- Aquatic Plant Central www.aquaticplantcentral.com/
- All Wet Thumbs Forum aquabotanicwetthumb.infopop.cc/eve
- Aquaria Central www.aquariacentral.com/forums/
- Aquatic Store www.fish-forums.com/board/
- Aquatic Quotient www.aquaticquotient.com/forum/
- The Krib www.thekrib.com
- My Fishtank.net www.myfishtank.net/forum/
- Plant Geek www.plantgeek.net/forum/
- The Planted Tank www.plantedtank.net/

Another good way to learn the hobby is to join your local aquatic plant club. Many clubs maintain their own internal mailing list, have plant trades, special speakers, local store discount arrangements, and other advantages no Internet-only based group can. Unfortunately for most people, there is no local aquatic plant club. The good news is that many clubs accept out-of-town members. Note that this writer lives in the mountains of Virginia, but has been in the Dallas-Fort Worth Aquatic Plant Club (www.aquatic-plants.org) since not long after its inception. I believe that being in a club, even if you live far away, is still more beneficial than only being a generic member of an email list or bulletin board.

Not a local society, the Aquatic Gardeners Association (www.aquatic-gardeners.org) is a national club organized for the promotion of planted aquaria. There is a quarterly full-color journal, a club mailing list, and a yearly (more or less) convention.

I think the best way to learn about aquarium plant keeping is to find a couple of plant buddies. I have learned volumes of information from reading various lists and boards, but nothing has helped me more than my almost daily emails with the webmaster of the DFWAPC web site. You learn to use and build off of each other's strengths and weaknesses. Once you get to know someone well, the advice you receive is more personally useful than that from anonymous people on the net.

## Miscellaneous

I'm sure that at this point you can't imagine what there is left to write about. Actually this could continue for many more pages, but I'm leaving the in-depth information for someone else to write. I'm going to finish with some odds-and-ends.

### *The Optimum Aquarium*

The Optimum Aquarium concept was introduced by the German company Dupla several years ago. Many in the U.S. do not use their methods as their products have sometimes been difficult to find and other systems have emerged. However, I believe their emphasis on the basics of light, $CO_2$, substrate, etc. is still important for all aquatic plant growers. The book *The Optimum Aquarium* has been out of print for quite awhile, but if you can ever find one to read, I highly recommend you do it. They are often available on eBay (www.ebay.com).

### Aquascaping

Finally you can grow plants, but your tanks still don't look as good as in the books. Now you need to learn how to aquascape. It's like landscaping, but you do it in your aquarium. There aren't really any comprehensive web pages on the subject, but as a good start, I suggest you search the Internet forums for and read the books on the amazing work of Takashi Amano. Also visit the Aquatic Gardeners Association web site for their online International Aquascaping Contest (showcase.aquatic-gardeners.org).

### Algae

Chances are that many of you are here because in your first attempt at growing plants, you found you could grow algae better. Don't worry. There are many places to help you with algae, and as you gain experience, you will find that it isn't so hard to get rid of.

### Balance

Successful aquatic plant growers will talk about balance. Personally it seems that when you have achieved aquatic balance, you can do almost nothing wrong, and your plants will grow easily and algae free. It is somewhat difficult to describe. Here are a couple pointers to get you on the right track.

1. Regardless of any other factor, adequate $CO_2$ must be supplied in some fashion. Most of you will require injected $CO_2$.

2. Light is the energy that drives your plants' nutrient needs. Light is the great equalizer. The amount of macro's, micro's, etc. you need will be determined mostly by the amount of light you have. Again, this is apart from $CO_2$. You always need appropriate levels of $CO_2$, period.

### Really Really Deep Topics

Occasionally you will see very involved discussions about various aspects of the hobby. Many cover physics, chemistry, biology, or other fields related to our pastime. They are sometimes very interesting and there is much to be learned, but often they have no real impact on your ability to grow aquarium plants. For example, not long ago there was a discussion on the APD about how gasses reach sonic velocity in a needle valve. The debate actually became somewhat heated. Does it make any difference to your plants how gas reaches sonic velocity in a needle valve? No. If a topic comes up that interests you, read until you drop, but don't let these complicated exchanges confuse or intimidate you. You can usually grow plants without the knowledge.

### Takashi Amano and the Nature Aquarium

If your interest in planted aquaria came from a crystal clear, sparkling, amazing picture of an aquascape on the Internet or a book, chances are it was one of the spectacular works of Takashi Amano. His aquascapes and the products of his business, Aqua Design Amano, or ADA, have inspired and partially driven the interest in aquatic gardening. Most information about he and his products is in Japanese, but the intense interest in them is slowly breaking down the language barrier. ADA products have recently become available in the US, which has further fueled enthusiasm. Not everyone is interested in his aquascaping style or feels that his products are worth the hype, but whatever you decide, these days you would be lacking if you didn't at least study Amano's work and methods.

## Conclusion

A few years ago, I noticed the shortening patience of experienced aquatic gardeners as they answered the same beginner questions over and over again. Then I attended a workshop by the Greater Washington Aquatic Plants Association (www.gwapa.org) a few months later. The club members had organized an excellent presentation with examples of lights, substrate, and a completely set up planted aquarium. At the end the speakers opened the floor to questions, but rather than the in-depth discussions on $CO_2$ and plants they were expecting, they were asked what temperature the water had to be for plants and what was a watt per gallon. As I mentioned in the beginning of this article, I felt that there was a lack of very basic information collected in one place to help people bridge the gap into aquatic plant growing. You can't learn how much light you need if you don't know how it's measured.

So there you have it. It was my intention to describe some of the processes, methods, materials, and equipment used to grow aquatic plants without over-influencing how you use them. While some influence is inevitable, I hope no one will set up an aquarium based solely on what is written here. Take these basics and use them to understand other sources you study. Remember, there is nothing here that is definite, and there is no point with which everyone will agree.

Now you know the basics, it's time to grow some plants.



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**Ben Belton** grew up near Charlotte, NC and has been growing aquatic plants with varying amounts of success since he was 16. He is a member of the AGA, DFWAPC, and GWAPA. He has a Doctor of Pharmacy degree and works for a hospital in the New River Valley of Virginia. When he is not up to his shoulder in an aquarium, Ben is usually hiking, in the gym, working on a web page, studying investing, traveling, or taking a nap. This article is dedicated to his parents, friends, and Ricky Cain who have put up with him being a plant geek for so many years. He would like to thank Jeff Ludwig, Cheryl Rogers, and the staff of AGA for their help in editing and layout.

***Cover photo by the author.***