Carbon in the Planted Aquarium

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Carbon is the backbone of all life. Every organic molecule of every living organism is predominantly carbon based. Given this simple fact, it becomes clear why carbon plays a pivotal role in the planted aquarium. Aquatic plants extract CO_2 (carbon dioxide) from their environment and employ it in a process called photosynthesis. Photosynthesis combines CO_2, water and light energy to produce simple carbohydrates and oxygen (O_2). The first and simplest carbohydrate produced from photosynthesis is 3-phosphoglycerate. It is from this simple molecule that larger and more complex carbohydrates arise (by way of a variety of enzymatic processes).

Growth rates of aquatic plants are strongly correlated[1] with availability of carbon and the plant's affinity for carbon uptake. Studies[1] have shown that plants with the greatest carbon affinity have the greatest growth rates, whereas those with lower carbon affinity have correspondingly slower growth rates. Because carbon availability is normally the limiting factor to growth, addition of CO_2 to a planted aquarium will always result in large increases in growth (assuming other critical elements are not lacking). Without additional CO_2 the growth rate will be dependent on the rate at which atmospheric CO_2 equilibrates into the water. CO_2 will dissolve into CO_2–free water to a degree that is dependent on the air pressure, temperature, pH and bicarbonate/carbonate content of the water. The final concentration of CO_2 in the water depends entirely on those factors. Once that concentration is achieved the level of CO_2 will not change unless the plants remove it or one of the other factors is altered. Plants remove CO_2 at a rate much greater than the rate at which it equilibrates into the water. So at the height of CO_2 utilization the plants limit their own growth by using up all available CO_2. Because CO_2 is an integral component of the bicarbonate buffer system a drop in CO_2 will necessarily result in a rise in pH. As the pH rises the influx of additional atmospheric CO_2 will be diminished by its conversion to bicarbonate. This is offset somewhat by hard water plants that can utilize bicarbonate directly. However, without routine water changes or buffer additions (Alkaline Buffer™ or Liquid Alkaline Buffer™) this path will eventually lead to complete depletion of the KH (carbonate hardness) which will result in dramatic pH swings from day to night (5.7 – 9.6).[1]

CO_2 injection bypasses this predicament by delivering a constant source of CO_2. Because the introduction of CO_2 will lower pH one has two options: (1) Monitor and calibrate the rate of CO_2 addition to precisely match the usage by the plants or (2) use a pH feedback metering system. (2) is ideal because as the pH falls below a certain point the CO_2 turns off, thus avoiding catastrophic pH drops.

If one is not quite ready for the initial investment in a CO_2 injection system but would still like to enjoy some of the benefits of adding additional carbon there is an alternative: Flourish Excel™. Flourish Excel™ provides a simple organic carbon molecule (similar to what is described above in the photosynthesis discussion) that plants can use as a building block for more complex carbohydrates. Because Flourish Excel™ is an organic carbon source it does not impact pH.

The chemical structure of Flourish Excel™ is quite similar to some of the products of photosynthesis such as Ribulose 1,5-bisphosphate and 2'-carboxy-3-keto-D-arabinitol 1,5 bisphosphate. Flourish Excel™ possesses the same basic 5-carbon chain seen in these molecules. The route through which Flourish Excel™ is used by plants involves two main processes: a) adsorption and b) transformation. Because the active component of Flourish Excel™ is charge neutral and of relatively low molecular weight it is readily adsorbed directly across the cellular membranes of most plants. Once present within the cell there are two possible modes of action. It may be biologically converted into CO_2 and then utilized in that fashion. Or, it may be converted into any number of more complex organic compounds needed for the life processes of the plant (e.g. sugars, starch, amino acids, etc).

These conversions (in either mode of action) are mediated by any of a variety of enzymes present (oxygenases, carboxylases, phosphorylases, etc). In order to determine the precise mechanism (i.e. down-conversion to CO_2, or up-conversion to longer chains) further studies involving radioactive C_{14} tracers would be necessary. However, with that said, our studies to date show that Flourish Excel™ imparts a measurable, quantitative growth benefit to plants. Thus, it is clear that the plants are utilizing the Flourish Excel™.

Our research has shown that Flourish Excel™ imparts not only a clear qualitative increase in plant health and vitality but also a clearly measurable increase in growth. Recent studies have shown growth enhancements using Flourish Excel™ that range from 200% - 500% (growth above normal growth seen without Flourish Excel™). These are only preliminary results of a currently ongoing study aimed at determining more precisely the relative growth response to Flourish Excel™ in comparison to a standard control and a CO_2 based control. The anecdotal evidence to date suggests that CO_2 injection will promote growth enhancements above the growth enhancements seen with Flourish Excel™ alone. However, one can still obtain a cumulative benefit by using Flourish Excel™ in conjunction with CO_2 as the two work quite well together.

1. Walstad, Diana, Ecology of the Planted Aquarium, Echinodorus Publishing, 1999, pp. 94-97.