Alternative Nitrate Reduction via Emergents

We describe techniques to reduce nitrates in your fish tank using a variety of plants...

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I had the good fortune of having limited access to an ichthyologist and marine biologist who operate a local fish store here in Southern California and work at an aquarium in San Diego. We began what became almost a full year of informal but largely quantified gatherings of data on nitrate reduction techniques and efficacy for freshwater aquariums. Some is unfortunately anecdotal, but much of it was quantified in a way that some aquarists may find helpful.

Filtration options for nitrate reduction, can be difficult, expensive and surprisingly fragile. The aerobic bacteria consume ammonia and nitrite, the anaerobic consume nitrates...but the latter are fussy eaters!

Nitrate reduction via filtration often has little to no effect as *it can take 6-8 months to build a sufficient anaerobic colony to actually reduce nitrates meaningfully...and this requires enormous volumes of media.*

Far more than would be need for the rest of the nitrogen cycle!

We began cultivating anaerobic colonies in pond media and found the amount of media required for an efficacious anaerobic colony to be far greater than would be practical in most instances. Nitrate reduction via anaerobic colony filtration is VERY inefficient and requires voluminous amounts of media for meaningful nitrate reduction.

One example is that a massive 900gph canister filter with some 6L of media capacity and TWO of these filters with a total of 12L of media *still* cannot support enough media for effective anaerobic colonies for a ‘typically stocked 125G SA cichlid tank’ for significant nitrate reduction.

Despite the deliberate architecture of this media (BioHome and Pond Matrix) to favor anaerobic colonization, anaerobic bacteria require a slower flow to maintain an oxygen-free environment. To that end the flow rates were rheostatic-ally altered as *we found the greatest growth rate of anaerobes to be around 50GPH.*

One such filter has ample amounts of flow and media capacity for aerobic colonies (the bacteria that removes ammonia and nitrite), but for anaerobic colonies (the bacteria that consumes nitrates), you'd need FOUR such canisters (25L pond media or similar) to have enough media to reduce nitrates just 10PPM!

This "Catch 22" inefficiency is compounded by the reduced flow rate such that nitrate reduction via media is very inefficient.

In addition, we also found that the anaerobic colonies are MUCH more fragile than aerobic such that they are easily killed by accident. I cannot quantify this section but I have experienced the results and I've yet to successfully neutralize rechargable media (with bleach) well enough to *NOT reduce the anaerobic colony count.*

In fact, re-using rechargable (with bleach) media that was then soaked in dechlorinator for 24 hours *still* killed off almost 6 out of 8 months growth of the anaerobic colony! Yet the aerobic bacteria saw no drop in population.

I went a different route after months of trying to get meaningful nitrate reduction in the filters. Instead of trying to get nitrate reduction with more filters or additional media, I tried emergent plants: roots in the water, leaves out the top.

I replaced part of the glass with plastic lighting grid to support the roots and stalks:

One tank was a 120G heavily stocked with adult SA cichlids--2 electric blue acaras, 2 large plecos and 8 severums in this case:

A 2nd tank, a 125G, was heavily stocked with larger fishes, plecos, oscars and pacus (I've since had to rehome my beloved pacus as they were approaching 18″ in length!):

120G - 125G

The following are before and after a two-week period with emergent plants above in these tanks:

***The 120 typically reached about 40ppm after a week when I'd do a WC.**

***Inside of two weeks, the 120G at 40ppm has yet to ever reach <u>10ppm</u>.**

***The 125 was more problematic with nitrates, as I was having enormous difficulty controlling them. This tank (prior to rehoming the pacus) would typically reach 80ppm-160ppm inside of 1 week (!) such that I was performing 2-3 WC's/week until I could rehome them!**

***Same time frame, the 80ppm-160ppm tank had still not risen to even <u>30ppm</u>!**

There was also little question that the nitrates fell further still, once we installed **grow lights**. This is not shown in the pictures as they were not installed yet.

With the lights on 12-16 hours/day or so, the 120 dropped from <u>10ppm to 5ppm</u>, or possibly 0; it's that difficult to read.

The 125 dropped to 10ppm and has yet to ever reach <u>20ppm</u> since adding the grow lights.

Here are two properties in play to be mindful of and they're entirely **photosynthetic**:

- **Terrestrial plants use more nitrates** vs ammonia than aquatic plants due to the availability of greater photosynthetic energy. They evolved with leaves under the sun, and in turn, enjoy more light energy which allows them to directly process nitrates more efficiently.
- **Aquatic plants first absorb ammonia** and will attempt to expend more energy if need be, photosynthetically, to consume nitrates so long as enough light energy is present.

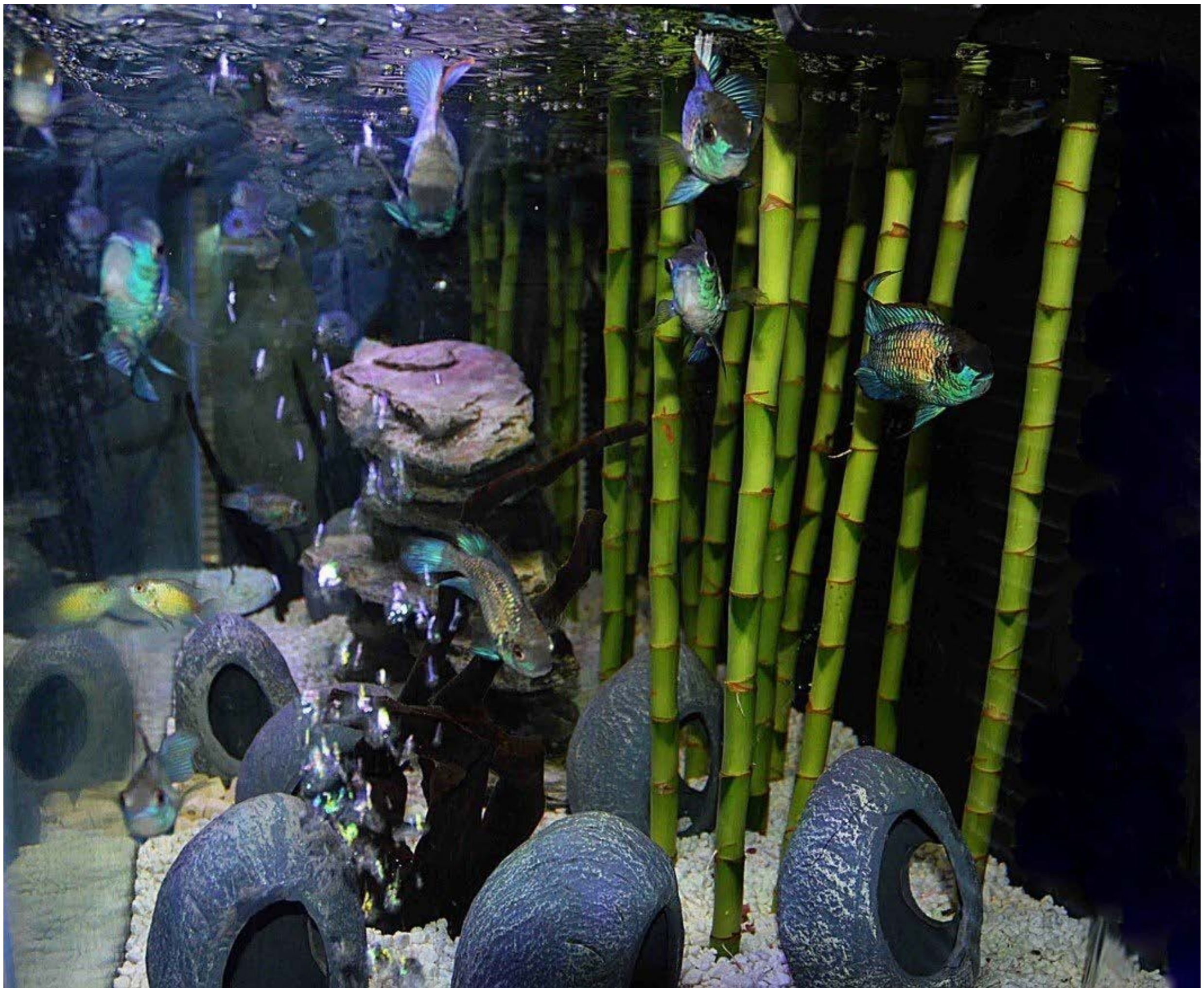
The latter is more efficacious when the lighting is stronger, which is not optimal for most aquatic plants nor the fish, as the efficacy of nitrate consumption is quite related to the amount of light the plants are exposed to. Naturally, submerged plants would see diminished light and evolve accordingly. But terrestrial plants evolved for this environment.

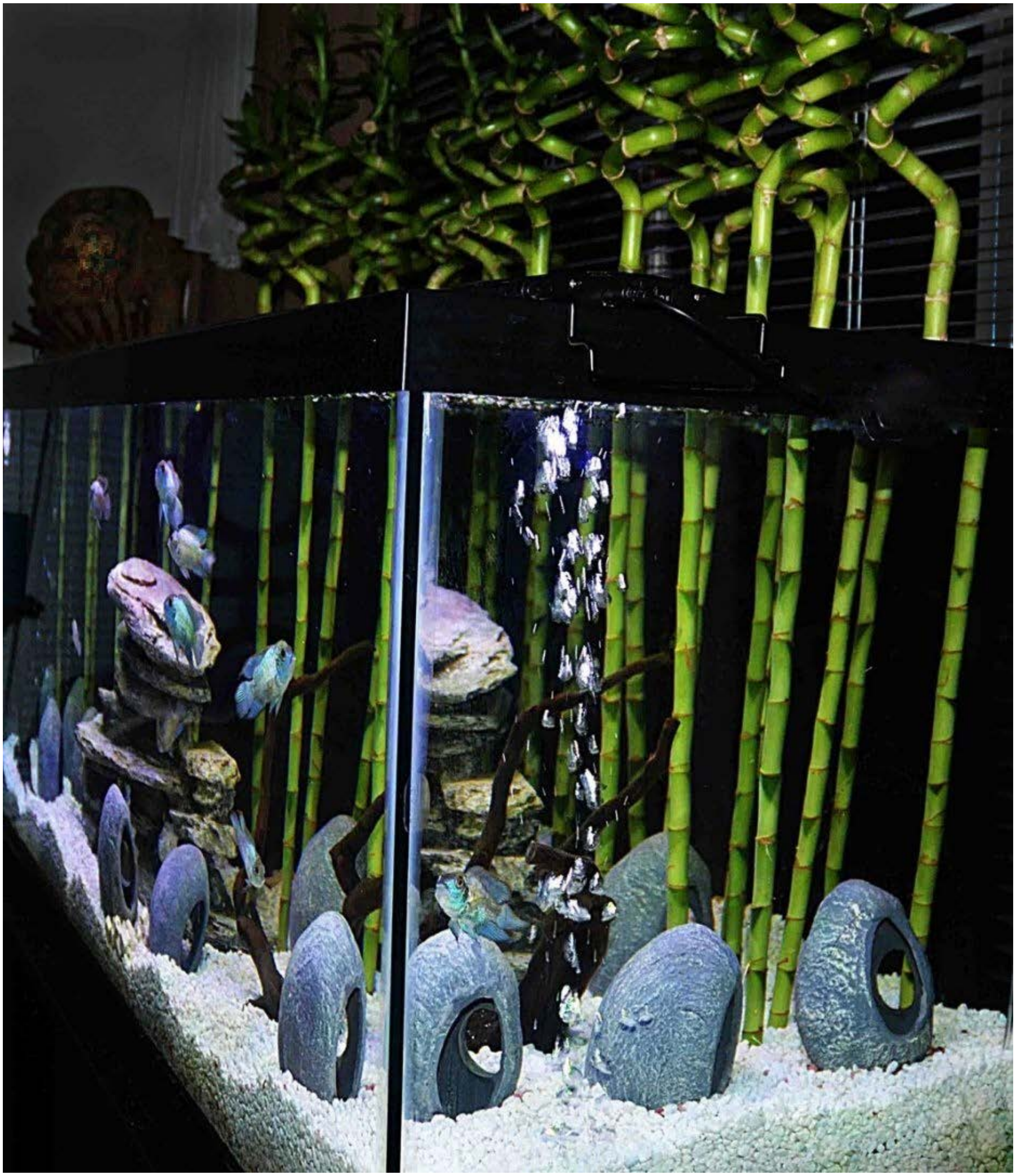
Specifically, there is a difference between aquatic and terrestrial plants in nitrate assimilation, and it's largely **spectral***.*

***** *<u>I've placed that data at the end of this piece as it's chemistry, and some may find it tedious.</u>*

I used pothos and monstera in my tanks as well as Lucky Bamboo in a 3rd tank. A single, $20 pothos plant has virtually eliminated nitrates in the 120 and the same with the 125 since rehoming the pacus:

The big (literally and numerically) surprise was the **dracaena,** or Lucky Bamboo. The pothos revealed its full potential in under 2 weeks. *Lucky Bamboo took longer to display results*, about 4 weeks vs only 2 weeks for pothos, but the 'bamboo' in particular has reduced nitrates so greatly, I'm not confident I can measure **any** at all with a liquid test kit now:





In my disbelief, I went out and bought a fresh liquid test kit to see if mine had spoiled; but again, NO nitrates! A fully stocked SA cichlid tank with 0 nitrates? It seemed crazy to me, but of all of the plants I've tried, Lucky Bamboo is the nitrate-eating champion thus far!

(What this older image does not show is their growth. In case you were wondering where all those nitrates went, the Lucky Bamboo has grown from 24" stalks to now 6' in height!)

I don't bother with rooting cuttings. I just wash the roots and let them drape into the tank through the plastic lighting grid. Of all my fishes, only the severums eat the roots (and the plecos eat the algae on the roots).

NOTE on Pothos Toxicity:

We also tested the pothos and others for toxins leaching into the water column. <u>It does not do so at any pH that would allow fish to survive</u>. Additionally, we describe how you can test for pothos (and others) toxins yourself with very inexpensive and commonly available home urinalysis test strips. I'll post this test next, as pothos toxicity is understandably a common concern for people considering emergent plants in their tanks.

I have seen my severums eat the pothos roots for over two years without incident:

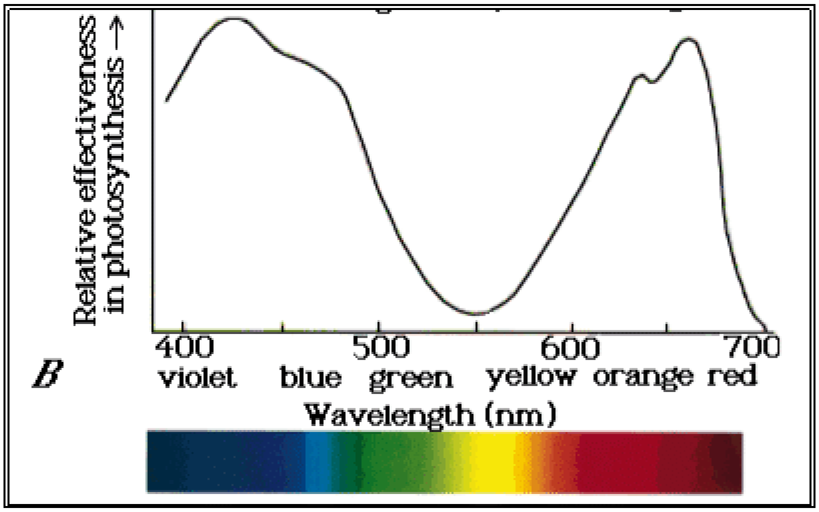
While it may not appeal to everyone, a single emergent plant can remove virtually all the nitrates directly from the water column if given enough time (weeks).

I wish this could be more extensive and exhaustive and less anecdotal, but given the limitations of our testing, *one thing I can say with confidence is there's no greater nitrate reduction one can get for a freshwater tank for $20!*

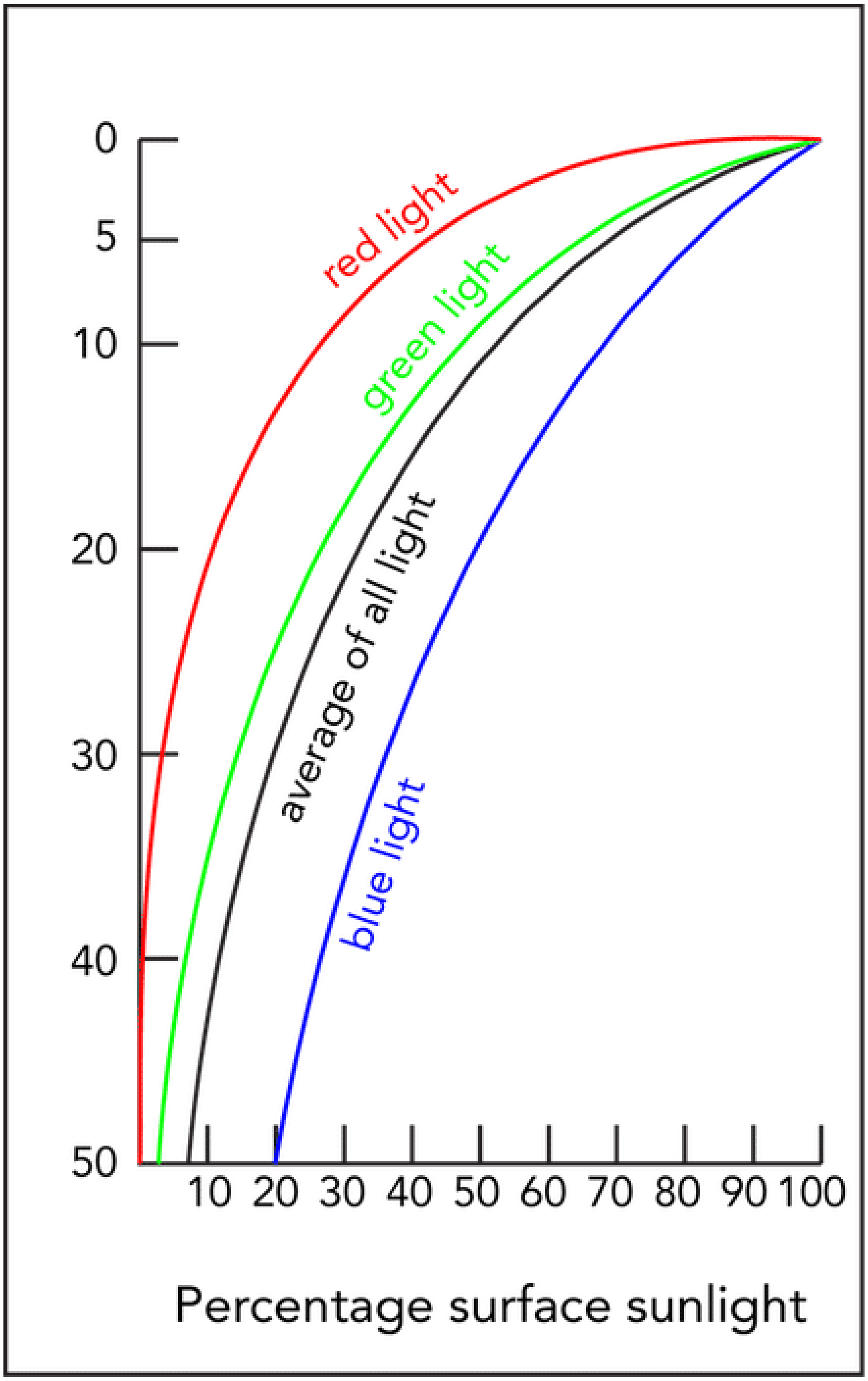
Many thanks to my good friend Alex for his guidance!

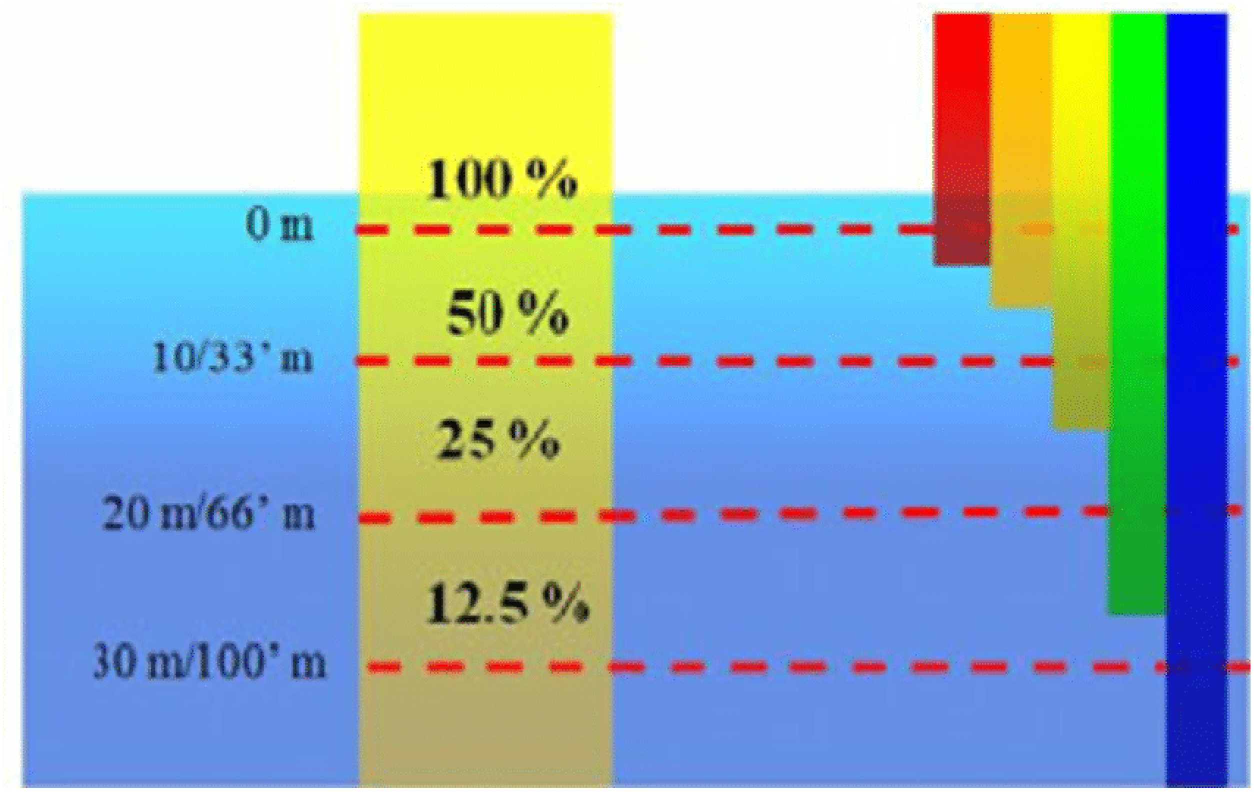
***** The Physics Behind Aquatic and Terrestrial Plants Nitrate Assimilation:**

What nutrients a plant assimilates, ammonia to ammonium or nitrates directly, is of course species-based but largely, it's wavelength based.



Terrestrial plants will typically see more red and white light whereas submerged plants not only see subdued white light (relatively), they see a spectral change towards blue which will exhibit much less photosynthetic energy than red such that the plant may not have the available energy to directly consume nitrates and will instead convert ammonia to ammonium.

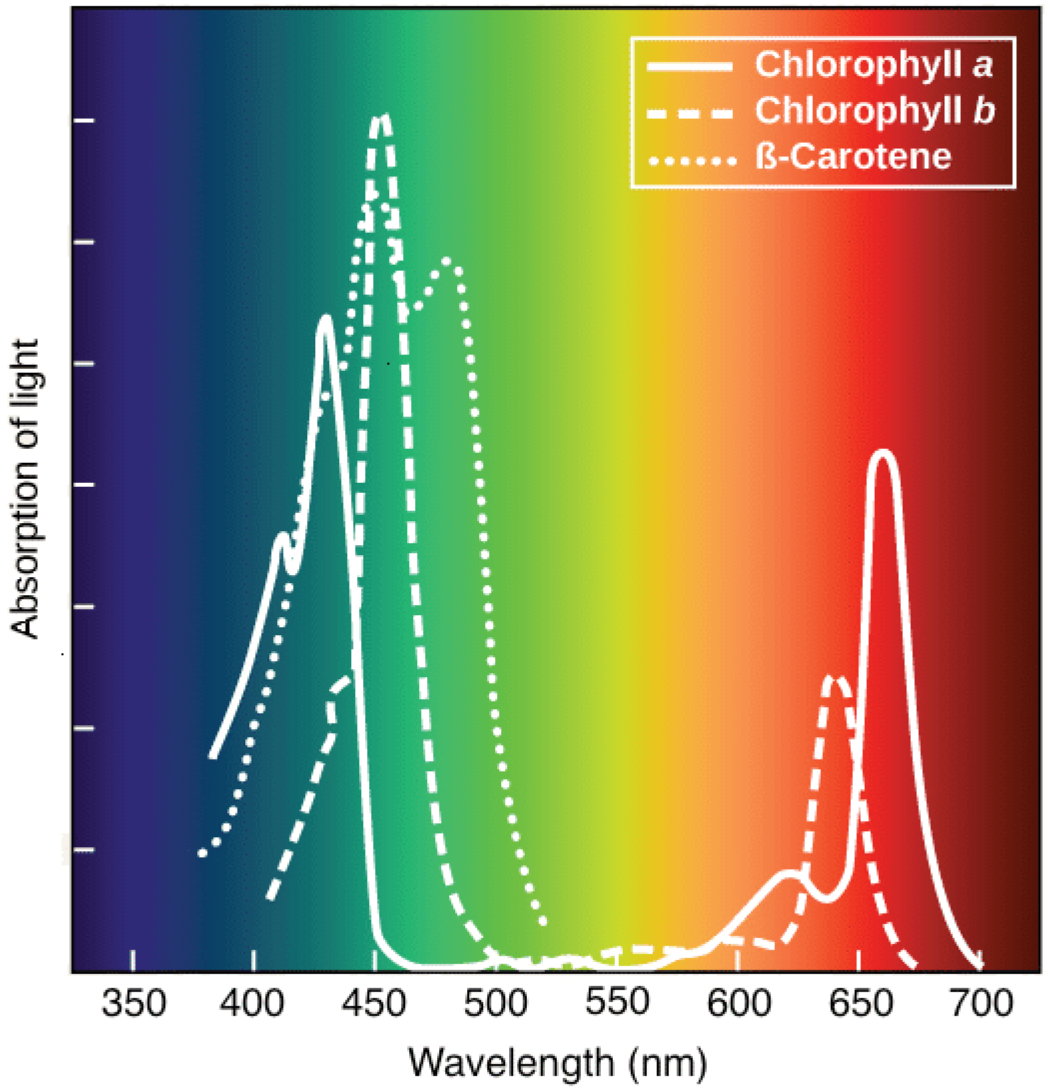

0
5
10
20
30
40
50
red light
green light
average of all light
blue light
10 20 30 40 50 60 70 80 90 100
Percentage surface sunlight



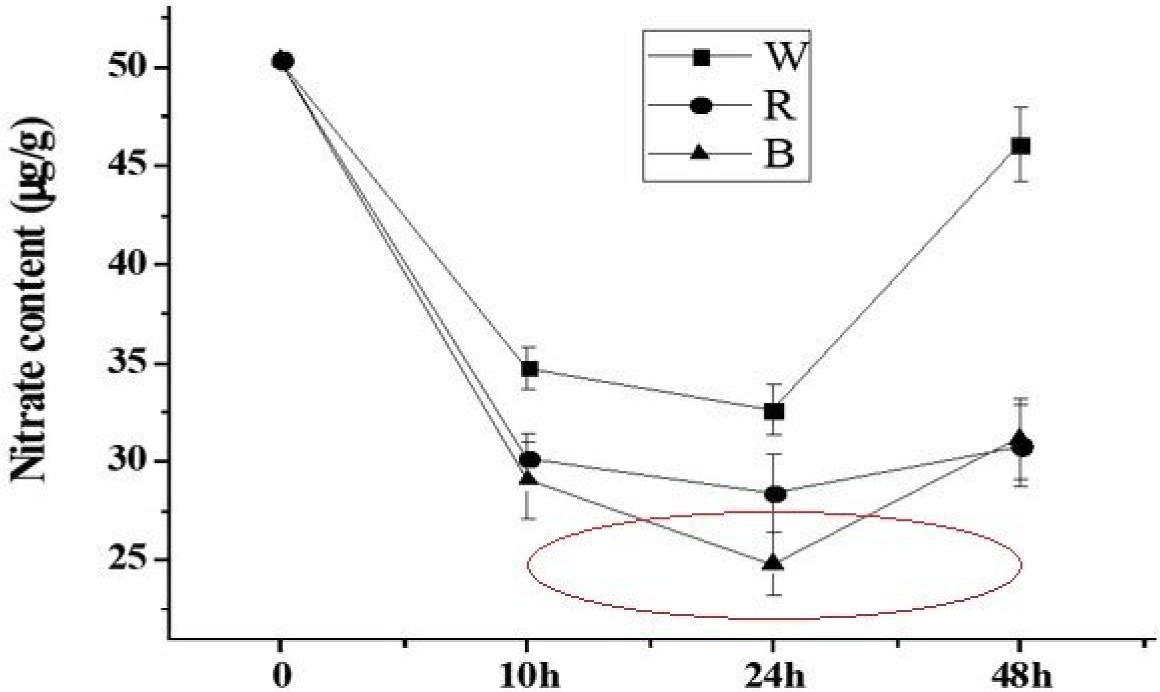
The ammonia/ammonium conversion requires much less energy which is but one reason aquatic plants tend to favor ammonia vs nitrates. This further compounded by the fact that ammonium is a cation and nitrate is an anion so ammonia is more readily processed by this metric as well as this is merely a stage of the entirety of the photosynthetic cycle (direct assimilation of ammonia by plants is caused by insufficient light energy). In aquatic plants, it only needs the addition of an ion (a charge) to create ammonium as opposed to the far greater energy required to assimilate nitrate itself (as the charged compound will innately contain additional energy to continue the process).

The environmental reason however is largely spectral. The wavelengths that power nitrate consumption reach peak efficacy at about 660nm, **Red**, or optimal efficacy for chlorophyll and phytochromes (below is such an example but it focuses on green light absorption).

Absorption Spectra of Pigments



Blue light too can power nitrate consumption but it is subdued by water penetration AND in that in concert with the shorter wavelengths and the ionic charges, it is much less efficient in processing nitrates as they require more energy for reduction as opposed to the simple conversion of ammonia to ammonium as aquatic plants do.

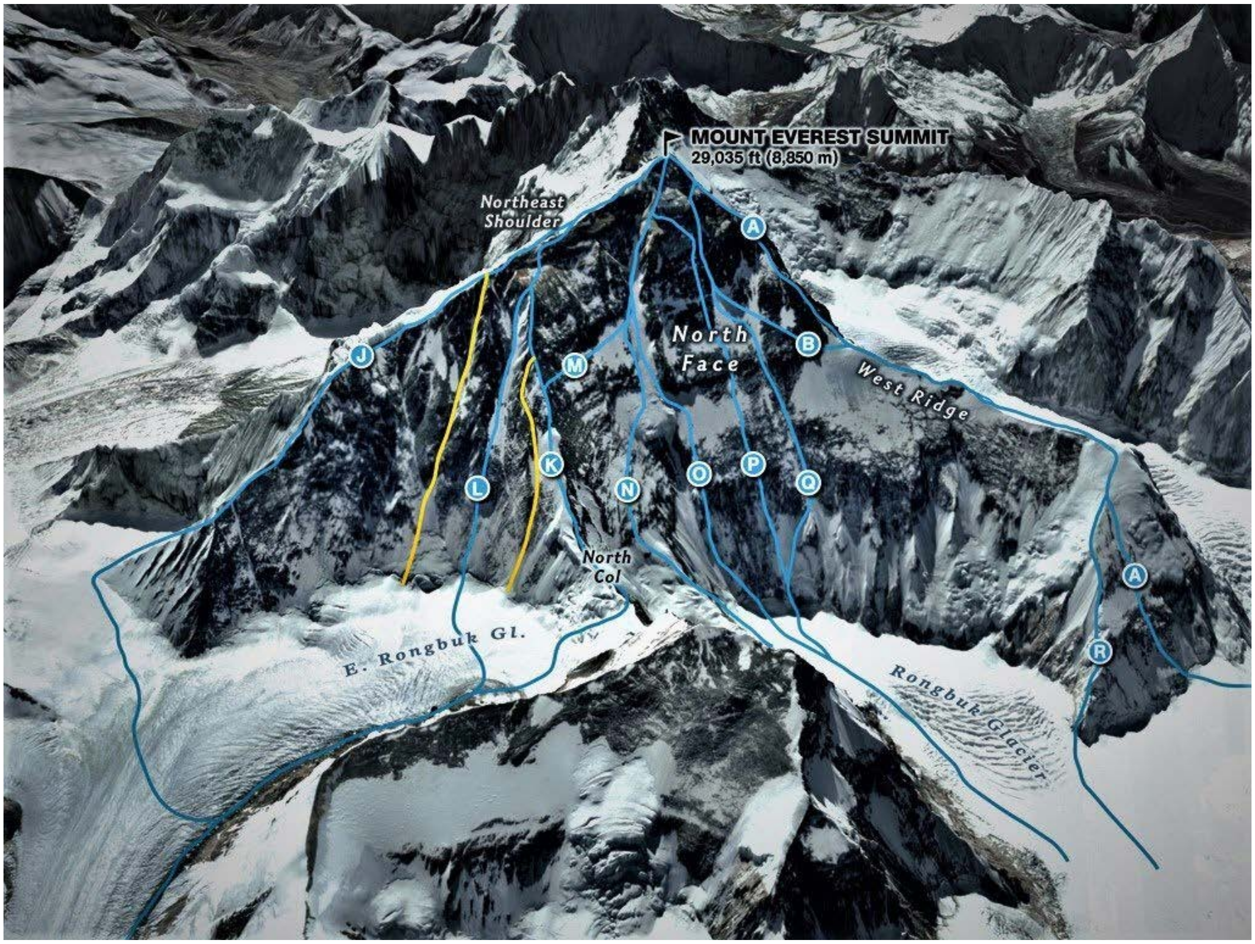


This chart shows how a plant assimilates nitrates in the first 48 hours of absorption *from any given moment.* It demonstrates how a submerged plant in subdued and/or bluer light cannot uptake nitrates as efficiently as terrestrial plants under red or white light. *The aquatic plant eventually catches up with nitrate assimilation in about 48 hours.*

The red circled area indicates the actual cation, the point where the plant assimilates ammonia to create ammonium!

This process is temporally but entirely bypassed by the terrestrials, direct to nitrate.

To that end, with brighter, whiter light and a touch of evolution, it's little wonder why floating plants are commonly called "nitrate sinks"! Perhaps it's only of interest to an old physicist but it is the last chart excites me the most!



The old Hindu edict; "Many Paths to the Same Summit" is certainly true here.

In inverse order of efficacy in nitrate reduction; be it filter media (anaerobically), aquatic plants or terrestrials , if given enough space, time and quantity, all of these can remove nitrates to similar levels. But their efficacy is very different as they will favor ammonia or nitrate and this changes over time and with the light quality.

All told, it's a lot easier for most of us to remove nitrates with plants than filters!

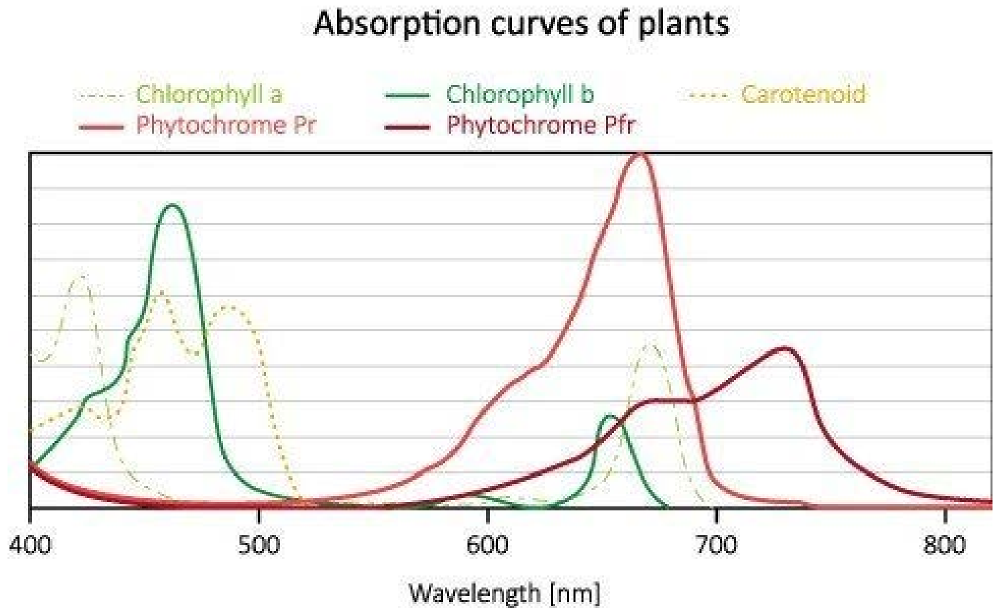
UPDATE:

Alex made an interesting and important point and allowed me to quote him below. Essentially, that although you can bias a plant towards the consumption of nitrate, ammonia or ammonium with different spectra, it's not necessarily good for the plant!

Here is his quote:

> *"There is a big misconception, even among those who work on LED lighting, about the importance of matching spectra to absorbance peaks. The problem is it is all an engineer's approach to biology that fails to capture the plasticity of living systems. The "blurple" grow lights are a manifestation of this. The idea is if you match the absorbance peaks of chlorophylls you will minimize the light energy you need to produce and maximize the energy proportion the plant can use. That's all well and good in concept, but plants have myriad antenna pigments they use to harvest other wavelengths, and they gain information from these. These are the colors people see in the autumn on deciduous trees. So, you are totally correct that full spectrum is now being recognized as better for plant growth and health. The best research LED grow light tout matching sunlight as closely as possible. Turns out plants aren't just machines that you can more efficiently plug energy into to get better output. They are living, complex organisms. That's what make it all so much fun!!!"*

The chart below (I love charts) further illustrates his points. Each stage in the photosynthetic process, does indeed accomplish varying goals for the plant. *For example, stomata regulation is largely accomplished by blue light yet red light enjoys the lion's share of CO2 assimilation.* That is, the entire spectrum has photosynthetic tasks that overlap but potentiate with specific light color and intensities. To that end, while you can bias a given plant's assimilation with lighting color, red/nitrate, yellow-green/ammonium, blue/ammonia, white is still best for the plant itself:


Absorption curves of plants
Chlorophyll a
Chlorophyll b
Carotenoid
Phytochrome Pr
Phytochrome Pfr
400
500
600
700
800
Wavelength [nm]