Substrate Heating Cables – (reprint) Part of the larger usenet "Aquatic Plant FAQ" series of articles in Tank Talk Volume 19 No. 3 1996

FAQ: SUBSTRATE HEATING CABLES
(contributed by George Booth)

Much of the mystery surrounding heating cables is that Dupla has been careful to hide the rationale to protect their product, i.e., keep it "magic".

I think a key concept is that we are NOT trying to mimic what happens in nature (even though the Dupla description implies that) but we are trying the achieve an equivalent biological affect.

In nature, you have sources of underground water moving to the surface or surface water moving to aquifers due to natural pressure differentials. Dupla mentions this in terms of "nutrient springs" in tropical streams. In our aquariums, there are no such natural pressures to cause any movement (except for UGF, etc).

The water column will tend to keep the gravel at water temperature through conductive heating; heat will "seep" downward. However, in glass tanks especially, the glass bottom is radiating heat into the room, cabinet, etc, unless insulation is provided. This will tend to keep the roots cooler than the water temperature. Even with insulation, you'll find the bottom of the substrate cooler than the top, just not as much.

Here is a list of substrate processes I think are important (no particular order of importance implied):

1. Provide warmth in the substrate for certain plant species (_Barclaya longifolia_, specifically). In this case the substrate should be warmer than the water. (``hot feet")
2. Provide warmth in the substrate to speed up biochemical processes.
3. Transport nutrients from the water into the substrate. Important nutrients would be ammonium (fish waste, etc), iron (from trace element additions), calcium, potassium and other trace elements. This will replenish nutrients used by the roots and provide long term viability (in terms of years).
4. Transport harmful products out of the substrate. Decomposition products may be harmful to plant roots. There is also conjecture that plants give off low level toxins to keep other plants out of their territory (successful weeds have made this an art form). If these toxins build up due to poor circulation, the plant may harm itself.
5. Provide a chelating medium that binds the divalent state of trace elements with an organic molecule, enabling the trace element to be adsorbed by root hairs.
6. Provide a reducing rather than oxidizing environment so that trace elements are kept in their divalent state (usable by plants) or are reduced from their oxidized trivalent state. Iron especially will rapidly oxidize in water with normal levels of oxygen.

Heating coils provide the ``hot feet" and warmth for biochemical processes directly. The convection currents generated by the "spot" heat source of the coils provide for nutrient and toxin transport. Laterite in the bottom 1/3 of the substrate provides the chelating medium. The slow convection currents, coupled with nitrifying bacteria in the gravel will reduce the concentration of oxygen getting to the bottom layer of the gravel, providing a reducing environment.

A _heating pad_ under the tank will tend to warm the entire bottom layer uniformly. This will provide hot feet and increased biochemical activity, but I suspect the heat will go through the gravel as conduction and _won't generate convention currents_. Thermodynamics theory says that conduction will occur up to a certain heat threshold and then convection currents will be formed with more heat. I think the linear hot zones generated by proper spacing of the coils along with the higher temperatures of the coils will provide this. Yes, there will be hot and cool zones for the roots but I think the other factors outweigh this.

Schemes that use warm water flowing in tubes in the gravel (Bioplast, for example) won't work, IMHO, because they can't generate enough heat. Bioplast wraps some tubing around a heater and pipes it through the gravel with a pump. The first foot or so of the tubing may get hot enough (though I doubt it) but the water in the coil will cool off rather quickly as it travels through the tube. If the tube is insulated enough to keep the water hot, then it won't transfer any heat to the gravel.

Reverse flow undergravel filtration (RUGF) will provide increased biochemical activity, toxin transport, and a reducing environment. It may provide ``hot feet" if you heat the water before putting it through the RUGF. Nutrient transport is kind of difficult since the water is usually filtered before going to the RUGF (to avoid injecting crud into the gravel) and trace elements probably will be oxidized in the filter (oxidizing is a bio-filter's purpose). Chelating is a problem because a RUGF will probably push the laterite up and out of the gravel. Don't get me wrong, a RUGF _may_ provide the six processes, but it would be difficult to get it set up with the right flows and even flow across the substrate and proper mechanical filtering, etc. A coil setup is a "no-brainer" if you have the correct wattage.

UGF will provide warmth for biochemical activity, and nutrient and toxin transport. Hot feet would be very tricky to achieve, if not impossible. Detritus pulled into the gravel can be chelated by the substrate, but a reducing environment is almost impossible unless a very slow flow is used and that would be hard to do evenly across the whole substrate.

We have three ~100g tanks with coils and one 85g tank with UGF. All grow plants equally well but the 85g is much more unstable. We think it is sensitive to too much detritus building up in the gravel; a thorough vacuuming every 6-9 months perks it up. The coil tanks require no gravel vacuuming and the 90g tank was rock solid biologically for at least three years. We replanted at that point because some of the plants had gotten out of control but we didn't "tear down" the tank - just replanted.

I think this is the key to the cables - long term stability. Plants will grow fine without them if you can accomplish most of the six things I mentioned. Just pulling up plants for trimming every month will accomplish as lot (stirring up the gravel, moving roots out of their toxin zone, etc).

Construction

Fully-automated systems can be purchased from commercial sources such as Dupla, though the cost can be a bit much for a beginner. You can save a great deal of money by buying just the cables and building the rest of the setup yourself. If you use a small enough wattage cable as a _supplement_ to your tank's main heater, the temperature controller can be ignored or replaced with a timer, requiring only a low voltage transformer! Furthermore, it is possible to make your own cables, taking the price down almost to that of a ``normal" heater.