Orchids Under Glass

A Custom Terrarium with Bells and Whistles

TEXT AND PHOTOGRAPHS BY DANIEL L. GEIGER

I PREVIOUSLY REPORTED ON BASIC considerations regarding growing orchids in a terrarium (Geiger 2008). After a couple years, I noticed some aspects that were not ideal:

- ♦ Overall size too small (that's always true, isn't it?)
- ♦ Lights on top of terrarium inconvenient
- ♦ Cooling during hot summer days with frozen water bottles problematic.
- ♦ Fogging and water droplets on front glass
- ♦ Humidity control not sufficiently adaptable
- ♦ Too much clutter with cables and tubing.

THE NEW TERRARIUM As I have a particular spot in our house for a terrarium, and because I wanted some special design options, I had a custom enclosure built through a local aquarium store. The first question was regarding the material of the tank. Glass is overall cheaper than acrylic and does not scratch as easily, but it can break, and it is more difficult to drill holes for tubing. Acrylic is more expensive, scratches more easily, but does not break, and one can drill holes easily. For the front, glass would be more suitable, but for the sides, where I wanted some tubing and equipment ports installed, acrylic would be more advantageous. Unfortunately, mixing acrylic and glass is not advisable, because the junctions of those two materials are not stable. I went with an all-glass tank 63 inches long × 24 inches high × 14 inches deep (157 × 60 × 35 cm). The planning of the internal layout and all the associated tubing and shop-drilled holes were done with scale plans drawn on the computer in the graphics application, *InDesign*.

Special design elements include drilled holes for line-in and line-out for a mister, automatic top-off system for waterfall/swamp cooler and cooling of swamp cooler. An internal compartment for the reservoir and a rail system to accommodate a piece of rock for the waterfall swamp cooler was installed at an angle. This geometry hides the equipment of the system in the rear portion of the triangular compartment.

[1] The terrarium in the author's dining room with the T5HO light suspended above. Behind the black cloth is the HerpKeeper control system (see page 36 for details.) In the background is a 4- × 9-foot (1.2- × 2.7-m) redwood-and-glass Santa Barbara greenhouse.

Integrating the water reservoir for the mister and top-off system into the main tank is not advisable, because the entire enclosure would have to be built to withstand the water weight in a relatively small portion of the overall tank. The glass has to be significantly thicker, meaning a heavier and more expensive tank.

With 20–20 hindsight, drilling holes through glass is not as difficult as it may sound. For the smaller reservoir tank I dared drilling my own holes. A decent hardware store usually has glass drill bits. With an electric drill, a steady hand, a bit of patience and a water spray bottle, a hole can be drilled in about five minutes. Given that a builder charges $20 per hole, the drill bit pays for itself with the second hole. Tempered glass cannot be drilled, as it will shatter.

MISTING After trying several misters, I found the MistKing (www.mistking.com) system. While not cheap, it is quiet. With the optional ZipDrip, any dripping from the nozzles can be eliminated. The starter kit from MistKing comes with a better timer, allowing timing down to one second. If you intend to get an integrated control system (see below) then purchasing à la carte may be better. The pump takes about five seconds to start up, so this time has to be added to the misting intervals.

For the nozzles, I selected the straight type because they are the least conspicuous. Some people may want to install a canopy over the terrarium, and then the premium line may be superior if an acrylic lid is installed, which can be drilled by any horticulturist.

I installed six misting nozzles about 9 inches (22.5 cm) apart with black zip ties (cable ties affixed through small holes drilled in the black plastic rim on which the tank's lid rests could also be used). The locking mechanism is pointing downward so the lid still closes reasonably tightly. The spray nozzles are almost completely hidden behind the top trim.

The MistKing tubing is the same as that for ¼-inch kitchen reverse-osmosis (RO) or water filtration systems. The tubing and connectors can be obtained at a hardware or specialized plumbing store, though usually not in black. Only the bulk-heads are difficult to find, i.e., the connectors to pass tubing through a wall.

For the water supply, I opted for a second, small custom tank measuring 9½ inches tall × 8¾ inches wide × 24 inches deep (24 × 22 × 60 cm). It fits precisely next to the main tank behind the board with the controllers that I constructed. This second tank has one drilled hole with a T-junction connecting the supply line for the mister and the top-off system for the waterfall or swamp cooler. One can also connect the RO outlet directly to the mister or an intermediate tank with top-off system.

LIGHTING Placing the growing lights on top of the tank makes removal of spent flowers or the application of fertilizer tedious. I opted for a hanging 60-inch (150-cm) Sunlight Supply Tek light with four T5 80 W Giesemann Powerchrome Midday 6000 K lamps with good color rendition index (CRI) of 90[1]. The whole fixture can easily be elevated or lowered to adjust light intensity and heat that affect the tank.

I chose the four-bulb setup because it is the same width as the tank, and as sets of two bulbs can be turned on and off separately I can mimic early morning–late afternoon with only two bulbs turned on, and midday with all four. In addition, the heat output of the lamps is reduced.

Two small computer fans on the fixture further mitigate the heating by the lamp. The temperature difference of the top glass with and without fans running is about 10 F. Computer fans vary in terms of size, flow rate and noise levels given in decibels (db). As my tank is installed in our kitchen–dining area, I selected low-noise SilenX iXtrema fans (60 mm, 8 db).

WATERFALL A waterfall was to provide the heat-exchange mechanism for the swamp cooler (see below). I wanted a film of water running over a smooth natural rock to minimize splash. Marble can be cut thin so that the tank glass would not crack from its weight. A U-shaped aluminum profile was glued to the back of the rock. To make the water flow over the front of the rock face, the back trough has to be about 2–3 mm higher than the level edge of the rock due to the surface tension of the water. A Rio 180

[2] *Dendrobium christyanum* (dwarf form) produces 1½-inch (3.75-cm) flowers that are larger than the pseudobulbs. It requires a summer rest, and is placed in a drier corner of the terrarium. Grower all plants shown: Daniel L. Geiger.

[3] *Dendrobium cucumerinum* requires excellent air flow so it is placed next to one of the computer fans.

[4] *Specklinia brighamii* produces yellow flowers measuring about ⅜ inch (1 cm). It grows better mounted on cork than potted and tolerates a lot of light (1,500–2,500 foot-candles) for a pleurothallid.

[1]Kindly communicated via email by Giesemann Lichtechnik & Aquaristic GmBH, Nettetal, Germany, which is good for T5HO lamps. Select full spectrum T5HO lamps have a CRI of up to 93. Regular fluorescent lamps such as cool white have a CRI of around 60.

mini powerhead pumping 45 gallons (170 L) per hour at a height (= "head" in pump language) of 24 inches (60 cm) turned out to provide just about the minimal flow required (~8 gallons [30 L] per hour per inch of the width of the waterfall).

Water loss due to splash can be avoided with the reservoir wall 1–2 inches (2.5–5 cm) above the water level. If the rock for the swamp cooler is immersed at the bottom in the reservoir, it reduces splash and makes for a more quiet operation; if you like a little gurgling fountain, then let the water drip back down into the reservoir.

SWAMP COOLER The tank can get excessively hot during peak summer days. Frozen plastic water bottles are an eyesore and can cause freezer burn on plants through direct contact. Some people have jerry-rigged a small air conditioner with duct tape and hose, but that was not appealing to me. Additionally, air conditioners remove moisture from the air (hence, the dripping from AC units), and tropical orchids rather like moist environments. Accordingly, some indirect means of cooling had to be accomplished, which will not lower humidity in the terrarium.

The idea is to cool a small volume of water quite strongly, and let that film of cold water flow over a flat piece of rock. A fan blows air over that wet rock transferring the heat of the air to the chilled water. Several coolers can be considered. Modified water coolers are unappealing and unproven. A pure electric cooler (Peltier elements), the Coolworks IceProbe, was too weak and failed after one day of operation.

The next step up in cooling power is a more conventional flow-through chiller available in the aquarium trade. After much deliberation and with the help of staff at a local aquarium shop I settled on a JBJ Arctica 1/15 HP chiller. It can cool the tank from 85 F (29 C) to 76 F (24 C) with water at 60 F in about an hour, the compressor active about half the time. There is a temperature gradi-


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[5] *Dendrobium aratriferum* grows in a small clay pot. It produces flowers that are half the size of the pseudobulb plus leaf. The flowers last only a single day, but are spectacular.

[6] *Schoenorchis fragrans* is a miniature — it grows only 1 inch (2.5 cm) tall. A more recent experiment, it seems to do well in the terrarium at intermediate light levels.

[7] *Leptotes bicolor* is a rather large plant for a terrarium; its thick pencil-shaped leaves are about 3–4 inches (7.5–10 cm) long. It produces rather long-lived and quite large flowers.

ent of about 2–4 F along the 5-foot (1.5-m) terrarium.

The plumbing is accomplished with various flexible hoses and some hard sprinkler tubing. The installed baffle at the entry to the reservoir turned out to be unnecessary with the 110 gallons (416 L)/h pump and the rather wide 1-inch (2.5-cm) tube diameter. The chiller can be detached to be stored elsewhere, and the tubing is out of sight. The chiller is only hooked up for about three months of the year.

AUTO TOP-OFF (ATO) Some of the water in the swamp cooler will be gradually lost due to evaporation and some splash. The pump and the chiller should not run dry, so an ATO is included. It consists of distilled water line fed by gravity flow, and a simple float valve. Gravity feed works by a higher water level in the reservoir tank, and no active pump is associated with it. I prefer gravity feed from a relatively small reservoir as opposed to having the water supply plumbed into a RO system, because in case of a malfunction, the tank can only flood to a relatively small extent. In summer about one liter per week is lost from the reservoir. In winter with the water being heated, the evaporation rate is much greater, and the ATO becomes convenient.

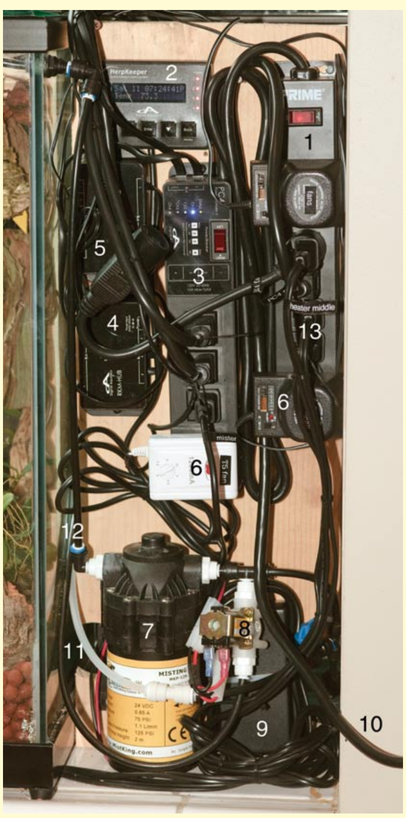
HEATING In winter the terrarium has to be heated at night for it to stay above 60 F (16 C). I installed three under-tank heat pads measuring 11 × 17 inches (27.5 × 42.5 cm), 25 W each, covering most of the underside of the tank. Heat pads come in two strengths: desert and rainforest, the latter reaching about half maximum temperature. As the roots of the plants should not be cooked I chose the latter (www.exo-terra.com/en/products/heat_wave_rainforest.php). However, they did not produce enough heat. How else to heat the tank? If it is possible to cool the tank indirectly through the waterfall, then it should also be possible to heat by the same principle. A secondary benefit is higher humidity, as the vapor pressure of water increases with temperature. A small 100 W aquarium heater (www.planetrenadirect.com/category/planetrena.rena.smartheater/) set to 80 F (27 C) kept the tank above 60 F (16 C) throughout the night. Humidity did increase and less misting was required, but the waterfall compartment lost water at a quicker rate. Given that the water heater is much cheaper ($25) compared with the three heat pads ($100) and produces better results, the water heater may be a good option for budget conscientious people. Whether some warming of the root zone has special merits on its own remains to be investigated.

Before I had the ATO installed, I manually topped off the waterfall reservoir with

[8] *Epidendrum peperomia* has overgrown its original mount and is covering some of the ghost wood branches. It flowers from about December through February or March.

[9] *Dendrobium pachyphyllum* has red-brown pseudobulbs that contrast with the green leaves. It grows on a stick-mount. The ¼-inch (.6-cm) flowers last only for one or two days.

Behind the Curtain



THE automated control for the terrarium's temperature and humidity is based on the Digital Aquatics HerpKeeper system and is mounted on a wood board with all components and wires labeled.

1. Main powerstrip connected to GFI protected outlet.
2. HerpKeeper control unit.
3. HerpKeeper controlled powerstrip with indicator lights.
4. Hub to connect additional units, essentially a small Ethernet hub, using Ethernet cables.
5. Moonlight controller.
6. Three variable power transformers for fans.
7. Mistking pump.
8. Mistking zip-drip.
9. Mistking power supply.
10. Main power cord.
11. White polyethylene tube connecting water reservoir behind control board to automatic top-off of reservoir for waterfall.
12. Black polyethylene tube supplying spray nozzles.
13. Under-tank heat element power cords.

— *Daniel L. Geiger.*

filtered tap water. After about two months, I cleaned the waterfall and finished the ATO setup. I noticed strong mineral deposits on the heater. With hindsight, this is not surprising, as I added mineral-rich tapwater, and only distilled water evaporated, leading to an accumulation of minerals. Using distilled, deionized, or RO water can help to reduce the problem.

ANTIFOGGING VENTILATION The front glass should be mostly free of water droplets. The misters will deposit some spray on the front glass, and under high humidity conditions, water may condense on the front glass obstructing the view. This problem had been addressed by a frog keeper with an ingenious venting system for a multitank arrangement (See www.mistking.com/pages.php?page id=7). Unfortunately, my attempts at replicating this approach failed. After some experimentation, four 60 mm downdraft fans, wired sequentially to one transformer and 1 foot (30 cm) apart, are affixed to the top rim of the terrarium with cable ties. While not 100 percent effective, it does improve the viewing conditions.

CONTROLS FOR TEMPERATURE AND HUMIDITY The control of the swamp cooler, heating elements and misters to maintain temperature and humidity within desired ranges was insufficiently developed. When it comes to advanced habitat control, the coral reef keepers are the clear leader in the field. Digital Aquatics has recently released the first such controller specifically designed for terrariums, the HerpKeeper.

After having tried numerous timers that are bulky and often cease to work after a while, the HerpKeeper is the answer to all those previous problems. I can only provide a brief overview here. The controller box is similar to a home thermostat with a few more options. An attached temperature and humidity probe gives its readings to the central controller. The controller can use timer functions to turn on/off outlets on modified four-outlet power strips at set times, intervals or when certain temperature or humidity conditions are reported from the probe. The temperature and humidity readings can also enact overrides (so-called alarms). For instance, I have set the mister to mist from 8 am to 8 pm for 15 seconds every hour, unless the humidity is greater than 70 percent, but between 8 pm and 8 am the interval is three hours.

While the product's capability and modular expansion options are staggering, the documentation is rudimentary. There is an active bulletin-board forum and email technical support is exquisite.

CONTROLLING CLUTTER The new orchid terrarium has a bit more complex infrastructure. However, I wanted to hide any cables and equipment as much as possible as not to distract from the intrinsic beauty of the display and the plants. As I do not have space underneath the bench, I use a wood board in front of the water tank to mount the HerpKeeper controller, power strips and the MistKing pump. The various plugs, outlets and tubes can be quite confusing, so I used a label maker to identify each, some even in more than one place. Cable ties additionally help to keep things neat and in place.

LANDSCAPING Landscaping involves several steps. First any localized pressure from pots and branches should be distributed so that the bottom glass does not break. At the bottom. I placed sheets of ¼-inch (0.6 cm) Styrofoam recycled from packaging material.

In the old tank, I used orchid bark and rocks for landscaping. The orchid bark does decay with time, so I went with expanded clay often used in hydroponics. It absorbs some water and thus, provides a humidity buffer but does not decompose. To hide pots at the front glass, I used thin pieces of slate, and where I wanted to create a bit of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[10] *Notylia barkeri*, one of the largest plants in the terrarium, bears 1-foot- (30-cm-) long inflorescences with more than 100 fragrant flowers.

[11] *Mystacidium capense* produces inflorescences with geometrically arranged spurs. It flowers occasionally in the terrarium.

[12] *Specklinia grobyi* is a free-flowering pleurothallid that can also take a lot of light. The inflorescences are about 3 inches (7.5 cm) long and bear ⅜-inch (1-cm) flowers that last about a week.

space between the plant and the front glass, I placed some cork used to mount epiphytic species.

For the epiphytes, I first transferred the old branches setup. Some of the orchids had grown onto those logs, so best to keep them where they are thriving. I added several additional pieces that also hide electrical cables. Some space was left intentionally open to allow for some taller species, such as *Lockhartia lunifera*.

PEST CONTROL In general, I don't mind a few animals in the tank. But vermin munching on buds or flower cannot be tolerated. Some isopods (roly-polies) of unknown source started to nibble on orchid buds. Dismantling the tank was not an option, manual eradication was bound to fail and I was not keen on using some strong chemical insecticide. On Orchidboard (www.orchidboard.com/community/terrarium-gardening/109-must-read-getting-rid-pests-terrariums.html) someone suggested dry ice (solid carbon dioxide) to suffocate the intruders. Some grocery stores, beverage or party supply houses sell dry ice for about US$1 per pound; 1–2 pounds should be more than enough for a 50–100 gallon (189–378 L) tank. Place the dry ice into a plastic container and wedge it under the tank cover, then add some hot water to sublimate the solid dry ice into gaseous CO_2. The CO_2 fills the tank with a thick fog, and the isopods start to die off immediately. An hour later, the dry ice had vanished and the tank was clear of the little miscreants. Plants did not show any adverse effects as the temperature drop in the tank was only about 5 F, but be careful that the dry ice container does not touch any plants as it will cause freezer burn. The treatment had to be repeated once to get rid of the newly hatched individuals; the CO_2 treatment does not kill eggs. Only use dry ice in well-ventilated areas as it is a breathing hazard.

WEEDS A second problem is unwanted plant growth. Moss overgrew *Acianthera luteola*[2] and suffocated the plant eventually. On the other hand, *Bulbophyllum acutebracteatum* took advantage of the moist grounds to root. The mosses also partially covered *Pinalia*[3] *amica* and *Dendrobium rigidum*[4]. The only remedy has been manual removal with fine forceps, but it is almost impossible to remove all pieces, so the procedure needs to be carried out periodically (every four to six months).

PLANTS How are the plants doing? Most of the original plants have been surviving; the losses were mainly the more cold–intermediate instead of warm-growing species (e.g., *Masdevallia* spp., *Lepanthes calodictyon*). The best species are *Angraecum distichum*, *Bulbophyllum roxburghii*,[5] *Bulbophyllum acutebracteatum*, *Dendrobium lichenastrum*,[6] *Den. rigidum*, *Epidendrum peperomia*,[7] *Lockhartia lunifera*, *Specklinia*[8] *tribuloides*, *Specklinia*[8] *grobyi* and *Cattleya*[9] *cernua*, disregarding the nibbling of the buds by the isopods on the last.

Ceratocentron fesselii is fickle. It set several inflorescences that started to mature over months, but then all of them wilted and fell off. Its leaves also shriveled, which leads me to believe, that I may have kept it in too bright light (1,150 foot-candles, shade recommended [http://www.orchidspecies.com/ceratfesseli.htm.]). Remounting it with moss and positioning it in shade shows some recovery, but it has not flowered yet. *Lockhartia lunifera* can grow 18 inches (45 cm) tall and requires an appropriately sized space. *Pinalia amica* is a slow grower, but the current five-pseudobulb plant produced three new ones. The rather short-lived inflorescences are spectacular, and worth the

wait. *Platystele ortiziana* is almost dying in summer, and usually recovering in winter. I received the plant potted in peat moss and have kept it that way. I suspect, excess water may also be a problem, and I have seen it recommended to be stick-mounted (http://www.andysorchids.com/pictureframe.asp?pic=images/Species/6310med.jpg&PicId=6310&PicNam=Platystele-ortiziana.). Similar overwatering problems may also be responsible for leaf loss in *Podangis dactyloceras*. I received it in orchid bark and perlite, but dry-out between watering is recommended (www.orchidspecies.com/podangisdactyleceras.htm.). I repotted it in expanded clay pellets but it did not survive. *Masdevallia* Pixie Shadow (*infracta* × *schroederiana*), an intermediate grower, has excellent vegetative growth in a shady portion, but did not produce flowers in the terrarium. In the greenhouse, at low to intermediate light levels, it is now producing a flower bud.

[13] *Bulbophyllum roxburghii* produces 2-inch (5-cm) umbrella inflorescences.

[2]Formerly *Pleurothallis caespitosa*.
[3]Formerly *Eria*.
[4]Formerly *Dockrillia rigida*.
[5]Formerly *Cirrhopetalum sikkimense*.
[6]Formerly *Dendrobium prenticei*.
[7]Formerly *Epidendrum porpax*.
[8]Formerly *Pleurothallis*.
[9]Formerly *Sophronitis*.
[10]Formerly *Haraella odorata*.
[11]Formerly *Oncidium variegatum*.

[14] Mats of moss growing on orchid bark. It suffocated *Acianthera luteola*[16] (brown leaf), but provided good rooting rounds for *Bulbophyllum acutibracteatum*. The spread has to be controlled manually.

[15] An isopod feeds on the leaves and buds of orchids. The population was eradicated with dry ice.

Some odd failures include *Haraella retrocalla*,[10] a well-regarded terrarium species and exquisite performer in my setting for several years, which eventually started to lose one leaf after the other, until none were left (pathogen?). A new specimen started to show the same symptoms, and has now been moved to a shaded greenhouse. *Tolumnia variegata*[11] produced one spike and multiple new fans, but the plant's leaves yellowed and eventually died, which may be a sign of too much light. 2,750–3,750 foot-candles are recommended, but even cutting that in half (see below for rationale) may still be too much. *Masdevallia zahlbruckneri* initially showed good growth and flowered, but after a few months dropped leaves and aborted flowers. It now lives in the shady greenhouse. *Bulbophyllum longissimum* is a very large species for a terrarium with leaves about one foot long. The flowers are just too gorgeous to pass up. After keeping the plant in the terrarium for about nine months with good vegetative growth, it has now been moved to the greenhouse, where it produced multiple inflorescences.

Some species are more recent additions, and while the initial observations are promising, it is too early to tell whether they will work in the long run: *Isabelia*[12] *violacea* (flowers, new pseudobulbs), *Cischweinfia sheehaniae*, *Bulbophyllum lasiochilum* (fickle, but if well grown then with excellent growth, several flowers), *Neofinetia falcata* and *Tolumnia calochila*,[13] *Restrepia muscifera* (flowered, producing new leaves), *Dendrobium*[14] *taylori* (flowered, good growth), *Dendrobium*[15] *aratiferum* (new leaves), *Dendrobium*[8] *cucumerina* (flowered, new leaves), *Masdevallia wendlandiana* (flowered, good growth). *Dendrobium christyanum* (dwarf form) has produced flowers since being placed in the terrarium, but has not yet produced new bulbs.

On pages 44–45, I list additional intermediate-warm-hot species that have been recommended for terrarium culture. This is a collation from internet boards, personal experience, and personal recommendations. I provide species name, temperature range (winter night minimum, summer daytime maximum), recommended published peak natural light intensity (see below for discussion and caveats), flowering season and watering requirements. Some large species have been omitted for practical reasons (e.g., *Vanilla planifolia*). Entries followed by an asterisk (*) are those that have worked well for me or that are recommended by multiple independent sources.

LIGHT LEVELS FOR PLANTS In general, published light level indications seem to be on the high side when applied to a terrarium setting. Specifically, *Epi. peperomia* has suggested light levels of 2,500–3,500 foot-candles (www.andysorchids.com.) and bright to partial full sun (www.orchidspecies.com/epiporpax.html), while my plant is showing visible signs of burning at 1,300 foot-candles (yellow leaves with brown edges), with shaded portions (250–500 foot-candles) being much healthier (solid green leaves). Note that the recommended and measured light intensities differ by an order of magnitude. Some plants have good vegetative growth in too low light but do not flower. This possibility can be excluded as my specimen flowers profusely in fall through spring.

This mismatch may be related to peak intensity compared to overall mean intensity; I presume that peak intensities are given in the cited sources. Outdoor light intensity is weaker by a factor of four to five in the early morning and late afternoon, compared with the peak hours (http://naturalfrequency.com/articles%5Caveragehourly), and varies by a factor two to three over the course of the year (www.solarpanelsplus.com/solar-insolation-levels/) at intermediate latitudes. In a terrarium, lighting is mostly provided by a constant, artificial light source, usually on a 12 hours on, 12 hours off cycle at full output. The total amount of light received over the course of a day is possibly a better measure, than the peak intensity. It is possible to convert the amount of natural daylight to the amount of artificially provided light in a terrarium setting (see the AOS website, www.aos.org, for mathematical derivation). Based on those calculations, around half of the usually indicated peak intensities are appropriate under continuous terrarium lighting regimes. We need to realize, however, that a number of factors are ignored here, including the spectrum of the light sources, spectral response of light meter, incident angle of light, nonlinear response of plants to light intensity (threshold illumination to photoinhibition), adaptation of plants to various light conditions, species-specific factors, population and

[12]Formerly *Sophronitella*.
[13]Formerly *Onchidium calochilum*.
[14]Formerly *Cadetia*.
[15] Formerly *Diplocaulobium*.
[16]Formerly *Pleurothallis caespitosa.*

strain-specific requirements and inaccuracy of published information. Hence, both the published recommended light levels as well as the correction factor advocated here should be taken as a starting point for experimentation and not a definitive value.

For instance, a strong peak in the T5HO lamps at approximately 430 nm (www.giesemann.de/63,2,,.html.) coincides with a high relative photosynthetic rate of plants at that wave length (www.life.illinois.edu/govindjee/paper/fig5.gif.). Natural sunlight at 430 nm has approximately 80 percent of maximum intensity (at approx. 480 nm [e.g., http://www.imaging-resource.com/ARTS/TESTS/SUNSOURCE2.HTM]), whereas the T5HO lamps emit about twice as much light at 430 nm compared with average maximum.

I measured light intensity given off by the T5HO lamps. Right at the lamp approximately 4,000 foot-candles are produced. At a sensible closest distance of about 5 inches (12.5 cm), which prevent excessive heat to reach the plants, and allows me to open the top of the terrarium, about 1,300 foot-candles are given off with two bulbs, about 3,000 foot-candles with all four running. These values drop to 620 foot-candles and 1,200 foot-candles in the middle of the terrarium, and 250 foot-candles and 500 foot-candles at the bottom of the terrarium, respectively.

If we assume as a first approximation that suggested light peak intensities should be cut in half for terrarium culture, then the maximum light intensity reaching any plant at any time should be around 1,500–2,000 foot-candles. These values are reached with the T5HO fixture at a distance of approximately 8–10 inches (20–25 cm) from the top of the terrarium. They will depend on many variables, such as exact bulb type, reflector design, and age of bulb.

Ideally, the daily and seasonal variation is mimicked in the terrarium. My four bulbs can be turned on and off in pairs. Two bulbs are on for 12 hours, and I only run all four bulbs during four hours. With this approach I can only double or halve the light intensity during the day, still falling short by a factor of two compared to natural daily light intensity changes.

In the aquarium trade there exist dimmable ballasts for metal discharge lamps, which can be managed by external controllers. Some metal discharge lamps have a excellent color spectrum (e.g., Iwasaki EYE colorArc with excellent CRI 96, and color temperatures of 4500 or 6500 K). Hence, there may be ways to deliver more natural light changes over the course of a day and throughout the seasons. For my application, the esthetics are better served by T5 fixtures than by metal discharge lamps. EcoZone (http://ecozonevivarium.com) lists some dimmable T8 and T5 fixtures.

The latest developments are LED light sources. They are used by some coral reef aquarists, and they also need high light output, but have different spectral requirements (higher UV contribution). LEDs use much less energy for the same light output, and also produce less heat. This area is promising in the future.

COST What does all this add up to? Below is a breakdown of costs:

- ♦ 100 gallon (378 L) custom tank ($700)
- ♦ Lights ($500)
- ♦ Misting system ($400)
- ♦ Chiller ($500)
- ♦ Waterfall ($50)
- ♦ Heating pads ($100)
- ♦ Water heater ($25)
- ♦ Controller (base: $200; with some optional additions $400)
- ♦ Miscellaneous ($300)
- ♦ Total (approximately $3,000, without plants).

While not cheap, the final result is both pleasing to the eye as well as to the plants. For me it is well worth it.

References

Geiger, Daniel L. 2008. Orchids Under Glass: Growing and Flowering Plants in a Terrarium. *Orchids* 77(11):846–853.

Daniel L. Geiger, PhD, is a marine invertebrate systematist working at the Santa Barbara Museum of Natural History. He is a member of the Orchid Society of Santa Barbara and the California Native Plant Society, and has been growing native California orchids outdoors, and more recently added an indoor terrarium with tropical orchids. Santa Barbara Museum of Natural History – Invertebrate Zoology, 2553 Puesta del Sol Road, Santa Barbara, California 93105 (email Geiger@vetigastropoda.com).


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18

[16] The rather uncommon orange-flowered *Bulbophyllum pecten-veneris*[17] is a compact plant with about 2-inch- (5-cm-) long inflorescences.

[17] *Masdevallia zahlbruckneri* is one of the masdevallias that tolerates somewhat higher temperatures, but requires low light (less than 500 foot-candles).

[18] *Bulbophyllum newportii* is a new addition to the terrarium. The straight inflorescence is about 1½ inches (3.7 cm) tall and bears about five to seven ¼-inch (0.6-cm) flowers.

[17]Formerly *Bulbophyllum tingabarinum.*

A Selection of Orchids

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Bulbophyllym lasiochilum

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Cattleya cernua

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Dendrobium christyanum

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Dendrobium taylorii

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Haraella retrocalla

Orchid	Temperature (F)	Light (foot-candles)	Flowering	Watering
Aerangis luteoalba var. *rhodosticta*	warm	light shade	winter spring	moist
Amesiella minor	52–80	500–1,500	winter	moist
*Angraecum distichum**		500–1,000	all year	
Angraecum didieri	55–58	1,500–2,500	all year	moist
Ascocentrum	58–88	2,500–3,500	spring	moist
Asconopsis (*Ascocentrum* × *Phalaenopsis*)				
*Bulbophyllum acutibracteatum**	warm–hot	500–1,000	autumn	moist
Bulbophyllum alagense	55–85	500–1,500	all year	moist
Bulbophyllum clandestinum[1]	cool–warm	partial shade	spring–autumn	
Bulbophyllum corolliferum[2]	58–88	1,200–2,500		
Bulbophyllum fascinator	58–88	1,500–2,500	summer–autumn	moist
Bulbophyllum inunctum	cool–hot	light shade	summer–autumn	moist
*Bulbophyllum lasiochilum**	58–88	2,500–3,500	all year	moist
Bulbophyllum longissimum	58–88	1,500–2,000	all year	moist
Bulbophyllum odoratissimum	cool–warm	partial shade	spring–summer	moist
Bulbophyllum pardalotum	hot	shade	all year	
Bulbophyllum pectin-veneris[3]	60–90	2,000–3,000	spring–summer	moist
*Bulbophyllum roxburghii**	hot	500–1,000	winter–spring	moderate
Cattleya[4] *cernua**	55–85	2500–3,500	winter–spring	moist
Cattleya[5] *lundii*	45–98	1,500–2,500	winter–spring	moist
*Ceratocentron fesselii**	cool–hot	shade	winter	moist
Ceratostylis philippinensis	55–85	1,500–2,500	winter–spring	moist
Chiloschista viridiflava	58–88	2,500–3,500	variable	moist
Christensonella[6] *uncata*	58–88	1,500–2,500	all year	moist
Cischweinfia pusilla	58–88	1,500–2,500	all year	moist
Dendrobium aberrans	55–85	2,500–3,500	winter–spring	moist
Dendrobium[7] *aratriferum*	55–85	2,500–3,500	all year	moist
Dendrobium atroviolaceum	58–88	2,500–3,000	winter–spring	moist
*Dendrobium christyanum**	40–95	2,500–3,500	spring–summer	moist
Dendrobium[7] *chrysotropsis*	cool–intermediate			
Dendrobium[8] *cucumerina**	cool–hot	part shade	winter– spring	moist
Dendrobium kingianum	40–95	2,750–3,750	winter–spring	moist
Dendrobium lichenastrum[9]*	58–85	2,500–3,500	all year	moist
Dendrobium[8] *linguiforme*	55–58	2,750–3,750	(autumn) winter (spring)	
Dendrobium oligophyllum	55–85	2,500–3,500	autumn–winter	moist
Dendrobium[8] *rigidum**	45–98	500–3,500	all year	moist
Dendrobium taylorii[10]*	55–85	500–1,500	all year	moist
Dendrobium toressae	cool–hot	part sun	spring	
Dendrochilum wenzelii	55–85	2,000–3,000	spring–summer	moist
Dinema[11] *polybulbon*	45–98	2,500–3,500	autumn–winter	moist
Dyakia hendersoniana	hot	part shade	spring summer	moist
Epidendrum longirepens	58–88	1,500–2,500	all year	moist
Epidendrum nocturnum	58–88	500–1,500	all year?	moist
Epidendrum peperomia[12]*	55–85	2,500–3,500	winter–spring	moist
Epidendrum schlechterianum[13]	warm–hot	shade	winter–spring	
Gastrochilus matsuran	intermediate–warm	intermediate		moist
Gomesa[14] *croesus*	cool–hot	part shade	spring–summer	moist
Gomesa[15] *eleuterosepala*†	cool–hot(?)	part sun	winter	
Gomesa[16] *radicans*	55–85	2,000–3,000	summer–autumn	
Grandiphyllum auricula[17]	55–85	2,500–3,500		
Grandiphyllum[14] *edwallii*	55–85	2,500–3,500	autumn–winter	

KEY † http://www.orchidspecies.com/rodrieuletherosepala.htm lists the species as cool growing, whereas the vendor (Santa Barbara Orchid Estate) labels it as temperature tolerant. * recommended by multiple sources or growing well in the author's terrarium. **Temperature** Cool: ~52–75 F; Intermediate: ~58–80 F; Warm: ~60–85 F; Hot: ~70–95 F. **Watering** Moist: no prolonged drying of roots, watering usually once a day; Moderate; some drying of roots between waterings, watering usually every two to three days. **Light** Shade: 500–1,500 foot-candles (f-c); Part Shade: 1,500–2,500 f-c; Intermediate: 1,500–3,500 f-c; Part Sun: 2,500–3,500 f-c.

Grown in the Terrarium

Orchid	Temperature (F)	Light (foot-candles)	Flowering	Watering
*Haraella retrocalla**	55–85	500–1,500	all year	moist
Isabelia[18] *violacea**	55–85	2500–3,500	winter–spring	moist
Leochilus carinatus	cool–hot	light shade	spring–winter	moist
*Leptotes pauloensis**	cool-hot	light shade	spring–winter	moist
*Lockhartia lunifera**	58–88	1,500–2,500	all year (?)	moist
Macodes petola	warm–hot	part shade	autumn	
Malaxis sp.	58–90	500–1,500	seasonal	moist
Masdevallia floribunda	45–98	500–1,500	summer	
Masdevallia herradurae	55–85	500–1,500	summer–autumn	moist
Masdevallia Pixie Shadow (*infracta* × *schroederiana*)	intermediate	shade	spring–summer	
Masdevallia wendlandiana	65–95	500–1,500	all year	moist
Masdevallia zahlbruckneri	cool–hot	500–1,500	all year	moist
Neobathiea grandidierana	cool–warm	shade	spring	
*Neofinetia falcata**	55–85	2,500–3,500	all year	moist
Nephelaphyllum sp.	warm	shade	spring summer	
*Notylia barkeri**	intermediate–hot	1,000–2,000	winter–spring	moist
Pinalia[19] *amica**	cool–warm	part shade	spring	moist
*Platystele ortiziana**	55–85	500–1,500	all year	moist
Pleurothallis allenii	55–85	1,500–2,500	spring–autumn	moist
Pleurothallis fastidiosa	warm–hot	shade	spring	
Pleurothallis luctuosa	55–85	1,500–2,500	all year	moist
Podangis dactyloceras	58–88	2,000–3,000	spring–summer–autumn	moist
*Restrepia muscifera**	55–85	500–1,500	all year	moist
Robiquetia sp.	cool–hot	part sun		moist
Sarcochilus ceciliae	cool–warm	part sun	spring–summer	moist
Scaphosepalum fimbriatum	warm–hot	500–1,000	all year	
Specklinia[20] *brighamii**	58–88	1,500–2,500	all year	moist
Specklinia[20] *grobyi**	40–95	1,500–2,500	all year	moist
Specklinia[20] *megalops*	55–85	1,500–2,500	all year	moist
Specklinia[20] *microphylla*	warm–hot	part sun	summer–autumn	
Specklinia[20] tribuloides*	55–88	500–1,500	all year	
Stelis microchila[21]	warm–hot	500–1,500	spring–autumn	
Stelis morganii	cool–warm	shade	spring	
Stelis[20] *restrepioides*	52–80	500–1,500	winter– spring	
Tolumnia calochila[22]*	65–95	2,500–3,500	all year	moist
Tolumnia variegata[23]*	60–90	2,750–3,750	winter–spring	
Trichoglottis triflora	45–98	2,000–3,000	winter–spring	moist
Zootrophion atropurpureum	warm	500–1,000	summer–winter	
Zygostates lunata	warm	shade	autumn–winter	
*Zygostates pellucida**	warm–hot	shade	variable	moist

[1]Formerly *sessile*.
[2]Formerly *Cirrhopetalum curtsii*.
[3]Formerly *Cirrhopetalum tingabarinum*.
[4]Formerly *Sophronitis*.
[5]Formerly *Laelia*.
[6]Formerly *Maxillaria*.
[7]Formerly *Diplocaulobium*.
[8]Formerly *Dockrillia*.
[9]Formerly *prenticei*.
[10]Formerly *Cadetia*.
[11]Formerly *Encyclia*.
[12]Formerly *porpax*.
[13]Formerly *congestoides*.
[14]Formerly *Oncidium*.
[15]Formerly *Rodrigueziopsis*.
[16]Formerly *Ornithophora*.
[17]Formerly *Oncidium harrisonianum*.
[18]Formerly *Sophronitella*.
[19]Formerly *Eria*.
[20]Formerly *Pleurothallis*.
[21]Formerly *barbata*.
[22]Formerly *Oncidium calochilum*.
[23]Formerly *Oncidium variegatum*.

— Compiled by Daniel L. Geiger.


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Isabelia violacea


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Lockhartia lunifera


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Restrepia muscifera


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Tolumnia calochila


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Zygostates pellucida