Successful cultivation of *Darlingtonia californica* in a hot climate via root zone chilling

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In fall of 2018, I was hired for my current position as conservatory technician at the Huntington Botanical Gardens. In this position I maintain the displays and interactive exhibits housed in the Rose Hills Foundation Conservatory for Botanical Science and assist visitors at the conservatory info desk. Shortly after I was hired, I got involved with my first major project – a re-design and re-planting of the main planter in the Southeastern bog wing of the conservatory. This planter now houses a wide variety of carnivorous plants native to the Southeastern U.S., including nearly all *Sarracenia* taxa, several *Dionaea* cultivars, and four *Pinguicula* species. I learned that the Southeastern bog wing of the conservatory was originally intended to feature both the aforementioned main bog planter, containing mostly taxa native to the Southeastern Coastal Plain, as well as a separate mountain bog planter that would house the California native pitcher plant *Darlingtonia californica*. The mountain bog planter exhibit was planned by Jim Folsom – the former garden director – and was intended to feature a semi-hydroponic flood table system incorporating a water chiller to imitate the cold-water seeps and mountain stream margin sites where *Darlingtonia* populations occur *in situ*. While the hardscape components and some of the plumbing for the mountain bog planter were installed during the conservatory's construction in 2004, a budgetary shortfall at the time prevented the project from being completed. The planned site for the exhibit was ultimately filled in and planted with Southern wax myrtle and other woody shrubs. Since I was interested in adding *Darlingtonia* to the range of carnivorous plants on display in the conservatory, I requested permission to take on the construction of the mountain bog planter some 15 years after its initial conception. Fortunately, sufficient funding was available, and I was granted permission to continue the project where it had left off.

Construction of the *Darlingtonia* exhibit encountered its first major obstacle shortly after the project was approved. The space I was given to build the mountain bog planter was its original intended site in the Southeastern bog wing of the conservatory, across the walkway from the main bog planter. While *Darlingtonia* – the intended focus of the mountain bog planter – hails from the opposite end of the country, the placement of the mountain bog planter was selected for its proximity to other temperate U.S.-native carnivorous plants on display in the conservatory. While the Southeastern bog wing of the conservatory is unheated (to satisfy winter dormancy requirements), it's relative lack of ventilation makes it the hottest section of the conservatory for about half of the year. From June through September, daytime highs generally range from 31–38°C with nighttime lows falling between 15–25°C. Winters are warm with daytime highs often exceeding 20°C and nighttime lows usually falling between 5–10°C. These temperatures, along with a supplemental misting system maintaining relative humidity at ~70% do an excellent job at reproducing the environment of the coastal Southeastern U.S., and are ideal for growing *Dionaea*, *Sarracenia*, and other varieties that occur there naturally. For *Darlingtonia* cultivation, however, the summer heat in the conservatory posed a significant problem. Using hobbyist forums and other online resources as reference, I could see that the growers who succeeded with *Darlingtonia* were largely confined to Northwestern Europe and the Pacific Northwest of the U.S. and Canada – regions with mild summers and cool nights. Schnell (1976) notes that extended periods of summer heat, particularly when nighttime temperatures exceed 20–22°C – typical of the Southeastern U.S. – are very likely to kill *Darlingtonia* plants. This was demonstrated in an experiment in which *Darlingtonia* plants were transplanted to sphagnum bogs in Virginia, 100% mortality was observed (Sheridan & Scholl 1993). Given the considerable difficulty of cultivating *Darlingtonia* in the Southeastern U.S., it quickly became apparent that considerable ingenuity would be required to successfully maintain a display planter of *Darlingtonia californica* in an environment replicating its climate.

The maintenance of cool root temperatures is perhaps the factor most critical to the survival of *Darlingtonia* both in cultivation and *in situ*. In observations of *Darlingtonia* populations in the vicinity of Gasquet, California, Ziemer (1973) notes that *Darlingtonia* are restricted to areas with a consistent source of cold water and describes several sites typical of the species where plants grow in shallow moving water on slopes, forming dense stands around a spring or stream water source. Throughout its range in habitat, *Darlingtonia* populations are almost always associated with running water from upslope seepages, with plants only rarely growing in standing water (DeBuhr 1974). While researching the upper temperature tolerance of *Darlingtonia in situ*, I found numerous reports of wild populations that may experience ambient air temperatures exceeding 30°C (Burdic 1988), occasionally reaching 40°C (Ziemer 1973), albeit for short duration. The roots however, bathed in water from a nearby spring or stream water source, are kept significantly cooler, maintained at ~11°C (Burdic 1988) only rarely exceeding 17–20°C (Brownfield 1988; Schnell 1976). Brownfield (1985) notes that cultivated *Darlingtonia* plants grown in pots can tolerate daytime high temperatures over 40°C for brief duration, and describes several steps taken to maintain cool root temperatures during periods of high ambient temperatures – these being the avoidance of standing water, temporary placement of plants in the shade, frequent overhead watering, and use of terra cotta pots with the pots' exterior frequently wetted. What I could infer from this is that for *Darlingtonia*, tolerance of high (~30°C+) temperatures is conditional – depending on the maintenance of a significantly lower root zone temperature. While the cited examples all discuss cool root zone temperatures enabling short term ambient air heat tolerance in *Darlingtonia*, I began wonder if maintaining sufficiently low root zone temperatures could also allow *D. californica* to tolerate 4–5 months each year of heat exceeding its usual temperature tolerance. I wanted to test this out, so root zone cooling was a high priority in the design process for the *Darlingtonia* exhibit.

Several months before I began to design the *Darlingtonia* exhibit, I attended an LACPS meeting held at the Cal State Fullerton biology greenhouses where I saw several large DIY plastic flood tables set up in the lath houses outside the greenhouses. These housed a wide assortment of *Sarracenia*, *Drosera*, *Dionaea*, and other temperate carnivorous plants which thrived in this environment. This setup was similar, albeit less elaborate, to the original plan for the mountain bog planter in the conservatory. Plants grew semi-hydroponically, growing in pots sitting in shallow water recirculating though the flood tables. Water recirculated through a flood table can facilitate cooling of the growing media, assuming the reservoir contains a sufficiently large volume of water and is shielded from the sun. Additionally, the shallow, recirculating water in a flood table planter can mimic the seep and wet meadow environments in which *Darlingtonia* grow *in situ*. Mazrimas (1990), reports that flood table culture is well suited to the cultivation of cool-growing carnivorous plants, such as *Darlingtonia*, and can increase ambient temperature tolerance by inhibiting the buildup of heat in the growing media. While this "passive" root zone cooling resulting from circulating water does reduce heat buildup in media and is particularly effective at preventing catastrophic temperature spikes on hot days, without some additional means of reducing water temperature it would very likely prove insufficient to maintain appropriate root zone temperatures for *Darlingtonia* in the conservatory during the summer months. Additionally, the methods of controlling root zone temperature described by Brownfield (1985) cited earlier are reliant on evaporative cooling and would likewise be of limited utility in the conservatory due to the high relative humidity. Sheriden and Scholl (1993) propose 20°C as the upper limit of root zone temperature tolerance in *Darlingtonia*. The roots of cultivated *Darlingtonia* plants have been observed to die if the root zone temperature reach or exceed 18°C, killing the plant if these conditions persist (Burdic 1988). In the Southeastern bog area of the conservatory, nighttime low temperatures only briefly and sporadically drop below 20°C throughout the summer and early fall months. To maintain root zone temperatures below this damage threshold, it was necessary to incorporate an electric water chiller into the flood table system that would comprise the mountain bog exhibit, as was intended in its initial design. I suspect this was easier to accomplish in 2020 than in 2004 given the proliferation of water chiller units available for the aquarium hobbyist and home hydroponics market. I selected a water chiller sold for the home hydroponics market by the manufacturer Active Aqua. The installation and use of this chiller and numerous similar models was incredibly user friendly, working on a standard residential 120v outlet and requiring no hardware other than hose clamps to secure plastic tubing to the water inlet and outlet (Fig. 1). I chose the largest and most powerful of the 4 models available (1/10, 1/4, 1/2, and 1 hp), which could appear at first glance to be extreme overkill for my initial "proof of concept" flood table build consisting of a single 1 × 2 m flood table and a 200 L reservoir. This ended up being the correct choice, since I had the chiller set to cool the water in a poorly insulated flood table down to a desired temperature of 10°C where the ambient temperatures would exceed 30°C several months of the year- a much more demanding application compared to a typical indoor hydroponic setup! I chose 10°C as my target for the water temperature in the flood table – adjusting temperature settings on the chiller accordingly – since it approximates root zone temperatures observed *in situ* and provides a comfortable buffer from temperatures where root death and overall plant decline is observed.

Figure 1: Mountain bog exhibit interior – 1 HP water chiller, water reservoir, and plastic tubing plumbing.

After assembling the flood table planter and sourcing plant material – 8 mature-sized divisions of *D. californica* – I was able to begin observing firsthand if maintaining a consistent cool root zone temperature via flood table culture with chilled water would prove sufficient for successful long-term cultivation of *D. californica* in the conservatory. While numerous reports exist of both wild and cultivated *Darlingtonia* tolerating extreme daytime heat, usually for short duration, it was entirely unknown to me whether maintaining an optimal root zone temperature would allow plants to tolerate high ambient temperature (particularly at night) for extended duration. I received the

Darlingtonia divisions in May of 2020 during an early heat wave – day temperatures in the bog area of the conservatory were already hovering around 32–33°C. I planted them in 23 × 23 × 13 cm square mesh pots in a 2:1 long fiber sphagnum and pumice mix, and immediately placed them in the flood table. Due to the heat in the conservatory and stresses of shipping and transplanting, I braced for the rapid decline that *Darlingtonia* are notorious for in cultivation. Surprisingly, no leaf discoloration or dieback was observed. A few weeks later, plants began to produce new pitchers about 15–20 cm in height, about half the size of the ones the plants arrived with. I initially attributed this to heat stress, but later learned from other growers that the first flush of *Darlingtonia* pitchers produced in spring is by far the largest, and that smaller pitchers produced later in the season are normal. The large (~30–45 cm) spring pitchers returned the following spring along with inflorescences. Stolons were produced the first growing season, quicky filling the pots with small *Darlingtonia* plantlets and sometimes bursting through the sides of the pots. During their first summer in my care, the *Darlingtonia* grew very well in spite of the oppressive ambient daytime heat and warm nights, which persisted into October.

Since the *Darlingtonia* plants filled less than half of the flood table, and I could not find any more available for sale that summer, I began to add several other types of carnivorous plants to the flood table. These included *Drosera rotundifolia*, *Sarracenia purpurea* subsp. *venosa* var. *montana*, *S. oreophila*, and *S. jonesii* (Figs. 2 & 3). The Appalachian *Sarracenia* taxa I selected to grow alongside *D. californica* since they share a somewhat similar ecology *in situ* (albeit on the opposite side of the county), and like *Darlingtonia* can be difficult to maintain in climates with hot summers and warm nights. These, like the *Darlingtonia*, performed well in the flood table planter. Due to the excellent performance of the *Darlingtonia* plants during the 2020 growing season, I was given permission to expand the mountain bog exhibit – adding a second 1 × 2 m flood table to my initial "proof of concept" build, as well as a larger 400 L water reservoir to accommodate the volume of water required for the expansion. The 1 hp water chiller I used in the initial build fortunately proved sufficient to maintain the larger water volume at ~10°C. The reconstruction and expansion of the mountain bog exhibit into its present configuration took place during the spring and summer of 2021, coinciding with the reopening the conservatory to the public (which had been closed for 2020 and part of 2021 due to concerns regarding the spread of Covid-19 in enclosed spaces). Of the two flood table planters now comprising the mountain bog exhibit, one is filled with *D. californica* and a couple varieties of *Disa* orchids, and the other contains Appalachian Mountain bog natives including *Drosera rotundifolia*, *Sarracenia purpurea* subsp. *venosa* var. *montana*, *S. oreophila*, *S. jonesii*, and a few other types of orchids (*Spiranthes odorata*, *Pogonia ophiglossoides, Galearis spectabilis*).

Conclusion

Maintenance of consistent cool root zone temperatures is the factor most critical for successful *Darlingtonia* cultivation. *Darlingtonia* grown "conventionally" – in regular pots and planters – are largely intolerant of ambient heat sufficient to raise growing media temperature to ~20°C or greater for more than a very brief duration. Mild summer days and/or a substantial diurnal temperature variation are generally required to maintain sufficiently cool root zone temperatures, largely limiting successful *Darlingtonia* cultivation to regions with a marine temperate climate. Providing optimal root zone temperature for *Darlingtonia* (~10°C) can be achieved by means other than controlling the ambient temperature. This can be accomplished relatively easily via semi-hydroponic flood table culture by incorporating a water chiller, which cools the water to the desired temperature

Figure 2: Flood table planter containing *Darlingtonia californica*, *Sarracenia*, and a couple varieties of *Disa* orchids.

as it circulates through the flood table system. My success growing *D. californica* in such a setup over the course of nearly three years in a hot-summer greenhouse environment (comparable to the coastal Southeastern U.S.) demonstrates that *Darlingtonia* plants grown semi-hydroponically with chilled water will tolerate ambient temperatures substantially warmer those grown conventionally. The "cold-water" flood table I built was easy to assemble and comprised entirely of components available at most hydroponic supply retailers. Building a similar flood table setup incorporating a water chiller is an excellent option for hobbyists interested in growing *Darlingtonia*, but located in a climate where it would normally be difficult or impossible. While the mountain bog exhibit at the Huntington Botanical Gardens was designed and built to a size more appropriate for a public garden display, a much smaller and less expensive but otherwise identical setup could be built with

Figure 3: Closeup of the *Darlingtonia* flood table planter.

a smaller flood table, water reservoir, and chiller (most brands offer 1/10 hp and 1/4 hp models) and could be housed in a greenhouse, indoors under lights, or outdoors, provided the water chiller could be kept both shielded from the elements and adequately ventilated. An understanding of heat flow and the use of insulation – on both the flood table plumbing and the flood table itself – will minimize condensation and also reduce the water chiller size and energy consumption required to achieve the desired water temperature. I hope that my method of *Darlingtonia* cultivation can be utilized so that it can be grown successfully in more varied climates, and ultimately become more widespread in cultivation.

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