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Growth and Photosynthesis Responses of Chihuahuan Desert Succulent Seedlings

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Introduction

Early stages of plant growth are crucial in plant population dynamics, as seedlings are not as tolerant as seeds or as sturdy as mature plants (Kitajima & Fenner 2000). During this vulnerable stage young plants should grow as fast as possible; establish roots for rapid water uptake; compete for light nutrients and space with other plants; and develop chemical and mechanical defenses for protection against herbivores (Kitajima & Fenner 2000, Fenner & Thompson 2005). In arid and semiarid zones light and water are two of the most important physical factors that limit development of new plants (Flores & Jurado 2003). Shade in places with abundant vegetation can induce stress by limiting photosynthesis and arresting seedling development (Kitajima & Fenner 2000), but it can also be beneficial by reducing overheating, excessive transpiration, and photoinhibition that seedlings growing in open areas may experience (Flores & Jurado 2003, Valladares 2004). Stress caused by drought or extreme temperatures increases the risk and severity of photoinhibition in arid environments (Flexas & Medrano 2002, Valladares 2004). Most studies done on desert seedling establishment have focused on evaluating survival (Ibáñez & Schupp 2001; Flores *et al*. 2004; Munguía-Rosas & Sosa 2008); there has been little research conducted on the mechanisms related to desert seedling growth facing light and water stress (Martínez-Berdeja & Valverde 2008; Miquelajáuregui & Valverde 2010; Romo-Campos *et al*. 2013).

Material and Methods

A field experiment was carried out in San Juanico Chico in the municipality of San Luis Potosí, S.L.P., Mexico, at 1870 m above sea level (22°14’07.5” N, 100°59’48.3” W). Vegetation is a small leaved desert scrub and has a mean annual rainfall from 300 to 450 mm and mean temperatures from 18°C to 25°C (INEGI, 2002). The studied species belong to Cactaeae (*Echinocactus platyacanthus* Link & Otto, *Ferocactus histrix* (DC) G.E.Linds., *Myrtillocactus geometrizans* (Mart. *ex* Pfeiff.) Console. and *Stenocactus coptonogonus* (Lem.) A.Berger *ex* A.W.Hill.) and Agavaceae (*Agave lechuguilla* Torrey, *Agave salmiana* Otto *ex* Salm-Dick and *Yucca filifera* Chabaud).

Seeds from all species were set to germinate in the glasshouse at different times to synchronize seedling emergence (Flores & Jurado 1998; Villar *et al*. 2004). One month after seedling emergence plants were individually transplanted into biodegradable pots, using local soil as substrate. Each seedling was placed in the field under similar environmental conditions, using the either the shade of *Prosopis laevigata* or open areas, in order to determine safe sites or microenvironments where species might establish inside permanent plots. This part of the experiment was carried out in September (2012) to coincide with the rainy season and allow for natural seedling establishment.

There were 15 *Prosopis laevigata* (mesquite) trees used as nurse plants. This species was selected as it is the most abundant in the area. Under each nurse plant 123 biodegradable pots were placed in holes leveled to the soil surface. There were three species per plot and 41 seedlings per species, randomly distributed. The same design was used in open areas.

Non-destructive measurements of ecophysiological variables were measured (i.e. variables related to chlorophyll fluorescence): Quantum yield of photosystem II photochemistry (ΦPSII) and electron transport rate (ETR), using the photosynthesis analyzer MINI-PAM (WALZ).

Seedling growth was also analyzed, determining relative growth rate (RGR): $RGR = (\ln W_2 - \ln W_1) / t_2 - t_1$. Where W_2 is the final biomass, W_1 is the initial biomass and "t" is the time in days (Ruedas et al. 2000). These variables were measured in the Ecology Lab of the Instituto Potosino de Investigación Científica y Tecnológica (IPICyT). Seedlings were harvested to coincide with photosynthesis eficiency measurements. Harvested seedlings were dried at 70°C for 3 days prior to weighing.

Factorial analyses were carried out (ANOVA), using species as factors, with seven levels (*Agave lechuguilla*, *Agave salmiana*, *Echinocactus platyacanthus*, *Ferocactus histrix*, *Myrtillocactus geometrizans*, *Stenocactus coptonogonus* and *Yucca filifera*) and light condition with two levels (low under the shade of nurse plants and high, in open areas). Response variables were RGR, ΦPSII and ETR. Multiple comparisons for means (*Tukey test*) were carried out, when significant differences were found. Statistical analyses were carried out using STATISTICA 8, with α of 5%. For five of the seven variables data had to be normalized prior to analyses (Sokal & Rohlf, 1995).

Results and Discussion

Relative Growth Rate (RGR)

There were effects of species ($F = 4.135$; $P = 0.001$) and light ($F = 4.012$; $P = 0.047$), without a significant interaction ($F = 1.361$; $P = 0.233$; Table 1). *Yucca filifera* and *Stenocactus coptonogonus* showed a lower RGR than the rest of the species, and growth was higher in open areas than under nurse plants. In general all species had low RGR in both environments, perhaps as a result of little rainfall. Many studies have shown that although seedling survival of desert plants is higher under nurse plants than in open areas RGR is similar in both environments (Berdeja & Valverde 2008; Miquelajáuregui & Valverde 2010; Romo-Campos *et al*. 2013).

Quantum yield of photosystem II photochemistry (ΦPSII)

For ΦPSII there were effects by species ($F = 13.0$; $P < 0.001$) and light condition ($F = 123.0$; $P < 0.001$), and the interaction was significant ($F = 4.2$; $P = 0.001$; Table 1). All species had a higher ΦPSII under nurse plants than in open areas, but was lower for *Yucca filifera* Values ranged between 0.53 (*Yucca filifera*) and 0.71 (*Stenocactus coptonogonus*). These results indicate that the presence of a nurse plant favours a better photosynthetic development. Similar results were found by Rodríguez-Calcerrada *et al*. (2008) for *Quercus* spp in Mediterranean environments and by Romo-Campos *et al*. (2013) for succulent seedlings of *Opuntia jaliscana* and *Opuntia streptacantha* (Cactaceae), this indicates that species with drought induced stress have a similar behavior under strong light, with certain degree of photoinhibition.

Electron Transport Rate (ETR)

For ETR there were effects of species ($F = 10.5$; $P < 0.001$) and light condition ($F = 193.4$; $P < 0.001$), with a significant interaction ($F = 8.4$; $P < 0.001$). There was a higher ETR for *Agave salmiana*, *Myrtillocactus geometrizans*, *Stenocactus coptonogonus* and *Echinocactus platyacanthus* than for the rest of the species. ETR was higher for seedlings in open areas than for those under nurse plants. *Agave salmiana*, *Ferocactus histrix*, *Myrtillocactus geometrizans*, *Stenocactus coptonogonus* and *Echinocactus platyacanthus* seedlings had a higher ETR in open areas than under nurse plants. Values for *Yucca filifera* and *Agave lechuguilla* seedlings were similar for both light environments. This results show that even though under the shade there were low ETR values, these were enough for a good ΦPSII, while in open areas some species might show photoinhibition due to damage to the photosystems. Our results were similar to those found by Hernández-González & Briones (2007), that found that ETR in seedlings of *Neobuxbaumia tetetzo* increased under higher solar radiation, suggesting that cacti seedlings adjust thier photochemical capacity to adapt to light environments.

Table 1. Quantum yield of photosystem II photochemistry (ΦPSII) (means ± standard error), electron transport rate (ETR) and relative growth rate (RGR) for succulent species in light two microenvironments. Different letters indicate differences ($P < 0.05$) within each factor (ΦPSII, ETR and RGR).

Species	ΦPSII		ETR		RGR	
	Under nurse plants	Open areas	Under nurse plants	Open areas	Under nurse plants	Open areas
Yucca filifera	0.53±0.04^{cd}	0.32±0.04^{g}	68.0±7.9^{e}	85.2±8.0^{cde}	0.003±0.002	-0.002±0.003
Agave salmiana	0.58±0.03^{abcd}	0.52±0.04^{de}	71.5±6.5^{de}	166.9±16^{ab}	0.007±0.001	0.009±0.001
Agave lechuguilla	0.58±0.04^{abcd}	0.36±0.04^{fg}	77.0±9.4^{de}	109.3±17.7^{cd}	0.001±0.002	0.009±0.002
Ferocactus histrix	0.67±0.02^{ab}	0.40±0.04^{efg}	73.7±5.8^{de}	117.0±9.3^{bc}	-0.001±0.003	0.003±0.003
Myrtillocactus geometrizans	0.59±0.02^{abcd}	0.49±0.02^{def}	69.4±5.6^{de}	163.1±19.1^{ab}	0.002±0.004	0.007±0.004
Stenocactus coptonogonus	0.71±0.01^{a}	0.52±0.03^{de}	91.7±8.2^{cde}	166.3±13.4^{ab}	-0.004±0.002	0.002±0.002
Echinocactus platyacanthus	0.66±0.03^{abc}	0.58±0.02^{bcd}	74.1±8.9^{de}	192.0±19.6^{a}	0.009±0.003	0.008±0.002

Conclusions and Outlook

The studied species had low RGR in both light microenvironments (under nurse plants and in open areas), and most of them had a lower ΦPSII in open areas. These results suggest that seedlings have better growth conditions under nurse plants than exposed to direct sunlight in open areas. Further studies analysing our variables with varying soil moisture are needed to better understand the role of nurse plants in desert plant dynamics.

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