Received: 27 June 2025 | Revised: 10 October 2025 | Accepted: 13 October 2025

DOI: 10.1111/1442-1984.70037

ORIGINAL ARTICLE

PLANT SPECIES BIOLOGY WILEY

Life-history traits and survival responses to light and water of the rare endemic species *Cuphea gaumeri* Koehne (Lythraceae)

Víctor Parra-Tabla | **Vanessa Hernández Mendoza**

Departamento de Ecología Tropical, Universidad Autónoma de Yucatán, Yucatán, México

Correspondence
Víctor Parra-Tabla, Departamento de Ecología Tropical, Universidad Autónoma de Yucatán, Km. 15.5 carretera Mérida-Xtmakuil, Yucatán 97000, México.
Email: victor.parratabla@gmail.com

Funding information
Programa de Apoyo al Profesorado, Grant/Award Number: 103.5.1.13.9359; Consejo Nacional de Ciencia y Tecnología, Paraguay, Grant/Award Number: CB- 2007-84112

Abstract

Endemic plant species represent a particular conservation challenge because they are often more susceptible to threats such as changes in climatic regimes. Therefore, it is essential to understand the role of variations in climatic variables in the life-history traits of endemic species. *Cuphea gaumeri*, a rare tropical endemic of the Yucatán Peninsula, Mexico, occurs in heterogeneous habitats, including evergreen and seasonally dry forests. We conducted a factorial experiment to evaluate the effects of light (sunlight vs. shade) and water availability on four demographic traits: germination, growth, reproduction, and survival. Germination percentage increased at high levels of water availability, and higher water levels reduced the number of days to germination regardless of light conditions. Plant growth increased under shaded conditions with medium to high water availability, highlighting the interaction between light and water. Time to reproduction was delayed in plants exposed to low water availability, whereas plants with higher water levels reproduced earlier, regardless of light conditions. Survival probabilities were highest for plants grown in sunlight with high water availability. This suggests that water can mitigate the stress caused by sunlight exposure by supporting metabolism and reducing light stress, which ultimately enhances plant performance and survival. Overall, the responses of *C. gaumeri* suggest adaptation to the seasonal flooding of its native habitats, resembling those observed in riparian species. These findings underscore the role of water availability in shaping life-history traits and highlight the importance of protecting seasonally flooded habitats. These insights can guide conservation strategies for tropical endemic species facing micro- and macro-environmental changes.

KEYWORDS

Coquinal, demographic traits, seasonal flooding, semiarid ecosystems, survival curves

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2025 The Author(s). *Plant Species Biology* published by John Wiley & Sons Australia, Ltd on behalf of The Ecological Society of Japan.

1 | INTRODUCTION

Understanding the ecological and evolutionary factors behind the restricted spatial distributions of endemic species has been extensively studied (e.g., Essl et al., 2009; Kidane et al., 2019; Kruckerberg & Rabinowitz, 1985; Lavergne et al., 2004; Myers et al., 2000). Endemic species play a crucial role in conservation biology, as they contribute significantly to the species richness of regions and help identify priority conservation areas (Myers et al., 2000). However, they are particularly vulnerable to habitat loss, invasive species, and climate change (Kidane et al., 2019; Pounds et al., 2006; Thomson, 2005). Their limited geographic ranges, small population sizes, and specialized habitats reduce their adaptability to these threats, emphasizing the need to understand their distribution patterns and life-history traits (Sękiewicz et al., 2024). Such knowledge is essential for assessing extinction risks and devising effective conservation measures (Brooks et al., 2002; Navarro & Guitián, 2003; Winkler et al., 2019).

Endemic angiosperms are often found in stressful habitats, such as arid regions or nutrient-poor soils (Baskin & Baskin, 2014; Valiente-Banuet & Verdú, 2007; but see Samain et al., 2022). In Mexico, high levels of endemism are associated with arid or semiarid areas (Dávila et al., 2002; Riemann & Ezcurra, 2005; Sosa et al., 2018). The Peninsula Biogeographic Province (PBPY), characterized by seasonally dry forests and scrublands, hosts a rich variety of endemic species, including trees, cacti, and herbs (Carnevali et al., 2021; Duno de Stefano et al., 2024). However, research on the life-history traits of these plants remains limited, mainly focusing on a few Cactaceae species (Cervera et al., 2006; Leirana-Alcocer & Parra-Tabla, 1999; Méndez et al., 2006). Given that the Yucatán Peninsula is projected to face significant climate impacts (IPCC, 2023), it is crucial to study how changes in temperature and precipitation affect endemic species. Furthermore, endemic species in these and other ecosystems may be particularly vulnerable because many depend on insect pollinators (Alonso et al., 2010; Alonso et al., 2013), which are highly sensitive to climate change (e.g., Harvey et al., 2020; Herrera et al., 2023). Disruptions in plant-pollinator interactions can negatively affect seed production, reducing the recruitment of new individuals and ultimately leading to population declines (Kidane et al., 2019).

Cuphea gaumeri (Lythraceae) is an annual herb found mainly in the dry areas of the northern Yucatán Peninsula (Duno de Stefano et al., 2024; GBIF.org, 2025). It is listed as "Least Concern" by the International Union for Conservation of Nature due to its local abundance (Carnevali et al., 2021; IUCN, 2021), but its limited geographic range classifies it as a "rare" species (Rabinowitz, 1981). *C. gaumeri* thrives in seasonally dry, thorny deciduous forests, especially in semiarid regions, and occupies diverse microenvironments, from sunny open areas to shaded spots that may flood during the rainy season (Duno de Stefano et al., 2024). At least 20 insect species, including the honeybee *Apis mellifera*, visit *C. gaumeri*. This suggests that *C. gaumeri* plays a significant role in plant-pollinator networks and serves as a valuable resource for beekeeping (Flores & Espejel, 1994; Parra-Tabla et al., 2017). Despite substantial knowledge of the pollination ecology of *C. gaumeri* (Alonso et al., 2013; Celaya et al., 2015; Parra-Tabla et al., 2017), its responses to environmental variations, such as light or shade exposure and flooded soils, in seed germination, plant growth, reproduction, and survival remain unknown. In addition, extensive livestock farming is another factor affecting its populations in these areas (Flores & Espejel, 1994). Understanding how *C. gaumeri* responds to environmental variations would improve our understanding of how endemic species of seasonally flooded sites adapt to micro- and macro-environmental changes, providing essential information for developing effective conservation strategies.

The objective of this study was to experimentally evaluate the effects of light exposure and variations in water availability on the germination, growth, reproduction, and survival of *C. gaumeri*. Specifically, we aimed to determine whether *C. gaumeri* can succeed in different environments with similar responses to varying levels of light and water availability, or whether there are "optimal" combinations that favor *C. gaumeri*. This information could be a valuable resource for conservation efforts and help clarify the distribution patterns of *C. gaumeri* in the PBPY.

2 | MATERIALS AND METHODS

2.1 | Study species

Cuphea gaumeri (Lythraceae) Koehne is a rare annual herbaceous plant endemic to the PBPY (Carnevali et al., 2021; Duno de Stefano et al., 2024). It is most abundant in the Mexican state of Yucatán but can be found throughout the Yucatán Peninsula (Figure S1). In Yucatán, *C. gaumeri* grows mainly in semiarid areas, such as seasonally dry forests and thorny deciduous forests, and sites known as "Coquinal" (seasonally flooded Coquinal, sensu Duno de Stefano et al., 2024). These habitats are characterized by rocky, impermeable soils, leading to partial flooding during the rainy season (June–October) (Duno de Stefano et al., 2024). During the dry season (March–May), maximum temperatures average ca. 38°C and can reach up to 42°C; during the rainy season (June to October), the average monthly rainfall is around 140 mm (SMN-CONAGUA, 2022). At these sites,

C. gaumeri grows in shaded environments under the canopy of shrubs or small trees, near surface water sources that accumulate during the rainy season, as well as in completely open and dry areas (Celaya et al., 2015; Figure 1). In these regions, local farmers introduce livestock that graze on pastures and various herbaceous species, including *C. gaumeri* and other endemic herbs and shrubs (Flores & Espejel, 1994). *Cuphea gaumeri* is self-compatible but requires insect pollinators to produce substantial fruit and seeds (Celaya et al., 2015). Like several other endemic herbaceous plant species from the PBPY, *C. gaumeri* has been described as pollen-limited species (Alonso et al., 2013). The fruits of *C. gaumeri* are dry and typically contain about 20 small, ovoid seeds measuring approximately 0.7–1.2 mm by 0.5–0.8 mm (Graham, 1988). Seeds of the *Cuphea* genus occupy an intermediate position between orthodox and recalcitrant types, as they can tolerate high temperatures and substantial desiccation (Crane et al., 2003). Their seeds can germinate immediately after dispersal. However, germination rates and plant vigor among *Cuphea* species are low, and seeds from several species exhibit primary dormancy, which can hinder establishment (Berti et al., 2007).

2.2 | Seeds sampling

The *C. gaumeri* seeds used in this study were collected from a population in the seasonally dry, flooded forest of San Felipe, Yucatán, located in the coastal region of the Gulf of Mexico (Figure S2). The flowering in this species occurs from August to September, and the fruits are produced from September to November (Celaya et al., 2015). We randomly selected 20 plants, each separated by a distance of 15–20 m, and collected 15–20 fruits. The fruits were then transported to the laboratory and placed in a dryer at 35°C for 24 h to accelerate their maturation. Of the fruits collected, only those from 15 plants ("mother plants") yielded a sufficient number of seeds for the experiment described below.

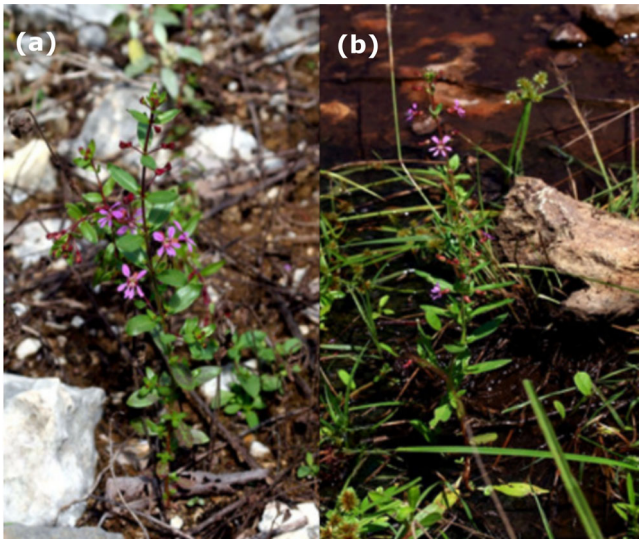


FIGURE 1 Individual plants of the Yucatán Peninsula Biotic Province endemic species *Cuphea gaumeri* (Lythraceae) growing in two microenvironments (a) dry and rocky microenvironment; (b) wet and flooded microenvironment, in a site of dry thorny flooded forest in the northern portion of the State of Yucatán. Photos: Used with the permission of Luis Salinas Peba.

2.3 | Experimental design

From the 15 mother plants (hereafter referred to as genetic families) and their collected fruits, 10 viable seeds per fruit were selected ($N = 900$ seeds). Of these seeds, 150 (15 genetic families per 10 seeds) were randomly distributed to each of the following treatments under a 2 × 3 factorial design with two light-exposure levels: 22.52 mol m^{-2} d^{-1} ("sunlight," hereafter) and 8.56 mol m^{-2} day^{-1} ("shade" hereafter) and three water availability levels ("water availability" hereafter): 105 mL (low), 175 mL (medium), 280 mL (high), applied every 48 h. The water was applied using a sprayer to simulate rainfall events. To control light exposure, we established the two light treatments using commercial shade nets (Malla-sombra Mx®). For the sunlight treatment, we used a net that allowed 60% of light to pass through, while for the shade treatment, an additional net was added to permit only 50% of light to pass. The specific light levels for each treatment (22.52 mol m^2 day^{-1} and 8.56 mol m^2 day^{-1}) were measured with a quantum sensor (wavelength range 400–700 nm; LI-190S, LI-COR, Lincoln, Nebraska, USA). The relative light intensity, compared to an open area, was approximately 18% for the shade and 45% for the sunlight treatments. These daily levels of photosynthetic photon flux in semi-open and shaded sites have been documented in seasonally dry forests of the Yucatán (González-Salvatierra et al., 2013). Water availability volumes were calculated based on soil water retention curves (Rundel & Jarrell, 1989). The three water availability volumes corresponded to different soil moisture levels: saturated soil, near saturation, and the permanent wilting point, represented by relative water contents of 40%, 25%, and 15%, respectively (Hernández Mendoza, 2014).

Each seed was semi-buried in a 500 mL plastic container with 400 g sieved, clayey black soil in high organic matter. This type of soil was chosen because it is similar to the soil of the site where the mother plants were located (Hernández Mendoza, 2014). The containers were distributed in a 6 × 4 m nursery, divided according to light exposure treatments, and oriented east–west

to avoid the effect of light received. Additionally, the containers were randomly rotated each week within their respective treatments.

From the seed sowing, daily censuses were conducted for 12 consecutive weeks to monitor germination. These censuses allowed us to calculate the germination percentage (number of germinated seeds/ number of seeds sown) and germination time (number of days taken for germination). After 12 weeks, the final cover (cm^2) was estimated by measuring the major (*D1*) and minor (*D2*) diameters, using the following formula: plant cover $= \pi \times (D1 \times D2)/4$ (Bonham, 1989). The final height (cm) was measured as the distance from the base of the plant to the tip of the apex of the aerial part. For each plant, we recorded the age at first reproduction (number of days until flowering), the total number of flowers produced, and their survival rate up to 50 days after the experiment. Although all plants were kept in the same greenhouse and rotated (within the same light level), we acknowledge that some microclimatic effects (e.g., the correlation between light intensity and vapor pressure deficit) may have affected our results.

2.4 | Data analysis

2.4.1 | Germination, plant growth, age at first reproduction, and flower production

Seed germination (proportion of germinated seeds) and days to germination, plant growth (final plant cover cm^2, and plant height cm), number of flowers produced, and age at first reproduction (number of days until flowering) were analyzed using generalized linear mixed models (GLMMs). Light exposure (sunlight vs. shade) and water availability (low, medium, and high) were considered fixed effects in all models. Genetic family and plant nested within genetic family were included as random effects in all models, except for the final plant cover model, where genetic family was excluded because the likelihood ratio test indicated it was not statistically significant (LRT = 0.12, $p = 0.75$). This suggests that variation among families contributes negligibly to the total variation in offspring plant cover. Therefore, including this random effect did not improve the model fit, and its removal simplified the model without compromising its explanatory power. A model with a binomial distribution and a logit link function was used for the proportion of germinated seeds. A model with a negative binomial distribution and a log link function was used for time to germination (days). For plant growth (plant cover and plant height), a normal distribution model with a log link function was used. The total number of flowers produced was analyzed using a model with a negative binomial distribution and a log link function. The magnitude of the differences in plant growth and flower production was compared using marginal means (Searle et al., 1980), while plant cover was compared using an effect size (rate ratio, Exp(*B*)), which represents the multiplicative effect of a predictor on the expected response (Gallucci, 2019). Finally, the age at first reproduction was analyzed using a Poisson distribution and a log link function.

The GLMM analyses were performed using Jamovi ver. 2.6 interface (The Jamovi Project, 2024) of the R statistical package, with the GAMLj3 module and the gamemixed function (Galluci, 2020). The fit of all GLMMs was tested with the DHARMa v0.4.6 package (Hartig, 2022). Model validation and residual diagnostics were also conducted using the DHARMa v0.4.6 package (Hartig, 2022). No model misspecifications were found for any of the models (Kolmogorov–Smirnov test, $p \geq 0.25$).

2.4.2 | Survival analysis

We used the nonparametric Kaplan–Meier method to assess the combined effects of light exposure and water availability on plant survival probabilities (Hosmer et al., 2008). This approach estimates the likelihood of survival over time while accounting for "censored" data (i.e., individuals that did not die by a specific cutoff time) (Machin et al., 2006). In this study, we designated the average age at first reproduction (47 days, see results) as the cutoff time. We used the average age at reproduction as a "reference point" to determine whether a treatment (light exposure, water availability or their interaction) accelerated or delayed reproductive maturity. This measure also helped us to identify a specific cutoff time at which plants potentially began contributing new individuals to the population (Kuss et al., 2008). We evaluated differences between survival curves using the log-rank test (i.e., significant differences in survival probabilities between treatments) (Hosmer et al., 2008). Comparisons between treatments were conducted using Bonferroni tests. Since the test for the proportional hazards assumption in the survival analysis was significant ($\chi^2{}_5 = 12.9$, $p = 0.02$), a Cox regression model including time-dependent interaction terms (time × treatment) was performed to account for changes in the hazard of the event over the follow-up period. For this analysis, each treatment was coded as a "dummy" response variable. Then, survival data were analyzed using Cox proportional hazards regression models, with plants under sunlight exposure and low water availability serving as the reference group. Hazard ratios (HRs) and 95% confidence intervals (CIs) were estimated for each treatment (Therneau &

Thomas, 2019). All analyses were performed using the Jamovi version 2.6 interface (The Jamovi Project, 2024) of the R statistical package, with the jsurvival function from the survival module.

3 | RESULTS

3.1 | Germination

The percentage of germinated *C. gaumeri* seeds was relatively low (38.6% ± 0.23%). The GLMM showed no significant differences due to the level of light exposure, nor its interaction with water availability (Table 1). However, significant differences were observed between water availability treatments (Table 1). The high water availability showed a germination percentage almost twice that of the medium and low levels (Figure 2). The interaction between light exposure and water availability significantly affected the time to germination (Table 1). Under shade and low water availability, days to germination were delayed by ca. 5 days compared to the low water availability and sunlight treatment (Figure 3; $z = 4.01$, $p < 0.001$). Additionally, plants exposed to sunlight with low water availability showed a lower time to germination than those with medium and high water availability ($z \geq 3.18$, $p \leq 0.02$). Under shaded conditions, the high and medium water availability showed no significant differences, but the medium water availability differed significantly from the low water availability ($z = 8.3$, $p = 0.02$).

3.2 | Growth, age at first reproduction, and flower production

Plant cover of *C. gaumeri* was significantly affected by light exposure levels, water availability, and their interaction (Table 2). Plants grown in shade with medium and high water availability showed the highest cover (Figure 4a) compared to all other treatments ($z \geq 8.1$, $p \leq 0.001$). Plants exposed to sunlight with high water

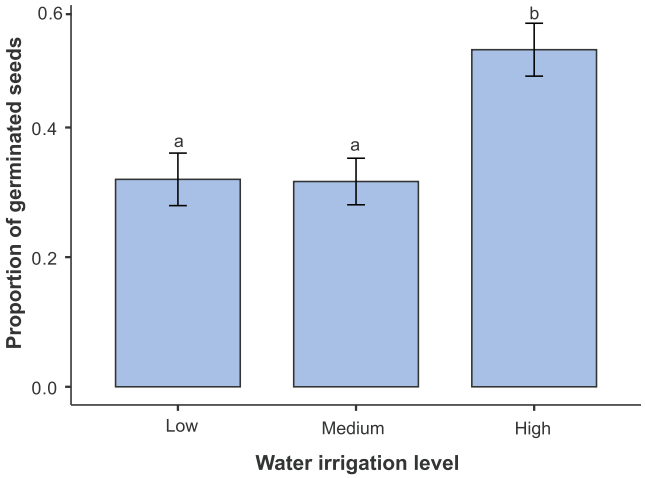


FIGURE 2 Germination percentage (mean ± 95% CI) of the endemic species *Cuphea gaumeri* (Lythraceae) under three water availability treatments ($n = 900$ seeds). Different letters indicate significant differences between treatments (Bonferroni test, $p < 0.05$).

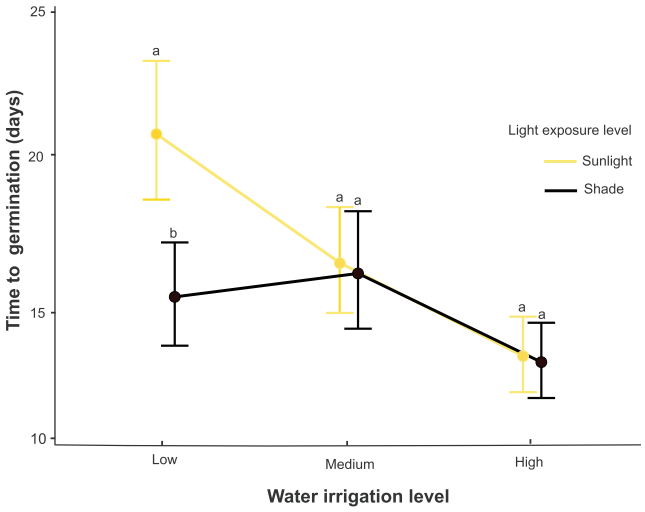


FIGURE 3 Mean time to germination (mean ± 95% CI) of the endemic species *Cuphea gaumeri* (Lythraceae) under the interaction of water availability and light exposure ($n = 347$ seeds). Different letters indicate significant differences within each availability level in the two light exposure levels (Bonferroni test, $p < 0.05$).

TABLE 1 Results of generalized linear mixed models (GLMMs) to evaluate the effect of light exposure and water availability on germination (proportion of seeds germinated) and time to germination (days) of the Peninsula Biogeographic Province endemic species *Cuphea gaumeri*.

Variable	Effect	χ^2	df	*p*
Germination	Light exposure	0.51	1	0.47
	Water availability	11.97	2	**<0.01**
	Light exposure × Water availability	0.25	2	0.88
Time to germination	Light exposure	7.37	1	**<0.01**
	Water availability	40.27	2	**<0.01**
	Light exposure × Water availability	10.39	2	**<0.01**

Note: Degrees of freedom (df) and significant effects are shown in bold type.

availability showed the lowest growth in plant cover (Figure 4a). Specifically, plants in shade with high water availability had an expected cover over six times higher (Exp(B) = 6.18, p = 0.002) than the reference treatment (sunlight + medium water). At the same time, shade with medium water also showed substantially higher cover. In contrast, low water availability limited growth regardless of light conditions (Figure 4a). Plant height was significantly affected only by water availability (Table 2). The higher the water availability level, the taller the plants were (Figure 4b). The estimated marginal means indicated a strong effect of water availability on plant growth. Plants with low water availability grew an average of 15.6 cm (95% CI: 14.1–17.3 cm), whereas those with medium water availability grew to 30.3 cm (95% CI: 27.6–33.3 cm). Plants under high water availability reached an average of 34.7 cm (95% CI: 32.3–37.4 cm).

Cuphea gaumeri plants produced their first flowers ca. 47 days of age (mean ± SD: 47.1 ± 6.10; median 47, Min 20–Max 65). The analysis showed significant effects of both water availability and light exposure, but not of their interaction (Table 2). Plants under low water availability and shade took more days to flower (Figure 5a,b). *C. gaumeri* produced more flowers with increasing water availability, without being affected by light exposure or its interaction with water availability (Table 2). Significant differences were observed among the three water availability levels ($z \geq 3.96$, $p < 0.001$, in all cases) (Figure 5c). Plants with low water availability produced an average of 2.9 flowers (95% CI: 2.2–3.8), whereas plants with medium water availability produced 12.2 flowers (95% CI: 9.6–15.6), and those under high water availability produced 22.0 flowers (95% CI: 18.4–26.4). The confidence intervals indicate a

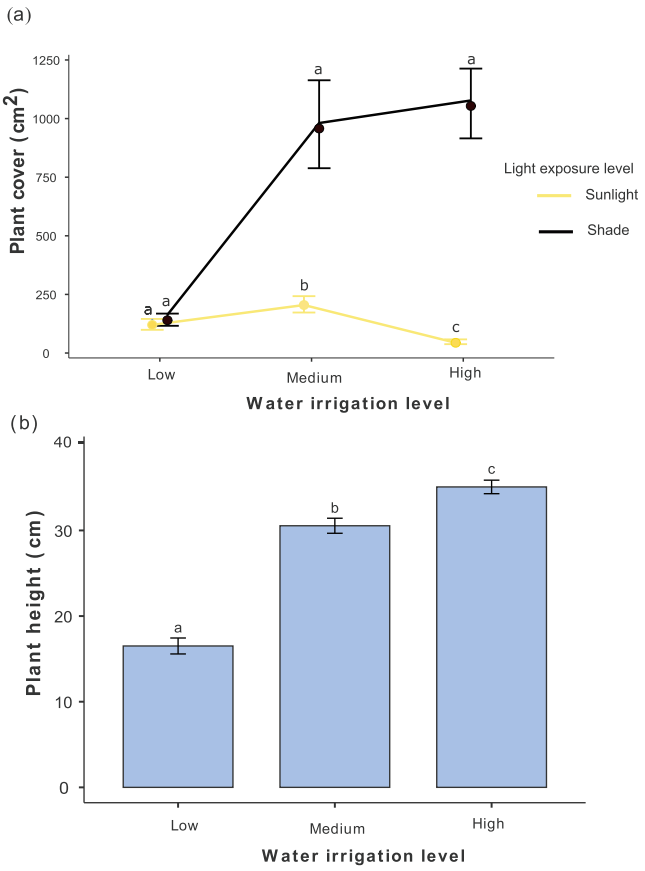


FIGURE 4 (a) Plant cover (mean ± 95% CI) of the endemic species *Cuphea gaumeri* (Lythraceae) under water availability and light exposure interaction (n = 307 plants). Different letters show significant differences within each water availability level across the two light exposure conditions (Bonferroni test, $p < 0.05$). (b) plant height (mean ± 95% CI) under three water availability treatments, of the endemic species *Cuphea gaumeri* (Lythraceae). Different letters indicate significant differences between treatments (Bonferroni test, $p < 0.05$).

Variable	Effect	χ^2	df	p
Plant cover	Light exposure	142.11	1	**<0.01**
	Water availability	159.86	2	**<0.01**
	Light exposure × Water availability	374.60	2	**<0.01**
Plant height	Light exposure	1.94	1	0.16
	Water availability	194.60	2	**<0.01**
	Light exposure × Water availability	2.69	2	0.26
Age at first reproduction	Light exposure	26.04	1	**<0.01**
	Water availability	40.27	2	**<0.01**
	Light exposure × Water availability	0.28	2	0.86
	Light exposure	0.04	1	0.85
Flower production	Water availability level	158.82	2	**<0.01**
	Light exposure × Water availability	4.16	2	0.12

Note: Degrees of freedom (df) and significant effects are shown in bold type.

TABLE 2 Results of generalized linear mixed models (GLMMs) to evaluate the effect of light exposure and water availability on plant growth (plant cover [cm^2] and plant height [cm]), age at first reproduction (days to flower production), and flower production (number) in Peninsula Biogeographic Province endemic species *Cuphea gaumeri*.

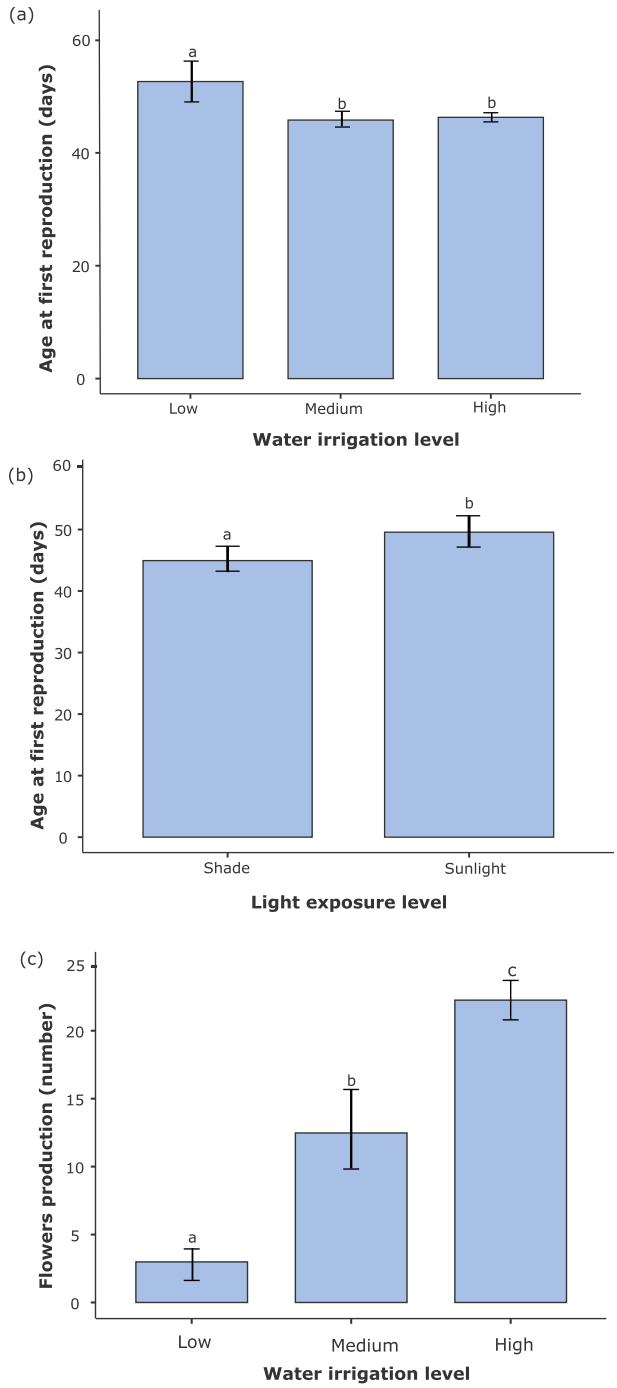


FIGURE 5 (a) Age at first reproduction (mean ± 95% CI) of the endemic species *Cuphea gaumeri* (Lythraceae) under three water availability treatments; (b) two levels of light exposure; (c) Number of flowers (flower production) under three water availability treatments ($n = 246$ plants). Different letters indicate significant differences between treatments (Bonferroni test, $p < 0.05$).

notable difference across all three water treatments, with flower production increasing consistently as water availability increases.

3.3 | Survival

More than half of *C. gaumeri* individuals survived to the reproductive age (57.56%; $N = 192$). The Kaplan–Meier analysis revealed significant differences among the treatments (Figure 6). The Bonferroni multiple comparison test showed differences in survival rates related to light exposure. The treatments with the highest survival probabilities were those under the sunlight exposure treatments, along with medium and high water availability. In contrast, the low water availability treatments and both levels of light exposure showed lower survival rates (Figure 6; $p \leq 0.03$). However, over time, the observed survival probabilities in each treatment varied (Figure 6). For example, except for the sunlight with low water irrigation (71%) and shade with high water availability (76%), the probability of survival at 12 days was >83%, with the plants under sunlight with high water availability showing the highest probability of survival (96.15%) (Figure 6). However, between 20 and 30 days, a significant change in survival probabilities between treatments was observed (Figure 6). In that period all treatments drastically reduced their survival probability, with the shade and low water availability treatment showing the lowest probability (0%). At 30 days, the probability of survival of plants under sunlight and medium and high-water availability was greater than 70% (Figure 6). In contrast, the shade treatment at any water availability level had survival probabilities <60%; among these, the shade and low availability treatment reached 0% survival before 30 days. Survival analysis using a Cox proportional hazards model revealed significant differences among treatments (Table 3). Plants with higher water availability consistently showed a reduced the hazard of the event (Table 3). Specifically, plants exposed to sunlight

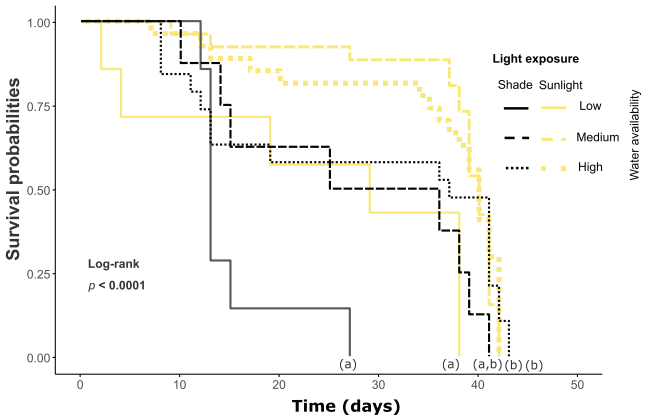


FIGURE 6 Survival curves of the endemic species *Cuphea gaumeri* (Lythraceae) under three water availability levels and two light exposure conditions ($n = 286$ plants). Different letters at the end of each curve indicate significant differences between treatments (Bonferroni test, $p < 0.05$).

TABLE 3 Results of the survival analysis to evaluate the effect of light exposure and water availability in the Peninsula Biogeographic Province endemic species *Cuphea gaumeri*.

Treatment	HR (95% CI)	*p*
Sunlight + low water	Reference group	–
Sunlight + medium water	0.25 (0.10–0.61)	**0.002**
Sunlight + high water	0.22 (0.09–0.54)	**0.001**
Shade + low water	2.02 (0.68–6.06)	0.207
Shade + medium water	0.66 (0.24–1.83)	0.419
Shade + high water	0.35 (0.14–0.88)	**0.025**

Note: Hazard ratios (HR) and 95% confidence intervals are reported. Significant differences for each treatment compared to reference treatment are shown in bold type.

with medium or high water availability had hazard reduced by 75% (Table 3). In shade, only plants with high water availability showed a significant reduction in hazard (Table 3), whereas shade with low or medium water availability did not differ significantly from the reference. Time-dependent interaction analysis (time × treatment) indicated that the effect of specific treatments changed slightly over the follow-up period, with hazard ratios decreasing further as time progressed (Table 3). For example, plants exposed to sunlight and medium water availability exhibited a hazard ratio of 0.99 per day (95% CI: 0.98–0.99; $p < 0.001$), indicating that the risk continued to decline over time (Table 3). These results suggest that both water availability and light conditions influence plant survival, with higher water levels consistently associated with lower hazard rates, particularly under sunlight exposure.

4 | DISCUSSION

Overall, our results suggest that the rare PBPY endemic species *Cuphea gaumeri* performs better in environments with high water availability across most of life-history traits analyzed. In addition, survival analysis indicated that plants maintain high survival probabilities when exposed to sunlight radiation as long as adequate water is available. These results suggest that water availability and solar radiation are determining factors that explain the distribution patterns of this species at the micro and macroenvironmental levels.

4.1 | Germination of Cuphea gaumeri

The germination success of endemic species has been one of the most studied traits because of its implications for conservation (e.g., Baskin & Baskin, 2014; Cervera et al., 2006; Navarro & Guitián, 2003; Shi-Kan et al., 2016). On average, slightly more than one-third of *C. gaumeri* seeds germinated, suggesting that they may not necessarily undergo a dormancy period, unlike other *Cuphea* species (Berti et al., 2007). Furthermore, our experiment revealed that seeds exposed to high-water availability showed ca. 30% higher germination success, regardless of the light exposure, underlining the importance of water as a triggering factor for *C. gaumeri* seed germination (Figure 2). As reported for many other plant species, including other *Cuphea*, high water availability may promote enzyme activation in the seeds of *C. gaumeri*, which in turn increases cell metabolism and promotes germination (Baskin & Baskin, 2014; Volk et al., 2006). The results further showed that the fastest germinating seeds (ca. 12 days) were those under high water availability, whether in sunlight or shade (Figure 3).

In contrast, seeds under low water availability and sunlight germinated about 7 days later than those under similar water conditions but in shade. These results suggest that water availability can reduce the adverse effects of light exposure on germination time. Since *C. gaumeri* can grow in open environments, high water availability is key to rapid germination. Similar germination patterns have been reported for the Yucatán dry forest and scrubland endemic *Mammillaria gaumeri* (Cactaceae) (Cervera et al., 2006), suggesting that this type of response may be common in these environments.

4.2 | Growth, age at first reproduction, and flower production of Cuphea gaumeri

After dispersal, *C. gaumeri* seeds encounter highly heterogeneous microenvironments, such as rocky soils in both open and shaded sites, which are often flooded. However, their highest germination success occurs under shaded and humid conditions. Since faster and more successful germination allows plants to compete more efficiently (Baskin & Baskin, 2014; Orcutt & Nilsen, 2000), reaching favorable microhabitats can be expected to have direct consequences for *C. gaumeri* growth and reproduction. Our results support this idea, as plants growing in shade with medium and high water availability had notably higher growth in both cover and height. Under these treatment combinations, plant cover was, on average about four times larger (~400 cm^2 more) than that of plants grown in sunlight, regardless of water availability. However, plants in shaded conditions with low water availability had similar cover to those grown in sunlight, suggesting that high water availability is required to promote growth under shaded conditions (Figure 4).

Interestingly, plant height increased with water availability, regardless of light exposure. The difference in height between plants under high and low water availability was approximately 15 cm (Figure 4). This height response is important because, in flooded sites where *C. gaumeri* grows, water level can reach 5–30 cm and persist for several consecutive weeks (Bautista et al., 2015; Duno de Stefano et al., 2024). Greater plant height is essential to avoid affecting photosynthesis (Garssen et al., 2015; Vervuren et al., 2003). For instance, Vervuren et al. (2003) found that the increased mortality risk in riparian plants was correlated with a decrease in photosynthetic photon flux caused by flooding from rising water levels.

Water availability plays a critical role not only in the growth of *C. gaumeri* but also in its reproductive success. Greater plant height and cover enhance photosynthetic capacity, which in turn affects reproduction through changes in flowering phenology and flower production (e.g., Lesica & Kittelson, 2010; Schmalenbach et al., 2014; Valencia et al., 2016). Consistent with observations in other semiarid species (Lesica & Kittelson, 2010; Valencia et al., 2016), we found that high water availability led to earlier flowering by reducing the age at first reproduction by about 6 days and doubling flower production (Figure 5). Additionally, our results showed that greater light exposure also accelerated flowering time by a similar magnitude, suggesting that light may influence reproductive timing via its effects on flower development rate (Botto & Smith, 2002). Together, these findings indicate that both water and light conditions can shape not only the growth, timing, and intensity of reproduction but also potentially influence individual fitness and long-term population persistence (see Kuss et al., 2008).

4.3 | Survival of Cuphea gaumeri

The survival analysis of *C. gaumeri* revealed a clear pattern: plants growing under low water availability, whether in shade or exposed to sunlight, experienced a rapid decline in survival probability within 5–10 days. In contrast, higher water availability increased the survival probability even under sunlight exposure (Figure 6). This result highlights the critical role of water in the survival of *C. gaumeri*, as plants exposed to sunlight with medium or high-water availability maintained a high survival probability (>75%) for up to 20–40 days. These results suggest that the adverse effects of sunlight exposure, a common condition in the semiarid forests of northern Yucatán (Cervera et al., 2006; González-Salvatierra et al., 2013), are minimized when water availability is adequate. Consequently, total or partial flooding events during the rainy season in the dry and thorny deciduous forests of the northern Yucatán Peninsula are critical for the survival of *C. gaumeri*. In line with the observed responses in growth and reproduction, *C. gaumeri*'s survival response to water availability suggests an adaptive response to seasonal flooding. In riparian species, it has been suggested that plant height above water level is critical for adult plant survival and, thus, for plant fitness (Garssen et al., 2015). Likewise, the remarkable growth of *C. gaumeri* suggests an adaptive response to recurrent seasonal flooding. It would be interesting to study the responses in other herbaceous species, including endemic species that inhabit the same vegetation types occupied by *C. gaumeri* (e.g., *Cienfuegosa yucatánensis*). We predict that the flooding responses of these species in the dry and thorny seasonal forest may be similar to those observed in riparian species (Garssen et al., 2015; Vervuren et al., 2003).

In arid and semiarid ecosystems, many plants benefit from "nurse plants," which help less stress-tolerant species survive and grow under high temperatures (Filazzola & Lortie, 2014). While research has primarily focused on interactions between shrubs and cacti (Valiente-Banuet & Verdú, 2007; Filazzola & Lortie, 2014), other plant species also show this effect (Pérez-Sánchez et al., 2015). In the dry deciduous forests and coastal scrublands of the PBPY, extreme temperatures make nurse plants vital for the persistence of herbaceous species (Hernández-Mendoza et al., 2023). Our findings indicate that *C. gaumeri* benefits from shade, which enhances traits such as time to germination, plant cover, and age at first reproduction. It often grows alongside small trees or shrubs (Guadarrama et al., 2015) that may serve as nurse plants. However, survival rates did not differ significantly between sunlight and shade under medium or high-water conditions; survival was 20% higher in sunlight when water was adequate for 20–40 days. Thus, while nurse plants benefit *C. gaumeri*'s life-history traits, water availability remains the key factor for its survival in semiarid ecosystems.

5 | CONCLUSION

Our experiment found that *C. gaumeri* thrives in low light and high water conditions, showing enhanced germination, growth, and flower production. Plants in open areas with sufficient water can also survive despite high solar radiation. This response illustrates the prevalence of *C. gaumeri* in the semiarid flooded areas of the PBPY. Similar patterns have been observed in other arid ecosystem species, where limited water delays germination and intensifies light stress, whereas sufficient water activates photoreceptors to enhance germination.

However, it is essential to conduct in situ experiments better to understand *C. gaumeri*'s responses to environmental variations. Additionally, reciprocal transplant experiments with plants from different origins could clarify phenotypic plasticity and local adaptation in this rare species, shedding light on genetic variation among populations and its importance in the adaptive responses of plants.

From a conservation perspective, it is important to note that the flooding sites where *C. gaumeri* grows are affected by livestock grazing, which impacts herbaceous species and soil dynamics. Thus, protective measures for these seasonally flooded environments (*coquinales*) are necessary, with a focus on reducing livestock pressure and considering microenvironmental heterogeneity in the design of protection or restoration areas.

AUTHOR CONTRIBUTIONS

Víctor Parra-Tabla: Conceptualization; formal analysis, writing and editing. **Vanessa Hernández Mendoza**: Investigation, methodology, review, original draft writing.

ACKNOWLEDGMENTS

This study was supported by CONACYT (CB-2007-84112) and Programa de Apoyo al Profesorado (103.5.1.13.9359) to Víctor Parra-Tabla. We appreciate the thoughtful comments and suggestions of Brian Suárez, the associate editor, and two anonymous reviewers on an earlier version of this manuscript. We thank Luis Abdala, Patricia Téllez, Luis Salinas, and Nicolas Salinas for their help in the field and lab work.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ORCID

Víctor Parra-Tabla https://orcid.org/0000-0002-2330-0669

REFERENCES

Alonso, C., Vamosi, J. C., Knight, T. M., Steets, J. A., & Ashman, T.-L. (2010). Is reproduction of endemic plant species particularly pollen limited in biodiversity hotspots? *Oikos*, *119*, 1192–1200.

Alonso, C., Navarro, C., Arceo-Gómez, G., Meindi, G., Parra-Tabla, V., & Ashman, T.-L. (2013). Among species differences in pollen quality and quantity limitation: Implications for endemics in biodiverse hotspots. *Annals of Botany*, *112*, 1461–1469. https://doi.org/10.1093/aob/mct213

Baskin, C. C., & Baskin, J. M. (2014). *Seeds: ecology, biogeography, and evolution of dormancy and germination*. Elsevier.

Bautista, F., Leirana, J., Aguilar, Y., Delgado, C., & Frausto, O. (2015). El medio físico: Clima, geoformas, suelos y agua. In S. J. Ramos, et al. (Eds.), *Ecología funcional de la Reserva de la Biósfera de Ria Lagartos* (pp. 20–39). SIIES-UADY-UNAM.

Berti, M., Johnson, B., & Manthey, L. (2007). Seed physiological maturity in *cuphea*. *Industrial Crops and Products*, *25*, 190–201. https://doi.org/10.1016/j.indcrop.2006.09.003

Bonham, C. D. (1989). *Measurements for terrestrial vegetation*. John Wiley & Sons.

Botto, J., & Smith, H. (2002). Differential genetic variation in adaptive strategies to a common environmental signal in *Arabidopsis* accessions: Phytochrome-mediated shade avoidance. *Plant, Cell & Environment*, *25*, 53–63. https://doi.org/10.1046/j.0016-8025.2001.00812.x

Brooks, T. M., Mittermeier, R. A., da Fonseca, G. A. B., Mittermeier, C. G., Rylands, A. B., Konstant, W. R., Flick, P., Pilgrim, J., Oldfield, S., Magin, G., & Hilton-Taylor, C. (2002). Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology*, *16*, 909–923.

Carnevali, G., Ramírez-Morillo, I., Pérez-Sarabia, J. E., Tapia-Muñoz, J. L., Estrada, H., Cetzal-Ix, W., Hernández-Aguilar, S., Can, L. L., Raigoza, N. E., Duno, R., & Romero-González, G. A. (2021). Assessing the risk of extinction of vascular plants endemic to the Yucatán peninsula biotic province by means of distributional data. *Annals of the Missouri Botanical Garden*, *106*, 424–457. https://doi.org/10.3417/2021661

Celaya, N., Arceo-Gómez, G., Alonso, C., & Parra-Tabla, V. (2015). Negative effects of heteroespecific pollen receipt vary with abiotic conditions: Ecological and evolutionary implications. *Annals of Botany*, *116*, 789–795.

Cervera, J. C., Andrade, J. L., Simá, J. L., & Graham, E. (2006). Microhabitats, germination, and establishment for *Mammillaria gaumeri* (Cactaceae), a rare species from Yucatán. *International Journal of Plant Sciences*, *167*, 311–319. https://doi.org/10.1086/498650

Crane, J., Miller, A., Van Roekel, J., & Walters, C. (2003). Triacylglycerols determine the unusual storage physiology of *Cuphea* seed. *Planta*, *217*, 699–708. https://doi.org/10.1007/s00425-003-1036-1

Dávila, P., Arizmendi, M. D. C., Valiente-Banuet, A., Villaseñor, J. L., Casas, A., & Lira, R. (2002). Biological diversity in the Tehuacán-Cuicatlán Valley, México. *Biodiversity and Conservation*, *11*, 421–442.

Duno de Stefano, R., Aguilar-Canche, M., Carnevali, F.-C. G., Ramírez-Morillo, I., Tapia-Muñoz, J. L., Reyes-Palomeque, G., & Angulo, D. F. (2024). Seasonally flooded Coquinal: Typifying a particular plant association in the northern Yucatán peninsula, México. *Botanical Sciences*, *2*, 513–533. https://doi.org/10.17129/botsci.3388

Essl, F., Staudinger, M., Stör, O., Schratt-Ehrendorfer, L., Wofang, R., & Nikfled, H. (2009). Distribution patterns, range size and niche breadth of Austrian endemic plants. *Biological Conservation*, *1242*, 2547–2558.

Flores, S., & Espejel, I. (1994). *Tipos de Vegetación de la Península de Yucatán*. Universidad Autónoma de Yucatán.

Filazzola, A., & Lortie, C. J. (2014). A systematic review and conceptual framework for the mechanistic pathways of nurse plants. *Global Ecology and Biogeography*, *23*, 1335–1345.

Gallucci, M. (2019). *GAMLj: General analyses for linear models* [Jamovi module]. https://gamlj.github.io/

Galluci, M. (2020). Models goodnes of fit in GAMLj. https://gamlj.githhub.on/

Garssen, A. G., Baattrup-Pedersen, A., Laurentius, A. C. J., Voesenek, J., Verhoeven, T. A., & Soons, M. B. (2015). Riparian plant community responses to increased flooding: A meta-analysis. *Global Change Biology*, *221*, 2881–2892. https://doi.org/10.1111/gcb.12921

GBIF.org. (2025). *GBIF Home Page*. https://www.gbif.org

González-Salvatierra, C., Andrade, J. L., Orellana, R., Peña-Rodríguez, L. M., & Reyes-García, C. (2013). Microambiente lumínico y morfología y fisiología foliar de *Bromelia karatas* (Bromeliaceaae) en una selva baja caducifolia de Yucatán, México. *Botanical Sciences*, *91*, 75–84. https://doi.org/10.17129/botsci.403

Graham, S. A. (1988). Revision of *Cuphea* section Heterodon (Lythraceae). *Systematic Botany Monographs*, *20*, 1–168.

Guadarrama, P., Salinas-Peba, L., & Castillo-Agüero, S. (2015). Estructura de la vegetación de la selva baja caducifolia y de la selva baja inundable. In S. J. Ramos, et al. (Eds.), *Ecología funcional de la Reserva de la Biósfera de Ria Lagartos* (pp. 86–103). SIIES-UADY-UNAM.

Hartig, F. (2022). *DHARMa: Residual diagnostics for hierarchical (multi-level/mixed) regression models*. R package version 0.4.6. https://CRAN.R-project.org/package=DHARMa

Harvey, J. A., Heinen, R., Gols, R., & Thakur, M. P. (2020). Climate change-mediated temperature extremes and insects: From outbreaks to breakdowns. *Global Change Biology*, *26*, 6685–6701.

Hernández, M. V. (2014). *Efecto del agua y lusz sobre la germinación, crecimiento, reproducción y supervivencia de la especie endémica de la península de Yucatán Cuphea gaumeri (Lythraeae)*. Undergraduate Thesis. UADY.

Hernández-Mendoza, V. B., Cervera, J. C., Navarro-Alberto, J., & Leirana-Alcocer, J. J. (2023). Microclimate and seed bank under *Pithecellobium keyense* (Fabaceae) in a coastal scrubland. *Biotropica*, *55*, 1174–1182. https://doi.org/10.1111/btp.13264

Herrera, C. M., Núñez, A., Valverde, J., & Alonso, C. (2023). Body mass decline in a Mediterranean community of solitary bees supports the size shrinking effect of climatic warming. *Ecology*, *104*, e4128.

Hosmer, D. W., Lemeshow, S., & May, S. (2008). *Applied survival analysis: Regression modeling of time-to-event data* (2nd ed.). John Wiley & Sons.

International Union for Conservation of Nature. (2021). *The IUCN Red List of Threatened Species. Version 2020-2*. https://www.iucnredlist.org

IPCC. (2023). In H. Lee & J. Romero (Eds.), *Cambio climático 2023: Informe de síntesis. Contribución de los Grupos de Trabajo I, II y III al Sexto Informe de Evaluación del Grupo Intergubernamental de Expertos sobre el Cambio Climático*. IPCC. https://doi.org/10.59327/IPCC/AR6-9789291691647.001

Kidane, Y. O., Steinbauer, M. J., & Beierkuhnlein, C. (2019). Dead end for endemic plant species? A biodiversity hotspot under pressure. *Global Ecology and Conservation*, *19*, e00670. https://doi.org/10.1016/j.gecco.2019.e00670

Kruckerberg, A. R., & Rabinowitz, D. (1985). Biological aspects of endemism in higher plants. *Annual Review of Ecology and Systematics*, *16*, 447–479.

Kuss, P., Rees, M., Ægisdóttir, H. H., Ellner, S. P., & Stöcklin, J. (2008). Evolutionary demography of long-lived monocarpic perennials: A time-lagged integral projection model. *Journal of Ecology*, *96*, 821–832. https://doi.org/10.1111/j.1365-2745.2008.01374.x

Lavergne, S., Thompson, J. D., Garnier, E., & Debussche, M. (2004). The biology and ecology of narrow endemic and widespread plants: A comparative study of trait variation in 20 congeneric pairs. *Oikos*, *107*, 505–518. https://doi.org/10.1111/j.0030-1299.2004.13423.x

Leirana-Alcocer, J., & Parra-Tabla, V. (1999). Factors affecting the distribution, abundance and seedling survival of *Mammillaria gaumeri*, an endemic cactus of coastal Yucatán, México. *Journal of Arid Environments*, *41*, 421–428. https://doi.org/10.1006/jare.1998.0490

Lesica, P., & Kittelson, P. M. (2010). Precipitation and temperature are associated with advanced flowering phenology in a semi-arid grassland. *Journal of Arid Environments*, *74*, 1013–1017. https://doi.org/10.1016/j.jaridenv.2010.02.002

Machin, D., Cheung, Y. B., & Parmar, M. K. B. (2006). Survival analysis: A practical approach (2nd ed.).

Méndez, M., Durán, R., Olmsted, I., & Oyama, K. (2006). Population dynamics of *Pterocereus gaumeri*, a rare and endemic columnar cactus of México. *Biotropica*, *36*, 492–504. https://doi.org/10.1111/j.1744-7429.2004.tb00345.x

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*, 853–858. https://doi.org/10.1038/35002501

Navarro, L., & Guitián, J. (2003). Seed germination and seedling survival of two threatened endemic species of the northwest Iberian Peninsula. *Biological Conservation*, *109*, 313–320. https://doi.org/10.1016/S0006-3207(02)00151-9

Orcutt, D., & Nilsen, E. (2000). *Physiology of plants under stress*. John Wiley & Sons.

Parra-Tabla, V., Celaya, C., Téllez, P., Salinas, L., Abdala-Roberts, L., & Alonso, C. (2017). Fenología de floración y polinización en herbáceas de la Reserva de la Biósfera Ría Lagartos. In J. Ramos (Ed.), *Ecología funcional de la Reserva de la Biósfera de Ría Lagartos* (pp. 105–121). IIES-UADY-UNAM, Mérida.

Pérez-Sánchez, R. M., Flores, J., Jurado, E., & Gonzáles-Salvatierra, C. (2015). Growth and ecophysiology of succulent seedlings under the protection of nurse plants in the southern Chihuahuan Desert. *Ecosphere*, *6*, 1–21. https://doi.org/10.1890/ES14-00408.1

Pounds, J. A., Alan Pounds, J., Bustamante, M. R., Coloma, L. A., Consuegra, J. A., Fogden, M. P. L., Foster, P. N., La Marca, E., Masters, K. L., Merino-Viteri, A., Puschendorf, R., Ron, S. R., Sánchez-Azofeifa, G. A., Still, C. J., & Young, B. E. (2006). Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature*, *439*, 161–167. https://doi.org/10.1038/nature04246

Rabinowitz, D. (1981). Seven forms of rarity. In H. Synge (Ed.), *The biological aspects of rare plant conservation* (pp. 584). John Wiley & Sons.

Riemann, H., & Ezcurra, E. (2005). Plant endemism and natural protected areas in the peninsula of Baja California, México. *Biological Conservation*, *122*, 141–150. https://doi.org/10.1016/j.biocon.2004.07.008

Rundel, P. W., & Jarrell, W. N. (1989). Water in the enviroment. In R. Percy, J. Ehleringer, H. A. Mooney, & P. W. Rundel (Eds.), *Plant physiological ecology. Field methods and instrumentation*. Chapman & Hall.

Samain, M.-S., Guzmán Díaz, S., Machuca, K., Fuentes, A. C. D., Martínez, D. V., Aldaba Núñez, F. A., Redonda-Martínez, R., Oldfield, R. S., & Martínez Salas, E. E. (2022). Meta-analysis of Red List conservation assessments of Mexican endemic and near endemic tree species shows nearly two thirds of these are threatened. *Plants, People, Planet*, *5*, 459–627. https://doi.org/10.1002/ppp3.10308

Schmalenbach, I., Zhang, L., Reymond, M., & Jiménez-Gómez, J. M. (2014). The relationship between flowering time and growth responses to drougth in the Arabidopsis Landsberg erecta x Antwero-1 population. *Frontiers in Plant Science*, *5*, 609.

Searle, S. R., Speed, F. M., & Milliken, G. A. (1980). Population marginal means in the linear model: An alternative to least squares means. *The American Statistician*, *34*, 216–221. https://doi.org/10.1080/00031305.1980.10483031

Sękiewicz, K., Salvà-Catarineu, M., Walas, Ł., Romo, A., Gholizadeh, H., Naqinezhad, A., Farzaliyev, V., Mazur, M., & Boratyński, A. (2024). Consequence of habitat specificity: A rising risk of habitat loss for endemic and sub-endemic woody species under climate change in the Hyrcanian ecoregion. *Regional Environmental Change*, *24*, 68. https://doi.org/10.1007/s10113-024-02222-7

Servicio Meteorológico Nacional-Comisión Nacional del Agua. (2022). *Precipitación y temperatura de Yucatán*. México. http://www.smn.conagua.gob.mx

Shi-Kan, S., Guan-Song, Y., Yue-Hua, W., & Shu-Zhuang, H. (2016). Seed germination and seedling emergence of *Euryodendron excelsum* H. T. Chang: Implications for species conservation and restoration. *Plant Biology*, *31*, 233–239. https://doi.org/10.1111/1442-1984.12105

Sosa, V., De-Nova, A., & Vásquez-Cruz, M. (2018). Evolutionary history of the flora of México: Dry forests cradles and museums of endemism. *Journal of Systematics and Evolution*, *56*, 523–536. https://doi.org/10.1111/jse.12416

The Jamovi Project. (2024). *jamovi (version 2.6)* [Computer Software]. https://www.jamovi.org

Therneau, T. M., & Thomas, L. (2019). *survival: Survival analysis* [R package]. https://CRAN.R-project.org/package=survival

Thomson, D. (2005). Measuring the effects of invasive species on the demography of a rare endemic plant. *Biological Invasions*, *7*, 615–624. https://doi.org/10.1007/s10530-004-5853-3

Valencia, E., Méndez, M., Saavedra, N., & Maestre, F. T. (2016). Plant size and leaf area influence phenological and reproductive responses to warming in semiarid Mediterranean species. *Perspectives in Plant Ecology, Evolution and Systematics*, *21*, 31–40. https://doi.org/10.1016/j.ppees.2016.05.003

Valiente-Banuet, A., & Verdú, M. (2007). Facilitation can increase the phylogenetic diversity of plant communities. *Ecology Letters*, *10*, 1029–1036. https://doi.org/10.1111/j.1461-0248.2007.01100.x

Vervuren, P. J. A., Blom, C. W. P. M., & De Kroon, H. (2003). Extreme flooding events on the Rhine and the survival and distribution of riparian plant species. *Journal of Ecology*, *91*, 135–146. https://doi.org/10.1046/j.1365-2745.2003.00749.x

Volk, G. M., Crane, J., Caspersen, A., Kovach, D., Gardner, C., & Walters, C. (2006). Hydration of *Cuphea* seeds containing crystallised triacylglycerols. *Functional Plant Biology*, *34*, 360–367. https://doi.org/10.1071/FP06291

Winkler, D. E., Yu-Chan, M. L., Delgadillo, J., Chapin, K. J., & Huxman, T. E. (2019). Early life history responses and phenotypic shifts in a rare endemic plant responding to climate change. *Conservation Physiology*, *7*, coz076. https://doi.org/10.1093/conphys/coz076

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Parra-Tabla, V., & Hernández Mendoza, V. (2026). Life-history traits and survival responses to light and water of the rare endemic species *Cuphea gaumeri* Koehne (Lythraceae). *Plant Species Biology*, *41*(1), e70037. https://doi.org/10.1111/1442-1984.70037