



Germination of four riparian species in a disturbed semi-arid ecosystem



Cynthia Peralta-García^a, María Esther Sánchez-Coronado^b, Alma Orozco-Segovia^b,
Susana Orozco-Segovia^c, Irene Pisanty-Baruch^{a,*}

^a Departamento de Ecología y Recursos Naturales, Facultad de Ciencias, Universidad Nacional Autónoma de México, Avenida Universidad 3000, Ciudad Universitaria 04510, Coyoacán, Mexico, D.F., Mexico

^b Departamento de Ecología Fisiológica, Instituto de Ecología, Universidad Nacional Autónoma de México, Apartado Postal 70-275, Ciudad Universitaria 04510, Coyoacán, Mexico, D.F., Mexico

^c Departamento de Física, Facultad de Ciencias, Universidad Nacional Autónoma de México, Avenida Universidad 3000, Ciudad Universitaria 04510, Coyoacán, Mexico, D.F., Mexico

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ABSTRACT

The Cuatrociénegas Valley (Coahuila, Mexico) is a highly diverse semiarid ecosystem. Its gypsum substrate has been altered because of the extensive extraction of water, resulting in the destabilization of underground water systems and an increasing formation of sinkholes that are colonized by riparian species. Sinkholes represent a set of microenvironments that could improve germination and seedling establishment of riparian species. We studied the effect of light (in controlled conditions: 18/32 °C, 12/12 h photoperiod), collection season (rainy and dry seasons), and time of storage on the germination, in field and controlled conditions, of four riparian species (*Samolus ebracteatus* var. *coahuilensis*, *Flaveria chlorifolia*, *Eustoma exaltatum*, and *Sabatia tuberculata*) that colonize the sinkholes. Seeds of each species were enclosed in permeable nylon bags and fixed to the substrate of randomly selected sinkholes. From September 2009 to July 2010, three bags per species per collection season were recovered every two months, and germinated seeds were counted. Recovered ungerminated and lab stored (control) seeds were germinated in controlled conditions. The low germination probabilities in the field (<0.47) contrast with the high probabilities (0.8) maintained by control and recovered seeds, regardless of the collection season or the light treatment. All the species showed two germination peaks in the field, coinciding with moisture availability. These results suggest the presence of conditional dormancy and the distribution of germination in time, evading the unsafe synchronic germination in the disturbed Cuatrociénegas environment.

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1. Introduction

Contemporary disturbance of arid and semi-arid ecosystems has led plant species to endure the presence of additional environmental stress factors (Baylei, 2011). Springs and wetlands in these regions are facing great pressures, due to natural and anthropogenic changes, the latter having the higher impacts (Capon and Dowe, 2006; Unmack and Minckley, 2008). Disturbance can modify the environment at different scales (Aragón et al., 2007; Orozco-Segovia and Sánchez-Coronado, 2009), creating or eliminating safe sites for seed germination and consequently for the recruitment and establishment of plant species.

Gypsum (di-hydrated calcium sulfate) soils are widely distributed in arid and semi-arid lands that have been poorly studied. These soils are easily eroded due to the richness in exchangeable sodium ions (Heinzen and Arulanandan, 1977; Umesh et al., 2011). Seed

germination is a critical step in the colonization process, which is basic to understand ecosystem dynamics (Baskin and Baskin, 2014). However, germination on gypsum substrates has scarcely been studied and is not well understood. Among seeds sown on moist filter paper and under controlled conditions, Escudero et al. (1997) did not find specific differences in germination responses in a set of 11 species of Mediterranean gypsophytes and gypsovags, and these authors recognize that the selective pressures affecting germination still need to be identified. Sánchez et al. (2014) report that germination of annuals growing in Mediterranean semi-arid ecosystems with gypsum soils is regulated by a complex interaction between seasonal temperatures and water availability to which species have plastic germination responses through both space and time.

Gypsum is a frequent substrate in the Cuatrociénegas Valley in Coahuila, Mexico where the intensive loss of water due to overexploitation for use in agriculture, specially for the cultivation of alfalfa (Aldama et al., 2007), has led to the formation of numerous sinkholes, at an unusually high rate (Pisanty et al., 2013). Sinkholes are depressions of different sizes and depths, formed by the dispersion and collapse of soils (Heinzen and Arulanandan, 1977) (Fig. 1). The sinkholes formed in the study site might be a set of numerous safe sites for seed germination

* Corresponding author.

E-mail addresses: cynpegarc@gmail.com (C. Peralta-García), esanchez@ecologia.unam.mx (M.E. Sánchez-Coronado), aorozco@ecologia.unam.mx (A. Orozco-Segovia), sos@ciencias.unam.mx (S. Orozco-Segovia), ipisanty@unam.mx (I. Pisanty-Baruch).



Fig. 1. Sinkholes surrounding the Churince System in the Cuatrociénegas Valley, Coahuila, Mexico.

in gypsum-rich semiarid environments (Pisanty et al., 2013). Soil can accumulate in these depressions, so seeds may or may not be buried in them and, consequently, they can be exposed to different light conditions, including darkness, depending on depth and size of the sinkholes, as well as on soil accumulation and plant cover. Temperature and light conditions that seeds meet for germination might limit or favor the colonization in these microenvironments, providing an example of colonization and microsuccessional processes similar to others reported for arid and semi-arid systems (Montaña, 1992; Vega and Montaña, 2004; Sánchez et al., 2014).

To understand the germination requirements of riparian species that colonize sinkholes in gypsum environments, we analyzed the germination response of the seeds of four riparian species that were stored in laboratory conditions and then were sown in the sinkholes. The studied species are two perennial: *Flaveria chlorifolia* A. Gray (Asteraceae) and *Samolus ebracteatus* HBK var. *coahuilensis* Henrickson (Primulaceae), an annual or short lived perennial species, *Eustoma exaltatum* (L.) Salisb. Ex G. Don, and the annual *Sabatia tuberculata* J.E. Williams, both Gentianaceae. *F. chlorifolia* is frequently associated with gypsum soils, and can be considered a gypsophyte (Johnston, 1941; Parsons, 1976), whereas *S. ebracteatus* var. *coahuilensis* has a wider distribution, but is also associated with gypsum soils, so it can be considered a gypsophage. *S. tuberculata* is a microendemic gypsophyte of the Cuatrociénegas Valley, while *E. exaltatum* can grow on more varied substrates (Villarreal-Quintanilla, 2001; Turner, 2014). In non-disturbed conditions these species occupy specific riparian habitats (CONANP, 1999), and they are frequent colonizers of sinkholes formed under disturbed conditions (Pisanty et al., 2013; Rodríguez-Sánchez, 2014). We also tested the effect of light on germination in controlled conditions. Because the four studied species show a widespread shedding season we included two collection dates (September–November and January–May; rainy and dry seasons, respectively).

Understanding the germination behavior of the species that are commonly found growing in the sinkholes is an opportunity to understand the role of germination in the colonization of disturbed gypsum microenvironments.

2. Materials and methods

2.1. Study area

The Cuatrociénegas Valley is located between 26°45' and 27°00'N, and 101°48' and 107°53'W, at 735 m a.s.l. Climate is dry, with extreme

temperatures from more than 50 °C in summer to less than 0 °C in winter (22 °C average annual temperature, SEMARNAP, 1999). Annual precipitation barely reaches 220 mm and occurs mainly in summer, but sporadic storms and hurricanes can cause intense precipitation both in the rainy and the dry seasons (INE, 2009; SEMARNAP, 1999; Fig. 2).

In the Cuatrociénegas Valley, the overexploitation of underground sources of water is very relevant and has led to the progressive loss of water in the hydrological systems that characterize this place. Since 2005, one of these systems, known as the Churince System (Fig. 3), has been progressively losing water and some of its parts are already dry.

2.2. Species

Sinkholes are first colonized by the perennials *S. ebracteatus* var. *coahuilensis* and *F. chlorifolia*, which are also the most frequent species among ca. ten other species that have been found in sinkholes. *S. tuberculata* was the only annual registered growing in these sinkholes during the study period. *E. exaltatum* can behave as an annual or as a short lived perennial. The main characteristics of these four species are described in Appendix A, Table A.1.

Seeds were collected in two periods in the 2008–2009 shedding season: in the rainy season (September to November 2008, RS-seeds) and in the dry season (January to May 2009, DS-seeds). In the laboratory, seeds were manually removed from the floral remnants and kept in paper bags at environmental conditions (19.03 ± 1.42 °C and relative humidity = $44.84 \pm 1.9\%$) until use. Over the experimental period, soil temperature was measured with Hobo data loggers (U23-001 OnsetComputer, Corp. Bourne, USA) that were placed in seven randomly chosen sinkholes.

2.3. General procedures for germination in controlled conditions

For germination in controlled conditions, seeds were sown in Petri dishes on 0.8% agar plates (Bioxon, Mexico), and five replicates per treatment were incubated in growth chambers (NuAire 1-3LL Fernbrook Lane Plymouth MN, USA) at fluctuating temperatures (18/32 °C (18/6 h); photoperiod was 12 h day⁻¹). Germination was recorded every other day and determined by radicle protrusion. The number of seeds per Petri dish varied depending on the number of seeds recovered from the field experiments. Control seeds were equal in number to the recovered seeds.

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