



# Distinct germination responses may contribute to the distribution pattern of two *Moquiniastrum* species in different phytophysiognomies from the Brazilian savanna



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## ABSTRACT

Understanding how germination traits can influence the distribution pattern of adult plants is still an important issue for seed ecologists and biologists. Here, we evaluated if seed germination responses to abiotic factors may be related to the occurrence of two *Moquiniastrum* species in different phytophysiognomies from the Brazilian savanna. To evaluate if germination responses are distinct between species, seeds of *M. barrosoae* (common to typical savanna) and *M. polymorphum* (common to typical and forested savanna) were set to germinate under different constant (5 to 40 °C) and alternating (15–30, 20–30, 25–30 and 25–35 °C) temperature regimes in light and dark conditions, different red:far-red ratios (0.1, 0.5, 2.0 and 7.2 R:FR) of light, and water availability (0 to –1.0 MPa) in controlled experiments. Seed germination responses were distinct between species, with *M. polymorphum* presenting higher germinability over a wider temperature range, with lower light requirement for germination, less sensitivity to alteration of R:FR ratios and higher tolerance to water limitation compared to *M. barrosoae*, which presented more specific environmental requirements to seed germination. Therefore, we demonstrate that seed germination responses may contribute to the distribution pattern observed in adult plants, since the more widely distributed species (*M. polymorphum*) presented higher germinability over a broader range of environmental conditions, which may enable this species to occur in different phytophysiognomies compared to the species with the more restricted distribution area (*M. barrosoae*).

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## 1. Introduction

Seed germination is one of the first traits expressed during the life cycle of plants, and has the potential to be strongly subjected to natural selection, because plants need to overcome the germination and seedling stage before they can express other adaptive characteristics in their life (Donohue et al., 2010). Accurate germination cuing can enable germination under optimal conditions for seedling survival and growth. So, seed germination traits may play an important role in the distribution pattern of plant species, because successful germination can be related to habitat preference (Donohue et al., 2010; Grubb, 1977; Leyer and Pross, 2009; Pearson et al., 2002).

A number of studies have investigated the relationship between germination traits and the species distribution pattern; some of them have failed to find such a relationship (e.g. Silveira et al., 2012; Thompson et al., 1999; Thompson and Ceriani, 2003). However, other studies reported that germination traits may be related to distribution patterns in plants, where species with wider distribution patterns present higher germinability in different conditions compared to species with narrower distribution (Luna and Moreno, 2010; Marques et al., 2014; Ranieri et al., 2012).

Environmental factors such as water availability, temperature regimes, luminosity and quality of light are key aspects that control seed germination. Suitable water availability is needed to initiate germination in non-dormant seeds, and different responses to water stress can reflect adaptation to drought (Baskin and Baskin, 2014). Temperature is the main factor regulating seed dormancy and germination (Probert, 2000); light can also influence dormancy, germinability and germination time of many species (Pearson et al., 2002; Smith, 2000).

The Brazilian Neotropical savanna (Cerrado) covers approximately 2 million km<sup>2</sup> (Eiten, 1972). In its domain, there is

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considerable seasonality, with the rainy and dry seasons well defined (Franco, 2002). Soils are acidic, with low content of organic matter and nutrients and high amounts of aluminum (Furley and Ratter, 1988).

The vegetation landscape of the Cerrado consists of different phytophysiognomies. The typical savanna (cerrado *sensu stricto*) is an open physiognomy and comprises a mix of scattered shrubs and trees often 3–8 m tall with more than 30% crown cover, with a rich herbaceous layer. The forested savanna (cerradão) is predominantly composed of trees often 8–12 m tall or even taller with crown cover of 50–90%, casting a considerable shade (Oliveira-Filho and Ratter, 2002). Although these two vegetation types can occur in the same area, they are structurally and floristically distinct (Pinheiro and Durigan, 2012). Some plant species of the savanna can occur in different vegetation types, but others are unique to one or only a few physiognomies, such as many non-arboreal species, which are restricted to open environments (Pinheiro and Durigan, 2012; Rossatto et al., 2008).

Different vegetation types impose distinct selective pressure on recruitment and germination, with forested savanna (closed canopy) possessing lower light intensity and lower red:far-red ratio (Salazar et al., 2012), milder temperatures (Kissmann et al., 2012) and higher soil water availability (Assis et al., 2011) than the typical savanna, which has a more open physiognomy.

In southern peripheral areas of the Cerrado, the sympatric Asteraceae species *Moquiniastrum barrosoae* (= *Gochnatia barrosii*) and *M. polymorphum* (= *G. polymorpha*) co-exist. However, they present a distinct distribution pattern in the mosaic of the Cerrado vegetation (Rossatto and Kolb, 2012). *Moquiniastrum polymorphum* has a wider distribution, occurring both in the more open and in the more closed vegetation types (typical or forested savanna and riparian forests), while *M. barrosoae* has a narrower distribution, occurring only in open areas of Cerrado (typical savanna or grasslands) (Durigan et al., 1999, 2004a).

In this way, we hypothesized that the distribution pattern of the two *Moquiniastrum* species over the different Cerrado phytophysiognomies is related to their distinct germination responses. To test this hypothesis, we sought to answer the following questions: (i) do the two *Moquiniastrum* species differ in their germination responses under key environmental factors, i.e. temperature, light requirement, light quality and water availability? (ii) does the more widely distributed species (*M. polymorphum*) have higher germinability over a broader range of environmental conditions? (iii) do seed germination responses contribute to the distribution pattern observed in adult plants?

## 2. Material and methods

### 2.1. Study site

Mature cypselae (hereafter referred to as seeds) were collected at the Assis Ecological Station (AES; 22° 33' 65" to 22° 36' 68" S, 50° 22' 29" to 50° 23' 00" W), a conservation area located in the western region of the state of São Paulo, Brazil. The climate at the AES according to the Köppen classification is between Cwa and Cfa, being characterized as subtropical, with rainfall concentrated from October to May and the dry season from June to September. The average annual rainfall and temperature recorded for a period of 20 years (decades 1970–1990) are 1400 mm and 21.8 °C, respectively. Elevations are ranging from 500 to 588 m (Secretaria do Meio Ambiente, 2010). The soils are predominantly weathered dystrophic oxisols (Juhász et al., 2006). The main vegetation of the study site consists of savanna physiognomies, where the forested savanna predominates (Durigan et al., 1999), which is a sclerophyllous woodland with 8–15 m tall trees, with 20 m<sup>2</sup>/ha of

basal area and 1800 individuals/ha (dbh ≥ 5 cm), creating a canopy cover of about 90%. In the AES the typical savanna vegetation also occurs, which is characterized by shrub vegetation with scattered trees and a discontinuous canopy cover (about 45% of tree cover), with 10 m<sup>2</sup>/ha of basal area and 900 individuals/ha (dbh ≥ 5 cm) (Pinheiro and Durigan, 2009; Secretaria do Meio Ambiente, 2010).

### 2.2. Study species and seed collection

*Moquiniastrum barrosoae* (Cabrera) G. Sancho is an erect shrub (about 2 m tall) that occurs predominantly in the typical savanna, being restricted to more open phytophysiognomies. In contrast, *Moquiniastrum polymorphum* (Less.) G. Sancho is a generalist tree (about 6–15 m tall), occurring both in open areas (typical savanna) and in closed physiognomies (riparian forest and forested savanna) (Durigan et al., 1999, 2004a). Seeds were collected from many individuals ( $n \geq 12$ ) for a suitable genetic sample of each species during dispersion peak, in October 2012 for *M. barrosoae* and January 2013 for *M. polymorphum*. Seeds of all individuals were mixed to form a single seed sample for each species.

### 2.3. Seed mass

Seeds of both species were dried for 48 h at 80 °C. Dry seed mass was determined by weighing the individual seeds (*M. barrosoae*  $n = 107$ ; *M. polymorphum*  $n = 100$ ) with a 0.1 mg precision balance.

### 2.4. Environmental features

We selected the two vegetation types where the species studied, the typical and the forested savannas, are more common. Measurements of superficial soil temperature (°C; 1 cm depth) and irradiance of light ( $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) were performed at around 08:00 and 12:00, in October 2012 and January 2013. These measurements were taken in five randomized replicates for each vegetation type, with 5 m between each other. The temperature was measured using an instant-read digital thermometer (IncoTerm®) and the irradiance of light was measured near the soil surface with a spherical quantum sensor (Li-250A, Biosciences, Lincoln, USA).

Precipitation and environmental temperature data from the study area were obtained from the online database of the Information Integrated Center of Agrometeorology (CIAGRO) of the São Paulo State government.

### 2.5. Temperatures and light effects on germination

To evaluate the effect of temperature and light on germination, seeds were subjected to constant temperatures of 5, 10, 15, 20, 25, 30, 35 and  $40 \pm 1$  °C, and alternate temperatures of 15–30, 20–30, 25–30 and  $25–35 \pm 1$  °C, under both light (12-h photoperiod of white light,  $60 \mu\text{mol m}^{-2} \text{s}^{-1}$ ) and continuous darkness. Four replicates of 25 seeds were placed on four sheets of filter paper moistened with distilled water in germination boxes. For dark treatments the germination boxes were wrapped in aluminum foil.

### 2.6. Different red:far-red ratios on germination

To evaluate germination responses to red:far-red (R:FR) ratios of light, seeds were subjected to four treatments of light with different R:FR ratios: (i) 7.2 R:FR ratio, obtained with white light; (ii) 2.0 R:FR ratio, obtained from the white light that passed through two red and two blue cellophane foils wrapping the germination boxes; (iii) 0.5 and (iv) 0.1 R:FR ratios, obtained by passage of incandescent light (two 25 W and two 60 W bulbs) through plastic film like insulfilm® with different levels of light filtering wrapping the germination

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