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Original article

Seedling growth and biomass allocation of endemic and threatened shrubs of rupestrian fields

Daniel Negreiros, G. Wilson Fernandes, Fernando A.O. Silveira, Clarissa Chalub*

Ecologia Evolutiva & Biodiversidade/DBG, ICB/Universidade Federal de Minas Gerais, AV Antonio Carlos 6627, CP 486, 30161-970 Belo Horizonte, MG, Brazil

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ABSTRACT

The increasing anthropogenic pressure in the rare rupestrian fields in southeastern Brazil has led to the expansion of degraded areas on the extremely nutrient-deficient quartzitic soils. On the other hand, the use of rupestrian field native species in reclamation programmes has been hampered by the lack of studies involving seedling physiological ecology. The present study evaluated biomass allocation and seedling growth rate during early seedling growth of four Fabaceae shrubs: *Collaea cipoensis*, *Calliandra fasciculata*, *Chamaecrista ramosa*, and *Mimosa foliolosa*. The following hypotheses were tested: (i) species proportionally allocate higher biomass to the roots, presenting a high root/shoot ratio; and (ii) species exhibit low phenotypic variation because they have adapted to poor nutritional environments. A 12-month greenhouse experiment was carried out to evaluate seedling growth and biomass allocation performance in substrates with contrasting levels of soil fertility. The four species studied presented values of root/shoot ratio lower than one in both fertility conditions of the substrate. Growth parameters for *Collaea* and *Calliandra* increased with increasing soil fertility, while no differences were observed for *Mimosa* and *Chamaecrista*. Although the four species are naturally adapted to low nutritional quality soils, seedling development was not hindered by high fertility substrate conditions. Despite the remarkable differences in fertility between the substrates, the responsiveness in growth and allocation in *Chamaecrista* and *Mimosa* was lower than that expected if the species would exhibit high phenotypic variation. The implications for rupestrian field restoration are discussed.

1. Introduction

A unique and rare vegetation physiognomy of the Brazilian Cerrado, a biodiversity hotspot (Myers et al., 2000; Marris, 2005), known as the rupestrian field, is exclusively found in the highlands of the Espinhaço mountain range and small disjunctions in southeastern and northeastern Brazil. The rupestrian fields occur in areas above 900 m a.s.l., on shallow, Al-rich, water- and nutrient-deficient soils where rocky outcrops prevail (Giulietti et al., 1987; Benites et al., 2007). These plant communities also experience high daily thermal amplitudes, strong winds, high sun exposure and constant fires (Ribeiro and Fernandes, 2000; Jacobi et al., 2007). In this speciose physiognomy plants are mainly sclerophyllous and

* *Corresponding author*. Ecologia Evolutiva & Biodiversidade/DBG, ICB/Universidade Federal de Minas Gerais, AV Antônio Carlos 6627, CP 486, 30161-970 Belo Horizonte, MG, Brazil. Tel.: +55 31 3409 2592; fax: +55 31 3409 2569.
E-mail address: gwilson@icb.ufmg.br (G.W. Fernandes).
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herbaceous with scattered shrubs and trees comprising a mosaic of habitats (Giulietti et al., 1997). Most of the endangered species of the Brazilian Cerrado are endemic to the rupestrian fields (see Menezes and Giulietti, 2000), making this physiognomy especially important for plant conservation.

The survival of many of the rare species of the rupestrian fields is adversely affected by mining activities, road construction, pasture, uncontrolled fires, predatory tourism and unmanaged ornamental plant collection. The intense mining activities practiced for centuries on a large scale in the Espinhaço range keep impacting on its flora. Mining has resulted in bare areas with exposed subsoil or gravel (Giulietti et al., 1997; Menezes and Giulietti, 2000) and, even after being abandoned for decades, no natural recovery has been documented. In Serra do Cipó, at the southern portion of the Espinhaço range, extensive erosion due to mining can be easily observed, also as a result of careless construction or paving of existing highways (see Viana et al., 2005) where the high susceptibility to erosion of the quartzitic soils had not been taken into consideration. Furthermore, the impact of highway construction has increased the deposition of soils brought from different areas and caused the introduction of many exotic invasive species. Consequently, the need for restoration is urgent.

The selection of adapted species is a key step to rehabilitation of degraded areas and should focus on native rather than exotic species. In Brazil, most rehabilitation programmes employ exotic species such as Australian *Eucalyptus* and African grasses (mainly *Brachiaria* and *Melinis*) which have been shown to be an important threat to biodiversity (Pivello et al., 1999). The main attribute that plant species adapted to environments with low resource availability must have is an inherent low growth rate, even when exposed to optimal levels of resources (Parsons, 1968; Grime and Hunt, 1975; Chapin, 1980). These species allocate fewer resources to growth because a higher level of supply is needed for functions that increase survival rates in adverse environments (Coley et al., 1985; Chapin et al., 1993; Arendt, 1997). In such species, the slow growth rate is associated with several attributes that include high plant module longevity, a great capacity for photosynthate storage and the investment in anti-herbivory compounds (Chapin, 1980; Coley et al., 1985; Fernandes and Price, 1991; Grime, 1993). The combination of all these features has been described as stress tolerance by Grime (1977), in which selection favours traits that support retention and conservative use of acquired mineral nutrients (Grime, 1993; Warembourg and Estelrich, 2001).

The selection of species to restore degraded areas under quartzite-derived soils at the Espinhaço range must consider the optimal exploitation of the adaptive potential of rupestrian field native flora. In this harsh environment, traits such as survival and resistance to different types of stress should be favoured rather than simple fast growth and soil covering (see Elias and Chadwick, 1979; Bradshaw, 2000). The use of legume species in soil protection has been emphasized due to their increased capacity for water retention and, mainly, because of the soil fertility improvement provided by the interaction with N-fixing bacteria (Garg, 1999; Temperton et al., 2007). Fabaceae constitute one of the most well-represented families in rupestrian fields and it is the third most represented family in Serra do Cipó, with 108 species (Giulietti et al., 1987). This study aimed to evaluate the biomass partitioning and growth responses of rupestrian field species when exposed to two levels of soil fertility. Information on restoration ecology of other Brazilian vegetation is available (Vieira and Scariot, 2006; Zamith and Scarano, 2006; Simões and Marques, 2007) but we are unaware of other studies addressing any aspect of rupestrian fields restoration. Studies on seedling growth and allocation patterns of rupestrian fields species are crucial for restoration since they will retrieve information on the ecophysiological adaptations to the harsh environment. Because restoration techniques strongly rely on seedling growth and survival, information on early seedling growth and allocation is required in order to accomplish successful programmes (Du et al., 2008).

Four native species were selected for the study. Three of them belong to the most speciose Fabaceae genera occurring in rupestrian fields: *Calliandra*, *Chamaecrista* and *Mimosa* (Giulietti et al., 1997; Menezes and Giulietti, 2000). The fourth species, *Collaea cipoensis* (Fortunato, 1995) is an endemic shrub of Serra do Cipó. Two hypotheses were tested in this study. The first hypothesis predicts that species proportionally allocate higher biomass to the roots. Being naturally adapted to poor soil environments with high light intensity, a high root/shoot ratio would be expected. High values of root/shoot ratio would be consistent with the expectation of the optimized growth process, where there is a great limitation for nutrients instead of light limitation (Chapin, 1980; Bloom et al., 1985; Wilson, 1988; Mooney and Winner, 1991; Moreira and Klink, 2000; Hoffmann and Franco, 2003). The second hypothesis predicts that species should exhibit low phenotypic variation. There is a trend for little responsiveness to the soil fertility variation in plants adapted to poor nutritional environments (Grime, 1977; Chapin, 1980; Bloom et al., 1985; Chapin et al., 1986, 1993). Hence, it is expected that growth performance and biomass partitioning will not differ in substrates with contrasting fertility conditions.

2. Materials and methods

2.1. *Studied site and species*

This study was conducted in a greenhouse located at the Reserva Natural Particular Vellozia (lat 19°16′45.7″S, long 43°35′27.8″W), Serra do Cipó, Minas Gerais, Brazil. Seeds were collected from plants occurring between 1060 and 1170 m a.s.l., where the climate is mesothermic, Cwb according to Köppen classification, with dry winters and rainy summers, with an average annual rainfall of 1500 mm and average temperature ranging from 17.4 to 19.8 °C (Galvão and Nimer, 1965).

Collaea cipoensis Fortunato (Papilionoideae) is a 2–4 m tall shrub, commonly found in grassy rupestrian fields (Fortunato, 1995). It occurs usually in soils with high organic matter accumulation, next to water courses. It has a very restricted area of distribution and is only known from Serra do Cipó (Fortunato, 1995). *Calliandra fasciculata* Benth. var. *bracteosa* (Bentham) Barneby (Mimosoideae), referred to as *Calliandra*, is a 0.4–2 m tall shrub. It occurs along and near the crest of