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The introduced tree *Prosopis juliflora* is a serious threat to native species of the Brazilian Caatinga vegetation

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HIGHLIGHTS

- *Prosopis juliflora* reduced growth of native Caatinga species tested.
- *P. juliflora* increased the mortality of all species of native plants tested.
- *Mimosa tenuiflora* and *Caesalpinia ferrea* had the lowest mortality and highest height.
- *M. tenuiflora* and *C. ferrea* may present a viable option to management systems.

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ABSTRACT

Despite its economic importance in the rural context, the *Prosopis juliflora* tree species has already invaded millions of hectares globally (particularly rangelands), threatening native biodiversity and rural sustainability. Here we examine seedling growth (leaf area, stem diameter, plant height) and seedling mortality across five native plant species of the Caatinga vegetation in response to competition with *P. juliflora*. Two sowing treatments with 10 replications were adopted within a factorial 2 × 5 randomized block design. Treatments consisted of *P. juliflora* seeds sowed with seeds of *Caesalpinia ferrea*, *Caesalpinia microphylla*, *Erythrina velutina*, *Mimosa bimucronata* and *Mimosa tenuiflora* (one single native species per treatment), while seeds of native species sowed without *P. juliflora* were adopted as controls. Overall, our results suggest that *P. juliflora* can reduce seedling growth by half and cause increased seedling mortality among woody plant species. Moreover, native species exhibit different levels of susceptibility to competition with *P. juliflora*, particularly in terms of plant growth. Such a superior competitive ability apparently permits *P. juliflora* to establish monospecific stands of adult trees, locally displacing native species or limiting their recruitment. The use of less sensitive species, such as *C. ferrea* and *M. tenuiflora*, to restore native vegetation before intensive colonization by *P. juliflora* should be investigated as an effective approach for avoiding its continuous spread across the Caatinga region.

1. Introduction

Biological invasions have emerged as a major threat for global biodiversity as they already represent one of the main causes of species extinction (Vitousek et al., 1996, 1997; Lenda et al., 2013). In addition to species extinction and biotic homogenization at multiple spatial scales, synergisms between human-mediated disturbances and biological invasions may threaten ecosystem integrity further by providing biomass for intense fires, for example (van Wilgen et al., 2008). In the case of plants, deliberate introductions of "useful species" represent the major source for the increment of exotic floras, from which many species achieve invasive status (Pyšek, 1998; Chapple et al., 2012).

Prosopis juliflora (Sw.) DC L., 1753 is an evergreen tree species, which is native of rangelands (i.e. steppe and savanna-like vegetation types) in South America, Central America and the Caribbean. It refers to a fast growing species, which is tolerant to arid conditions and saline soils; i.e. a drought-resistant species (Pasiecznik et al., 2004; El-Keblawy and

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Al-Rawai, 2005) like others within this genus (Adams et al., 2010). In addition to its aggressive nature, *P. juliflora* can provide valuable goods and services, such as timber, firewood and soil rehabilitation (Pasiecznik et al., 2001). These "desirable" characteristics have fuelled intentional introductions of *P. juliflora* across rural areas globally, with the consequent invasion of millions of hectares of rangelands in South Africa, East Africa, Australia, coastal Asia (Pasiecznik, 1999), and America (Kemp and Michalk, 2005). *P. juliflora* is now one of the top global invasive plant species according to the International Union for Conservation of Nature (IUCN).

One of the key attributes frequently exhibited by invasive species is their superior competitive ability as compared to native species (Rejmánek and Richardson, 1996). For example, *P. juliflora* can displace both agricultural and exotic plants and native species (Mwangi and Swallow, 2005) by delaying seed germination and reducing plant growth in terms of roots, shoots, leaf area, stem diameter, and plant height (Inderjit et al., 2008). Studies suggest that allelopathic substances produced by *P. juliflora*'s leaves, fruits, seeds, roots and flowers (Noor et al., 1995) affect species such as *Bambusa arundinacea* (Retz.) Willd. (Poaceae) (Inderjit et al., 2008) and *Echinochloa crus-galli* (L.) Beauv (Poaceae) (Goel et al., 1989; Nakano et al., 2003, 2004). Direct competition in addition to allelopathy may be the forces behind the successful invasion of sedimentary lowlands and alluvial river plains by *P. juliflora* (Pegado et al., 2006; Siddiqui et al., 2009), although evidence in favor of such a superior competitive ability is still scarce. In these more humid habitats (wetlands, riverbanks, alluvial plains), the first individuals form small agglomerates, from which *P. juliflora* expands and forms monospecific and persistent stands (Archer, 1995; Rajwant et al., 2012).

The Caatinga vegetation is a mosaic of scrub vegetation and patches of dry forest (Leal et al., 2005), which has been considered as a seasonally dry tropical forest in northeast Brazil (Bullock et al., 1995; Pennington, 2006; Santos et al., 2011). This singular biogeographic area (covering ca. 800,000 km^2) supports more than 1500 plant species, including a myriad of endemics; i.e. nearly 1/3 of the Caatinga flora consists of endemic species (Araújo et al., 2007; Albuquerque et al., 2012). As a semiarid region devoted primarily to activities such as agriculture and cattle-raising, the Caatinga has experienced deliberate species introductions as attempts to improve or turn viable farming-based activities (Cavalcante and Major, 2006). This region has also faced intensive habitat degradation from soil exhaustion, particularly in the case of low-input agriculture and over grazing by livestock, creating a sort of synergism between human poverty and environmental degradation (Leal et al., 2005; Santos et al., 2011).

In this socio-ecological context, *P. juliflora* was introduced in the Caatinga region in the 1940s (Pegado et al., 2006) as a source of forage for livestock, charcoal, firewood, cuttings and stakes, among other uses (Pometti et al., 2007). Economically, *P. juliflora* is a key element across several land use systems that apparently have improved rural livelihoods (Rajwant et al., 2012) and prevented further soil degradation (El-Keblawy and Abdelfatah, 2014). Conversely, *P. juliflora* has naturally spread over degraded river banks and other habitats previously disturbed by human activities (i.e. *P. juliflora* has achieved the invasive status), establishing monospecific stands which, in the case of the Caatinga vegetation, compete with a myriad of native plant species such as *Caesalpinia pyramidalis* Tul. (Fabaceae) (Pegado et al., 2006) and *Pilosocereus tillianus* R. Gruber & Schatzl (Cactaceae) (Larrea-Alcázar and Soriano, 2006). In this region, *P. juliflora* is also able to compete with traditional short-cycle crops such as maize (*Zea mays* L., Poaceae) and cotton (*Gossypium hirsutum* L., Malvaceae) (Porto Filho, 1981). One single *P. juliflora* tree is able to produce between 630,000 and 980,000 seeds per year (Hardin, 1988) which are then consumed and scarified by livestock, with a subsequent deposition in the ground and mixed with manure, resulting in increased germination and invasive potential (Felker, 2003).

For the sake of both the Caatinga biodiversity and rural sustainability we must understand the mechanisms providing the increased invasive potential exhibited by *P. juliflora* and inform stakeholders about restoration and/or management techniques to mitigate potential negative impacts resulting from spread of this plant at regional scale. Here we examine the seedling performance across five native woody plant species of the Caatinga vegetation as exposed to competition with *P. juliflora* in two experimental conditions: native species growing alone (controls) or in mixed stands with *P. julifora* (treatments). Seedling growth (height, stem diameter and leaf area) and mortality were monitored during a six-month period. We hypothesize that plants experiencing interspecific competition will exhibit lower total biomass than those that grow alone (Laird and Aarssen, 2005). We discuss the uncovered patterns in the context of biological invasion, particularly the ecology of *P. juliflora* and sustainable development of the Caatinga region.

2. Materials and methods

2.1. Experimental site and native plant species

The study was carried out in 2006 at the experimental station of the Center for Agricultural Research in the Semi-Arid Tropic, which is located in the Petrolina municipality (09° 23′S and 40° 30′W, 376 m a.s.l.), Northeast Brazil (Fig. 1). Five woody species from the Fabaceae family were selected because species of this family usually form symbiotic associations with *Rhizobium* (Rhizobiales: Rhizobiaceae). In fact, most of the Fabaceae species are able to establish symbiotic relationships with nitrogen-fixing bacteria in the Caatinga vegetation, helping to maintain soil fertility (Teixeira et al., 2006). Additionally, Fabaceae species represent a substantial portion of the Caatinga flora (from herbs to tree species), with characteristic taxa inhabiting the majority of the Caatinga

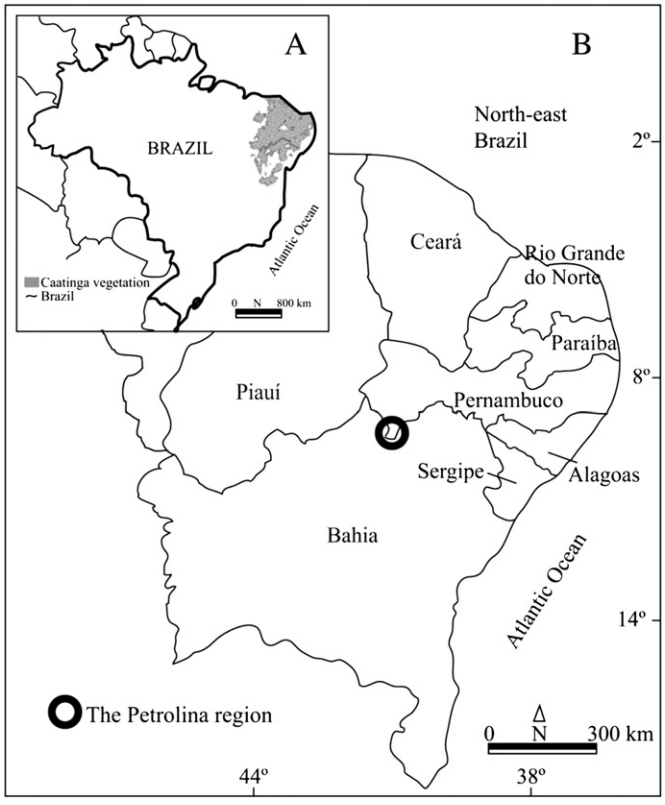

Fig. 1. The area covered by the Caatinga vegetation (A), and location of the Petrolina region, north-east Brazil (B).
Source: adapted from Leal et al. (2007).