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Original article

Factors related to establishment of *Prosopis caldenia* Burk. seedlings in central rangelands of Argentina

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Abstract

Prosopis caldenia Burk. is one of the woody species that is increasing in abundance due to poor grazing management in the semi-arid phytogeographic region of central Argentina, commonly known as the Caldenal. The objective of this study was to evaluate the effect of herbaceous cover, cattle dung, soil disturbance, and water supply on emergence and survival of *P. caldenia* seedlings on sites with different grazing histories: (i) a site exposed to long-term continuous grazing by cattle (grazed site), and (ii) a long-term exclosure to domestic livestock (ungrazed site). Removal of grass cover, addition of cattle dung, and water supply enhanced seedling emergence and survival, especially in the grazed site. Results suggest that factors (direct and indirect) associated with prolonged grazing history markedly affect *P. caldenia* establishment. This in turn alters the grass-woody plant balance, which might reduce the potential capacity of livestock production in the Caldenal.

Keywords: Overgrazing; Woody encroachment; Seedling establishment; *Prosopis caldenia*; Caldenal

1. Introduction

Encroachment of woody plants into arid and semi-arid rangelands during the last century has been widely recognised and is a process that seems to be related to climatic change, alteration of grazing intensity and frequency due to livestock introduction, reduction in fire frequency, and interactions among these factors (Westoby et al., 1989; McNaughton, 1992; Archer, 1994, Schultka and Cornelius, 1997; Valone and Kelt, 1999; Polley et al., 2002; Zalba and Villamil, 2002). Shrub encroachment may reduce the production of desirable grasses and adversely affect livestock management (Archer and Smeins, 1991).

Natural semi-arid grasslands have varying precipitation, fire and grazing regimes that modify plant community composition (Archer, 1994). Livestock grazing can influence ecosystem processes and plant community dynamics both directly and indirectly. Direct effects are those related to alterations in plant physiology and morphology resulting from defoliation and trampling. Indirect effects result from changes in microenvironment, soil physical and chemical properties, plant competitive interactions, and fire regimes (Archer and Smeins, 1991; Archer, 1995). In turn, alterations caused by combined direct and indirect effects of grazing may create conditions suitable for establishment of seedlings of woody plants (Jacoby, 1986).

Many decades of overgrazing have occurred in the temperate semi-arid phytogeographic region of central Argentina known as the Caldén District (Caldenal) (Cabrera, 1976), since the introduction of domestic livestock. This may have contributed to increased abundance of *Prosopis caldenia* Burk. (Fabaceae), a native thorny deciduous woody species, across the region (Peláez et al., 1992). Reduction of above- and below-ground grass biomass through chronically high levels of herbivory by domestic ungulates can be expected to

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decrease the competitive ability of grasses, which would, in turn, favour establishment of woody species (Van Auken, 2000). Walker et al. (1981) and Scholes and Archer (1997) identified herbaceous biomass as the key factor limiting shrub encroachment, because herbaceous vegetation competes with woody seedlings for soil resources, and thus reduces the probability of woody seedling establishment. Reduction of herbaceous cover due to livestock overgrazing could facilitate woody seedling establishment in response to relaxation of grass competition (Archer and Smeins, 1991).

The influence of domestic herbivores as seed dispersal agents may also be important in regulating plant dynamics. *P. caldenia* pods are readily consumed by cattle. Seeds of *P. caldenia* exhibit a degree of dormancy imposed by the presence of a hard seed coat. Germination depends on seed scarification that takes place during the passage of seeds through the digestive tract of domestic livestock (Peláez et al., 1992; Peinnetti et al., 1993). Moreover, cattle dung deposition often creates a favourable environment for emergence and survival of woody seedlings (Malo and Suarez, 1995; Cypher and Cypher, 1998). However, grazing animals can increase compaction of soil surface by trampling (Archer, 1995). According to Braunack and Walker (1985), soil surface compaction may favour recruitment of woody plants over grasses. However, Distel et al. (1996) suggest that soil compaction associated with grazing negatively affects the growth and survival of seedlings of *P. caldenia*, which may in turn limit their establishment.

In general, the presence of woody species in plant communities in arid and semi-arid regions depends on their capacity to germinate, emerge, and persist during drought periods (Breshears and Barnes, 1999). For this reason, establishment of many woody species is a rare event that occurs only when seeds germinate during periods when competition for soil water is minimal (Jordan and Noble, 1981; Gutterman, 1986; Schwinning and Ehleringer, 2001).

Population parameters such as recruitment, longevity and survival provide a quantifiable link between the individual plant and community-level processes, and should therefore help forecast impending changes in community composition (Archer and Smeins, 1991). Overgrazing has occurred for many decades in our study area, and this may have triggered the increase of woody vegetation (Bóo and Peláez, 1991; Bóo et al., 1997).

Previous studies have evaluated various aspects of *P. caldenia* related to germination (Peláez et al., 1992; De Villalobos and Peláez, 2001; De Villalobos et al., 2002) and establishment (Peláez et al., 1992; Distel et al., 1996). However, information on the role of defoliation of herbaceous vegetation, and microsite conditions as affected by grazing history on *P. caldenia* establishment is lacking. The objectives of this study were to evaluate the effect of different defoliation intensities of herbaceous vegetation, cattle dung and water supply on seedling emergence and survival of *P. caldenia* under contrasting grazing histories.

2. Study site

The study was conducted during the 1995/96 and 1996/97 growing seasons, in a representative site of the Caldenal located in the south-eastern corner of La Pampa province, Central Argentina (38°45′S, 63°45′W). Cow-calf operations are the primary economic activity in the Caldén District, a temperate semi-arid phytogeographic region of 40,000 km^2 characterized by grass–shrubs associations (Cabrera, 1976). The vegetation, climate and soil of the region have been described previously (INTA, 1980). *Prosopis flexuosa* DC., *P. caldenia* Burk., *Condalia microphylla* Cav. (Rhamnaceae) and *Larrea divaricata* Cav. (Zygophyllaceae) are the dominant woody species. The most abundant perennial tussock grass species are *Stipa tenuis* Phil. and *Piptochaetium napostaense* (Speg.) Hackel. Other common grasses in the region are *Stipa speciosa* Trin. et Rupr., *S. gynerioides* Phil., and *S. clarazii* Phil. Average annual precipitation is 400 mm, concentrated mainly in fall and spring, and the annual water deficit is about 400 mm. Average annual temperature is 15 °C, June having the coldest (7 °C) and January the warmest (23.6 °C) mean monthly temperatures. The soil in the area is a well-drained Calciustoll, with medium to heavy texture. A petrocalcic horizon is found at an average depth of 40–60 cm (Peláez et al., 1994).

3. Materials and methods

Two experimental sites were selected within the study area. Each site comprised an area of 20 ha. One site had been subject to 35 or more years of heavy sustained grazing (5–6 ha/animal unit/yr) by cattle (grazed site). During this study, plots established in this experimental site were protected from cattle grazing. The other site had been protected from livestock grazing since 1982 (ungrazed site). The sites were 75 m distant from each other, on similar soils. Herbaceous foliar cover (grasses and forbs) and the density of perennial grasses were estimated along five 20 m long transects, randomly located in each experimental site. These data were collected using the canopy-cover method of Daubenmire (1959). Twenty quadrats (20 × 50 cm) were used to measure plant cover along each transect. Sampling was carried out in September 1995.

Two hundred plots were randomly established in each experimental site in September 1995. Each plot comprised an area of 0.1 m^2. On each site, the following treatments were established: herbaceous vegetation not defoliated, herbaceous vegetation moderately defoliated (herbaceous vegetation clipped at height of 15 cm), herbaceous vegetation heavily defoliated (herbaceous vegetation clipped at height of 5 cm), bare soil (herbaceous vegetation totally removed), and bare soil disturbed (herbaceous vegetation totally removed and soil disturbed among 0–25 cm depth). Twenty plots were used for each treatment. Ten seeds of *P. caldenia* were planted at a depth of 1 cm in each plot in October