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Effects of the pruning intensity and tree size on multi-stemmed *Prosopis flexuosa* trees in the Central Monte, Argentina

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ABSTRACT

Forestry use in *Prosopis flexuosa* woodlands in the Central Monte is limited by low wood productivity and by most of the trees being multi-stemmed. Desert inhabitants have turned pruning into a common practice to get some forest products, increase wood production and improve tree shape. In this study we tested pruning practices used by locals on trees of different diameter classes and different pruning intensities in the aeolian plains of the Central Monte Desert. Two trials were conducted: (a) we tested the effects of pruning on three types of trees: adult multi-stemmed trees (7.5–15 cm basal diameter; $n = 12$ for pruned trees and 10 for control), young trees (3–7.5 cm basal diameter; $n = 20$ for pruned trees and 18 for control), and saplings (<3 cm basal diameter; $n = 15$ for pruned trees and 18 for control); (b) we compared the effects of different pruning intensities: heavy pruning (50% of crown removed and $n = 10$), intermediate pruning (25% of crown removed; $n = 10$), and unpruned individuals ($n = 10$). Basal diameters of all stems, total tree height, largest and smallest crown diameters were measured yearly. We estimated the equivalent basal diameter (EBD) and crown volume. Linear mixed models (LMM), in continuous variables, and general linear mixed models (GLMM), in discrete variables, were used for evaluating the effects of the treatments on the different variables. The response observed in pruned trees was an increased length of branches, which in both trials translated into increased crown diameter and volume. No initial response was recorded in basal diameter growth of the remaining stem. In adult trees, an increase in basal diameter was detected five years after pruning. A greater response of crown growth was found in individuals subjected to heavy pruning vs. individuals under intermediate pruning. Results suggested that pruning could improve the shape of *Prosopis* in the short run, and increase stem diameter growth in the long run, as observed for other tree species of *Prosopis* that received pruning throughout the world. This suggests that this practice could be potentially used to obtain poles and firewood without a decrease in wood productivity but with an increase in branch growth, and, in consequence, it could be included in silvicultural management of woodlands dominated by multi-stemmed trees and in models of sustainable management at local scale.

1. Introduction

The man of the desert has, since ancient times, resorted to pruning as a management tool to get diverse profits from dryland trees. The genus *Prosopis* consists of more than 40 species of trees and shrubs widely distributed across arid and semiarid regions of the Americas, east of Asia and north of Africa (D'Antoni and Solbrig, 1977). Numerous adaptations (response to herbivory, tolerance to drought and saline soils) have allowed these legumes to dominate the woody vegetation in arid regions (Fagg and Stewart, 1994). Since antiquity, there is a close relationship between trees of this genus and different human groups (D'Antoni and Solbrig, 1977; Roig, 1993). The great variety of products and ecosystem services that these trees provide determines that they be considered multiple-use species (F.A.O., 1994; Cony, 1995; Tewari and Harsh, 1998). In different regions, the wood's good quality, color and mechanical features have given rise to markets for forest products derived from extraction of plant parts (pruning) and, in some cases, from thinning or selective logging of *Prosopis* trees (Patch and Felker, 1997a, 1997b; Felker and Guevara, 2003; Villagra et al., 2005).

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Pruning, as an improver of wood quality, is amongst the most commonly used silvicultural practices in the management of *Prosopis* woodlands (Patch et al., 1998). Removal of secondary stems and small branches seeks to improve growth habit and increase the quantity and quality of wood produced (Patch and Felker, 1997b; Elfadl and Luukkanen, 2003). In Arizona, USA, such pruning combined with inhibition of resprouting buds has been applied to young trees of *Prosopis glandulosa*. Pruning is also associated with significantly increased photosynthetic rate in *P. juliflora* (Elfadl and Luukkanen, 2003), a response which can also be used to optimize wood and fruit production of *Prosopis* species (Diaz Celis, 1995; Pasiecznik et al., 2001). The effect of pruning and thinning has generally been studied in plantations but not in native woodland (Elfadl, 1997; Patch and Felker, 1997a, 1997b).

In defining management practices, the shape of the tree determines the quality of forest products to be obtained. According to Meyer et al. (1971), those *Prosopis* species belonging to the Algarobia section show a high tendency to have apical dominance and, consequently, good crown development. *Prosopis flexuosa* is a tree with deciduous leaves that occurs in arid regions of Argentina and the central north of Chile, occupying vast sectors of the South American arid diagonal (Alvarez and Villagra, 2009). Open woodlands of this species grow on sandy plains with water available from water tables lying close to the ground surface (between 6 and 12 m) where it behaves as a phreatophyte (Rundel et al., 2007; Aranibar et al., 2011). In north-western Argentina, single-stemmed trees represent 83% of the *P. flexuosa* population (Mooney et al., 1977; Cony et al., 2004); therefore, these woodlands show the possibility of controlled management with extraction of forest products of high economic value (wood for furniture or floorboards). In contrast, in Southern *Prosopis* woodlands in the Central Monte desert, more than half of the trees are multi-stemmed or have their main stem highly branched with secondary branches showing nearly horizontal growth (semi-erect), or with pendulous lateral branches that reach the ground (decumbent) (Alvarez et al., 2006; Villagra et al., 2005). These characteristics and the low productivity (140–170 kg ha^{-1} $year^{-1}$) restrict forestry use of the woodlands of Mendoza. Moreover, the growth rate of multi-stemmed individuals decreases rapidly since 60 years of age whereas single-stemmed trees do not show such decrease, suggesting the existence of competition between stems in adult individuals (Alvarez et al., 2011a). Thus pruning could eliminate such competition, preventing the observed reduction in growth rate. However, the consequences of pruning would depend on the balance between the positive and negative effects produced by this treatment. Among the positive effects are decreased competition between stems and reallocation of assimilates or photosynthetic compensatory effects (increase in the photosynthetic capacity of remaining foliage) (Helms, 1965; Heinchel and Turner, 1983). Among the negative ones, in addition to the obvious reduction of the photosynthetic area of the plant, are root mortality and loss of reserves (Allen, 1986; Peter and Lehmann, 2000; Bayala et al., 2004).

We hypothesize that pruning eliminates competition between stems, so we expect a higher annual growth of the remaining stem in pruned trees than in control trees. Furthermore, as this competition among stems increases with the age of the tree (Alvarez et al., 2011a), we expect a higher response to pruning in adult than young and sapling *Prosopis* trees. Finally, we hypothesize that growth response to pruning will be lower in heavily pruned trees than in trees subjected to intermediate pruning due to the higher proportion of crown biomass loss. Our objectives were: (a) to analyze whether pruning increases diameter or crown growth in *P. flexuosa* individuals of different diameter classes from the Central Monte desert and (b) to investigate the effects of pruning intensity on both stem diameter and crown growth in young *P. flexuosa* trees.

2. Materials and methods

2.1. Study area

The study area is located in the central plains of north-eastern Mendoza, Argentina (32–33 S, 67–68 W; 500–550 m elevation). This area, including Telteca Reserve (38.507 ha) and surrounding lands, is representative of the central zone of the Monte Biogeographic Province (González Loyarte et al., 1990). It is located in a sedimentary basin between two geological structures with positive relief, the Cordillera de Uspallata in the west and the San Luis Sierras to the east. The aeolian reworking of Holocene sediments originated a system of transverse sand dunes up to 20 m height separated by 100–200 m wide troughs (González Loyarte et al., 1990). The climate is arid with total annual precipitation around 156 mm (1972–2007 average), and large daily and annual temperature ranges. Mean temperature is 18.5 °C, with absolute maximum and minimum being respectively 48 °C and −10 °C (Estrella et al., 1979).

This study was conducted in open woodland of *P. flexuosa* (25% of tree cover), accompanied by *Trichomaria usillo* and *Suaeda divaricata* as main shrubs (tree density: 155 trees per ha^{-1}, between 103 and 186 trees). Diameter structure indicates low number of trees of intermediate classes, between 20 and 35 cm in equivalent basal diameter (the diameter corresponding to a one-stemmed individual with an equivalent basal area), and absence of individuals with large diameter stems. This woodland has the highest concentration of individuals with diameter between 2.5 and 17.5 cm (Alvarez et al., 2006). In all, 61% of adult trees have more than one stem (trees were considered adults with diameter >7.5 cm).

2.2. Experimental design

2.2.1. Trial I. Pruning in Prosopis individuals of different diameter classes

Three types of multi-stemmed *P. flexuosa* trees were selected according to basal diameter of the main stem (SBD). Individuals with SDB between 7.5 and 15 cm were considered adults, those with SBD between 3 and 7.5 cm were considered young, and saplings were those individuals with SBD < 3 cm. For each diameter class, we selected individuals with similar growth habit on similar site quality: 24 adult trees, 40 young trees and 36 saplings. Half the trees in each class were pruned and the other half was left unpruned. As some mortality was observed after the first year of the assay (two control adults and two control young trees and three pruned saplings), the final N for each diameter class was: pruned adult trees = 12; control adult trees = 10; pruned young trees = 20; control young trees = 18; pruned saplings = 15; and control saplings = 18.

Prior to pruning (July 2003), for all trees we recorded: basal diameter of all stems (using diameter tape or digital calliper), total tree height and lowest crown height (with digital hypsometer, resolution: 0.1 m) and largest and smallest crown diameters (with diameter tape, distance: 0.01 m). Equivalent basal diameter (EBD) was estimated for each tree using the formula:

$$EBD = 2\sqrt{(SBD_1/2)^2 + (SBD_2/2)^2 + \cdots + (SBD_n/2)^2}$$

where SBD_1, SBD_2 and SBD_n are the diameters at the base of the n tree stems (Alvarez et al., 2011a).

For each individual we estimated crown volume (V) following the formula proposed by Sharifi et al. (1982):