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Original Research

# Defoliation Intensity and Simulated Grazing Strategy Effects on Three C4 Rangeland Bunchgrasses☆

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ABSTRACT

Defoliation intensity and timing are two important factors determining plants response to grazing. These factors can be managed by adjusting stocking rate and applying a grazing strategy. In a 6-yr clipping experiment conducted in northwestern Argentina, we assessed the effect of different defoliation intensities (~30%, ~50%, and ~70% removal of the annually produced aboveground biomass) and simulated grazing strategies (continuous grazing, two-paddock rest-rotation, three-paddock rest-rotation, dormant season grazing) on plots of three C4 native bunchgrasses (*Pappophorum vaginatum, Trichloris crinita,* and *Digitaria californica*). Response variables were mean and trend of clipped-off biomass during the 6 yr of treatments, number of inflorescences, and aboveground biomass produced on the year following treatments end (to evaluate residual effect of treatments). Results were species dependent. Mean clipped-off biomass increased with defoliation intensity in *T. crinita* and *D. californica*. However, defoliation intensity negatively affected clipped-off biomass trend in *T. crinita* and the production of *P. vaginatum* and *T. crinita* during "residual effect" evaluation. The three species responded positively at least in one response variable to the amount of rest periods in the grazing strategy. Our results are not fully consistent with the concept that forage production is more influenced by defoliation intensity than by grazing strategy: In two of the three species, grazing strategy presented greater impact on response variables than defoliation intensity. When significant "defoliation intensity × grazing strategy" was detected, intensity tended to be more detrimental as grazing strategy allows fewer rest periods. We observed a residual effect of treatments in the three species (generally, negative effect of defoliation intensity and positive effect of grazing strategies with more rest periods). Our results show that dormant season utilization and rest periods are beneficial for maximizing mean clipped-off biomass and ensuring clipped-off biomass trend. High defoliation intensities can maximize short-term clipped-off biomass, but it may produce negative residual effects and trends.


## Introduction

Defoliation intensity and timing are two of the most important factors in determining the plants' response to grazing. In livestock systems, these factors can be managed by adjusting the stocking rate (which affects the consumed percentage of aboveground biomass produced annually) and applying a grazing strategy (which determines the temporal and spatial distribution of animals in the field, and hence the periods of grazing and rest) (Briske et al., 2008; Distel, 2013).

Most grazing and clipping studies indicate that defoliation adversely affects primary productivity (Belsky, 1987; Milchunas and Lauenroth, 1993; Oesterheld et al., 1999; Ferraro and Oesterheld, 2002). While plant productivity generally decreases with defoliation intensity, the proportion of removed biomass increases (Parsons et al., 1983) and then there is a tradeoff between maximizing plant growth and sustainability (at lower intensities) and maximizing the proportion of biomass removed by grazing animals (at greater intensities; Briske et al., 2008).

Several authors have indicated that plant and livestock production is more influenced by the stocking rate than the grazing strategy (Van Pollen and Lacey, 1979; O'Reagain and Turner, 1992; Holechek et al., 1998; Briske et al., 2008). Briske et al. (2008) found insufficient evidence to support that rotational-intensive-grazing strategies (involving days to weeks of deferment after short grazing periods) achieve a productive advantage over the continuous grazing strategy. However, as Briske et al. (2008) and other authors indicate, allowing periods of long deferment (nongrazing during part of the growing season) or rest (nonuse for 12 consecutive mo, as defined by Howery et al., 2000) could be a useful tool to maintain or improve rangeland productivity (Holechek et al., 1999; Müller et al., 2007; Davies et al., 2014; O'Reagain et al., 2014).

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Interaction between grazing intensity and grazing strategy was less investigated in rangelands than improved pastures, maybe due to the greater complexity of conducting range experiments (Holechek et al., 1999; Schwinning and Parsons, 1999). Rangeland studies have generally not found an interactive effect between grazing intensity and grazing strategy on plant productivity (Cassels et al., 1995; Derner and Hart, 2007). However, evidence from individual plant experiments indicate that grasses can respond better to defoliation when there is a longer time interval between clippings (Oesterheld and McNaughton, 1991; Ferraro and Oesterheld, 2002). Then it is possible to expect that defoliation intensity differentially affects plants according to the timing of grazing and rest periods to which they are subjected (grazing strategy).

To add complexity, individual plants and plant communities can respond to disturbance with certain time lags. Climatic events or grazing can influence plants per months or years after its occurrence (Barnes, 1989; Fabricante et al., 2009; Taylor and MacLean, 2009; Sala et al., 2012), considering that this type of response is generally omitted in investigations.

In a long-term study conducted in the arid Chaco region of Argentina, we assessed by means of defoliation (the most important direct effect of grazing) the effect of different defoliation intensities and grazing strategies on three native grasses. We worked on monospecific plots of these species to include the effect of intraspecific competition between plants that may alter the response to defoliation (McNaughton, 1992). We evaluated the response of the species in terms of the clipped-off biomass (an estimate of yield to grazers, according to McNaughton et al., 1983) over the 6 yr of treatment application (Briske et al., 2008) and the residual effect of treatments 1 yr after its cessation (Barnes, 1989). The aim was to respond the following questions: 1) How does the clipped-off biomass of native grasses vary under different defoliation intensities and grazing strategies? 2) Is there a residual effect of defoliation intensities and grazing strategies in these species? 3) Is there an interactive effect between defoliation intensity and grazing strategy over the response variables? 4) Which factor (defoliation intensity or grazing strategy) has more influence on response variables?

## Methods

### Study Area

The investigation was performed at the "Instituto Nacional de Tecnología Agropecuaria" (INTA) La Rioja Experimental Station (lat 30°27′S, long 66°11′W) in northwestern Argentina, specifically the Arid Chaco ecological region (Morello et al., 1985). The region has a subtropical climate (Morello et al., 1985), with hot summers (20 − 25 days with >40°C temperatures) and mild winters (5 − 10 days with <0°C temperatures; Prohasca, 1959). Mean temperature is 26°C for the warmest month (January) and 11°C for the coldest one (July). In the study site, mean annual precipitation is 469 mm, with 80% occurring in the southern hemisphere warm season between November and March. The frost period is from June to August (Bazán, 1993). Vegetation growing season coincides with the warm season (Blanco et al., 2009), extending 3 − 6 mo between November and April according to the variation of the beginning and end of the rainy season. Vegetation goes dormant during the rest of the year—the cold and dry season (grasses do not grow during this period). For practical reasons, in this study we consider "year" as the period from September to August. Typical vegetation of the region is a subtropical xerophytic shrubland, with scattered trees and a patched herbaceous layer. The main trees are *Aspidosperma quebracho-blanco* and *Prosopis* spp. The most common shrubs correspond to the *Larrea, Mimozyganthus,* and *Senna* genera. The herbaceous layer is composed of mainly C4 perennial grasses of the *Aristida, Digitaria, Pappophorum, Setaria,* and *Trichloris* genera (Morello et al., 1985; Blanco et al., 2009). Predominant soils are coarse textured, with low organic matter content (<1.5% of soil mass) and neutral to basic pH (Gómez et al., 1993). At the study site, soil was classified as *Typic Torriortent* (SAGyP–INTA, 1990).

### Study Species

We studied three native forage grasses: *Pappophorum vaginatum* (Buckley), *Digitaria californica* ([Benth.] Henr.) and *Tricholoris crinita* ([Lag.] Parodi). They are C4 perennial bunchgrasses of summer growth. According to Peterson et al. (2007), *P. vaginatum* and *T. crinita* present an amphitropical disjunct distribution, occurring in two broad regions centered in subtropical arid and semiarid rangelands of South and North America. In addition to these environments, *D. californica* is also present in Central America and the Caribbean (Vega and Rúgolo de Agrasar, 2005; Sánchez-Ken, 2012).

### Experimental Approach

A completely randomized block design (with six replicates) was established in a previously existing pasture of each species. In each one, we applied a factorial experiment evaluating 3 defoliation intensities and 4 grazing strategies, resulting in 12 defoliation treatments. Experimental units (plots) had 0.75 $m^2$ (1.5 m long × 0.5 m wide) and were separated by edges of 0.5 m. Each species was planted separately by seeds in the summer of 1997, on a previously cleared and disked site. Used seed was collected from nearby rangeland areas. After establishment, until the beginning of the experiment (2002 − 2003), pastures were grazed every dormant season by cows at moderate grazing intensity (leaving a stubble height of 10 − 15 cm). At the beginning of the experiment, the pasture of each species had a mean density of 22 − 23 $plants.m^{-2}$.

As mentioned, stocking rate is the main management determinant of the grazing intensity (i.e., defoliation intensity, the percentage of aboveground biomass produced annually that is consumed by animals). For its part, grazing strategy is the main determinant of the temporal and spatial distribution of animals over an entire area (subareas receiving grazing or rest) (Briske et al., 2008; Distel, 2013). Distribution of animals according to a rotational grazing strategy implies that subareas subjected to grazing in one period of time have higher animal density than the overall density of the entire area, or than a continuously grazed area with the same overall animal density (Howery et al., 2000). As has been recognized, even continuous grazing is not a continuous process, because it involves a succession of discrete defoliation events at the bite-patch scale, each followed by a regrowth period (Morris, 1969; Parsons et al., 2001). We considered these concepts to conduct our experiment. We used percentages of tissue removal as surrogates of overall grazing intensity (Holechek and Galt, 2000), and temporal distribution of defoliation (intra-annually and interannually) as a surrogate of grazing events for the different grazing strategies (Schwinning and Parsons, 1999). Periods of increased animal density for a grazing strategy were simulated by increasing proportionally defoliation frequency, while during periods of rest we did not apply defoliation. To investigate grass response to grazing, a grazed paddock could be considered as a collection of small-sized patches (Schwinning and Parsons, 1999). We are confident that our experimental approach was able to simulate what occurs with patches of the studied species in paddocks subjected to different grazing intensities and strategies.

### Treatments

Defoliation treatments began in October 2002 and ended in July 2008 for *P. vaginatum* and *D. californica*. For *T. crinite,* treatment began in December 2003 and ended in June 2009 (during 6 yr in each species). These periods of time were considered adequate to assess trends in grazing studies (Biondini and Manske, 1996).

We simulated defoliation intensity by clipping plants to different stubble height (Oesterheld, 1992; Holechek and Galt, 2000). In a