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Vegetation response to a controlled fire in the Phytogeographical Province of the Monte, Argentina

Respuesta de la vegetación a un fuego controlado en la Provincia Fitogeográfica del Monte, Argentina

Peláez[1] DV, HD Giorgetti[2], OA Montenegro[2], OR Elia[3], GD Rodríguez[2], RM Bóo[1*], MD Mayor [4**], CA Busso [3]

Abstract. Fire is a major ecological process within most terrestrial ecosystems. Therefore, understanding the vegetation response to fire is essential to its management. Our objective was to study the effect of a controlled fire, conducted at the end of summer season, on cover and density of the most common woody and herbaceous species in Phytogeographical Province of the Monte, Argentina. In general, after the control fire, the woody species mean percentage cover was significantly lower ($p<0.05$) in the fire treatment than in the control (no controlled fire). This effect was persistent during the study period. No significant differences ($p>0.05$) were detected in woody species mean density among treatments throughout the whole study. Desirable perennial grass mean percentage foliar cover, except at two sampling dates, was higher ($p<0.05$) in the controlled fire treatment than in the control. Contrarily, mean percentage foliar cover of intermediate perennial grasses was lower in the fire treatment than in the control, although differences were not always significant ($p<0.05$). No significant differences ($p<0.05$) in desirable perennial grass density were detected among treatments. Intermediate perennial grass density was consistently lower in the fire than in the control treatment, although differences were not always significant at $p<0.05$. Desirable annual grass and forb foliar covers were slightly higher in the fire than in the control treatment. Our results suggest that the reduction of woody species cover might have favored the foliar cover increase of the desirable perennial grasses. Moreover, our results suggest that a single, controlled

Resumen. El fuego es un proceso ecológico clave en la mayoría de los ecosistemas terrestres. Por lo tanto, la comprensión de la respuesta de la vegetación al fuego es esencial para su manejo. El objetivo de este trabajo fue estudiar el efecto de un fuego controlado, realizado a fines del verano, sobre la cobertura y densidad de las principales especies leñosas y herbáceas en la Provincia Fitogeográfica del Monte, Argentina. En general, después del fuego controlado el porcentaje de cobertura media de las especies leñosas fue significativamente menor ($p<0,05$) en el tratamiento quemado que en el control (sin fuego controlado). Este efecto persistió durante el período de estudio. No se detectaron diferencias significativas ($p>0,05$) en la densidad media de las especies leñosas a lo largo del período de estudio. La cobertura foliar media de las gramíneas perennes deseables, excepto en dos fechas de muestreo, fue significativamente mayor ($p<0,05$) en el tratamiento quemado que en el control. Contrariamente, el porcentaje de la cobertura media de las gramíneas perennes intermedias fue menor en el tratamiento quemado que en el control. Sin embargo, las diferencias no siempre fueron significativas ($p<0,05$). No se observaron diferencias significativas ($p>0,05$) entre tratamientos en la densidad de las gramíneas perennes deseables. La densidad de las gramíneas perennes intermedias fue consistentemente menor en el tratamiento quemado que en el tratamiento control, pero sólo ocasionalmente las diferencias fueron significativas ($p<0,05$). La cobertura foliar de las gramíneas y dicotiledóneas anuales fue levemente menor en el tratamiento quemado que en el control. Nuestros resultados sugieren que la reducción de la cobertura de las especies le-

[1] Departamento de Agronomía (UNS), CIC, CERZOS, Altos del Palihue, 8000 Bahía Blanca, Argentina.
[2] Chacra Experimental de Patagones, MAA de la Provincia de Buenos Aires, C.C. 118, 8504 Carmen de Patagones, Argentina.
[3] Departamento de Agronomía (UNS), CERZOS, CONICET, Altos del Palihue, 8000 Bahía Blanca, Argentina.
[4] Departamento de Agronomía (UNS), Altos del Palihue, 8000 Bahía Blanca, Argentina.
Address Correspondence to: D.V. Peláez; *e-mail*: dpelaez@criba.edu.ar; fax 054-0291-4595127; Phone 054-0291-4595102.
* Dr. Roberto Miguel Bóo passed away on 30 October, 2007
** Agr.Eng., M.Sc. Mirta Doris Mayor passed away on 4 December, 2008
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burn would not seem to start a plant species replacement sequence, and that the plant community would persist with no variation in the density of the major woody species and the most prominent perennial grasses.

Keywords: Controlled fire; Desirable grasses; Undesirable woody species; Monte region; Argentina.

ñosas podría favorecer el incremento de la cobertura foliar de las gramíneas perennes deseables. Además, los datos obtenidos indican que una sola quema controlada no parece comenzar una secuencia de reemplazo de especies vegetales y que la comunidad persistiría sin variaciones en la densidad de las principales especies leñosas y gramíneas perennes.

Palabras clave: Fuego controlado; Gramíneas deseables; Leñosas indeseables; región del Monte; Argentina.

INTRODUCTION

Fire is a natural disturbance that occurs in most terrestrial ecosystems. It is also a tool that humans have used to manage a wide range of natural ecosystems worldwide (Whelan, 1995). Fire effects on vegetation can vary significantly among fires, and on different areas of the same fire. The (1) pattern of fuel consumption, (2) amount of subsurface heating, (3) fire behavior and (4) fire duration influence injury, mortality, and recovery of vegetation. Controlled and/or prescribed fires have been suggested as a mechanism for slowing woody vegetation expansion, preventing catastrophic wildfires, and restoring understory vegetation quantity and quality.

Shrub encroachment in many regions of the world has been attributed primarily to the combined effects of grazing, drought and alteration of the fire regime (Busby & Noble, 1986). Since the introduction of domestic livestock in semiarid rangelands of Argentina, many decades of overgrazing have occurred. This may have triggered the abundance increase of woody vegetation in these ecosystems. Grazing may reduce competitive ability of grazed plants, favoring woody species growth. This will produce at the same time an alteration of the fire frequency, due to the reduction of fine fuels (Bóo et al., 1997). In the south of the Phytogeographical Province of the Monte (known as the Monte: Cabrera, 1976), wildfires are common during the hot and dry summer months (Busso, 1997). These fires often occur under hot, dry and windy climatic conditions, and may cause undesirable effects on the ecosystem. However, controlled fires of moderate intensity can control woody plants, increase forage production and facilitate cattle management. In the Monte region, information is lacking on the effects of controlled fire on native vegetation. The objective of this work was to study the effect of a controlled fire, conducted at the end of summer season, on cover and density of the most common woody and herbaceous species in the region.

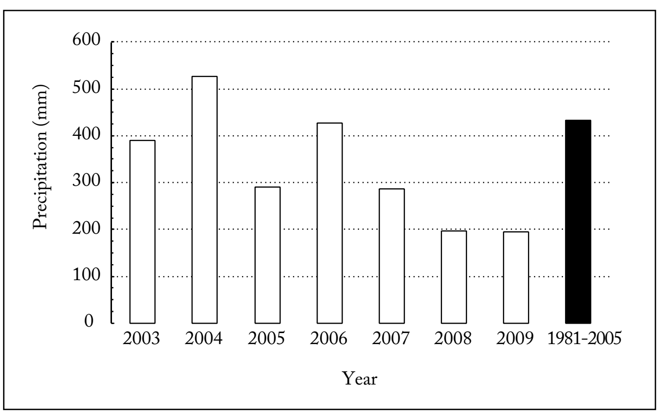
MATERIALS AND METHODS

Study site. Research was conducted in a representative site of the Phytogeographical Province of the Monte (Cabrera, 1976). The study site is within the Experimental Farm of Patagones (40° 39´ S, 62°54´ W; 40 m.a.s.l.) located 22 km north of Carmen de Patagones, province of Buenos Aires (Argentina).

Climate, soil characteristics and vegetation of this temperate, semi-arid region have been described elsewhere (Cabrera, 1976, Giorgetti et al., 2000). Long-term (1981-2005) average annual precipitation is 434.6 mm, concentrated mainly during fall and spring. Annual water deficit oscillates among 400 to 800 mm. During the study period, annual precipitation is shown in Figure 1. Average annual temperature is 14.6 °C, being July the coldest month (6.2 °C) and January (21.9 °C) the warmest one. The absolute maximum recorded temperature is 41.4 °C, and the absolute minimum -9.9 °C. The region is a typical plain. Soil texture ranges from loamy and loam-sandy to loam-clay-sandy.

The community is characterized by an open shrubby layer which includes herbaceous species of different grazing value (Giorgetti et al., 1997). Dominant woody species are *Condalia microphylla*, *Chuquiraga erinacea*, *Larrea divaricata*, *Schinus fasciculatus*, *Brachyclados lycioides*, *Prosopis alpataco* and *Prosopidastrum globosum*. The herbaceous layer is dominated by perennial grasses as *Nassella tenuis* (ex *Stipa tenuis*), *Piptochaetium napostaense*, *Poa ligularis* and *Nassella clarazii* (ex *Stipa clarazii*). Other common perennial grasses in the region include *Pappophorum vaginatum*, *Sporobolus cryptandrus*, *Stipa ichu* (ex *Stipa speciosa*), *Jarava plumosa* (ex *Stipa papposa*) and *Aristida pallens*.

Fig. 1. Annual precipitation recorded during the study period and long-term (1981-2005) average precipitation at the study site.
Fig. 1. Precipitación anual durante el período de estudio y precipitación promedio registrada para el período 1981-2005 en el sitio de estudio.



Controlled fire application. Within the Experimental Farm of Patagones, experimental units (n=16; 23 ha each) separated by 20-m firebreaks, were established to conduct experimental controlled burns. All experimental units were excluded from cattle grazing in August 2003. On 8 March 2004, eight experimental units were exposed to headfires (n=8) and eight experimental units were left unburned (n=8). Since November 20, eight months after the controlled fire, each treatment was grazed using a rotational grazing and two similar herds. Stocking rate was 7.8 ha/animal unit. Prior to the controlled burns, each unit was sampled to determine the amount of fine fuel using ten 0.5 x 0.5 m quadrats. Fine fuel was considered as all material on the ground, including litter, less than 3 mm in diameter. Field instruments were used to measure air temperature, relative humidity and wind speed at the time of the controlled burns.

Vegetation measurements. Three 20m permanent transects were randomly placed in each experimental unit. Woody species cover was estimated by the line intercept method (Canfield, 1941) throughout those transects. Each transect was the central axis of a quadrat (2 x 20 m) where all individuals were counted to estimate woody plant density. Foliar cover and density on perennial grasses were estimated with the canopy-cover method of Daubenmire (1959). With this purpose, 20 (20 X 50 cm) quadrats were used in the same transects. Only foliar cover was estimated for annual grasses and forbs. Sampling was carried out before and after the controlled burns. Prior to fire, sampling date was December 2003 for perennial grasses and annual both grasses and forbs; it was March 2004 for woody species. After fire, perennial grasses and annual both grasses and forbs were sampled in December 2004, 2005, 2006 and 2007. At the same time, woody species sampling was conducted in March 2005, 2006, 2007, 2008 and 2009. Herbaceous species were classified following Cano (1988), according to their degree of acceptance by livestock, as desirable perennial grasses, intermediate perennial grasses, desirable annual grasses or desirable annual forbs (Table 1).

Statistical analysis. Statistical analysis was restricted to compare (1) unburned (control) *versus* controlled fire treatments within each sampling date, and (2) changes within each controlled fire treatment before the controlled fire *versus* the sampling dates after it. Woody and herbaceous vegetation data were analyzed following a completely randomized design using a one-way ANOVA. Differences among density (transformed to square root) and cover means (transformed to arcsin) were determined with Tukey´s test (Snedecor & Cochran, 1980).

RESULTS

Prior to the controlled fire (March 2004), mean percentage cover was similar ($p>0.05$) in both treatments for the woody species (Fig. 2A). After the controlled fire, except in March 2006, mean percentage cover was significantly lower ($p<0.05$) in the fire than in the control treatment in the woody species. This effect was persistent during the study period (Fig. 2A).

Mean percentage cover was significantly reduced ($p<0.05$) for *Chuquiraga erinacea*, *C. microphylla* and *S. fasciculatus* by the controlled burn, and this reduction persisted for the entire study period. Nevertheless, these woody species tended to recover their cover at the end of the fifth growing season after the controlled burn (Table 2). The controlled fire also reduced the mean percentage cover of other prominent woody species in the Monte region, such as *G. decorticans* and *L. divaricata;* however, differences were not significant ($p>0.05$) (Table 2). Mean percentage cover of the remaining woody species (i.e., *Prosopis alpataco*, *Baccharis ulicina*, *Baccharis crispa*, *Prosopidastrum globosum*, etc.) was also reduced by the controlled fire, but differences were only detected significant ($p<0.05$) between the first (2004, before controlled fire) and the last sampling date (Table 2).

Table 1. Herbaceous species classified according to their degree of acceptance by livestock.
Tabla 1. Especies herbáceas clasificadas de acuerdo a su grado de aceptación por el ganado.

PERENNIAL SPECIES		ANNUAL SPECIES	
Desirable grasses	Intermediate grasses [1]	Desirable grasses	Desirable forbs
Bromus brevis	*Aristida pallens*	*Bromus mollis*	*Erodium cicutarium*
Koeleria permollis	*Aristida trachyanta*	*Hordeum pusilum*	*Medicago minima*
Nassella tenuis	*Aristida spegazzinii*	*Schismus barbatus*	
Nassella clarazii	*Stipa ichu*	*Vulpia* spp.	
Jarava plumosa			
Piptochaetium napostaense			
Poa ligularis			
Poa lanuginose			
Sporobolus cryptandrus			

[1] Perennial grasses grazed when desirable perennial grasses are not available.
[1] Gramíneas perennes pastoreadas cuando las gramíneas perennes deseables no están disponibles.

Fig. 2. Woody species mean percentage cover (A) and density (B) in the control and fire treatments. In each sampling date, columns with the same letter are not significantly different (p>0.05). Each column is the mean of n=8 and vertical bars represent the S.E.
Fig. 2. Porcentaje medio de la cobertura (A) y densidad (B) de las especies leñosas en los tratamientos control y fuego. En cada fecha de muestreo, columnas con la misma letra no son significativamente diferentes (p>0,05). Cada columna es la media de n=8 y las barras verticales representan el E.E.

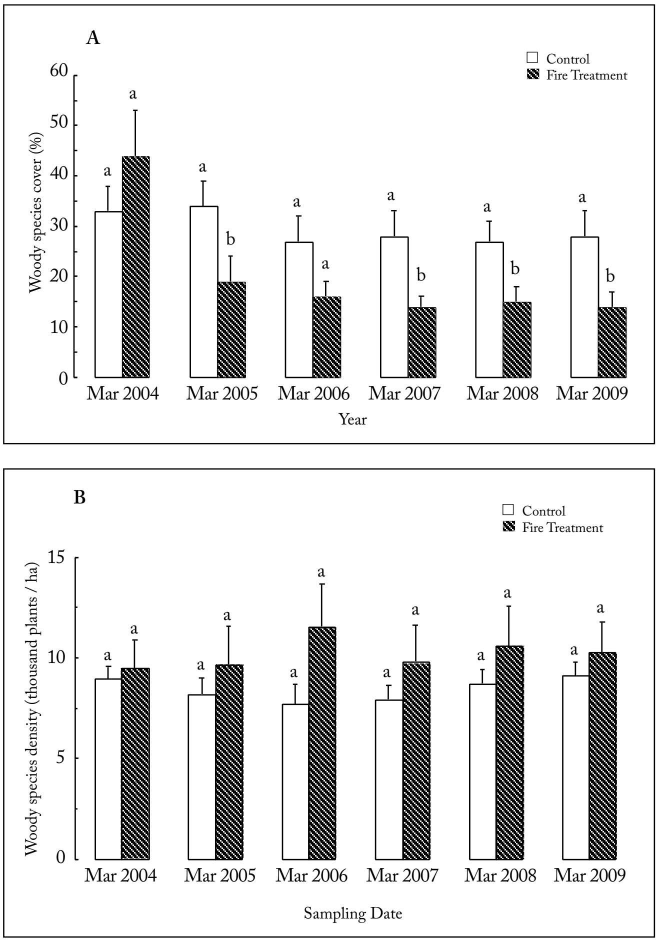


Fig. 3. Desirable (A) and intermediate (B) perennial grass mean percentage foliar cover in the control and fire treatments. In each sampling date, columns with the same letter are not significantly different (p>0.05). Each column is the mean of n=8 and vertical bars represent the S.E.
Fig. 3. Porcentaje medio de la cobertura foliar de las gramíneas perennes deseables (A) e intermedias (B) en los tratamientos control y fuego. En cada fecha de muestreo, columnas con la misma letra no son significativamente diferentes (p>0,05). Cada columna es la media de n=8 y las barras verticales representan el E.E.

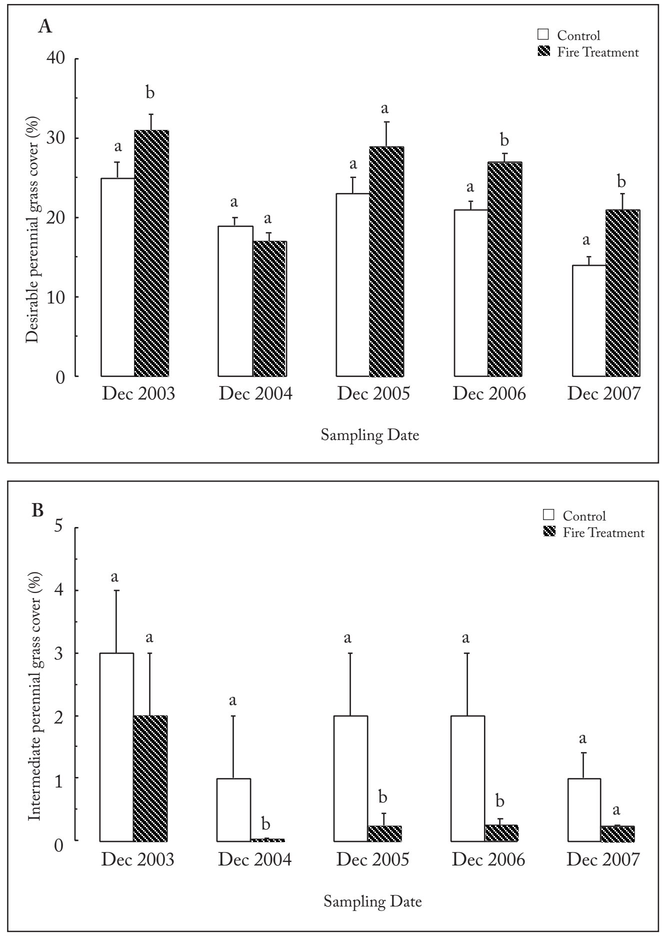


Table 2. Woody species mean cover prior to the controlled fire (March 2004), and at the end of the first (March 2005), second (March 2006), third (March 2007), fourth (March 2008) and fifth (March 2009) growing seasons following the controlled fire. Within each column, means with the same letter are not significantly different (p>0.05).
Tabla 2. Cobertura promedio de las especies leñosas antes del fuego controlado (Marzo 2004), y al final de la primera (Marzo 2005), segunda (Marzo 2006), tercera (Marzo 2007), cuarta (Marzo 2008) y quinta (Marzo 2009) estación de crecimiento luego del fuego controlado. Dentro de cada columna, los promedios con la misma letra no son significativamente diferentes (p>0,05).

	WOODY SPECIES COVER (%)					
Sampling date	*Ch. erinacea*	*C. microphylla*	*S. fasciculatus*	*G. decorticans*	*L. divaricata*	Others
March 2004	9.0 ± 2.0 a	6.0 ± 1.0 a	6.0 ± 2.0 a	4.0 ± 2.0 a	2.0 ± 1.0 a	18.0 ± 6.0 a
March 2005	1.0 ± 3.0 b	1.0 ± 0.3 bc	1.0 ± 0.5 bc	2.0 ± 2.0 a	0.2 ± 0.1 a	10.0 ± 2.0 a
March 2006	2.0 ± 4.0 b	1.0 ± 0.3 bc	1.0 ± 0.5 bc	2.0 ± 1.0 a	0.4 ± 0.2 a	9.0 ± 2.0 ab
March 2007	2.0 ± 0.0 b	1.0 ± 0.5 c	0.0 ± 0.0 c	2.0 ± 1.0 a	0.1 ± 0.1 a	9.0 ± 2.0 ab
March 2008	3.0 ± 1.0 b	1.0 ± 0.3 b	2.0 ± 1.0 ab	2.0 ± 1.0 a	0.2 ± 0.2 a	0.3 ± 0.1 ab
March 2009	2.0 ± 1.0 b	2.0 ± 1.0 b	2.0 ± 1.0 b	2.0 ± 1.0 a	0.2 ± 0.1 a	0.3 ± 0.1 b

Table 3. Woody species mean density prior to the controlled fire (March 2004), and at the end of the first (March 2005), second (March 2006), third (March 2007), fourth (March 2008) and fifth (March 2009) growing seasons following the controlled fire. Within each column, means with the same letter are not significantly different (p>0.05).

Tabla 3. Densidad promedio de las especies leñosas antes del fuego controlado (Marzo 2004), y al final de la primera (Marzo 2005), segunda (Marzo 2006), tercera (Marzo 2007), cuarta (Marzo 2008) y quinta (Marzo 2009) estación de crecimiento luego del fuego controlado. Dentro de cada columna, los promedios con la misma letra no son significativamente diferentes (p>0,05).

	WOODY SPECIES DENSITY (thousand plants/ha)					
Sampling date	*Ch. erinacea*	*C. microphylla*	*S. fasciculatus*	*G. decorticans*	*L. divaricata*	Others
March 2004	2.6 ± 0.6 a	0.4 ± 0.1 a	0.7 ± 0.1 a	0.8 ± 0.3 a	0.2 ± 0.08 a	9.5 ± 1.4 a
March 2005	2.0 ± 0.4 a	0.4 ± 0.1 a	0.6 ± 0.1 a	0.7 ± 0.3 a	0.1 ± 0.04 a	9.7 ± 1.9 a
March 2006	2.3 ± 0.5 a	0.4 ± 0.1 a	0.7 ± 0.1 a	0.9 ± 0.3 a	0.1 ± 0.06 a	11.6 ± 2.1 a
March 2007	2.6 ± 0.6 a	0.4 ± 0.1 a	0.6 ± 0.1 a	0.9 ± 0.3 a	0.1 ± 0.04 a	9.8 ± 1.8 a
March 2008	2.5 ± 0.6 a	0.4 ± 0.1 a	0.8 ± 0.1 a	0.9 ± 0.4 a	0.1 ± 0.07 a	10.6 ± 2.0 a
March 2009	2.4 ± 0.6 a	0.3 ± 0.1 a	0.7 ± 0.1 a	0.9 ± 0.4 a	0.1 ± 0.05 a	10.3 ± 1.5 a

Table 4. Desirable (DPG) and intermediate (IPG) perennial grass mean foliar cover and density, and desirable annual grass (DAG) and forb (DAF) mean foliar cover prior to the controlled fire (December 2003), and at the end of the first (December 2004), second (December 2005), third (December 2006) and fourth (December 2007) growing seasons following the controlled fire. Within each column, means with the same letter are not significantly different (p>0.05).

Tabla 4. Cobertura foliar y densidad promedio de las gramíneas perennes deseables (DPG) e intermedias (IPG), y cobertura foliar promedio de las gramíneas (DAG) y dicotiledóneas (DAF) anuales deseables antes del fuego controlado (Diciembre 2003), y al final de la primera (Diciembre 2004), segunda (Diciembre 2005), tercera (Diciembre 2006) y cuarta (Diciembre 2007) estación de crecimiento luego del fuego controlado. Dentro de cada columna, los promedios seguidos por la misma letra no son significativamente diferentes (p>0,05).

	FOLIAR COVER (%)			
Sampling date	DPG	IPG	DAG	DAF
December 2003	31.0 ± 2.0 a	2.00 ± 1.00 a	8.0 ± 1.0 a	7.0 ± 1.0 a
December 2004	17.0 ± 1.0 c	0.02 ± 0.02 b	5.0 ± 2.0 ab	8.0 ± 2.0 a
December 2005	29.0 ± 3.0 a	0.24 ± 0.17 b	1.0 ± 1.0 bc	0.1 ± 0.1 b
December 2006	27.6 ± 1.0 ab	0.25 ± 0.12 b	2.0 ± 1.0 bc	4.0 ± 1.0 a
December 2007	21.0 ± 2.0 bc	0.23 ± 0.01 b	0.2 ± 0.9 c	0.2 ± 0.1 b

	DENSITY (thousand plants/ha)	
Sampling date	DPG	IPG
December 2003	280.7 ± 39.7 a	19.5 ± 9.0 a
December 2004	261.8 ± 30.6 a	3.7 ± 1.2 a
December 2005	299.7 ± 35.8 a	5.6 ± 2.3 a
December 2006	324.5 ± 39.9 a	3.3 ± 1.3 a
December 2007	322.7 ± 36.2 a	4.1 ± 1.7 a

Woody species mean density was similar (p>0.05) among treatments throughout the study period. However, woody species mean density was slightly greater in the fire than in the control treatment after the controlled fire (Fig. 2B). In the fire treatment, densities of the main woody species did not show significant differences (p>0.05) in the study period (Table 3).

Mean percentage foliar cover of desirable perennial grasses (Table 1) was significantly higher (p<0.05) in the controlled fire treatment than in the control, except in the December 2004 and 2005 sampling dates (Fig. 3A). In the controlled fire treatment, a significant reduction (p<0.05) in percentage foliar cover was detected at the end of the first growing season after the controlled burn on desirable perennial grasses. One year later, original foliar cover values tended to be re-established (Table 4). Contrarily, mean percentage foliar cover of intermediate perennial grasses (Table 1) was lower in the fire treatment than in the control. However, differences were not always significant (Fig. 3B; p>0.05). In the fire treatment, intermediate perennial grass foliar cover was significantly reduced (p<0.05) by the controlled fire (Table 4).

Fig. 4. Desirable (A) and intermediate (B) perennial grass mean density in the control and fire treatments. In each sampling date, columns with the same letter are not significantly different (p>0.05). Each column is the mean of n=8 and vertical bars represent the S.E.
Fig. 4. Densidad media de las gramíneas perennes deseables (A) e intermedias (B) en los tratamientos control y fuego. En cada fecha de muestreo, columnas con la misma letra no son significativamente diferentes (p>0,05). Cada columna es la media de n=8 y las barras verticales representan el E.E.

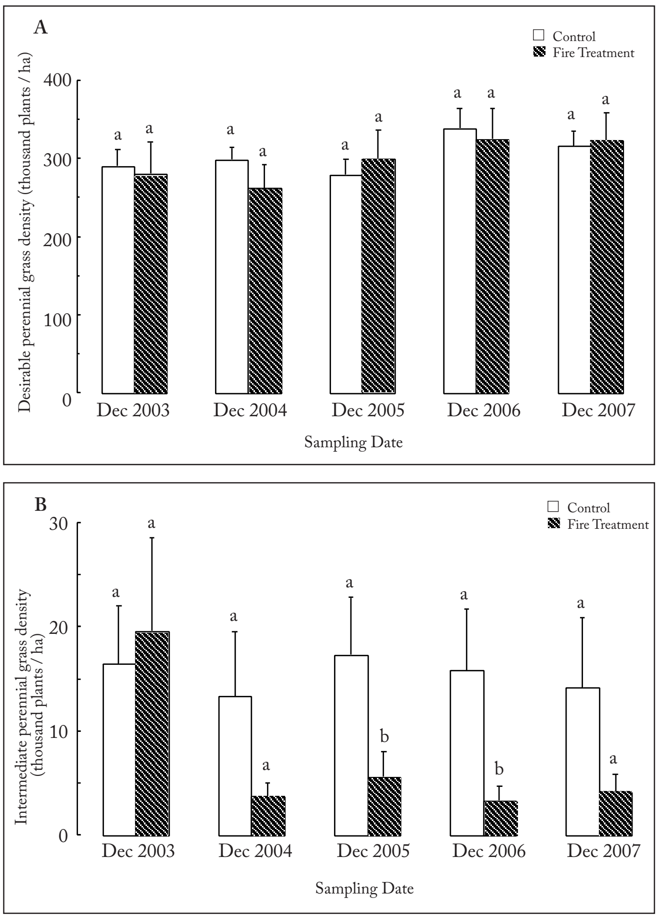
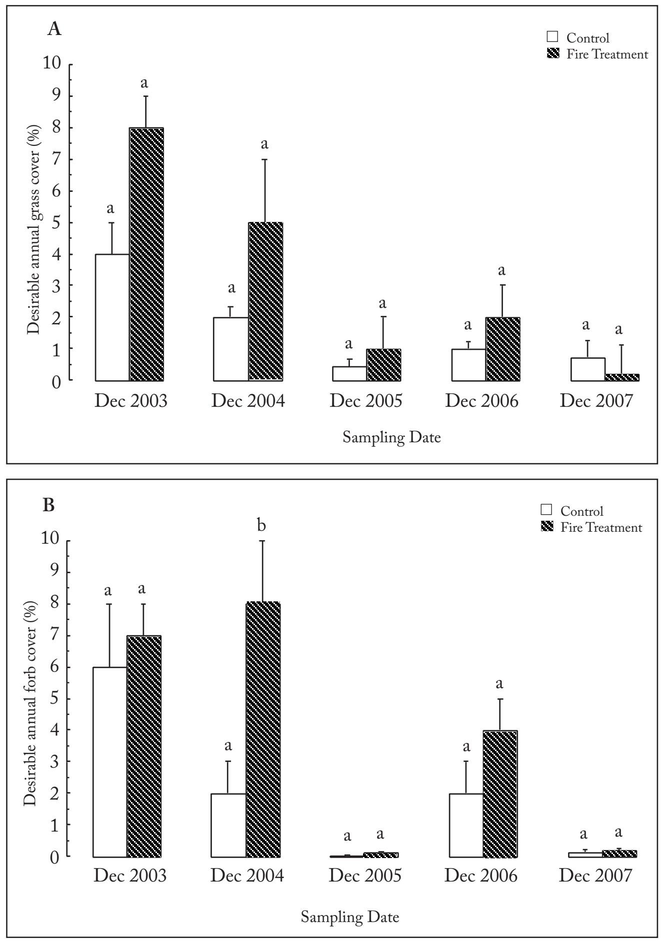


Fig. 5. Desirable annual grass (A) and forb (B) mean foliar cover in the control and fire treatments. In each sampling date, columns with the same letter are not significantly different (p>0.05). Each column is the mean of n=8 and vertical bars represent the S.E.
Fig. 5. Porcentaje medio de la cobertura foliar de las gramíneas (A) y dicotiledóneas anuales deseables (B) en los tratamientos control y fuego. En cada fecha de muestreo, columnas con la misma letra no son significativamente diferentes (p>0,05). Cada columna es la media de n=8 y las barras verticales representan el E.E.



In general, desirable annual grass and forb foliar covers were higher in the fire treatment than in the control treatment. However, significant differences were only detected between treatments for the desirable annual forbs in the March 2004 sampling (Figs. 5 A and B). In the fire treatment, the two annual herbaceous groups showed a similar response (Table 4).

No significant differences ($p<0.05$) in desirable perennial grass density were detected either among treatments or sampling dates within the fire treatment (Fig. 4A). Intermediate perennial grass density was consistently lower in the fire than in the control treatment, although significant differences ($p<0.05$) were only detected in the December 2005 and 2006 sampling dates (Fig. 4B).

DISCUSSION

A safe fire prescription guide (Wright & Bailey, 1982) was chosen to conduct the controlled burns, since no information was available on the volatility of fuels in the Monte region. Conditions between the beginning and end of the controlled burns (14:00-19:00h) were 28-26 °C air temperature, 25-35% relative humidity and 8-11 km/h wind speed, fine fuels were on average 890 (737-1075) kg/ha dry wt. This amount of fine fuel can be considered moderate to low. Consequently, we assumed that the controlled burns were from moderate to low intensities. This could explain, at least in part, their little effect on the woody species density. Temperatures of grassland headfires are a linear function of the amount of uncompacted fine fuel for burning (Wright & Bailey, 1982). Fine fuel characteristics, such as quantity and arrangement, strongly influence how a given site will burn under specific environmental conditions. The nature of fuel consumption determines the (1) peak temperature reached, (2) duration of heat, and (3) stratification of heat above and below the surface (Miller, 2001). Attempts to control *P. glandulosa* with prescribed fire have often failed, probably due to the lack of sufficient fine fuels (Bock et al., 2007).

Controlled burn significantly reduced the woody species mean percentage cover. This reduction persisted during the whole study period (Fig. 2A). *Condalia microphylla*, *Ch. erinacea* and *S. fasciculatus* were the woody species that contributed most to this response; however, these species tended to recover their original cover at the end of fifth growing season after the controlled burn (Table 2). It is likely that this recovery was limited by the intense drought occurred during 2005, 2007 and 2008 in the study region (Fig. 1). The remaining woody species remained more or less stable during the same time period (Table 2). Bóo et al. (1997) reported a significant reduction in the cover of *C. microphylla*, *Ch. erinacea*, *Prosopis flexuosa* and *L. divaricata* after a wildfire, and two controlled fires of different intensities. In general, the effects persisted at least two years after the burns. Similar results were observed by Kröpfl et al. (2007) for *Ch. erinacea* and *C. microphylla* after a summer wildfire.

The increase detected in the woody species density after the controlled fire (Fig. 2B) is more apparent that real. This is the result that some woody species patchs, such as those of *B. ulicina* or *P. globosum* (among other groups), were considered as one individual before the controlled burn, but they were considered as more than one individual after the controlled burn. Density of the most prominent woody species was not affected in the burn treatment (Table 3). The clustered nature of the woody species in the study site, with no occurrences in several sampling plots, produced high experimental errors and no significant results. A more intensive sampling or a different sampling design might be necessary to study the woody species density changes in detail. Our results agree partially with those of Bóo et al. (1997). They reported that woody species densities, with the exception of *L. divaricata*, were not significantly affected by controlled fires. After a wildfire occurred in summer, Kröpfl et al. (2007) found a significant reduction in the *Ch. erinacea* density, but they did not detect significant changes in the *C. microphylla* density.

In general, desirable perennial grasses had a high mean percentage foliar cover in the controlled fire treatment (Fig. 3A). Reduced competition from woody plant species for light, water and/or nutrients after fire might explain, at least in part, this response. Controlled or prescribed burning of rangelands generally (1) reduce consumption of water by woody species, (2) release plant nutrients in the soil for plant use, (3) reduce temporarily the amount of vegetation that intercept precipitation from light rains, and (4) reduce the shrub and tree covers (Vallantine, 1989). At the end of the study period, desirable perennial grasses tended to reestablish their original foliar cover (Table 4). Its recovery was most likely affected by the intensive drought occurred during the study period (Fig. 1). Bóo et al. (1996) found that *P. napostaense*, *S. clarazii* and *S. tenuis* (within our desirable perennial grass group) showed a sustained increase in foliar cover after exposure to different fire intensities.

The mean percentage foliar cover of intermediate grasses was notably lower in the controlled burn than in the control treatment (Fig. 3B). This result suggests that this group of perennial grasses would be less tolerant to fire or the combined effects of fire, drought and grazing. Significant reductions in percent foliar cover occurred in *S. speciosa* (within our intermediate perennial grass group) after different burn intensities (Bóo et al., 1996).

In general, no significant differences were detected in the desirable and intermediate perennial grass densities after the controlled fire. However, very important reductions in density occurred in the intermediate perennial grasses (Figs. 4A and 4B). Population distribution of perennial grasses, as in the case of the woody species, would be responsible that subtle changes were not found. Our results partially agree with those of Bóo et al. (1996) for some desirable perennial grasses (such as *P. napostaense*, *S. tenuis*, *S. clarazii)*, and an intermediate perennial grass (such as *S. speciosa)*.

Whelan (1995) emphasized that the most obvious pattern after burning was the occurrence of a suite of annual species that temporarily occupy a site. Scheintaub et al. (2009) reported a decrease in annual grasses and a positive response of annual forbs to the combination of fire and a wet spring. At the end of the first growing season after fire (December 2004), foliar cover of desirable annual forbs was significantly higher in the burn than in the control treatment (Fig. 5B). Desirable annual grasses had a similar behavior, but we did not detect significant differences (Fig. 5A). Percentage foliar cover was drastically reduced in both groups in the remaining sampling dates (Figs. 5A and 5B). In the Monte region, germination and growth of annual species is favored in wet years (i. e. Peláez et al., 1995). Thus, at least in part, above normal precipitation during 2004 (527mm) and the intense drought period 2005-2009 (Fig. 1) could contribute to explain the observed results.

The final response of plants to fire is the result of interactions between characteristics of the fire itself, processes that occur after fire such as climatic conditions and herbivory, and survival attributes of the plants in response to fire and post-fire processes (Peláez et al., 2003). With these considerations in mind, our results indicate at present that the controlled burn reduced the woody species cover, which improves access and availability of forage to grazing animals in the dense woody areas. Also, our results suggest that the reduction of the woody species cover might have favored the foliar cover of desirable perennial grasses. Finally, a single controlled burn did not seem to start a plant replacement sequence, and the plant community persisted with no variation in the density of the major woody species and the most prominent perennial grass species. The effects of repeated moderately severe controlled burns, with proper grazing management, may be the key factor to reduce woody species density and improve grazing in the Monte region.

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