J. Range Manage.
54: 617–621 September 2001

# Effect of fire on perennial grasses in central semiarid Argentina

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## Abstract

**Fire is a key factor in the temperate semiarid region of central Argentina. The objectives of this work were to evaluate the effect of different fire intensities applied during different seasons under field conditions on the mortality of *Piptochaetium napostaense* (Speg.) Hack., *Stipa tenuis* Phil., and *Stipa gynerioides* Phil., 3 of the dominant grasses within the region and to determine their thermal death points in the laboratory. Ten plants of each species were exposed to low fire intensity (300–400°C), high fire intensity (500–600°C), and no fire (control) in April and December 1994, May 1995, and January 1996. Fire treatments were applied with a portable propane plant burner. The thermal death point was determined (during fall and spring) using the Wright's technique. Although mortality with high fire intensity was always higher than mortality with low fire intensity for all species, differences were not significant ($p > 0.05$). Pooling both treatments, the highest ($p < 0.05$) average mortality for *P. napostaense* (55%) and *S. tenuis* (85%) was observed after the May burn. Average mortality for *S. gynerioides* was similar ($p > 0.05$) for all burning dates. Only after the May burn, was average mortality of *P. napostaense* and *S. tenuis* higher ($p < 0.05$) than average mortality of *S. gynerioides*. The thermal death point was similar in all studied species. It was 65°C during the fall, and 68°C during the summer. This could explain, at least in part, similar mortalities (except after the May burn) between species and the date of burning found in this study.**

**Key Words: fire mortality, fire intensity, thermal death point, *Piptochaetium napostaense* (Speg.) Hack., *Stipa tenuis* Phil., *Stipa gynerioides* Phil.**

Research was funded by Universidad Nacional del Sur (UNS), Comisión de Investigaciones Científicas (CIC), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), and Agencia Nacional de Promoción Científica y Tecnológica.

Authors wish to thank Mr. Sergio Aman and Mr. Arturo Ferro for their field assistance during this research, and Mr. Raúl Cepeda who provided the land for this research.

Manuscript accepted 5 Nov. 00.

## Resumen

**El fuego es un factor clave en la región semiárida templada del centro de Argentina. Los objetivos de este trabajo fueron evaluar los efectos de diferentes intensidades de fuego aplicadas en distintas épocas del año bajo condiciones de campo sobre la mortalidad de *Piptochaetium napostaense* (Speg.) Hack., *Stipa tenuis* Phil., y *Stipa gynerioides* Phil., 3 de las gramíneas dominantes en la región y determinar sus puntos de muerte térmica en el laboratorio. Diez individuos de cada especie fueron expuestos a baja intensidad de fuego (300–400°C), alta intensidad de fuego (500–600°C), y ausencia de fuego (control) en abril y diciembre de 1994, mayo de 1995 y enero de 1996. Los tratamientos de fuego fueron aplicados con un quemador portátil. El punto de muerte térmica fue determinado en otoño y primavera usando la técnica de Wright. En todas las especies, la mortalidad con alta intensidad de fuego fue mayor a la mortalidad con baja intensidad de fuego, pero las diferencias no fueron significativas ($p > 0.05$). Combinando ambos tratamientos, el mayor ($p < 0.05$) promedio de mortalidad para *P. napostaense* (55%) y *S. tenuis* (85%) fue observado después de la quema de mayo. El promedio de mortalidad de *S. gynerioides* fue similar ($p>0.05$) en todas las fechas de quema. Sólo luego de la quema de mayo, el promedio de mortalidad de *P. napostaense* y *S. tenuis* fue mayor ($p < 0.05$) que el promedio de mortalidad de *S. gynerioides*. El punto de muerte térmica fue similar en todas las especies estudiadas. El mismo fue de 65°C durante el otoño, y 68°C durante el verano. Esto podría explicar, al menos en parte, las mortalidades similares (excepto después de la quema de mayo) entre especies y fechas de quema encontradas en este estudio.**

Death of perennial grasses following fire is usually attributed to heat. The likelihood of death of a whole plant will depend upon both the extent of injury to its component parts and which tissues are affected by the heat (Whelan 1995). Vascular plant tissues can be killed over a wide range of temperatures if the given temperature is maintained for the appropriate length of time (Wright and Bailey 1982). The lowest temperature that results in no survival after a fixed period of exposure, usually ten minutes, is referred as the thermal death point (Wright 1970). Combinations of temperature and exposure time have been used to measure death by heat in plants in relation to fire.

Characteristics such as temperature, intensity and duration, and season and frequency of fire have important effects on vegetation responses to fire (Gibson et al., 1990). Other factors such as phenological stage (Wright and Klemmedson 1965), amount of fuel per plant (Wright 1971), growth form (Wright 1986), localization of regrowth tissues (Whelan 1995), and climatic conditions after fire (Bunting 1985) can also modify the effect of fire on the mortality of perennial grasses.

Fire is a key factor in the Caldén District (Bóo 1990), a temperate, semiarid phytogeographic region of 40,000 km$^2$ in central Argentina (Cabrera 1976), commonly known as the Caldenal. Some studies have investigated the effect of controlled fires on grass species in the Caldenal (Lutz and Graff 1980, Busso et al. 1993, Bóo et al. 1996, Peláez et al. 1997). However, information on the effect of different fire intensities during different seasons of the year on mortality of individual grass species is lacking, and thermal death points are unknown. The objectives of this work were to evaluate the effect of different fire intensities applied during different seasons of the year on the mortality of *Piptochaetium napostaense* (Speg.) Hack., *Stipa tenuis* Phil., and *Stipa gynerioides* Phil. under field conditions, and to determine their thermal death points in the laboratory. The first 2 species are abundant in the Caldenal and preferentially eaten by cattle, whereas *S. gynerioides* is largely neglected (Bóo et al. 1993, Bontti et al. 1999), thus increasing in abundance under heavy grazing (Distel and Bóo 1995).

## Study Area

The study area is located in the southeastern corner of the province of La Pampa (38°45'S, 63° 45'W), and comprises an area of 20 ha which has been closed to grazing since 1982 (Fig. 1). Vegetation, climate, and soil of the region have been described by others (INTA 1980, Bóo and Peláez 1991). The herbaceous layer is dominated by grasses such as *Piptocahetium napostaense* and *Stipa tenuis*. *Stipa gynerioides* and *Stipa speciosa* Trin. et. Rupr. are also abundant. The dominant woody species are *Prosopis caldenia* Burk., *Prosopis flexuosa* DC., *Condalia microphylla* Cav., and *Larrea divaricata* Cav.

Annual mean temperature is 15.3°C with June being the coldest month (7°C) and January (23.6°C) the warmest. Average annual precipitation is 344 mm, and is concentrated in the fall and spring. The annual water deficit is about 400 mm (Peláez et al. 1994).

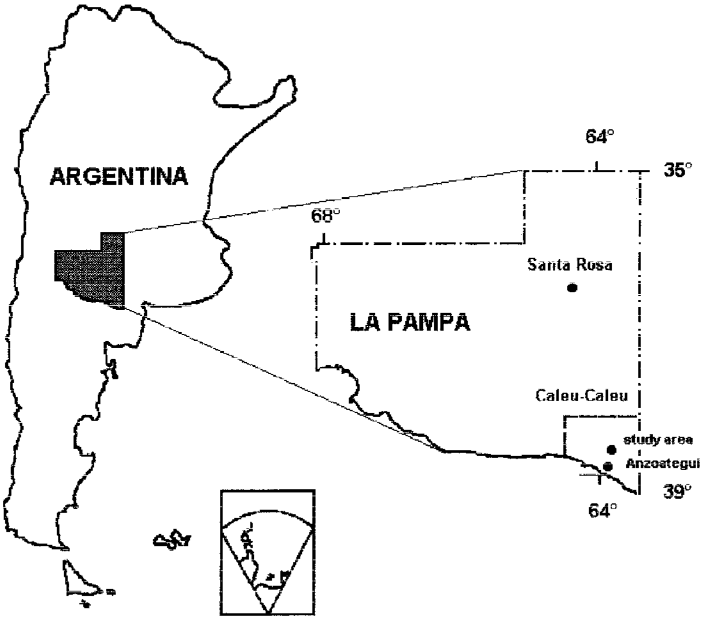


**Fig. 1. Geographic localization of the study area. Department of Caleu-Caleu, province of La Pampa, Argentina.**

The soil at the site is a Calciustoll, well drained with a medium to heavy texture. A petrocalcic horizon is found at an average depth of 40-60 cm (Peláez et al. 1997).

## Materials and Methods

### Mortality in the Field.

Individuals of *Stipa tenuis*, *Piptochaetium napostaense*, and *Stipa gynerioides* were randomly selected within the study area. Ten plants of each species were exposed to low fire intensity, high fire intensity, and no fire (control) in April and December 1994, May 1995, and January 1996.

Fire treatments were applied with a portable propane plant burner similar to the one described by Britton and Wright (1979). Low and high fire intensity treatments were obtained applying fire until the temperature in the crown had reached 300–400°C and 500–600°C, respectively. Temperatures were measured at 1 second intervals with a type K thermocouple (chromel-alumel) located at the soil surface level in the center of the plant without touching the soil or the plant, in the same way as reported by Bóo et al. (1996). Temperatures were recorded by connecting the thermocouples to a Campbell 21 XL datalogger. Further details regarding

**Table 1. Mortality percentages of *Piptochaetium napostaense*, *Stipa tenuis*, and *Stipa gynerioides* treated with high fire intensity (HI), low fire intensity (LI), and no fire (CT). Treatment dates were April and December 1994, May 1995, and January 1996.**

| Date | Species | Mortality | | |
|---|---|---|---|---|
| | | HI | LI | CT |
| | | (%) | | |
| April ‘94 | *P. napostaense* | 20 | 0 | 0 |
| | *S. tenuis* | 10 | 0 | 0 |
| | *S. gynerioides* | 0 | 0 | 0 |
| December ‘94 | *P. napostaense* | 10 | 10 | 0 |
| | *S. tenuis* | 40 | 10 | 0 |
| | *S. gynerioides* | 10 | 0 | 0 |
| May ‘95 | *P. napostaense* | 60* | 50* | 0 |
| | *S. tenuis* | 90** | 80** | 0 |
| | *S. gynerioides* | 20 | 10 | 0 |
| January ‘96 | *P. napostaense* | 10 | 0 | 0 |
| | *S. tenuis* | 0 | 0 | 0 |
| | *S. gynerioides* | 30 | 10 | 0 |

*,**significant at the 0.05 and 0.01 levels respectively.

Table 2. Basal diameter (n = 20) per plant for *Piptochaetium napostaense*, *Stipa tenuis*, and *Stipa gynerioides* in each burning date. In each row, values with the same letter are not significantly different ($p < 0.05$).

| Date | Basal Diameter | | |
|---|---|---|---|
| | *P. napostaense* | *S. tenuis* | *S. gynerioides* |
| | (cm) | | |
| April '94 | 6.4 a | 7.2 a | 11.4 b |
| December '94 | 6.6 a | 6.9 a | 12.4 b |
| May '95 | 6.1 a | 6.6 a | 10.7 b |
| January '96 | 6.7 a | 7.0 a | 8.7 b |

Table 3. Average mortality percentages (high and low fire intensity treatments pooled) of *Piptochaetium napostaense*, *Stipa tenuis*, and *Stipa gynerioides* after the April and December 1994, May 1995, and January 1996 treatments. In each column, values with the same letter are not significantly different ($p < 0.05$).

| Date | Average Mortality | | |
|---|---|---|---|
| | *P. napostaense* | *S. tenuis* | *S. gynerioides* |
| | (%) | | |
| April '94 | 10 b | 5 b | 0 a |
| December '94 | 10 b | 25 b | 5 a |
| May '95 | 55 a | 85 a | 15 a |
| January '96 | 5 b | 0 b | 20 a |

the burn techniques have been described by Peláez et al. (1997).

Surviving individuals of *S. tenuis*, *P. napostaense*, and *S. gynerioides* were counted at the end of the growing season following each fire. During each studied period and every 15–30 days, soil temperature (n = 10) and soil moisture (n = 10) at 10 and 30 cm of depth were determined using copper-constantan thermocouples and a gravimetric method (Wilcox 1951). Mortality data based on the number of individuals were analyzed using Chi-square (Snedecor and Cochran 1980).

### Thermal Death Point and Evaluation

Duration of temperatures necessary to kill growing points of *Stipa tenuis*, *Piptochaetium napostaense*, and *Stipa gynerioides* were determined in 2 seasons of the year, summer and fall, following the technique described by Wright (1970). Summer and fall are the seasons with the highest occurrence of wildfires in the Caldenal. Fresh plants were randomly collected within the study site during April and December, 1997, and were kept in their sod prior to treatments. Culm bases (n = 6) 2.5 cm long and stripped of dead leaves were randomly selected from these plants. They were placed in dry stoppled test tubes and heated for various lengths of time in a constant temperature bath at 5°C intervals from 50 to 100°C. The culm bases were not placed in the test tubes until the air temperature within the test tubes was equal to the bath temperature. Temperatures within the test tubes were monitored with thermocouples connected to a Campbell 21 XL datalogger.

After each heat treatment, the culm bases were incubated at 30°C in continuous darkness for 15 hours in a 0.5% solution of triphenyl tetrazolium chloride to test viability. Growing points were considered dead only if absolutely no red or pink coloring was visible.

## Results and Discussion

A significant mortality ($p < 0.05$) was only detected in *Piptochaetium napostaense* and *Stipa tenuis* ($p < 0.01$) after the May, 1995 treatments (Table 1). Although no statistical differences ($p > 0.05$) were found, field observations showed that mortality with the high fire intensity was slightly higher than mortality with the low fire intensity. This trend was similar in all the studied species (Table 1). These results partially agree with those reported by Bóo et al. (1996) who found that mortality of *P. napostaense*, *S. tenuis*, and *Stipa gynerioides* increased significantly ($p < 0.01$) with increasing fire intensity in most cases.

The high mortality, regardless of fire intensity, observed in *P. napostaense* and *S. tenuis* (Table 1) after the May 1995 treatment date can be explained by the severe drought that occurred during that year (Fig. 2), or by the combined effects of fire and drought. Becker et al. (1997) found that regrowth of *P. napostaense* and *S. tenuis* after defoliation was drastically affected by water stress. Peláez *et al.* (1997) found that fire reduced viability of axillary buds of *P. napostaense*, *S. tenuis*, and *S. gynerioides*, which in turn may restrict the subsequent regrowth. Availability of soil water during plant regrowth after fire appears to be more significant than direct fire damage (Redmann 1978). According to Whelan (1995), the interaction between fire and other ecological factors, such as herbivory and drought, has the potential to produce mortality

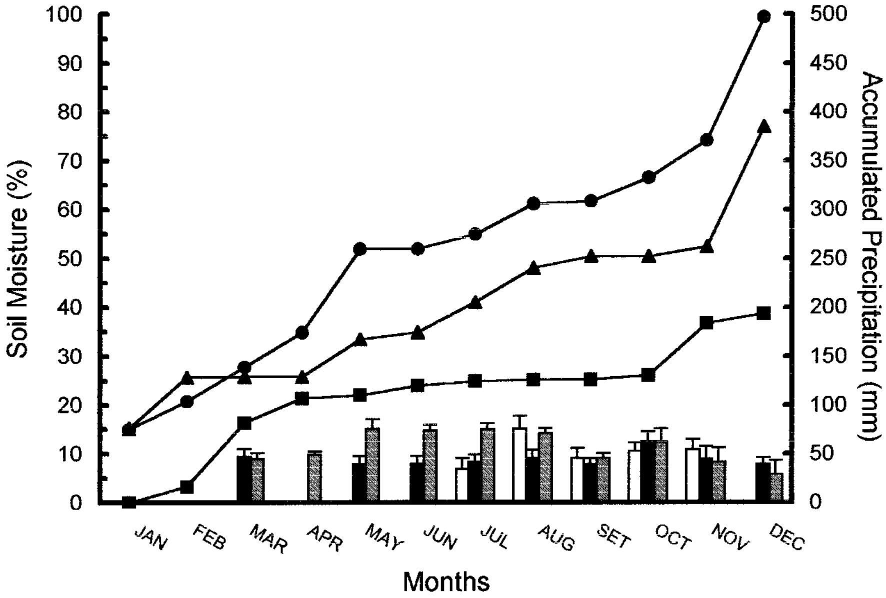


Fig. 2. Average soil moisture (%) between 10–30 cm in depth during each study period: 1994 ❑, 1995 ■, and 1996 ■, and accumulated precipitation (mm): 1994 ▲, 1995 ■, and 1996 ●. Each column is the mean of N = 20, vertical bars represent mean standard deviations.

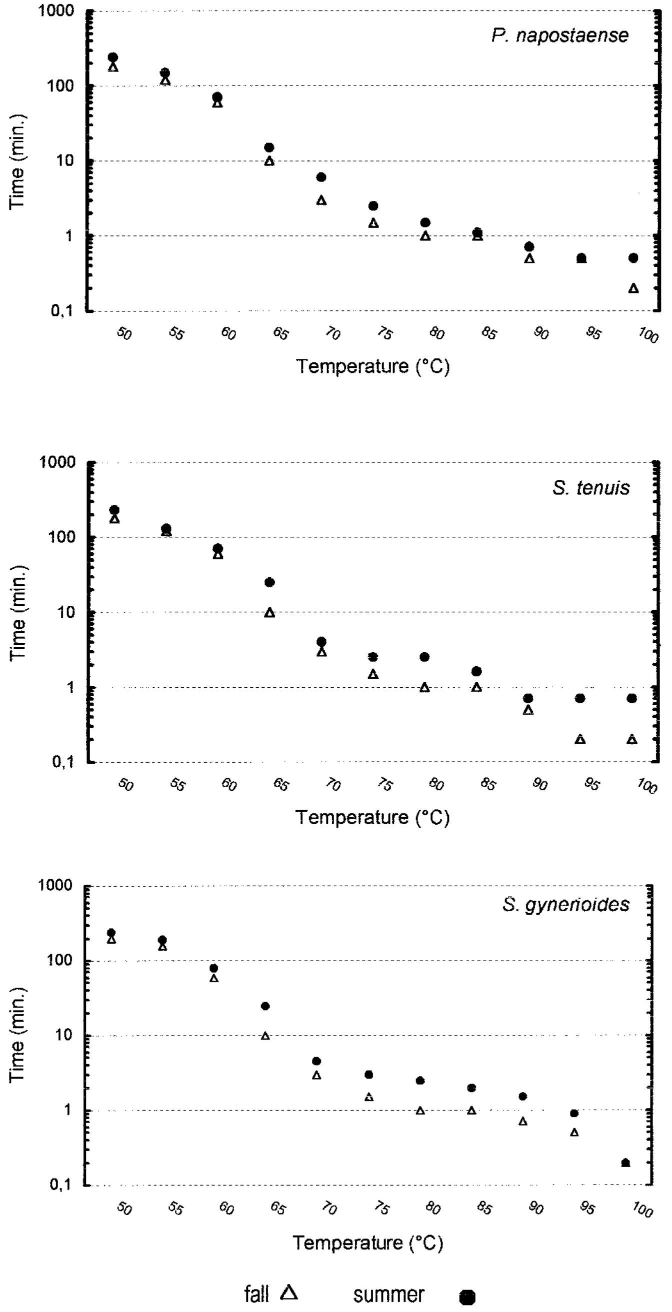


**Fig. 3. Time required to kill growing points of *Piptochaetium napostaense, Stipa tenuis,* and *Stipa gynerioides* at different temperatures during 2 seasons of the year.**

where fire alone would have had little impact. The reason for the much lower mortality observed in *S. Gynerioides* after the May 1995 treatment (Table 1) is a matter of speculation. A higher number of growing points per plant in this species due to the fact that the burned plants of *S. gynerioides* had a greater size ($p < 0.05$) than the burned plants of *S. tenuis* and *P. napostaense* (Table 2), could be a cause because some surviving plants of *S. gynerioides* had only a few active tillers after fire. On the other hand, the anatomical characteristics of the blades and stems of *S. gynerioides* (Metcalfe 1960, Lindström *et al.* 1998) would suggest that this species is very tolerant of water stress (Kramer 1983). On average, plants of *S. gynerioides* exposed to water stress grew more and had a higher number of new tillers than plants of *S. tenuis* (Busso personal communication). At least in part, the results obtained in our study would suggest that *S. gynerioides* is less susceptible to the combined effects of fire and drought than *P. napostaense* and *S. tenuis*.

The highest ($p < 0.05$) average mortality (pooling both treatments) for *P. napostaense* and *S. tenuis* was observed after the May burn (Table 3). Average mortality for *S. gynerioides* reached a maximum of 20% after the January burn but differences among burn dates were not significant ($p > 0.05$). When species' mortalities were compared within each burning date, only after the May burn was average mortality in *P. napostaense* (55%) and *S. tenuis* (85%) higher ($p < 0.05$) than in *S. gynerioides* (15%). This does not agree with results reported by Bóo *et al.* (1996) who found that mortality of *S. gynerioides* was higher than mortality of *P. napostaense* and *S. tenuis* after 1 accidental fire and 2 controlled fires. These differences might be due to different temperatures associated with different fuel loads reported by Bóo *et al.* (1996). They found heavier fuel accumulation and registered higher temperatures in the proximity of individuals of *S. gynerioides* than in the proximity of individuals of *P. napostaense* and *S. tenuis*. In our research temperatures were controlled, and the same for all species.

Several studies have emphasized the importance of season of fire on the mortality of perennial grasses. The importance of season has been related to moisture content (Wright 1971), phenological stage (Trollope 1984), and level of carbohydrate storage in plants (Wright and Klemmedson 1965). However, with the exception of the significant mortality found in *P. napostaense* and S. *tenuis* after the May 1995 burn, we did not find a significant ($p > 0.05$) number of dead plants after the other treatment dates (Table 1). Plants that are resting in a dehydrated state or at the beginning of the growing cycle can be more fire-tolerant than those that are metabolically active and fully hydrated (Anderson *et al.* 1970). This would partly explain the results obtained in our study because fire treatments were applied at the beginning (April and May) and at the end (December and January) of the annual growing cycle (Distel and Peláez 1985).

An inverse relationship was found between time and temperature combinations which proved to be lethal to the growing points of *P. napostaense*, *S. tenuis*, and *S. gynerioides* (Fig. 3). In all species for a given temperature, more time was necessary to kill the growing points during the summer than during the fall. Jameson (1961), Wright (1970) and Whelan (1995) reported similar results. This seasonal variation in heat resistance was in general attributed to changes in the moisture content of the plants. However, Wright and Bailey (1982) suggested that other factors such as content of pectin, lignin, salt, sugar, and density of plant tissue might be involved in the tolerance of plant tissue to heat.

The thermal death points of *P. napostaense*, *S. tenuis*, and *S. gynerioides* were similar. It was 65°C during the fall, and 68°C during the summer (Fig. 3). The thermal death point at the cellular level for herbage of average mesophytic plants usually lies between 50 and 55°C (Whelan 1995). However, Jameson (1961) found that lethal temperatures of culms for four grasses varied between 60 and 74°C. According to Wright and Bailey (1982), the widely quoted temperature of 60°C for one minute to kill plant tissue appears to be erroneous because the time to kill plants tissue at this temperature may vary from 2 to 60 min, depending on moisture content of tissues. Thus, the death of plant tissue is an exponential function between temperature and time if the moisture content is constant. In general, the results obtained in different studies would indicate a similar capacity of vegetal tissues to tolerate heat exposure among different grass species. Therefore, survival of plant exposed to intensive fire must be related to the protection of critical tissues from excessive heat exposure, and/or their metabolic activity at the time of fire. The similar thermal death points of *P. napostaense*, *S. tenuis*, and *S. gynerioides* would further indicate similar mortalities (except after the May treatment) between species and date of burn found in this study.

The effect of fire on mortality of perennial grasses depends on several environmental and biotic factors. A species that suffers high mortality in one fire may survive well in another, not because of plant factors, but because the fires and/or post-fire environmental conditions were different. Therefore, the final response of grasses to fire is the result of interactions among characteristics of the fire itself, processes that occur after fire such as climatic conditions and herbivory, and survival attributes of the plants in relation to the fire and to the post-fire processes.

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