

EFFECT OF FIRE ON SEED PRODUCTION OF TWO NATIVE GRASSES IN THE BRAZILIAN CERRADO

EFEECTO DEL FUEGO SOBRE LA PRODUCCIÓN DE SEMILLAS DE DOS GRAMÍNEAS DEL CERRADO BRASILEÑO

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ABSTRACT

The objective of this study was to compare the effect of fire on seed production of *Echinolaena inflexa* (*Ei*) and *Trachypogon filifolius* (*Tf*), both perennial native grasses, codominants in the Cerrado region of Brazil. For *Ei*, peak flowering occurred in January, while for *Tf* the peak was in March. Fire had a negative effect on overall seed production of *Ei*, in spite of flowering by this species in the burned area. For *Tf*, the intense flowering in the burned area and the lack of inflorescences in the unburned area indicates a fire-related positive effect on seed production.

Key words: fire, Cerrado, *Echinolaena inflexa*, *Trachypogon filifolius*, seed production

RESUMEN

Se estudió el efecto de la quema sobre la producción de semillas de *Echinolaena inflexa* (*Ei*) y *Trachypogon filifolius* (*Tf*), gramíneas nativas, perennes y codominantes de las sabanas brasileñas (Cerrados). El mes de mayor floración de *Ei* fue enero y el de *Tf* fue marzo. Los resultados mostraron diferencias significativas en la producción de semillas de ambas especies, bajo el tratamientos de quema y no quema. En *Ei*, el fuego reduce la producción de semillas, a pesar que esta especie produjo culmos florales en el sitio quemado. En *Tf*, la floración intensa en el sitio quemado y la reducida formación de inflorescencias en el sitio no quemado, evidenció el efecto positivo del fuego sobre la producción de semillas en esta especie.

Palabras clave: fuego, Cerrado, *Echinolaena inflexa*, *Trachypogon filifolius*, producción de semillas.

INTRODUCTION

Fire is an important natural component of the Cerrado and other savanna regions at the end of the

dry season, when most of the herbaceous biomass is dry. Fire is often used as a management tool in native pastures to alter the density of target species, by increasing or decreasing seed production or

because of differences in resprouting response. Silva (1987) postulated that savanna grasses react differently to fire depending on their phenology and architecture. The basal grasses that flower in the rainy season apparently are induced by the occurrence of fire, and are called precocious species. The erect grasses that flower at the end of the growing season are called late species (Silva *et al.* 1990). Also, there is evidence that complete fire exclusion can produce changes in the composition and dominance of grass species in savannas (Medina and Silva 1991, San José and Fariñas 1991). This could be related to changes in the nutritional status of the soil and differential reproductive strategies of species. In some cases, the effect of fire was due to increases in fertility, including both seed production and seedling recruitment. Thus, the growth rate of the grass populations is higher in the burned areas (Canales *et al.* 1994), as well as species extinction rate higher under fire exclusion. Several studies have shown the effect of fire on stimulation of flowering of species in the herbaceous layer (Curtis and Partch 1950, Old 1969, Strugnell and Pigott 1978, Hover and Bragg 1981, Canales and Silva 1987, Baruch *et al.* 1989, Silva *et al.* 1990, Leigh *et al.* 1991, Laubhan 1995). The reasons suggested to explain the stimulus for flowering after fire were: heating of the soil and higher light levels in function of removal of accumulated dry matter (Curtis and Partch 1950, Daubenmire 1968), reduction of competition among established individuals (Frost and Robertson 1987), or an increase in the supply of available nutrients (Old 1969, Cavalcanti 1978). Coutinho (1990) believes that the destruction of the aboveground parts of the plants, which may occur through fire, cutting or exposition of the plants to a period of water stress, stimulates flowering.

The objectives of this study were to determine to effect of fire on 1) flowering period and 2) seed production in two species of native grasses of the Brazilian Cerrado, *Echinolaena inflexa* (Poir.)

Chase and *Trachypogon filifolius* (Hach.) Hitchc. (= *Trachypogon macroglossus* Trin (Tarciso Filgueiras, pers. comm.)). The growth architecture of these species is different, *E. inflexa* has ramified, linear culms and does not form bunches while *T. filifolius* has cespitose culms and forms bunches. These species coexist in the Cerrado region of central Brazil (Filgueiras 1991), and are considered to be important as forage resources.

MATERIAL AND METHODS

This study was realized in an area of “campo sujo” on the Fazenda Água Limpa (15°44’S 48°06’W), property of the Universidade de Brasília, during the period of July 1991 to May 1992. The area was located within the Project “Effects of burning on floristic composition, productivity and forage quality of the Cerrado”, a joint project between EMBRAPA/CPAC and the University of Brasília. There are several different types of plant community physiognomies in the Cerrado based on water availability, variation in relief and edaphic factors. The “campo sujo” is a common physiognomy, with shrubs in low density distributed over a grass matrix. The climate of this region is classified as Aw (tropical savanna) in the Koeppen system and the region has well defined periods of drought (May to September) and rain (October to April). The main soil class at this site is yellow-red latosol (acrustox, according to the American classification). As in most of the Cerrado, the principal characteristic of this soil is that it is dystrophic with relatively high concentrations of aluminum.

The burn treatment was located in an area of 1.8 ha of “campo sujo” which has been subjected to annual burning at the beginning of the dry season (May) since 1989 and was burned in the second half of July 1991. An adjacent area of 0.9 ha, unburned

since May 1989, was used as the control plot. Prior to the burn, individuals of both species were located and their position was marked with numbered metal stakes to facilitate identification after the burn. When regrowth started after the burn, sprouts (ramets) of *E. inflexa* and *T. filifolius* of the previously marked individuals were located. Each ramet was considered to be an "individual", and was marked at its base with a piece of copper wire, 1 mm in thickness and ensheathed in colored plastic, to facilitate its identification at each measurement date. In the burned area 150 ramets of each species were marked. In the unburned area 54 ramets of each species were marked, using the same procedure as in the burned area. The number of ramets marked in the unburned area was lower than in the burned area for two reasons. First, large variance in the growth rate of these ramets was not expected, and second due to the difficulty in finding individuals under dense herbaceous cover.

After resprouting started, all marked ramets, in both the burned and unburned areas, were measured monthly. The measurements made were: 1) height (in cm), 2) number of ramets flowering and 3) number of spikelets/ramet. Height was measured as the distance between the soil surface and the highest point of the individual, either the apical leaf or an inflorescence, when present. Each ramet that flowered had its mature spikelet, or spikelets, removed and taken to the laboratory where the spikelets were individually dried at 70 °C, weighed and the number of caryopses/spikelet counted.

Statistical analyses were done using Statistix 4.1 and data are presented as means with one standard deviation. The heights of *T. filifolius* were square root transformed before analysis to homogenize variance. Differences between frequency distributions were tested using the Kolmogorov-Smirnov test for two samples.

RESULTS

In the unburned area the height of the marked ramets of both species was relatively constant over the study period (Figure 1). Resprouting and growth of ramets of both *E. inflexa* and *T. filifolius* in the burned area began in September 1991, two months after the prescribed fire and both species increased in height over the study period (Figure 1). The final mean height of all marked ramets of *E. inflexa* in the burned area was significantly different than that

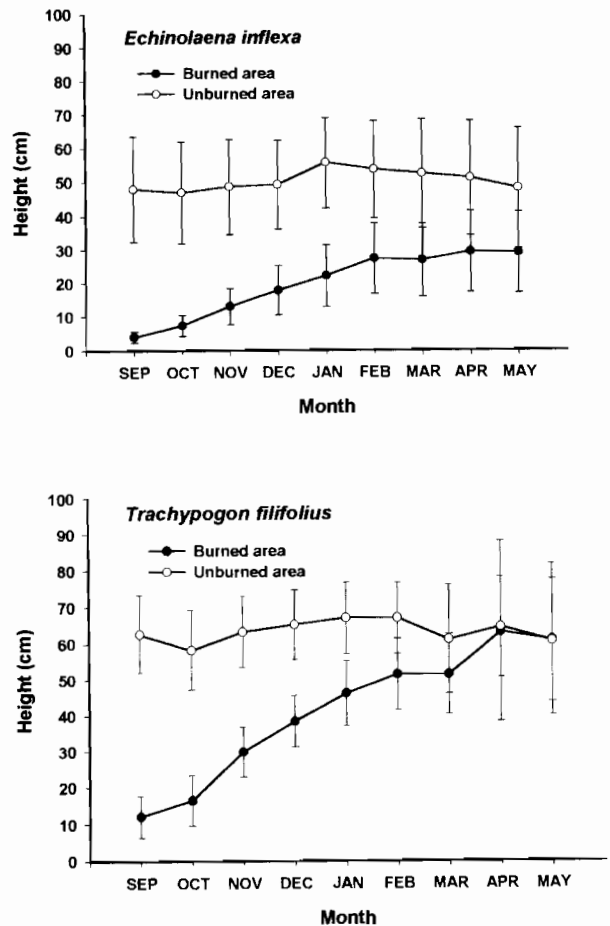


Figure 1. Mean height (± 1 standard deviation) of marked ramets of *Echinolaena inflexa* and *Trachypogon filifolius* in burned and unburned plots in a "campo sujo" near Brasilia, Brazil.

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Table 1. Comparison of height (cm) of flowering (F) and non-flowering (NF) ramets of *E. inflexa* and *T. filifolius* in burned and unburned areas of a “campo sujo” near Brasília, Brazil.

	Burned		Unburned	
	F	NF	F	NF
<i>Echinolaena inflexa</i>	31.4 ± 11.01	22.2 ± 6.63	58.0 ± 12.39	42.6 ± 11.91
<i>Trachypogon filifolius</i>	93.4 ± 26.83	54.2 ± 11.64	—	67.0 ± 9.84

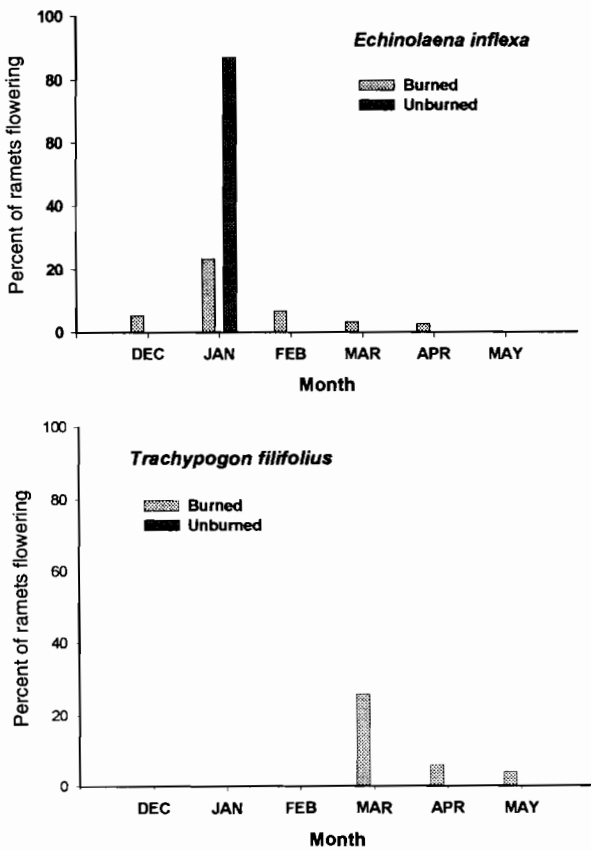


Figure 2. Temporal distribution of flowering in *Echinolaena inflexa* and *Trachypogon filifolius* in burned and unburned plots in a “campo sujo” near Brasília, Brazil.

of the ramets in the unburned area ($t = 8.61$, $p < 0.01$). For *T. filifolius*, the final height of the marked ramets in the burned area was not significantly different than that of the marked ramets in the unburned area ($t = 0.095$, $p > 0.05$). For *E. inflexa* the mean height of the ramets that flowered was not significantly different from those that did not flower ($t = 0.74$, $p > 0.05$), while for *T. filifolius* the ramets that flowered were significantly taller than those that did not flower ($t = 11.78$, $p < 0.01$) (Table 1).

These species had different phenological patterns with respect to flowering, which began from 2 to 6 months after the beginning of the rainy season in October 1991 (Figure 2). For *E. inflexa*, in the burned area, flowering began in the first half of December and lasted until March, while in the unburned area flowering was concentrated in January. *Trachypogon filifolius* only flowered in the burned area, where flowering starting in the second half of March and lasted until May. The percentage of ramets of *E. inflexa* that flowered was higher in the unburned area (87%) than in the burned area (41.3%). For *T. filifolius*, 36% of the ramets in the burned area produced inflorescences while none of the ramets in the unburned area produced inflorescences (Table 2). For both species, the difference in flowering pattern was significant between sites, $\chi^2 = 31.52$ ($p < 0.001$) for *E. inflexa* and $\chi^2 = 24.62$ ($p < 0.001$) for *T. filifolius*.

For *E. inflexa* the distribution of the number

Table 2. Flowering of *E. inflexa* and *T. filifolius* in “campo sujo” in a Cerrado near Brasília, Brazil. N= sample size, F= number of flowering ramets, Sp= number of spikelets, Sp/F= ratio of spikelets/flowering ramets.

	Burned				Unburned			
	N	F	Sp	Sp/F	N	F	Sp	Sp/F
<i>Echinolaena inflexa</i>	150	62	116	1.87	54	47	146	3.1
<i>Trachypogon filifolius</i>	150	54	118	2.18	54	0	0	0

of flowering spikelets/ramet (Figure 3) was significantly different in the burned and unburned area ($D = 0.46, p < 0.001$), but there was no difference in the distribution of flowering spikelets/ramet between species in the burned area ($D = 0.08, P = 0.768$). In the burned plot the ratio of spikelets/flowering ramet was similar between species, but was different between the burned and unburned area for *E. inflexa* (Table 2). The difference in the ratio for *E. inflexa* was due to branching of the ramets in the unburned area with subsequent production of spikelets on the branches. The number of caryopses in the spikelets of *E. inflexa* ranged from 6 to 21 ($\bar{X} = 11.8 \pm 3.4$) with a dry weight of caryopses between 0.01 to 0.05 g ($\bar{X} = 0.03 \pm 0.01$). For *T. filifolius*, the spikelets contained between 23 and 135 caryopses ($\bar{X} = 63.0 \pm 21.0$) with dry weights of caryopses ranging between 0.07 to 0.27 g ($\bar{X} = 0.14 \pm 0.05$). Although tests of viability using tetrazolium were not done, a visual inspection of the caryopses showed that for both species only about 50% had embryos, with the rest aborted or undeveloped.

DISCUSSION

The rapid resprouting response of *E. inflexa* is in accordance with data from Rosa (1990) who followed the recuperation of a “campo limpo”, approximately 5 km distant from the present study site. In that study *E. inflexa* was one of the dominant

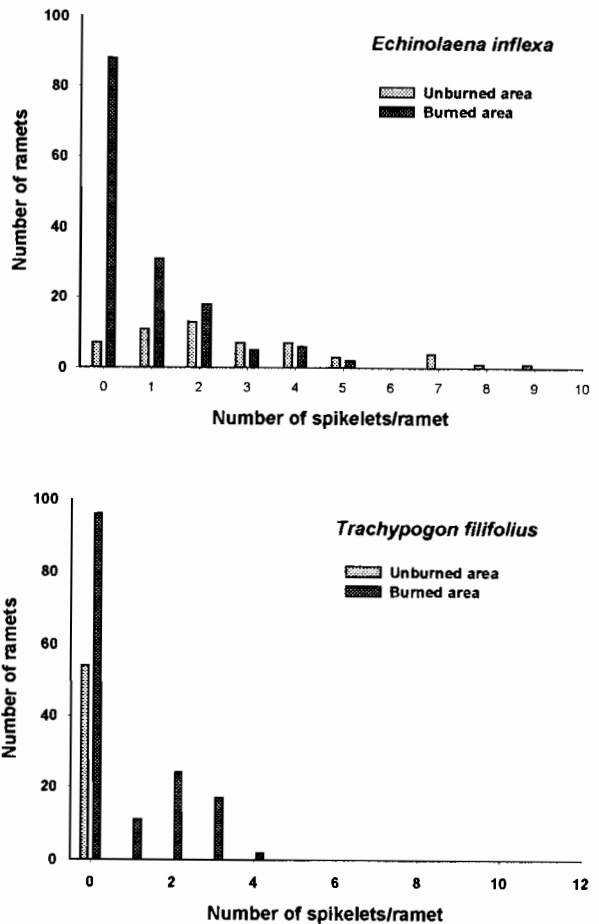


Figure 3. Distribution of the number of spikelets/flowering ramet in *Echinolaena inflexa* and *Trachypogon filifolius* in burned and unburned plots in a “campo sujo” near Brasília, Brazil.

species, along with *Trachypogon polymorpha*.

The phenological strategies of grass species in the Llanos of Venezuela, have been characterized according to: 1) the period of flowering during the growing season (early or late flowering species), 2) the periodicity of assimilation of carbon (annual or seasonal), 3) life form (annual or perennial) and 4) type of growth (continuous or seasonal) (Sarmiento and Monasterio 1983). Under this classification system the occurrence of flowering is related to the presence of sufficient resources for reproduction. In regard to flowering season, these species have different patterns with *E. inflexa* being an intermediate species and *T. filifolius* a late flowering species, even though both flowered in the middle of the rainy season. This a characteristic of several perennial grass species in the savannas, and appears to be an adaptive strategy to counter the effects of drought and fire (Baruch *et al.* 1989).

Reproduction depends on allocation of available resources and, in general, individuals with a larger photosynthetic area can produce more seeds. In both species flowering occurred on those ramets which were larger, although for *E. inflexa* the difference was not statistically significant. In the case of bunch grasses, like *T. filifolius*, flowering is dependent on localization of culms within the bunch, the age of the bunch and the age of the culm (Langer 1957). In this sense, it is possible to consider bunches as heterogeneous populations, with each ramet having a different morphology and physiology, and thus the difference in response to the conditions which determine flowering. The differences between duration of flowering are associated with the ecology the species, but also can to depend the effects of disturbances, such as fire. After removal of meristematic tissue by the fire, the reestablishment of a photosynthetic dossel of perennial grasses depends of the production of new tillers through activation of axillary buds (Busso 1993). In *E.*

inflexa, the longer flowering duration in the burned area may have reflected the time necessary to activate the tillers to grow.

The difference in the percentage of each species that flowered in the areas with and without fire suggests that there might be specialization within individuals, so that the energy needed to develop the inflorescences comes from each tiller, and those tillers that did not flower might provide energy for those that did (Silva 1983). The lack of flowering of many tillers may be an adaptation and the smaller height of these vegetative tillers may be a consequence of the shunting of resources to other tillers. It is possible that the tillers which remained in a vegetative state will flower in the next growth period, indicating that the perennial habitat is a function of resource allocation.

The higher percentage of flowering ramets of *E. inflexa* in the unburned area compared to the burnt area demonstrates a negative effect of fire on seed production in this species, and we can conclude that fire is not a determinant in the reproductive effort in this species. This conclusion is supported by the difference in the ratio of spikelets/individual for those tillers which actually produced inflorescences. Miranda (1997) also encountered a similar pattern for *E. inflexa*, with a higher number of inflorescences/individual in an unburned area compared to individuals in a burned area. However, fire stimulated seed production in *T. filifolius*, which did not have any reproduction in the unburned area. A similar pattern of the reduction of fertility by fire exclusion was observed in species of grasses in the Venezuelan Llanos where fire significantly reduced the reproductive effort, through reduction in flowering percentage, seed production and seed-to-seedling (Silva *et al.* 1990, Canales *et al.* 1994). Fire exclusion also contributed to the ramification of tillers of *E. inflexa*, and consequently a higher number of inflorescences produced per tiller.

We can say little about the mechanisms by which fertility is reduced by fire exclusion. The decreased seed production could reflect reduced individual growth rates, as reported for perennial savannas grasses (Silva *et al.* 1990). Therefore, *E. inflexa* seems to be more resistant to fire exclusion than *T. filifolius*. Also, the low percent of caryopses for both *E. inflexa* and *T. filifolius* with an embryo present, is an indication that seedling recruitment might be limited by seed availability (Lattera *et al.* 1994), and that vegetative reproduction might be more important than sexual reproduction after fire.

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LITERATURE CITED

- BARUCH, Z., A.B. HERNÁNDEZ, and M.G. MONTILLA. 1989. Dinámica del crecimiento, fenología y repartición de biomasa en gramíneas nativas e introducidas de una sabana neotropical. *ECOTROPICOS* 2:1-13.
- BUSSO, C.A. 1993. Fire effects on bud viability and growth of *Stipa tenuis* in semiarid Argentina. *Annals of Botany* 71:377-381.
- CANALES, J., M.G. TREVISAN, J.F. SILVA and H. CASWELL. 1994. A demographic study of the annual grass (*Andropogon brevifolius* Schwarz) in burnt and unburned savanna. *Acta Oecologica* 15:261-273.
- CANALES, M.J., and J.F. SILVA. 1987. Efecto de una quema sobre el crecimiento y demografía de vástagos en *Sporobolus cubensis*. *Acta Oecologica* 8:391-401.
- CAVALCANTI, L.H. 1978. Efeito das cinzas resultantes da queimada sobre a produtividade do estrato herbáceo subarbustivo do Cerrado de Emas. Tese de Doutorado, USP, São Paulo.
- COUTINHO, L.C. 1990. Fire in the ecology of the Brazilian Cerrado. Pp. 82-105, in J.G. Goldammer, (ed.): Fire in the tropical biota. Springer-Verlag, Berlin.
- CURTIS, J.T., and M.L. PARTCH. 1950. Some factors affecting flower production in *Andropogon gerardi*. *Ecology* 31:488-489
- DAUBENMIRE, R. 1968. Ecology of fire in grasslands. *Advances in Ecological Research* 5:209-266.
- FILGUEIRAS, T.S. 1991. A floristic analysis of the gramineae of Brazil's Distrito Federal and a list of the species occurring in the area. *Edinburgh Journal of Botany* 48:73-80.
- FROST, P.G.H. and F. ROBERTSON. 1987. The ecological effects of fire in savannas. Pp. 93-139, in B.H. Walker (ed.): Determinants of tropical savannas. IUBS, Oxford.
- HOVER, I.E. and T.B. BRAGG. 1981. Effect of season of burning and mowing on an eastern Nebraska *Stipa-Andropogon* prairie. *American Midland Naturalist* 105:13-18.
- LANGER, R.H.M. 1957. Growth and nutrition of timothy grass (*Phleum pratense*) II. Growth of the plant in relation to tiller development. *Annals of Applied Biology* 45:582-541.
- LATTERA, P., L. RICCI, O.VIGNOLIO and O.N. FERNANDEZ. 1994. Effects of fire and grazing on the regeneration of *Paspalum quadrifarium* by seeds in the Flooding Pampa, Argentina. *Ecologia Austral* 4:101-109.
- LAUBHAN, M.K. 1995. Effects of prescribed fire on moist-soil vegetation and soil macronutrients. *Wetlands* 15:159-166.
- LEIGH, J.H., D.H. WOOD, A.V. SLEE, and M.D. HOLGATE. 1991. The effects of burning and simulated grazing on productivity, forage quality, mortality and flowering of eight subalpine herbs in Kosciusko National Park. *Australian Journal of Botany* 39:97-118.
- MEDINA, E. and J.F. SILVA. 1991. Savannas of northern South America: a steady state regulated by water-fire interactions on a background of low nutrient availability. Pp. 59-69, in P.A. Werner (ed.): Savanna Ecology and Management, Blackwell Scientific Publications, Oxford.
- MIRANDA, M. I. 1997. Colonização de campo sujo de Cerrado por *Echinoalaena inflexa* (Poaceae). Master's Thesis, Departamento de Ecologia, Universidade de Brasília, Brasília, DF, Brasil.

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- OLD, S.M. 1969. Microclimates, fire and plant production in a Illinois prairie. *Ecological Monographs* 39:355-384.
- ROSA, C.M.M. 1990. Recuperação pós-fogo das espécies de um campo sujo de Cerrado. Master's thesis, Departamento de Ecologia, Universidade de Brasília, Brasília, DF, Brasil.
- SAN JOSÉ, J.J. and M.R. FARIÑAS. 1991. Temporal changes in the structure of a *Trachypogon* savanna protected for 25 years. *Acta Oecologica* 12:237-247.
- SARMIENTO, G. and M. MONASTERIO. 1983. Life forms and phenology. Pp. 79-108, in F. Bourliere (ed.): *Tropical savannas. Ecosystems of the World*, V. 13. Elsevier, Amsterdam.
- SILVA, J.F. 1987. Responses of savannas to stress and disturbance: species dynamics. Pp. 141-156, in B.H. Walker (ed.): *Determinants of tropical savannas. IUBS Monograph Series No. 3*. Paris.
- SILVA, J.F., J. RAVENTOS, and H. CASWELL. 1990. Fire and fire exclusion effects on the growth and survival of two savanna grasses. *Acta Oecologica* 11(6):783-800.
- STRUGNELL, R.G. and C.D. PIGOTT. 1978. Biomass, shoot-production and grazing of two grassland in the Rwenzori National Park, Uganda. *Journal of Ecology* 66:73-96.

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