



## **Alien grasses in Brazilian savannas: a threat to the biodiversity**

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**Abstract.** African grasses used as forage are spreading fast in cerrado (Brazilian savanna) patches, probably displacing native species. An analysis of the graminoid species abundance was performed in Cerrado Pé-de-Gigante Reserve (São Paulo State, Brazil), where their relative frequency, density, dominance and the value of importance were assessed in two cerrado forms: cerrado sensu stricto (denser) and campo cerrado (open). Thirty-six transects were determined, along which 324 0.5 m × 0.5 m herbaceous samples were taken. Ordination by CCA analysis was performed to detect gradients in the graminoid species distribution, according to shading, distance from the reserve border and aspect. Interspecific associations among the species were tested. A total of 93 species were sampled, predominantly Poaceae and Myrtaceae families. Two alien grasses were found, *Melinis minutiflora* and *Brachiaria decumbens*, with very high values of importance. Light availability proved to be the most important analyzed environmental factor related to graminoid distribution, strongly correlated with the abundance of *M. minutiflora*. Both alien grasses were negatively associated with most native graminoids, suggesting they exert a strong competitive pressure on the native herbaceous community. Attention must be taken to the introduction of alien species in the country.

**Key words:** African grasses, biological invasion, Brazilian savanna, cerrado, edge effect

### **Introduction**

The Brazilian cerrados – savanna vegetation type – comprise a gradient from the grassland form (named ‘campo limpo’) to a sclerophyllous woodland form (named ‘cerradão’), where basically the herbaceous layer gives place to arboreal elements, and the most apparent variation is in tree density and height. The intermediate ecotonal scrub forms are: ‘campo sujo’, ‘campo cerrado’ and ‘cerrado sensu stricto’, in an increasing density of trees. In cerradão, the canopy cover is around 30–60%; in cerrado sensu stricto, 30–40%; in campo cerrado, around 10%; in campo sujo, up to 1%, and there is no tree cover in campo limpo (Eiten 1972, 1983; Coutinho 1978, 1982a) (Figure 1). According to local conditions of soil, topography, ground water and fire history, a combination of these forms may appear in a cerrado patch, as a mosaic.

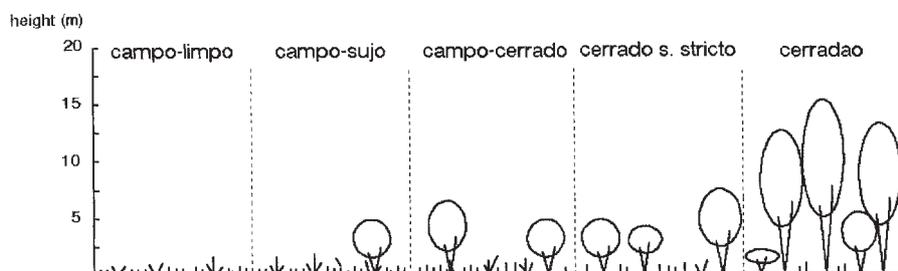


Figure 1. A gradient of cerrado (Brazilian savanna) physiognomies, from the grassland ('campo limpo') to the woodland ('cerradao') form (modified from Coutinho, 1982a).

The herbaceous layer holds a great deal of Asteraceae, Fabaceae, Rubiaceae and Cyperaceae species, but the bulk of it is formed by Poaceae, mainly C4 grasses. Among the woody elements, the dominant families are Myrtaceae, Fabaceae, Ceasalpiniaceae, Melastomataceae, Mimosaceae (Batalha 1997; Goodland and Ferri 1979; Klink and Joly 1989; Mantovani 1983).

In the more open forms, African grasses once brought to the country as forage, have spread in such a magnitude that they are present today in practically every cerrado fragment, dominating patches of the environment and outcompeting native herbs, as already stressed by some authors (Coutinho and Hashimoto 1971; Filgueiras 1990; Klink 1996a,b; Pivello et al. 1999), and therefore, representing a threat to the natural biodiversity. As stressed by D'Antonio and Vitousek (1992), grasses are especially threatening invaders, as they can spread very easily, they are very competitive against native plants in many circumstances, most of them tolerate fire and they are able to modify the environment severely.

The most common grasses invading cerrados are *Melinis minutiflora* Beauv., *Brachiaria decumbens* Stapf, *Hyparrhenia rufa* (Nees) Stapf, *Andropogon gayanus* Kunth and *Panicum maximum* Jacq., and they seem to enter cerrados through the borders, first establishing in disturbed spots and then spreading all over. It has been observed that termite or ant mounds may function as toeholds for the spread of invader species (Coutinho 1982a,b). The intense fragmentation of cerrado environments, transforming the natural vegetation into patches surrounded by pastures and crop cultures and creating borders, favors the dissemination of invader grasses even more.

Although they have a very aggressive behaviour against native grasses, concerning spreading and establishment, the planting of such exotic grasses continues to be encouraged by agricultural agencies because of their high productivity as forage, and there is no control, concerning the bad effects they can bring. Several negative ecological effects of some introduced species on native communities are known nowadays (Williamson 1996; Cronk and Fuller 1995; Pysek et al. 1995) and it is time to establish a control scheme for their introduction and dissemination in the country. Also in this sense, Hobbs and Humphries' proposal for management actions centered in the ecosystem, and not only focusing the invader species (Hobbs and Humphries 1995),

is very pertinent and stresses the important role of landscape ecology as a working approach.

Regarding the great problem that alien invasive grasses are posing to cerrado reserves and parks in Brazil, the present study was designed to: (a) verify the level of invasion by alien graminoid species in the Cerrado Pé-de-Gigante Reserve; (b) verify changes in the density of invasive plants according to distance from the edge; (c) explore relationships between graminoid species and some physical environmental conditions; (d) investigate association patterns among alien and native graminoid species.

### **Study area**

This study was carried out in the Cerrado Pé-de-Gigante Reserve (21°37'30" S; 47°37'30" W), which is part of the Vassununga State Park, in Santa Rita do Passa Quatro municipality, São Paulo State, Brazil. The Reserve comprises 1225 ha, in altitudes ranging from 590 to 740 m (Mesquita Jr. 1998).

Regional climate is tropical with wet summer and dry winter, corresponding to Walter and Lieth's type II (Walter 1986); annual rainfall is around 1300 mm. The relief is gently rolling, formed by extensive and flat topped hills. A big depression in the Central part of the Reserve, in the form of a big footprint, caused by fluvial erosion in the sandy soils, gave it the name, since 'Pé-de-Gigante' means giant's foot. Soils are predominantly acid and ferruginous, chemically poor, sandy and well drained, prevailing the Red-Yellow Latosol (Oliveira et al. 1982).

Although the Reserve is covered by assorted cerrado physiognomies, from the more open forms – dominated by grasses – to the woodland cerrado type, the regional landscape also includes semideciduous mesophyllous forest, where soil is richer. Today, only fragments of the original vegetation remain in a silvicultural–agricultural matrix.

### **Methods**

The present study was carried out in cerrado *sensu stricto* and campo cerrado patches inside the Cerrado Pé-de-Gigante Reserve, where intense invasion by alien grasses was identified.

The herbaceous layer (including plants up to 1 m tall) was sampled through 324 0.5 m × 0.5 m quadrats (sample units), where every plant was identified at species level, the number of individuals of each species was counted, and the area covered by each species was estimated. Quadrats were placed along transects starting at Reserve borders delimited by dirt roads, or marginal to a grassland which follows a drainage canal inwards the Reserve, distant 0, 10, 20, 30, 40, 50, 60, 80 and 100 m from the edge (dirt road or grassland). Six groups of six transects each (as replicates), were ar-

ranged following the directions NE, N, NW, SW, W and E, corresponding respectively to groups A, B, C, D, E and F, in Figure 2. Groups A to D were placed in cerrado sensu stricto patches, while groups E and F were placed in campo cerrado patches. Inside the group, transects were distant about 100 m from each other (Figure 2). Sampling effort was proportional to the area occupied by the cerrado form in the Reserve.

As the primary concern of this study was the graminoid species, which constituted the great majority of alien species in the area, more detailed analyses were carried out for Poaceae and Cyperaceae families.

To detect gradients in the distribution of the most frequent graminoid species associated with meaningful environmental variables in both cerrado sensu stricto and campo cerrado, ordination by canonical correspondence analysis (CCA) was performed with the CANOCO package, version 3.12 (Ter Braak 1991). The analysis was done using a matrix of species abundance in the sample units with information on shading, distance from the Reserve edges, and aspect (represented in degrees, being the highest values in the South). Shading was estimated with an arbitrary scale, from 1 to 9, which considered the height of arboreal elements and the projection of their

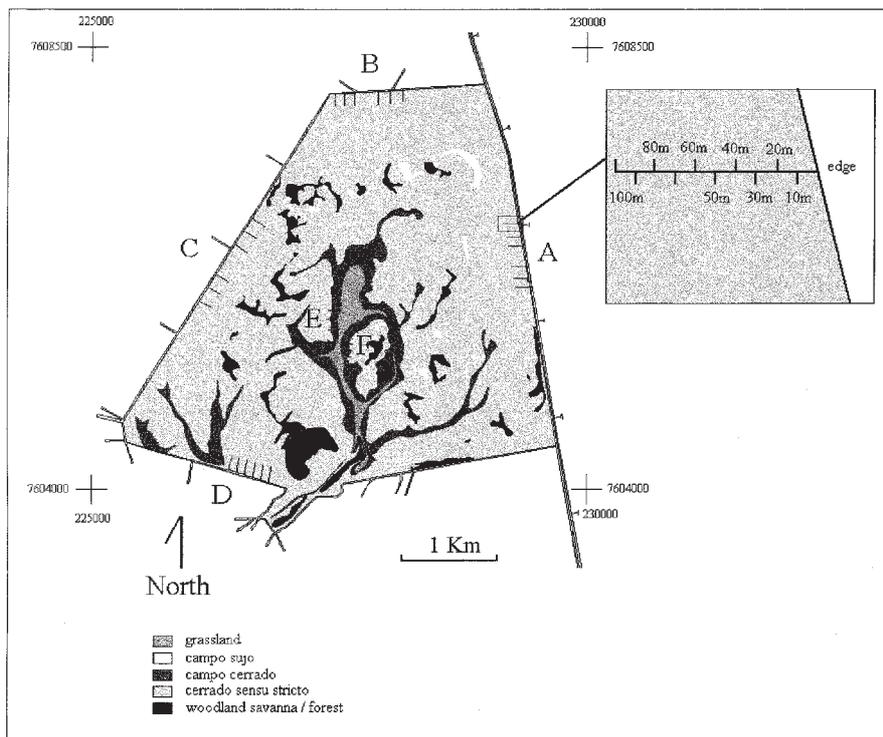


Figure 2. Experimental design adopted in this study. Six groups of six transects each are indicated at different aspects in the reserve: A, B, C, D, E and F (respective directions were: NE, N, NW, SW, W and E).

canopies on the quadrat (1 = no trees in the quadrat and no shading; ... 9 = tall trees in the quadrat and maximum shading).

Only graminoid species occurring in at least 4 samples were included in the analysis, comprising one Cyperaceae and 6 Poaceae species. *Brachiaria decumbens* Stapf. (Poaceae) was excluded from the CCA because this species showed a very typical distribution pattern, occurring only in pure stands and very close to the road margins. In such case, the inclusion of this species would bias the analysis.

Significance of species-environment canonical axes was assessed via unrestricted Monte-Carlo permutations test, also using the CANOCO package (Ter Braak 1991). Results are presented in a triplot diagram of species, sites and environmental variables.

A phytosociological analysis was carried out in order to analyze the behavior of graminoids and the other species, separately in cerrado sensu stricto and in campo cerrado, considering: the relative species density, relative dominance, and relative frequency, as well as the percentual value of importance, as follows (Mueller-Dombois and Ellenberg 1974):

- DR (relative density) =  $100n_i/N$  (%), where  $n_i$  = number of individuals of species  $i$  and  $N$  = number of all individuals
- DoR (relative dominance) =  $100c_i/C$  (%), where  $c_i$  = cover area of species  $i$  and  $C$  = cover area of all species
- FR (relative frequency) =  $100Oc_i/Oc$  (%), where  $Oc_i$  = number of occurrence of species  $i$  and  $Oc$  = number of occurrence of all species VI (value of importance) =  $(DR + DoR + FR)/3$  (%)

To explore interspecific associations among the graminoids in cerrado sensu stricto and in campo cerrado,  $\chi^2$  contingency tables (following Ludwig and Reynolds 1988) were prepared based on a binary matrix of presence-absence data. To remove the influence of the most obvious community heterogeneity, the analysis was conducted in separate subsets of campo cerrado and cerrado sensu stricto. An overall measure of community association tendencies was also obtained through the variance ratio measure. The significance of  $\chi^2$  association tests was assessed at the 0.05 level.

A further interspecific analysis focused on relationships among species abundances, applying Spearman Rank Correlation to species cover values on sample units. The test was performed using the SPSS package (SPSS 1996). Significance of correlation coefficients was assessed at the 0.05 level.

## Results

### *Phytosociological analysis*

The dominant families in cerrado sensu stricto were Poaceae, Myrtaceae, Asteraceae and Malpighiaceae and, in campo-cerrado, Poaceae and Myrtaceae. Eighty-five

species were sampled in cerrado sensu stricto and 36 in campo cerrado, 28 of them being common to both cerrado forms. Considering the graminoid species (Cyperaceae and Poaceae), we sampled 15 and 11 species, respectively in cerrado sensu stricto and in campo cerrado. Two alien grasses were sampled: *Melinis minutiflora* Beauv. and *Brachiaria decumbens* Stapf., both of African origin (Tables 1 and 2).

In cerrado sensu stricto, the graminoid species were present in 53.69% of the samples and accounted for 55.78%, 74.05%, 53.68% and 61.18% of the relative density, relative dominance, relative frequency, and value of importance, respectively (Table 1). In campo cerrado, graminoid species were present in 77.42% of the samples, representing 78.82%, 90.30% and 77.41% of the relative density, relative dominance and relative frequency, respectively, accounting for 82.17% of the value of importance (Table 2).

*Brachiaria decumbens* was sampled only in cerrado sensu stricto and *Melinis minutiflora* only in campo cerrado. These alien species were very abundant where they occurred, being responsible for, respectively, the second and the first values of importance in the communities (Tables 1 and 2). *B. decumbens* occurred in every sample unit at the 0 m distance and, in most samples, it covered 100% of the quadrat; in only one sample it was collected at 10 m from the road. On the other hand, *M. minutiflora* was more disseminated in the central part of the Reserve, following the drainage and tracks.

Apart from these two species and *Tristachya leiostachya*, the same graminoid species appeared as the most frequent in both cerrado forms, sometimes changing positions in rank value of importance. *Tristachya leiostachya* did occur in both forms, but it was much less important in cerrado sensu stricto.

#### *Multivariate analysis*

The results of the CCA, considering both cerrado forms, are summarized in Table 3 and Figure 3. The dispersion along the first axis reflects changes in species composition along a gradient, while the second and third axes reflect only a change in species abundance. The three environmental variables analyzed were poorly correlated to each other.

There is a significant and strong effect of at least one environmental variable on species distribution, evident in the first axis (correlation coefficient of 0.79, Table 3). Much lower values of 0.20 and 0.16 were found in the second and third axes. Overall correlation and first canonical species-environment axis were significant according to a Monte-Carlo test (respectively  $F = 36.15$ ;  $P = 0.01$  and  $F = 13.30$ ;  $P = 0.01$ ). The first axis strongly correlated with canopy density and the second and third axes respectively correlated with the border distance and aspect. Shading was the most important variable, accounting for about 90% of the total variance observed.

Figure 3 also shows *Melinis minutiflora* at the extremity of the gradient related to canopy cover, suggesting that it is strongly associated with unshaded areas. The

Table 1. Graminoid (Poaceae and Cyperaceae) and non-graminoid species sampled in the cerrado sensu stricto herbaceous layer at the Cerrado Pé-de-Gigante Reserve (Santa Rita do Passa Quatro, SP) and their phytosociological parameters, following Mueller-Dombois and Ellenberg (1974).

Species	Family	<i>n</i>	Oc	<i>c</i> (m <sup>2</sup> )	DR (%)	DoR (%)	FR (%)	VI (%)
<i>Rhynchospora exaltata</i> Kunth	Cyperaceae	136	113	11.883	27.59	35.28	26.04	29.63
<i>Brachiaria decumbens</i> Stapf*	Poaceae	25	24	5.510	5.07	16.36	5.53	8.99
<i>Ichnanthus sericeus</i> Hack.	Poaceae	39	29	1.567	7.91	4.65	6.68	6.41
<i>Loudetiopsis chrysothrix</i> (Nees) Conert	Poaceae	28	24	2.380	5.68	7.07	5.53	6.09
<i>Axonopus barbigerus</i> (Kunth) Hitchc.	Poaceae	14	13	1.349	2.84	4.01	3.00	3.28
<i>Echinoalaena inflexa</i> (Poir.) Chase	Poaceae	11	10	0.914	2.23	2.71	2.30	2.42
<i>Axonopus marginatus</i> (Trin.) Chase	Poaceae	11	9	0.782	2.23	2.32	2.07	2.21
<i>Scleria comosa</i> (Nees) Steud.	Cyperaceae	2	2	0.050	0.41	0.15	0.46	0.34
<i>Cyperus diffusus</i> Vahl	Cyperaceae	2	2	0.037	0.41	0.11	0.46	0.33
<i>Aristida jubata</i> (Arechav.) Herter	Poaceae	2	2	0.036	0.41	0.11	0.46	0.32
<i>Digitaria insularis</i> (L.) Fedde	Poaceae	1	1	0.180	0.20	0.53	0.23	0.32
<i>Tristachya leiostachya</i> Nees	Poaceae	1	1	0.175	0.20	0.52	0.23	0.32
<i>Bulbostylis hiriella</i> (Schrad.) Urban	Cyperaceae	1	1	0.036	0.20	0.11	0.23	0.18
<i>Eragrostis articulata</i> (Schrank) Nees	Poaceae	1	1	0.021	0.20	0.06	0.23	0.17
<i>Panicum cayennensis</i> Lam.	Poaceae	1	1	0.021	0.20	0.06	0.23	0.17
Non-graminoid		218	201	8.741	44.22	25.95	46.32	38.82
Total		493	434	33.682	100.00	100.00	100.00	100.00

DR = relative density ( $100n_i/N$  [%]); DoR = relative dominance ( $100c_i/C$  [%]); FR = relative frequency ( $100O_{c_i}/O_c$  [%]); VI = value of importance ( $(DR + DoR + FR)/3$  [%]);  $n_i$  = number of individuals of species *i*; *N* = total number of all individuals;  $c_i$  = cover area of species *i*; *C* = cover area of all species;  $O_{c_i}$  = number of occurrence of species *i*;  $O_c$  = number of occurrence of all species; \* = alien species.

Table 2. Graminoid (Poaceae and Cyperaceae) and non-graminoid species sampled in the campo cerrado herbaceous layer at the Cerrado Pé-de-Gigante Reserve (Santa Rita do Passa Quatro, SP) and their phytosociological parameters, following Mueller-Dombois and Ellenberg (1974).

Species	Family	<i>n</i>	Oc	<i>c</i> (m <sup>2</sup> )	DR (%)	DoR (%)	FR (%)	VI (%)
<i>Melinis minutiflora</i> P. Beauv.*	Poaceae	68	67	13.649	34.34	58.57	36.02	42.98
<i>Echinoalaena inflexa</i> (Poir.) Chase	Poaceae	25	22	1.881	12.63	8.07	11.83	10.84
<i>Ichmanthus sericeus</i> Hack.	Poaceae	19	15	1.440	9.60	6.18	8.06	7.95
<i>Loudetopsis chrysothrix</i> (Nees) Conert	Poaceae	12	11	1.565	6.06	6.72	5.91	6.23
<i>Axonopus marginatus</i> (Trin.) Chase	Poaceae	9	8	0.784	4.55	3.36	4.30	4.07
<i>Rhynchospora exaltata</i> Kunth	Cyperaceae	9	7	0.737	4.55	3.16	3.76	3.82
<i>Tristachya leiostachya</i> Nees	Poaceae	5	5	0.495	2.53	2.12	2.69	2.45
<i>Axonopus barbigerus</i> (Kunth) Hitchc.	Poaceae	4	4	0.320	2.02	1.37	2.15	1.85
<i>Panicum cayennensis</i> Lam.*	Poaceae	3	3	0.034	1.52	0.15	1.61	1.09
<i>Sporolobus indicus</i> (L.) R. Br.	Poaceae	1	1	0.109	0.51	0.47	0.54	0.50
<i>Imperata brasiliensis</i> Trin.*	Poaceae	1	1	0.029	0.51	0.13	0.54	0.39
Non-graminoid		42	42	2.261	21.18	9.70	22.59	17.83
Total		198	186	23.304	100.00	100.00	100.00	100.00

DR = relative density ( $100n_i/N$  [%]); DoR = relative dominance ( $100c_i/C$  [%]); FR = relative frequency ( $100Oc_i/Oc$  [%]); VI = value of importance ( $(DR + DoR + FR)/3$  [%]);  $n_i$  = number of individuals of species *i*; *N* = total number of all individuals;  $c_i$  = cover area of species *i*; *C* = cover area of all species;  $Oc_i$  = number of occurrence of species *i*;  $Oc$  = number of occurrence of all species; \* = alien species.

Table 3. Summary of CCA results (significant values in bold).

AXES	Axis 1	Axis 2	Axis 3	Total inertia
Eigenvalues	0.603	0.034	0.020	4.805
Species–environment correlations	0.793	0.197	0.162	
Cumulative percentual variance:				
of species data	12.5	13.2	13.7	
of species–environment correlation	91.8	96.9	100	
Distance	<b>-0.3463</b>	<b>0.1756</b>	0.022	
Canopy cover	<b>-0.7865</b>	-0.0243	0.0049	
Terrain orientation	-0.1892	0.0205	<b>-0.1558</b>	
				Sum of unconstrained eigenvalues 4.805
				Sum of canonical eigenvalues 0.657

other species are placed in intermediate positions of the gradient, reflecting their occurrence in relatively shaded sample units. The species considered do not seem to be especially affected by the distance of the border nor by the aspect, however, it can be noticed that *Axonopus barbigerus*, *Echinolaena inflexa* and *Loudetiopsis chrysothrix* are positioned relatively far from the border, opposite to *Melinis minutiflora*, and that *M. minutiflora* and *A. barbigerus* also show a negative tendency in relation to the aspect, suggesting a best fit of such species in the Northern positions.

#### Interspecific associations

Interspecific association analysis through  $\chi^2$ -test indicated a strongly negative global association among the graminoids, both in cerrado sensu stricto and campo cerrado (variance ratio = 0.337 in cerrado sensu stricto and 0.379 in campo cerrado). Table 4 summarizes all species relationships, showing that *Melinis minutiflora* is negatively associated with every other graminoid in campo cerrado. In cerrado sensu stricto, a similar overall exclusion pattern was found for *Brachiaria decumbens* and *Rhynchospora exaltata*. The only positive and significant association found was between *Echinolaena inflexa* and *Loudetiopsis chrysothrix*, in campo cerrado.

The Spearman rank correlation analysis, considering species abundances, shows a very similar pattern of relationships (Table 4). All significant correlation coefficients found in both cerrado physiognomies were negative and, here too, *M. minutiflora*, in campo cerrado, and *B. decumbens* and *R. exaltata*, in cerrado sensu stricto, presented the highest negative correlation coefficients with the species showed in Table 4, indicating exclusion.

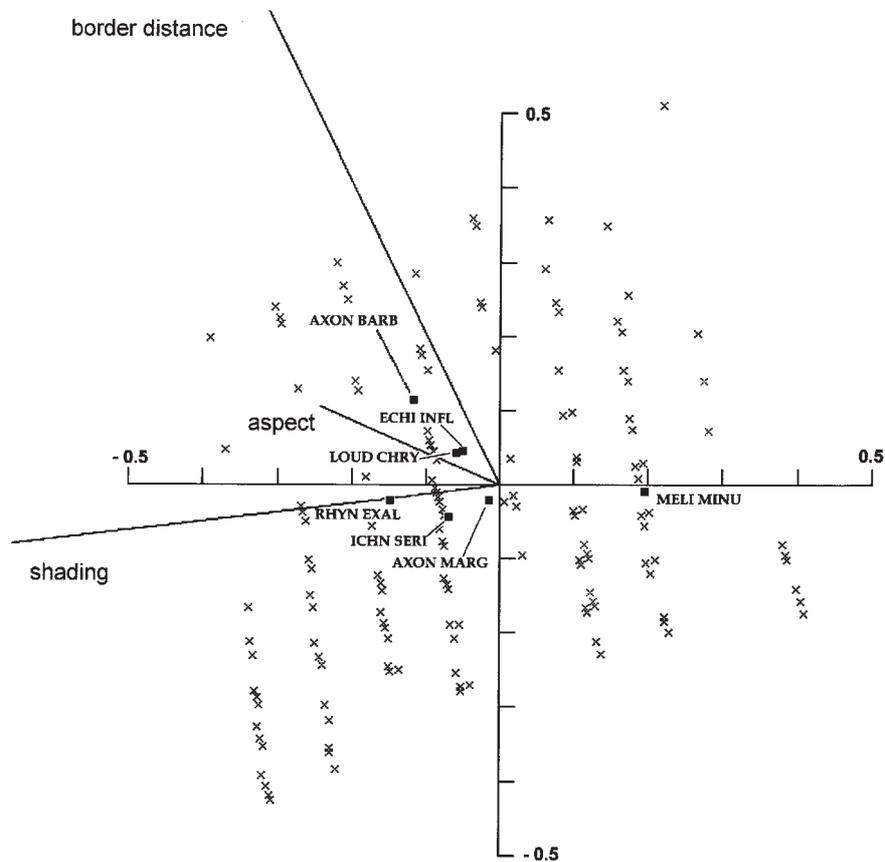


Figure 3. Triplot of the first two canonical axes, showing the seven most frequent graminoid species and the environmental variables analyzed (shading, aspect and the distance from the reserve border).

## Discussion

The results of the present study reveal that the herbaceous community distribution is dictated by *Melinis minutiflora*, in campo cerrado, and by *Rhynchospora exaltata*, in cerrado sensu stricto. Especially *M. minutiflora*, but also *R. exaltata*, act as a background herb, or a matrix, above which other species occupy smaller patches. In an about 10 m wide strip bordering the Reserve, the 'matrix' is formed by *Brachiaria decumbens*.

The  $\chi^2$  association tests and Spearman rank correlation analysis suggest these three species – *M. minutiflora* and *B. decumbens*, both alien grasses, and *R. exaltata*, a native Cyperaceae – have an exclusion effect over native grasses. In campo cerrado, *M. minutiflora* has probably displaced native grasses, notably *Echinolaena inflexa*, which showed the highest values of frequency, dominance and density among

Table 4. Interspecific associations ( $\chi^2$  and Spearman tests) among graminoid species in campo cerrado and cerrado sensu stricto physiognomies (NS = non significant).

Species × species	Cerrado physiognomy	Association type	
		$\chi^2$ -test	Spearman test
<i>Melinis minutiflora</i> × <i>Echinolaena inflexa</i>	Campo cerrado	–	–
<i>Melinis minutiflora</i> × <i>Loudetiopsis chrysothrix</i>	Campo cerrado	–	NS
<i>Melinis minutiflora</i> × <i>Ichnanthus sericeus</i>	Campo cerrado	–	–
<i>Melinis minutiflora</i> × <i>Rhynchospora exaltata</i>	Campo cerrado	–	–
<i>Melinis minutiflora</i> × <i>Axonopus barbigerus</i>	Campo cerrado	–	–
<i>Melinis minutiflora</i> × <i>Axonopus marginatus</i>	Campo cerrado	–	–
<i>Echinolaena inflexa</i> × <i>Loudetiopsis chrysothrix</i>	Campo cerrado	+	–
<i>Brachiaria decumbens</i> × <i>Rhynchospora exaltata</i>	Cerrado sensu stricto	–	–
<i>Brachiaria decumbens</i> × <i>Ichnanthus sericeus</i>	Cerrado sensu stricto	–	–
<i>Brachiaria decumbens</i> × <i>Loudetiopsis chrysothrix</i>	Cerrado sensu stricto	–	–
<i>Rhynchospora exaltata</i> × <i>Axonopus barbigerus</i>	Cerrado sensu stricto	–	–
<i>Rhynchospora exaltata</i> × <i>Loudetiopsis chrysothrix</i>	Cerrado sensu stricto	–	–

the native herbs. In another cerrado patch in the same region – the Emas Cerrado – Pivello et al. (1999) verified that *E. inflexa* and *M. minutiflora* were probably using similar ecological resources, but they were not excluding each other. It has been observed in the present study area, during three years of observation, that *M. minutiflora* has been expanding fast. In cerrado sensu stricto, where *M. minutiflora* is much less abundant (it was not sampled here), *R. exaltata* is the dominant, except in the strip where *B. decumbens* occur. The co-occurrence between *E. inflexa* and *Loudetiopsis chrysothrix* in campo cerrado, attested by the  $\chi^2$ -test, and the negative correlation between their abundances, verified through the Spearman correlation test, probably indicate competition but not exclusion yet. However, these suggestions must be confirmed experimentally.

*M. minutiflora* is best fit to unshaded areas, directed to the North, where sun incidence is higher. According to Klink and Joly (1989), *M. minutiflora* and *B. decumbens* are C<sub>4</sub> species, always collected by those authors in full sun habitats. *Ichnanthus* spp. and *Echinolaena inflexa* are C<sub>3</sub> species, found by them in shaded places. The results of the present study agree with Klink and Joly's (1989), according to these species. On the other hand, *Axonopus* sp. and *Loudetiopsis* sp. – C<sub>4</sub> native species – were found in partially shaded places in the present study and not by those authors.

The distribution of *M. minutiflora* was concentrated in the central part of the Reserve, close to drainage canals. Although it has not been verified experimentally, field observations indicate that this species seems to prefer more humid sites.

Most theoretical models which try to explain plant invasions suggest that 'invaders' need environmental disturbance to become pests (Cronk and Fuller 1995; Groves and Burden 1986; Williamson 1996). Klink (1996a) and Coutinho (1982b) stress the need of disturbance for the invasion of African grasses in cerrados. The

history of the present study area, used by cattle ranching until 2 to 3 decades ago, and the preferred location of the alien grasses, lead to the same belief, concerning their initial establishment. However, it has been observed that, although *M. minutiflora* and *B. decumbens* abundance is much higher the Reserve borders, in tracks or in disturbed soil, *M. minutiflora* is also present in small spots where there is no evident disturbance, but always in open areas. It is then necessary to test if the most important factor for their establishment is light or disturbed soil, as well as water availability.

Also considering the abundance and distribution patterns of *M. minutiflora* and *B. decumbens* – the first was not sampled bordering the roads, where *B. decumbens* dominate, but it was very frequent in tracks inside the Reserve – it seems that *M. minutiflora* established first in the area, followed by *B. decumbens*, which is more aggressive, as evidenced in Emas Cerrado by Pivello et al. (1999). In that area, *B. decumbens*, which was first limited to the road margins, was able to reach the central part of that reserve in a few years. It is very possible that the same is occurring in Pé-de-Gigante Reserve. Pivello et al. (1999) also indicate herb species impoverishment in Emas Cerrado, due to alien grass expansion.

The threat to cerrado plant diversity is today a fact. Surveying the grasses native to cerrado core region, in Central Brazil, Filgueiras (1991) identified around 240 species, 13 of them rare and probably threatened to extinction. Species as *Gymnopogon doelli* – which have physiological attributes that make them less competitive, as low seed production and dormancy (Carmona et al. 1997) – deserve special attention. African grasses, on the other hand, ‘have higher allocation of biomass to leaf production, higher photosynthetic capacity, and are more efficient in the use of nitrogen than native savanna species’ (Baruch et al. 1985; Bilbao and Medina 1990), and also produce more seeds, with higher and faster germination capacity compared to the native species (Klink 1996b), being able to displace native cerrado herbs, as also agree Coutinho and Dionello (1980) and Klink (1996b).

Although there is a new trend among ecologists in accepting the establishment of some alien species as a natural migrating process (Peretti 1998), it is necessary to identify those which are causing serious ecological damage, as we believe are *M. minutiflora* and, in a much higher degree, *B. decumbens*, in cerrados. It may be possible that, with time, invader species lose dominance. However, it was observed in Emas Cerrado (Pivello et al. 1999) that while *M. minutiflora* seemed to have lost dominance with time, *B. decumbens* replaced it, instead of a native grass, and with an even higher dominance.

Some predictions concerning pasture species invasive ability are really worrying, as Lonsdale (1994) says there is a probability of 81% of a pasture species becoming a weed. Therefore, in the case of areas severely colonized by alien grasses, we think eradication procedures must also be taken. However, we also believe it is extremely difficult to eliminate the African grasses in nature reserves for a number of reasons. First, they seem to resist to most mechanical treatments (Pivello 1992; Zúniga 1985); chemical treatment with herbicides are not welcome in natural reserves and,

biological control, less aggressive to the environment, would cause an economical problem, since these species are planted in pastures. This conflict between pastoral interests and those of conservation has also been stressed elsewhere (Lonsdale 1994). However, such species need to be controlled and a next challenge is how to do this, considering all the environmental and economical interests.

We think a most feasible way to control such species leads to the landscape management, as proposed by Hobbs and Humphries (1995), and to the establishment of new economical policies concerned with alien species, as highlighted by Houston and Schreiner (1995). Thus, not only economical interests must be viewed but also environmental aspects which, sooner or later, end up reflecting in the economic scenario. But together with control, people awareness and education on the effects of unplanned introductions, the establishment of regulations for species introduction, prevention and containment in legislation (Cronk and Fuller 1995), weediness prediction of a species before its introduction (Lonsdale 1994), are other necessary actions. As Lonsdale (1994) defends, “research should focus on increase the long-term profitability of pastoralism, not the short-term productivity of land..., terms which are often assumed to be synonymous”.

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