Artículo Científico

Response of degraded pastures in the Brazilian Cerrado to chemical fertilization

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Introduction

The total area of planted pastures in Brazil has recently been estimated to be over 100 million hectares (Mha) and, with the exception of 8 Mha of temperate forage species planted in the southern region, most of the remaining area is planted with grasses of African origin, predominantly *Brachiaria* spp. (Zimmer and Euclides Filho, 1997). In the Cerrado region estimates of the area planted to these species range from 40 to 50 Mha (Macedo, 1995; Zimmer and Euclides Filho, 1997).

These pastures are usually installed after the savanna has been cleared and planted to rice or another grain crop, and the *Brachiaria* takes advantage of the residual fertilizer applied to these crops. For 2 to 3 years these pastures are generally productive usually supporting three or more animals per hectare, and liveweight gains of over 500 kg/ha per year. Subsequently grass regrowth starts to decrease, animal weight gains diminish, and the pastures become invaded by non-palatable species, bare patches appear in the sward and often the soils become compacted and invaded by termite mounds. The cause of this process of pasture decline, or degradation, is generally attributed to overgrazing, especially in the dry season, and the fact that maintenance fertilization is rarely practiced (Kichel and Miranda, 1999; Macedo, 1995; Paulino et al., 1995). The lack of regrowth is attributed to a decline in soil fertility, especially the availability of N and P, and also to soil compaction (Andrade and Leite, 1988; Paulino et al., 1995; Sanzonowicz et al., 1986; Werner, 1984). The recent data of Rezende et al. (1999) suggest that pasture decline is initiated when high animal stocking rates cause a reduction in the deposition of senescent plant material (litter) and nutrients recycled by this pathway. Implicit in this hypothesis is the suggestion that nutrients deposited on the soil as animal excretions are less efficiently recycled, which in the case of N may be due to higher losses from leaching or volatilization (Ferreira et al., 1995a, 1995b; MacDiarmid and Watkin, 1972; Vallis and Gardener, 1984) and, in contrast to litter, the distribution of dung and urine is non-uniform, much of them being deposited in rest areas and close to the drinking troughs where the vegetation is so trampled that it cannot benefit from this nutrient input.

For the recovery or reform of these pastures it is generally recommended that the sward should be ploughed and harrowed and the new pasture re-seeded either immediately, or after the planting of an arable crop which gives a quick financial return to pay for the operations (Kichel and Miranda, 1999; Kluthcouski et al., 1991; Zimmer and Miranda, 1994). However, many land owners in the Cerrado region lack the machinery necessary for planting and harvesting grain crops and/or access to credit to pay for pasture reform, so today is estimated that between 50% and 80% of the *Brachiaria* pastures (20 to 40 Mha) in the Cerrado region are moderately to severely degraded (Kichel and Miranda, 1999; Macedo, 1995). The object of this study was to examine the possibility of recovering the re-growth of degraded *Brachiaria* pastures with the use of chemical fertilizers only, without disturbing the soil and without re-seeding, at three different sites in the Cerrado region.

Materials and methods

Sites. The trials were installed at three different sites in the Cerrado region: (1) Fazenda Barreirão, Pirancanjuba, Goiás; (2) Field station, Embrapa-Gado de Corte, Campo Grande, Mato Grosso do Sul; and (3) Fazenda Cachoeira, Uberlândia, MG. At sites 1 and

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2 the degraded pasture was of *B. decumbens* and at site 3 *B. ruziziensis*. All trials were conducted during the rainly season, being planted on 17 December 1996, 7 January 1997, and 6 January 1997, respectively, for sites 1, 2, and 3. The soil type and analysis for each site are given in Table 1.

Experimental design. The experimental design was the same for all three sites consisting of nine treatments with six replications. The treatments consisted of the application of N, P, K, and S at two different levels (0 and 100 kg/ha of N, P_2O_5, and K_2O) and 65 kg/ha of S; plus a treatment with N, P, and K, but without S, to examine the possibility of responses to this element, given the fact that the usual sources of N and P (ammonium sulphate and single super-phosphate) contain S. The 54 plots each measuring 2.0 x 1.5 m with a 0.5 m border between each one were arranged in a complete block design.

Installation and fertilization. At the start of each experiment all plants in the area were cut to a uniform height of 10 cm (uniformization cut) and the material discarded. The fertilizers were then applied uniformly to each plot in the forms of ammonium sulphate (22% N, 24% S), potassium chloride (61% K), single superphosphate (20% P_2O_5, 13% S, 19% CaO), and micronutrients (fritted trace elements FTE BR-12). The control treatment was left without fertilizer addition and in the NPK treatment (without S) the source of N was calcium nitrate (22% N, 13.6% CaO) and of P triple superphosphate (45% P_2O_5, 20% CaO, 1.5% S). To balance the S and Ca contained in the ammonium sulphate and single superphosphate additions of agricultural gypsum (18.5% S, 32.5% CaO) were made in the treatments without N or P. For full details of the quantities of fertilizers applied in the different treatments see Table 2.

Harvests. At site 1 (Fazenda Barreirão) the harvest was made at 71 days after the uniformization cut, at site 2 (Campo Grande) after 41 days, and at site 3 (Fazenda Cachoeira) after 45 days. An area of 1.0 x 1.0 m at the center of each plot was cut to a height of 10 cm and the material dried at 65 °C for > 72 h and weighed.

Table 1. **Soil type and chemical analysis of the soils at the three sites before fertilizer application.**

Soil type (Brazilian classification)[a]	Prof. (cm)	pH in H_2O	Al^{3+}	$Ca^{2+} + Mg^{2+}$	Ca^{2+}	Mg^{+2}	P	K
			mmol$_c$/dm^3				mg/kg	
Site 1:								
Dark red Latosol (cl)	0-20	5.0	0.1	2.5	1.9	0.7	0	34
Site 2:								
Dark red Latosol (cl)	0-20	5.6	0	6.5	4.5	2.0	1.3	20
Site 3:								
Dark red Latosol (sa)	0-20	5.3	0.6	0.4	nd[b]	nd	1.1	51

a. Soils classified as: cl = clayey texture; sa = sandy texture.
b. nd = not determined.

Table 2. **Quantities (g) of fertilizers added per plot (3 m²).**

Treatment	Ammonium sulphate	Calcium nitrate	Single super-phosphate	Triple super-phosphate	KCl	FTE BR-12	Gypsum
NPKS	150	—	150	—	49.2	9	—
NPS	150	—	150	—	—	9	—
NKS	150	—	—	—	49.2	9	126
PKS	—	—	150	—	49.2	9	126
NS	150	—	—	—	—	9	126
PS	—	—	150	—	—	9	126
KS	—	—	—	—	49.2	9	126
NPK	—	136	—	66.7	49.2	9	—

Results and discussion

In all soils the available phosphorus (Mehlich I) was very low, being undetectable at site 1 (Fazenda Barreirão) (Table 1). Potassium levels were lowest at sites 1 and 2, but these levels (~20 mg/kg) are not exceptionally low for *Brachiaria* which is well adapted to low fertility conditions.

The dry matter (DM) production of the grasses did not respond significantly to additions of sulphur, in fact there was a strong tendency at all three sites for DM yields to be higher in the NPK treatment than that where NPK and S was added (Table 3). It is almost certain that this was not due to any toxic effect of higher levels of S, but to the fact that the N in this treatment was added as calcium nitrate. In degraded pastures the microbial biomass is usually limited by the availability of N, and when ammonium is added to these soils, N uptake by plant roots tend to be in severe competition with N incorporation into the microbial biomass (Cadisch et al., 1996; Cantarutti et al., 1999; Robertson et al., 1993). It is well documented that the microbial biomass holds a strong preference for the assimilation of ammonium over nitrate (Brown et al., 1974; Davidson et al., 1991; Recous and Mary, 1990), so it is probable that the higher DM responses of the grasses to this latter form of N was due to their greater ability to compete for nitrate. The other advantage of nitrate over ammonium may be that plant uptake of the latter causes acidification of the rhizosphere, whereas nitrate has a tendency to elevate rhizosphere pH which in these acid soils may be advantageous for the uptake of other nutrients (Bernardo et al., 1945; Franco and Munns, 1982).

Table 3. **Dry matter (g/m^2) response of *Brachiaria* spp. to the application of nutrients at three different sites in the Brazilian Cerrado. Means of six replicates.**

Treatment	Site 1 (Fazenda Barreirão)	Site 2 (Campo Grande)	Site 3 (Fazenda Cachoeira)
NPK	644.2 a*	701.1 a	323.9 a
NPKS	584.7 ab	482.0 abcd	233.3 ab
NPS	443.0 b	626.6 ab	187.1 b
NKS	282.6 c	589.4 abc	147.7 bc
PKS	196.6 c	336.4 d	52.9 e
NS	290.1 c	496.2 abcd	139.8 bcd
PS	184.1 c	340.2 d	75.3 cde
KS	189.8 c	354.8 cd	66.0 de
Control	188.4 c	388.2 bcd	67.4 cde
C.V. (%)	10.5	13.8	18.9

* Means followed by the same letter in the same column are not significantly different at P = 0.05 (Tukey test). Statistical analyses made on transformed data ($\sqrt{x}$).

There were no significant responses of the application of K or P, alone or together at any site in the absence of N, and there was only a modest but significant response to the application of N alone at one site (Fazenda Cachoeira) (Table 3). Separating the main interactions of N and P in these data shows very clearly the importance of the addition of N together with P for the best recovery of the sward (Table 4). The addition of P in the absence of N made almost no effect on the recovery of the pasture at any of the three sites. In the presence of N there were large and significant ($P < 0.05$) DM responses at Fazenda Barreirão (site 1) and Fazenda Cachoeira (site 3), of 64% and 46%, respectively. At site 2 (Campo Grande) there was no significant response to P addition in the presence of N suggesting that P was less deficient at this site, which is consistent with the results of the soil analysis (Table 1). For the principal interactions of P and K there were no significant responses to P addition in the presence of applications of K at sites 2 and 3 (Table 5), but there was a significant ($P < 0.05$) response to P at Fazenda Barreirão which can be explained by the fact that available P in this soil was undetectable using the Mehlich 1 extraction technique.

At all sites the complete fertilization with N, P, and K showed a strong tendency to give the highest DM yields, and this was especially so ($P < 0.05$ at sites 1 and 3) when calcium nitrate was used as an N source instead of ammonium sulphate (Table 3).

Table 4. **Dry matter production of degraded pastures of *Brachiaria* spp. Main interactions of the effects of the application of P and N fertilizers. Means of six replicates.**

Treatment	Dry matter accumulation (g/m^2)		
	Fazenda Barreirão	Campo Grande	Fazenda Cachoeira
Minus N:			
-P	189.0 c*	371.5 b	66.7 c
+P	190.3 c	338.3 b	64.1 c
Mean	189.7 B	354.9 B	65.4 B
With N:			
-P	286.3 b	542.8 a	143.7 b
+P	513.8 a	663.8 a	210.2 a
Mean	400.1 A	603.3 A	177.0 A
C.V. (%)	11.3	13.7	19.0

* Means in the same column followed by the same letter are not significantly different at P = 0.05 (Tukey test – lower case letters) and F test (capital letters). Statistical analyses made on transformed data ($\sqrt{x}$).

Table 5. **Dry matter production of degraded pastures of *Brachiaria* spp. Main interactions of the effects of the application of P and K fertilizers. Means of six replicates.**

Treatment	Dry matter production (g/m^2)		
	Fazenda Barreirão	Campo Grande	Fazenda Cachoeira
Minus P:			
- K	239.2 b*	442.2 a	103.6 a
+ K	236.1 b	472.1 a	106.8 a
Mean	237.6 B	457.1 A	105.2 A
With P:			
- K	313.6 ab	483.4 a	131.2 a
+ K	390.6 a	518.7 a	143.1 a
Mean	352.1 A	501.1 A	137.1 A
C.V. (%)	16.4	15.5	20.2

* Means in the same column followed by the same letter are not significantly different at P = 0.05 (Tukey test – lower case letters) and F test (capital letters). Statistical analyses made on transformed data ($\sqrt{x}$).

Conclusions

At all three sites in the Cerrado region it was shown that N was the most limiting macronutrient for the recovery of degraded pastures of *Brachiaria* spp. When N was no longer limiting P became the next most limiting nutrient. There were no signs of any deficiency of S in these degraded pastures. The utilization of complete fertilization with NPK and micronutrients gave the best recovery of plant DM production, and the results suggested that calcium nitrate was more efficient than ammonium sulphate for this purpose.

These results suggest that at many sites in the Cerrado, pastures may be recovered by addition of chemical fertilizers only, without ploughing and re-seeding. Similar results were reported earlier for pastures at higher levels of fertilization for *B. decumbens* and *Panicum maximum* in the State of São Paulo (Primavesi and Primavesi, 1997).

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Resumen

Se estima que en la región de los Cerrados de Brasil existen por lo menos 40 millones de hectáreas cubiertas con especies de *Brachiaria* y otras gramíneas de origen africano, de las cuales más del 50% se encuentran degradadas, siendo su productividad anual inferior a 50 kg/ha de peso vivo animal. Los productores en esta región no tienen la maquinaria ni los recursos suficientes para arar y resembrar sus pasturas con el fin de que recuperen su productividad. En este estudio se evaluó el efecto de la fertilización sin remoción del suelo, como una opción para recuperar pasturas de *Brachiaria*. Para el efecto se establecieron tres ensayos, dos con *B. decumbens* y uno con *B. ruziziensis*, en los cuales se aplicaron nueve tratamientos en seis repeticiones, consistentes en diferentes combinaciones de N, P, K y S (0 y 100 kg/ha de N, P_2O_5 y K_2O) y 65 kg/ha de S, más un testigo sin fertilización. La evaluación de producción de MS se realizó a 41 y 71 días. En ausencia de N no se encontró respuesta a la aplicación de P, K o S solos o en mezcla. Se encontró una ligera respuesta, aunque significativa, a la aplicación de N en el sitio donde el P era menos deficiente. En los tres sitios se encontró que el N era el nutrimento más limitante para la producción de *Brachiaria*, seguido del P. La aplicación de un fertilizante completo con NPK más microelementos dio los mejores resultados. El nitrato de calcio fue más eficiente que el sulfato de amonio para recuperar la productividad de estas pasturas. Los resultados sugieren que en muchos sitios del Cerrado de Brasil es posible recuperar pasturas degradadas de *Brachiaria* sin necesidad de remover el suelo y resembrar.

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