RESPONSE OF ANDROPOGON GRASS TO P FERTILIZERS AND LIME IN A DARK-RED LATOSOL OF THE CERRADOS[1]

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ABSTRACT - This study intended to determine (i) the amount of P required for the establishment of andropogon grass (*Andropogon gayanus* Kunth) in an acid soil; (ii) the effect of moderate amount of lime on the response to P; (iii) the relative efficiency of a low reactivity of rock phosphate (RP) and (iv) the effect of the rate of P applied at establishment on the response to annual refertilization rates. The effect of P applied at establishment, from two P sources and three annual refertilization rates were investigated at two lime levels in a virgin clayey Haplustox. Lime reduced the amount of P needed to produce 2000 kg/ha of forage dry matter yield from 180 to 78 P kg/ha^{-1}. Forage yield obtained with a rock phosphate RP improved on time reaching similar yield than with same level of P applied as triple superphosphate (TSP) in the fourth year. Initial P rates of 52 P kg/ha^{-1} applied as TSP were high enough when lime was also applied. Higher P rates improved first and second year productivity only. Check plots receiving 13 or 26 P kg/ha^{-1} annually produced more forage yield by the third year than plots receiving highest initial P rate.

Index terms: andropogon, P fertilization, liming, refertilization, rock phosphate, acid soils.

RESPOSTAS DO CAPIM ANDROPOGON À APLICAÇÃO DE FÓSFORO E CALCÁRIO EM LATOSSOLO VERMELHO-ESCURO DOS CERRADOS

RESUMO - Essa pesquisa visou determinar: (1) a quantidade de P necessária para o estabelecimento de (*Andropogon gayanus* Kunth) em solo ácido; (2) o efeito de níveis de calcário sobre a resposta da gramínea a P; (3) a eficiência relativa de Fosfato de Rocha (FR) de baixa solubilidade; (4) o efeito da quantidade de P aplicado no estabelecimento do andropógon nas reposições anuais de P. Foram estudados os efeitos de duas fontes de P no estabelecimento e em três níveis de reposição anual, na presença de duas doses de calcário em um Latossolo argiloso. O calcário reduziu a quantidade de P de 180 para 78 kg/ha necessária para produzir 2.000 kg de matéria seca (MS)/ha. A produção de MS obtida com aplicação de FR atingiu produção semelhante a obtida com a mesma quantidade de P aplicada como SFT no quarto ano. A aplicação inicial de 52 kg de P/ha como SFT assegurou bom estabelecimento na presença de calcário. Níveis altos de P aumentaram a produtividade no primeiro e segundo ano. Os tratamentos com reposição anual de 13 ou 26 kg de P/ha produziram mais no terceiro ano do que aqueles que receberam altos níveis de P no estabelecimento.

Termos para indexação: andropógon, adubação, fósforo, calagem, refertilização, fosfato de rocha, solos ácidos.

INTRODUCTION

The establishment of pastures in central Brazil has been based on grasses introduced from relatively more fertile soils of the savannas of Africa. Grasses of the genus Hyparrhenia, Melinis, Panicum and Setaria were established by broadcasting seeds on

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disturbed, relatively rich soils of cleared "Cerradão" areas. The expansion of pastures into poorer soils on "campo cerrado" and "campo limpo" phases of Cerrado was possible with the introduction of less demanding grasses of the genus Brachiaria and, more recently, Andropogon. Although these grasses are well adapted to acid, infertile soils, the need for application of P fertilizer has been recognized early in the process of pasture development. The well known Ca and Mg deficiencies of cerrado soils justify the use of P sources rich in these nutrients or the application of dolomitic lime at moderate rates which do not change soil pH but supply the needed Ca and Mg nutrients. The need for application of additional nutrients in some specific soil conditions has been documented, especially for legume-based pastures (Couto & Sanzonowicz, 1983).

Although some tropical grasses can utilize efficiently residual fertilizer previously applied to crops and pastures (Couto et al. 1985), the establishment of these grasses on newly opened areas of low fertility soils requires relatively high rates of P fertilizers.

The objectives of the experiment reported in this paper were: (i) to determine the amount of P required for establishment of Andropogon pastures in a virgin soil of the Cerrados, (ii) to determine the relative efficiency of sources of P, (iii) to examine the convenience of annual refertilization of the established pasture when water soluble P sources are used and, (iv) to determine the effect of moderate amounts of lime on the response of Andropogon to P.

MATERIALS AND METHODS

A field experiment was established in a recently cleared area of Cerrado at the Centro de Pesquisa Agropecuária dos Cerrados (CPAC) Research Station near Planaltina, DF, Brazil. The soil has been classified as Dark-Red Latosol, Cerrado phase in the Brazilian soil classification system which corresponds to a clayey, kaolinitic isohyperthermic, Typic Haplustox in the U.S. Soil Taxonomy. The soil is known to have a high P fixing capacity (Le Mare 1982, Smyth & Sanchez 1980), high Al saturation throughout a deep, well drained profile with very fine granular structure. Detailed description of this and other soils of the Cerrados is given elsewhere (Goedert 1983).

The experiment consisted of two lime levels (0 and 1.5 ton/ha^{-1} of a product containing 43% CaO and 9% MgO) and two sources of P, triple superphosphate (TSP, 21% total P and 20% water soluble P) and one rock phosphate (RP) of low reactivity (10.8% total P and 0.1% P soluble in 2% citric acid). TSP was applied at 26, 52, 104 and 208 P kg/ha^{-1} and PR at 52 and 104 P kg/ha^{-1} on the base of total P. Two additional treatments consisting of PR at 52 P kg/ha^{-1} plus 26 P kg/ha^{-1} as TSP and a check (0 P kg/ha^{-1}) were also included. A blanket application of Zn, Mo, S, K and Mg was made in all plots at rates of 4, 0.2, 90, 74 and 46 kg/ha^{-1} respectively. No nitrogen was applied at planting nor during the five years of duration of the experiment.

Lime levels were applied to 26x54 m plots in a randomized complete block design and P levels and sources to subplots 12x12 m ramdomized within lime treatments. Each subplot was subdivided into 4x12 m sub-subplots the second year and three refertilization levels (0, 13 and 26 P kg/ha^{-1}, on the base of total P) were applied to plots receiving TSP annualy thereafter, at the beginning of the rainy season. Plots receiving PR received the same refertilization rates the second year only and those corresponding to PR and TSP treatment (PR+TSP) were not refertilized during the experiment. Alleys 2 m wide were kept between subplots but there was no separation between sub-subplots. Sampling area was 0.95x12 m or two 1x4 m quadrats within each subplot and forage was cut every time modal height reached 40 cm. The experiment was established in November 1979 and cut once during the first rainy season. Two to three cuts were made each year thereafter, with a total of eleven cuts over five rainy seasons reported in this paper.

Experimental error was computed for each refertilization treatment assigned to sub-subplots, independently, within each initial rate and source. All comparisons between treatments have been made at the level of sub-subplot, on the basis of a mean standard error.

RESULTS AND DISCUSSION

First year response

Forage yields during the first growing season were extremely low with all P sources other than TSP, ranging from 62 kg/ha^{-1} for the check to 347 kg/ha^{-1} for the highest rate of PR (104 P kg/ha^{-1}). Triple superphosphate and phosphate rock applied at 52 P kg/ha^{-1} combined with 26 P kg/ha^{-1} as triple superphosphate, were the only treatments yielding significantly higher than the check.

The slow growth rates and low yields observed during the first year with these P sources contrast with those observed in plots receiving TSP which yielded over 3000 kg/ha^{-1} at the highest P rates, despite the well known slow initial growth rate of Andropogon seedlings.

Forage yield increased sharply with increasing P rates applied as TSP. Although there were no statistically significant differences in forage yield obtained with 26 and 52 P kg/ha^{-1} when no lime was applied, there was considerable increase in forage yield with all other P rates up to the maximum of 208 P kg/ha^{-1} (Fig. 1). This shows the extreme P deficiency of the soil and the ability of Andropogon to respond to higher soil fertility despite its adaptation to acid, infertile soils.

The rather low lime rate applied increased forage response to P fertilizer, as shown by the significant difference in yields corresponding to 26 and 52 P kg/ha^{-1} in the presence of lime, and the higher yield observed with lime at all P rates except the lowest. The favourable effect of a moderate application of lime is clearly shown in Fig. 1, where there was same production at considerably lower levels of P when lime was applied. Data available do not establish whether this is the result of reduced P fixation, improved P uptake or effect of improved Ca nutrition.

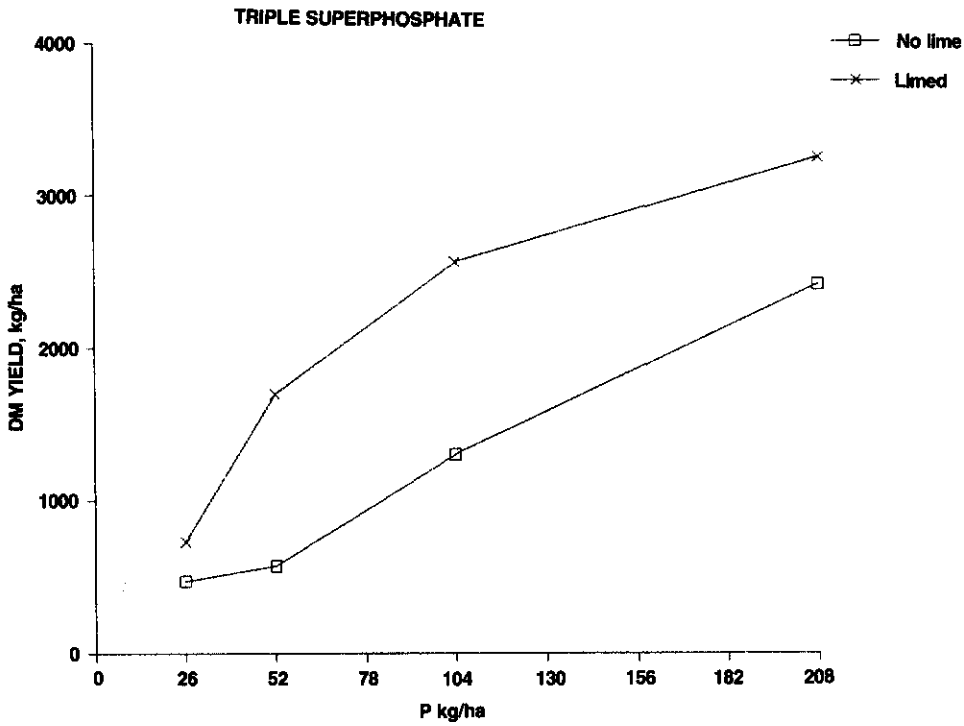

FIG. 1. Annual forage yield of *A. gayanus* with P rates applied as TSP at establishment, without lime and with 1.5 ton/ha^{-1} of lime.

Effect of initial rates over years

The combined analysis of results of all cuts collected during the second to fifth years was done by adding together all cuts performed within the same growing season.

There was a highly significant difference in yield observed between initial levels of P applied as TSP, during the first and second years. It became less important in magnitude in time and was almost negligible in the fourth and fifth years. Similar effects were observed with lime which considerably improved yields and plant response to P fertilizer during the first and second years of the experiment but showed less effect in later years (Fig. 2).

This was the result of improved performance in time of Andropogon growing on plots receiving no lime and lower P rates and a declining forage yield on plots at higher P rates, probably as a result of other nutrient deficiencies despite all plant residues being returned to each plot.

The effect of N deficiency on forage yield of Brachiaria and Andropogon pastures established earlier was repeatedly observed by means of N application to small plots within enclosures. However, no N is applied to pastures in the Cerrado because of the high price of N fertilizer relative to the value of livestock products in dominantly cow-calf operations.

The improved performance of Andropogon over the years on plots not receiving P fertilizer is shown dramatically by check plots. The

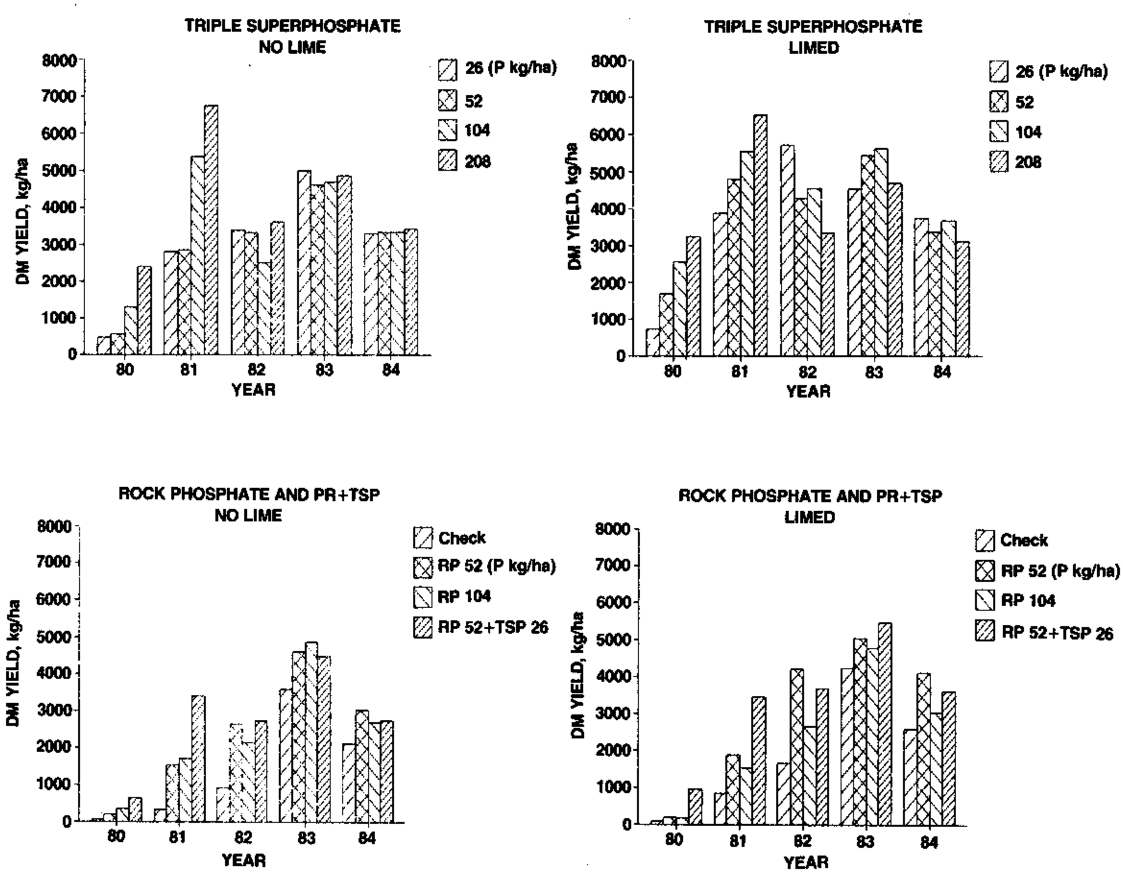

FIG. 2. Annual forage yield of *A. gayanus* with several rates of P from TSP and PR applied at establishment, without annual refertilization.

ability of Andropogon to develop an extensive root system in acid, infertile soils and utilize soil P more efficiently than other grasses has been shown in previous research (Goedert et al.' 1985, Couto et al. 1985). The ability of native strains of vesicular Micorrhiza to multiply in the presence of Andropogon roots and its beneficial effect on P absorption by plants growing in soils where andropogon was previously grown is being studied by other researchers at CPAC. However, the increasing importance in time of organic P in the supply and cycling of plant P should not be overlooked in permanent pastures (Cole et al. 1978).

Rock phosphate, which performed very poorly initially, improved in time, reaching productivity levels similar to those obtained with TSP in the fourth year. The application of 26 P kg/ha^{-1} together with 52 P kg/ha^{-1} as PR was considerably better than PR alone initially, but the effect was only slightly better than 26 P kg/ha^{-1} as TSP (Fig. 2).

The relative efficiency of PR in time, expressed as percent of forage yield obtained with the same rate of P as TSP applied at planting is shown in Fig. 3. Forage yields obtained with PR+TSP (52 P kg/ha^{-1} and 26 P kg/ha^{-1} respectively), is expressed as percent of forage yield of plots receiving 26 P kg/ha^{-1} as TSP in the same figure. The graphs show that despite the low reactivity of the PR used, forage yields obtained with this source were similar to those obtained with the same level of P applied as TSP in the fourth year. Rock phosphate plus TSP yielded higher than TSP alone initially, when no lime was applied,

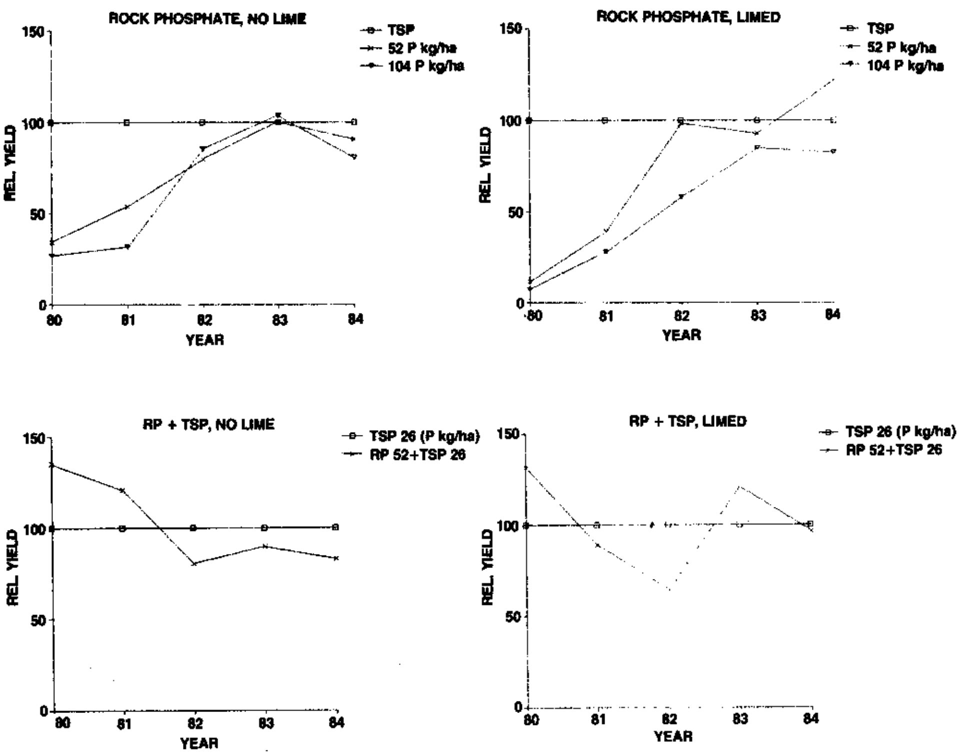

FIG. 3. Relative annual forage yield of *A. gayanus* with two levels of P applied as PR, expressed as percentage of yield obtained with same rate of TSP and, relative yield of PR (52 P kg/ha^{-1}) plus TSP (26 P kg/ha^{-1}), expressed as percentage of yield obtained with TSP only (26 P kg/ha^{-1}), applied at establishment.

but declined in time to yield levels similar to TSP alone.

Effect of refertilization rates

The effect of annually applied TSP was greatest at 26 P kg/ha^{-1}, especially when lime was not applied. Table 1 presents a summary of forage yields obtained at all rates of annual refertilization for all initial levels of P. The most frequently observed response was at 26 P kg/ha^{-1}, probably the result of 13 P kg/ha^{-1} being too low for soils of such high P fixing

TABLE 1. Total annual forage yield of Andropogon grass with several initial rates of P fertilizers and three annual refertilization rates.

Year	Initial P rate	Annual refertilization rates (P kg/ha)					
		0	13	26	0	13	26
		No lime			Limed		
	P kg/ha	Annual forage yield, kg/ha					
		Triple superphosphate					
81	26	2813	2830	3832	3877	4118	4178
82	26	3390	3302	2988	5712	4589	3948
83	26	4991	5569	6014	4536	5999*	5977*
84	26	3302	2983	3525	3748	3500	3525
81	52	2854	4272*	3060	4802	5015	5972
82	52	3318	3258	2951	4281	4859	4684
83	52	4611	5331	6769*	5434	6217	6208
84	52	3344	3039	3016	3380	3944	3759
81	104	5368	4352	6080	5544	6796	7944*
82	104	2509	3680	4344*	4553	4744	4765
83	104	4693	5500	6227*	5619	5688	6439
84	104	3341	3644	3796	3676	3936	4067
81	208	6756	7800	6360	6529	7284	7104
82	208	3613	4640	4290	3355	5042*	4438
83	208	4868	5635	5669	4694	6357*	5688
84	208	3423	3158	4296	3130	4530*	4332
		Rock phosphate +					
81	52	1540	1614	1384	1877	2030	1249
82	52	2647	2650	3512	4214	4987	4650
83	52	4618	4944	5415	5040	7321*	7258*
84	52	3034	3141	2934	4115	3969	4042
81	104	1704	1891	1707	1540	1673	1477
82	104	2145	3020	3633*	2649	5845*	3559
83	104	4872	5394	6232*	4779	6609*	8140*
84	104	2697	3429	3111	3032	4563*	3462
		Check					
81	0	326	768	1218	836	2025	2500
82	0	914	2250	3670*	1661	4779*	5967*
83	0	3584	5903*	7411*	4237	7163*	8040*
84	0	2116	4112*	4321*	2589	4634*	4418*

+ Refertilization rates applied the second year only.

* Significantly different to 0 P refertilization rate (p=0.05).
Mean standard error = 499 (n=3).

capacity. The fact that there was response to refertilization at all levels of initially applied P shows the importance of freshly applied P in this soil. Initial rates higher than 26 P kg/ha^{-1} improved pasture establishment and forage yield in the early years of the experiment but annually applied fertilizer was needed for all initial rates to mantain high forage production.

Response to PR applied the second year was observed at both initial levels. The most frequent response to refertilization was observed in limed plots which received RP. This effect is probably due to more vigorous plants responding to annually applied P, more than the result of lower efficiency of RP in the presence of lime. The higher yield observed in limed plots seems to confirm this.

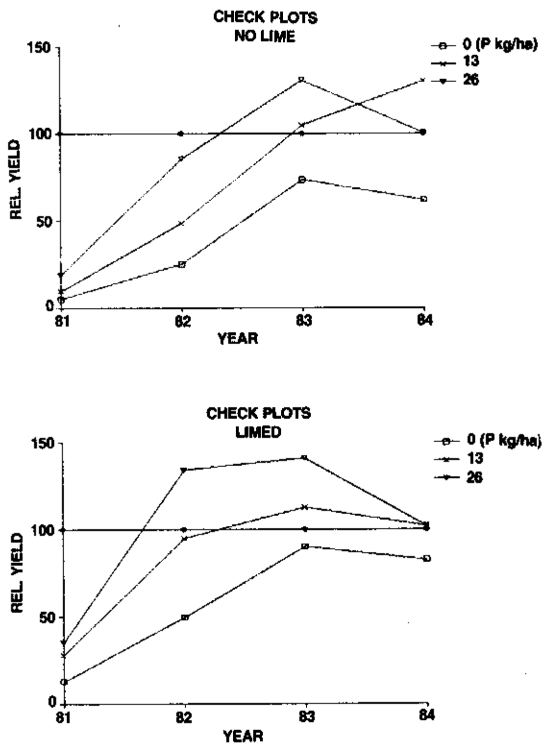

FIG. 4. Relative annual forage yield of *A. gayanus* in check plots (0 P at establishment) receiving 0, 13 or 26 P kg/ha^{-1} annually, expressed as percentage of yield obtained with highest innitial P rate (208 P kg/ha^{-1}) as TSP and same annual refertilization rate.

Check plots responded more to annual refertilization than plots receiving P fertilizers and in four years reach productivity levels close to or higher than those observed in plots receiving high initial P applications (Fig. 4). Morover, check plots receiving no annual refertilization produced considerable forage yield (over 4200 kg/ha^{-1}) by the fourth year.

There was little opportunity for fertility transfer between plots under cutting management; all plant residues were returned to each individual plot. Also, a very limited volume of soil of other plots could be explored by plants growing in check plots since plots were relatively large with respect to the sampling area. The high performance of Andropogon in check plots without refertilization should be attributed to the deep root system that the grass develops over time and permits the exploration of a large volume of soil, and confirms the ability of this grass to use efficiently low available sources of P (Goedert & Lobato 1984). Also, the association of Andropogon with indigenous micorrhizal fungi, observed by other researchers, could explain the improved yields over time observed in check plots.

CONCLUSIONS

1. First year Andropogon forage yields were closely related to the level of P applied as TSP, up to 208 P kg/ha^{-1}. The moderate rate of lime applied improved forage response to P and maximum forage yield. The amount of P fertilizer required to produce 2 ton/ha^{-1} was reduced from about 180 P kg/ha^{-1} without lime to about 78 P kg/ha^{-1} with lime. A P rate of approximately 52 P kg/ha^{-1} was high enough for successful establishment and good production of Andropogon when lime was applied. Higher P rates improved first and

second year productivity but had no advantage thereafter.

2. Forage production from plots receiving RP was no higher than the check plots during the first year but their efficiency improved in time, reaching productivity levels comparable to those obtained with TSP by the fourth year. Rates of P (from RP) higher than 52 kg/ha^{-1} did not improve yield during the five years of the experiment. The application of TSP with PR improved initial performance of PR but yields were not appreciably better than for TSP alone.

3. Although it required considerably more time, Andropogon established without P fertilizers or lime, reaching levels of productivity similar to fertilized plots by the fourth or fifth year, confirming its excellent adaptation to acid, low fertility soils.

4. Annual refertilization produced significant forage yield increase during most years, specially with 26 P kg/ha^{-1}, but the response was independent of sources and initial P rate. Response to annual refertilization was more frequent in the presence of lime, especially at the 13 P kg/ha^{-1} rate.

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