ANDROPOGON GRASS CONSORTIUM WITH STYLO IN TWO TIMES: THE FORAGE RESPONSE AND SOURCES OF PHOSPHORUS RATES

CONSÓRCIO DE CAPIM ANDROPÓGON COM ESTILOS ANTES EM DOIS MOMENTOS: RESPOSTA DA FORRAGEM A NÍVEIS E FONTES DE FÓSFORO

Rilner Alves FLORES[1]; Leonardo Santos COLLIER[1]; Carlos Leandro Rodrigues dos SANTOS[2]; Bernardo Melo Montes Nogueira BORGES[3]; Leandro Rosatto MODA[3]; Átila Reis da SILVA[4]

1. Professor, Doctor, Soils Sector of the School of Agronomy, UFG, Goiania, GO, Brazil. rilner1@hotmail.com; 2. Post Doctorate in Agronomy, Institute of Exact Sciences and Earth, UFMT, Barra do Garças, MT, Brazil; 3. Doctoral Student, Department of Soils and Fertilizers, FCAV/UNESP, Jaboticabal, SP, Brazil; 4. Post Doctorate in Agronomy, UFG/University of Rostock, Goiania/Rostock, Brazil/Germany

ABSTRACT: The use of legumes intercropped with forage in the Brazilian savannah (Cerrado) region is an alternative to reverse the process of pasture degradation. The natural phosphorus deficiency in this region and the high retention capacity of this nutrient in the soil are factors that directly affect the sustainability of the production system. The objective of this study was to evaluate the effect of a phosphate with medium solubility (Arad) compared to more soluble sources such as triple superphosphate and mono-ammonium phosphate, on the formation and maintenance of pastures of *Andropogon gayanus* with or without the introduction of *Stylosantes guianensis* in pasture already established in the Brazilian savannah. Two experiments were carried out under field conditions in an Oxisol using a randomized block design with split plots, plots with two sources of phosphorus (Arad and super-triple or MAP) and subplots with different levels of phosphorus. The study showed that andropogon grass, even though characterised as forage requiring low fertilization, responded to increased fertilization, especially with the use of more soluble sources of P at planting. From the second year on, with the introduction of *Stylosantes guianensis*, verified effects were seen on legumes in their efficiency of utilization of residual fertilization from the first year; however, this didn't affect legume dry matter production resulting from the P sources used for the andropogon grass. The mixed stands of andropogon grass and *Stylosantes guianensis* made it more advantageous to increase the P sources using phosphate fertilizer with lower solubility (Arad), when compared to MAP.

KEYWORDS: *Stylosantes guianensis*. Natural phosphate. Phosphorus solubilization. Pastures.

INTRODUCTION

The beef cattle industry is an important economic activity for Tocantins state, an area located on the biome Cerrado (Brazilian savannah) where about 80% of the pastures are in some stage of degradation (MACEDO et al., 1995). In addition, one of the main limiting factors for production in this region is its phosphorous deficiency, allied to the capacity of the soil to fix this nutrient (FERNANDES; MURAOKA, 2002).

In the savannah soil, phosphorous rates can reach values inferior to 0.5 ppm. According to Lobato et al. (1985), the minimum P requirement for the majority of forages varies from 3.72 to 19.02 ppm. Due to this, phosphorous fertilization becomes necessary, since this nutrient plays an important role in root system development and tillering of the grasses, mainly at the beginning of development when the root system stele are not developed and restricted to a smaller soil volume, requiring phosphorous.

Although *Andropogon gayanus* is considered to be a forage adapted to acidic soils with high rates of toxic aluminium and minimal demands for phosphorous and nitrogen (BATISTA; GODOY, 1993), studies carried by Couto et al. (1985) cited by Lobato et al. (1985), and Passos et al. (1997), verified positive responses to P addition, suggesting that even for andropogon, there is a necessity for P fertilization during the initial stage of pasture implantation.

Due to the wide distribution of andropogon in soils of sandy texture with low acidity in Tocantins, it is possible to produce a greater efficiency in the natural phosphates when compared to other regions. For this forage, fertilization with natural phosphates could provide phosphorous during the culture cycle, but they are low solubility P sources. When forages are consociated with legumes, besides nitrogen transfer (VARGAS; HUNGRIA, 1997), the legumes can acidify the soil at the rhizosphere, facilitating the solubilisation of P (EIRA, 1992), and thereby increase P absorption by the forage.

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The use of consortium forages and legumes in the region has proven to be an alternative to reverting the soil degradation process and increasing aliment availability for animals (PAULINO; PAULINO, 2003; FLORES et al., 2007; SILVA; SALIBA, 2007). One of the alternatives for the consortium is *Stylosantes guianenses* cv. Mineirão; research has shown the adaptation of the legume to this climate region, with high yields of dry matter and good nutritional quality (EMBRAPA, 1993).

Some results from Flores et al. (2007) showed that intercropping with andropogon and stylo produced a greater amount of biomass than andropogon alone, resulting in a lower cost for cattle feed. Paciullo et al. (2003), studying the intercropping of forage and stylo, observed similar results, confirming the superiority of the consortium.

The natural phosphorous deficiency in Brazilian savannah soil is well known. Studies show that andropogon responds positively to P fertilization, increasing dry matter production (SOUZA et al., 2000; CARNEIRO et al., 2007), as related in studies of different forage (RAMOS et al., 1997; SANTOS et al., 2002; MOREIRA et al., 2006). Therefore, there is a necessity for studies that aim to establish the ideal P rates in pastures intercropped with legumes in the Brazilian savannah area.

Therefore, the objective of our study was to evaluate the effect of medium to high solubility phosphate sources at an *Andropogon gayanus* cv. Planaltina pasture intercropped with stylo already established in the Brazilian savannah region.

MATERIAL AND METHODS

Two experiments were conducted under field conditions at Federal University of Tocantins, Campus Gurupi. They were conducted in an Oxisol, the first in October 2001 and the second in August 2002.

For characterisation of the area and correction of soil fertility in both experiments, a soil sample was collected at the 0–0.2m depth, and chemical analysis was performed as described in EMBRAPA (1997). The first field presented the following characteristics: pH ($CaCl_2$): 5.5; organic matter: 17 g dm^{-3}; Phosphorous: 0.5 mg dm^{-3}; Potassium: 0.7 $mmol_c$ dm^{-3}; Calcium: 8 $mmol_c$ dm^{-3}; Magnesium: 3 $mmol_c$ dm^{-3}; total acidity [hydrogen (H) + aluminium (Al)]: 40 $mmol_c$ dm^{-3}, sum of bases (SB): 11.7 $mmol_c$ dm^{-3}, cation exchange capacity (CEC): 51.7 $mmol_c$ dm^{-3}, base saturation (BS): 22.6%. At the second field the findings were: pH ($CaCl_2$): 4.2; M.O.: 19 g dm^{-3}; Phosphorous: 1.1 mg dm^{-3}; Potassium: 0.79 $mmol_c$ dm^{-3}; Calcium: 20 $mmol_c$ dm^{-3}; Magnesium: 10 $mmol_c$ dm^{-3}; total acidity [hydrogen (H) + aluminium (Al)]: 41 $mmol_c$ dm^{-3}, sum of bases (SB): 30.79 $mmol_c$ dm^{-3}, cation exchange capacity (CEC): 71.79 $mmol_c$ dm^{-3}, base saturation (BS): 42.9%.

Based on these findings, in both experiments, liming was conducted, based on the chemical results as cited by Cantarutti et al. (1999). In the first and second experiments, 0.89 and 0.87 t ha^{-1} of lime were incorporated by harrowing the soil, increasing BS up to 40 and 55%, respectively.

The first experiment was set in a randomized block design with split plots (2x4), with two sources of phosphorous: triple superphosphate (TS) and reactive natural phosphate (Arad); four different phosphorous rates, 0, 50, 100 and 200 kg ha^{-1} were selected, with four replicates. Each plot consisted of 2x3 m, divided into four subplots of 1.0 m². The P fertilizers were incorporated with a power tiller at seeding, 50 days after liming.

The second experiment was also conducted in randomized blocks with split plots (2x4+1) with two sources of phosphorous: Monoammonium phosphate (MAP) and Arad; with different P rates in the subplots - 0, 50, 100 and 200 kg ha^{-1} - plus an additional treatment without the intercropping, fertilized with 100 kg ha^{-1} de P_2O_5, with four replicates. The P fertilizers were incorporated at seeding 47 days after liming. Because of the content of N in the MAP used, it was compensated proportionally to Arad for each P rate.

In both experiments, N and K fertilization followed the recommendations of Cantarutti et al. (1999), 100 kg ha^{-1} of N and K_2O, divided into two applications (50 and 100 days after germination), as urea and KCl.

In the first experiment, the seeding was on December 15th 2001, using seeds of *Andropogon gayanus* Kunth cv. Planaltina, planting 60 kg of 60% pure live seeds (PLS). After the second harvest year for each experiment (2002/2003 and 2003/2004, respectively) the consortium was established with *Stylosantes guianensis* cv. Mineirão, planting 1.25 kg of seeds ha^{-1} with 85% PLS, after light scarification for a dormancy break. With that was established the consortium of andropogon grass and stylo, evaluating dry matter at both harvests. In the second experiment, seeding was carried out on December 1st 2002, utilizing seeds of *Andropogon gayanus* Kunth cv. Planaltina, using the same seed amount as in the first experiment, where it was introduced along with the forage planting, *Stylosantes guianensis* cv. Mineirão, just as in the first experiment.

Dry matter production was evaluated using a 0.25 m² metal square in each plot, cutting the grass 20 cm from the soil surface, weighing the green matter and drying in lab oven at 65 ºC. The dry matter of stylo wasn't weighed because of its low height in both years.

In the first experiment, the total dry matter production of the first year was evaluated after cutting, 90 days after germination added to the second and third cuts, 30 and 60 days after the first cut of andropogon grass. In the second and third harvest years, dry matter production was evaluated using two annual cuts with a gap of 60 days.

In the second experiment, the dry matter production of andropogon was evaluated as in the first study in the two harvest years.

A variance analysis was performed for the resulting data using the statistics program AgroEstat (BARBOSA; MALDONADO JR., 2011). When the F value was significant (PIMENTEL-GOMES; GARCIA, 2002), polynomial regression analysis was also carried out.

RESULTS AND DISCUSSION

In the first experiment, the dry biomass production of andropogon grass with the more soluble source of P in the first year (harvest 2001/2002) was superior to production with using the less soluble source (Arad), independent of the applied rate (Table 1). It is noteworthy that the P application on the soil affected the dry matter production of andropogon (Table 1), being observed a square adjust for the triple phosphate and a linear adjust for the Arad, in which the highest production obtained was 7.9 and 5.9 t ha^{-1} using 159 and 200 kg ha^{-1} P_2O_5, respectively (Figure 1a).

In the second year of evaluation (2002/2003 harvest) with the legume, the production of andropogon dry matter was already higher when supplied with triple superphosphate (6.64 t ha^{-1}) compared to Arad (5.37 t ha^{-1}), independent of the P rate applied (Table 1). It was also observed that the P application affected the grass dry matter, the same as in the first year (Table 1), been observed quadratic adjust for the triple superphosphate and linear for Arad, the highest production being 8.3 and 6.3 t ha^{-1} at rates of 164 and 200 kg ha^{-1} P_2O_5, respectively (Figure 1b).

When evaluating the dry matter yield of andropogon grass in the third harvest year (2003/2004), there were no differences comparing the two sources (Table 1). That could be associated with the consortium with the legume, probably caused by acidification of the rhizosphere, solubilizing less soluble sources of P and improving its use of this nutrient by plants (EIRA, 1992). The effect of time in improving the efficiency of the less soluble source could also be due to this residual effect, in that the phosphorous could be better utilized with the development of the root system.

Table 1. Dry matter yield of andropogon Grass due to P sources and rates applied in Experiment 1, Gurupi County – TO.

Treatments	Harvest 2001/2002	Harvest 2002/2003	Harvest 2003/2004	Accumulated Yield
Source (S)	------------	------------ t ha^{-1}	------------	------------
Triple super phosphate	6.60 a	6.64 a	7.60 a	20.84 a
Arad	5.03 b	5.37 b	7.61 a	18.01 b
DMS (5%)	0.76	0.55	0.96	1.37
F	18.54**	23.14**	0.01^{ns}	18.45**
P_2O_5 Rates (R)				
F	8.43**	22.01**	1.76^{ns}	18.86**
Interaction SxR				
F	0.72^{ns}	3.90*	1.48^{ns}	4.18*
C.V.	17.76	12.47	17.13	9.62

ns, *, ** – non significant and significant at 5% and 1% of probability by Tukey's test, respectively.

The cumulative dry matter production from three years was higher using the more soluble source of P (20.8 t ha^{-1}) compared to the less soluble source (18.0 t ha^{-1}), independent of the phosphorous rate applied (Table 1). It could still be noticed that phosphorous application to the andropogon grass, with the late stylo introduction, promoted a significant increase in dry matter yield (Table 1), been observed a square adjust with the more soluble source and linear for Arad, less soluble source, where the highest yields obtained were 26.2 and 20.1 t ha^{-1} using rates of 167 and 200 kg ha^{-1} P_2O_5, respectively (Figure 1d).

The higher biomass accumulation observed after the fertilizer treatment with the more soluble source may be caused by its higher solubility compared to the less soluble (GONÇALVES et al., 2008). An adequate phosphorous supply to plants plays an important role in root system development as well as in grass tilling, promoting a greater yield (SANTOS et al., 2002).

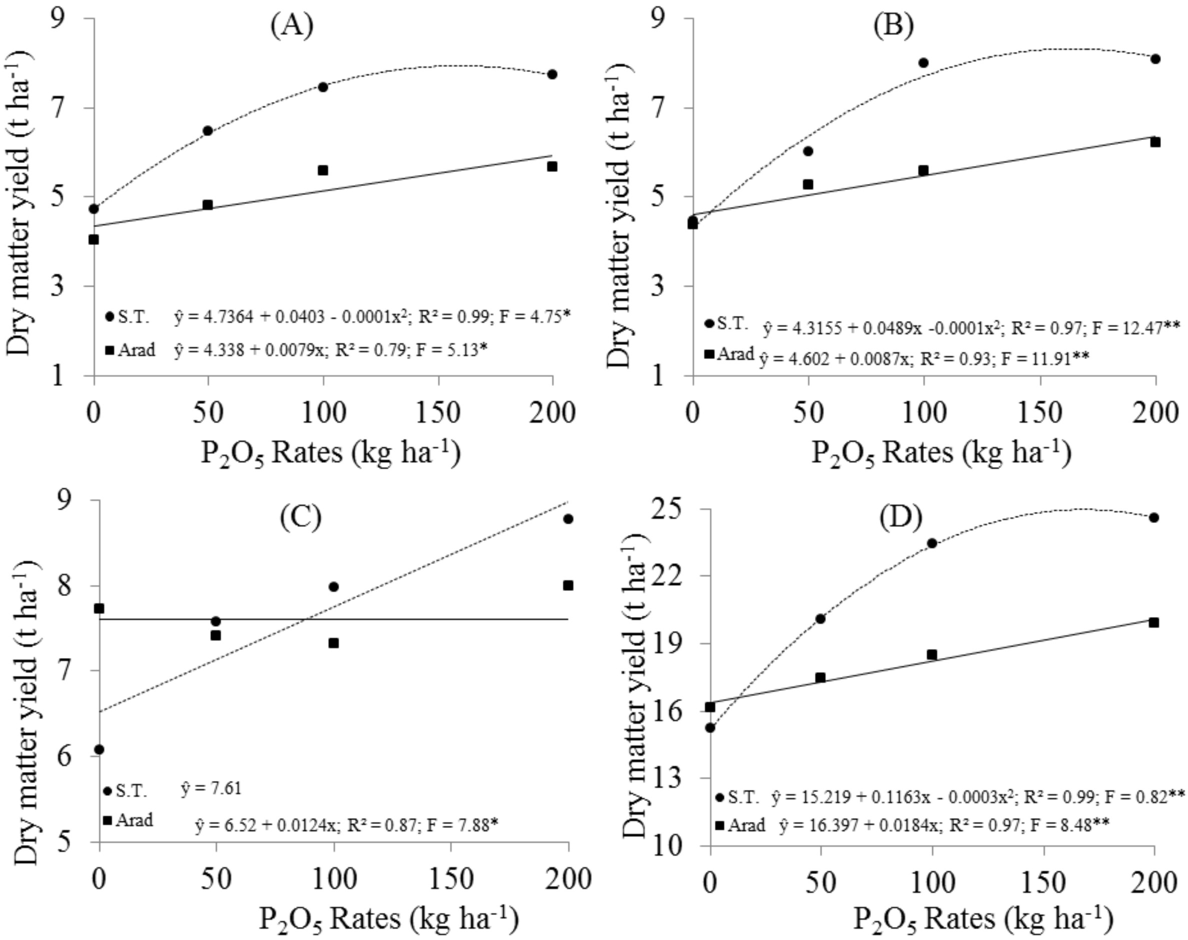

Figure 1. Changes in dry matter yield harvest in 2001/2002 (A), 2002/2003 (B), 2003/2004 (C) harvests and three year accumulated harvest (D) of andropogon grass with different P sources and rates of application in Experiment 1 in Gurupi County – TO, **,* - significant at 1 and 5% of probability by the F test.

The superiority at early times of the more soluble source is a strong indicator of its solubility. Therefore, it is possible that phosphorous contained in the less soluble source began to be available to the plants after the third year, which was when it equalized to the other source. Yet it can be noted that there was no difference in dry matter yield related to the two sources applied, suggesting a higher residual P for the natural source compared to the first year's results. This increase in residual P was also obtained by Corrêa and Freitas (1997) with Tanzania grass over the years.

In studies conducted in Typic Quartzipisamment with brachiaria grass, Costa et al. (2008) showed a higher content of phosphorous at the fourth cut when fertilized with Arad, while when fertilized with triple super phosphate the highest content was in the first cut. In the same paper the authors showed that in an Oxisol the behaviour of the triple super phosphate was different, in, that the highest content was observed at the fourth grass cut. In contrast to these results, Costa et al. (2008) evaluating the biomass accumulation of brachiaria grass in Oxisol, observed that Arad responded equally to triple super phosphate over the cuts. Similar results were observed by Horowitz and Meurer (2003), who described the agronomic efficiency of reactive phosphates as similar to highly soluble phosphates in the first year and higher when considering its residual effects.

We should not discard the possible contributions of the stylo and grass consortium, from the second year on, either its proportional biological N fixation as reported by Paulino and Paulino (2003) and/or increase in phosphorous absorption due to possible solubilisation caused by stylo root exudates (EIRA, 1992). Some works report an improvement in P nutrition due to the consortium of grass and stylo relative to monoculture (PACIULLO et al., 2003; PAULINO; PAULINO, 2003; FLORES et al., 2007; SILVA; SALIBA, 2007).

Attempting to assess what occurred after three years of grass cultivation (accumulated yield), it can be noticed that the use of triple super phosphate for andropogon implantation was more effective than Arad (Table 1), and that the use of fertilization increased the difference when compared to the control treatment. The introduction of stylo after the forage was established failed to increase the use of the less soluble source in the first year, thus in the second year the yield was the same, which shows the contribution of this legume to phosphorous use in andropogon.

In the second experiment, there was no significant difference in the dry matter yield of andropogon grass consorted with stylo in the first year (2003/2004 harvest), caused by the P source applied (Table 2). However, the P application rate incrementally affected the dry matter yield of consorted andropogon grass (Table 2), a linear adjust being observed for both sources, reaching 11.1 and 11.5 t ha^{-1} using the highest rate applied, 200 kg ha^{-1} P_2O_5, respectively (Figure 2a). It can also be noted that the consorted andropogon grass yield (9.7 t ha^{-1}) was inferior to the control treatment, without the consortium and with P application (Table 2). This result can possibly be attributed to a competition effect between andropogon and stylo at the beginning for the available phosphorous, which could be limiting for andropogon in the first year.

Table 2. Dry matter yield of andropogon Grass due to P sources and rates applied in Experiment 2, Gurupi County - TO.

Treatments	Harvest 2003/2004	Harvest 2004/2005	Accumulated Yield
Source (S)	---------------------------------t ha^{-1} ---------------------------------		
MAP	9.57 a	11.60 b	21.17 b
Arad	9.84 a	15.62 a	25.47 a
DMS (5%)	0.68	1.09	1.26
F	0.69^{ns}	58.30**	49.70**
P_2O_5 Rates (R)			
F	14.03**	37.62**	53.22**
Interaction SxR			
F	0.31^{ns}	12.02**	9.23**
Additional			
Factorial	9.71	13.61	23.32
SC + 100 de P_2O_5	14.09	10.23	24.93
F (Add. vs. Factorial)	78.77**	18.29**	3.11^{ns}
C.V.	9.13	11.27	7.34

^{ns}, *, ** – non significant and significant at 5% and 1% of probability by Tukey's test, respectively.

From the second year on, the dry matter yield of andropogon was superior using the less soluble source when compared to the highly soluble source, around 4 t ha^{-1} (Table 1). It can also be noticed that P application increased the dry matter yield when consorted with stylo (Table 1) after factoring in a linear adjustment for the two sources of P (Figure 2b). There was no difference at the end of the two harvest years of andropogon when compared with the control treatment.

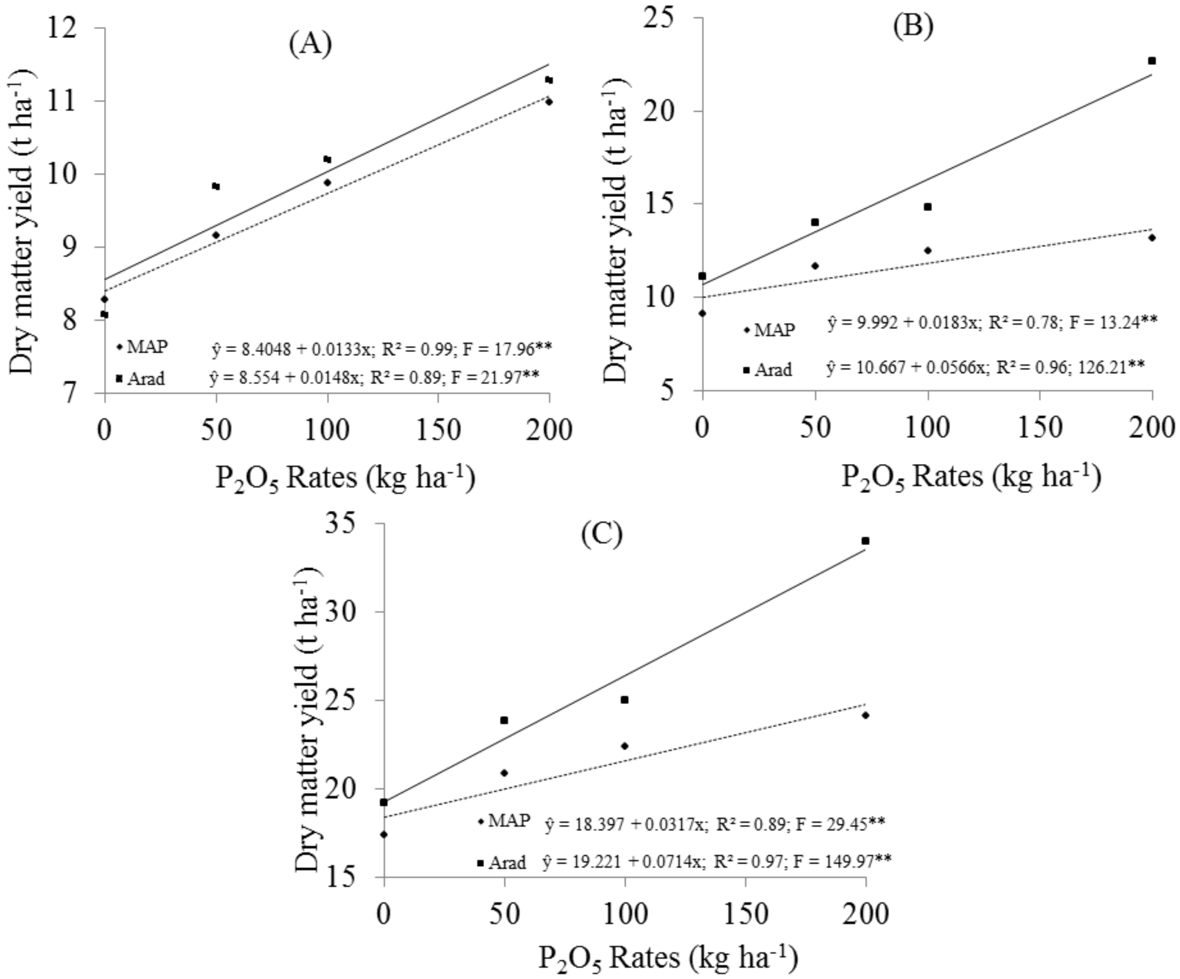

Figure 2. Variations in dry matter yield of harvest from 2003/2004 (A), 2004/2005 (B) and accumulated two year yield (C) of andropogon grass with different P sources and rates of application in Experiment 2, Gurupi County – TO, **,* significant at 1 and 5% level of probability by the F test.

The use of the less soluble source for cultivation of the grass consorted with the stylo provided a greater biomass accumulation compared to the more soluble source, a gain of 20% when evaluated over the two year cultivation (Table 2).

It is important to mention that the accumulated grass yield consorted with stylo indicates an increase in efficiency of P use from Arad (even at low rates), besides the slower initial growing of the stylo, not acidifying the rhizosphere, contributing to P solubilization Paciullo et al. (2003) cited by Boddey and Cantarutti (1997) and Boddey (1996). The enhanced effectiveness of P use, which increased from the second year on, most evidently with Arad's highest rate, which did not present initial solubilization, may also have absorbed P less than the more soluble source, maintaining the residual effect.

The evaluation of andropogon pasture formation after two years suggests that the option of using Arad in the presence of stylo was satisfactory, particularly for higher doses of fertilizer, which did not occur for the more soluble source in the studied soil conditions.

Based on these results, we can conclude that andropogon, even though classified as requiring little fertilization, responded to the increase in P fertilization, especially with the use of more soluble P sources at seeding. From the second year, with the introduction of *Stylosantes guianensis* cv. Mineirão, the effects of the legume were verified in the efficiency of utilization of the residual fertilization from the first year; however, the legume did not influence the dry matter yield resulting from P sources used for the andropogon grass. The consorted seeding of stylo and andropogon grass becomes more advantageous with increasing P rates of less soluble sources compared to the more soluble one.

RESUMO: O uso de leguminosas consorciadas com gramíneas na região do Cerrado brasileiro é uma alternativa para reverter os processos de degradação das pastagens. Tanto a natural deficiência de fósforo nesta região como a alta capacidade de fixação deste nutriente ao solo são fatores que afetam diretamente a sustentabilidade do sistema produtivo. O objetivo deste estudo foi avaliar o efeito do fosfato natural de média solubilidade (Arad) comparada a fontes mais solúveis, na formação e manutenção de pastagens de *Andropogon gayanus* com introdução de *Stylosantes guianensis* na pastagem já estabelecida em região dos cerrados. Foram realizados dois experimentos em condições de campo sob um Latossolo Vermelho Amarelo usando o delineamento de blocos ao acaso com parcelas subdivididas, tendo nas parcelas duas fontes de fósforo (Arad e super triplo ou MAP) e nas subparcelas diferentes níveis de fósforo. O estudo mostrou que o andropógon mesmo sendo caracterizado como capim de baixa exigência em fertilidade responde ao aumento da adubação fosfatada, principalmente com o uso de fontes mais solúveis de P no plantio. A partir do segundo ano, com a introdução de *Stylosantes guianensis* verificou-se efeito da leguminosa na eficiência de aproveitamento do residual da adubação do primeiro ano, contudo, a leguminosa não influenciou a produção de matéria seca decorrente das fontes de P empregadas para o capim andropógon. O plantio consorciado de *Stylosantes guianensis* e capim andropógon, tornou mais vantajoso o aumento da adubação fosfatada com fontes de P de solubilidade menor (Arad), quando comparado ao MAP.

PALAVRAS-CHAVE: *Stylosantes guianensis*. Fosfato natural. Solubilização de fósforo. Pastagens.

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