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SEÇÃO VIII - FERTILIZANTES E CORRETIVOS

EFFECTIVENESS OF FUSED MAGNESIUM POTASSIUM PHOSPHATE FOR MARANDU GRASS[1]

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SUMMARY

The current high price of KCl and great dependence on importation to satisfy the Brazilian demand indicate the need for studies that evaluate the efficiency of other K sources, particularly those based on domestic raw material. For this purpose, a greenhouse experiment was conducted with samples of a sandy clay loam Typic Haplustox, in a completely randomized 4 x 3 x 2 factorial design: four K rates (0, 60, 120, and 180 mg kg^{-1}), three sources (potassium chloride (KCl), fused magnesium potassium phosphate (FMPP) and a mixture of 70 % FMPP + 30 % KCl) and two particle sizes (100 and 60 mesh), with three replications. Potassium fertilization resulted in significant increases in shoot dry matter production and in K concentrations, both in soil and plants. The K source and particle size had no significant effect on the evaluated characteristics. Potassium critical levels in the soil and the shoots were 1.53 mmol$_c$ dm^{-3} and 19.1 g kg^{-1}, respectively.

Index terms: *Brachiaria brizantha*, particle size, critical level.

RESUMO: *EFICIÊNCIA DO TERMOFOSFATO MAGNESIANO POTÁSSICO PARA O CAPIM-MARANDU*

O alto custo atual do KCl e a grande dependência de sua importação para suprir a demanda nacional sugerem a necessidade de estudos que procurem avaliar a eficiência de outras fontes de K, principalmente aquelas baseadas em matéria-prima nacional. Nesse sentido, foi conduzido um experimento em casa de vegetação com amostras de um Latossolo Vermelho distrófico textura média, adotando-se o delineamento inteiramente casualizado em esquema fatorial 4 x 3 x 2, sendo quatro doses de K (0, 60, 120 e 180 mg kg^{-1} de K), três fontes [(cloreto de potássio (KCl)], termofosfato magnesiano potássico (FMPP) e a mistura de 70 % FMPP + 30 % KCl) e duas granulometrias (100 e 60 mesh), com três repetições. Verificou-se

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que a adubação potássica promoveu incrementos significativos na produção de matéria seca (parte aérea) e nos teores de K no solo e na planta, não havendo diferenças entre as fontes e suas granulometrias. Os níveis críticos de K no solo e na parte aérea das plantas foram de 1,53 mmol$_c$ dm^{-3} e 19,1 g kg^{-1}, respectivamente.

Termos de indexação: Brachiaria brizantha, potássio, granulometria, nível crítico.

INTRODUCTION

Although K is an element required in large quantities by forage plants, its importance is often neglected, perhaps due to the knowledge that this nutrient is recycled through the urine and feces of grazing animals (Coutinho et al., 2004). However, Cantarutti et al. (2001) and Braz et al. (2002) point out that, considering space and time, the act of excretion is different from the act of grazing; thus, excreta are concentrated and nutrients are transferred to restricted places which do not influence the overall production of the pasture. A large proportion of excreta are concentrated near fences, feed troughs, watering troughs and shaded areas. Thus, deficiencies of this element, concealed or not, can significantly reduce production and persistence of pastures.

Potassium application has resulted in significantly higher dry matter yields of *Brachiaria brizantha* Stapf. cv. Marandu grass when cultivated in a K deficient medium, as shown by the experiments of Mattos & Monteiro (1998) and Gama-Rodrigues et al. (2002).

In Brazil, for K fertilization exclusively water-soluble salts are used, mainly KCl, mostly imported from Canada and Russia, among other countries (Lopes, 2005). According to the author, domestic production is small, representing only 11 % of the consumption. This situation is aggravated by the fact that the Taquari/Vassouras mine, only exploited source of K fertilizer in Brazil, can only be used until 2017. Associated to this fact, there has been a substantial price increase of KCl on the international market, leading to increasing concerns about the K fertilizer issue in Brazil.

Alternative K sources have long been investigated, with a view to a preferential use of abundant raw materials in Brazil, such as nepheline syenites, from the region of Poços de Caldas-MG (Valarelli & Guardani, 1981). It was verified, however, that the solubility of these materials is low, which makes their use as a direct K source for plants unviable (Siqueira et al., 1985). Faquin et al. (1987) showed however, that a thermal treatment of a mixture of nepheline syenite with dolomitic lime facilitates the K release to plants.

Recently, fused Mg phosphate production technology has come into use and fused Mg K phosphate became available on the domestic market. It is obtained by a thermal treatment at, at least, 1,000 °C (fusion) of Mg compounds added to phosphate rock, silicates (dolomite, serpentinite, Mg slag) and K (syenites, slate, phyllite), with fast cooling of the mixture with water jetting (Brasil, 2008). This hydrothermally treated product is insoluble in water, but very soluble in citric acid.

Due to the fact that this product was recently introduced, its effectiveness ought to be evaluated, because this fertilizer, in theory, could offer advantages when compared to water-soluble K sources, such as KCl. Neptune et al. (1980) mentioned that using the product of thermally treated rocks containing K can reduce K losses through leaching and problems caused by saline effects, which can affect the germination and satisfactory development of some crops. Consequently, there is less concern about the splitting of applications, overconsumption of the nutrient by plants, even when applied at high rates.

Since the fertilizer is water-insoluble and the release speed of citric acid-soluble K to plants unknown, it would be interesting to apply a mixture with KCl, a highly water-soluble K source, which would meet the initial crop requirements. Faquin et al. (1987) observed lower K accumulation in shoots in a first crop cycle of maize when treated with a mixture of nepheline syenite and dolomitic lime exposed to different temperatures, than with KCl application.

Still, considering that the material is water-insoluble, it could be speculated that the agronomic effectiveness of this fertilizer, as well as its residual effect, may be related to its particle size, as the subdivision of a material increases its exposure surface per unit of mass and consequently, all contact-related phenomena, e.g., dissolution velocity, are intensified if particles are smaller.

Therefore, the purpose of this study was the evaluation of K fertilization effects using KCl and/or, fused Mg K phosphate with different particle sizes on dry matter yield and soil and shoot K concentrations of marandu grass and determine critical K level in soil and shoots.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse, in pots containing 4.3 kg soil samples, classified as sandy clay loam Typic Haplustox. These samples were collected from the 0–20 cm soil layer and later fertility was chemically analyzed according to Raij et al. (1987) and the following chemical properties were measured: pH ($CaCl_2$) 5.2; MO = 17 g dm^{-3}; P (resin) = 5 mg dm^{-3}; K = 0.6 mmol$_c$ dm^{-3}; Ca^{2+} = 32 mmol$_c$ dm^{-3}; Mg^{2+} = 9 mmol$_c$ dm^{-3}; H + Al^{3+} = 25 mmol$_c$ dm^{-3}; CTC = 67 mmol$_c$ dm^{-3}; V = 62 %.

A complete randomized 4 x 3 x 2 factorial design was used, with three replications: four K rates (0, 60, 120, and 180 mg kg^{-1} K), three sources [KCl (standard source), fused magnesium K phosphate (FMPP) and a mixture of 70 % FMPP and 30 % KCl] and two particle sizes (100 and 60 mesh), totalizing 72 plots. The rates were calculated based on the total nutrient level of each source. FMPP had the following properties: P_2O_5 total = 85.2 g kg^{-1}; 20 g L^{-1} citric acid soluble P_2O_5 at a 1:100 ratio = 51.7 g kg^{-1}; K_2O total = 61.0 g kg^{-1}; 20 g L^{-1} citric acid soluble K_2O at a 1:100 ratio = 56.0 g kg^{-1}; Ca = 173.5 g kg^{-1}; Mg = 87.7 g kg^{-1} and SiO_2 = 367.0 g kg^{-1}. The two particle sizes were: (a) 100 mesh: 100 % of the product passing through sieve no. 100 (sieve opening = 0.149 mm); (b) 60 mesh: 100 % product passing through sieve no. 20 (sieve opening = 0.84 mm) and 60 % retained by sieve no. 100.

All basic fertilization applied in the treatments was composed of: N = 10 mg kg^{-1} and S = 11 mg kg^{-1} (ammonium sulfate p.a.); B = 0.5 mg kg^{-1} (boric acid p.a.); Zn = 3.0 mg kg^{-1} (zinc sulfate p.a.) and P = 200 mg kg^{-1}. FMPP also acted as a P source; so, the missing part of the P rate at sowing was completed with fused Mg phosphate without K, according to the particle size in the treatments. The fertilizers were applied to the entire soil volume of each pot and then distilled water was added and the samples were incubated for 18 days. At the end of this period, the first soil samples were taken (70 g soil).

Forty *Brachiaria brizantha* cv. Marandu seeds were sown in each pot and thinned to five plants per pot, six days after seedling emergence. Immediately after thinning, a fertilization of 100 mg kg^{-1} N and 110 mg kg^{-1} S (ammonium sulfate p.a.) was sidedressed. Twenty seven days after emergence of the plants, the first cutting of the shoot was carried out, 10 cm above the soil surface. Furthermore, the second soil samples were taken, each trial with 70 g of soil. After this sampling, a sidedressing of 100 mg kg^{-1} N and 110 mg kg^{-1} S (ammonium sulfate p.a.) was applied. The other nutrients were not reapplied. The second cutting of the plants was carried out 27 days after the first, also at 10 cm above the soil surface.

Throughout the experimental period, the soil was maintained at approximately 80 % of its maximum water retention capacity by daily irrigation with a quantity of distilled water determined by daily weighing of the pots.

All harvested plant material was washed, oven-dried (65 °C), weighed to determine the shoot dry matter, and ground for K analysis according to Bataglia et al. (1983). The exchangeable K concentration was determined for each soil sample according to Raij et al. (1987).

The results were submitted to variance analysis according to Banzatto & Kronka (2006), and the relationship between the rates, particle size and K sources adjusted to the results by means of regression analysis. Critical K levels were calculated by the relationship between relative dry matter yield and K concentrations in plant or soil. The critical K level in the shoots was associated with a relative yield of 90 %. The linear-plateau model described by Alvarez V. (1994) was used to determine the soil critical K level, which was defined by the intersection of the two lines.

RESULTS AND DISCUSSION

Higher K rates resulted in significant increases ($p < 0.01$) in the soil nutrient concentration in the two sampling periods ($F = 190.67$; $F = 60.25$). However, no significant differences were verified regarding K sources ($F = 0.34^{ns}$ and $F = 0.59^{ns}$, in the first and second sampling, respectively). Siqueira et al. (1985) demonstrated that the performance of K rocks *in natura*, simply crushed, as a K source for plants, is not satisfactory due to the difficulty of K release. Thus, this linear increase in soil K concentrations (Figure 1), independent of the K source, indicates that hydrothermal treatment together with Mg fusion additives improves the release of K contained in K rocks (Eichler & Lopes, 1983; Siqueira & Guedes, 1986; Faquin et al., 1987). The thermal treatment probably reduces reticular retention energy of the K atom (a measure of stability of a crystalline network based on energy that is released by each mol), improving its release to plants.

It is noteworthy, however, that there was no significant difference between FMPP and KCl in the first soil sample, contrary to results of Eichler & Lopes (1983) using an experimental product obtained from the thermally treated mixture of K rock and dolomitic lime, which, at first, released less K than KCl. This difference could be related to not only temperature and time of heating, but also to components of the mixture and their proportions. Serpentinite was used to obtain FMPP, while in the previously mentioned research lime was used. Such additives have the role of reducing the mixture fusion temperature, which according to Kirsch (1972) is more favorable for a structural alteration in the original minerals and subsequently for the formation of other compounds that release K in soil. Results of Faquin et al. (1987), in which initial effectiveness of alternative K sources was much lower than KCl, would suggest another

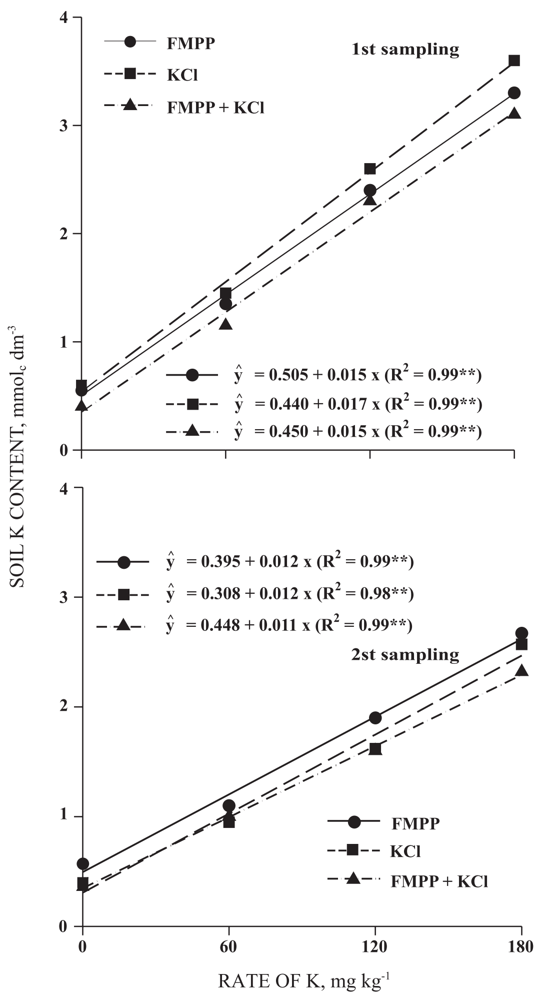

Figure 1. Effects of K rates and sources (KCl, fused magnesium potassium phosphate (FMPP) and 70% FMPP + 30% KCl mixture) on soil K content at different sampling times.

explanation: the cooling process. FMPP is quickly cooled by jetted water, however, the product used by Faquin et al. (1987) was cooled down slowly, which might influence the product solubility, since the purpose of the rapid cooling is to avoid mineral re-crystallization, which reduces product solubility (Rahal, 1990).

With regard to the supply of other nutrients, literature is often concerned about particle size. In theory, fertilizer dissolution speed is higher according to the greater the specific surface of the particles, i.e., the smaller the material particle size. However, in this study this fact was not observed, as there were no significant differences between K concentration in soil due to particle sizes ($F = 4.59^{ns}$ and $F = 0.05^{ns}$, in the first and second cuttings, respectively). Figure 2 shows soil the K concentration variations for the two particle sizes evaluated.

As K rate increased, concentrations of this nutrient increased ($p < 0.01$) in the plant shoots ($F = 6.02$; $F = 115.89$), not depending of the K source (Figure 3). Considering the control (no K) and the 180 mg kg^{-3} K rate, K concentrations in forage varied from 8.0 to 29.2 g kg^{-1} in the first sampling and from 7.0 to 23.8 g kg^{-1} in the second. Mattos & Monteiro (1998) also observed that K fertilization increased concentrations of this nutrient in Marandu grass shoots.

In the plants of the treatments that did not receive K fertilization typical K deficiency symptoms were observed in both cuttings, characterized as inverted v-shaped chlorosis along the edges of older leaves, advancing towards the main vein. Similar symptoms were described by Mattos & Monteiro (1998). The appearance of these symptoms was associated with concentrations below 0.5 mmol$_c$ dm^{-3} K in the soil and 8.8 g kg^{-1} K in shoots. These visual symptoms were not observed in treatments where 60 mg kg^{-1} K was applied, which resulted in concentrations above 1.3 and 1.1 mmol$_c$ dm^{-3} K in the soil and 14.6 and 12.3 g kg^{-1} K in forage grass in the first and second

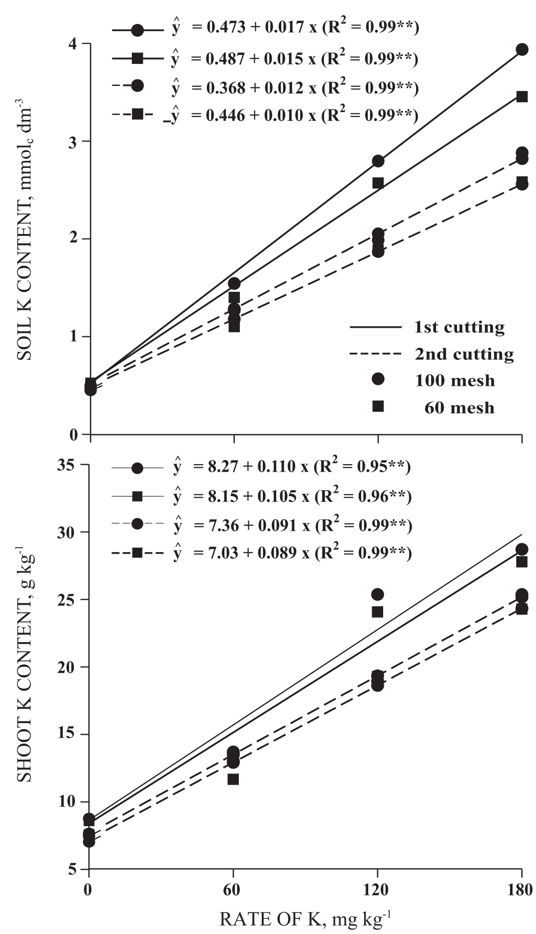

Figure 2. Effects of rates and particle size of K sources on soil and shoot K content at different sampling times.

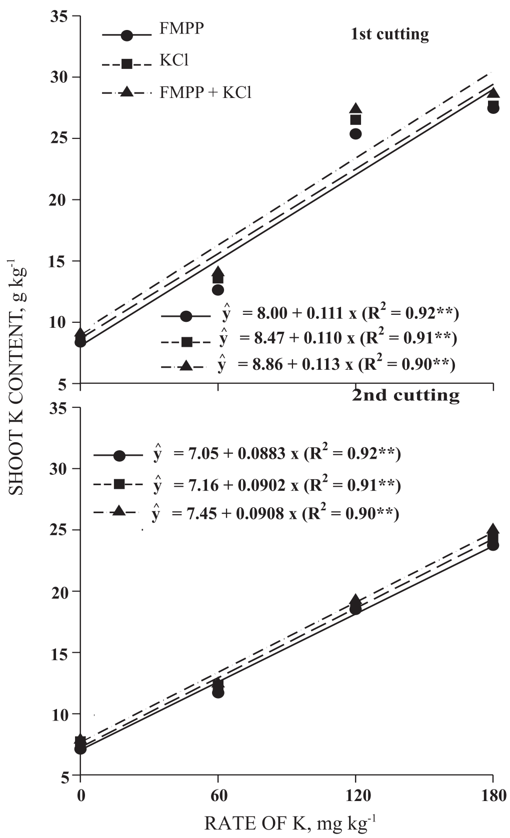

Figure 3. Effects of K rates and sources (KCl, fused magnesium potassium phosphate (FMPP) and 70% FMPP + 30% KCl mixture) in shoot K concentration of marandu grass.

soil samples, respectively. Carvalho et al. (1991) also verified that K deficiency symptoms in *Brachiaria decumbens* disappeared when shoot concentrations were between 10 and 15 g kg^{-1} K.

There were no significant differences in the K concentration in the grass shoots in relation to the source used in the two soil samplings ($F = 1.12^{ns}$ and $F = 0.31^{ns}$). Studies that compared water-insoluble K sources (hydrothermally treated) with KCl confirm the results presented here, also showing that these sources are as efficient as KCl, resulting in similar plant nutrient concentrations and/or accumulation to those obtained with the use of a water-soluble source (Neptune et al., 1980; Siqueira & Guedes, 1986). It must be emphasized, however, that Faquin et al. (1987) verified a similar effect to that of KCl when considering the residual effect.

As well as for soil K levels, particle size of sources did not influence K concentrations in Marandu grass shoots, in the first ($F = 1.13^{ns}$) or second ($F = 0.56^{ns}$) cutting. Variations in the K concentration in the shoots due to K rates applied in the two particle sizes can be seen in figure 2.

Dry matter production of the two cuttings, according to previous results, was also significantly increased ($p < 0.01$) when K was supplied ($F = 37.98$; $F = 90.42$). In the first cutting there was an increase of approximately 74 % and in the second this increase was about 246 %, in a comparison of treatments using a higher rate to those without K application (Figure 4). Better tillering and occurrence of largest leaf area in both cuttings were visually observed in the treatments with K application, which could explain the increase of dry matter production shown. In fact, it has been reported that providing K increases tillering (Mattos & Monteiro, 1998) and leaf area (Rodrigues et al., 2006) of forage grass reflected in the production of shoot dry matter.

Additionally, dry matter production in the second cutting was higher than in the first (Figures 4 and 5) in all treatments except the control (no K), in which there was a reduction of approximately 24 % between the cuttings. Increase in production from the first to the second cutting was also observed by Mattos &

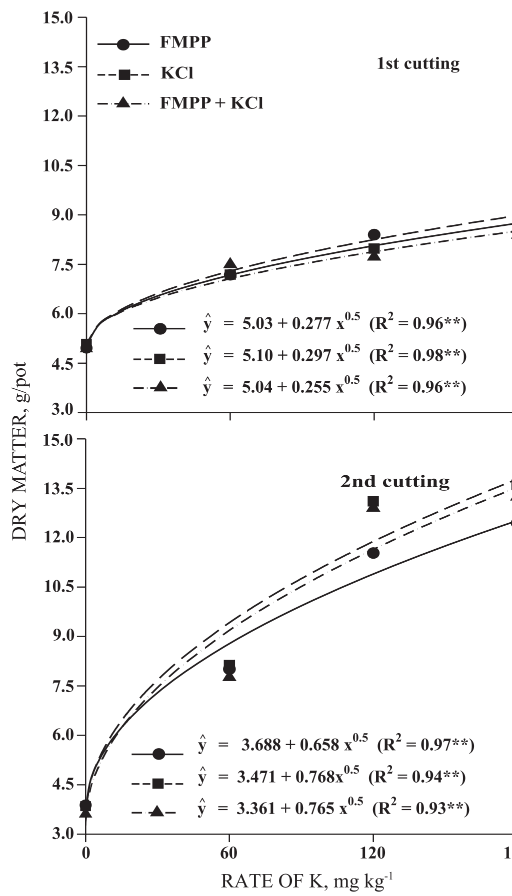

Figure 4. Effects of K rates and sources (KCl, fused magnesium potassium phosphate (FMPP) and 70% FMPP + 30% KCl mixture) on dry matter production of marandu grass.

Monteiro (1998) with *Brachiaria brizantha* cv. Marandu. This could be attributed to the fact that, by the time of the first cutting, the plant destines more energy to form and establish its root system, while by the time of the second cutting the already established plant uses its reserves to form and maintain the shoots (Lavres Junior & Monteiro, 2002). Once established, the roots are organs that are preferentially used for storage of non-structural carbohydrates (Rodrigues et al., 2007). These compounds, along with the N reserves, are the plants main energy source during the process of regrowth and, according to Marschner (1995), K deficiency could compromise the extent of these reserves due to the fact that this nutrient is linked to N metabolism and the transport of plant sugars.

For shoot dry matter production, in both cuttings, there were no significant difference between the sources ($F = 0.009^{ns}$ and $F = 0.65^{ns}$). In accordance to previous results, this confirms the initial hypothesis of this study, demonstrating that FMPP is highly promising as K source. Other authors have also observed increases in crop production after K fertilization with the hydrothermally treated product of K rocks (Neptune et al., 1980; Siqueira & Guedes, 1986; Faquin et al., 1987). The results also suggest that K solubility in citric acid could be a good criterion to predict availability of water-insoluble K sources.

The fertilizer particle size did not significantly influence shoot dry matter in either cutting ($F = 0.54^{ns}$ and $F = 0.002^{ns}$). Interestingly, the particle size behavior was similar, independent of the K rate (Figure 5). This result indicates the possibility of using the product with larger particles without losing effectiveness. This is important under field conditions, as it permits, during the application of the product, a better discharge and less compaction problems during application, that is, the product will tend to be less compacted under the compression loads in the fertilizer compartment during field transportation.

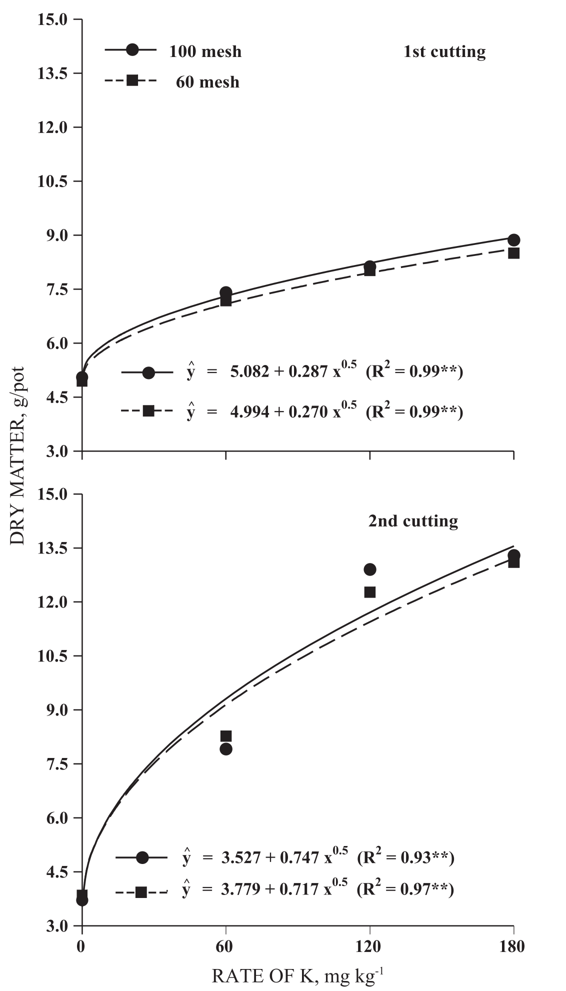

Figure 5. Effects of rates and particle size of K sources on dry matter production of marandu grass (two cuttings).

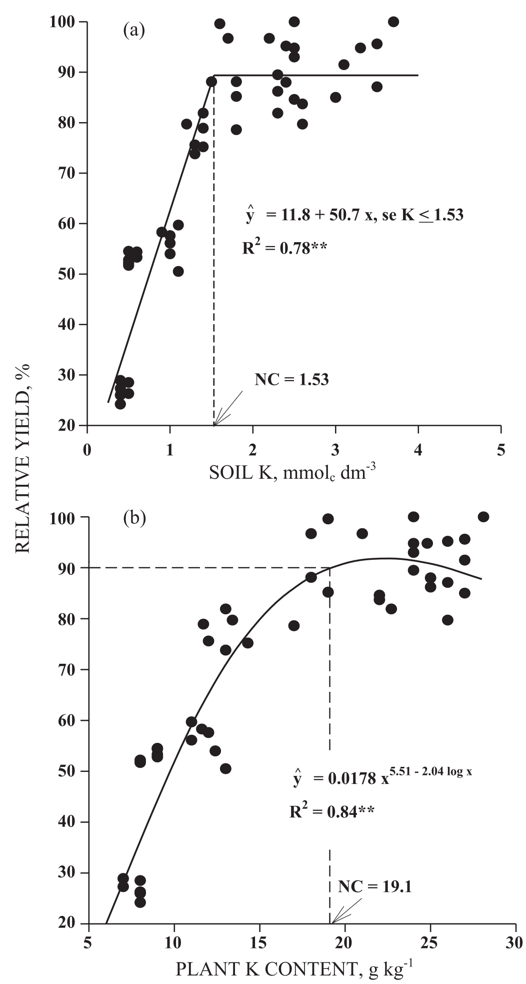

Figure 6. Critical K level in soil (a) and in shoot (b) of marandu grass.

On the other hand, it is rather self-evident that a re-calibration of the soil chemical analysis should be supported, since the fertility classes currently used for forage grass were established for annual crops (Raij, 1991). For this reason, a critical level was determined, to establish two classes of K application response. The relationship between the relative production of dry matter and K levels in soil is shown in figure 6. The critical level established (K = 1.53 $mmol_c$ dm^{-3}) is very close to the one determined by Coutinho et al. (2004), using data from three experiments with Cynodon grass. It is also noteworthy that, although the critical level values were established for annual crops, the critical level determined here is very close to the levels used in most Brazilian States (Raij et al., 1996; Alvarez V. et al., 1999). In this experiment, the values served to separate situations of probable positive fertilizer response from others in which the probability was null or very low.

The critical K level in the plants was around 19.1 g kg^{-1} (Figure 6). This concentration is within the range suggested by Werner et al. (1996) for *Brachiaria brizantha* (12 to 30 g kg^{-1} K).

CONCLUSIONS

1. Potassium fertilization resulted in significant increases in shoot dry matter production and in soil and plant K concentrations, with no significant differences between FMPP, KCl and a mixture of both, nor in relation to the particle size of these sources.

2. Critical K levels in soil and marandu grass shoots were 1.53 $mmol_c$ dm^{-3} and 19.1 g kg^{-1}, respectively.

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