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Potassium fertilization for corn grown under bread grass straw

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ABSTRACT

Several studies related to potassium fertilization in Brazil indicate lack of response to this nutrient. However, most of these surveys were conducted in soils with K levels from medium to high, Another aspect that should be considered is the presence of cover crops, which may affect the response to this nutrient. The aim of this study was to evaluate the effect of K_2O levels associated with ground cover with 'Marandu' grass (bread grass) on corn yield and soil K content. The experiment consisted of 8 treatments established in a randomized block design in a split plot arrangement. Each dose of K_2O (0, 75, 150 and 225 kg ha^{-1}), in the form of potassium chloride, corresponded to a plot and the subplots were formed by the presence or absence of bread grass straw. In the soil with low K content, corn yield response was noticed, regardless the presence of bread grass straw. Surface application of potassium fertilizer, with or without straw, increases the soil K levels, even in deeper layers. The use of bread grass as a cover crop increases the potassium fertilization efficiency, with a consequent increase in corn yield.

Palavras-chave:
doses de K_2O
potássio trocável
Zea mays
Brachiaria brizantha

Adubação potássica para o milho cultivado sob palhada de Capim Marandu

RESUMO

No Brasil, muitos trabalhos referentes à adubação potássica para a cultura do milho apontam para a ausência de resposta a este nutriente mesmo que a maioria dessas pesquisas seja desenvolvida em solos com teores de K de médio a alto; outro aspecto que deve ser levado em consideração é a presença de plantas de cobertura no sistema que podem influenciar a resposta a este nutriente. Objetivou-se avaliar o efeito de doses de K_2O associadas à cobertura vegetal do solo com capim Marandu sobre a produtividade do milho e o teor de K no solo. O experimento consistiu de 8 tratamentos estabelecidos em delineamento de blocos casualisados com parcelas subdivididas. Cada dose de K_2O (0, 75, 150, 225 kg ha^{-1}) correspondeu a uma parcela sendo as subparcelas formadas pela presença ou ausência de *Brachiaria brizantha* cv. Marandu. Em solo com baixo teor de K, o milho responde à adubação potássica, independente da presença de palha de capim Marandu. A adubação potássica aplicada em superfície com ou sem palhada, eleva os teores de K do solo mesmo em camadas mais profundas; como planta de cobertura, o capim Marandu aumenta a eficiência da adubação potássica com consequente aumento de produtividade da cultura do milho.

Introduction

Despite the large amount of potassium absorbed by corn (*Zea mays*), most studies related to potassium fertilization in Brazil indicate lack of response to this nutrient (Coelho, 2005; Pavinato et al., 2008). However, to understand better the low frequency of response to potassium fertilization in maize observed in most tests, one should proceed to a critical analysis of the conditions in which these studies were conducted. Some studies have reported diverse responses to potassium fertilization for corn when the exchangeable content in the soil is below the critical level, indicating that plants can absorb non-exchangeable forms and/or not detected by traditional soil analysis methods used to predict their availability (Coelho, 2005).

The K dynamic in tropical and subtropical soils is affected by the nutrient in high yield systems and by the leaching losses in sandy soils and/or with low organic matter content. In such cases the addition of high doses of K in the soil has little contribution to formation of reserves (Kist, 2005).

Organic matter has a close relationship with the cation exchange capacity (CEC). This influences the K retention in the soil, allowing greater or lesser mobility of the nutrient in the soil profile, and may be the main characteristic that affects the K availability to plants (Andreotti, 2008).

The increase in organic matter content in clayey Latosol (Oxisol) in no-tillage system is enough to cause a significant increase in the CEC of these soils with low-activity clays predominance (Ciotta et al., 2002). However, the effectiveness of the no-tillage system is related, among other factors, to the quality and quantity of straw produced by cover crops, the persistence of these residues over the soil, the rate of decomposition and nutrient release (Torres & Pereira, 2008).

After several years of cultivation using species with little straw production, a reduction in organic matter content is common and, therefore, the commitment of chemical, physical and biological properties of the soil. On the other hand, well-managed pastures, especially those formed by *Brachiaria* species, have high ability to maintain or even increase the organic matter content of the soil, being more efficient in recycling nutrients than annual crops, especially for K (Vilela et al., 2003).

The combination of no-tillage, crop rotation and/or intercropping crop and pasture can establish a better soil condition, by combining species with different nutritional requirements, biomass production and root systems (Amaral et al., 2004). Moreover, the performance of ground cover plants and their effects on crops must be validated at each location according to soil conditions and climate.

Considering as hypothesis the fact that *Brachiaria* species used as cover crop affect the availability of K, the objective of this study was to evaluate the effect of K_2O levels associated with ground cover with bread grass on corn yield and K content in the soil.

Material and Methods

The experiment was conducted in Botucatu-SP, in the crop seasons 2007/2008 and 2008/2009, in an area with 10 years of sorghum and pearl millet conventional tillage for forage production. The geographical location of this area is defined by the coordinates 22° 51 'S and 48° 26 'W and 786 m of altitude.

The climate, according to Köppen classification, is the type Cwb, which means mesothermal climate with dry winter. The soil was classified as LatossoloVermelho distroférrico (Brazilian Soil Classification System) with clay texture, with wavy smooth relief and good drainage. The soil sample collected (0-20 cm) and subjected to chemical analysis as described in Raij et al. (2001), showed the following results: pH ($CaCl_2$) = 5.8, OM = 23 g dm^{-3}, P (resin) = 16 mg dm^{-3}, K, Ca, Mg, Al and H + CTC, of: 0.8, 29, 95, 22, 26, 78; $mmol_c$ dm^{-3}, respectively.

The experiment was conducted in a split plot randomized block design with five replications. The plots consisted of K_2O doses (0, 75, 150 and 225 kg ha^{-1}), and the subplots formed by the presence or absence of *Brachiaria brizantha* cv. Marandu (bread grass) grown in crop season 2007/2008 as cover plants. Each subplot occupied an area of 35 m^2 (5 x 7 m). The K_2O levels were only applied in the crop season 2008/2009, before corn sowing with the simple hybrid DKB177.

The bread grass sowing in subplots formation was held on 22/11/2007, using a tractor pneumatic seeder, with five individual rows spaced 0.40 m, using a depth of approximately 2 to 3 cm, applying 7 kg ha^{-1} of seeds with cultural value of 76%. For a uniform distribution throughout the rows, doser disks for sorghum crop were used. No fertilizer was applied to this crop.

Mowing was performed every three months, in order to control the development of forage. The chopped material remained in the area after the operations. At each mowing operation, the areas corresponding to the plots with no cover plants were kept clean by applying glyphosate at 3.5 L ha^{-1}.

On 17/11/2008, 360 days after bread grass sowing, the entire experimental area was desiccated by application of 4.0 L ha^{-1} glyphosate. At this time, the subplots with bread grass as cover crop had a dry mass of approximately 13 Mg ha^{-1}. One day before this desiccation, leaves were collected for K determination. After laboratory analysis, following the methodology described in Malavolta et al. (1997), it was found that the plants contained an average of 7.3 g K kg^{-1} dry mass.

As a source of K_2O, potassium chloride was used, diluted in water to facilitate application in total area, performed on 16/12/2008. For application of K_2O levels, a constant pressure backpack sprayer was used, pressurized CO_2, with 5 nozzles (S.S. CO. Fulljet FL-8VC) bar, pressure of 3.1 kg cm^{-3} and application speed of 1 m s^{-1}.

Corn sowing was held on 17/12/2008 with soil revolving only in the row, using a tractor seeder with three individual rows spaced 0.90 m, distributing 6 seeds m^{-1}. At the time of corn sowing, experimental area received 30 and 90 kg ha^{-1} of N and P_2O_5, respectively, as urea and triple superphosphate in the seed furrows. In top dressing, 20 days after emergence of corn seedlings, 150 kg ha^{-1} N as urea were applied. The fertilizer was distributed and incorporated with tractor 20 cm from corn plants between the rows.

After corn harvest, soil samples were collected from the plots at 0-5, 5-10, 10-20, 20-40 and 40-60 cm to determine the levels of exchangeable K, according to methodology described in Raij et al. (2001). During this period the corn productivity was also assessed using the grain mass harvested in the area of each subplot, expressed as kg ha^{-1} and adjusted to 13% moisture content.

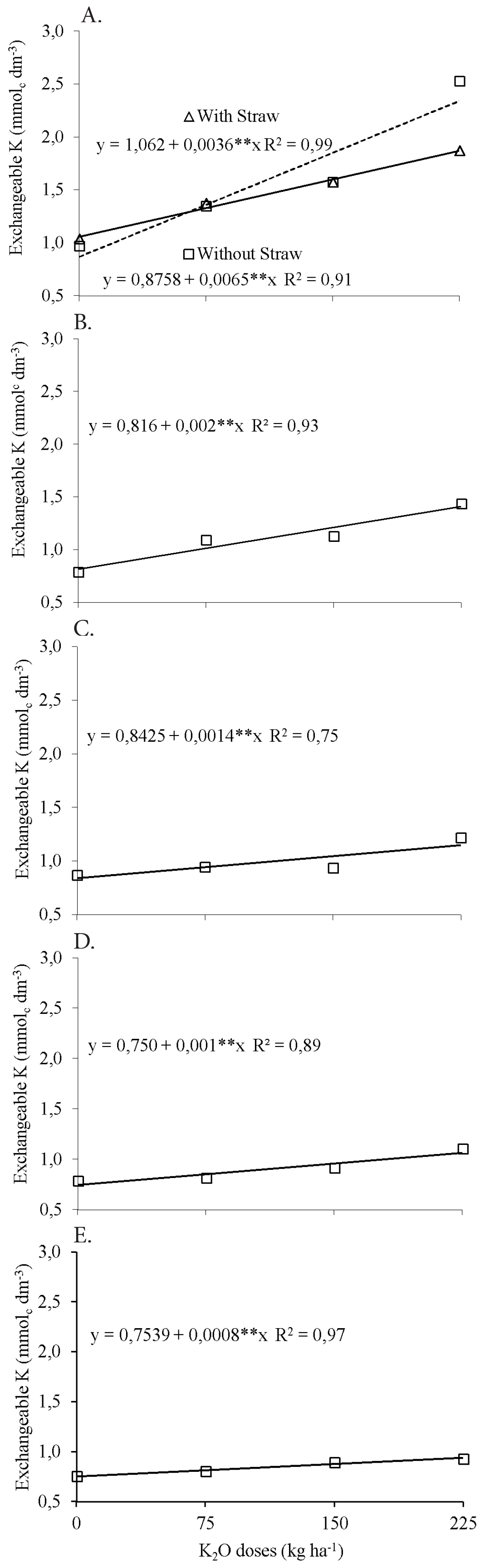
The original data were subjected to analysis of variance at 0.05 and 0.01 probability level by the F test. The potassium levels data were subjected to regression analysis obtaining linear and quadratic equations and were accepted until 0.05 probability significance by the F test, with the highest coefficient of determination (R^2)

Results and Discussion

The K_2O doses linearly increased the exchangeable potassium levels in the soil at all depths sampled (Figure 1A, B, C, D and E). The leaching process influenced these results, since during the period between the application of the potassium fertilizer and collecting soil for analysis, there was rainfall of approximately 870 mm.

This gradual increase in K levels in deeper layers is important for availability of nutrient to plants, since it is more homogeneously distributed in the volume of soil explored by the roots (Rehm & Lamb, 2004).

According to Werle et al. (2008), the K movement in the soil profile was related to its initial content in soil, resulting from potassium fertilizer rates of 0, 60, 120 and 180 kg ha^{-1} of K_2O. The K leaching in a medium textured soil profile increased when



** Significant at 0,01 probability

Figure 1. Soil exchangeable potassium in 0-5 (A), 5-10 (B), 10-20 (C), 20-40 (D) and 40-60 (E) cm deep layer as a function of K_2O doses

K_2O levels above 80 kg ha^{-1} were applied regardless of the mode of fertilizer application, in the furrow or broadcast (Rosolem & Nakagawa, 2001).

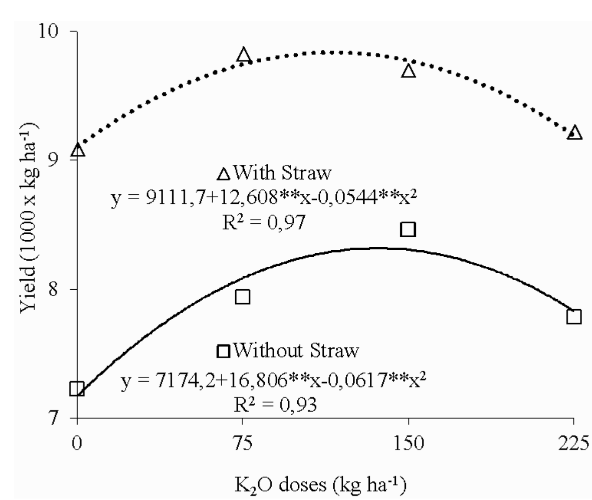
There was a significant interaction between plots and subplots for K exchangeable content in the 0-5 cm soil layer, where treatment with straw showed low levels compared to that without straw when 225 kg ha^{-1} of K_2O was applied (Figure 1A). This may be due to the higher buffering power of these plots for K, once during the straw decomposition a release of organic compounds occurs and they can complex K. According to Pavinato et al. (2009), on no-tillage systems, the potassium availability in solution may be reduced, by the possible complexation with organic compounds or soil functional groups.

However, according to Rosolem et al. (2006), the crop residue on the surface can improve the soil structure and increase water infiltration rates, and consequently, enhance nutrient leaching under no-tillage areas.

Grain yield showed a quadratic behavior in response to the application of K_2O levels, regardless the presence or absence of straw (Figure 2). The reason for this behavior may be in the use of high doses of K_2O, which may have promoted soil salinization. Raij et al. (1981) evaluating potassium fertilization in corn, found a depressing effect with 90 kg ha^{-1} of K_2O, and the authors attributed this effect partly due to the localized application of fertilizer (KCl) in the planting furrow.

The maximum agronomic yield (MAY) of the hybrid DKB177 grown in plots with straw was 9842.3 kg ha^{-1} and without straw 8318.4 kg ha^{-1}. The maximum agronomic dose corresponded to 115.9 kg ha^{-1} of K_2O for the subplot with straw and 136.2 kg ha^{-1} of K_2O for the subplot without straw.

MAY doses found in this study may be considered high compared to most studies with potassium fertilization in corn conducted in Brazil, which generally are between 40 and 60 kg ha^{-1} K_2O (Coelho, 2005). However, it should be noted that in this study, fertilizer (KCl) was applied in total area whereas in most of the studies mentioned above, this fertilizer was applied in the seed furrows. It is noteworthy also that the soil K content at the beginning of this experiment was considered low.



** Significant at 0,01 probability

Figure 2. Corn grain yield as a function of K_2O doses

Evaluating alone the qualitative factors of variation (subplot) it is possible to observe that only for 5-10 cm depth layer, the treatment without straw had higher exchangeable K compared to that with subplots (Table 1). For the other evaluated depths there was no significant difference between the subplots.

Table 1. Exchangeable potassium levels after harvest in the soil and yield of corn grown with and without bread grass as cover crop

Treatments	Soil exchangeable K - Depth (cm)					Yield kg ha^{-1}
	0 to 5	5 to 10	10 to 20	20 to 40	40 to 60	
	mmol$_c$dm^{-3}					
With straw	1.47	1.02	0.98	0.92	0.84	9,459.7
Without straw	1.61	1.20	1.02	0.90	0.85	7,851.0
F	6.655**	3.048^{ns}	1.234^{ns}	2.997^{ns}	1.105^{ns}	42.549**
CV%	17.38	16.02	23.91	7.65	14.63	11.4

ns e ** = not significant e significant at 0.01 by the F test, respectively

These results are different from those presented by Torres & Pereira (2008). After evaluating the dynamics of potassium in crop residue cover crops in the 'Cerrado', these authors observed that the bread grass showed the highest release rate, increasing the K content in the soil.

The presence of straw increased the grain yield compared to treatments without straw. This crop residue on the soil directly influences fertility, reducing acidity and increasing the content of organic matter, with direct effect on CEC when compared to areas under conventional tillage system (Andreotti, 2008).

Crusciol et al. (2009) also found that corn cultivation in areas where bread grass was introduced into the crop rotation system the grain yield increased approximately 1110 kg ha^{-1}, as did in case of oats (330 kg ha^{-1}) and soybeans (405 kg ha^{-1}).

Conclusions

1. In the soil with low K content, corn yield response was noticed, regardless the presence of bread grass straw.

2. Surface application of potassium fertilizer, with or without straw increases the soil K levels, even in deeper layers.

3. The use of bread grass as cover crop increases the potassium fertilization efficiency, with a consequent increase in corn yield.

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