Title:
Potassium doses and frequency of application to alfalfa in a tropical soil

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Abstract:
The objective of this study was to evaluate the effect of doses and frequency of application of potassium fertilizer on the alfalfa dry matter yield and potassium content in plant and soil. The experimental was carried out in a Typic Hapludox and was designed in randomized blocks in 4 X 4 factorial with 3 replications. The treatments were 4 levels of potassium in topdressing fertilization (0, 600, 1200 and 1800 kg ha-1 year-1 of K2O) and 4 frequency of application (12 = after each cutting, 6 = after two cuttings, 4 = after three cuttings; and 2 = two applications per year). The use of 1420 kg.ha-1 per year of K2O applied after two cuttings (6 applications per year) increased alfalfa dry matter yield until 30500 kg ha-1 and provided the best use of K at the higher doses of fertilizer. Alfalfa shoot total K removal reached 704 kg ha-1 per year of K2O with the application of 1623 kg ha-1 per year of K2O. At the end of the experiment, soil exchangeable K increased with K rates, and the differences were observed util 0.6 m of depth.

Introduction

Providing an adequate supply of nutrients is important for alfalfa production and is essential to maintain high quality and profitable yields. Potassium fertilization is essential for alfalfa production (Rassini and Freitas, 1998) and is the most common nutrient input for this crop in the high weathered, low-fertile and acids soils of tropical regions. High-yielding alfalfa removes large amounts of potassium from the field in each cutting (Smith, 1975 and Lanyon and Smith, 1985). Lloveras et al. (2001) found extractions from 1500 to 1700 $kg.ha^{-1}$ (with productivity of 21.5 $t.ha^{-1}$ DM) in soil of high fertility.

Potassium is taken up by plants in ionic form, and diffusion to plant roots accounts for the majority of plant uptake, while mass flow contributes to only a small fraction of total plant K. The salts of K in general show high solubility and can reach high concentrations in soil solution, which may lead to depletion by leaching and excessive absorption by plants (Havlin et al., 1999).

This macronutrient is involved in many essential metabolic roles within the alfalfa plant as photosynthesis, ATP production, sugars translocation, starch production, nitrogen fixation, and protein synthesis, and its deficiencies result in decreases in photosynthesis, increase in respiration, slow growth, suppressed yields, and lost income (Lanyon and Smith, 1985).

The objective of this study was to evaluate the effect of doses and frequency of application of potassium fertilizer on the alfalfa dry matter yield and potassium content in plant and soil.

Material and methods

A two-year growing season field study was conducted at Embrapa Cattle Southeast, in Sao Carlos (22°01’S and 47°54’W; 856m above sea level), Brazil. The climate is a Cwa (Köeppen), with yearly average of low and high temperatures of 16.3 and 23.0°C, respectively, and a total precipitation of 1502 mm falling mostly in summer. Soil type was a Typic Hapludox, with the following chemical properties in the 0-0.2, 0.2-0.4 and 0.4-0.6m layers: pH_{CaCl2} = 5.9, 5.3 and 5.1; organic matter = 21, 11 and 10 $g.dm^{-3}$; P_{resine} = 42, 10 and 3 $mg.dm^{-3}$; K = 1.3, 0.9 and 0.5 $mmol_c.dm^{-3}$; Ca = 29, 14 and 11 $mmol_c.dm^{-3}$; Mg = 13, 5 and 2 $mmol_c.dm^{-3}$; CEC = 69, 50 and 48 $mmol_c.dm^{-3}$; and basis saturation = 63, 39 and 28%; and the physical characteristics: sand = 730, 710 and 689 $g.kg^{-1}$; clay = 253, 273 and 302 $g.kg^{-1}$; and silt = 17, 17 and 9 $g.kg^{-1}$.

Irrigated alfalfa (*Medicago sativa* cv. Crioula) was sown with planting density of 20 kg ha^{-1} of seed inoculated with *Sinorhizobium meliloti*. Dolomite lime was applied to increase basis saturation at 80% before planting. Plots were fertilized uniformly at planting with 120 $kg.ha^{-1}$ P_2O_5 (single superphosphate) and 30 $kg.ha^{-1}$ of FTE BR-12 (1.8% of B, 0.8% Cu, 3% Fe, 2% Mn, 0.1% Mo, 9% Zn). Soil liming and phosphorus and micronutrients fertilization was repeated always when soil testing indicated fertility decrease. The experiment was carried out in $3.2m^2$-plots, formed by eight sowing 2m-length rows, with a 0.2m-interlinear space.

The experimental design was in 4X4-factorial randomized blocks with three replications. Treatments comprised 4 levels of potassium: 600, 1200 and 1800 $kg.ha^{-1}$ of K_2O as KCl; and 4 frequency of application: after each cutting (12 applications), after two cuttings (6), after three cuttings (4); and two applications per year (2).

Alfalfa shoot dry matter yield was evaluated when the crop was 10% of flowering. A minimum of six 1-m length rows was harvested per plot. Twenty-five growing seasons were evaluated. Total macronutrients concentration in shoot samples were determined (Nogueira et al., 2000) after hot nitric-percloric digestion by flame photometry (K) and atomic absorption spectrophotometry (Ca and Mg). After 25 alfalfa forage cuttings soil samples were collected at 0-0.2, 0.2-0.4 and 0.4-0.6m-depth for exchangeable K determination.

Data were tested for differences among treatments using analysis of variance and response function and equations were adjusted.

Results and discussion

Dry matter yield of alfalfa at first and second growing season as a function of K fertilizer level and frequency of application is illustrated in Figure 1. The highest DM yield in both years (36890 and 24131 kg.ha^{-1}) was obtained with 1411 and 1432 kg.ha^{-1} of K_2O applied after two cuttings. These values are approximately 57 and 59% higher than those obtained without potassium fertilizer. Results are consistent with those observed by Smith (1975), Rassini and Freitas (1998) and higher than those reported by Kafkafi et al. (1977) and Lloveras et al. (2001).

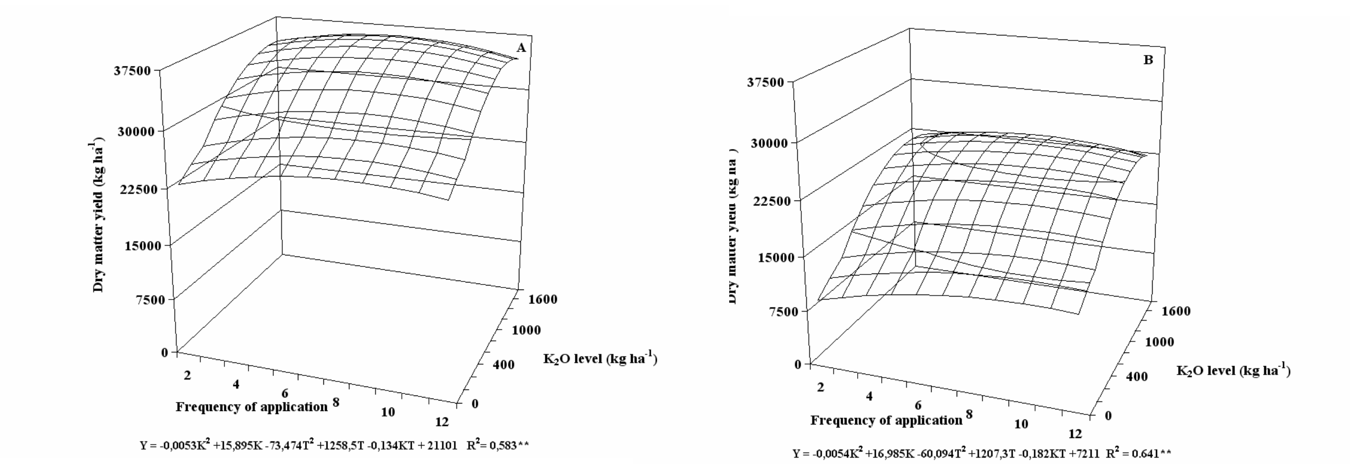

Figure 1. Alfalfa dry matter yield at 1st (A) and 2nd (B) crops season.

Maximum K concentrations in alfalfa shoots were 35.2 g.kg^{-1} achieved with 1610 kg.ha^{-1} of K_2O (Figure 2) and 58% higher than the control. These results are similar to Smith (1975) and Sheaffer et al. (1986) on soils responsive to K fertilization. The values of potassium levels in alfalfa shoot were considered adequate (Werner et al., 1997). Maximum potassium fertilization levels lead to insufficient Mg concentration in shoot (<3 g.kg^{-1}). The effect of competition was greater with Ca, since the lower levels of potassium fertilization lead to inadequate Ca concentration in shoot. The competition between K, Ca and Mg for alfalfa uptake was also reported by Smith (1975), Lanyon and Smith (1985) and Lloveras et al. (2001).

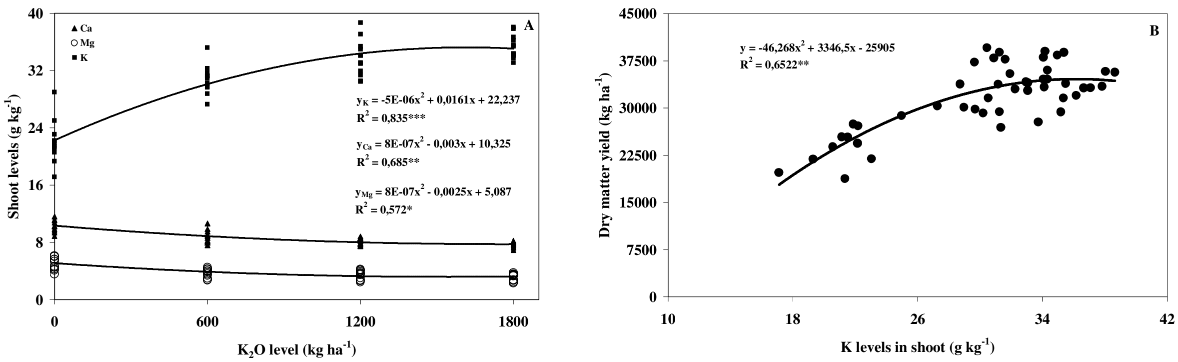

Figure 2. Alfalfa K, Ca and Mg levels in shoot according to levels of potassium fertilizer (A) and alfalfa dry matter yield as a function of K levels in shoot (B).

Dry matter production and shoot K levels showed a positive correlation (Figure 2B), where yield increased with increasing K concentration. The luxury consumption (Havlin et al., 1999) where alfalfa plants continue to absorb K even when available K exceeds plant needs, may be observed since great amounts of K were accumulate but without any increase in crop yield.

The total amount of K removed with the aboveground herbage increased with applied K and frequency of application (Figure 3). Removal of K_2O reached 704 kg.ha^{-1} per year with the application of 1623 kg.ha^{-1}, compared with 205 kg.ha^{-1} for the control treatment. Lloveras et al. (2001) found linear increases on potassium removal with increased K fertilization.

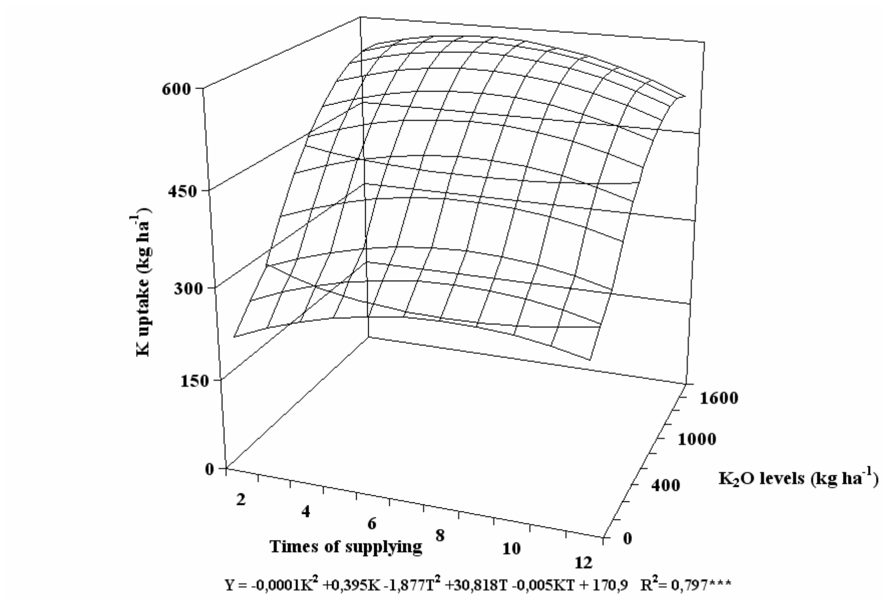

Figure 3. Alfalfa total K uptake in aboveground biomass.

The highest levels of potassium fertilization increased linearly both surface and deep soil K^+ (Figure 4). Considering the high levels of potassium fertilizer used in this experiment and the low ability of tropical soil to sorb and hold K (due to low CEC) a K movement in the soil profile was observed leading to values considered high (>3,1 $mmol_c.dm^{-3}$) at 0.2-0.4 and 0.4-0.6m-depth. Values of K^+ in the soil for the maximum yield (30.5 $t.ha^{-1}$) would be 3.4; 1.9 and 1.6 $mmol_c.dm^{-3}$.

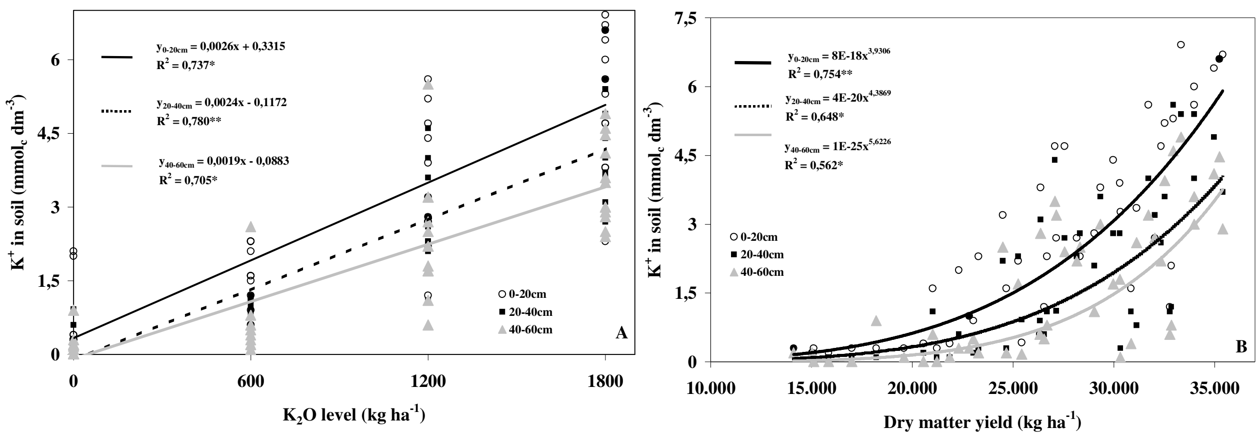

Figure 4. Potassium levels in soil according to levels of potassium fertilizer (A) and alfalfa dry matter yield as a function of K levels in soil (B).

Conclusion

The use of 1420 $kg.ha^{-1}$ per year of K_2O applied after two cuttings (6 applications per year) increased alfalfa dry matter yield until 30500 $kg.ha^{-1}$.

Alfalfa shoot total K removal reached 704 $kg.ha^{-1}$ of K_2O with the application of 1623 $kg.ha^{-1}$ per year of K_2O.

Soil exchangeable K increased with K rates until 0.6m-depth.

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