MACRONUTRIENTS IN THE *Eucalyptus Dunnii* Maiden ROWS SUBMITTED TO POTASSIUM FERTILIZATION IN VARIABLE CHARGE SOILS[1]

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[1] Received on 15.09.2016 accepted for publication on 31.10.2017.
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ABSTRACT – The contribution of nutrient cycling from eucalyptus residues in an Integrated Crop-Livestock System (ICLS) extracting potassium (K) in deeper layers and releasing on the surface should be further investigated in soils with variable charge. The objectives of this study were to evaluate the effects of K rates (0, 100, 200 and 300 kg ha^{-1} yr^{-1} of K_2O) applied on the soil surface in the entire area in rows of ICLS with eucalyptus, and relate these doses to macronutrient levels in the soil. The implemented experimental design was a randomized complete block using a split plot with three replications. The plot consisted of two rows and subplot by K rates. Soil fertility attributes were conducted at 6, 12 and 30 months after the start of the experiment. Medium to high concentrations of K were observed in profile up to 12 months, and very low concentrations of K were observed in the profile 30 months after the experiment was initiated. High concentrations of Ca, Mg were observed throughout the profile favoring saturation in an effective cation exchange capacity (ECEC). However, high K saturation in ECEC was observed at 6 and 12 months, and this decreased at 30 months of study. No leaching was observed, although acidity was high.

Keywords: *Agrosilvopastoral system, nutrient cycling, Typic Hapludox soil.*

MACRONUTRIENTES EM RENQUES DE *EUCALYPTUS Dunnii* Maiden SUBMETIDOS À ADUBAÇÃO POTÁSSICA EM SOLOS DE CARGA VARIÁVEL

RESUMO – A contribuição da ciclagem de nutrientes provenientes dos resíduos de eucalipto em sistema integrado de produção agropecuária (SIPA), extraindo o potássio (K) de camadas mais profundas e liberando-o na superfície, merece ser melhor investigada em solos com carga variável. Os objetivos deste trabalho foram avaliar os efeitos de doses de K (0, 100, 200 e 300 kg ha^{-1} ano^{-1} de K_2O) aplicadas na superfície do solo, em área total, nos renques de um SIPA com eucalipto, e relacionar estas doses com os teores de macronutrientes no solo. O delineamento experimental adotado foi o de blocos completos casualizados com parcela subdividida e três repetições. A parcela foi composta por dois renques e a subparcela pelas doses de K. Os atributos de fertilidade do solo foram realizados aos 6, 12 e 30 meses após o início do experimento. Concentrações de média a alta de K no perfil foram verificadas até 12 meses e concentrações baixas foram observadas após 30 meses do início do experimento. Altas concentrações de Ca e Mg foram verificadas no perfil estudado, favorecendo a saturação destes na capacidade de troca de cátions efetiva (CTCe). A saturação do K na CTCe reduziu aos 30 meses, apesar da adequada saturação aos 6 e 12 meses. Não foi observada lixiviação, embora a acidez fosse alta.

Palavras-Chave: *Integração lavoura-pastagem-floresta; ciclagem de nutrientes; Latossolo Vermelho distrófico.*

http://dx.doi.org/10.1590/1806-90882018000100017

1. INTRODUCTION

The soils originated by Furnas Formation belonging to the Second Paraná Plateau are composed of shales, predominantly quartzite and medium to coarse granulation quartz (Retzlaf et al., 2006), which originate soils of low fertility (Reissmann and Wisniewski, 2000). In this context, different nutrient contents in the source material may influence the composition of tree species within the landscape unit (Foster and Bhatti, 2006).

The tree component of an Integrated Crop-Livestock System (ICLS) provides a differentiated microclimate, resulting in a decrease in the radiation percentage, a decrease in air and soil temperature, an increase in the percentage of humidity in the air, a decrease in evapotranspiration, and improvement in maintenance of soil moisture (Menezes et al., 2002; Bernardino and Garcia, 2009). This last factor has been determinant in the availability of K to the plants because the movement of the soil solution can be driven by differences in water potential (mass flow) or by differences in concentration (diffusion). When the concentration of K in the soil solution is high, mass flux is the predominant ion-root contact mechanism; on the other hand, diffusion is the dominant ion-root contact mechanism in the transport of K to the roots at low concentrations (Oliveira et al., 2004; Malavolta, 2005; Marschner, 2012).

The contribution of eucalyptus residues to K release is large (Cunha et al., 2005) due to its ability to absorb it from deeper layers (below 20 cm) and then release it into the superficial layer (0-20 cm) (Witschoreck et al., 2003; Freycon et al., 2015). The amount of K available in the first 20 cm of most soils has been insufficient to supply the average demand for eucalyptus (Silveira et al., 2005). On the other hand, annual crop fertilization in an ICLS gradually changes the chemistry of exchange complex, mainly in the 0-20 cm layer, with elevation of the cation exchange capacity (CEC), organic carbon (OC), and effective cation exchange capacity (ECEC). With this, the residual effect of fertilization increases, which may reduce the need of several applications during the eucalyptus production cycle (Silveira et al., 2005).

Considering the above, it is expected that potassium fertilization will increase losses by K leaching due to high mobility and K biochemical cycling. The objective of this study was to understand the effects of potassium fertilization (0, 100, 200 and 300 kg ha^{-1} yr^{-1} K_2O) on the dynamics of macronutrients in variable charge soil in rows of an ICLS with *Eucalyptus dunnii*.

2. MATERIALAND METHODS

The study was conducted at the Experimental Station Farm Model of the Paraná Agronomic Institute (Latitude: 25º06'24 '' S, longitude: 50º02'35 '' W and average elevation: 1015 meters), Ponta Grossa (PR), Brazil. The cumulative rainfall of 2012-2014 was 1700, 1706, 1614 mm respectively, and of 748 mm for the summer and fall of 2015. The average annual temperature of 2012-2014 was 18.5; 17.8; and 18.7 ºC respectively, and 19.1 ºC for the summer and fall of 2015. The data were obtained from a SIMEPAR Meteorological Station (25135001) in the Ponta Grossa region. The climate of the region according to the Köppen classification is Cfb type, humid subtropical mesothermic. The main chemical and physical attributes of the soil in the rows collected in May 2012 before the application of K doses in the 0 to 60 cm layer were: pH ($CaCl_2$) 4.4, OC 16.9 g dm^{-3}, 16.0; 15.4; 1.4 $mmol_c$ dm^{-3} of Ca, Mg, K, respectively; as well as 580.2; 116.5 and 303.3 g kg^{-1} of sand, silt and clay, respectively.

The experimental design was a randomized block with subdivided plots and three replications. The 24 plots of 24 m² each consisted of rows 1 and 2 and the subplots of doses 0, 100, 200 and 300 kg ha^{-1} $year^{-1}$ of K_2O in KCl form applied to the soil surface. The rows were subdivided due to a distance between each other of 20 m and the greater slope of row 1 in relation to row 2 (smoothly undulating relief). The eucalyptus seedlings were planted in 2007 in a double-lane, east-west direction, transversely the terrain slope and spaced 3 meters between plants and 4 meters between rows. The K doses were split into two applications; half in the fall (April), and the other half in the spring (October), meaning at the moment of winter crops (white oats) and summer crops (soybean or corn) respectively, which was another experiment analyzed concomitantly to the present study.

Twelve (12) single samples of the 0-5, 5-10, 10-15, 15-20 cm layers and three simple samples of the 20-40 and 40-60 cm layers were collected using a gouge and dutch auger, respectively, for determining OC, pH, H + Al, K, Ca, and Mg to form a composed sample by subplot. The dry soil samples were analyzed to determine the following attributes: pH, H + Al, K, Ca, Mg and Al (Pavan et al., 1992), as well as OC by the Walkley-Black method (Cantarella et al., 2001). The sum of bases (SB), potential and effective cation exchange capacity (CEC and ECEC), base saturation (V%), aluminum saturation (m%) and K, Ca and Mg saturation in ECEC were calculated (KECEC, CaECEC and MgECEC respectively) according to Pavan et al. (1992).

The results were submitted to the Bartlet analysis, the data were transformed to obtain homogeneous variances when significant, and then variance analysis (ANOVA) was calculated. Regression equations were elaborated when ANOVA was significant, adopting the coefficient of determination as the criterion of choice, and Tukey's test ($p < 0.05$) for the means comparison of the soil concentrations between rows using Statgraphics® Centurion Software.

3. RESULTS

3.1 Soil attributes at 6 months

There were no significant interactions between row and dose for soil attributes. Differences between rows ($p < 0.05$) were observed for SB in the 0-5 cm layer, Mg and SB in the 5-10 cm layer, Mg in the 10-15 cm and 15-20 cm layers, and KECEC in the 40-60 cm layer (Table 1). Significant dose effects for Mg and KECEC in the 0-5 cm layer, K in the 5-10 cm layer (Figure 1) and CEC in the 20-40 cm layer (Table 4) were observed.

3.2 Soil attributes at 12 months

Interactions were observed for the ECEC and SB attributes in the layer of 0-5-cm, and CaECEC in the 20-40 cm layer (Table 4). A significant effect of the rows was only observed for SB in the 15-20 cm layer, and CaECEC, V% and m% in the 20-40 cm layer (Table 2). The dose effect was significant for K, ECEC, SB and KECEC in the 0-5 cm layer (Table 4), K and KECEC in the 5-10 cm layer (Figure 1), K and KECEC in the 10-15 cm layer (Table 4).

3.3 Soil attributes at 30 months

No interactions were observed for the analyzed variables. Differences between rows were observed for pH in the 10-15 cm layer, along with pH, CEC and

Table 1 – Average concentrations of soil chemical attributes in rows submitted to the K dose treatments 6 months after the start of the experiment.
Tabela 1 – *Concentrações médias dos atributos químicos do solo nos renques submetidos aos tratamentos de doses de K, aos 6 meses após o início do experimento.*

Layer	Variation	OC	pH $CaCl_2$	Ca	Mg	K	CEC	ECEC	SB	KECEC	CaECEC	MgECEC	V	m
cm		g dm^{-3}					$mmol_c\ dm^{-3}$					%		
0-5	Row 1	24.0 a	5.0 a	34.5 a	23.1 a	2.3 a	130.9 a	60.5 a	59.9 b	3.8 a	57.3 a	37.9 a	46.3 a	1.0 a
	Row 2	25.5 a	5.1 a	35.1 a	24.3 a	2.3 a	130.0 a	62.2 a	61.8 a	3.8 a	57.0 a	38.6 a	47.9 a	0.6 a
	CV%	9.9	6.4	14.0	28.2	24.1	12.6	12.6	12.5	27.2	13.9	21.6	13.9	166.6
5-10	Row 1	20.4 a	4.5 a	13.7 a	17.71 b	2.0 a	121.9 a	38.3 a	34.0 b	5.8 a	34.4 a	48.0 a	27.3 a	11.8 a
	Row 2	21.0 a	4.4 a	15.5 a	21.07 a	2.0 a	126.9 a	41.8 a	38.5 a	4.9 a	36.4 a	50.5 a	30.6 a	8.3 a
	CV%	12.0	5.3	42.0	32.8	25.6	19.8	27.9	28.2	45.1	25.5	21.2	21.8	62.9
10-15	Row 1	14.4 a	4.2 a	8.8 a	30.7 a	1.3 a	141.9 a	50.8 a	40.8 a	3.7 a	22.4 a	50.2 a	25.0 a	23.8 a
	Row 2	16.2 a	4.3 a	9.5 a	18.6 b	1.3 a	128.4 a	37.5 a	29.4 a	3.6 a	24.6 a	49.5 a	22.8 a	22.3 a
	CV%	18.1	6.2	59.9	134.1	26.8	27.7	74.1	91.5	51.7	48.2	23.5	41.2	45.8
15-20	Row 1	14.3 a	4.1 a	4.9 a	9.4 b	1.3 a	118.0 a	27.3 a	15.6 a	5.2 a	17.4 a	36.7 a	13.6 a	40.9 a
	Row 2	15.4 a	4.0 a	5.1 a	11.8 a	1.1 a	123.2 a	29.7 a	18.0 a	4.0 a	16.8 a	39.0 a	14.6 a	40.3 a
	CV%	16.0	4.7	72.5	37.0	23.3	17.6	23.8	33.1	41.8	59.1	27.5	30.0	35.0
20-40	Row 1	16.6 a	4.1 a	7.5 a	16.4 a	1.0 a	132.4 a	39.0 a	25.0 a	2.6 a	19.4 a	41.3 a	18.8 a	36.7 a
	Row 2	18.0 a	4.1 a	9.9 a	16.4 a	1.1 a	137.0 a	41.2 a	27.4 a	2.8 a	22.6 a	40.2 a	20.0 a	34.4 a
	CV%	13.3	2.3	85.1	41.1	42.6	9.5	21.1	29.4	44.6	81.3	36.9	28.2	24.4
40-60	Row 1	10.9 a	4.1 a	1.0 a	8.6 a	0.7 a	112.0 a	25.0 a	10.3 a	2.9 b	3.9 a	33.7 a	9.0 a	59.6 a
	Row 2	14.5 a	4.2 a	1.1 a	9.7 a	0.6 a	115.1 a	25.8 a	11.4 a	2.4 a	4.1 a	37.6 a	10.0 a	55.9 a
	CV%	26.9	1.3	76.3	32.6	42.5	8.7	11.6	29.2	46.0	67.3	27.8	27.2	16.6

Transformations made: COSR(C_B); COSR(C_F); 1/pH_C; DIFF(pH_D); COSR(Ca_D); COSR(Ca_E); COSR(Mg_C); COSR(Mg_D); COSR(CEC_C); COSR(ECEC_C); 1/SB_C; COSR(SB_E); COSR(SB_C); COSR(KECEC_E); COSR(KECEC_F); COSR(CaECEC_E); COSR(MgECEC_C); COSR(MgECEC_E); COSR(V%_C). The presented means for each transformed variable refer to the original values and the comparison of means test to the transformed variables. Means followed by the same letter for each layer do not differ from each other by the Tukey test when $p < 0.05$.

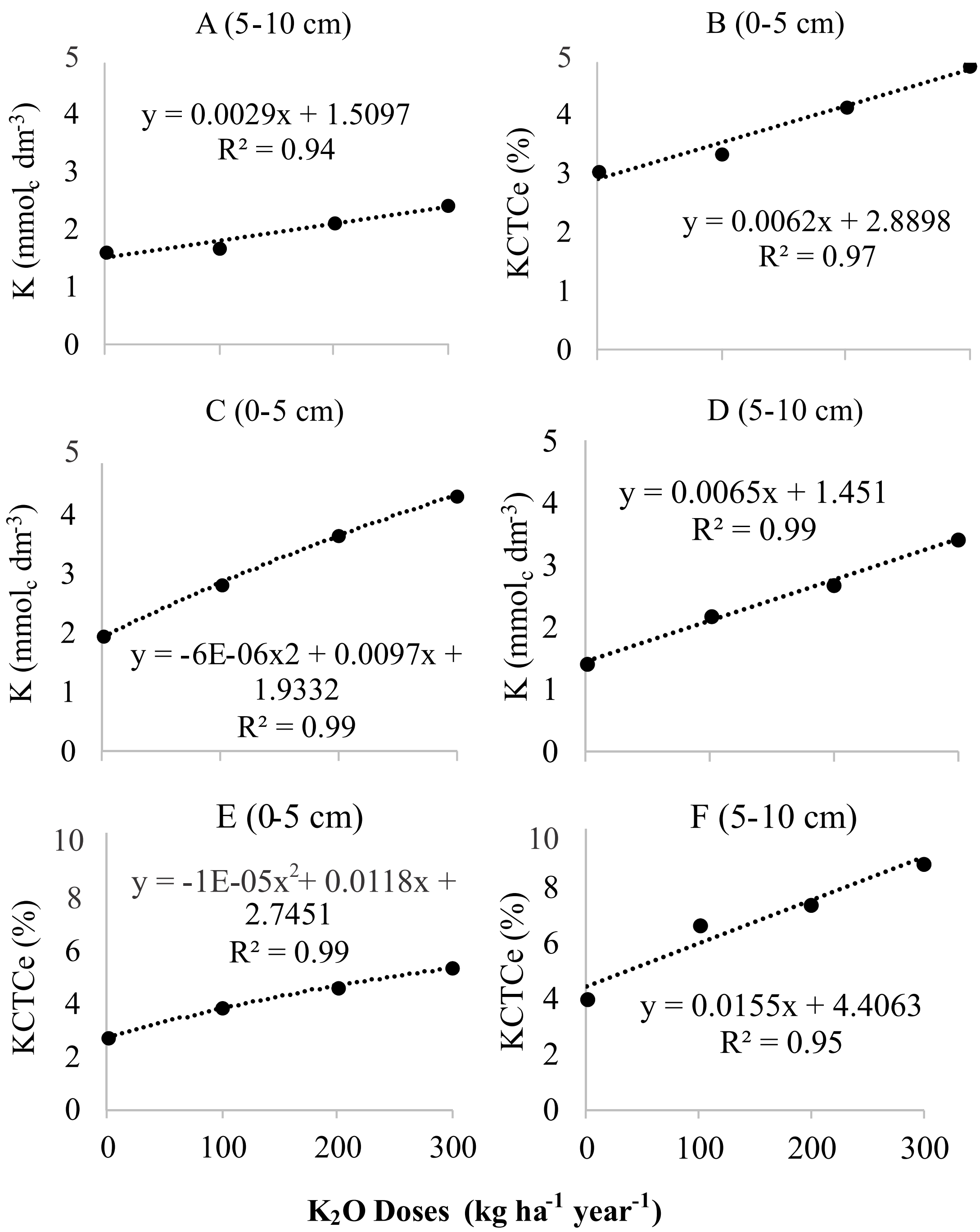

Figure 1 – Potassium concentration (K) in the 5-10 cm layer (1A), percentage of potassium in the effective cation exchange capacity (KECEC) in the 0-5 cm layer (1B) at 6 months, K in the 0-5 cm (1C) and 5-10 cm layers (1D), KECEC in the 0-5 cm layer (1E) and KECEC in the 5-10 cm layer (1F) at 12 months after application of K_2O rates.

Figura 1 – *Concentração de potássio (K) na camada de 5-10 cm (1A), percentual de potássio na capacidade de troca catiônica efetiva (KCTCe) na camada de 0-5 cm (1B) aos 6 meses, concentração de potássio na camada de 0-5 cm (1C) e 5-10 cm (1D), KCTCe na camada de 0-5 cm (1E) e KCTCe na camada de 5-10 cm (1F) do solo, aos 12 meses após aplicação das doses de K_2O.*

Table 2 – Average concentrations of soil chemical attributes in rows submitted to the K dose treatments 12 months after the start of the experiment.

***Tabela 2** – Concentrações médias dos atributos químicos do solo nos renques submetidos aos tratamentos de doses de K, aos 12 meses após o início do experimento.*

Layer	Variation	OC	pH $_{CaCl_2}$	Ca	Mg	K	CEC	ECEC	SB	KECEC	CaECEC	MgECEC	V	m
cm		g dm^{-3}				mmol$_c$ dm^{-3}						%		
0-5	Row 1	24.6 a	4.8 a	35.5 a	35.3 a	3.2 a	129.8 a	74.7 a	73.9 a	4.2 a	47.6 a	47.3 a	57.1 a	1.0 a
	Row 2	25.3 a	4.8 a	38.1 a	36.5 a	3.2 a	136.4 a	78.4 a	77.8 a	4.1 a	48.8 a	46.3 a	57.2 a	0.8 a
	CV%	9.9	4.6	14.7	16.6	32.3	8.0	10.9	11.2	27.7	11.3	11.0	10.6	91.1
5-10	Row 1	20.8 a	4.4 a	14.7 a	15.5 a	2.5 a	104.3 a	35.9 a	32.7 a	7.0 a	40.7 a	42.3 a	31.8 a	10.1 a
	Row 2	20.4 a	4.4 a	14.6 a	16.8 a	2.4 a	106.6 a	36.3 a	33.8 a	6.6 a	39.8 a	46.3 a	32.3 a	7.3 a
	CV%	14.3	5.3	25.1	26.4	36.6	9.5	13.8	20.1	33.2	19.0	22.6	25.8	88.7
10-15	Row 1	17.2 a	4.0 a	8.2 a	12.7 a	1.9 a	108.8 a	31.1 a	22.9 a	6.3 a	25.8 a	40.1 a	21.2 a	27.9 a
	Row 2	19.2 a	4.1 a	8.1 a	11.9 a	1.8 a	114.3 a	30.1 a	21.7 a	5.8 a	26.3 a	39.5 a	19.5 a	28.4 a
	CV%	17.4	5.6	58.0	32.4	34.9	9.7	14.9	32.3	30.2	48.8	21.5	36.4	52.7
15-20	Row 1	16.3 a	4.0 a	3.9 a	6.7 a	1.3 a	112.5 a	22.7 a	11.8 b	5.6 a	16.4 a	29.3 a	10.9 a	48.8 a
	Row 2	17.6 a	4.0 a	3.2 a	6.9 a	1.2 a	117.3 a	23.5 a	11.2 a	5.1 a	13.5 a	29.4 a	9.9 a	52.0 a
	CV%	10.6	3.1	75.0	26.1	36.9	12.6	15.3	35.3	35.8	67.3	18.2	43.6	27.3
20-40	Row 1	14.9 a	3.9 a	1.8 a	5.5 a	1.1 a	115.9 a	20.6 a	8.5 a	5.1 a	8.2 b	26.0 a	7.5 a	60.8 a
	Row 2	15.8 a	3.9 a	2.3 a	4.5 a	1.2 a	126.4 a	20.7 a	8.0 a	5.6 a	9.2 a	21.1 a	6.5 b	64.2 b
	CV%	18.8	4.3	169.0	48.8	47.4	10.3	16.6	72.6	37.1	127.4	31.5	79.7	27.6
40-60	Row 1	8.4 a	4.0 a	0.9 a	4.5 a	0.6 a	96.0 a	16.9 a	5.9 a	3.4 a	5.1 a	26.4 a	6.2 a	65.1 a
	Row 2	10.0 a	4.0 a	0.6 a	4.8 a	0.6 a	101.4 a	18.0 a	6.0 a	3.5 a	3.5 a	26.1 a	6.1 a	66.9 a
	CV%	25.9	1.3	64.8	30.6	52.0	10.6	12.2	26.9	48.6	63.3	25.2	30.6	10.9

Transformations made: DIFF(pH_C); DIFF(pH_D); FIRST(pH_E); COSR(Ca_D); COSR(Ca_E); COSR(Ca_F); COSR(Mg_B); COSR(Mg_C); COSR(Mg_E); COSR(CEC_E); COSR(ECEC_D); COSR(ECEC_E); COSR(SB_D); COSR(SB_E); COSR(KECEC_D); COSR(CaECEC_A); COSR(CaECEC_D); COSR(CaECEC_E); COSR(MgECEC_A); COSR(MgECEC_B); COSR(V%_D); FIRST(V%_E); COSR(m%_E). The presented means refer to the original values for each transformed variable, and the comparison of means test to the transformed variables. Means followed by the same letter for each layer do not differ from each other by the Tukey test when p <0.05.

ECEC in the 20-40 cm layer (Table 3). Dose effects for OC in the layer of 10-15 cm and CaCEC in the layer of 5-10 cm were also observed (Table 4).

4. DISCUSSION

4.1 Soil attributes at 6 months

Higher concentration of exchangeable Mg in the layer of 5-10 cm favored the higher SB in the same layer in row 2. Higher SB in row 2 in the 0-5 cm and 5-10 cm layers at 6 months favored higher V% in the same layers. On the other hand, the percentage of negative charged soil neutralized by basic reaction cations (V%) in the 5-10 cm layer was below 45% (CQFSRS/SC, 2004).

Zaia and Gama-Rodriges (2004) found lower concentrations of Ca, Mg and K in the soil under eucalyptus in relation to the present study; however, they were more acidic soils. An increase of Mg in row 2 at 6 months in the 5-10 cm and 15-20 cm layers was observed (Table 1), which corroborates with the highest concentration of OC, although this was not significant since soil organic matter exchange (MOS) sites control bivalent cations such as Ca and Mg (Vitti et al., 2006). A higher concentration of Mg was only observed in row 1 for the 10-15 cm layer.

Linear adjustment with increasing doses of K was only observed for K in the 5-10 cm layer (Figure 1A), and for KECEC in the 0-5 cm layer (Figure 1B). As a result of the increasing responses of the K application, upon entering the system the fertilizers altered the composition of the solution, and consequently promoted changes in the chemical balance between the solid and liquid phases (Ernani et al., 2007). Average K concentrations (CQFSRS/SC, 2004) were verified up to 20-40 cm at 6 months (Table 1), and especially at 12 months (Table 2); however, this effect could not be observed at 30 months (Table 3).

There was a quadratic adjustment (Table 4) for CEC in the 20-40 cm layer with K doses, along with a higher CEC value at the dose of 200 kg ha^{-1} year^{-1}.

Table 3 – Average concentrations of soil chemical attributes in rows submitted to the K dose treatments 30 months after the start of the experiment.

Tabela 3 – *Concentrações médias dos atributos químicos do solo nos renques submetidos aos tratamentos de doses de K, aos 30 meses após o início do experimento.*

Layer	Variation	OC	pH $CaCl_2$	Ca	Mg	K	CEC	ECEC	SB	KECEC	CaECEC	MgECEC	V	m
cm		g dm^{-3}		mmol$_c$ dm^{-3}							%			
0-5	Row 1	23.4 a	4.7 a	46.7 a	29.9 a	1.3 a	150.9 a	79.4 a	78.0 a	1.8 a	60.8 a	35.6 a	51.1 a	1.9 a
	Row 2	24.0 a	4.7 a	45.4 a	35.4 a	1.3 a	156.1 a	83.8 a	82.0 a	1.6 a	56.8 a	39.6 a	52.1 a	2.0 a
	CV%	8.4	5.4	16.0	57.9	25.8	11.3	22.5	22.4	36.8	23.2	36.5	13.0	80.3
5-10	Row 1	24.1 a	4.3 a	31.5 a	29.5 a	0.9 a	144.3 a	67.7 a	61.8 a	1.3 a	46.8 a	42.9 a	42.6 a	9.0 a
	Row 2	24.2 a	4.5 a	32.2 a	36.5 a	1.0 a	152.1 a	75.6 a	69.7 a	1.4 a	42.8 a	47.7 a	45.7 a	8.1 a
	CV%	5.0	6.0	23.3	30.4	33.2	11.4	20.2	21.9	35.7	18.9	17.4	15.7	44.0
10-15	Row 1	18.3 a	4.0 b	25.9 a	41.1 a	0.7 a	163.9 a	79.2 a	67.6 a	0.9 a	31.8 a	52.5 a	41.0 a	14.8 a
	Row 2	18.3 a	4.3 a	32.8 a	41.4 a	0.7 a	166.2 a	87.1 a	74.9 a	0.9 a	36.6 a	48.0 a	44.8 a	14.5 a
	CV%	8.0	6.0	45.8	23.4	40.8	10.7	18.9	21.6	49.6	31.7	21.2	13.8	27.2
15-20	Row 1	17.0 a	4.0 a	12.5 a	44.6 a	0.7 a	159.1 a	70.6 a	57.7 a	1.0 a	17.8 a	62.8 a	36.1 a	18.4 a
	Row 2	18.3 a	4.1 a	11.6 a	53.4 a	0.8 a	167.8 a	78.1 a	65.7 a	1.0 a	15.0 a	67.9 a	39.1 a	16.1 a
	CV%	7.2	4.0	35.6	22.9	42.7	9.6	16.0	18.4	45.1	39.3	11.6	12.1	22.8
20-40	Row 1	17.3 a	3.9 b	4.0 a	21.1 a	0.7 a	122.9 b	40.3 b	25.7 a	1.7 a	10.1 a	51.6 a	20.9 a	36.7 a
	Row 2	17.6 a	4.0 a	4.4 a	22.5 a	1.1 a	137.5 a	42.1 a	28.0 a	2.7 a	10.4 a	53.0 a	20.3 a	34.0 a
	CV%	9.0	5.3	22.9	21.4	57.5	8.1	13.2	19.2	57.5	21.6	10.4	17.1	13.4
40-60	Row 1	17.4 a	4.1 a	3.3 a	13.9 a	0.9 a	117.1 a	30.0 a	18.2 a	3.0 a	11.0 a	46.2 a	15.5 a	39.8 a
	Row 2	17.5 a	4.1 a	4.2 a	15.6 a	0.8 a	125.1 a	32.2 a	20.5 a	2.6 a	12.7 a	48.0 a	16.4 a	36.8 a
	CV%	9.0	1.0	41.1	22.9	49.3	7.5	14.4	22.3	48.0	32.4	11.7	19.0	14.5

Transformations made: CORS(pH_E); 1/(K_C); DIFF(K_D); DIFF(Ca_C); DIFF(Mg_D); CORS(CEC_B); CORS(CEC_D); COSR(SB_D); DIFF(KECEC_D); COSR(CaECEC_D); CORS(V%_C). The presented means refer to the original values for each transformed variable, and the comparison of means test to the transformed variables. Means followed by the same letter for each layer do not differ from each other by the Tukey test when $p < 0.05$.

In addition, a negative quadratic fit (Table 4) was observed for Mg in the 0-5 cm layer. Therefore, the small effect of K doses after 6 months from the start of the experiment points to a short interval for evaluating such responses. Despite the higher KECEC in row 1 in the 40-60 cm layer, it was not possible to verify a standard behavior of KECEC between the rows at 6 months (Table 1).

Higher concentrations of OC at all evaluation times was observed in relation to the initial OC. This possibly occurred due to conservation management (branches remaining on the soil) in the rows, and the high relation C:N of the eucalyptus litter (Gama-Rodrigues et al., 2008), thus minimizing decomposition by microorganisms, and gradually increasing OC reserves for sandy soils (Leite et al., 2010), as is the case of the present study.

Acidity reduction, especially of the rhizosphere, results in complexation and/or precipitation of the Al, thereby reducing the solubility and absorption, and consequently relieving the phytotoxic effects of this ion (Souza et al., 2011). This effect was clearly observed in the 0-5 cm layer with pH 5.0 and m% less than 1, although it was not significant.

4.2 Soil attributes at 12 months

Linear fit of the interaction for ECEC and SB indicate higher concentrations in row 1 (Table 4) at 12 months in the 0-5 cm layer. On the other hand, quadratic reductions were observed for CaECEC with K doses in row 1 (Table 4) in the 20-40 cm layer, probably due to the competitive inhibition between K at high concentrations and Ca (Malavolta et al., 1997).

Lower m% in the 20-40 cm layer in row 1 may be attributed to the higher V% in the same layer. It is important to note that the high verified m%, mainly in the subsurface layers (15-60 cm, Table 2), is attributed to the higher Al content, as the OC reduction in the profile reduces complexation, with the exchangeable form predominating. However, eucalyptus does not have Al toxicity problems and the high m% is not restrictive to growth (Bellote and Ferreira, 1993). Quadratic fit for K with doses was observed in the 0-5 cm layer , which favored linear fit

Table 4 – Regression equations for concentration of macronutrients in different layers of soil, as affected by potassium rates and the interaction of the main factor (rows) and secondary (rates).
Tabela 4 *–Equações de regressão referentes às concentrações de macronutrientes em diferentes camadas de solo, em função de doses de potássio, e da interação do fator principal (renques) e secundário (doses).*

Attributes	Unit	Layer	Equation	R^2	P
			6 months		
K	$mmol_c\ dm^{-3}$	5-10 cm	$y = 0.0029x + 1.5097$	0.94	0.0298
Mg	$mmol_c\ dm^{-3}$	0-5 cm	$y = -0.0001x^2 + 0.0006x + 28.512$	0.99	0.0134
CEC	$mmol_c\ dm^{-3}$	20-40 cm	$y = -0.0005x^2 + 0.1898x + 124.9$	0.99	0.0253
KECEC	%	0-5 cm	$y = 0.0062x + 2.8898$	0.97	0.0145
			12 months		
K	$mmol_c\ dm^{-3}$	10-15 cm	$y = 0.0042x + 1.2178$	0.95	0.0229
ECEC	$mmol_c\ dm^{-3}$	0-5 cm	$y = 0.0328x + 71.628$	0.92	0.039
SB	$mmol_c\ dm^{-3}$	0-5 cm	$y = 0.0324x + 71.003$	0.92	0.0417
KECEC	%	10-15 cm	$y = -0.00002x^2 + 0.0179x + 4.114$	0.99	0.0097
			30 months		
OC	$g\ dm^{-3}$	10-15 cm	$y = 0.0001x^2 - 0.0373x + 19.717$	0.99	0.0346
CaECEC	%	5-10 cm	$y = -0.0004x^2 + 0.1085x + 42.721$	0.99	0.0176
Attributes	Row	Layer	Equation	R^2	P
			12 months		
SB	1	0-5 cm	$y = 0.0559x + 65.54$	0.93	0.034
SB	2	0-5 cm	$\hat{y}=\bar{y}= 77.8$	-	-
ECEC	1	0-5 cm	$y = 0.0553x + 66.363$	0.95	0.0243
ECEC	2	0-5 cm	$\hat{y}=\bar{y}= 78.4$	-	-
CaECEC	1	20-40 cm	$y = -0.00001x^2 - 0.0001x + 0.4387$	0.99	0.0479
CaECEC	2	20-40 cm	$\hat{y}=\bar{y}= 9.17$	-	-

for ECEC and SB and quadratic fit for KECEC in the same layer.

A linear effect for K in the 5-10 cm layer similarly favored KECEC in the same layer , as well as the linear effect for K in the 10-15 cm layer (Table 4) quadratically favored KECEC (Table 4). These K adjustments with K doses even occurred under good fertility conditions at 12 months (Table 2) (CQFSRS/SC, 2004). It is remarkable that K is mobile in the soil (Marschner, 2012) and decreasing K concentration in depth can be attributed to the use and rapid cycling by the root system. Due to eucalyptus roots distribution, which explores a considerable volume of soil through fine roots, it may have prevented nutrient losses through deep percolation (Laclau et al., 2013). No K leaching was observed in this study, even with 58% of sand in the 0-20 cm layer, as the applications were split in order to avoid large losses, as suggested by Costa et al. (2012).

4.3 Soil attributes at 30 months

The less acidic pH in row 2 favored higher CEC and ECEC in the 20-40 cm layer (Table 3). The same trend can be observed for pH in row 2 in the 10-15 cm layer. Quadratic fit of K doses were observed for OC in the 10-15 cm layer (Table 4), where the highest responses were found at the highest dose (300 kg ha^{-1} year). Long-term fertilization influenced the increase of OC stock (Table 3). Such response may have contributed to CEC generation in soils under subtropical conditions (Raij, 1981), which affects cation retention and reduces leach losses. A CEC and ECEC increase was observed (Table 3) during the experiment in relation to 6 months (Table 1) because of conservation management of rows, thus corroborating with Grayston et al. (1996) who verified an increase in OC over time associated with eucalyptus presence.

Quadratic fits were also observed for CaECEC in the 5-10 cm layer (Table 4). However, lower doses of K provided the highest CaECEC, although synergisms occur between K and Ca in low concentration (Malavolta et al., 1997).

Despite high KECEC at 6 and 12 months at close to 5% (Vitti et al., 2006), this situation was not repeated at 30 months, which represented less than 2% of the ECEC (Table 3). This reduction of KECEC was not expected at 30 months, since fertilization as well as the natural pruning were continuous. On the other hand, CaECEC up to 15 cm is adequate, which is between 35-45%, but MgECEC is much larger than the appropriate range, between 5 and 20% (Vitti et al., 2006). This corroborates the low Ca:Mg ratio in the profile at 30 months. Dijkstra and Fitzhugh (2003) found that Ca was the most important cation of CEC, and K represented less than 5% of ECEC, corroborating the results obtained here at 30 months (Table 3). On the other hand, the MgECEC was representatively higher than Ca, which is not common since subtropical acid soils usually contain less Mg than Ca, because Mg is not so strongly adsorbed by the clay and the SOM is more susceptible to leaching (Vitti et al., 2006; Salvador et al., 2011). Moreover, Marschner (2012) reported 5-10% of Mg from leaves is connected to pectates in the cell wall, which may be encouraging as the mineralization occurs, the Mg availability increases in the exchange complex.

In addition, the K recommendation for eucalyptus when the clay content is between 15-35% and K exchangeable between 1.5 and 3 $mmol_c\ dm^{-3}$ in the 0-20 cm layer is 40 kg of $K_2O\ ha^{-1}$ (Silveira et al., 2005). In addition, K fertilization management in the present experiment focused on grain and forage production in ICLS, and even despite this, little fertilization response was observed since *E. dunnii* has a medium response to fertilization (Gonçalves and Mello, 2000). The results of soil with values above 1.0 $mmol_c\ dm^{-3}$ have been contradictory, since most of the time there are no responses to the application of this nutrient, and when they occur they are justified by the close Ca: Mg ratio (<1 unit) or by the high values of Ca + Mg in soil (> 8 mmolc dm^{-3}) (Silveira and Malavolta, 2000).

5. CONCLUSIONS

Conservationist management of rows favors the highest concentrations of exchangeable bases, particularly at 30 months of experimentation, contributing to increases in OC, CEC and ECEC, as well as increases in CaECEC, MgECEC and KECEC. Reduced exchangeable K at 30 months may be associated with the higher concentration of Mg in ECEC. High K mobility in depth was not verified, rejecting the hypothesis that there would be leaching. Little response to potassium fertilization was observed at macronutrient concentrations.

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