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Urochloa decumbens grown with different *Eucalyptus* clones in an integrated crop-livestock-forest system[1]

Urochloa decumbens na integração lavoura-pecuária-floresta com diferentes clones de eucalipto

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ABSTRACT - The objective of this study is to evaluate the forage mass, chemical composition, mineral content, and mineral absorption in signal grass (*Urochloa decumbens*) grown with different eucalypt clones in an integrated crop-livestock-forest (iCLF) system. The split-split-plot scheme included three replicates arranged in a completely randomized block design. The eucalyptus clones GG 100 and I 144 (*Eucalyptus grandis* × *Eucalyptus urophylla*) and VM 58 (*Eucalyptus grandis* × *Eucalyptus camaldulensis*) were distributed in the plots. The split plots corresponded to the growth ages of signal grass (10, 17, 24, 31, 38, 45, and 52 days after corn harvest for silage). The split-split plots corresponded to two sampling sites: center of the inter-row and soil under the *Eucalyptus* canopy. The *Eucalyptus* clones did not affect the forage mass of the grass. Forage mass was increased linearly as the grass matured and was more readily available in the center of the inter-row than under the tree canopy. The grass grown with clone I 144 presented better chemical composition, with higher levels of crude protein and phosphorus and lower levels of neutral detergent fiber. The *Eucalyptus* clones did not significantly affect mineral absorption. However, the *Eucalyptus* clones, grass age, and sampling sites significantly changed potassium absorption. It is concluded that the forage mass of signal grass is suitable for use in grazing at 38 to 52 days after corn harvest in the iCLF system in the autumn season in the Midwest region of Minas Gerais, without compromising the chemical composition of the grass.

Key words: Chemical composition. Mineral absorption. Growth ages. Sampling sites.

RESUMO - Objetivou-se avaliar a massa de forragem, composição química, teor e extração de minerais do capim-braquiária (*Urochloa decumbens*) sob diferentes clones de eucalipto na integração lavoura-pecuária-floresta (iLPF). Utilizou-se o esquema de parcelas subsubdivididas, no delineamento em blocos casualizados, com três repetições. Nas parcelas, distribuíram-se os clones de eucalipto GG 100 e I 144 (*Eucalyptus grandis* x *Eucalyptus urophylla*) e VM 58 (*Eucalyptus grandis* x *Eucalyptus camaldulensis*), nas subparcelas, as idades de crescimento do capim-braquiária (10; 17; 24; 31; 38; 45 e 52 dias após a colheita do milho para silagem), e, nas subsubparcelas, os locais de amostragem, no centro da entrelinha e sob a copa de eucalipto. Verificou-se que os clones de eucalipto não afetaram a massa de forragem do capim-braquiária, que foi incrementada linearmente com o avanço da idade de crescimento, com maior disponibilidade no centro da entrelinha do que sob a copa das árvores. O capim-braquiária cultivado com o clone I 144 apresentou melhor composição química, com altos teores de proteína bruta e fósforo e baixo teor de fibra em detergente neutro. Não houve efeito dos clones de eucalipto na extração de minerais, somente efeito da interação tripla clones, idades e locais de amostragem na extração de potássio. Conclui-se que o capim-braquiária apresenta massa de forragem adequada para pastejo entre 38 e 52 dias após a colheita do milho em iLPF, sem comprometimento de sua composição química, na estação de outono na região Centro-Oeste de Minas Gerais.

Palavras-chave: Composição Química. Extração de minerais. Idades de Crescimento. Locais de Amostragem.

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INTRODUCTION

An integrated crop-livestock-forest (iCLF) system is characterized by the production of grain, fibers, wood, meat, and milk in the same area in consortium, rotation, or succession (BALBINO *et al*., 2011). This system resembles the integrated crop-livestock system and, according to Vilela *et al*. (2011), the synergism between the components of these systems improves the physical, chemical, and biological properties of the soil. Besides that, this synergism interrupts the disease cycle and reduces the number of insect pests and weeds, reduces economic risks by the diversification of activities, and reduces costs associated with the recovery and renewal of degraded pastures. In addition, these systems allow the increase in the income of producers by the economic exploration of more than one marketable product in the property (PACIULLO *et al*., 2011).

A requirement for the success of these sustainable systems is the right choice of its constituent plant species. The trees should exhibit rapid growth, and their canopies should allow the entry of light for the growth of the understory (OLIVEIRA *et al*., 2007). *Eucalyptus* trees meet these requirements. Several crops have been developed using the iCLF system. Corn has been distinguished by its tradition of cultivation, wide use in human and animal feeding, and adaptation to intercropping.

With respect to forage species, it is necessary to select species that are tolerant to shading, with high production capacity, and that are adapted to the edaphoclimatic conditions of the region where they are grown (ANDRADE *et al*., 2003).

The nutritional needs of plants are assessed by quantifying the nutrients they absorb during their lifecycle. Absorption is dependent on crop biomass and nutrient concentration. Quantifying plant biomass and nutrient content at different growth ages is necessary to guide the nutritional management of soil and animals because forage plants play an essential role in supplying minerals to grazing animals.

One of the problems of pastures in Brazil is degradation, and the iCLF system may help minimize this problem (COELHO *et al*., 2014). The iCLF system can improve soil conditions, including soil coverage, nutrient cycling, and organic matter content, demonstrated by improving the nutritive value of shaded pastures (PACIULLO *et al*., 2007; SOARES *et al*., 2009).

The objective of this study is to evaluate the forage mass, chemical composition, mineral content and mineral absorption at different growth ages of signal grass grown in the center of the inter-row and under the canopy of different *Eucalyptus* clones after corn harvest in an integrated crop-livestock-forest system.

MATERIAL AND METHODS

The study was conducted at the Experimental Farm of Santa Rita/EPAMIG, in the municipality of Prudente de Morais, state of Minas Gerais, Brazil, located at 19°27’15” S and 44°09’11” W, and altitude of 732 m. According to Köppen’s classification, the climate of the region is type Aw, with dry season from May to October and wet season from November to April. The climate data were recorded during the growth of the signal grass (from the beginning of March until April 20), which occurred soon after the corn harvest. The accumulated rainfall was 246 mm, the average maximum temperature was 29.3 °C, and the average minimum temperature was 17.9 °C.

The soil type was Dystrophic Red-Yellow Latosol (EMBRAPA, 2006) and presented the following characteristics in the 0-20 cm depth layer: pH (in H_2O), 5.4; exchangeable Al, 0.2 $cmol_c$ dm^{-3}; Ca + Mg, 3.4 $cmol_c$ dm^{-3}; P-Mehlich 1, 3.7 mg dm^{-3}; K, 70.3 mg dm^{-3}; organic matter content, 10.6 g dm^{-3}; V, 35%; m, 4.7%; base sum, 4.1 cmolc dm^{-3}; total cation exchange capacity, 11.6 cmolc dm^{-3}; effective cation exchange capacity, 4.3 $cmol_c$ dm^{-3}; clay, 670 g kg^{-1}; silt, 130 g kg^{-1}; and sand, 200 g kg^{-1}.

Each split-split plot contained three replicates arranged in a completely randomized block design. The following *Eucalyptus* clones were distributed in the plots: GG 100 and I 144 (*Eucalyptus grandis* × *Eucalyptus urophylla*) and VM 58 (*Eucalyptus grandis* × *Eucalyptus camaldulensis*). The split plots corresponded to the seven growth ages of the grass (10, 17, 24, 31, 38, 45, and 52 days after corn harvest corn for silage), and the split-split plots corresponded to two sampling sites (center of the inter-row and under the tree canopy). *Eucalyptus* trees were planted in a double row (3 x 2) + 20 m, with 434 trees ha^{-1}. The hybrid corn variety was BRS 3060, grown for silage, and the perennial grass was signal grass (*Urochloa decumbens* cv. Basilisk).

The study was conducted in pastures under degradation, formed approximately 15 years prior, with a predominance of signal grass. The signal grass was evaluated in the second year of implantation in the iCLF system.

The pasture was dried with the herbicide glyphosate at the dose of 1.8 kg ha^{-1} of active ingredient 20 days before planting corn and signal grass. Corn and grass were sown in November under the no-tillage system using a mechanized seeder for intercropping. The sowing design comprised three rows of corn spaced 70 cm apart and nine rows of signal grass spaced 23 cm apart, coinciding with the deposition of grass seeds on corn lines plus two rows of grass between maize lines. The seeder was regulated for a platform of 55,000 corn plants ha^{-1}. A rate of 4 kg ha^{-1} of viable pure seeds was used for sowing the grass.

Planting was carried out at a distance of 1.5 m to the eucalyptus planting lines. Crop fertilization and cover fertilization were performed using 350 kg ha^{-1} of 08-28-16 +Zn and 400 kg ha^{-1} of 25-00-25, respectively, and the latter was divided in two applications, the first at 20 days after plant emergence and the second at 40 days after emergence. A sub-dose of nicosulfuron (10 g ha^{-1} of a.i.) was applied using a traction sprayer to retard the growth of signal grass and avoid competition with corn for water, light, and nutrients. The cover crop, silvicultural, and phytosanitary treatments were performed according to the needs of each culture.

Corn for silage was harvested at 108 days after sowing. The first sampling of signal grass was made ten days after corn harvest by collecting the forage in an area of 1 m^2 at weekly intervals, totaling seven samplings. All samplings were made 10 cm from the soil using a sickle. Before each cut, grass height was measured from the soil to the curvature of the leaves, and the mean of three heights in 1 m^2 was calculated. The samplings were made in the center of the inter-row and under the canopy 2.0 m from the trees.

All grass samples were weighed and dried in a forced air oven at 55 °C until constant weight was achieved for calculating the air-dried sample (ADS). The dried samples were weighed, milled in a Willey mill using a 1-mm sieve, and transferred to glass containers for further analysis.

Forage mass (FM), plant height, dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and the concentrations and absorption of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) were determined in the grass shoot. DM, CP, and NDF were analyzed according to methods described by Silva and Queiroz (2002). The other macronutrients were analyzed by nitric-perchloric digestion to obtain the extract for measuring P, K, Ca, Mg, and S. P was determined by colorimetry using a digital spectrophotometer; K was determined by flame photometry; Ca and Mg were determined by atomic absorption spectrophotometry, and S was measured by turbidimetry using a digital spectrophotometer according to the method described by Malavolta, Vitti, and Oliveira (1997). The absorption of minerals by the grass was calculated by the product of mineral content in the plant tissue and forage mass.

Data were subjected to analysis of variance at a level of significance of 5%. The qualitative variables significant for the *Eucalyptus* clones (% of CP, NDF, and P) were submitted to the Tukey's test. The quantitative variables related to the growth age of signal grass [% of CP, P, K, Mg, N, and absorption (kg ha^{-1}) of Ca and S], interaction between growth age and sampling sites [FM, plant height, % of NDF and Ca, and absorption (kg ha^{-1}) of P and Mg], interaction between *Eucalyptus* clones and growth age (% of DM), and interaction among *Eucalyptus* clones, growth age, and sampling sites (absorption (kg ha^{-1}) of K) underwent a regression analysis. Data were analyzed using SISVAR software (FERREIRA, 2011).

RESULTS AND DISCUSSION

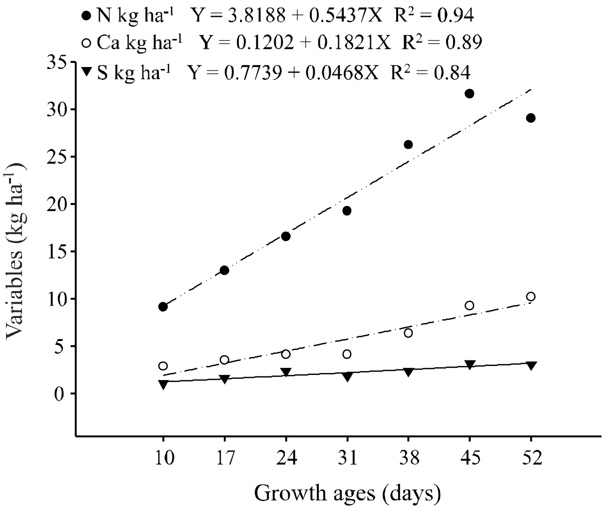
Eucalyptus clones significantly affected ($P<0.05$) the levels of CP, NDF, and P of signal grass. The grass grown with clone I 144 presented higher levels of CP and P and lower NDF compared with clone VM 58, indicating the better chemical composition of the former (Table 1). However, this result needs to be better evaluated because there were no marked differences in canopy architecture and projection between two these *Eucalyptus* clones (VIANA *et al*., 2012). It is of note that the mean nutrient content was higher in plants grown for 10 to 52 days after corn harvest in the autumn season (corresponding to the period in which the evaluations were made).

Table 1 - Crude protein (CP), neutral detergent fiber (NDF), and phosphorus (P) of signal grass grown with different *Eucalyptus* clones (mean of seven growth ages and two sampling sites)

Eucalyptus clones	CP	NDF	P
		(% DM)	
GG 100	10.20 b	68.50 ab	0.22 ab
I 144	11.40 a	67.00 b	0.24 a
VM 58	9.70 b	68.90 a	0.21 b

The means followed by the same letter in each column are not significantly different using Tukey's test ($p<0.05$)

Figure 1 - Absorption of N, Ca, and S (kg ha^{-1}), and regression equations and coefficients of determination (r^2) of signal grass harvested at different growth ages (means of three clones and two sampling sites)



The growth age significantly changed ($p<0.05$) the absorption of N, Ca, and S, with a tendency of linear increase in the absorption of these nutrients (Figure 1) as well as an increase in mean levels of PB, P, K, and Mg of signal grass grown with different *Eucalyptus* clones at two sampling sites.

For the concentrations of CP, P, K, and Mg, the obtained equations did not provide adequate adjustment of the data, with mean DM concentrations of 10.46%, 0.23%, 2.62%, and 0.25%, respectively, as a function of the growth ages of signal grass. Costa *et al*. (2007) observed a linear decrease in P content in *Urochloa brizantha* cv. Xaraés; however, the growth age from 15 to 60 days did not significantly affect the levels of K and Mg.

The absorption of N, Ca, and S was also affected by the sampling site of signal grass, with higher absorption of N, Ca, and S in the center of the inter-row of *Eucalyptus*, corresponding to 25.7, 7.1, and 2.5 kg ha^{-1}, respectively, where the highest FM was observed. However, the signal grass grown under the tree canopy presented a comparatively lower absorption of N, Ca, and S, corresponding to 15.7, 4.5, and 1.6 kg ha^{-1}, respectively, demonstrating that shading contributed to the decrease in the absorption of these minerals, and a similar result was observed for FM, which was also lower under the tree canopy because the absorption of minerals depends on FM (Table 2).

There was an interaction effect ($p<0.05$) between growth age and sampling site for the variables FM, plant height, NDF, concentration of Ca and P, and absorption of P and Mg, with a tendency of a linear increase in the absorption of these nutrients, except for Ca, as the growth age-progressed at the two sampling sites (Table 2).

At early growth ages, signal grass presented low FM, which was increased linearly as the plants matured. The FM ranged from 0.7 to 2.7 t ha^{-1} in the center of the inter-row and from 0.4 to 1.8 t ha^{-1} under the tree canopy (Table 2). The lowest FM was observed under the tree canopy, evidencing the adverse effect of shading on this variable, and this result may be related to competition with *Eucalyptus* for other growth resources, including water and nutrients. A similar result was observed in other studies (OLIVEIRA *et al*., 2007; SOARES *et al*., 2009; SOUSA *et al*., 2007). Rodrigues *et al*. (2014) found that the FM of signal grass was higher in the center of *Eucalyptus* inter-row using different spatial arrangements and sampling sites. However, Coelho *et al*. (2014) evaluated different spatial arrangements, sampling sites, and cutting age and found that the FM of signal grass was not affected in the center of the inter-row and under the *Eucalyptus* canopy.

The FM of signal grass was not significantly changed ($p>0.05$) by the *Eucalyptus* clones, with a mean of 1.30 t ha^{-1}. This yield was similar to the national average for signal grass. However, it should be considered that yield was determined from 10 to 52 days of plant growth, with lower yields at the beginning of growth. Coelho *et al*. (2014) found smaller FM values for signal grass, with a mean of 0.44 t ha^{-1}, with cut intervals of 35 to 63 days.

The tendency of increase in the height of signal grass was similar to that of FM. In the two sampling sites, a linear increase ($p<0.05$) in FM was observed as a function of the growing age, varying from 28.3 to 85.3 cm in the center of the inter-row and from 28.0 to 77.2 cm under the tree canopy. The lowest height was obtained under the *Eucalyptus* canopy, where there was higher shading, and might be attributed to the lower plant growth in this condition (Table 2). Martuscello *et al*. (2009) observed a different result, wherein the height of grasses of the genus *Urochloa* was increased as shading was increased. The *Eucalyptus* clones did not significantly affect grass height in the present study, with a mean height of 54.7 cm.

The equations found for NDF content in the signal grass, as a function of growth ages in the two sampling sites, did not provide an adequate adjustment of the data, with a mean NDF concentration of 67.9% in the center of the inter-row and 68.3% under the *Eucalyptus* canopy (Table 2). A linear increase in the NDF content was expected with the increase in the age of the plants in the center of the inter-row because the nutritional value of most forage species is decreased as plants grow. However, Coelho *et al*. (2014) observed that NDF was not significantly affected by different cutting ages in the signal grass.

Table 2 - Regression equations and determination coefficients (r^2) of forage mass (FM), plant height, and neutral detergent fiber (NDF); calcium concentration (Ca); and absorption of phosphorus (P) and magnesium (Mg) of signal grass as a function of the growth age in two sampling sites (means of three clones)

Sampling site	Regression equations	r^2
	FM (t ha^{-1})	
Center of the inter-row	$\hat{Y} = 0.0241 + 0.0513X$	0.91
Under the canopy	$\hat{Y} = 0.1773 + 0.0261X$	0.79
	Height (cm)	
Center of the inter-row	$\hat{Y} = 14.6987 + 1.3568X$	0.93
Under the tree canopy	$\hat{Y} = 16.3352 + 1.1699X$	0.93
	NDF (% DM)	
Center of the inter-row	$\overline{X} = 67.9\%$	
Under the tree canopy	$\overline{X} = 68.3\%$	
	Ca (% DM)	
Center of the inter-row	$\overline{X} = 0.46\%$	
Under the tree canopy	$\hat{Y} = 0.6771 – 0.0171X + 0.0003X^2$	0.65
	P (kg ha^{-1})	
Center of the inter-row	$\hat{Y} = –0.0426 + 0.1067X$	0.95
Under the tree canopy	$\hat{Y} = 0.5316 + 0.0456X$	0.75
	Mg (kg ha^{-1})	
Center of the inter-row	$\hat{Y} = –0.1770 + 0.1259X$	0.92
Under the tree canopy	$\hat{Y} = 0.5719 + 0.0586X$	0.66

Paciullo *et al*. (2007) observed that the NDF content was lower in shaded pastures than in pastures under full sun. Paciullo *et al*. (2011) evaluated *Urochloa decumbens* grown under the canopy of different tree species after corn harvest and found that these tree species did not significantly affect the NDF content of the grass. Moreira *et al*. (2009) studied *B. brizantha* cv. under shading of ipê (*Zeyheria tuberculosa*) and aroeira (*Myracrodruon urundeuva*) under full sun and observed that shading did not significantly affect the NDF content.

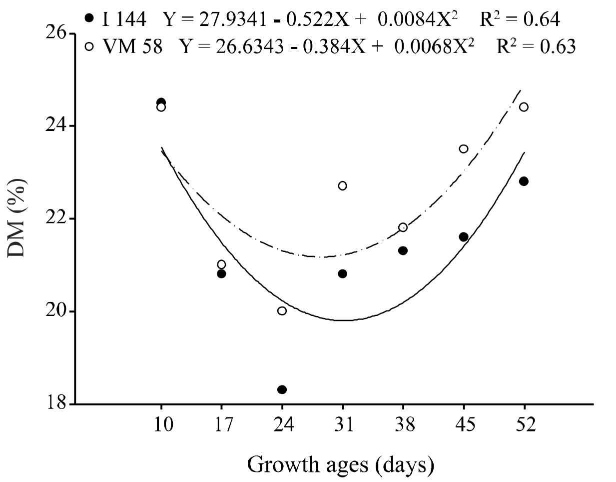
The levels of Ca in the forage harvested in the inter-row and under the tree canopy were similar, with a mean value of 0.46% (Table 2). Oliveira *et al*. (2007) evaluated *Urochloa brizantha* cv. Marandu under different cropping arrangements with *Eucalyptus* in an iCLF system and found that Ca and K concentrations were higher in signal grass grown under *Eucalyptus* rows and Mg concentrations were higher in the inter-row. These results are different from those of this study.

In addition, the absorption of P and MG was increased linearly as the growth ages advanced in the inter-row and under the tree canopy, ranging from 1.1 to 5.6 kg ha^{-1} and 1.0 to 2.9 kg ha^{-1} for P, respectively, and from 1.4 to 6.7 kg ha^{-1} and 1.2 to 3.6 kg ha^{-1} for Mg, respectively (Table 2).

The absorption of macronutrients was calculated by the product of FM of the grass shoot and mineral concentration. For P concentrations, the equations found did not provide adequate adjustment of the data, the FM varied linearly, and the linear increase in nutrient absorption as the growth ages advanced evidenced the stronger effect of FM on this variable (Table 2).

There was a significant ($p<0.05$) interaction effect between *Eucalyptus* clones and growth age for the DM content of signal grass, with a quadratic response as a function of the growth age (Figure 2). Coelho *et al*. (2014) observed a linear increase in the DM content of signal grass as a function of the cutting age of regrowth (35, 42, 49, 56, and 63 days). However, Castro *et al*. (2007) studied the production performance of *Urochloa brizantha* at four cutting ages (28, 56, 84, and 112 days) and observed that the DM content was increased linearly as the grass matured and ranged from 18.8% to 27.5%. In contrast, Lacerda *et al*. (2009) reported that the DM content in a silvopastoral system with *Tabebuia serratifolia* and *Hymenaea courbaril* was not significantly affected by three growth ages (35, 49, and 63 days).

Figure 2 - Dry matter (DM) (%), regression equations, and determination coefficients (r^2) of signal grass as a function of growth ages using clones I 144 and VM 58 (means from two sampling sites)



The lowest DM concentrations (19.8% and 21.2%) were observed at 31.1 and 28.2 days of growth under clones I 144 and VM 58, respectively. At the beginning of the growth of signal grass after corn harvest, the forage probably increased the production of young tissues, resulting in lower DM levels. However, the DM levels were later increased as the grass matured (Figure 2). The equations found for clone GG 100 did not provide adequate adjustment of the data, with a mean DM content of 22% at different growth ages.

The interaction between clones, growth ages, and sampling sites was significant ($p<0.05$) only for K absorption (Figures 3 and 4) of signal grass grown under *Eucalyptus* clones at different growth ages in the two evaluated sampling sites.

There was a quadratic response ($p<0.05$) for K absorption of signal grass grown under the canopy of clone GG 100 at different growth ages, and maximum absorption (32.4 kg ha^{-1}) occurred at 42.8 days. However, there was a linear increase in the absorption using the other clones. In the center of the inter-row, K absorption ranged from 18.1 to 58.2 kg ha^{-1} for clone GG 100 and from 14.9 to 52.2 kg ha^{-1} for clone I 144. Absorption of K varied from 8.6 to 90.6 kg ha^{-1} for clone VM 58. Under the *Eucalyptus* canopy, K absorption by signal grass grown under the canopy of *Eucalyptus* clones I 144 and VM 58 ranged from 8.4 to 39 kg ha^{-1}, and from 15.9 to 34.9 kg ha^{-1}, respectively.

Figure 3 - Absorption of potassium (K) (kg ha^{-1}) of signal grass, regression equations, and determination coefficients (r^2) at seven growth ages in the center of the inter-rows of three *Eucalyptus* clones

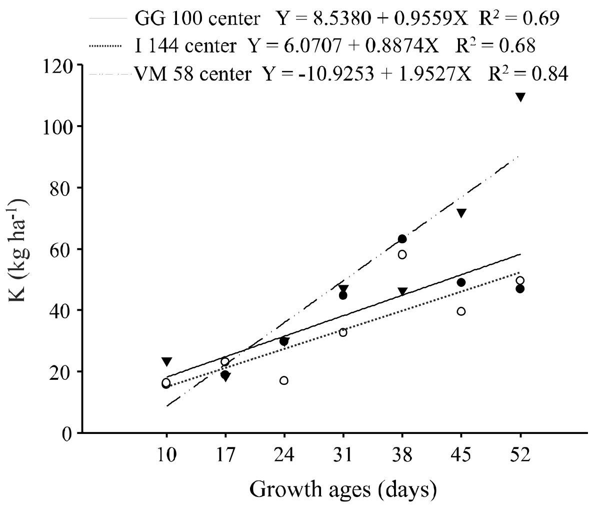
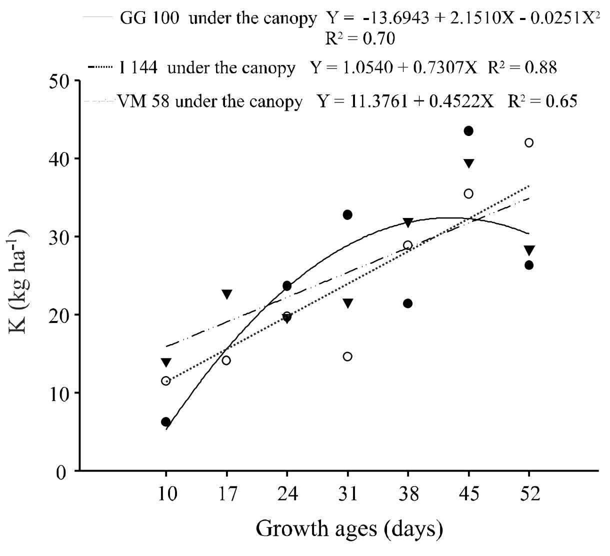


Figure 4 - Absorption of K (kg ha^{-1}) of signal grass, regression equations, and determination coefficients (r^2) at seven growth ages under the canopy of three *Eucalyptus* clones



CONCLUSION

Forage production of signal grass is suitable for grazing between 38 and 52 days after corn harvest in the iCLF system in the Midwest of Minas Gerais without compromising its chemical composition in the autumn season. When grown under the canopy of *Eucalyptus* clone I 144, the grass showed a better chemical composition, with higher levels of PB and P and lower NDF content. Under the evaluated growth conditions, signal grass absorbed K, N, Ca, Mg, P, and S in decreasing order, and absorption was higher in the center of the inter-row.

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