

LIXIVIAÇÃO DE POTÁSSIO EM UM LATOSSOLO CULTIVADO COM CAFÉ

MATEUS DE PAULA GOMES¹; CARLOS HENRIQUES SILVA REZENDE²; JOSÉ ADINAN SOUZA³ E GENELÍCIO CRUSOÉ ROCHA⁴

¹ Centro de Ciências Biológicas e da Natureza - Universidade Federal do Acre - Distrito Industrial, s/n, Campus Universitário, 69920-900, Rio Branco, AC, Brasil. E-mail: mateus.dpg@gmail.com

² Departamento de Solos - Universidade Federal de Viçosa - Avenida Peter Henry Rolfs, s/n, Campus Universitário, 36570-900 Viçosa, MG, Brasil. E-mail: phn.carlos@gmail.com

³ Departamento de Solos - Universidade Federal de Viçosa - Avenida Peter Henry Rolfs, s/n, Campus Universitário, 36570-900 Viçosa, MG, Brasil. E-mail: adinansouza@yahoo.com.br

⁴ Departamento de Solos - Universidade Federal de Viçosa - Avenida Peter Henry Rolfs, s/n, Campus Universitário, 36570-900 Viçosa, MG, Brasil. E-mail: genelicio.rocha@ufv.br

1 RESUMO

O objetivo deste estudo foi avaliar as perdas de potássio por lixiviação em um Latossolo cultivado com café. O experimento foi conduzido em uma lavoura cafeeira localizada em Viçosa, Minas Gerais, cujo solo foi classificado como Latossolo Vermelho-Amarelo de textura argilosa. Utilizou-se delineamento em blocos casualizados em esquema fatorial (3 x 2) + 1, sendo três doses de K₂O: 200, 400 e 600 kg ha⁻¹; duas formas de adubação: aplicação única e parcelada, e um tratamento controle, com quatro repetições, totalizando 28 parcelas. Em cada parcela foram instalados três tensiômetros nas profundidades de 0,90, 1,00 e 1,10 m para determinar o fluxo da água no solo, também foi instalado um extrator de solução do solo a 1,0 m de profundidade. O fluxo de potássio foi calculado a partir do produto do fluxo da água no solo pela concentração de potássio na solução do solo. O teor inicial de potássio no solo favoreceu a lixiviação do K. Houve aumento de 59, 104 e 140% na lixiviação de K₂O quando as doses foram de 200, 400 e 600 kg ha⁻¹ de K₂O, respectivamente, mas a forma de aplicação do fertilizante não influenciou nas perdas do nutriente.

Palavras-chave: potássio no solo, adubação, perda de potássio.

**GOMES, M. P.; REZENDE, C. H. S.; SOUZA, J. A.; ROCHA, G. C.
POTASSIUM LEACHING IN A LATOSOL CULTIVATED WITH COFFEE**

2 ABSTRACT

This study aimed to evaluate potassium loss by leaching in a Latosol cultivated with coffee. An experiment was conducted in a coffee plantation in Viçosa, Minas Gerais, whose soil was classified as Red-Yellow Latosol with a clay texture. A randomized block design in a (3 x 2) + 1 factorial arrangement with three doses of K₂O: 200, 400, and 600 kg ha⁻¹; two forms of fertilization: single and parceled application, and one control treatment, with four replications, totaling 28 parcels. In each plot, three tensiometers were installed at the depths of 0.90, 1.00, and 1.10 m to determine the flow of water in the soil, a soil solution extractor at a depth of 1.0 m was also installed. The potassium flow was calculated from the product of the water flow in the soil by concentrating potassium in the soil solution. The initial potassium content in the

soil favored the leaching of K. There was an increase of 59, 104, and 140% in the leaching of K₂O when the doses were 200, 400 and 600 kg ha⁻¹ of K₂O, respectively, but the form of application fertilizer did not influence nutrient losses.

Keywords: potassium in soil, fertilizing, potassium loss.

3 INTRODUCTION

Brazil is the world's largest coffee producer and exporter, with Brazilian exports accounting for 30.6% of global exports in the 2018/2019 harvest (INTERNATIONAL COFFEE ORGANIZATION, 2020). To achieve high productivity, Brazilian coffee production uses high fertilizer rates combined with efficient pest and disease management and genetic improvement.

Potassium (K) is the second most demanded nutrient by coffee plants, after nitrogen (MATIELLO *et al.*, 2010), and is the most exported nutrient by fruits, which are present mainly in the husk. K regulates several enzyme complexes and participates in oxidative phosphorylation and carbohydrate translocation, and K deficiency results in reduced photosynthesis. Furthermore, this nutrient influences the efficiency of phosphorus and water use by plants, cell wall development, and tolerance to some pests and diseases (CARVALHO *et al.*, 2013; SANTOS; JUNQUEIRA; FREITAS, 2013). Specifically, in coffee crops, K is associated with increased productivity and beverage quality (MANCUSO *et al.*, 2014; VINECKY *et al.*, 2016).

Successive K fertilization of crops promotes a residual effect that improves soil chemical conditions. However, available K levels in the soil rapidly decline during periods of intense crop extraction (LACERDA *et al.*, 2015). Therefore, high doses of this nutrient are often applied even when adequate levels are present in the soil, which can lead to K losses.

Potassium losses through leaching are more significant in areas with high rainfall, sandy soils, and low CEC. However, enrichment of the soil profile with K from soluble sources can also result in losses of this nutrient through leaching in clayey soils with high CEC (WERLE; GARCIA; ROSOLEM, 2008; MONACO *et al.*, 2009; DUARTE; PEREIRA; KORNDÖRFER, 2013).

Loss of K through leaching reduces the efficiency of potassium fertilization and results in economic (ALBUQUERQUE *et al.*, 2011) and environmental losses. Therefore, the objective of this study was to evaluate potassium loss through leaching in an Oxisol cultivated with Arabica coffee for high productivity.

4 MATERIALS AND METHODS

The experiment was conducted at Fazenda Laje, which is located in the municipality of Viçosa, Minas Gerais, with geographic coordinates of 20° 41' S and 42° 48' W. The soil was classified as a Red–Yellow Latosol cultivated densely with coffee (*Coffea arabica* L.) in a system of level terraces. The climate of the region is classified as Cwa according to the international Köppen classification (1931) (humid temperate with dry winters and hot summers).

A randomized block design was used in a factorial scheme (3 × 2) + 1, with three doses of K₂O: 200, 400 and 600 kg ha⁻¹; two forms of fertilization, single and split application and a control treatment without fertilization; and four replicates, totaling 28 plots.

Each experimental plot consisted of 18 plants (three planting lines with six plants per line), with the two central plants considered useful areas and the remaining plants considered borders.

Potassium chloride was used as the K₂O source. Applications were made in the canopy projection of the plants, with doses applied all at once or in split applications of 100 kg ha⁻¹. The maintenance fertilization also included 150 kg ha⁻¹ of nitrogen via urea.

In each plot, a soil solution extractor was installed at a depth of 1.0 m between the two plants in the plot's usable area. A vacuum pump applied a pressure of -10 kPa to each solution extractor. The pressure used was equivalent to the field capacity pressure for the soil under study. The samples were collected after rainfall, within a maximum of 24 hours, via a syringe and polyethylene tubing.

After collection, the solutions were transferred to plastic containers and stored in a refrigerator until the potassium concentration was analyzed. The potassium levels in the solution were determined via flame photometry. To determine the initial potassium levels in the soil solution, sampling began before the first fertilization application.

With respect to the soil water matric potential, three tensiometers were installed in each plot, located 0.6 m away from the solution extractor, at depths of 0.90, 1.00, and 1.10 m. Each tensiometer was coupled to a mercury manometer via a polyethylene tube, providing high sensitivity. Readings were taken at three-day intervals or after rainfall. This allowed the calculation of the total water potential at each depth and the total potential gradient between depths of 0.90 and 1.10 m, as per Libardi (2005).

Undisturbed soil samples were collected at a depth of 1.00 m to determine the hydraulic conductivity of the saturated soil (K_0). The determination of the hydraulic conductivity of the unsaturated soil ($K\theta$) was performed indirectly through the soil water retention curve adjusted by the van Genuchten model (1980), the hydraulic conductivity of the saturated soil (K_0) and the soil moisture at a depth of 1.0 m, according to the mathematical model proposed by Mualem (1976).

To determine the water retention curve, undisturbed soil samples (1 m deep) were placed on a tension table where the equilibrium moisture content was determined at stresses of 2, 4, 6, and 8 kPa. Subsequently, undisturbed soil samples (1 m deep) were placed in a Richards extractor to determine the equilibrium moisture content at stresses of 10, 30, 50, 100, 500, 1000, and 1500 kPa. These results were modeled via the Soil software. Water Retention Curve – SWRC.

The Darcy–Buckingham equation was used to calculate the vertical soil water flux. Potassium flux was calculated by multiplying the soil water flux by the potassium concentration in the soil mixture. To estimate the soil water balance, a rain gauge was installed in the experimental area to correlate the soil water flux dynamics with precipitation over time.

The chemical characterization of the soil was performed in each plot in the layers of 0–0.2 m, 0.2–0.4 m and 0.4–0.6 m (Table 1), and the physical characterization was determined in each plot at intervals of 0.10–1.2 m in depth. The soil texture did not present variations that could interfere with the internal drainage process of the soil along the profile, with all samples being classified in the textural class as clay (> 50% clay) (EMBRAPA, 1979).

Table 1 Chemical characterization of the soil in the experimental area

Depth	pH	P	K	Ca ²⁺	Mg ²⁺	Al ³⁺	H+Al	SB	t	T	V	m
(m)		- mg dm ⁻³ -					cmol c dm ⁻³				-- % --	
0-0.2	5.70	105.4	115.0	3.9	0.2	0.0	2.3	4.4	4.4	6.7	66.0	0
0.2-0.4	6.50	78.3	285.5	3.1	0.4	0.0	1.7	4.3	4.3	6.1	71.2	0
0.4-0.6	5.73	17.1	193.7	2.3	0.3	0.0	1.9	3.1	3.1	4.9	63.4	0

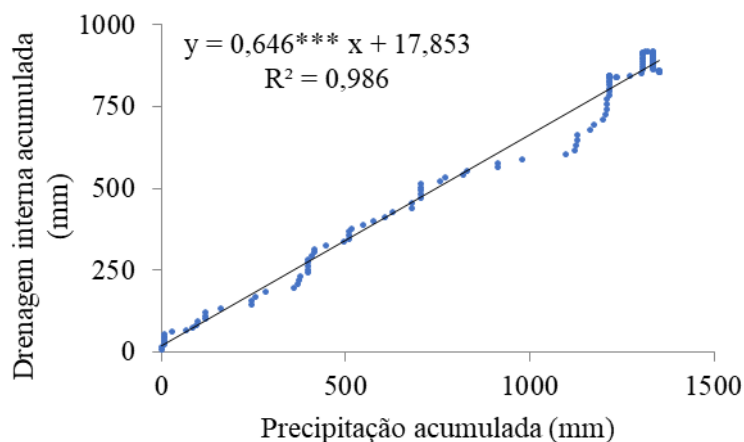
pH in a water ratio of 1:2.5; P and K: Mehlich extractant 1; Ca, Mg and Al: KCl extractant 1 mol L⁻¹.

The data were subjected to analysis of variance via the Statistical Software Analysis System (SAS), and regression models were subsequently adjusted for K loss as a function of the fertilizer dose applied and the accumulated internal drainage as a function of the accumulated precipitation.

5 RESULTS AND DISCUSSION

The accumulated rainfall during the experiment was 1352 mm, and the internal soil water drainage was 857 mm, corresponding to 63% of the total rainfall. There was a good correlation between rainfall and internal drainage, demonstrating the efficiency of the methodology used to calculate soil water flow (Figure 1).

Figure 1 Linear regression fit between accumulated precipitation and accumulated internal drainage, where *** is significant at the 0.1% probability level.



Chemical analysis of the soil in the experimental area indicated that successive fertilization over time resulted in the migration of K to the deeper soil layers, which presented high potassium contents (Table 1). Ernani *et al.* (2007) reported that the addition of KCl to the soil surface promoted the vertical movement of K, but the percolated amounts of nutrients were small.

Potassium has good mobility in the soil, especially in sandy textured soils with low CEC values (UCKER *et al.*, 2016). However, successive applications of high doses of K can increase mobility and, consequently, the levels of this nutrient at greater depths, even in clayey soils, regardless of CEC (ROSOLEM *et al.*, 2010).

The fertilizer application method did not influence nutrient losses (Table 2),

although KCl is a highly soluble source of K, releasing approximately 72% of the K in 24 h (BLEY *et al.*, 2017). This finding indicates that in clay soils, split K doses can be dispensed with the aim of reducing fertilizer application costs, even when high

doses are used and under conditions of heavy rainfall. However, it should be noted that the 1 m depth considered in this study does not apply to coffee crops in the early stages of development or to crops with shallower root systems.

Table 2 Summary of the ANOVA results for cumulative K₂O leaching

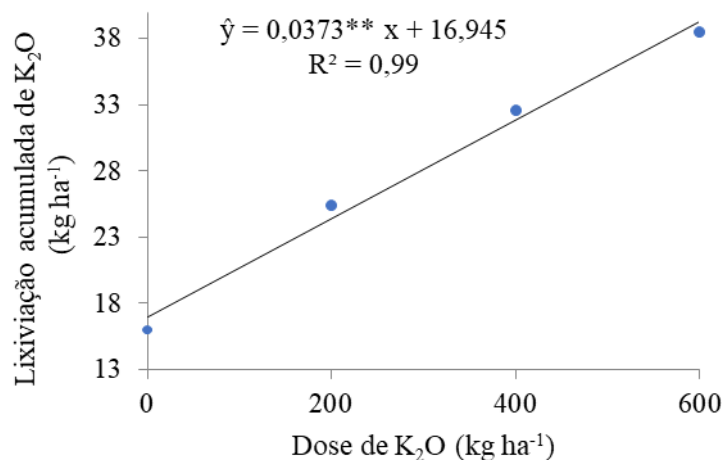
Source of Variation	Degrees of Freedom	Mean Square
Block	3	388.3 *
Application	1	34.8 ^{ns}
Dose	2	340.5 °
Application x dose	2	15.3 ^{ns}
Factorial x additional	1	896.5 **
Residue	18	82.9
Total	27	
CV (%)	30.51	

where ** is significant at the 1% level, * is significant at the 5% level, ° is significant at the 10% level and ^{ns} is not significant.

The K₂O rates had positive and linear effects ($p < 0.1$) on accumulated potassium leaching (Table 2). The accumulated K₂O loss at the zero rate was 16 kg ha⁻¹ within 96 days of the experiment (Figure 2). There was an increase of 59, 104, and 140% in K₂O leaching when the rates were 200, 400, and 600 kg ha⁻¹ K₂O, respectively. In this case, the initial potassium content in the soil favored nutrient leaching. Werle, Garcia, and Rosolem (2008) reported that the residual effect of potassium fertilization increases

the amount of percolated K even in clayey soil. According to the authors, the movement of K in the soil profile is related to the initial content resulting from previous potassium fertilization, regardless of the soil texture. Silva Filho *et al.* (2019) reported no K leaching into the deeper layers (below 0.4 m) of a dystrophic Red--Yellow Argisol with a sandy loam texture (61% sand), regardless of the applied dose; however, the soil in question had very low initial K levels in all the layers analyzed.

Figure 2 Regression adjustment for accumulated K₂O leaching as a function of the applied K₂O dose, where ** is significant at the 1% probability level.



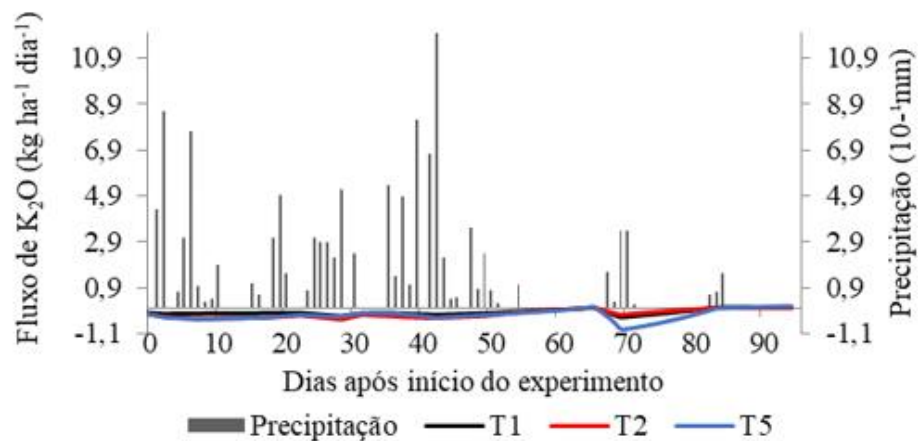
Although the increase in the dose resulted in greater K leaching, the losses corresponded to only 4.72, 4.15 and 3.74% of the fertilizer applied (excluding the K₂O leaching from the zero-dose treatment) for the doses of 200, 400 and 600 kg ha⁻¹ K₂O, respectively. Bley *et al.* (2017) reported K losses of less than 1% of the total available K, regardless of the dose applied in a clayey

soil with an initial content of 85 mg dm⁻³ of K.

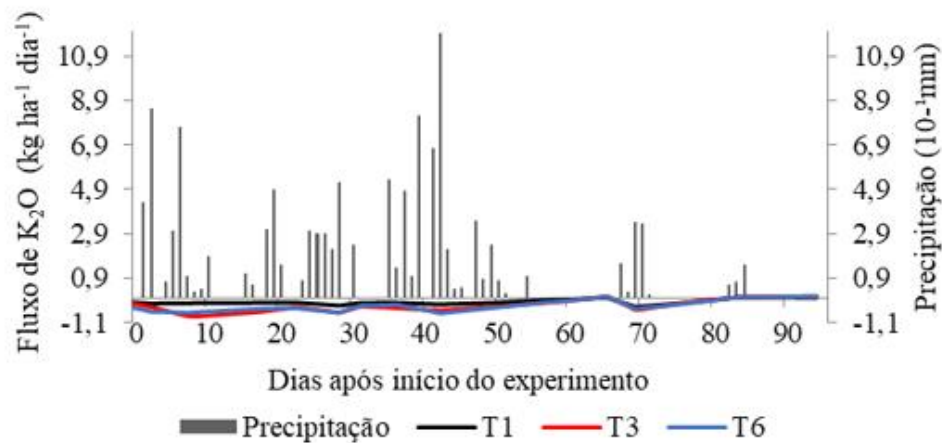
K leaching tends to increase with increasing water volume (MENDES *et al.*, 2016). However, in the present study, even with high rainfall, the K₂O flux was low throughout the experiment and was slightly influenced by precipitation, not exceeding 1 kg ha⁻¹ day⁻¹ (Figure 3).

Figure 3 K_2O flux in the soil throughout the experiment. T1 = 0 kg ha^{-1} of K_2O , T2 and T5 = 200 kg ha^{-1} of K_2O in single and split applications, respectively (A); T1 = 0 kg ha^{-1} of K_2O , T3 and T6 = 400 kg ha^{-1} of K_2O in single and split applications, respectively.

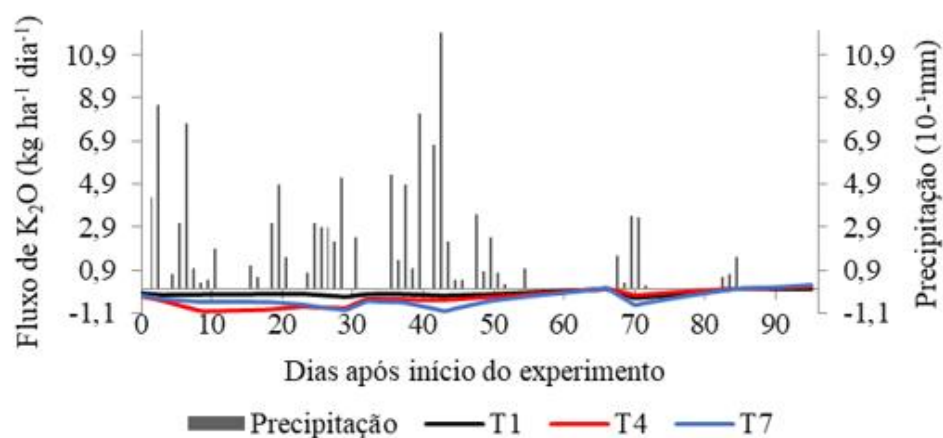
A.



B.



C.



Small peaks of K₂O leaching were observed after the rains that followed dry periods (Figure 3). Despite the high initial K levels in the soil, the soil texture and CEC were important in terms of K leaching, regardless of the precipitation and fertilizer application method. Mendes *et al.* (2016) reported losses of 3.26% and 7.99% of the K applied to clayey soil when the irrigation depth was 150% and 200% of the water depth required to bring the soil to moisture at field capacity, respectively. When the same water depths were applied to sandy soil, losses were 43.91% and 57.04% of the K applied, respectively.

6 CONCLUSION

The fertilizer application method (split or single application) did not influence K leaching.

K leaching was slightly influenced by the rainfall volume.

KCl doses.

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