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Long-Term Impact of Eucalyptus on the Chemical Characteristics of Distroferric Red Latosol

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ABSTRACT

The expansion of eucalyptus plantations in Brazil and in the world raised the issue of the impacts generated by this activity. In this context, the present study aimed to evaluate long-term impacts of some eucalyptus species on the chemical characteristics of Oxisol. Therefore, the soil under *Eucalyptus cloeziana, E. grandis, E. pilularis* and *Corymbia maculata*, cultivated since 1974, and under a Tropical Semideciduous Forest in an advanced stage of regeneration, was evaluated. Samples up to a meter deep were collected, and pH, exchangeable Al, H+Al, Ca, and Mg, available P and K, organic matter, m, t, T, SB, and V were analyzed. Data were subjected to analysis of variance and to the Scott-Knott test. The results revealed a low-fertility soil, with high acidity and high levels of exchangeable aluminum. The chemical conditions of the studied profiles differed little among themselves, but were slightly higher under native forest, especially for higher levels of organic matter. Among the eucalyptus species, the profile under *E. cloeziana* showed the best chemical characteristics, followed by *E. grandis, E. pilularis* and *C. maculata*. In terms of growth, *E. grandis* and *C. maculata* showed the best performance, followed by *E. cloeziana* and *E. pilularis*. The eucalyptus species showed a far superior basal area, compared to the native forest, indicating a high growth efficiency on low-fertility soils.

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INTRODUCTION

Despite its great utility and economic importance (Abraf, 2012), eucalyptus is commonly labeled as the cause of negative impacts on the environment (Vital, 2007). Part of these problems, such as "Eucalyptus dries the ground"; "Eucalyptus impoverishes the soil"; "nothing is born under Eucalyptus"; "in Eucalyptus monocultures, no animals are found"; "green desert", have already been scientifically demystified (Scolforo, 2008; Silva, 2009).

One of the forms to evaluate the impact of Eucalyptus plantations is the comparison with a reference ecosystem, such as a remnant native forest (Fonseca *et al*., 1993; Drumond *et al*., 1997; Melloni *et al*., 2008, Leite *et al*., 2010). Trees absorb and use mineral nutrients in their growth, promoting a gradual depletion of soil reserves and their concentration in the biomass. However, the biogeochemical circulation allows the reincorporation of part of the nutrients to the soil, which is an essential process in the sustainability of a forest ecosystem over time (Selle, 2007).

In the case of planted commercial forests, the higher demand for soil nutrients occurs when trees are at a juvenile stage. As the population matures, the absorption rate of nutrients in the soil is compensated by replenishment through litter deposition and internal recirculation in the trees (Poggiani and Schumacher, 2000; Laclau *et al*., 2010).

According to Laclau *et al*. (2003), there is an initial growth period during which most nutrient requirements of the population are supplied by the uptake from soil reserves. In a second phase, characterized by the closing of the canopy, recycling processes increase within the ecosystem. The authors report in their study that the internal translocation of nutrients in trees meets about 50% of the annual K requirements, 30% of N and P requirements, and smaller amounts of Ca and Mg. Litter returns about a quarter of the annual amounts of the absorbed P and K to the soil, and half the absorption of N, Ca and Mg. The authors conclude that, under

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conditions of soils with very low nutrient reserves available, mineralization of the organic material is a key mechanism, which provides substantial proportions of tree requirements.

Studies involving the availability and nutrient dynamics in the soil under short-rotation eucalyptus are commonly discussed in the scientific community (Guo *et al*., 2002; Zaia and Gama-Rodrigues, 2004; Lima *et al*., 2008; Santana *et al*., 2008; Gatto *et al*., 2010; Leite *et al*., 2010). However, studies involving long-term impacts of eucalyptus plantations on soil fertility are relatively scarce in the literature (Fonseca *et al*.,1993; Martins *et al*., 2002; Kolm and Poggiani, 2003; Melo *et al*., 2005).

However, long-term studies are essential to elucidate the effects of Eucalyptus in a state of maturity and dynamic equilibrium with the environment, without the effect of short-cutting cycles and export of nutrients.

Thus, the present study aims to evaluate long-term chemical conditions of the soil under Eucalyptus plantations and native forests.

MATERIAL AND METHODS

This study was conducted at Federal University of Lavras – UFLA, Lavras, Brazil; coordinates 21°13'40" S and 44°57'50" W, 925 m altitude, Cwa climate according to Koppen's classification, average temperature of 20.4ºC, average rainfall of 1,460 mm (Dantas, 2007), undulated relief, with slopes between 5 and 15% and typical loamy Oxisol.

Two areas were studied (Figure 1). The first area is comprised of the experimental test of species and origins of eucalyptus, installed by Brazilian Agricultural Research Corporation – EMBRAPA, in January 1974. The species *Eucalyptus grandis, E. pilularis, E. cloeziana* and *Corymbia maculata* were evaluated in four plots of 10 x 15 m, with 5 x 5 trees, spaced 3 x 2 m. In the implementation of the experiment, ploughing and harrowing were performed in the total area, as well as basic manure with 70 g per pit NPK (9-30-5) + micronutrients + aldrin, corresponding to 120 kg ha^{-1} of the formula (Moura *et al*., 1980).

The other studied area is adjacent to the experiment of EMBRAPA, and is occupied by the remnant Montana Tropical Semideciduous Forest, with a 5.8-ha emergent canopy (Dias and Oliveira Filho, 1996). This type of vegetation belongs to the Atlantic Forest biome, according to the classification proposed by IBGE (2012).

According to Oliveira Filho *et al*. (1994), the study of the vegetation in the area found 184 species of trees and shrubs, distributed in 119 genera and 52 families. The species with the highest importance value (IVI) in the phytosociological survey conducted in the area were: *Copaifera langsdorffii, Ocotea odorifera, Amaioua guianensis, Casearia arborea* and *Tapirira obtusa*. The remnant studied forest has never undergone clearcutting and has approximately the same geographical boundaries since at least the 1920s.

For the chemical characterization of the soil in the studied areas, the samples were collected at seven depths: 0-3, 5-8, 10-13, 15-18, 20-23, 60-63 and 100-103 cm. In the experimental area of the eucalyptus species, the samples were collected in the center of each plot and, in the area of native forest, in four randomly selected points. The collections were performed in January 2011. The samples were analyzed following EMBRAPA (1997): pH in water, ratio 1:2.5 (soil:water); exchangeable Al^{3+}, Ca^{2+} and Mg^{2+}, extracted with 1 mol L^{-1} KCl, analyzed by titration with 0.025 mol L^{-1} NaOH and determined by titration with 0.0125 mol L^{-1} EDTA, respectively; available P and K in a Mehlich-1 extractor (0.05 mol L^{-1} HCl + 0.0125 mol L^{-1} H_2SO_4), analyzed by colorimetry and flame photometry, respectively; and the organic matter was determined by wet digestion. The values of effective (t) and potential (T) cation exchange capacity, sum of bases (SB), exchangeable (Al^{3+}) and potential ($H^+ + Al^{3+}$) acidity, base saturation of the exchange complex (V) and aluminum (m) were also calculated. All laboratory tests were performed at the Laboratory of Soil Fertility in the Soil Science Department at UFLA.

The growth of the eucalyptus species was evaluated by basal area averages and density of trees per hectare in the sample plots. For the native forest, the average density of 1,291 ± 271 trees ha^{-1} was considered, average basal area of 22.9 ± 6.0 m² ha^{-1}, average height of 13 m, maximum height 25 m and maximum DBH 80 cm, according to the data of the complete inventory of the area (Nunes *et al*., 2003).

Data about the soil samples were subjected to analysis of variance with the statistical software SISVAR (Ferreira, 2008), considering a 5x7 double factorial design, in which five treatments corresponded to the four species of eucalyptus and native forest, and seven depths in the soil profile, with four replications. The means were compared by the Scott-Knott cluster analysis, as well as the calculation of the confidence interval, at 5% probability.

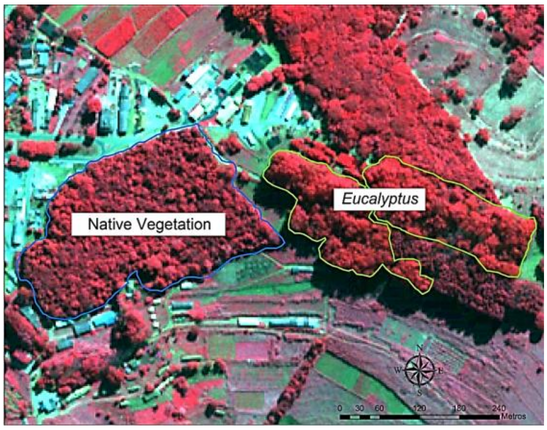

Fig. 1: Image of the areas studied, showing the experiment with eucalyptus and the remnant Tropical Semideciduous Forest (Braga *et al*, 2013).

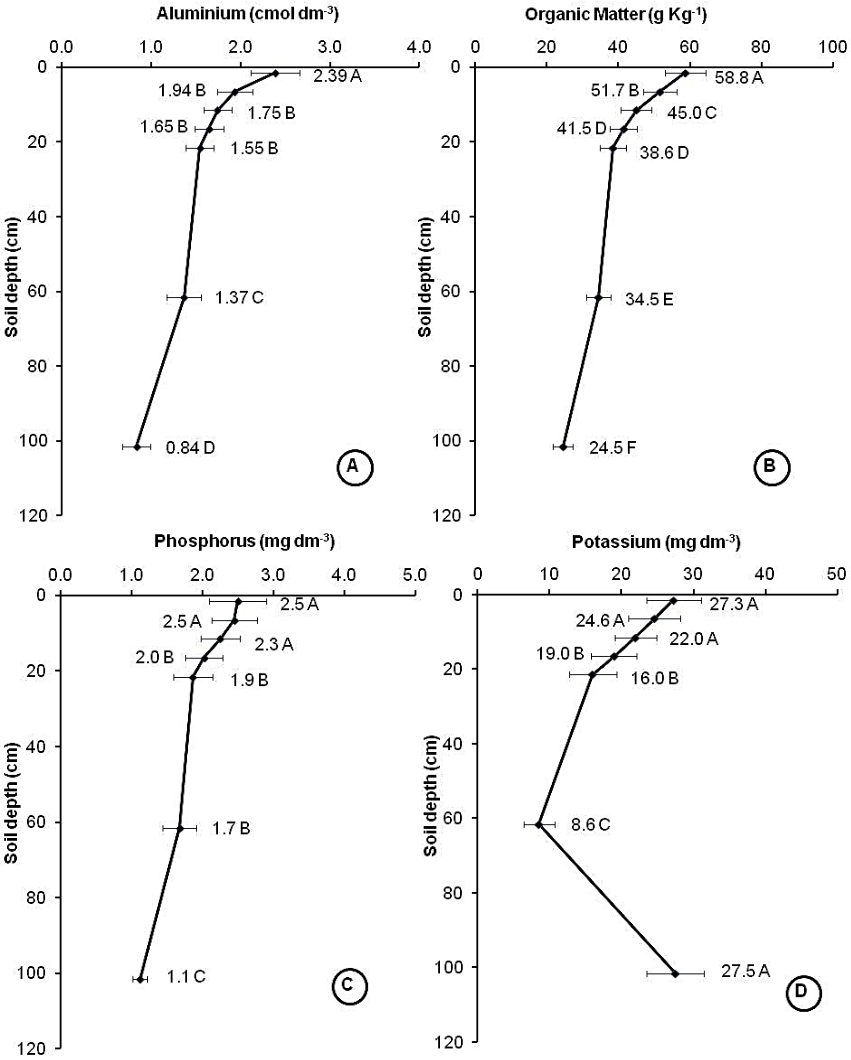

Fig. 2: Exchangeable aluminum (A), organic matter (B), phosphorus (C) and potassium (D) available in the soil profile. Means followed by the same letter do not differ by the Scott-Knott test at 5% significance. The bars indicate the confidence intervals by the t test at 5% significance.

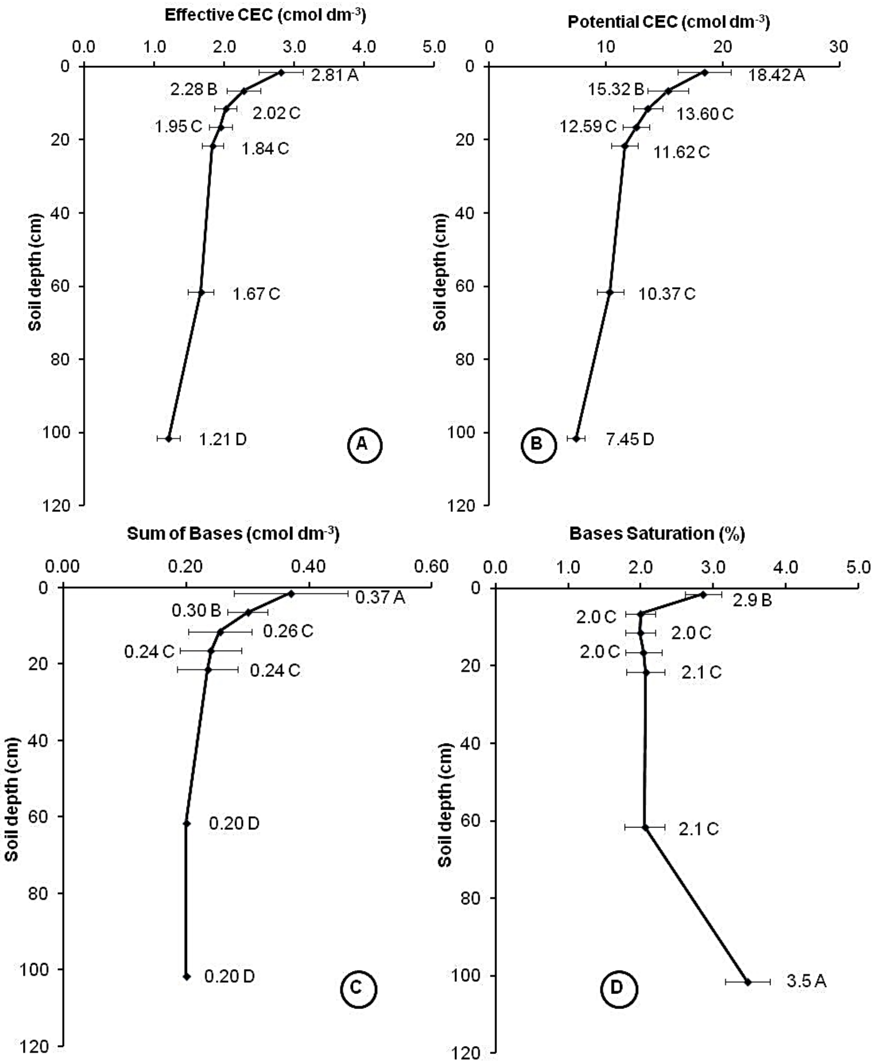

Fig. 3: Effective (A) and potential (B) cation exchange capacity, sum of bases (C) and base saturation (D) in the soil profile. Means followed by the same letter do not differ by the Scott-Knott test at 5% significance. The bars indicate the confidence intervals by the t test at 5% significance.

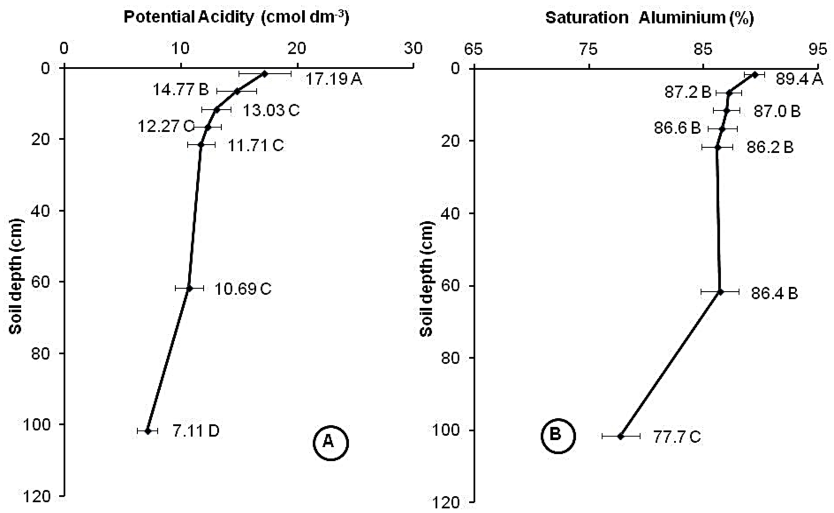

Fig. 4: Potential acidity (A) and aluminum saturation (B) in the soil profile. Means followed by the same letter do not differ by the Scott-Knott test at 5% significance. The bars indicate the confidence intervals by the t test at 5% significance.

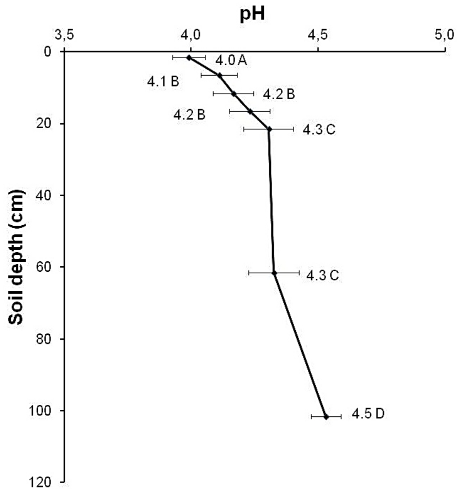

Fig. 5: pH available in the soil profile. Means followed by the same letter do not differ by the Scott-Knott test at 5% significance. The bars indicate the confidence intervals by the t test at 5% significance.

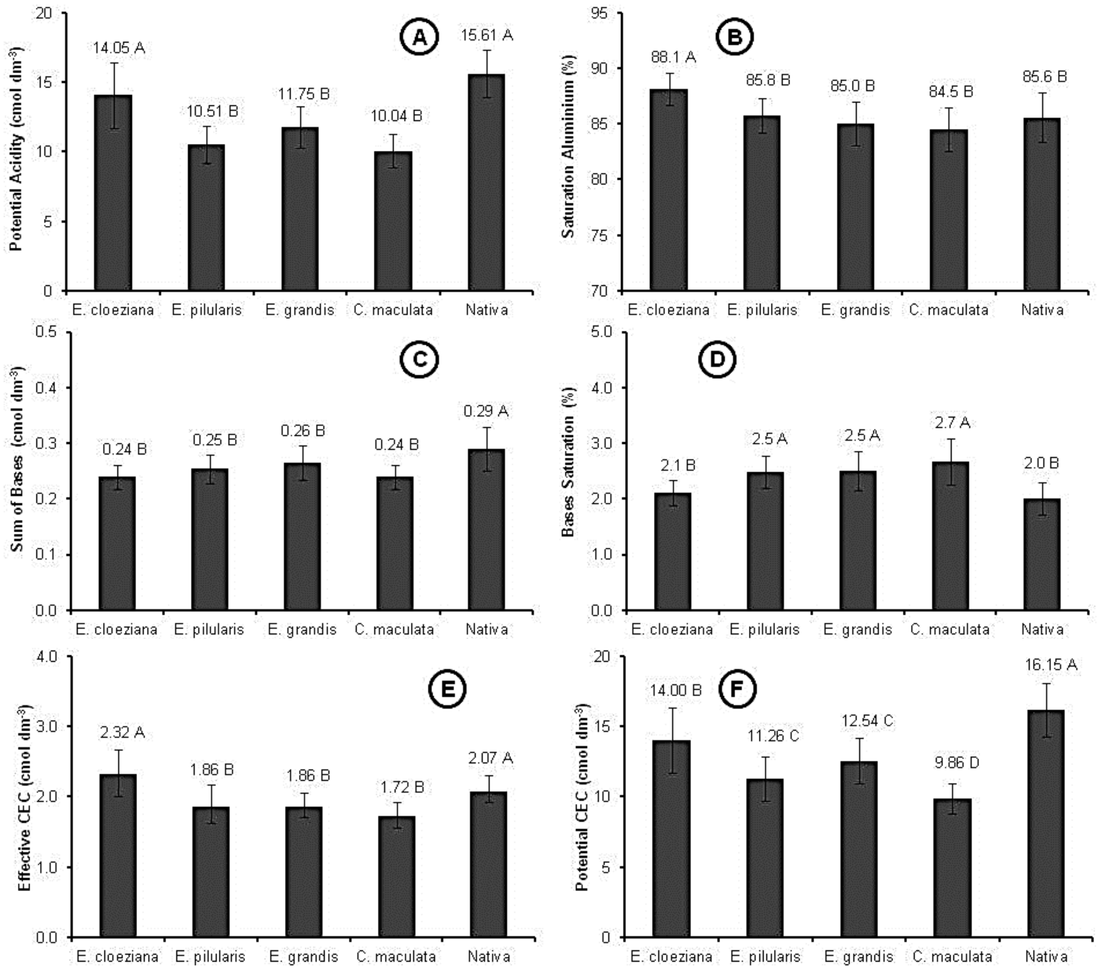

Fig. 6: Average levels of potential acidity (A), aluminum saturation (B), sum (C), base saturation (D), effective CEC (E) and potential CEC (F) in the soil profiles under different vegetal covers. Means followed by the same letter do not differ by the Scott-Knott test at 5% significance. The bars indicate the confidence intervals by the t test at 5% significance.

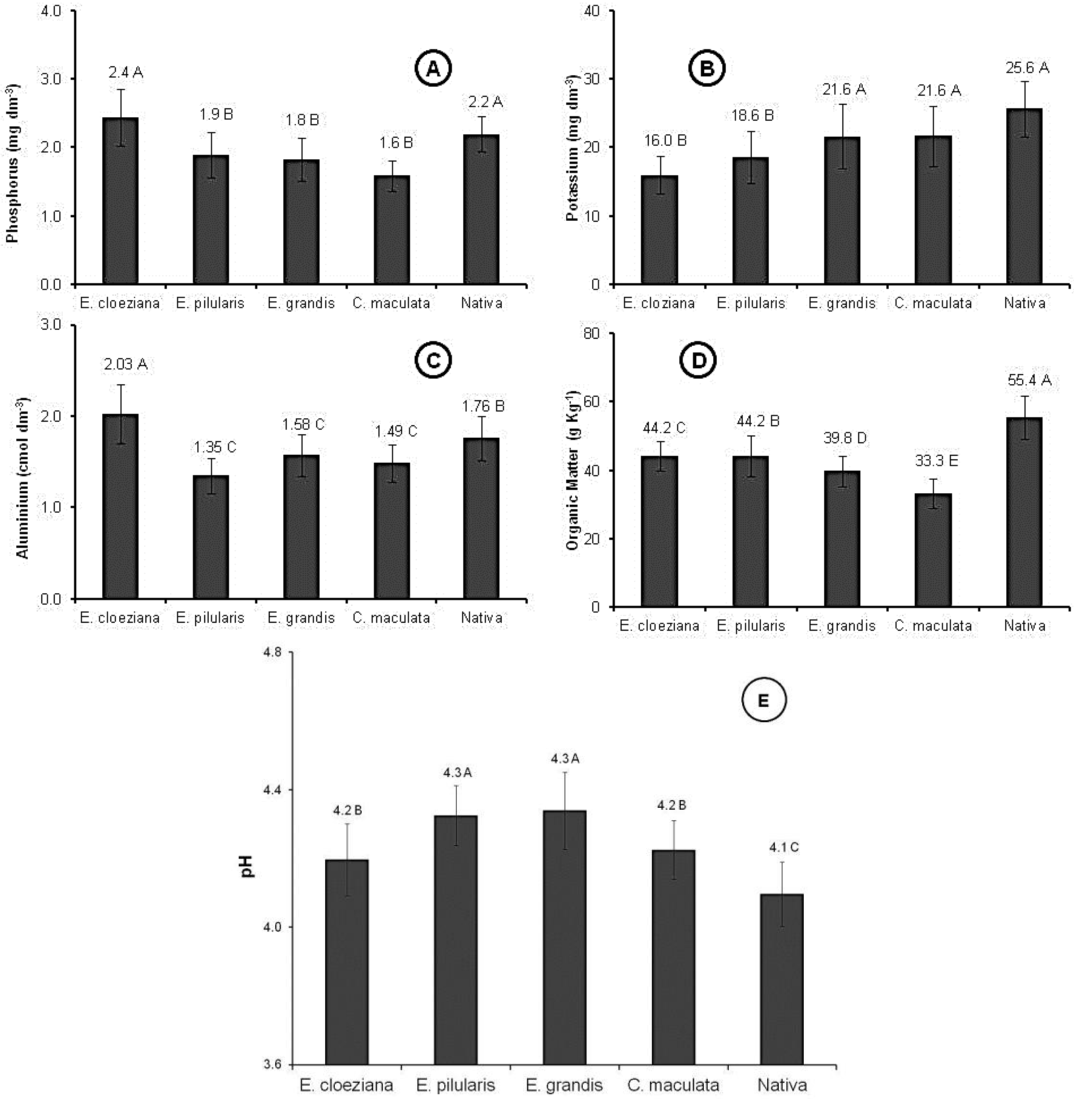

Fig. 7: Average levels of phosphorus (A), potassium (B), aluminum (C) organic matter (D) and pH (E) in the soil profiles, up to 1 m deep, under different vegetal covers. Means followed by the same letter do not differ by the Scott-Knott test at 5% significance. The bars indicate the confidence intervals by the t test at 5% significance.

RESULTS AND DISCUSSION

The results of the variance analysis showed significant and isolated effects on the studied chemical characteristics only for the factors vegetal cover and depth of the soil profile, while the interaction of these two factors had no significant effect, indicating that the fertility differences in depth were not derived from the different vegetal covers studied. Thus, the analysis of the effects of vegetal cover and depth on fertility were performed separately.

In general, the levels of Ca, Mg, P, t, T, Al, H+Al and organic matter decreased along the soil profile. This fact was also observed by Fonseca *et al*. (1993) and by Drummond *et al*. (1997) in soils under the Atlantic Forest and Eucalyptus, as well as by Melo *et al*. (2005) under cerrado. An exception occurred for K, which showed pulse accumulation at 100 cm (Figures 2 to 5).

The levels of organic matter were inversely correlated with pH and V, and directly correlated with P, m, Al, H+Al, SB and CEC (cation exchange capacity), a phenomenon commonly observed in soils (Raij, 2012).

Vegetal cover defined the average fertility of the profiles, except for the levels of exchangeable Ca and Mg, which showed no significant differences under native forest or Eucalyptus (Figures 6 and 7).

The profile under native forest had the highest average of organic matter levels, slightly higher average values of P, K, H+Al, SB and CEC, and lower pH and V values in relation to Eucalyptus. Leite *et al*. (2010) found, after several rotations with Eucalyptus, an increase in the levels of organic matter, compared to the soil under degraded pasture, but below the level observed under native forest. On the other hand, Fonseca *et al*. (1993) report higher fertility levels in profiles under eucalyptus, compared to native forest.

Considering the eucalyptus species, *E. cloeziana* conditioned the soil with the highest level of fertility. According to Barros *et al* (1990a), *E. cloeziana* presents a high plasticity and can develop properly in different site conditions. Compared with other eucalyptus species in northwestern Bahia, *E. cloeziana* showed the highest volumetric production in the treatment without manure and was the most responsive species to fertilization with *E. urophylla* (Barros *et al*., 1990b). Melo and Resck (2003) observed an average litter deposition of 7 t ha^{-1} yr^{-1} by *E. cloeziana*, containing, in kg ha^{-1}, 40 of N, 2 of P, 14 of K, 27 of Ca, 11 of Mg and 2.9 of S.

Despite the low natural fertility of the studied soils, the eucalyptus species maintained fertility levels similar to those found for the native forest, with a satisfactory growth, and a basal area up to five times higher (Table 1). The fact confirms the high efficiency of Eucalyptus for biomass production, even in extremely limiting environmental conditions, demonstrating a low requirement in relation to the levels of soil fertility (Barros e Novais, 1999; Gonçalves and Benedetti 2000). According to Laclau *et al*. (2003), despite the limited fertility of the soil, biogeochemical cycles of nutrients provided by Eucalyptus are efficient enough to produce large amounts of biomass. Therefore, the waste deposited on the soil is important in maintaining the nutritional status of the trees and in forest productivity (Bellote *et al*., 2008), as well as biological, biochemical and geochemical cycles of nutrients in tropical Eucalyptus plantations (Laclau *et al*., 2010).

In terms of performance of the eucalyptus species, two distinct groups were observed: *E. grandis* and *C. maculata*, with a higher growth; *E. cloeziana* and *E. pilularis*, with lower values of basal area and stand for area (Table 1).

Table 1: Basal area, density and DBH for the different vegetal covers.

Vegetal Cover	Basal área [2] m² ha^{-1}	Trees ha^{-1}	DBH (cm) [3] maximum	DBH (cm) [3] medium
Eucalyptus grandis	118.5 A	1.450	73	32
Corymbia maculata	111.7 A	1.600	68	30
Eucalyptus cloeziana	89.5 B	1.350	67	29
Eucalyptus pilularis	89.2 B	1.200	54	31
Tropical Semideciduous Forest [1]	22.9	1.291	80	15

[1] According to Nunes *et al*. (2003). [2] Means followed by the same letter do not differ by the Scott-Knott test at 5% probability. [3] Diameter at breast height.

By analyzing the level of soil fertility and performance, *E. grandis* showed to be the most efficient species, with the highest growth and an intermediate storage of nutrients in the soil. *C. maculata* showed a good growth, but it was the species that most depleted soil nutrient reserves. *E. cloeziana* and *E. pilularis* grew most slowly, but *E. cloeziana* presented the largest stock of nutrients in the profile among the eucalyptus species.

Conclusions:

The studied soil was characterized by a low natural fertility, high acidity and high levels of exchangeable aluminum and organic matter.

The chemical characteristics of the profiles under eucalyptus and native forest differed little among themselves, but were slightly higher under native forest, with emphasis on the content of organic matter.

Among the studied eucalyptus species, *E. cloeziana* conditioned the profile as the best chemical conditions, followed by *E. grandis, E. pilularis* and *C. maculata*.

In terms of growth, *E. grandis* and *C. maculata* showed the best performance.

The eucalyptus species demonstrated low nutritional requirements and a high efficiency, growing properly in a soil with an extremely low natural fertility.

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