LIME AND GYPSUM APPLICATIONS ON SOIL CHEMICAL ATTRIBUTES AND INITIAL GROWTH OF EUCALYPTUS

Camila Adaime Gabriel[1*], Paulo Cezar Cassol[2], Marcia Aparecida Simonete[3], Letícia Moro[4], Priscylla Pfleger[5], Gilmar Luiz Mumbach[5]

[1*] State University of Santa Catarina, Master in Soil Science, Lages, Santa Catarina, Brazil – camilaadaimegabriel@gmail.com
[2] State University of Santa Catarina, Department of Soil and Natural Resources, Lages, Santa Catarina, Brazil – paulo.cassol@udesc.br
[3] Blumeterra Commerce and Services Ltd., Technical Manager, Otacílio Costa, Santa Catarina, Brazil – marciasimonete@gmail.com
[4] Education Department of the State of Santa Catarina/CEDUP Caetano Costa, Technical Professor, São José do Cerrito, Santa Catarina, Brazil – leticia_moro@hotmail.com
[5] State University of Santa Catarina, Doctoral student, Graduate Program in Soil Science, Lages, Santa Catarina, Brazil - cyllapfleger@hotmail.com; gilmarmumbach@hotmail.com

Received for publication: 16/01/2018 - Accepted for publication: 10/05/2018

Abstract

Eucalyptus crops in Southern Brazil are generally conducted in acidic soils, thus their yield can be increased by lime and gypsum applications. The objective of this study was to evaluate the effect of lime and gypsum applications on soil chemical attributes and initial growth of *Eucalyptus benthamii* and *Eucalyptus dunnii* in a Humic Cambisol (Inceptisol). The experiment was conducted in a greenhouse, with seedlings of both species of eucalyptus grown in soil treated with different rates of lime (0, 3, 6, and 12 Mg ha^{-1}), and gypsum (0, 6, 3, 12.6, and 25.2 Mg ha^{-1}). At 90 days after application of the treatments, the soil chemical attributes and growth components of eucalyptus seedlings. The lime increased the production shoot dry weight, however, the response to gypsum was negative. The lime increased the soil pH, exchangeable calcium (Ca), base saturation (V %), and slightly the soil electrical conductivity, decreased the soil aluminium saturation (m %), and promoted little reduction in the exchangeable potassium (K) and magnesium (Mg) contents. The gypsum didn't alter the soil pH, but decreased the m%, increased soil phosphorus (P) contents, and expressively increased the electrical conductivity, which may have had a negative effect on the eucalyptus growth. In conclusion, the addition of limestone decreases the soil acidity and benefits the growth of eucalyptus seedlings. However, the addition of gypsum has no expressive effects upon those variables, but it can decrease the growth of seedlings when the rates are excessive.
Keywords: Soil acidity correctives, acid soils, *Eucalyptus dunnii*, *Eucalyptus benthamii*.

Resumo

Incorporação de calcário e gesso e o efeito em atributos químicos do solo e no crescimento inicial de eucalipto. Os cultivos de eucalipto no Sul do Brasil são geralmente conduzidos em solos ácidos, portanto, sua produtividade pode aumentar com a aplicação e calcário e gesso. O objetivo deste estudo foi avaliar o efeito de doses de calcário e gesso em atributos químicos do solo e no crescimento inicial de *Eucalyptus benthamii* e *Eucalyptus dunnii*, em Cambissolo Húmico. Foi conduzido um experimento, em casa de vegetação, com mudas de ambas as espécies de eucalipto, cultivadas em solo tratado com quatro doses de calcário (0, 3, 6 e 12 t ha^{-1}) e gesso agrícola (0, 6,3, 12,6 e 25,2 t ha^{-1}). Aos 90 dias após a aplicação dos tratamentos, foram determinados os atributos químicos do solo e componentes de crescimento das mudas de eucalipto. O calcário aumentou a produção de massa seca de eucalipto, contudo, a resposta ao gesso foi negativa. O calcário aumentou o pH, o teor de cálcio (Ca) trocável, a saturação por bases (V%) e, levemente, a condutividade elétrica, diminuiu a saturação por alumínio (m%) e promoveu pequena redução nos teores de potássio (K) e magnésio (Mg) trocáveis do solo. O gesso não alterou o pH do solo, porém diminuiu a saturação por Al, aumentou o teor de fósforo (P) e aumentou expressivamente a condutividade elétrica, o que pode ter influenciado negativamente o crescimento do eucalipto. Concluiu-se que a adição de calcário diminui a acidez do solo e beneficia o crescimento de mudas de eucalipto, enquanto a adição de gesso não afeta expressivamente essas variáveis, mas pode diminuir o crescimento dessas mudas quando em excesso.
Palavras-chave: Corretivos da acidez, solos ácidos, *Eucalyptus dunnii*, *Eucalyptus benthamii*.

INTRODUCTION

Brazil is the second largest producer of cellulose of the world, and large part of the raw material for its production is from eucalyptus plants. The area with eucalyptus species in Brazil reached 5.7 million hectares in 2016, and presented a higher mean yield (35.7 m^{-3} ha^{-1} year^{-1}) than that found in Australia, country of origin of the eucalyptus (22 m^{-3} ha^{-1} $year^{-1}$) (IBÁ, 2017). The state of Santa Catarina, Brazil, has a significant planted area with eucalyptus. Large part of its eucalyptus forests is in the Santa Catarina Plateau region, in which *Eucalyptus dunnii* Maiden and *Eucalyptus benthamii* Maiden et Cambage are the main clonal species used due to their adaptation to the edaphoclimatic conditions of this region (FLORIANI *et al.*, 2011).

Eucalyptus crops in the Santa Catarina Plateau region are mainly grown in soils with high acidity and low nutrient availability. The recommendations in the Manual of Liming and Fertilization of Rio Grande do Sul and Santa Catarina (CQFS-RS/SC, 2016) are little focused on reference pH values for eucalyptus crops because this species is generally considered tolerant to soil acidity and presence of exchangeable aluminium (Al). Thus, liming can be carried out based on the soil calcium (Ca) and magnesium (Mg) requirements, which must be greater than 4 $cmol_c$ dm^{-3}, and 1 $cmol_c$ dm^{-3}, respectively. However, the planting of eucalyptus in chemically poor soils can be detrimental to the plant's initial growth.

Correcting soil pH, and Ca and Mg contents are usually carried out by applying dolomitic limestone (CRUSCIOL *et al.*, 2014). However, despite the benefits of liming to acidic soils in neutralizing toxic Al and supplying nutrients (FAGERIA *et al.*, 2014; ANIKWE; IBUDIALO, 2016), the growth response of eucalyptus to liming not always has been considered (DIAS *et al.*, 2015). Rodrigues *et al.* (2016) evaluated the response of 18-month-old *Eucalyptus urophylla* x *Eucalyptus grandis* plants grown in a dystrophic Red-Yellow Latosol (Oxisol) to the application of Ca (lime) and gypsum in Três Marias, state of Minas Gerais, Brazil, and found a positive response, especially of soils presenting exchangeable Ca^{2+} contents of zero or undetectable.

Gypsum ($CaSO_4 2H_2O$) is a byproduct of the phosphate fertilizer production and can be applied to soils to supply Ca and sulfur (S) and reduce Al activity, although it does not change the soil pH (ANIKWE; IBUDIALO, 2016, ARAÚJO *et al.*, 2016). Increasing Ca availability in the soil subsurface and reducing Al activity (CRUSCIOL *et al.*, 2014) can generate expansion and deepening of the root system of plants and optimize the shoot growth. Rodrigues *et al.* (2016) observed a positive response of eucalyptus growth to the application of gypsum combined with lime. However, few studies have evaluated growth responses of eucalyptus or other forest species to application of gypsum, singly or combined with lime.

Therefore, the response of eucalyptus clones to the application of lime and gypsum regarding their initial growth needs to be better evaluated, especially in acidic Cambisol (Inceptisol) soils of the Southern Santa Catarina Plateau. The present study considered that liming improves the soil chemical quality, increasing shoot and root growths of *Eucalyptus dunnii* and *Eucalyptus benthamii,* even at low rates; and the application of gypsum increases exchangeable Ca contents and Ca saturation and decreases exchangeable Al, and Al saturation, improving root and shoot growths of eucalyptus seedlings, especially when combined with lime. Therefore, the objective of this study was to evaluate the effect of applying different lime rates, singly and combined with gypsum rates, on soil chemical attributes and initial growth of clonal eucalyptus seedlings grown in a Humic Cambisol (Inceptisol).

MATERIAL AND METHODS

The experiment was carried out in a greenhouse at the Agroveterinary Sciences Center, in Lages, state of Santa Catarina, Brazil, from October 2014 to March 2015. The soil used was classified as Humic Cambisol (Inceptisol) (Cambissolo Húmico Alumínico Léptico) (EMBRAPA, 2013). It was collected at the Cavazotti Farm (50º 04’ 59” W, 27º 29’ 59” S, and altitude of 886 m) of the company Klabin SA in Otacílio Costa, state of Santa Catarina, Brazil, from the 0.00 – 0.20 m layer in an area with forest planting at the fourth rotation. The soil was air dried, passed through an 8 mm mesh sieve and sampled for analysis, according to Tedesco *et al.* (1995). The soil analysis showed 22.7% of clay, 20.8% of silt, 56.5% of sand, 4.1 of pH (in H_2O), 4.6 of pH-SMP, 5.0% of organic matter, 19.4 mg dm^{-3} of phosphorus (P), 77.2 mg dm^{-3} of potassium (K), 0.90 $cmol_c$ dm^{-3} of Ca, 0.42 $cmol_c$ dm^{-3} of Mg, 7.29 $cmol_c$ dm^{-3} of Al, 21.8 $cmol_c$ dm^{-3} of H+Al, 1.5 $cmol_c$ dm^{-3} of sum of bases, 8.8 $cmol_c$ dm^{-3} of effective CEC, 23.3 $cmol_c$ dm^{-3} of CEC pH 7, 82.8% of Al saturation, and 6.5% of base saturation.

The experiment was conducted in a randomized block design, using a 2 x 4 x 4 factorial arrangement, consisting of two eucalyptus species (*Eucalyptus benthamii*, and *Eucalyptus dunnii*), four lime rates (0, 3, 6, and 12 Mg ha^{-1}), and four gypsum rates (0, 6.3, 12.6, and 25.2 Mg ha^{-1}), with three replications, totaling 96 experimental units. The lime rates corresponded to 0, 1, 1.5, and 2 times the need of this soil amendment to increase the soil pH in water to 5.5, based on the SMP method (CQFS-RS/SC, 2016). The gypsum rates corresponded to the amount of Ca equivalent to the respective lime rates. The powder dolomitic limestone used contained 29.5% of calcium oxide, and 20.5% of magnesium oxide. The gypsum used had 19.1% of Ca.

The clonal seedlings of *E. benthamii* and *E. dunnii* were grown up to 20 cm at the nursery of the Klabin SA company, in 8-liter pots with 2 kg of dry soil, and the treatments were incorporated by manual stirring. The soil was moistened to about 80% of its water retention capacity and left to rest for seven days. The soil of all experimental plots was fertilized at planting with N, P, and K at rates representing 20, 120, and 40 kg ha^{-1}, using NH_4NO_3, K_2HPO_4,

.ISSN eletrônico 1982-4688
DOI: 10.5380/rf.v48i4.57455

and K_2SO_4, respectively, and 10, 5, and 2 g per plant of the micronutrients B, Zn, and Cu, using borax, zinc sulfate, and copper sulphate, respectively. The nutrients were applied with incorporation of 5 mL of the nutrient solution per kg of solo for all treatments to avoid that deficiencies of these nutrients affected the results.

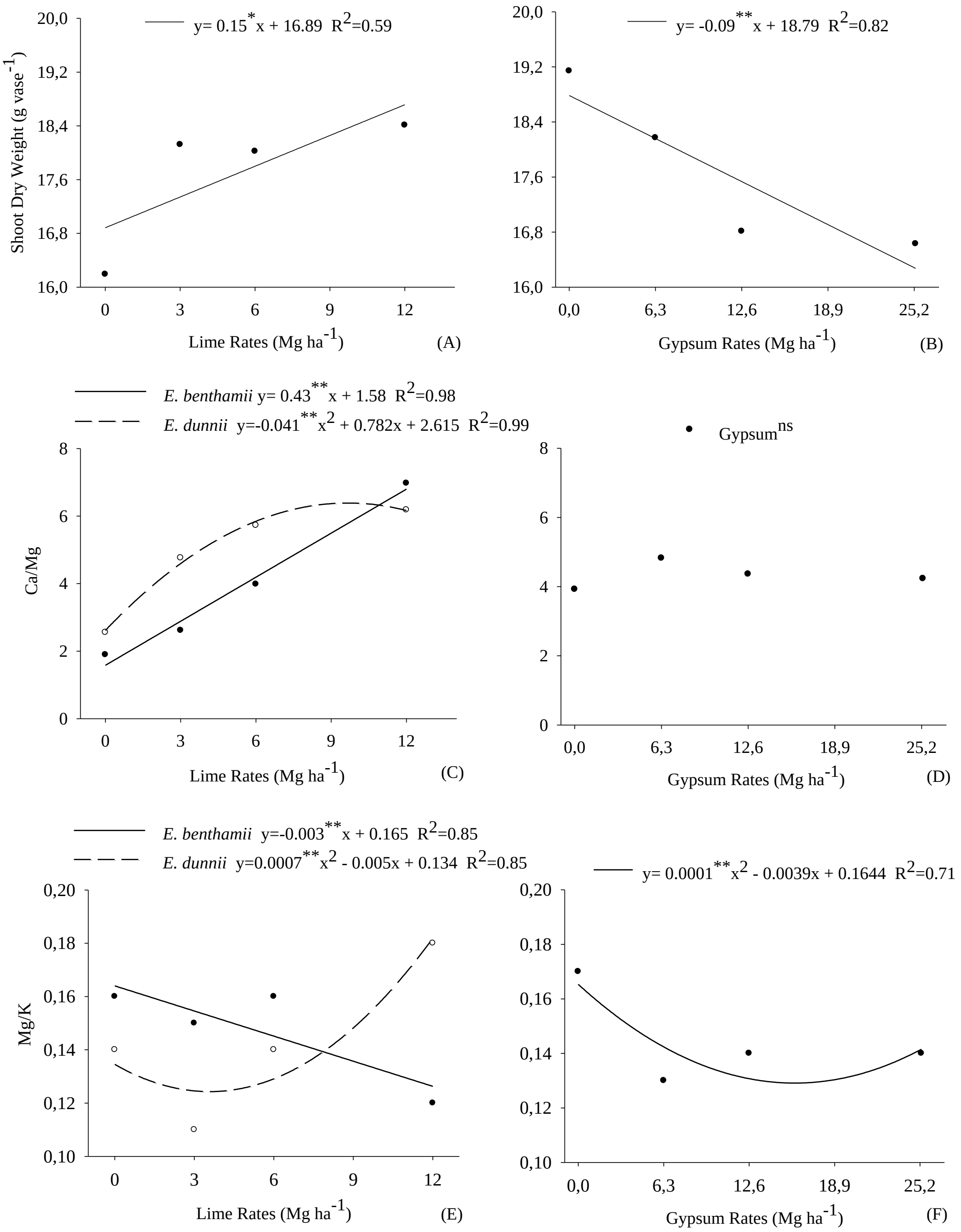
The plants grew for 90 days with daily replenishing of the soil moisture to maintain it at approximately 80% of its water retention capacity, by weighing the pots and adding equal amounts of distilled water to them. The stem base diameter of the plants was measured using a caliper ruler, and their height was measured using a graduated ruler at 90 days after planting (DAP). These measures were used to calculate the cylindrical volume of the plants, according to the equation proposed by Dias *et al.* (2015). The leaves, stem, and roots of the plants were collected separately at 90 DAP, washed with water, dried in an oven at 65 ºC, and evaluated for shoot and root dry matter, and leaf Ca, Mg, and K contents using wet digestion with sulfuric acid (TEDESCO *et al.*, 1995).

The plants were removed from the pots, and soil samples were collected at five points of each pot, composing a single sample per pot. The samples were dried in an oven at 65 °C and their pH in water, exchangeable Al, Ca, and Mg (extracted by 1M KCl), and available P, and K (extracted by Mehlich 1) were evaluated, according to the methodology described by Tedesco *et al.* (1995). P was quantified by colorimetry in a UV-visible spectrophotometer at 882 nm (UV-1800, Shimadzu, Kyoto, Japan), K was quantified by flame photometry (DM-62, Digimed, São Paulo, Brazil), and Ca, Mg and Al contents by atomic absorption spectrophotometry (Analyst 200, PerkinElmer, Waltham, USA). The pH value in water was determined using a pH meter (DM-22, Digimed) with a pH electrode (DME-CV1, Digimed). The pH-SMP was used to estimate the soil potential acidity (H+Al), Al saturation, and base saturation. The soil electrical conductivity (SEC) was also evaluated, using a solution prepared with soil and distilled water at ratio of 1:1, with readings performed immediately after the solution preparation.

The data were subjected to analysis of variance by the F test ($p < 0.05$). Significant means were subjected to regression analysis (response surface). Individual effects of the treatments were evaluated using the Tukey's test at 5% of significance. The statistical program Statistical Analysis System 9.1.3 was used for the analyses (SAS, 2003).

RESULTS

The application of lime increased the shoot dry weight of both eucalyptus clones (Figure 1A), while the application of gypsum caused an inverse result (Figure 1B). The interaction between lime and gypsum had no effect on the shoot dry weight, and Ca to Mg and Mg to K ratios in leaves. The application of lime increased the leaf Ca to Mg ratio of both eucalyptus species (Figure 1C), but the leaf Mg to K ratio decreased in *E. benthamii* and increased in *E. dunnii* plants (Figure 1E). The application of gypsum had no effect on the leaf Ca to Mg ratio (Figure 1D) but all gypsum rates caused a small reduction in the leaf Mg to K ratio (Figure 1F). The lime rates used, singly or combined with gypsum rates, had no effect on the plant height, stem base diameter, and cylindrical volume of the plants (data not shown).



Points represent the means of the main effects of the two soil amendments; **: significant at 1% of probability of error; *: significant at 5% of probability of error; ns = not significant.

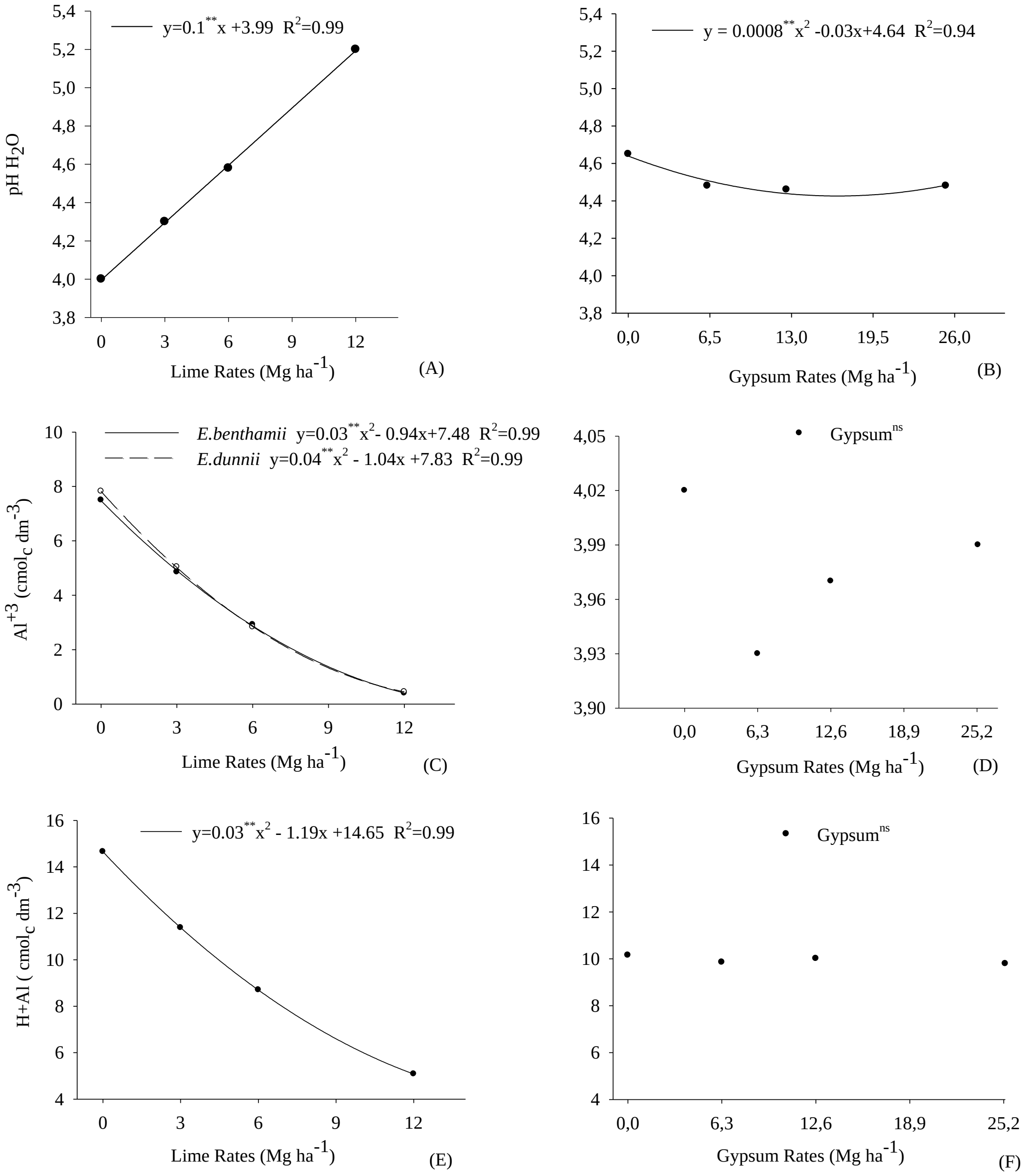
Figure 1. Effect of lime and gypsum rates on mean shoot dry weight (A and B), leaf Ca to Mg ratio (C and D) and leaf Mg to K ratio (E and F) of *Eucalyptus benthamii*, and *Eucalyptus dunnii* cultivated in a Humic Cambisol (Inceptsol).

Figura 1. Efeito das doses de calcário e gesso para as variáveis massa seca de parte aérea (A e B), relação Ca/Mg (C e D) e relação Mg/K (E e F) nas folhas de mudas de *Eucalyptus benthamii* e *Eucalyptus dunnii*, cultivadas em Cambissolo Húmico.

The interaction between lime and gypsum had no effect on the pH in water, exchangeable Al, and potential acidity. The increasing lime rates increased the soil pH (Figure 2A), reaching a pH of 5.2 with the highest rate applied, and decreased the soil exchangeable Al (Figure 2C), and potential acidity (H+Al) (Figure 2E).

.ISSN eletrônico 1982-4688
DOI: 10.5380/rf.v48i4.57455

The application of gypsum had no effect on the exchangeable Al (Figure 2D), and H+Al (Figure 2F), but caused a small reduction in the pH of the soil (Figure 2B).

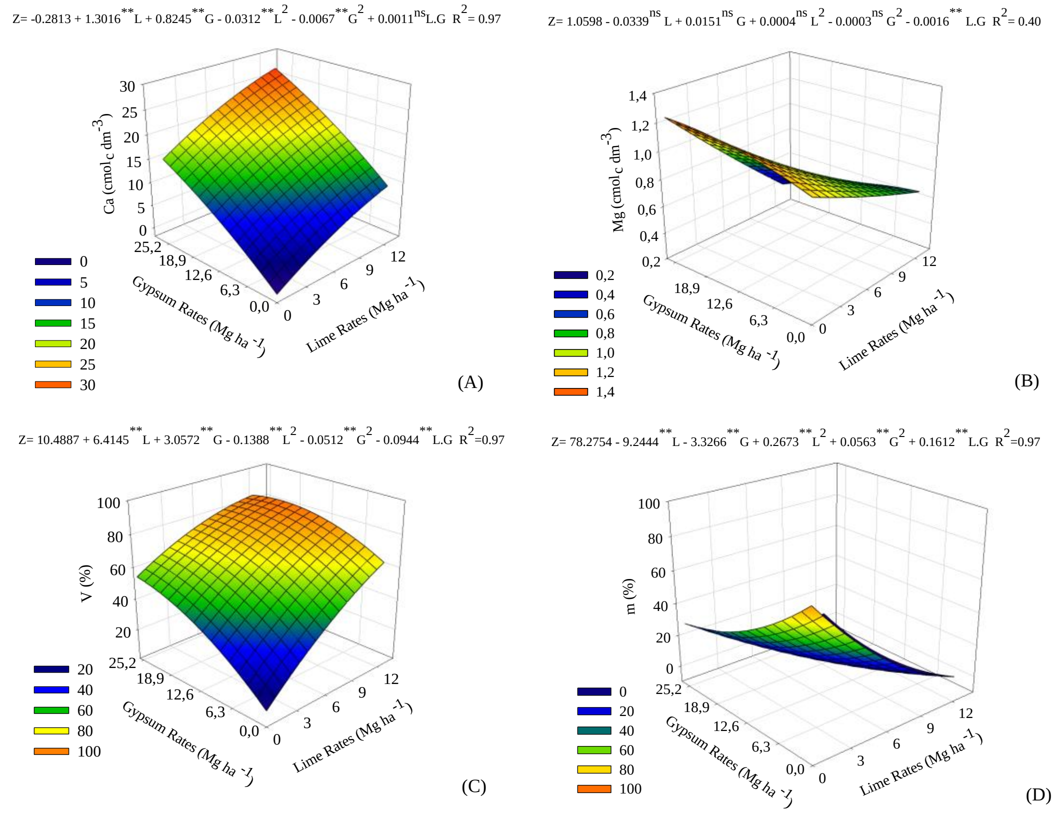


Points represent the means of the main effects of the two soil amendments; **: significant at 1% of probability of error; *: significant at 5% of probability of error; ns = not significant.

Figure 2. Effect of lime and gypsum rates on the pH in water (A and B), exchangeable Al (C and D) and H+Al (E and F) in a Humic Cambisol (Inceptisol) cultivated with *Eucalyptus benthamii* and *Eucalyptus dunnii*.

Figura 2. Efeito das doses de calcário e gesso para as variáveis pH em água (A e B), alumínio trocável (C e D) e H+Al (E e F) em Cambissolo Húmico cultivado com mudas de *Eucalyptus benthamii* e *Eucalyptus dunnii*.

The interaction between lime and gypsum affected exchangeable Ca and Mg contents, base saturation, and Al saturation. The application of lime and gypsum increased the soil exchangeable Ca (Figure 3A), and base saturation (Figure 3C) and decreased the Al saturation (Figure 3D). However, different effect was observed on Mg (Figure 3B); the application of lime, singly and combined with gypsum, resulted in a slight reduction in exchangeable Mg.



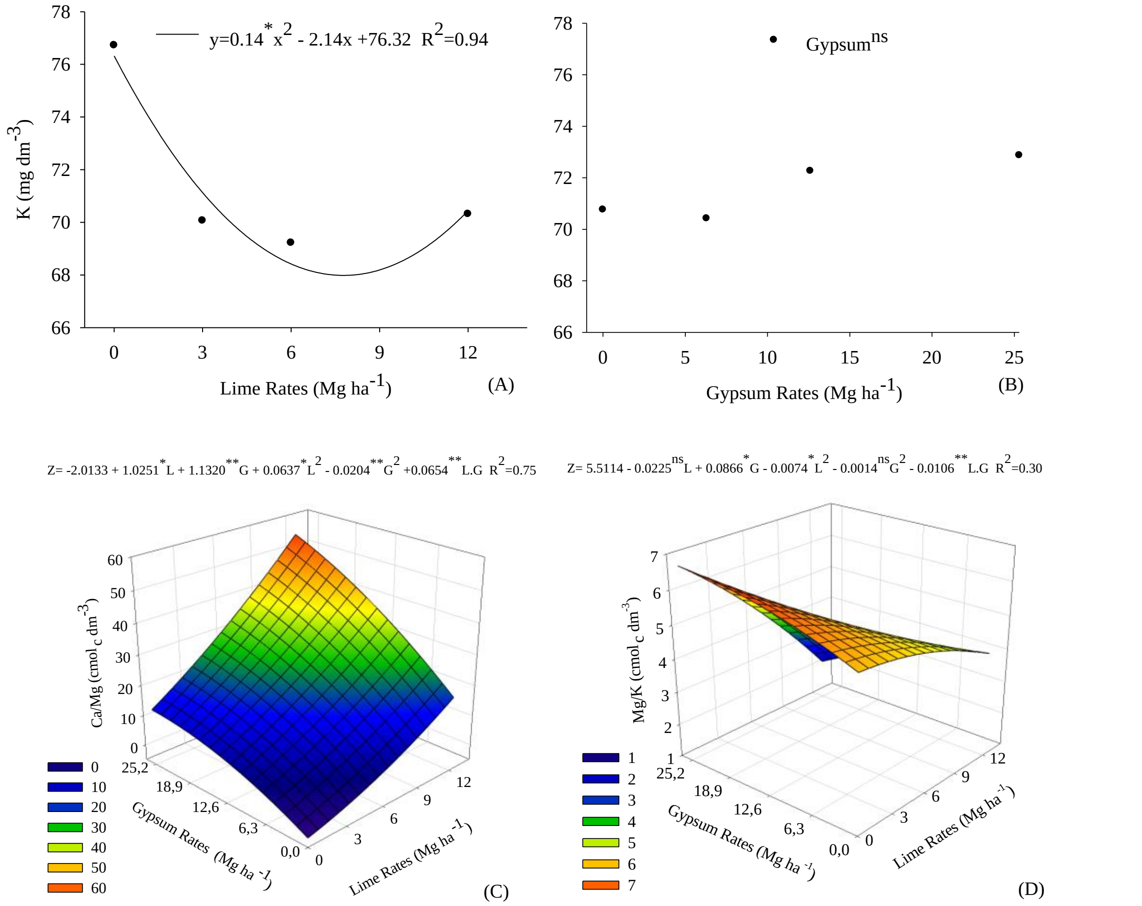
L: lime; G: gypsum; **: significant at 1% of probability of error, *: significant at 5% of probability of error, ns: not significant.

Figure 3. Effect of the interaction between lime and gypsum rates on the exchangeable Ca (A), exchangeable Mg (B), base saturation (V %) (C) and Al saturation (m %) (D) of a Humic Cambisol (Inceptisol) cultivated with *Eucalyptus benthamii* and *Eucalyptus dunnii*.

Figura 3. Efeito da interação entre as doses de calcário e gesso para as variáveis Ca trocável (A), Mg trocável (B), saturação por bases (V%) (C) e saturação por alumínio (m%) (D) em Cambissolo Húmico cultivado com mudas de *Eucalyptus benthamii* e *Eucalyptus dunnii*.

The interaction between lime and gypsum rates had no effect on the exchangeable K contents, but affected the Ca to Mg and Mg to K ratios. The lime rates reduced the soil K content (Figure 4A). However, the gypsum rates had no effect on the exchangeable K content (Figure 3B). The application of lime combined with gypsum increased the Ca to Mg ratio (Figure 4C) but caused a little reduction in the Mg to K ratio (Figure 4D).

FLORESTA, Curitiba, PR, v. 48, n. 4, p. 573-582, out/dez.2018
Gabriel. C. A. *et.al.*
.ISSN eletrônico 1982-4688
DOI: 10.5380/rf.v48i4.57455

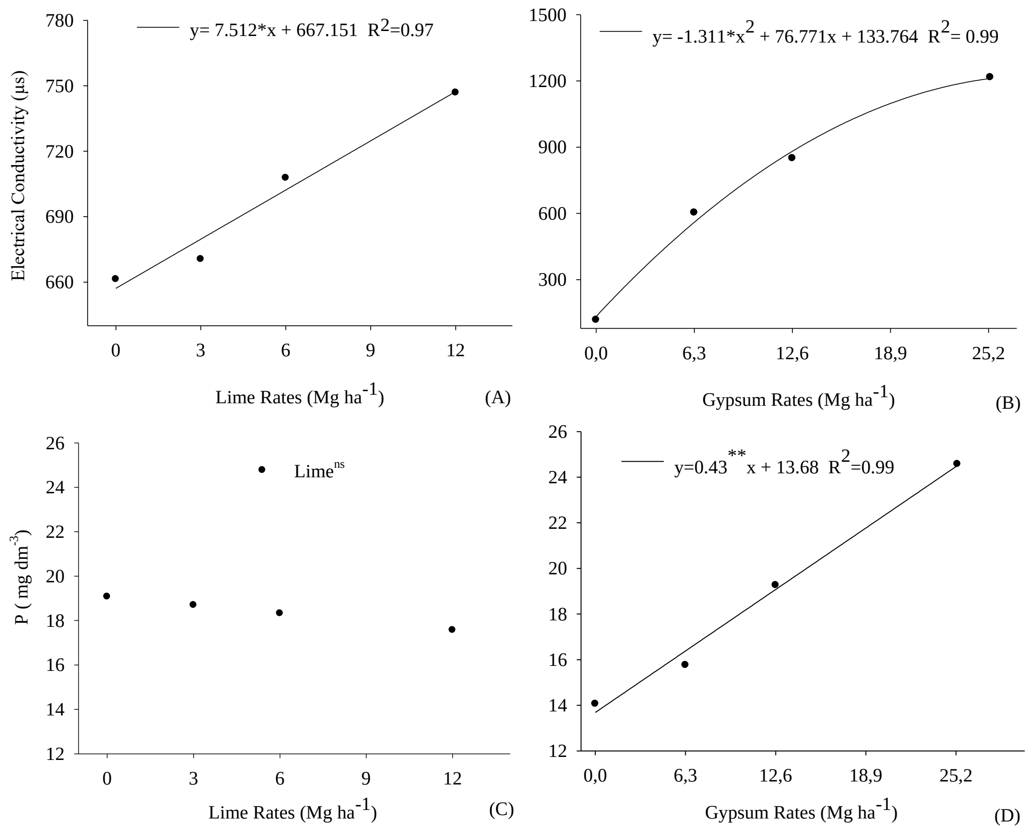


Points represent the means of the main effects of the two soil amendments; **: significant at 1% of probability of error; *: significant at 5% of probability of error; ns: not significant; L: lime; G: gypsum.

Figure 4. Effect of lime and gypsum rates on the exchangeable K content (A and B) and effect of the interaction between lime and gypsum rates on Ca to Mg ratio (C) and Mg to K ratio (D) of a Humic Cambisol (Inceptisol) cultivated with *Eucalyptus benthamii* and *Eucalyptus dunnii*.

Figura 4. Efeito das doses de calcário e gesso para a variável K trocável (A e B) e efeito da interação entre as doses de calcário e gesso para as variáveis relação Ca/Mg (C) e relação Mg/K (D) em Cambissolo Húmico cultivado com mudas de *Eucalyptus benthamii* e *Eucalyptus dunnii*.

The interaction between lime and gypsum had no effect on the SEC and P availability. However, the SEC increased with application of lime (Figure 5A) and gypsum (Figure 5B), with the most pronounced effect with the application of gypsum. The application of lime had no effect on P availability (Figure 5C), however, the gypsum applied increased the soil nutrient availability (Figure 5D).



Points represent the means of the main effects of the two soil amendments; **: significant at 1% of probability of error; *: significant at 5% of probability of error; ns: not significant.

Figure 5. Effect of lime and gypsum rates on the Electrical conductivity (A and B), and available P (C and D) of a Humic Cambisol (Inceptisol) cultivated with *Eucalyptus benthamii* and *Eucalyptus dunnii*.

Figura 5. Efeito das doses de calcário e gesso para as variáveis CE (A e B) e P disponível (C e D) em Cambissolo Húmico cultivado com mudas de *Eucalyptus benthamii* e *Eucalyptus dunnii*.

DISCUSSION

The growth of the eucalyptus clones used presented different responses to the lime and gypsum rates applied. The highest lime rate applied increased the shoot dry weight in 12%, when compared to untreated plants (control). This increase was not observed for plant height, stem base diameter, and cylindrical volume and was probably due to the increase in leaf area of the plants. The positive response to liming can be attributed to the improvement of the soil chemical attributes, especially the decrease of exchangeable Al, which favors the growth and metabolism of roots and, consequently, of plants. This result was also found by Simonete *et al*. (2013). Therefore, this supply of essential elements such as Ca and Mg to the plants and the possible increase in soil available P are important for the development of plants (ERNANI, 2016).

Contrastingly, the higher rate of gypsum applied decreased the shoot dry weight in 13% compared to the control. This negative effect on plant development can be attributed to the significant increase in soil electrical conductivity, which can inhibit nutrient uptake, and to the toxic effect of certain ions in high concentration (GONÇALVES *et al.*, 2000).

The soil pH increased 0.1 per tonne of lime used. This increase was low due to the high buffering power of the soil used. The effect of liming on the neutralization of soil acidity is known, and the rates to be applied vary according to the soil type and desired pH (ROCHA *et al.*, 2008; CQFS-RS / SC, 2016). However, the pH found with the application of gypsum was not expected, since it is a neutral reaction salt that presents no effect on the soil acidity (ERNANI, 2016). Moreover, gypsum applications may cause small decreases in pH of extremely acidic soils due to the increase in Ca in the soil solution, which removes the Al from negative charges, or to the increase of electrolyte concentrations in the soil solution (ERNANI *et al.*, 2001).

The application of lime promoted not only increases in pH, but other soil benefits - reductions of potential acidity, decreases in exchangeable Al, and Al saturation, and increases in base saturation. These effects are well known and

FLORESTA, Curitiba, PR, v. 48, n. 4, p. 573-582, out/dez.2018
Gabriel. C. A. *et.al.*
.ISSN eletrônico 1982-4688
DOI: 10.5380/rf.v48i4.57455

described in the scientific literature (PÁDUA *et al.*, 2006; SORATTO, CRUSCIOL, 2008; ZANDONÁ *et al.*, 2015). The gypsum rates used had no effect on the exchangeable Al contents, and potential acidity. Zandoná *et al.* (2015) evaluated the effect of gypsum and lime on soil chemical attributes and observed reductions in Al content due to the application of gypsum; they attributed this result to the release of hydroxyls that occurs in the presence of sulfate molecules, forming aluminum hydroxide molecules, which are non-toxic compounds to plants.

When the gypsum is applied at medium to high rates, it can reduce the Al activity in the soil solution by forming the ion pair $AlSO_4$ (ERNANI, 2016). Moreover, gypsum application provides significant inputs of Ca to the soil, increasing its base saturation and reducing Al activity, and Al saturation in the exchange complex. Under field conditions, these effects are extended to subsurface layers of the soil (CRUSCIOL *et al.*, 2014, ANIKWE; IBUDIALO, 2016).

The lime and gypsum applications increased the soil Ca because these products contain this nutrient (SIMONETE *et al.*, 2013, CRUSCIOL *et al.*, 2014). Differently from the expected, Mg availability reduced with liming; this was attributed to a possible specific adsorption of this nutrient. The application of lime reduced K availability probably due to the adsorption of this nutrient to negative charges, which were increased by increasing the soil pH (ERNANI, 2016) and may have decreased the amount of this nutrient extracted by the Mehlich 1 solution. The application of lime had no effect on P availability. The application of gypsum increased P availability in 0.43 mg dm^{-3} per tonne of gypsum; this was attributed to the presence of this nutrient in its composition (CAIRES *et al.*, 2011; CRUSCIOL *et al.*, 2014), since it is a byproduct of chemical industries of phosphate fertilizers.

The soil amendments tested can increase the soil electrical conductivity (SEC) (ERNANI, 2016). Gypsum is a neutral salt that presented greater effect on the SEC, with an increase of 76.8 μS cm^{-1} per tonne of gypsum applied, whereas the application of lime increased the SEC in 7.5 μS cm^{-1} per tonne of lime. This higher effect of gypsum on SEC may have had a negative effect on the eucalyptus seedling development. According to Gonçalves *et al*. (2000), a high SEC may cause phytotoxic effects on eucalyptus; and substrates with SEC above 1000 μS cm^{-1} can damage plants, especially during their initial growth.

CONCLUSION

- Clonal seedlings of *Eucalyptus benthamii* and *Eucalyptus dunnii* grown in pots respond positively to application of lime at rates intended to raise the soil pH in water to 5.2. However, this response was not positive with the application of gypsum.
- Soil liming increases soil pH, exchangeable Ca content, base saturation, and cause small increases in soil electrical conductivity, and significant reductions in Al saturation. However, it may reduce exchangeable K and Mg contents.
- Gypsum does not change the soil pH but decreases the soil Al saturation and increases the soil Ca and P contents. However, it can significantly increase the soil electrical conductivity, which may negatively affect the eucalyptus growth.
- Based on the results found, the application of gypsum is not recommended for eucalyptus seedlings. However, the application of a low rate of lime is recommended for these plants because it can benefit their initial growth.

REFERENCES

ANIKWE, M. A. N.; IBUDIALO, E. A. N. Influence of lime gypsum application on soil properties and yield of cassava (Manihot esculenta Crantz.) in a degraded Ultisol in Agbani, Enugu Southeastern Nigeria. **Soil & Tillage Research**, v. 158, p. 32-38, 2016.

ARAÚJO, L. G; FIGUEIREDO, C.C; SOUSA, D.M.G; NUNES, R.S; REIN, T.A. Influence of gypsum application on sugarcane yield and soil chemical properties in the brazilian Cerrado. **Australian Journal of Crop Science**, v. 11, p. 1557-1563, 2016.

CAIRES, E. F.; MASCHIETTO, E. H. G.; GARBUIO, F. J.; CHURKA, S.; JORIS, H. A. W. Surface application of gypsum in low acidic Oxisol under no-till cropping system. **Scientia Agricola**, v. 68, n. 2, p. 209-216, 2011.

COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO – CQFS RS/SC. **Manual de calagem e adubação para os Estados do Rio Grande do Sul e Santa Catarina.** 11. ed. Porto Alegre, SBCS/NRS, 2016. 376 p.

CRUSCIOL, C. A. C.; FOLTRAN, R.; ROSSATO, O. B.; McCRAY, J. M.; ROSSETTO, R. Effects of surface application of calcium-magnesium silicate and gypsum on soil fertility and sugarcane yield. **Revista Brasileira de Ciência do Solo,** v. 38. p. 1843-1854, 2014.

DIAS, L. P. R.; GATIBONI, L. C.; BRUNETTO, G.; SIMONETE, M. A.; BICARATTO, B. Eficiência relativa de fosfatos naturais na adubação de plantio de mudas de *Eucalyptus dunnii* Maiden e *Eucalyptus benthamii* Maiden et Cambage em solo sem e com calagem. **Ciência Florestal**, v. 25, p. 37-48, 2015.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (EMBRAPA). **Sistema Brasileiro de Classificação de Solos**. Ed. 3. Brasília: Embrapa Solos, 2013.

ERNANI, Paulo Roberto. **Química do solo e disponibilidade de nutrientes.** Lages, 2016, p. 118 – 209.

ERNANI, P. R; RIBEIRO, M. S; BAYER, C. Modificações Químicas em solos ácidos ocasionadas pelo método de aplicação de corretivos da acidez e de gesso agrícola. **Scientia Agricola**, v.58, n.4, p.825-831, 2001.

FAGERIA, N.K; MOREIRA, A; MORAES, L.A.C; MORAES, M.F. Influence of lime and gypsum on yield and yield components of soybean and changes in soil chemical properties. **Communications in Soil Science and Plant Analysis**, v. 45, p. 271-283, 2014.

FLORIANI, M. M. P.; STEFFENS, C. A.; CHAVES, D. M. Rustificação de plantas de *Eucalyptus dunnii* Maiden e a relação entre as concentrações de carboidratos solúveis totais e de prolina foliar e a tolerância ao frio. **Revista Árvore**, v. 35, p. 21-29, 2011.

GONÇALVES, J. L. M.; SANTERELLI, E. G.; NETO, S. P. M.; MANARA, M. P. Produção de mudas de espécies nativas: substrato, nutrição, sombreamento e fertilização. In: GONÇALVES, J. L. M.; BENEDETTI, V. (eds.). **Nutrição e fertilização florestal**. Piracicaba: IPEF, 2000, p. 309 - 350.

INDÚSTRIA BRASILEIRA DE ÁRVORES (IBÁ). **Relatório Ibá 2017: desempenho industrial**. Disponível em:< http://iba.org/images/shared/Biblioteca/IBA_RelatorioAnual2017.pdf >Acesso em: 09 de abril de 2018.

PÁDUA, T. R. P.; SILVA, C. A.; MELO, L. C. A. Calagem em Latossolo sob influência de coberturas vegetais: neutralização da acidez. **Revista Brasileira de Ciência do Solo,** v. 30, p. 869-878, 2006.

ROCHA, J. B. de O; POZZA, A. A. A; CARVALHO, J. G; SILVA, C. A; CURI, N. Efeito da calagem na nutrição mineral e no crescimento inicial do eucalipto a campo em Latossolo húmico da Zona da Mata (MG). **Scientia Forestalis**, Piracicaba, v. 36, n. 80, p. 255-263, dez. 2008.

RODRIGUES, F.A.V; ALVAREZ, V. H; BARROS, N, F; SILVA, I. R; NEVES, J, C.L. Produtividade de eucalipto aos 18 meses de idade, na região do Cerrado, em resposta à aplicação de cálcio, via calcário e gesso agrícola. **Scientia Forestalis**, volume 44, n. 109, p.67-74, 2016.

SAS Institute Inc® 2003 **SAS Ver. 9.1.3** SAS Institute Inc.: Cary, NC, USA. Lic. UDESC.

SIMONETE, M. A.; CHAVES, D. M.; TEIXEIRA, C. F. A.; MORO, L.; NEVES, C. U. Fornecimento de cálcio para plantas de *Eucalyptus saligna* por meio de aplicação de resíduo industrial lama de cal. **Revista Brasileira de Ciência do Solo**, v. 37, p. 1343-1351, 2013.

SORATTO, R. P; CRUSCIOL, C. A. C. Atributos químicos do solo decorrentes da aplicação em superfície de calcário e gesso em sistema plantio direto recém-implantado. **Revista Brasileira de Ciência do Solo**, v. 32, p. 675-688, 2008.

TEDESCO, M. J; GIANELLO, C; BISSANI, C. A; BOHNEN, H; VOLKWEISS, S. J. **Análise de solo, plantas e outros materiais**. 2.ed. Porto Alegre, Universidade Federal do Rio Grande do Sul, 1995. 174p.

ZANDONÁ, R. R.; BEUTLER, A. N.; BURG, G. M.; BARRETO, C. F.; SCHMIDT, M. R. Gesso e calcário aumentam a produtividade e amenizam o efeito do déficit hídrico em milho e soja. **Pesquisa Agropecuária Tropical**, v. 45, n. 2, p. 128-137, 2015.

.ISSN eletrônico 1982-4688
DOI: 10.5380/rf.v48i4.57455