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Growth, nutrition and health of coffee seedlings grown with increasing limestone doses in the substrate

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Abstract

During coffee crop formation, seedlings quality is an essential factor to ensure the plants full development. Applying limestone to the substrate is a common practice to correct acidity, thus increasing nutrient availability. Therefore, we aimed to evaluate the effect of increasing limestone doses in the substrate regarding growth, nutrition, health, and quality of coffee seedlings. The experiment was conducted in the plant nursery at the IFSULDEMINAS – Inconfidentes Campus, with an experimental design in randomized blocks with five replications; the treatments received the following limestone doses per cubic meter of substrate: T1: 0 g; T2: 600 g; T3: 1,200 g; T4: 1,800 g; T5: 3,000 g. After 208 days of sowing, samples were collected for leaf analysis. The growth and quality of the seedlings and their incidence and severity of *Cercospora* were also evaluated. A statistical difference was found in leaf analysis for nitrogen, potassium, and manganese absorption, with no statistical difference for *Cercospora coffeicola* leaf spots in all treatments. Therefore, the increasing limestone doses do not influence growth, nutrition, and health of the coffee seedlings of the Mundo Novo 376/4 cultivar.

Keywords: *Coffea arabica*. Soil fertility. Liming. *Cercospora coffeicola.*

Introduction

According to data from the Brazilian National Supply Company – CONAB (2022), the expectation for coffee harvest in 2022 is growth in the total area, of which 2,236.99 thousand hectares should be used for national coffee, 416.77 thousand hectares of new areas, increasing by 6.4% compared to the 2021 harvest.

Thus, there is a demand for seedlings that will form the new areas of coffee production, since the production of good-quality, strong, healthy, and well-developed coffee seedlings is essential to achieve profitable and sustainable production of new crops (TOMAZ et al., 2012). According to Oliveira, Abreu, and Oliveira (2019), since coffee is a perennial crop, it is essential to adopt the necessary care during the phase of crop implantation, especially in the selection of seedlings, for the adequate crop formation.

In the phase of commercial-scale production of seedlings and aiming at lower costs, it is necessary to employ appropriate techniques and the use of substrate that can provide the nutrients for the development of plants that will be selected during crop formation, resulting in high productivity, cost reduction, and increased income (SANTOS et al., 2020; OLIVEIRA; ABREU; OLIVEIRA, 2019; TOMAZ et al., 2012).

During seedling production, it is common to use substrate that has a part of land removed from subsurface layers of the soil, a material that usually has low pH, high aluminum content, and calcium and magnesium deficiency. These negative conditions influence the development and productivity of coffee and can reduce root development, making its system inefficient in absorbing water and nutrients in deeper parts of the soil (COSTA et al., 2020).

Correction of acidic soils is commonly done with limestone. Liming is an agricultural investment with economic return. However, one should cautiously consider the dosage, so that when incorporating limestone into the soil, acidity is reduced, changing its chemical characteristics, improving the effective cation-exchange capacity (CEC), favoring microbial activity, and increasing the availability of nutrients such as phosphorus and potassium (GUARÇONI, 2017).

Brandão et al. (2020) and Korzune et al. (2021) highlighted the occurrence of differentiated responses in the development of seedlings due to changes in limestone doses used in the production of vegetable and citrus seedlings, since the practice of liming, by correcting soil acidity, provides calcium (Ca^{2+}) and magnesium (Mg^{2+}) and increases effective CEC and percentage of soil base saturation.

Therefore, this study aimed to evaluate the effects of increasing limestone doses in the substrate regarding growth, nutrition, health, and quality of coffee seedlings.

Material and methods

This study was conducted in the plant nursery of the Farm School of the Federal Institute of Education, Science and Technology of the South of Minas Gerais (IFSULDEMINAS) – Inconfidentes Campus, Inconfidentes, Minas Gerais, Brazil. According to the Köppen-Geiger classification, its climate is Cwa (humid temperate with dry winters and hot summers), with average temperatures from −3ºC to 18ºC (SÁ JÚNIOR, 2009).

The experiment was conducted from July 4, 2021 to February 6, 2022 in a closed greenhouse with a black shading screen, with a 50% shade cloth. Irrigation was performed by micro-sprinklers with a 0.230 L min^{-1} flow, to keep the soil close to the field capacity, which was finished before surface run off.

To produce seedlings, polyethylene plastic bags with 22 cm height and 11 cm diameter and 36 holes were used, in which two seeds of the cultivar Mundo Novo 376/4 were sown. The seeds were deposited approximately 1.5 cm underground and protected with a burlap sack until the seedlings emerged.

According to recommendations for the use of soil improvers and fertilizers in Minas Gerais (RIBEIRO, GUIMARÃES, ALVAREZ, 1999), to prepare the substrate, considering one cubic meter, the proportion was 70% subsoil, 30% manure with 5 kg of simple superphosphate and 0.5 kg of potassium chloride.

The chemical analysis of the soil used for the substrate composition in which the coffee seedlings of the cultivar Mundo Novo 376/4 were sown was carried out at the Laboratory of Soil Fertility of IFSULDEMINAS – Inconfidentes Campus Table 1 shows the results of such analysis.

Table 1 – Chemical attributes of the soil before liming and cultivation of *Coffea arabica*, cultivar Mundo Novo 376/4. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, Brazil, 2022.

pH in water	P	K	Al	Ca	Mg	H+Al	SB	CEC	V (%)	m (%)	Ca/Mg	Mg/K
	mg dm^{-3}		-------------------- $cmol_c$ dm^{-3} -------------------									
5.69	1.3	22.8	0.00	0.6	0.05	1.71	0.70	2.41	28.96	0.00	11.32	0.89

Source: Laboratory of Soil Fertility of IFSULDEMINAS – Inconfidentes Campus (2021).

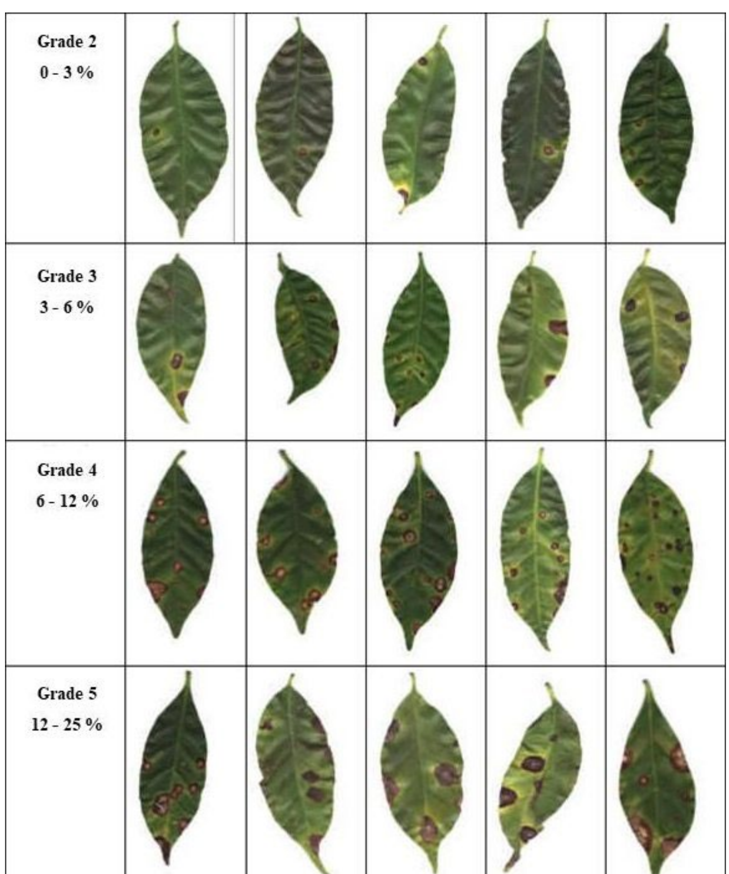
The experimental design was composed of randomized blocks, five treatments, with five replications, and 50 plants per experimental unit. The ten central plants of each treatment were evaluated for growth, quality, and health analyses. Furthermore, ten other seedlings were used for leaf analysis of macro and micronutrients, and these plants were stored in paper bags, labelled, and sent to the Soils and Leaves Laboratory of the Procafé Foundation.

The treatments received the following doses of dolomitic limestone per cubic meter of substrate, incorporated during preparation: Treatment 1 (T0): 0 g, considered as control; Treatment 2 (T600): 600 g; Treatment 3 (T1,200): 1,200 g; Treatment 4 (T1,800): 1,800 g; Treatment 5 (T3,000): 3,000 g, in which after substrate preparation sowing was performed. The limestone used had 95% PRNT, 43.22% CaO and 8% MgO contents.

When the seedlings reached the cotyledon leaves stage, thinning was performed, which consisted of the removal of the surplus seedling, less developed or defective. Moreover, throughout the development of the experiment, cultural treatments were manually conducted in the plant beds for weed control.

On day 208 after sowing, the incidence and severity of Cercospora spots (*Cercospora coffeicola*) were evaluated. For severity evaluation, Figure 1 shows a diagrammatic scale based on the Weber-Fechner law of visual acuity. (OLIVEIRA et al, 2001). The grades were assigned by three evaluators after visual pre-calibration, to reduce any biased evaluation.

Figure 1 – Diagrammatic scale for evaluation of cercospora (*Cercospora coffeicola*). IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, Brazil, 2022.



Source: Oliveira et al (2001).

The following parameters were also evaluated: leaf area, expressed in square centimeters (cm^2), following the methodology of Barros et al. (1973); leaf number, counting in units; aerial part height (cm), measured with a millimeter ruler, measuring from the stem to the apical bud; stem diameter (mm), measured using a precision caliper; leaf, stem, and root dry matter (g), determined after being washed with distilled water, dried on towel paper, and packed on kraft paper in a forced air circulation oven at 60ºC for 72 hours; total dry matter (g), obtained by summing the leaf, stem, and root dry matter; relationship of aerial part dry matter with root dry matter (RAPR); relationship of aerial part height with stem diameter (RHD); and Dickson quality index (DQI) obtained using the DQI equation [total dry matter/(RHD+RAPR)] (DICKSON, LEAF, HOSNER, 1960).

The collected data were subjected to analysis of variance, applying regression for treatments with 5% probability. In the absence of significant results or with R^2 inferior to 60%, the data were presented in a table of means. The SISVAR statistical software was used for all analyses (FERREIRA, 2008).

Results and discussion

We observed no effects in the different limestone doses for the variables leaf area, plant height, stem diameter, leaf number, aerial part dry mass, root dry mass, total dry mass, considering a 5% significance level (Table 2).

Pimentel et al. (2016) in a study on the effects of limestone doses on the growth and quality of macaw palm seedlings also found that the correction of acidity in the substrate had little effect on the initial development of seedlings. Pedroso et al. (2012) also did not find a significant response when considering liming level in the development of young *Swietenia macrophylla* plants for height, diameter, and stem dry mass.

The same effect was observed by Santos et al. (2019) when evaluating the growth of *Leucochloron incuriale* seedlings, concluding on the lack of influence of liming on height, stem diameter, aerial part dry matter, root dry matter, and total dry matter. This can also be observed in this study since we found no significant difference in the growth of coffee seedlings. This may show that seedlings of tree species are less

Table 2 – Mean growth parameters for the variables: leaf area (LA) in cm^2, leaf number (LN); plant height (H) in cm, stem diameter (SD) in mm, aerial part dry mass (APDM) in g, root dry mass (MSR) in g, and total dry mass (MST) in g, in *Coffea arabica* seedlings, cultivar Mundo Novo 376/4 due to increasing limestone doses at 208 days of nursery. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, Brazil, 2022.

Treatments	LA	NL	H	SD	APDM	RDM	TDM
					------ g plant^{-1} -----		
T0	83.99	6.76	14.04	2.43	5.97	3.25	9.22
T600	95.19	6.66	14.65	2.33	6.77	3.56	10.33
T1,200	82.23	6.36	13.89	2.24	5.81	3.09	8.90
T1,800	98.51	6.66	15.73	2.33	6.76	3.17	9.93
T3,000	91.52	7.06	14.97	2.34	6.50	3.17	9.67
CV (%)	27.69	12.51	13.91	10.34	23.20	14.86	19.56
F (p<0.05)	0.81	0.77	0.62	0.83	0.76	0.60	0.77

Source: Authors (2022).

responsive to liming, even in acid pH and low base saturation (Table 1).

In the evaluation of RHD, RAPR, and DQI, we observed no effect of the different limestone dosages used (Table 3).

We found a statistical difference in the analysis of macronutrients with 5% probability level for nitrogen (N) and potassium (K), however the adjustments of the regressions did not obtain 60% R^2. Thus, we performed the statistical analysis of the mean values found (Table 4).

We found no statistical difference between the means of Ca, Mg, and S contents. However, the leaf content of Mg found in the treatments is within the reference value considered appropriate for the crop, ranging from 0.31 to 0.45 dag kg^{-1} (RIBEIRO, GUIMARÃES, ALVAREZ, 1999).

According to the manual for the use of soil improvers and fertilizers in the state of Minas Gerais (RIBEIRO, GUIMARÃES, ALVAREZ, 1999), the content of leaf nitrogen (N) recommended for coffee ranges from 2.90 to 3.20 dag kg^{-1}, thus we only found an adequate

Table 3 – Quality parameters for the variables: relationship of aerial part height with stem diameter (SD), relationship of aerial part dry mass with root dry mass (RAPR) and Dickson quality index (DQI) in seedlings of *Coffea arabica*, cultivar Mundo Novo 376/4 due to increasing limestone doses at 208 days of nursery. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, Brazil, 2022.

Treatment	RHD	RAPR	DQI
T0	5.84	1.84	1.19
T600	6.29	1.80	1.23
T1,200	6.20	1.83	1.07
T1,800	6.77	2.05	1.09
T3,000	6.43	1.97	1.12
CV (%)	11.24	16.23	15.13
F (p<0.05)	0.37	0.66	0.55

Source: Authors (2022).

Table 4 – Mean macronutrient contents: nitrogen (N), phosphorus (P) and potassium (K) in seedlings of Coffea arabica, cultivar Mundo Novo 376/4, due to increasing limestone doses. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, Brazil, 2022.

Treatment	N	P	K	Ca	Mg	S
			dag kg^{-1}			
T0	2.83 ab	0.41 a	2.69 ab	1.30 a	0.38 a	0.15 a
T600	2.59 a	0.42 a	2.53 ab	1.36 a	0.38 a	0.13 a
T1,200	2.81 ab	0.42 a	2.23 a	1.34 a	0.45 a	0.14 a
T1,800	2.85 ab	0.40 a	2.80 b	1.54 a	0.37 a	0.12 a
T3,000	3.07 b	0.40 a	2.42 ab	1.35 a	0.39 a	0.13 a
*Reference	2.90 – 3.20	0.12 – 0.16	1.80 – 2.20	1.00 – 1.30	0.31 – 0.45	0.15 – 0.20
CV (%)	5.71	4.42	9.15	13.91	10.60	16.82
F (p<0.05)	0.005	0.47	0.035	0.49	0.12	0.34

Means followed by the same letters in the columns do not differ from each other by the Tukey's test at 5% significance level.

*Leaf contents of nutrients considered suitable for coffee (RIBEIRO, GUIMARÃES, ALVAREZ 1999).

Source: Authors (2022).

leaf content in the treatment with 3,000 g m^{-3} limestone (T3,000), whereas for phosphorus (P), the treatments did not cause a significant influence (Table 4).

Observing the potassium (K) contents, we found a statistical difference in the means of the treatments of 1,200 g m^{-3} (T1,200) and 1,800 g m^{-3} (T1,800). The mean levels were higher than the recommendation of 1.80 to 2.20 dag kg^{-1} (RIBEIRO, GUIMARÃES, ALVAREZ, 1999). This content increase occurred mainly in the 1,800 g m^{-3} dose, showing that the levels verified are a consequence of incorporating potassium chloride during the preparation of the substrate.

We also found no significant difference in the statistical analysis of the mean values of the micronutrients Zn, Fe, Cu, and B (Table 5). According to the manual for the use of soil improvers and fertilizers in Minas Gerais (RIBEIRO, GUIMARÃES, ALVAREZ, 1999), the leaf content suitable for coffee of the nutrients copper (Cu) and iron (Fe) is 8–16 ppm and 70–180 ppm, respectively. However, we found higher levels, with a minimum content of 27.75 ppm for Cu and 399.25 for Fe in the treatment with no limestone.

The maximum manganese content of 43 mg kg^{-1} was reached for the 0 g m^{-3} limestone dose and the minimum content of 31 mg kg^{-1} for the 1,850 g m^{-3} limestone dose. We then observed a decrease in the absorption of this nutrient due to the increased limestone dosage (Figure 2).

According to the manual of recommendations for the use of soil improvers and fertilizers in Minas Gerais (RIBEIRO, GUIMARÃES, ALVAREZ, 1999), the appropriate leaf contents of Mn ranges from 50 to 200 mg kg^{-1}; thus, the values found in all treatments are lower than the recommended.

According to Malavolta (1996), Mn deficiency is often associated with high soil pH (7.0 or higher), high organic matter content, high soil moisture, and excessive liming, as this favors the transformations of Mn into less available forms to the plant. Moreover, high levels of copper (Cu), iron (Fe), zinc (Zn), and high availability of calcium (Ca) or magnesium (Mg) can also decrease Mn absorption.

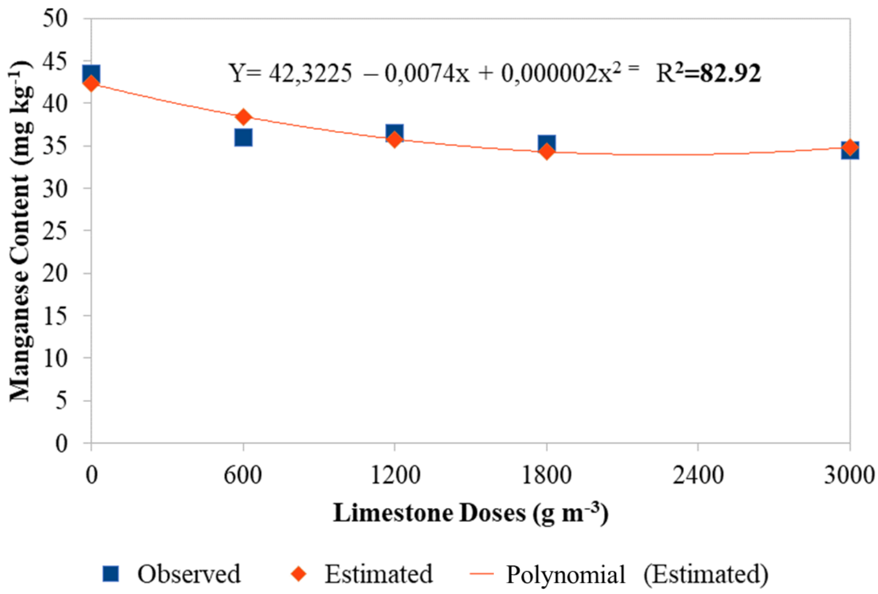
Moreira et al. (2000) verified the availability of nutrients in a limestone Vertisol for rice production and suggested that high pH values and high calcium concentration interfere in the concentration of nutrients in the soil. This condition can be observed in this study, especially in the 1,800 g m^{-3} treatment (Table 4), in which Ca content is higher than recommended; thus, Mn has its solubility reduced.

Table 5 – Mean macronutrient contents: nitrogen (N), phosphorus (P), and potassium (K) in seedlings of *Coffea arabica*, cultivar Mundo Novo 376/4, due to increasing limestone doses. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, Brazil, 2022.

Treatment	**Zn**	**Fe**	**Cu**	**B**
	mg kg^{-1} (ppm)			
T0	14.0	399.25	27.75	12.05
T600	13.5	344.50	48.75	13.05
T1,200	16.0	478.75	22.75	13.80
T1,800	16.25	310.75	22.00	13.17
T3,000	13.00	326.20	21.75	12.42
CV (%)	36.17	22.56	75.24	20.71
F ($p<0.05$)	0.86	0.08	0.35	0.9

Source: Authors (2022).

Figure 2 – Leaf content of manganese (Mn) in seedlings of *Coffea arabica*, cultivar Mundo Novo 376/4 due to increasing limestone doses. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, Brazil, 2022.



Source: Authors (2022).

Furthermore, according to Moreira et al. (2000), Fe and Mn compete for the same adsorption site, and their interactions occur at two levels: in the accumulation, when Fe restricts Mn absorption, and at the metabolic level, when Mn affects Fe activity by decreasing its concentration, thus showing that the high Fe accumulation found may have restricted Mn absorption.

In a study on the effects of liming on cowpea productivity, Rodrigues et al. (2021) obtained an increased base saturation and calcium and magnesium contents and decreased potassium and aluminum contents; however, they emphasized that soil attributes and base saturation index had more satisfactory values with reduced limestone doses. Thus, we observed in this study a decreased Mn absorption due to the increased dosage of limestone, showing that high limestone doses may lead to nutritional imbalance in the plant.

Nutritional problems in the plant can trigger an increased incidence and severity of several diseases, such as Cercospora spots (*Cercospora coffeicola*), which can aggressively affect coffee. However, we found no statistical difference between treatments for the level of incidence and severity of Cercospora spots in this experiment (Table 6).

Therefore, considering the results obtained in this study, we found that it was not necessary to incorporate limestone to the substrate to produce coffee seedlings.

Table 6 – Incidence and severity of Cercospora spots (*Cercospora coffeicola*) in seedlings of *Coffea arabica*, cultivar Mundo Novo 376/4 due to increasing limestone doses at 208 days of nursery. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, Brazil, 2022.

Treatment	INCIDENCE	SEVERITY
T0	1.24	3.6
T600	0.96	2.86
T1,200	1.16	3.06
T1,800	1.02	3.12
T3,000	1.18	3.40
CV (%)	29.22	13.69
F ($p<0.05$)	0.63	0.11

Source: Authors (2022).

Conclusion

Increasing limestone doses do not influence growth, quality, nutrition, and health of coffee seedlings of the cultivar Mundo Novo 376/4.

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