Pesquisa Florestal Brasileira
Brazilian Journal of Forestry Research
http://pfb.cnpf.embrapa.br/pfb/
e-ISSN: 1983-2605
Artigo

Basalt rock dust incorporated to substrate favors *Monteverdia ilicifolia* seedlings initial growth

Natália Saudade de Aguiar[1*], Alexandre Dal Forno Mastella[1*], Mônica Moreno Gabira[1*], Letícia Siqueira Walter[1*], Francival Cardoso Felix[1*], Daniele Cristina Pereira de Matos[1*], Ivar Wendling[2*], Alessandro Camargo Angelo[1*], Rozimeiry Gomes Bezerra Gaspar[1*], Dagma Kratz[1*]

[1]Universidade Federal do Paraná, Centro de Ciências Florestais e da Madeira, Avenida Prefeito Lothário Meissner, 632, CEP 80210-170, Curitiba, PR, Brazil
[2]Embrapa Florestas, Estrada da Ribeira, Km 111, Bairro Guaraituba, Caixa Postal 319, CEP 83411-000, Colombo, PR, Brazil

[*]**Corresponding author:**
talia.saguiar@yahoo.com.br

Index terms:
Espinheira-santa
Shading
Substrate components

Termos para indexação:
Espinheira-santa
Sombreamento
Componentes de substratos

Received in 10/08/2020
Accepted in 20/12/2021
Published in 01/07/2022

Abstract - This study aims to analyze the incorporation of basalt rock dust to a commercial substrate based on pine bark under two light conditions on initial growth of *Monteverdia ilicifolia* (Mart. Ex Reissek) Biral seedlings. We evaluated four proportions of rock dust: 0% (control), 10%, 20%, and 30% on plants kept unshaded and under 50% shading for 140 days. The unshaded condition associated with basalt rock dust incorporated to substrate presented the higher seedlings growth. Incorporating rock dust in any proportion to the substrate increased stem diameter and biomass, resulting in a greater Dickson quality index (DQI) in unshaded seedlings. The rock dust in a proportion of 10% showed better results in seedlings growth. Moreover, 20% and 30% of rock dust reduced stem diameter, biomass, and DQI, when compared to 10% of rock dust, possibly due to the substrate physical characteristics. We recommend incorporating 10% of rock dust to the pine bark-based substrate for *M. ilicifolia* seedlings production in an unshaded environment.

Pó de rocha basáltica incorporado ao substrato favorece o crescimento inicial de mudas de *Monteverdia ilicifolia*

Resumo - Este estudo objetivou analisar a incorporação de pó de rocha basáltica ao substrato comercial a base de casca de pinus sob duas condições de luminosidade no crescimento inicial das mudas de *Monteverdia ilicifolia* (Mart. Ex Reissek) Biral. Foram testadas quatro proporções de pó de rocha: 0% (controle), 10%, 20% e 30% em plantas mantidas sem sombreamento e com sombreamento de 50%, por 140 dias. O cultivo sem sombreamento associado com a incorporação de pó de rocha ao substrato favoreceu o crescimento das mudas. A incorporação de pó de rocha em qualquer proporção incrementou o diâmetro do colo e a biomassa, resultando em maior índice de qualidade de Dickson (IQD) nas mudas sem sombreamento. A proporção de 10% de pó de rocha apresentou resultados melhores no crescimento das mudas. As proporções de 20% e 30% de pó de rocha reduziram o diâmetro do colo, a biomassa e o IQD, quando comparados com 10% de pó de rocha, possivelmente pelas características físicas do substrato. Nós recomendamos a incorporação de 10% de pó de rocha ao substrato a base de casca de pinus para o crescimento de mudas de *M. ilicifolia*, em ambiente sem sombreamento.

https://doi.org/10.4336/2022.pfb.42e202002142

Introduction

Monteverdia ilicifolia (Mart. Ex Reissek) Biral belongs to the Celastraceae family (Biral & Lombardi, 2020) and is known as espinheira-santa or cancorosa (Benedetti et al., 2009). It occurs naturally in the Atlantic Rainforest, Central Brazilian Savanna, Pampa, and Pantanal, with a wide distribution in the South, Central-west, and Southeast regions of Brazil (Biral & Lombardi, 2020). Due to its potential, the species is included in the National Policy of Medicinal and Herbal Plants and in the List of Medicines distributed by Brazilian Unified Health System (Brasil, 2020). *M. ilicifolia* stands out among native medicinal plants for its therapeutic properties of protection and treatment of gastric ulcers (Carlini, 1988). There is a growing depletion of *M. ilicifolia* natural populations due to exploitation (Nicoloso et al., 2000), turning it an important species for management and conservation purposes (Dranski et al., 2017).

The species presents significant environmental plasticity. It grows under different edaphic conditions, soil hydromorphic regimes, and luminosity, occurring naturally in full sun and diffuse light environments (Radomski & Bull, 2010; Borges et al., 2019). For adult plants of *M. ilicifolia*, shading condition affects biomass production, specific leaf area, leaf nutrient concentrations and polyphenols contents (Radomski et al., 2004; Radomski & Bull, 2010; Rocha et al., 2014; Borges et al., 2019); thus, shading seems to be an important factor for the species. Despite being classified as a late secondary species, tolerant to shade in the juvenile stage (Souza et al., 2008), there is little information on the effect of shading on young plants, especially for seedlings production.

The increasing demand for forest seedlings has increased the demand for substrates with high availability, low cost, and adequate physical characteristics. Industrial, agroindustrial and urban residues have a high potential to be used as substrate components, although it is still necessary to adequate substrates to species needs (Kratz & Wendling, 2013). The mineral processing of basalt generates a significant amount of rock dust residues and environmental impacts; these residues can be used as natural fertilizers and have low commercial value (Nunes et al., 2014). The law nº 12,890/2013 (Brasil, 2013) regulates and allows the inclusion of soil remineralizers or rock dust as a category of input. Studies on forest seedlings production indicated the possibility of using rock dust as a substrate when mixed with other components, increasing the economic viability of seedling production (Wolschick et al., 2016). The rock dust when added to commercial substrates increments the growth of forest seedlings (Welter et al., 2011, 2014; Ehlers & Arruda, 2014). The positive effect of rock dust on plants growth can be associated with slow release of nutrients in the soil solution (Alovisi et al., 2017). Although, the use of basalt rock dust to complement substrates for forest seedlings production is still incipient, lacking research on how to use this material to guarantee the adequate growth of different species.

We developed this study considering the hypothesis that the adequate proportion of rock dust incorporated to substrate increases seedlings' growth; and that seedling produced under shading conditions present better growth, especially in the juvenile phase. Therefore, this study aimed to evaluate different proportions of basalt rock dust in the substrate for *M. ilicifolia* seedlings growth under two luminosity conditions.

Material and methods

The research was conducted between 20 November, 2019 and 7 April, 2020 in the nursery of the Department of Forest Sciences of the Federal University of Paraná, Curitiba, Paraná, Brazil (25°27'02" S, 49°14'15" W, 935 m altitude). The climate of the region is Cfb, according to the Köppen classification, characterized as humid subtropical with mild summer, with annual average temperature of 17 ºC and annual rainfall of 1,550 mm (Alvares et al., 2013).

Monteverdia ilicifolia seedlings were donated by Chauá Society® (Campo Largo, Paraná, Brazil). They were produced from seeds collected from parent trees in the species natural occurrence areas. Seedlings with approximately 5 cm height were transplanted and conducted in 100 cm^3 polyethylene tubes with a commercial substrate of decomposed pine bark, carbonized pine bark, coconut fiber, and vermiculite, with different proportions of rock dust. The substrates physical and chemical analysis were performed according to Normative Instruction nº 17/2007 of the Ministry of Agriculture, Livestock, and Supply (Brasil, 2007). We characterized it for bulk density, macroporosity, total porosity, water retention capacity at 10 cm (v/v), pH, and electrical conductivity. The rock dust used in this experiment was supplied by Reminer®, extracted from

Mandaguari, Paraná, Brazil. The chemical composition of the rock dust was provided by the manufacturer and is presented in Table 1 and 2.

Table 1. Chemical composition of the rock dust added to the substrate for *Monteverdia ilicifolia* seedlings production.

Nutrient	Proportion	Nutrient	Proportion
P	904 ppm	SiO_2	51.0%
Mn	375 ppm	Fe_2O_3	15.5%
Zn	65 ppm	Al_2O_3	12.9%
B	< 10 ppm	CaO	9.9%
Mo	0.6 ppm	Na_2O	2.4%
Fe	4.32%	TiO_2	2.2%
Al	1.54%	K_2O	1.1%
Ca	1.22%	P_2O_5	0.2%
Mg	0.36%	MnO	0.2%
Na	0.33%	S	< 0.01%
K	0.11%		

Source: Reminer®

Table 2. Granulometry, cation exchange capacity (CEC), effective cation exchange capacity, and water retention capacity (WRC) of the rock dust added to the substrate for *Monteverdia ilicifolia* seedlings production.

Granulometry	Sifted (%)
Sieve nº 40 – 0.425 mm	70.0
Sieve nº 50 – 0.300 mm	61.6
Sieve nº 80 – 0.180 mm	53.0
Sieve nº 200 – 0.075 mm	40.2
CEC	138.94 mmolc dm^{-3}
Effective CEC	50.8 mmolc dm^{-3}
WRC	41.3%

Source: Reminer®

The treatments consisted of rock dust addition to the commercial substrate, in the following proportions (v/v): 0% rock dust (control) and 10%, 20% and 30% rock dust. The four substrate formulations were submitted to two luminosity conditions (unshaded and shaded). For the shaded treatment, we used polyethylene screens (sombrite) with 50% reduction in light. The experiment was carried out on a completely randomized design in a 4 x 2 factorial scheme (proportions of rock dust x luminosity conditions), with 5 replications of 12 plants, totaling 480 plants.

For nutrient management, we used 5 kg m^{-3} of controlled-release fertilizer 16-08-12 (N-P-K, 9 months release); in the recommended dose established by Navroski et al. (2016) for *Eucalyptus dunnii*. Plants were irrigated four times a day during 10-20 min by micro-sprinkler (114 L h^{-1}), totaling 8-15 mm day^{-1} with irrigation time varying according to climatic conditions and seedlings water requirement. Plants remained in a greenhouse with plastic cover and side openings without temperature and humidity control.

At 140 days, we evaluated all seedlings for survival, height (cm) – with a graduated ruler – and stem diameter (mm) – with a digital caliper. Roots and shoot dry biomass were evaluated with the destructive analysis of five plants per repetition. The seedlings were cut at stem height, and roots were washed in running water to clean all substrate residues. Then, the plants were packed in identified paper bags, dried in a forced-air circulation oven at 60 ºC until constant weight measured on a precision scale (0.001 g). With these data, we calculated height/diameter ratio (HD ratio), total biomass, and Dickson quality index – DQI (Equation 1).

$$DQI = \frac{TB}{\left(\frac{H}{D}\right) + \left(\frac{SB}{RB}\right)} \tag{1}$$

Where: DQI = Dickson quality index; TB = total biomass; SB = shoot biomass; RB = roots biomass; H = height; D = stem diameter.

For statistical analysis, we verified the assumptions of data normal distribution (Shapiro Wilk test, $p <$ 0.05) and homogeneity of variances (Bartlett test, $p <$ 0.05). Variables that did not meet the assumptions were transformed by Box-Cox. Subsequently, we performed an analysis of variance (ANOVA) and Tukey test ($p <$ 0.05) using a double factorial design for height, diameter, H/D ratio, biomass, survival, and DQI. For substrates analysis, we performed Tukey test ($p < 0.05$) with complete randomized design. We performed statistical analyses in the R software (R Core Team, 2019).

Results

The incorporation of basalt rock dust to the substrate caused a considerable increase in substrate bulk density, from 617.45 kg m^{-3} in the control treatment (0% rock dust) to 1,111.67 kg m^{-3} in the formulation with 30% rock dust (Table 3). Macro and total porosity reduced with the incorporation of rock dust to the commercial substrate. However, water holding capacity did not differ with the addition of rock dust and pH was not altered, although the electrical conductivity reduced with the addition of rock dust to the substrate.

There was no interaction of luminosity condition and basalt rock dust proportions for survival, height, and height/diameter ratio (H/D ratio) of *M. ilicifolia* seedlings (Table 4). Height did not differ between luminosity conditions or between rock dust proportions. Regarding luminosity condition, unshaded seedlings presented a higher survival rate (92%), while shaded seedlings survival was 65% (Table 5). Unshaded seedlings also presented higher H/D ratio (4.96) than shaded seedlings (3.93). For the variables that showed significant interaction (stem diameter, shoot, roots and total biomass, and DQI), there was no difference between the luminosity conditions in the control treatment (0% rock dust). However, when rock dust was applied in any proportion (10%, 20%, and 30%), the unshaded seedlings showed higher values than the shaded ones. Unshaded seedlings with 10% rock dust had biomass more than 2.5 times higher than those grown under shaded conditions. Seedlings in both shaded and unshaded environments are presented in Figure 1.

The addition of rock dust had no significant effect on survival, height, and H/D ratio (Table 4). For the variables that showed significant interaction (diameter, shoot, roots and total biomass, and DQI), the effect of different proportions of rock dust in the substrate was observed only in unshaded seedlings (Table 5). For all these variables, considering the unshaded seedlings, the lowest means occurred in the control treatment (0% rock dust) and the highest ones with the addition of 10% rock dust. For biomass and DQI, means were 3.7 times greater with the addition of 10% rock dust when compared to the control treatment (0% rock dust). Thus, the addition of rock dust in any proportion increased stem diameter, biomass, and DQI values compared to the control treatment. However, when compared with 10% of rock dust, there is a significant reduction in means with the highest proportions of rock dust (20% and 30%).

Table 3. Physical and chemical characteristics (average and standard deviation) of substrates with distinct proportions of rock dust incorporated to a commercial substrate.

Substrates	**Physical characteristics**			
Basalt rock dust (%)	**BD (kg m^{-3})**	**WHC_{10} (%)**	**Macro (%)**	**TP (%)**
0	617.45 ± 7.86 d	52.68 ± 1.45 a	30.22 ± 1.69 a	82.89 ± 0.61 a
10	901.29 ± 9.72 c	54.75 ± 1.06 a	23.94 ± 3.99 ab	78.69 ± 3.17 ab
20	1,045.53 ± 10.40 b	55.62 ± 1.13 a	17.29 ± 0.67 b	72.92 ± 1.77 b
30	1,111.67 ± 8.68 a	55.47 ± 0.93 a	18.45 ± 7.04 b	73.91 ± 6.60 ab
Substrates	**Chemical characteristics**			
Basalt rock dust (%)	**pH**	**EC (dS m^{-1})**		
0	5.89 ± 0,08 a	0.336 ± 0,003 a		
10	6.07 ± 0,01a	0.276 ± 0,003 b		
20	6.09 ± 0,03 a	0.264 ± 0,007 b		
30	6.12 ± 0,01 a	0.276 ± 0,007 b		

BD – bulk density; WHC_{10} – water holding capacity at 10 cm (v/v); Macro – macroporosity; TP – total porosity; pH - hydrogenionic potential; EC - electrical conductivity. Means followed by the same letter in columns do not differ by the Tukey test ($p < 0.05$).

Table 4. Analysis of variance (ANOVA) of *Monteverdia ilicifolia* seedlings at 140 days.

Source of variance	Degree of freedom	Sum of squares	Mean square	F-value	p-value
Survival					
Luminosity	1	7335.1	7335.1	44.241	0.000 ***
Rock dust	3	852.4	284.1	1.714	0.183
Luminosity x rock dust	3	241.3	80.4	0.485	0.694
Residuals	32	13734.4	165.8		
Coefficient of variation	16.39%				
Height					
Luminosity	1	0.021	0.021	0.018	0.891
Rock dust	3	9.27	3.089	2.753	0.058
Luminosity x rock dust	3	4.836	1.611	1.436	0.25
Residuals	32	35.912	1.122		
Coefficient of variation	16.26%				
Diameter					
Luminosity	1	0.729	0.729	24.375	2.38^{-05} ***
Rock dust	3	0.685	0.228	7.641	0.0005 ***
Luminosity x rock dust	3	0.319	0.106	3.563	0.024 *
Residuals	32	0.957	0.0299		
Coefficient of variation	11.5%				
H/D ratio					
Luminosity	1	10.774	10.774	32.982	2.287^{-06} ***
Rock dust	3	0.909	0.303	0.928	0.438
Luminosity x rock dust	3	1.334	0.444	1.361	0.272
Residuals	32	10.453	0.326		
Coefficient of variation	12.84%				
Shoot biomass					
Luminosity	1	1.369	1.369	68.772	1.78^{-09} ***
Rock dust	3	0.873	0.291	14.620	3.60^{-06} ***
Luminosity x rock dust	3	0.430	0.143	7.209	0.0007 ***
Residuals	32	0.637	0.019		
Coefficient of variation	36.46%				
Roots biomass					
Luminosity	1	0.054	0.054	48.46	6.93^{-08} ***
Rock dust	3	0.068	0.022	20.227	1.54^{-07} ***
Luminosity x rock dust	3	0.019	0.006	5.846	0.002 ***
Residuals	32	0.036	0.001		
Coefficient of variation	31.56%				
Total biomass					
Luminosity	1	1.971	1.971	76.498	5.39^{-10} ***
Rock dust	3	1.416	0.472	18.328	4.20^{-07} ***
Luminosity x rock dust	3	0.630	0.21	8.16	0.0003 ***
Residuals	32	0.824	0.025		
Coefficient of variation	32.56%				
Dickson quality index					
Luminosity	1	0.033	0.033	92.482	5.84^{-11} ***
Rock dust	3	0.022	0.007	21.060	1.017^{-07} ***
Luminosity x rock dust	3	0.009	0.003	9.219	0.0001 ***
Residuals	32	0.011	0.0003		
Coefficient of variation	30.62%				
Survival					
Luminosity	1	7335.1	7335.1	44.241	0.000 ***
Rock dust	3	852.4	284.1	1.714	0.183
Luminosity x rock dust	3	241.3	80.4	0.485	0.694
Residuals	32	13734.4	165.8		
Coefficient of variation	16.39%				

Table 5. Survival, height, stem diameter, height/diameter ratio, roots, shoot and total biomass, and Dickson quality index of *Monteverdia ilicifolia* seedlings at 140 days as a function of luminosity conditions (shaded and unshaded) and basalt rock dust proportions in the commercial substrate.

Luminosity conditions	Basalt rock dust (%)				Mean
	0	10	20	30	
			Survival (%)		
Unshaded	88.3 ± 13.9	95.0 ± 4.6	90.0 ± 9.1	95.0 ± 4.6	92.1 a
Shaded	53.3 ± 13.9	68.3 ± 19.9	68.3 ± 9.1	70.0 ± 18.3	65.0 b
			Height (cm)		
Unshaded	6.27 ± 0.7 ^{ns}	6.71 ± 0.9	6.46 ± 0.2	6.71 ± 1.0	
Shaded	5.89 ± 1.5	7.84 ± 1.7	5.80 ± 0.6	6.44 ± 1.0	
			Stem diameter (mm)		
Unshaded	1.35 ± 0.2 aC	1.94 ± 0.2 aA	1.55 ± 0.1 aBC	1.70 ± 0.1 aAB	
Shaded	1.30 ± 0.1 aA	1.45 ± 0.2 bA	1.41 ± 0.2 aA	1.31 ± 0.1 bA	
			H/D ratio		
Unshaded	4.95 ± 0.2	4.72 ± 0.4	4.93 ± 0.3	5.27 ± 0.6	4.96 a
Shaded	4.37 ± 0.9	3.92 ± 0.5	3.66 ± 0.8	3.78 ± 0.5	3.93 b
			Shoot biomass (g plant^{-1})		
Unshaded	0.24 ± 0.18 aC	0.93 ± 0.22 aA	0.50 ± 0.11 aB	0.61 ± 0.15 aB	
Shaded	0.08 ± 0.08 aA	0.22 ± 0.13 bA	0.25 ± 0.12 bA	0.25 ± 0.07 bA	
			Root biomass (g plant^{-1})		
Unshaded	0.06 ± 0.02 aC	0.23 ± 0.04 aA	0.13 ± 0.05 aB	0.14 ± 0.04 aB	
Shaded	0.03 ± 0.03 aA	0.09 ± 0.04 bA	0.07 ± 0.01 bA	0.07 ± 0.02 bA	
			Total biomass (g plant^{-1})		
Unshaded	0.30 ± 0.20 aC	1.16 ± 0.24 aA	0.63 ± 0.15 aB	0.74 ± 0.18 aB	
Shaded	0.11 ± 0.10 aA	0.31 ± 0.14 bA	0.32 ± 0.12 bA	0.33 ± 0.08 bA	
			Quality dickson index		
Unshaded	0.03 ± 0.02 aC	0.14 ± 0.03 aA	0.08 ± 0.02 aB	0.09 ± 0.02 aB	
Shaded	0.01 ± 0.01 aA	0.04 ± 0.01 bA	0.03 ± 0.01 bA	0.03 ± 0.01 bA	

Different small letters represent statistical differences between luminosity conditions and capital letters represent statistical differences between basalt rock dust proportions by the Tukey test ($p < 0.05$).

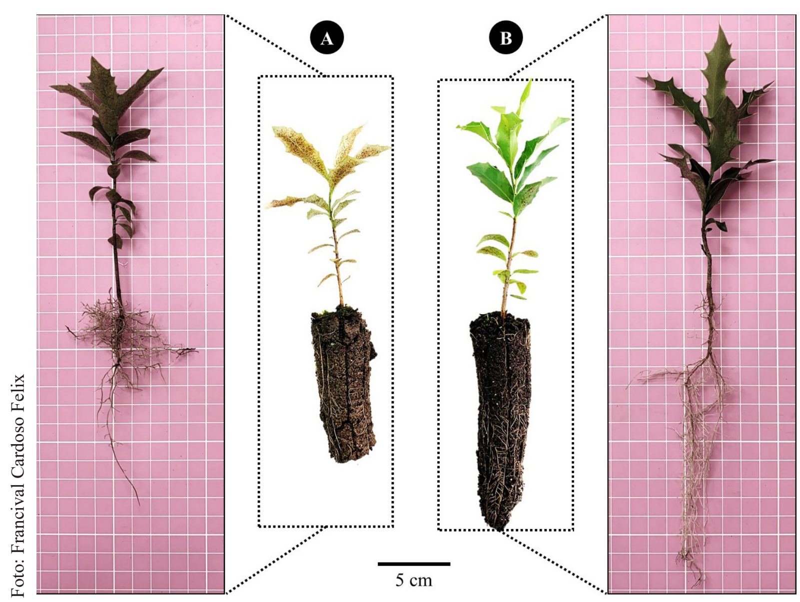

Figure 1. *Monteverdia ilicifolia* seedlings at 140 days under different luminosity conditions, shaded (A) and unshaded (B), in control treatment (0% basalt rock dust).

Discussion

Adding rock dust to the substrate favored growth of *Monteverdia ilicifolia* seedlings in the unshaded environment. The best results were obtained with 10% rock dust, especially for biomass and Dickson quality index (DQI). The positive effect of rock dust on plants growth can be attributed to its mineral composition, as a source of nutrients to plants (Gillman et al., 2002). In an experiment carried out by Alovisi et al. (2017), basalt rock dust made P and K available to the soil within 30 days, while the highest availability of Ca and Mg and increased pH occurred within 90 days, possibly because they are minerals of low solubility and slow alteration. The authors concluded that there was a little release of nutrients until 90 days, indicating that this material cannot be used as the primary source of nutrients to plants. As in our study we fertilized seedlings with controlled-release fertilizer, rock dust may have exercised complementary fertilization. We did not evaluate nutrients contents in the substrates and plants, but the incorporation of rock dust just reduced electrical conductivity, not the pH.

For Knapik & Angelo (2007b), *Prunus sellowii* seedlings grown in a substrate with basalt rock dust accumulated more Ca, Mg, B, Cu, and Fe in leaves comparing to seedlings without rock dust, although this component did not affect seedlings growth at 135 days. However, as in our study, Welter et al. (2014) also found good results in a study with *Euterpe oleracea*, in which seedlings biomass reached values 70% higher with the incorporation of rock dust. When evaluating initial development of *Myrciaria dubia* seedlings, Welter et al. (2011) observed that treatments without rock dust (0 g kg^{-1}) and with 0.42 g kg^{-1} rock dust produced lower quality seedlings than those with higher doses of rock dust, proving the efficiency of rock dust as a component of the substrate. Thus, we can infer that basalt rock dust favors the growth and quality of *M. ilicifolia* seedlings, especially in the lowest proportion tested in our study.

We observed that the highest proportions of rock dust (20% and 30%) caused a slight decrease in seedlings growth comparing to the treatment with 10% rock dust. This reduction may have occurred due to inadequate substrate physical characteristics, such as high density and lower macroporosity, causing restriction of oxygen supply and hindering root system growth. The commercial substrate presented physical characteristics outside the range defined by Gonçalves & Poggiani (1996) for plant substrates, even without adding rock dust (density from 450 to 550 kg m^{-3} and macroporosity from 35% to 45%). The addition of rock dust increased the substrate density, which may have restricted roots growth in treatments with 20% and 30% rock dust. The reduction of total porosity and macroporosity with the addition of rock dust indicates that this material with thin particles clogs the pores, reducing the aeration space, which can be detrimental to root development (Fermino & Mieth, 2018). The negative effects of high rock dust proportions have already been observed in *P. sellowii* seedlings, and results were attributed to the density of pine bark with rock dust (Knapik & Angelo, 2007b). Similar results were observed by Ehlers & Arruda (2014) with *Eucalyptus grandis* seedlings, when treatments with 10% and 20% rock dust were better for plant growth; however, treatment with 40% rock dust caused a reduction of seedlings stem diameter and height. Despite the significant increase in bulk density, and reduction in macro and total porosity by rock dust incorporation, these formulations presented better growth conditions to seedlings than the control treatment (0% rock dust) in our study.

Thus, the use of basalt rock dust with pine bark-based substrate can provide good chemical characteristics to the substrate; however, we must pay attention to its interference in density, porosity, aeration and water infiltration, which can cause compression effect (Knapik & Angelo, 2007a, 2007b). In our study, even without the addition of rock dust, the substrate had a high density and low macroporosity, which may have hindered the growth of seedlings in the tubes. Other substrates, including rock dust, must be evaluated for seedlings production of this still little-studied species. Despite that, the incorporation of rock dust was positive for *M. ilicifolia*, which could be maximized with water management more suitable for these substrate formulations. The reduced speed of water infiltration may result in less use of watering, suggesting differentiated irrigation management, with a higher number of irrigations per day at lower intensities (Knapik & Angelo, 2007a). Thus, we suggest testing different irrigation depths for substrate formulations with rock dust.

Despite treatments response, seedlings did not show satisfactory growth after 140 days, with a maximum height of 7.85 cm in unshaded environment, with 10% rock dust. This is attributed to the species slow growth rate (Nicoloso et al., 2000), also verified by Peccatti et al. (2019), who found a maximum height of 7.9 cm and a stem diameter of 0.8 mm at 180 days after sowing. In an experiment with *M. ilicifolia* seedlings in a forest understory, Hanisch et al. (2013) found an average height of 37 cm after 16 months of planting, and authors also attributed the slow growth to low light intensity.

Considering that *M. ilicifolia* is a species of forest understory, with spontaneous occurrence in shaded sites (Rocha et al., 2014), we expected that seedlings survival would be higher in shaded conditions, but it was not confirmed. Shaded seedlings presented lower survival and we also observed yellowing and falling leaves, indicating possible stress caused by low radiation. Unshaded plants presented superior results for biomass and Dickson quality index when rock dust was applied; corroborating our results, Radomski & Bull (2010) concluded that the amount of light available for *M. ilicifolia* in natural populations was the major regulator of N and K absorption, resulting in higher shoot biomass production in a population under full sunlight. For Rocha et al. (2014), full sunlight was also the most appropriate management for the production of *M. ilicifolia* leaves, influencing the sprouting capacity of population after partial pruning. However, differing from our results, Borges et al. (2019) found no differences for height, stem diameter, and biomass production of *M. ilicifolia* plants with different canopy cover (0% - 60%) in two agroforestry systems in the State of Santa Catarina, Brazil, during the first three years after planting.

Conclusions

The use of basalt rock dust can complement substrates formulation, promoting higher growth of *M. ilicifolia* seedlings.

The unshaded condition associated with basalt rock dust incorporated to substrate presents the higher *Monteverdia ilicifolia* seedlings growth. We recommend incorporating 10% of rock dust to the substrate. Rock dust in higher proportions (20% and 30%) also favor high seedling growth, but we must pay attention to its interference in substrate physical characteristics.

Acknowledgments

This work was partially supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) - Finance Code 001 and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

References

Alovisi, A. M. T. et al. Alterações nos atributos químicos do solo com aplicação de pó de basalto. **Acta Iguazu**, v. 6, n. 5, p. 69-79, 2017. Edição especial: II Seminário de Engenharia de Energia na Agricultura.

Alvares, C. A. et al. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, v. 22, n. 6, p. 711-728, 2013. https://doi.org/10.1127/0941-2948/2013/0507.

Benedetti, E. L. et al. Crescimento e sintomas em mudas de espinheira-santa com omissão de nitrogênio, fósforo e potássio. **Floresta**, v. 39, n. 2, p. 335-343, 2009. http://dx.doi.org/10.5380/rf.v39i2.14560.

Biral, L. & Lombardi, J. A. *Monteverdia ilicifolia* (Mart. ex Reissek) Biral. In: Flora do Brasil. Rio de Janeiro: Jardim Botânico do Rio de Janeiro, [2020]. Avaliable from: http://reflora.jbrj.gov.br/reflora/listaBrasil/FichaPublicaTaxonUC/FichaPublicaTaxonUC.do?id=FB605053. Access on: May, 8, 2020.

Borges, R. et al. Effect of cover on the development and production of secondary compounds of *Maytenus ilicifolia* and *Ilex paraguariensis* in agroforestry systems. **Ciência Florestal**, v. 29, n. 4, p. 1630-1643, 2019. https://doi.org/10.5902/1980509832280.

Brasil. Lei nº 12.890, de 10 de dezembro de 2013. Altera a Lei nº 6.894, de 16 de dezembro de 1980, para incluir os remineralizadores como uma categoria de insumo destinado à agricultura, e dá outras providências. **Diário Oficial [da] República Federativa do Brasil**, Brasília, DF, dez. 2013. Avaliable from: http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2013/Lei/L12890.htm. Access on: April, 21, 2020.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa SDA nº 17. Métodos Analíticos Oficiais para Análise de Substratos para Plantas e Condicionadores de Solo. **Diário Oficial [da] República Federativa do Brasil**, Brasília, DF, Seção 1, n. 99, 24 de maio de 2007. Avaliable from: http://antigo.agricultura.gov.br/assuntos/insumos-agropecuarios/insumos-agricolas/fertilizantes/legislacao/in-17-de-21-05-2007-aprova-metodo-substrato.pdf. Access on: May, 1, 2020.

Brasil. Ministério da Saúde. **Relação Nacional de Medicamentos Essenciais**: Rename 2020. Brasília, DF: Ministério da Saúde, 2020. 217 p. Avaliable from: http://portalarquivos2.saude.gov.br/images/pdf/2019/dezembro/24/Rename-2020-final.pdf. Access on: April, 29, 2020.

Carlini, E. L. A. (coord.). **Estudo de ação antiúlcera gástrica de plantas brasileiras:** *Maytenus ilicifolia* (espinheira-santa) e outras. Brasília, DF: CEME/AFIP. 1988. 87 p.

Dranski, J. A. L. et al. Manejo hídrico na rustificação em mudas de *Maytenus ilicifolia* [(Schrad.) Planch.]. **Biotemas**, v. 30, n. 1, p. 45-54, 2017. https://doi.org/10.5007/2175-7925.2017v30n1p45.

Ehlers, T. & Arruda, G. O. S. F. de. Utilização do pó de basalto em substratos para mudas de *Eucalyptus grandis*. **Floresta e Ambiente**, v. 21, n. 1, p. 37-44, 2014. http://dx.doi.org/10.4322/floram.2014.002.

Fermino, M. H. & Mieth, P. Análise de substratos para produção de mudas de espécies florestais. In: Araújo, M. M. et al. **Produção de Sementes e Mudas**: um enfoque à silvicultura. Santa Maria, RS: UFSM, 2018. 448p.

Gillman, G. P. et al. Amending highly weathered soils with finely ground basalt rock. **Applied Geochemistry**, v. 17, p. 987-1001, 2002. https://doi.org/10.1016/S0883-2927(02)00078-1.

Gonçalves, L. M. & Poggiani, F. Substratos para produção de mudas florestais. In: Congresso Latino Americano de Ciência do Solo, 13, 1996, Águas de Lindoia. **Resumos** [...]. Piracicaba: Sociedade Latino-Americana de Ciência do Solo, 1996.

Hanisch, A. L. et al. Persistência de plantas medicinais em sistemas agroflorestais no município de São Bento do Sul, SC, Brasil. **Revista Brasileira de Plantas Medicinais**, v. 15, n. 4, p. 774-779, 2013. http://dx.doi.org/10.1590/S1516-05722013000500019.

Knapik, J. G. & Angelo, A. C. Crescimento de mudas de *Prunus sellowii* Koehne em resposta a adubações com NPK e pó de basalto. **Floresta**, v. 37, n. 2, 2007a. http://dx.doi.org/10.5380/rf.v37i2.8655.

Knapik, J. G. & Angelo, A. C. Pó de basalto e esterco equino na produção de mudas de *Prunnus sellowii* Koehne (Rosaceae). **Floresta**, v. 37, n. 3, p. 427-436, 2007b. http://dx.doi.org/10.5380/rf.v37i3.9939.

Kratz, D. & Wendling, I. Produção de mudas de *Eucalyptus dunnii* em substratos renováveis. **Floresta**, v. 43, n. 1, p. 125-136, 2013. http://dx.doi.org/10.5380/rf.v43i1.25989.

Navroski, M. C. et al. Effect of the volume of the core and fertilizer rates on the growth of *Eucalyptus dunnii* Maiden. **Revista Agrarian**, v. 9, n. 31, p. 26-33, 2016.

Nicoloso, F. T. et al. Recipientes e substratos na produção de mudas de *Maytenus ilicifolia* e *Apuleia leiocarpa*. **Ciência Rural**, v. 30, n. 6, p. 987-992, 2000. https://doi.org/10.1590/S0103-84782000000600011.

Nunes, J. M. G. et al. Evaluation of the natural fertilizing potential of basalt dust wastes from the mining district of Nova Prata (Brazil). **Journal of Cleaner Production**, p. 1-8, 2014. https://doi.org/10.1016/j.jclepro.2014.04.032.

Peccatti, A. et al. Effect of *Trichoderma* spp. on the Propagation of *Maytenus ilicifolia* Mart. ex Reissek. **Journal of Agricultural Science**, v. 11, n. 3, 2019. https://doi.org/10.5539/jas.v11n3p435.

R Core Team. **R**: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing, 2019.

Radomski, M. I. & Bull, L. T. Caracterização ecológica e fitoquímica de quatro populações naturais de *Maytenus ilicifolia* no Estado do Paraná. **Pesquisa Florestal Brasileira**, v. 30, n. 61, p. 01-16, 2010. https://doi.org/10.4336/2010.pfb.30.61.01.

Radomski, M. I. et al. Caracterização de ambientes de ocorrência natural e sua influência sobre o peso específico e o teor de polifenóis totais de folhas de espinheira-santa (*Maytenus ilicifolia* Mart.). **Revista Brasileira de Plantas Medicinais**, v. 6, n. 2, p. 36-43, 2004.

Rocha, J. N. et al. Desenvolvimento de *Maytenus ilicifolia* e de seus polifenóis totais sob condição de sombreamento e poda. **Revista Brasileira de Plantas Medicinais**, v. 16, n. 3, p. 663-669, 2014. https://doi.org/10.1590/1983-084X/11_112.

Souza, J. R. P. et al. Desenvolvimento da espinheira-santa sob diferentes intensidades luminosas e níveis de poda. **Horticultura Brasileira**, v. 26, n. 1, 2008. http://dx.doi.org/10.1590/S0102-05362008000100008.

Welter, M. K. et al. Efeito da aplicação de pó de basalto no desenvolvimento inicial de mudas de camu-camu (*Myrciaria dubia*). **Revista Brasileira de Fruticultura**, v. 33, n. 3, p. 922-931, 2011. http://dx.doi.org/10.1590/S0100-29452011000300028.

Welter, M. K. et al. Initial growth of açaí seedlings in function of basalt powder doses. **International Journal of Agriculture Innovations and Reserach**, v. 3, n. 1, p. 18-23, 2014.

Wolschick, P. R. D. et al. Efeito do pó de rocha basáltica sobre a germinação de *Cedrela fissilis*. **Agropecuária Catarinense**, v. 29, n. 3, p. 76-80, 2016.