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Área Agrícola

# REMINERALIZER AND CONTROLLED-RELEASE FERTILIZER INCREASE *Mimosa scabrella* Benth. SEEDLINGS GROWTH

## FERTILIZANTE DE LIBERACIÓN CONTROLADA Y REMINERALIZANTE INCREMENTAN EL CRECIMIENTO DE LAS PLÁNTULAS DE *Mimosa scabrella* Benth.

***Alexandre Dal Forno Mastella*** • *alexandremastella@gmail.com*
PhD student Forest Engineering, Federal University of Paraná, Curitiba, Brazil.

***Mônica Moreno Gabira*** • *monica.gabira@gmail.com*
PhD student Forest Engineering, Federal University of Paraná, Curitiba, Brazil.

***Letícia Siqueira Walter*** • *leticiasiqueira.walter@gmail.com*
PhD student Forest Engineering, Federal University of Paraná, Curitiba, Brazil.

***Rodrigo Condé Alves*** • *rconde@gmail.com*
Master's degree in Forest Engineering.

***Chaiane Rodrigues Schneider*** • *chai.rodriguesschneider@gmail.com*
PhD student Forest Engineering, Federal University of Paraná, Curitiba, Brazil.

***Karen Koch Fernandes de Souza*** • *karenkfs@yahoo.com.br*
Professor in Educational State Center "Newton Freire Maia", Pinhais, Brazil.

***Dagma Kratz*** • *kratzdagma@gmail.com*
Professor in Federal University of Paraná, Curitiba, Brazil.

***Alessandro Camargo Ângelo*** • *alessandrocangelo@gmail.com*
Professor in Federal University of Paraná, Curitiba, Brazil.



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## ABSTRACT

**Contextualization:** *M. scabrella* is a native tree species of the Brazilian Mixed Ombrophilous Forest, with a high ecological importance and economic potential.

**Knowledge gap:** There is a lack of information about the use of resources that favour the seedlings production of this species.

**Purpose:** This study aimed to determine the most appropriate doses of controlled-release fertilizer (CRF) combined with the addition of remineralizer for production of *M. scabrella* seedlings.

**Methodology:** Seedlings were produced using four doses of CRF (0, 4, 8, and 12 Kg/m$^3$) and four doses of remineralizer (0%, 10%, 20%, and 30%), in a 4 x 4 factorial scheme. At 180 days of seedling production, growth in height and stem diameter, shoot (SDB), root (RDB) and total biomass (TDB), and Dickson quality index (DQI) were evaluated.

**Results and conclusions:** The use of remineralizer provided an increase in density and water retention capacity of substrates, as well as a reduction of macroporosity and total porosity. Combined with doses of 4 and 8 Kg/m$^3$, CRF contributed to the increase of biomass and DQI. The addition of 10% remineralizer, associated with 4.0 Kg/m$^3$ CRF, provides adequate growth to produce *M. scabrella* seedlings. Above this percentage of remineralizer and CRF dose, species growth rate is reduced.

***Keywords:*** *basalt rock dust; forest restauration; mine residues; native species; plant nutrition*

## RESUMEN

**Contextualización:** *M. scabrella* es una especie arbórea nativa del Bosque Mixto Ombrófilo brasileño, de gran importancia ecológica y potencial económico.

**Vacío de conocimiento:** Aún se carece de información sobre el uso de recursos, como sustratos y manejo de nutrientes, que favorecen la producción de plántulas de esta especie.

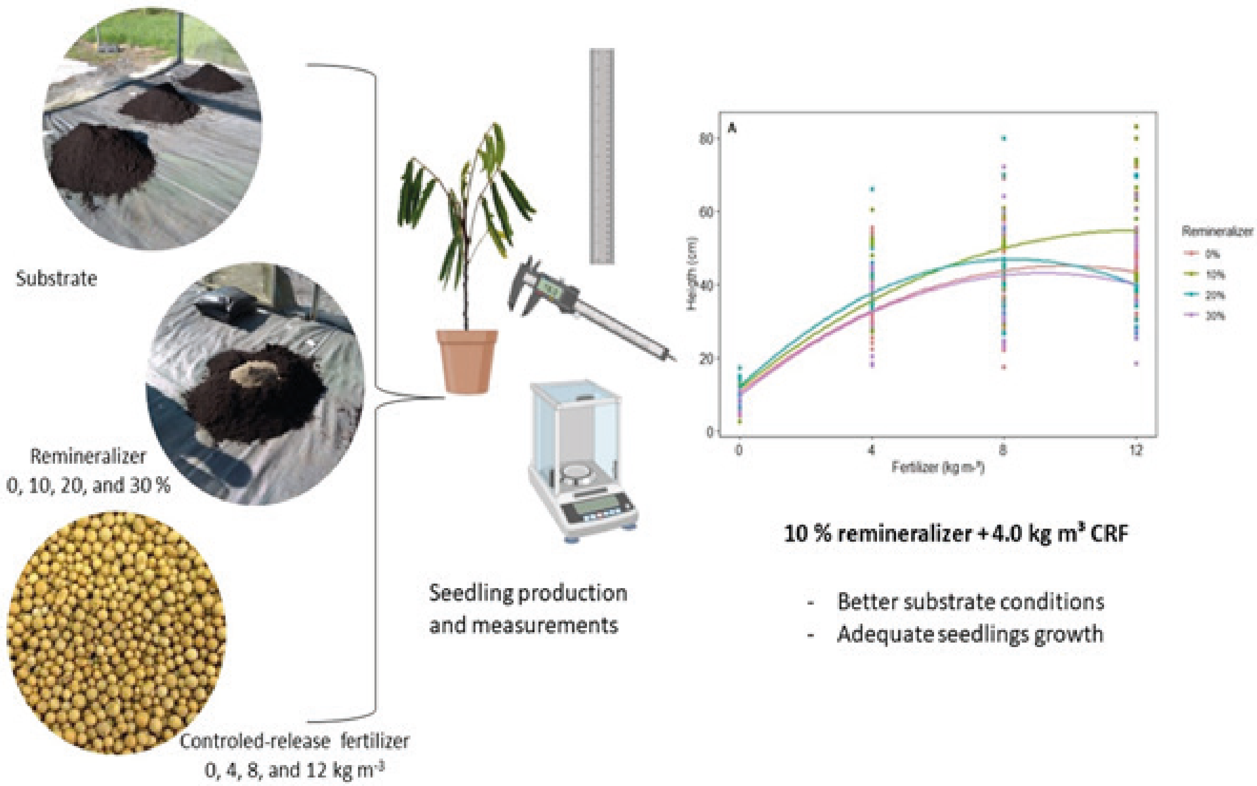
**Propósito del estudio:** Este estudio tuvo por objeto determinar las dosis más adecuadas de fertilizante de liberación controlada (CRF), combinado con la adición de remineralizador al sustrato, para la producción de plántulas de *M. scabrella*.

**Metodología:** Las plántulas se produjeron utilizando cuatro dosis de CRF (0, 4, 8 y 12 Kg/m$^3$) y cuatro dosis de remineralizador (0%, 10%, 20% y 30%), en un esquema bifactorial 4x4. A los 180 días de la producción de plántulas, se evaluó el crecimiento en altura y diámetro del tallo, el brote (SDB), la raíz (RDB) y la biomasa total (TDB), y el índice de calidad Dickson (DQI).

**Resultados y conclusiones:** El uso del remineralizador proporcionó un aumento de la densidad y la capacidad de retención de agua de los sustratos, así como una reducción de la macroporosidad y la porosidad total. Cuando se combinó con dosis de 4 y 8 Kg/m$^3$ CRF, contribuyó al aumento de la biomasa y del DQI. La adición de un 10% de remineralizador, asociado con 4,0 Kg/m$^3$ CRF, proporciona un crecimiento adecuado para producir plántulas de *M. scabrella*. Por encima de este porcentaje de remineralizador y dosis de CRF, la tasa de crecimiento de las especies se reduce.

***Palabras clave:*** *polvo de roca basáltica; restauración de bosques; residuos de minas; especies nativa; nutrición vegetal*

**GRAPHICAL ABSTRACT**




***Source:*** *Authors*

## 1. INTRODUCTION

*Mimosa scabrella* Benth. is a pioneer, leguminous tree species, from the Mixed Rainforest of South America (Carvalho, 2003). Its geographical distribution ranges from the south of Minas Gerais and Rio de Janeiro States, to the north of Rio Grande do Sul State, where it is observed most frequently (Machado et al., 2008). *M. scabrella* is an important source of wood for energy generation, but also has ornamental, forage, melliferous, and medicinal potential (Saueressig, 2014). When is used for forest restoration of degraded areas, it promotes the enrichment of the soil with organic compounds and facilitates spontaneous succession due to its rapid growth, providing a diversified composition of canopy cover and other life forms (Citadini-Zanette et al., 2017).

The production and commercialization of *M. scabrella* seedlings are important for the implementation of new plantations in restoration, monoculture, or mixed systems with Ilex paraguariensis A.St.-Hil (yerba mate), for example. However, there is still a lack of information about *M. scabrella*, and the resources that favor seedlings production of this plant. Among the factors that affect seedlings quality are seeds, substrates, fertilizers, and pesticides (Restrepo et al., 2013). Many studies point to the need for alternative materials in place of those traditionally used, as substrates and fertilizers, looking for greater sustainability in the production chain (Fragoso et al., 2017; Kratz et al., 2017; Stuepp et al., 2017; Gabira et al., 2020a, 2020b). In addition to material choice, the correct management of these resources in the nursery garden ensures better profitability and satisfactory results in the field (Mikula et al., 2020).

The proper use of fertilizers is one of the most important factors to ensure the quality of forest seedlings and their effective development in the field (Cortina et al., 2013). Doses and sources of fertilizers to be applied should be carefully considered to ensure the optimization of these resources (Madrid-Aispuro et al., 2020). Several

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studies indicate that the use of controlled-release fertilizers (CRF) ensures efficiency in nutrients availability throughout seedling production process, reducing losses due to leaching or damage due to excess of nutrients in substrates (Stüpp et al., 2015; Van Eerd et al., 2018; Cabreira et al., 2019). In addition, the use of CRF in seedlings production demonstrates a balance between plant physiological demands, according to the availability of nutrients (Santos et al., 2020; Cabreira et al., 2019; Brito et al., 2018). Regarding *M. scabrella*, studies indicate high salinity resistance (Avrella et al., 2019a) and a positive response to fertilization with CRF (Stüpp et al., 2015).

The use of volcanic rock waste as an alternative or complement to the use of fertilizers has been presented in some studies, searching for better sustainability of mining waste (Theodoro et al., 2013; Machado et al., 2016). Brazil produces large quantities of this waste due to its intense mining activity, and urgently needs adequate ways to dispose of this material (Dalmora et al., 2020). In 2013, through Law No. 12,890/2013, the use of rock dust as a soil remineralizer for agricultural purposes was instituted in Brazil (Brasil, 2013b). Among the advantages of using rock powder as a remineralizer, we can mention the ease of obtainment, the possibility of using it in natura (Da Silva et al., 2013), and the significant cost reduction (Machado et al., 2016). Remineralizers can also have corrective effects in soil acidity, influencing nutrient availability for plants and biomass production (Souza et al., 2017, 2018). However, further studies are needed regarding its use in seedlings production in containers with restricted volume, as the physical characteristics of this material can significantly alter substrate properties.



In this study, we considered the hypothesis that the use of adequate amounts of CRF combined with the addition of remineralizer to the substrate may increase growth and quality of *M. scabrella* seedlings, enabling a more efficient and sustainable production. Thus, the aim of this study was to determine the most appropriate doses of CRF and remineralizer for *M. scabrella* seedlings growth.

## 2. MATERIAL AND METHODS

The research was conducted at the Arboreto Project Forest Nursery, located at Canguiri Farm Experimental Station Center of the Universidade Federal do Paraná (UFPR) (25°23'20.76"S and 49°7'26.40"W at 895m altitude over the sea) located in Pinhais, Paraná, Brazil. The region's climate is Cfb type, according to the Köppen classification, characterized as humid subtropical with mild summer (Alvares et al., 2013).

The experiment started in June 2019, in a greenhouse without temperature and humidity control. During the experimental period, the minimum and maximum temperature averages were, respectively, 14.19ºC and 16.09ºC, with an average relative humidity of 88%. The greenhouse was protected by a roof, front and rear covered by light-diffusing plastic, and sides made up of shade screen and retractable light-diffusing plastic, the floor was covered with plastic ground cover. Irrigation with micro-sprinkler (52 L $h^{-1}$) was adjusted according to climatic conditions and seedling water requirement, varying from 2 to 8 min, with frequency from 3 to 4 times a day. We carried out a physical and chemical analysis of the substrate needed for the seedlings. Physical analysis followed the Normative Instruction No 17/2007 of the "Ministério da Agricultura, Pecuária e Abastecimento" (Brasil, 2007); according to this we evaluated: bulk density, macroporosity, total porosity, and water retention capacity. Chemical analysis determined the substrate hydrogenionic potential (pH) and its electrical conductivity (EC).

For seedlings production, the commercial substrate (CS) MecPlant Florestal2C®, based on semi-composted pine bark with vermiculite, pH regulator, and macronutrients was used, along with the soil remineralizer (R) Reminer®. Substrate physical characteristics were: WHC 60% [p/p], CTC 200 mmol c/Kg, maximum humidity 60%, average density of 375g/l, pH 5.3 – 5.8, and CE 1.2 – 1.7. According to the remineralizer producer, the batch of remineralizer used in our experiment had the following nutritional contents: 1.54% Al; B < 10 ppm; 1.22% Ca; 4.32% Fe; 0.11%

K; 0.36% Mg; 375 ppm Mn; 0.6 ppm Mo; 0.33% Na; 904 ppm P; S < 0.01%; 65 ppm Zn; 51% $SiO_2$; 12.90% $Al_2O_3$; 15.5% $Fe_2O_3$; 9.93 % CaO; 5.39 % MgO; 0.24 % $P_2O_5$; 2.42 % $Na_2O$; 1.07 % $K_2O$; 0.23 % MnO.

Analysis was performed on compositions with doses of 0% to 30% of remineralizer, with 10% intervals (v $v^{-1}$): 100CS/0R, 90S CS/10R, 80CS/20R, 70CS/30R. As base fertilization, we used four doses (0, 4, 8, and 12 kg $m^{-3}$) of Controlled Release Fertilizer (CRF) Osmocote® 5M (18-05-09) and MiniPrill (18% total N, 5 % $P_2O_5$, 9 % $K_2O$, and 3.5% S). Those, applied to the four formulated compositions, completed 16 treatments. The plants were the repetitions of the treatment: 15 repetitions in 16 treatments. There were 240 plants distributed in 5 blocks, making a total of 1,200 plants in the experiment.

*M. scabrella* seeds used in this experiment were donated by the Chauá Society®. The physical dormancy of the seeds was overcome by its immersion in hot water at 80 °C, allowing it to cool until room temperature (18h), following the recommendations of the Ministry of Agriculture, Livestock and Food Supply (Brasil, 2013a). Seedlings were produced by directly sowing three to four seeds per container (110 $cm^3$ tubes). The containers were covered with vermiculite to maintain the humidity and temperature, and reducing the growth of undesirable plants. After sowing, the tubes were placed in metal trays of 545 cells without spacing, suspended at 0.5 m from the ground, and stored in the greenhouse for 30 days. Seedling spacing was increased at 90 days to 4 x 4 cm, maintaining this configuration until 180 days. Seedling thinning was carried out after 30 days, when the seedling reached about 5 cm height, keeping the seedling more centralized in the tube, which had a greater shoot height.

At 180 days after sowing, we measured shoot height (H) and stem diameter (D) of all plants with a millimeter ruler and a digital caliper (0.01 mm). Destructive analysis was performed on five plants per repetition to obtain shoot biomass (SDB) and root biomass (RDB). Roots were washed, then packed in identified paper bags and dried in an oven at 70ºC for 72h. Subsequently, they were weighed in an analytical balance with 0.001g precision. We used H, D, SDB, and RDB to calculate total biomass (TDB) and Dickson quality index (DQI) (Dickson et al., 1960).

### Statistical analysis

The experimental design was randomized blocks in a bifactorial scheme (4 CRF doses x 4 remineralizer %) composed of five blocks with 15 plants (sample unit), resulting in 1,200 plants. For statistical analysis, we initially verified the assumption of homogeneity of variances by Bartlett test ($p < 0.05$) and normality by Shapiro-Wilk test. Data referring to substrate characterization were submitted to an Analysis of Variance (ANOVA) and Tukey test ($p < 0.05$). Other parameters were submitted to descriptive statistics and polynomial regression curves were adjusted for all variables. Equations were validated using the Bootstrap algorithm, which removes in each adjust one observation and tests to the others. This procedure was repeated 1,000 times to validate the models we obtained. We used the R software (R Core Team, 2019) to perform all the statistical analysis.



## 3. RESULTS AND DISCUSSION

The addition of a remineralizer provided significant changes in all substrate characteristics (Table 1). The reduced size of rock dust particles resulted in increased density and water retention capacity of the substrates, and reduced macroporosity and total porosity. The substrate 70CS/30R showed the highest density value (910.49 kg/ $m^{-3}$), and the lowest values of macroporosity and total porosity, 11.82% and 67.11%, respectively. CS, on the other hand, had the lowest density and water retention capacity – 579.68 Kg $m^{-3}$ and 44.64%, respectively – and the highest macroporosity and total porosity, 37.24% and 81.88%, respectively. There was a small variation in pH and EC between substrates, despite the statistical difference. The commercial substrate showed the highest average EC value (0.42 dS $m^{-1}$) and the lowest pH (6.32), while the substrate 70CS/30R had the lowest average EC value (0.31 dS $m^{-1}$) and the highest pH (6.69). We observed linear changes in EC and pH as the percentage of remineralizer in the substrate increased.

**Table 1.** Bulk density (D), macroporosity (Macro), water holding capacity (WHC), total porosity (TP), electrical conductivity (EC), and hydrogenionic potential (pH) of substrates used in *M. scabrella* seedlings production

| Substrate | Physical characteristics | | | | Chemical characteristics | |
|---|---|---|---|---|---|---|
| | D (kg m-³) | Macro (%) | WHC (%) | TP (%) | EC (dS cm⁻¹) | pH |
| 100CS | 579.68 d | 37.24 a | 44.64 b | 81.88 a | 0.42 a | 6.32 d |
| 90CS/10R | 715.29 c | 23.92 b | 52.63 a | 76.55 b | 0.38 b | 6.41 c |
| 80CS/20R | 840.39 b | 16.56 c | 56.22 a | 72.78 b | 0.34 c | 6.53 b |
| 70CS/30R | 910.49 a | 11.82 d | 55.29 a | 67.11 c | 0.31 d | 6.69 a |

Averages followed by the same letter in the column do not differ from each other by Tukey test at 5% probability. 100CS – 100% commercial substrate; 90CS/10R – 90% commercial substrate + 10% remineralizer; 80CS/20R – 80% commercial substrate + 20% remineralizer; 70CS/30R – 70% commercial substrate + 30% remineralizer.

***Source:*** *Authors.*

The addition of remineralizer to the substrates provided an increase in density and water retention capacity, and reduced macroporosity and total porosity. Although the differences, substrates physical and chemical characteristics remained within the expected standards for substrates used in forest seedlings production (Pascual et al., 2018). Thus, despite *M. scabrella* results, all substrates of this study can be used in forest nurseries, considering the intrinsic needs of the species. Total porosity is important for gas exchange in plant root systems (Pascual et al., 2018), and balance between macro and micropores will determine the water and nutritional management to be adopted in the nursery.



The changes observed in this experiment were related to particle size and shape (Fermino et al., 2018), since remineralizer is composed of fine and dense particles. To a certain degree, an increase in water retention capacity is beneficial for plants since they are restricted to small containers and depend on the water retained in substrates to maintain themselves (Stüpp et al., 2015). On the other hand, water excess reduces substrate aeration, inhibiting root growth, and causing tissue death and decay (Pascual et al., 2018). *M. scabrella* is a species that thrives best in environments with less water accumulation and does not tolerate substrates with high water saturation (Avrella et al., 2019b, 2019c). Water accumulation increased with the addition of remineralizer, causing a reduction in plant growth at doses higher than 20%.

The pH values varied between 6.32 and 6.69 in our study. The adequate values of pH for forest seedling production, in general, should be between 5.2 and 6.5 (Pascual et al., 2018). The subtle increase in pH, associated with the addition of the remineralizer, is related to the origin of the remineralizer, and was observed by Aquino et al. (2020) when evaluating different types of rocks with potential use as natural fertilizers. Significant changes in substrate pH provide differences in nutrients availability, even though we did not observe such effects in this experiment. Despite there were many minerals in remineralizer, these were not readily available (Ramos et al. 2015); therefore, we consider that its effect on plant growth was more related to changes in substrates physical characteristics.

The descriptive statistics exhibit a summary of the data obtained in the evaluation at 180 days after sowing (Table 2). Height showed high variance due to the difference between the maximum (83.0 cm) and minimum (2.5 cm) values measured. This behavior is a consequence of different substrate compositions, with the lowest values observed in the treatment composed only of a commercial substrate, without CRF (Figure 1). However, other variables showed low variance and standard deviation, with low minimum values at the end of experimental period.

**Table 2.** Descriptive statistics of height, stem diameter, shoot, root, and total biomass, and Dickson Quality Index of *M. scabrella* seedlings at 180 days, submitted to increasing doses of CRF (Osmocote® 5M (18-05-09) MiniPrill) and remineralizer

| Parameters | Minimum | Medium | Maximum | Variance | St. Dev. | CV (%) |
|---|---|---|---|---|---|---|
| Height (cm) | 2.5 | 33.89 | 83.0 | 312.95 | 17.69 | 0.52 |
| Stem diameter (mm) | 0.28 | 2.36 | 5.28 | 0.90 | 0.95 | 0.40 |
| Shoot biomass (g) | 0.026 | 0.74 | 2.1 | 0.25 | 0.50 | 0.67 |
| Root biomass (g) | 0.08 | 0.76 | 2.18 | 0.25 | 0.50 | 0.66 |
| Total biomass (g) | 0.10 | 1.50 | 4.28 | 0.91 | 0.95 | 0.63 |
| Dickson Quality Index | 0.004 | 0.09 | 0.28 | 0.003 | 0.05 | 0.58 |

Variance - Sample variance; St. Dev. - Standard Deviation; CV - Coefficient of variation.

***Source:*** *Authors.*

The effect of CRF doses, associated with the addition of remineralizer to the commercial substrate, is clear on plant growth results (Figure 1). Except for treatment with 10% remineralizer, we observed greater plant growth as CRF increased to 8 kg $m^{-3}$, followed by reduced growth in plants subjected to 12 kg $m^{-3}$ CRF. This result in the highest CRF dose indicates a potential toxic effect caused by excess of nutrients on plants when combined with the remineralizer. Although *M. scabrella* is considered a promising species for its use in saline soils, it presents a vulnerability to drought in the field (Avrella et al. 2019a). Salt excess in plant rhizosphere inhibits water flow because of the osmotic effect external to roots, resulting in salt and water stress (Taiz et al. 2014).

In this experiment, seedlings produced with up to 20% remineralizer and at least 4 kg $m^{-3}$ of CRF showed morphological parameters similar to those observed by Avrella et al. (2019a) in fertilized *M. scabrella* plants subjected to salt stress of up to -0.2 MPa. Stüpp et al. (2015), on the other hand, obtained lower values of height and diameter in *M. scabrella* seedlings submitted to different CRF doses. Height values obtained in this experiment indicate the formation of seedlings suitable for planting in the field even before 180 days. The high values for this variable, not accompanied by compatible values of stem diameter and biomass, caused low DQI values. The harmony between plants' morphological characteristics, expressed through the DQI, indicates the appropriate balance between seedling shoot and root parts (Binotto et al., 2010). However, higher seedlings have an advantage in the field concerning to weeds, especially in the first six months after planting, which are the most critical for plantation success (Stuepp et al., 2020).

Regarding the effect of treatments on plants, we observed that remineralizer and CRF provided changes in *M. scabrella* seedling growth, with a quadratic behavior for all variables. In general, plants submitted to doses of 10% remineralizer had greater growth and biomass accumulation when were compared to plants from other treatments, with significant differences according to the increase in CRF dose, starting with 4 kg $m^{-3}$ (Figure 1). As it was expected, treatments without fertilizer and remineralizer showed the lowest average values for all variables, indicating the efficiency of using these resources for efficient production of *M. scabrella* seedlings.

The highest mean values for height and stem diameter were, respectively, 43.16 cm and 2.65 mm, those results were obtained adding 10 % remineralizer and 12 kg $m^{-3}$ CRF to the substrate. It indicates that higher doses of remineralizer and CRF than those used in this study hindered seedling development. Despite similar behavior of height and stem diameter, factor levels had more influence on the height of plants that had higher variability and standard deviation (Table 2). Stem diameter, on the other hand, showed numerically similar averages (CV 0.40%), without major differences between treatments. The addition of remineralizer, combined with 4 and 8 kg $m^{-3}$ CRF, contributed to an increase in biomass and DQI of *M. scabrella* seedlings. As it was expected, in

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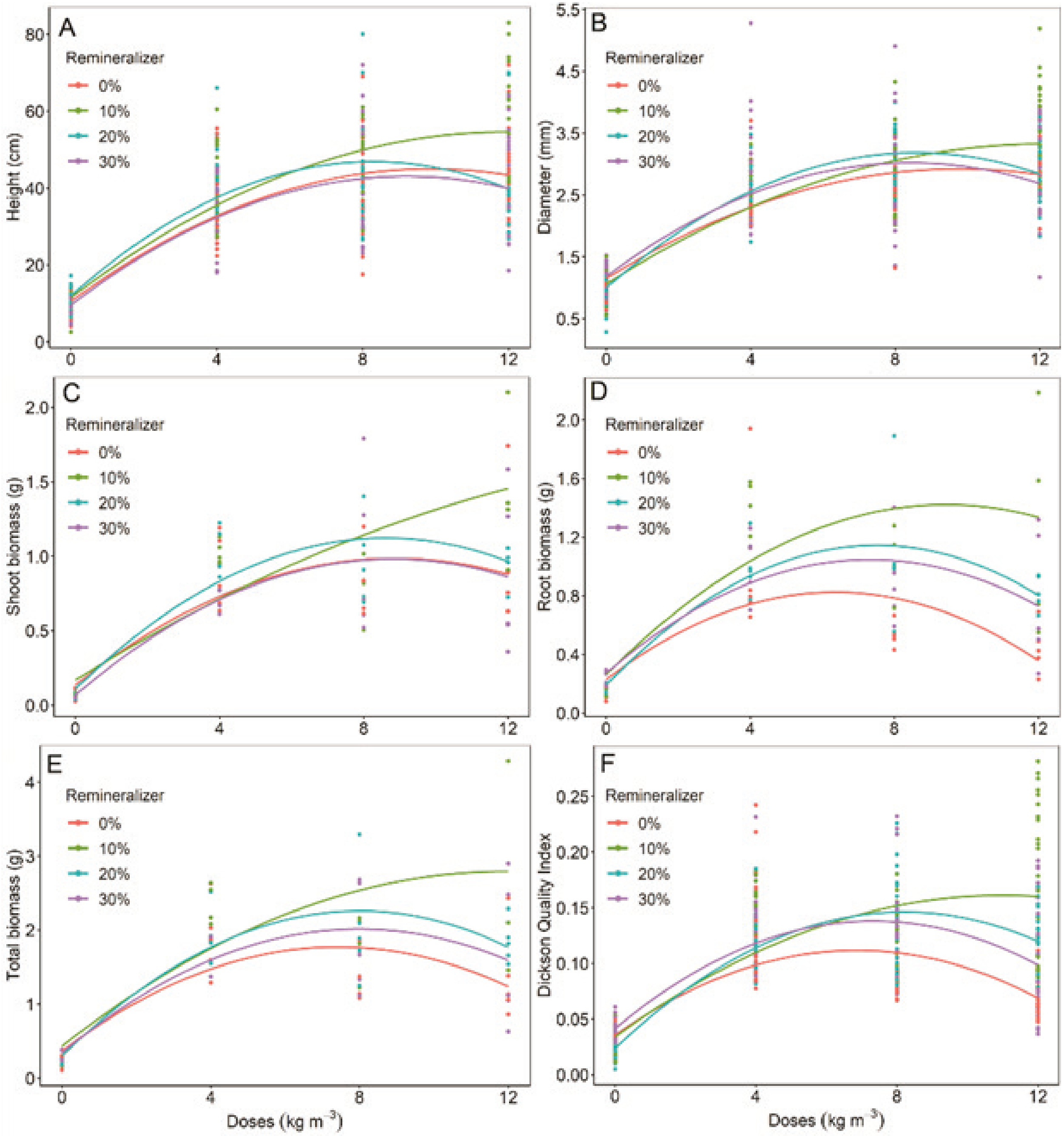


**Figure 1.** Polynomial regression for height (A), stem diameter (B), shoot (C), root (D), and total biomass (E), and Dickson Quality Index (F) of *M. scabrella* seedlings submitted to increasing doses of CRF (Osmocote® 5M (18-05-09) MiniPrill) and remineralizer.

***Source:*** *Authors*

the treatment composed only of commercial substrate (CS), biomass was lower than other treatments. As a result of the combination of all other variables, DQI also indicates that the use of 10% remineralizer, combined with 4 and 8 kg m$^{-3}$ CRF, for seedlings has an appropriate balance of morphological characteristics. Table 3 shows the components of the adjusted equations of all variables. Coefficients were significant in all polynomial equations, using the CRF values for each remineralizer concentration as a dependent variable. The values obtained for adjusted R-square were not higher than 0.77, a result explained by the high variability within the blocks under analysis.

**Table 3.** Polynomial regression equations fitted for height, stem diameter, shoot, root, and total biomass, and Dickson quality index of *M. scabrella* seedlings submitted to increasing doses of CRF (Osmocote® 5M (18-05-09) MiniPrill) and basalt rock dust.

| Parameter | Remineralizer | Equations | $R^2$ |
|---|---|---|---|
| Height | 0 % | $H = 10.49 + 6.98^{**}x - 0.35^{**}x^2$ | 0.61 |
| | 10 % | $H = 11.52 + 7.21^{**}x - 0.30^{**}x^2$ | 0.71 |
| | 20 % | $H = 11.97 + 8.42^{**}x - 0.51^{**}x^2$ | 0.64 |
| | 30 % | $H = 9.54 + 7.28^{**}x - 0.39^{**}x^2$ | 0.59 |
| Stem diameter | 0 % | $D = 1.15 + 0.36^{**}x - 0.018^{**}x^2$ | 0.69 |
| | 10 % | $D = 1.06 + 0.37^{**}x - 0.015^{**}x^2$ | 0.72 |
| | 20 % | $D = 1.00 + 0.50^{**}x - 0.027^{**}x^2$ | 0.77 |
| | 30 % | $D = 1.18 + 0.43^{**}x - 0.026^{**}x^2$ | 0.48 |
| Shoot biomass | 0 % | $SDB = 0.13 + 0.19^{**}x - 0.011^{**}x^2$ | 0.55 |
| | 10 % | $SDB = 0.16 + 0.15^{**}x - 0.003^{ns}x^2$ | 0.65 |
| | 20 % | $SDB = 0.10 + 0.23^{**}x - 0.013^{**}x^2$ | 0.74 |
| | 30 % | $SDB = 0.06 + 0.20^{**}x - 0.011^{**}x^2$ | 0.49 |
| Root biomass | 0 % | $RDB = 0.23 + 0.18^{**}x - 0.014^{**}x^2$ | 0.38 |
| | 10 % | $RDB = 0.26 + 0.24^{**}x - 0.013^{**}x^2$ | 0.47 |
| | 20 % | $RDB = 0.19 + 0.25^{**}x - 0.016^{**}x^2$ | 0.68 |
| | 30 % | $RDB = 0.27 + 0.21^{**}x - 0.014^{**}x^2$ | 0.47 |
| Total biomass | 0 % | $TDB = 0.36 + 0.37^{**}x - 0.025^{**}x^2$ | 0.51 |
| | 10 % | $TDB = 0.43 + 0.39^{**}x - 0.016^{**}x^2$ | 0.56 |
| | 20 % | $TDB = 0.30 + 0.49^{**}x - 0.030^{**}x^2$ | 0.74 |
| | 30 % | $TDB = 0.34 + 0.41^{**}x - 0.026^{**}x^2$ | 0.51 |
| Dickson Quality Index | 0 % | $DQI = 0.035 + 0.02^{**}x - 0.001^{**}x^2$ | 0.45 |
| | 10 % | $DQI = 0.034 + 0.023^{**}x - 0.001^{**}x^2$ | 0.49 |
| | 20 % | $DQI = 0.023 + 0.029^{**}x - 0.001^{**}x^2$ | 0.71 |
| | 30 % | $DQI = 0.041 + 0.026^{**}x - 0.001^{**}x^2$ | 0.42 |

** Significant at $p < 0.01$; ns – Not significant; $R^2$ – Adjusted R-squared.

***Source:*** *Authors.*

In this study we observed that high doses of nutrients have adverse effects on *M. scabrella* seedling growth, reducing increments in its morphological characteristics. The addition of remineralizer to the substrate provided satisfactory seedling growth in a concentration of 10%. On the other hand, it harmed plant development when the amount was equal or greater than 20%. This study will be fundamental for the establishment of *M. scabrella* seedlings production that pretend a greater sustainability of the process using residues from mining industry, and look for an adequate nutritional management of the plants with CRF.

## CONCLUSIONS

The 10% remineralizer doses associated with 4.0 kg $m^{-3}$ CRF were the most suitable for *M. scabrella* seedlings growth. The combination of remineralizer and CRF in the doses above mentioned increased seedlings' height, stem diameter, and biomass; therefore, increasing seedlings' quality parameters.

## CONTRIBUTIONS OF THE AUTHORS

***Alexandre Dal Forno Mastella***: research, conceptualization, writing. ***Mônica Moreno Gabira***: research, writing, data analysis, review. ***Letícia Siqueira Walter***: research, writing, data analysis, review, ***Rodrigo Condé Alves***: research, conceptualization, methodology, original draft, research, data analysis, review. ***Chaiane Rodrigues Schneider***: research, review. ***Karen Koch Fernandes de Souza***: research, review and editing. ***Dagma Kratz***: research, supervision, review, methodology. ***Alessandro Camargo Ângelo***: research, supervision, project manager, acquisition of resources.

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**Conflicto de intereses**
*Los autores declaran no tener ningún conflicto de intereses.*