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ROCK DUST ASSOCIATED WITH ORGANIC SUBSTRATES AND ITS EFFECT ON THE GROWTH OF AROEIRA

PÓ DE ROCHA ASSOCIADO A SUBSTRATOS ORGÂNICOS E SEU EFEITO SOBRE O CRESCIMENTO DA AROEIRA

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Abstract

The use of rock dust for the production of seedlings of forest species is an option due to its chemical characteristics and ease of use. Thus, this work evaluated the use of rock dust for the formation of seedlings of aroeira (*Myracrodruon urundeuva*) in soil Typic Quartzipisamment with addition of organic materials. The treatments were: T1. 20% dust + 40% humus; T2. 40% dust + 30% humus; T3. + 50% humus; T4. 20% dust + 40% vermicompost; T5. 40% dust + 30% vermicompost; T6. 50% vermicompost; T7. 20% dust + 40% commercial; T8. 40% dust + 30% commercial; and, T9. 50% commercial. The experimental design was completely randomized, with four replications, with results submitted to analysis of variance and multivariate, after 105 days of planting. The addition of rock dust at 20% of concentration, together witht he presence of vermicompost has provided the best growth rates.

Keywords: Basaltic rock, Vermicompost, *Myracrodruon urundeuva*.

Resumo

A utilização de pó de rocha para a produção de mudas de espécies florestais é uma opção devido as suas características químicas e facilidade de utilização. Assim, este trabalho avaliou a utilização de pó de rocha para a formação de mudas de aroeira (*Myracrodruon urundeuva*) em solo Neossolo Quartzarênico com adição de matéria orgânica. Os tratamentos foram: T1. 20% pó + 40% húmus; T2. 40% pó + 30% húmus; T3. 50% húmus; T4. 20% pó + 40% vermicomposto; T5. 40% pó + 30% vermicomposto; T6. 50% vermicomposto; T7. 20% pó + 40% comercial; T8. 40% pó + 30% comercial; e, T9. 50% comercial. O delineamento experimental foi inteiramente casualizado, quatro repetições, com resultados submetidos à análise de variância e multivariada, 105 dias de plantio. A adição de pó de rocha em 20%, em conjunto com o vermicomposto, propiciou as melhores taxas de crescimento.

Palavras-chave: Rocha basáltica, Vermicomposto, *Myracrodruon urundeuva*.

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INTRODUCTION

Currently, unconventional inputs have become attractive at low cost, which can improve soil properties, and increase plants production. For these reasons, several studies evaluate the effects of these new inputs, such as rock dust ([4], [16], [20], [21] and [27]). Basaltic rock dust is a mining residue with potential to be reused as a component of substrates in the production of forest seedlings because it contains important mineral elements, such as macronutrients, contributing to the fertility of the substrate due to the predominance of easily weathered minerals, and cation-rich ones, with gradual release of these nutrients [10] [11].

For [10], [11], [16] and [25], rock dust also brings other advantages, for instance reduction in labour, once this application requires no frequent fertilization due to its prolonged effect, once the dust is not readily soluble in water, it is not leached by the rain or irrigation. The same authors also highlight the pH correction, the non-salinization of the soil, the non-absorption in excess of potassium, which benefit the absorption of calcium and magnesium, and the decrease of the fixation of soluble phosphorus by the presence of silica.

The growing demand for forest species, concomitant with the little basic information that involves the seedlings production of species of interest, it has driven new studies on production methods with a standard in quality. The seedlings are mainly responsible for the vigor of the plants, and it is necessary that they present a pattern of height, stem diameter, and root system, for example, being them indicative of quality.

The substrate is an external factor that influences the process of rooting, and the quality of the roots formed, playing an important role in the initial survivance of the plant. Therefore, new mixtures of components, suitable for their physical and mineral characteristics, continue to be studied. The mixture of organic materials to the substrate favors its chemical, physical, and biological characteristics, creating a more suitable environment for the development of the plant as a whole; it improves water retention capacity, and oxygen diffusion rate, as well as it increases the availability of essential nutrients, and so the use of different components to form the substrate, and it is important to evaluate its growth [22].

Numerous forest species are heavily exploited in Brazil, for instance Anacardiaceae such as aroeira (*Myracrodruon urundeuva* Allem.). It is a medium to large tree, reaching between 15 and 30 meters heigh, 80 to 100 cm of diameter, and having a large geographic distribution in South America, occurring in the Northeast, Southeast, and Midwest regions [2] [5].

It is a tree species of multiple uses and has a very dense wood, considered noble and used for the production of luxury furniture, and in civil construction, with great durability in natural conditions. In this way, aroeira has been undergoing a process of intense exploitation, often in a predatory manner, causing the devastation of its natural populations [5]. Given its importance, it is necessary to make efforts to produce seedlings for large-scale planting.

The objective of this study was to evaluate the effect of the addition of rock dust to different organic substrates for the production of *Myracrodruon urundeuva* in sandy soil.

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MATERIAL AND METHODS

This study is quantitative, experimental research carried out through sampling, thus producing accurate and safe numerical results [18].

The experiment was carried out between November 2018 and February 2019, at Campus Agrárias, Universidade, Campo Grande, Mato Grosso do Sul, located at an altitude of 665 m, and according to the classification of Koppen-Geiger its climate being located in the transition band between the subtype mesothermic moist without drought or small drought (Cfa), and the subtype tropical humid with hot rainy season in summer, and dry in winter (Aw).

The soil used as the basis for all treatments, Typic Quartzipisamment (TQ), was collected in the Cerrado area of Legal Reserve, being withdrawn in depth of 0-20 cm, dry and sifted (sieve of 2 mm). The analysis was performed according to [9] for pH in H_2O, P and K, method of Mehlich^{-1}, Ca, Mg and Al + H, method KCl (1 M), and [6], for organic matter, colorimetric method, resulted in the following attributes: texture, 84% sand, 4% silt, and 12% clay; pH H_2O, 6.1, and pH $CaCl_2$, 5.5; assimilable phosphorus, 15 mg dm^{-3}; exchangeable potassium, 40 mg dm^{-3}; exchangeable calcium, 2.4 cmol$_+$ dm^{-3}; exchangeable magnesium, 1.2 cmol$_+$ dm^{-3}; and organic matter 20.1 g dm^{-3}.

To the soil used as base basaltic rock dust, organic substrate (humus derived from bovine manure), vermicompost, and commercial organic substrate were added. The organic substrate (OS) presented the following specifications: total number = 5%; pH = 6; relationship C/N = 14; cation exchange capacity (CEC) = 80 mmolc kg^{-1}; and humidity = 50%. The vermicompost (VC), elaborated with residues of the rumen of cattle under earthworm action *Eisenia foetida*: pH = 7.0; electric conductivity = 1.23 mS dm^{-1}; P = 260 mg kg^{-1}, K^+ = 600 mg kg^{-1}; Ca^{++} = 25 cmol$_+$ dm^{-3}; H = 6.54 cmol$_+$ dm^{-3}; density = 0.39 g cm^{-3}; and organic matter = 12.94%. The commercial substrate (CS), elaborated with residue of *Pinus* and vermiculite, pH = 5.5; density = 0.45 g cm^{-3}; water retention capacity = 165%; electric conductivity = 1.5 mS dm^{-1}; and humidity = 25% [28]. The rock dust (RD), 0,28% phosphorus, 1.14% de calcium, 0,08 potassium, 50.9% of SiO_2 and 0.69% magnesium, among other elements [1].

The experiment was conducted in a completely randomized experimental design, using nine treatments: T1) RD 20% + OS 40% + TQ 40%; T2) RD 40% + OS 30% + TQ 30%; T3) RD 0% + OS 50% + TQ 50%; T4) RD 20% + VC 40% + TQ 40%; T5) RD 40% + VC 30% + TQ 30%; T6) RD 0% + VC 50% + TQ 50%; T7) RD 20% + CS 40% + TQ 40%; T8) RD 40% + CS 30% + TQ 30%; and T9) RD 0% + CS 50% + TQ 50%.

After homogenization, the substrates were packed in plastic bags of polyethylene (20 cm wide x 30 cm tall) with volumetric capacity of 3 L (3 dm^{-3}), and in each bag a seedling was placed. The seeds used were obtained from 12 matrices in forest areas of the municipality of Campo Grande, and after germination occurred and the seedlings reached four centimeters of height, they were transplanted to the planting bags. After transplantation, the bags were kept for two days in the shade for acclimatization, and subsequently conducted to the field in full sun.

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At 105 days after planting, the plants were collected, and after cleaning the parts were separated in underground and aerial, measured (cm) and weighed (g), and then had their diameter of stem (mm) evaluated. Subsequently, the material was packed in paper bags, identified, and placed in a forced ventilation oven at 60 °C, during 48 h for the evaluation of the dry mass (g), and determination of the quality index of Dickson (QID).

In order to evaluate if the different treatments influenced the phytochemical production of the plants, the dried leaves were ground (2.5 g), extracted with ethanol (99.5%) in an ultrasonic bath, followed by static maceration, with the resulting solution being filtered and the solvent evaporated. The procedure was repeated for three days, obtaining the crude ethanolic extracts. The phytochemical characterization of the samples occurred following the methodology adapted from [15], and analyses performed in triplicates. To determine the presence of the classes of secondary metabolites, the intensities of the characterization reactions were classified as: 0 (zero) for negative reaction, partial intensity (10%), low (50%), mean (75%), and high intensity (100%) [13].

The results were submitted to analysis of variance and multivariate, using the *software* SAS (*Statistical Analysis System*).

RESULTS AND DISCUSSION

The addition of rock dust in different proportions led to a trend of substrate neutrality, increasing or decreasing the pH of the substrates (Table 1), with the evaluated parameters presenting variations. On the other hand, it did not increase the amount of potassium, phosphorus, and magnesium. The amount of calcium increased, though.

Table 1 - Chemical parameters and amount of Organic Matter (OM) found on the different substrates used (dr = dust rock, os = organic substrate, vc = vermicompost, cs = commercial substrate, ss = sandy soil, pH = hydrogen potential, H_20 = water, P = phosphorus, K = potassium, Ca = calcium, Mg = magnesium, mg/dm^3 = milligrams per cubic decimeter, and cmol/dm^3 = centimol/cubic decimeter

Treatments	pH H_20	P (mg/dm^3)	K (mg/dm^3)	Ca (cmol/dm^3)	Mg	OM
dr20 + os40 + ss40	7.3	78.9	155.5	12.7	7.2	29.5
dr40 + os30 + ss30	7.3	73.3	132.0	12.9	5.3	23.4
dr0 + os50 + ss50	7.9	89.9	149.5	10.3	6.2	41.1
dr20 + vc40 + ss40	5.8	39.4	54.0	10.6	2.5	36.4
dr40 + vc30 + ss30	6.4	33.2	44.7	11.3	4.9	28.4
dr0 + vc50 + ss50	5.3	35.0	51.5	7.2	3.2	41.1
dr20 + cs40 + ss40	7.6	48.6	112.0	11.2	4.1	33.5
dr40 + cs30 + ss30	7.2	44.4	118.0	12.0	6.5	28.1
dr0 + cs50 + ss50	6.9	68.1	126.0	7.8	7.3	35.6

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The results obtained were partially similar to those presented by [21], while evaluating the fertility of the soil through the addition of crushed basalt, with alteration of pH, and maintenance of potassium levels. Opposite to it, it increased the amount of magnesium, and did not affect the calcium. [16] have shown that the addition of crushed basalt at the highest concentrations provided the maximum reduction of the active acidity, raising the pH, and promoting the increase of calcium, magnesium, zinc, iron, and copper contents in the soil.

[22], while evaluating the growth of *Astronium fraxinifolium* Schott in different substrates, indicated that the ground basalt presented small contributions to the evaluated chemical attributes, and correlated the result to the experiment time (165 days), incipient period to change these parameters. However, the data showed increases in pH, K, Ca, and Mg, with the increase of the doses of basalt applied, being these results similar to those found by this research. [19], while studying the growth of *Jatropha curcas* L. in response to fertilization with superphosphate and rock dust, also did not find any influence on the morphological characteristics of seedlings, and they mention the insufficient time for the release of nutrients and the action of soluble fertilizer to meet the needs of plants as reasons for it.

However, the growth results of aroeira plants were affected by the different substrates, indicating that the addition of rock dust, in the concentration of 20%, with the addition of fertilizer in the form of vermicompost (40%) (T4), produced the best seedlings with better dry weight of the root, shoot, and total, besides greater height and diameter of the stem (Table 2).

Table 2 - Growth of aroeira plants on substrates containing different percentages of dust rock, organic substrate, vermicompost or commercial substrate and, sandy soil (ss)

Organic product (%)	ss	Root (g)	Aerial (g)	Total (g)	Height (cm)	Stem (mm)	QID
				No rock dust			
Organic 50	50%	1.3ab	9.6b	10.1b	42.7ab	9.6a	0.23
Vermicomp 50		0.7c	6.1c	6.1bc	32.2c	8.1b	0.14
Commercial 50		0.5c	2.5d	3.0cd	23.8d	8.2b	0.08
				20% rock Dust			
Organic 40	40%	1.5a	8.4bc	9.6b	37.8bc	10.4a	0.27
Vermicomp 40		1.6a	13.6a	15.7a	47.9ª	9.0ab	0.25
Commercial 40		1.2bc	1.0d	1.2d	15.2e	4.4d	0.03
				40% rock Dust			
Organic 30	30%	1.4ab	5.9c	7.5b	35.3bc	9.1ab	0.16
Vermicomp 30		0.1d	1.1d	1.3d	16.3e	6.1c	0.18
Commercial 30		1.0bc	7.0bc	7.3b	35.8bc	9.2ab	0.04
CV		22,92	10,65	11,42	11,73	14,42	
DMS		0,46	1,2	1,5	5,7	1,7	

*Means followed by the same letter (column) do not differ by Tukey's test (5% probability).

Taking that the addition of rock dust allows a continuous release of ions into account, the growth trend of the species in this substrate is to keep being more expressive than the other substrates tested, increasing differences in growth over time, which would confirm the assertion of [22].

The vermicompost is the result of the alteration of organic residues by the action of earthworms; this fertilizer has been extensively studied for containing humidifying microorganisms, and alkalinizing bacteria [23]. According to [24], the result of this reaction is earthworm excrement rich in nutrients, mainly N, Ca, P, Mg, and K, presenting an excellent cation exchange capacity, and high organic matter content.

Although other treatments have also shown significant growth of the root (T1, T2, T3 e, T5), height (T3), and stem diameter (T1, T2, T3 e, T5), only T4 treatment stood out in all parameters analyzed, demonstrating their better suitability for aroeira species. A thick stem indicates the presence of reserve substances, showing that the seedling is suitable for field planting, because the energy to form new roots comes from the stem.

[11], while evaluating the growth of *Eucalyptus grandis* W. Hill ex Maiden concluded that the basalt powder, in dosages of 10 to 20%, in addition to substrates such as vermiculite and peat-based compound, favored the development of the aerial part and the diameter of the stem, a result similar to those found by this work. [7] working with eucalyptus and geological materials of Andesite Rock also verified effect gains of eucalyptus diameter demonstrating the benefits of using rock waste to grow seedlings.

The second-best treatment (T3), with addition of organic substrate (50%) to the sandy substrate (50%), was also partially adequate, although with lower development of the aerial part, demonstrating that a greater organic fertilization is beneficial to the studied species. A similar result was obtained by [26], which indicated the use of cattle manure, among others, for the production of seedlings of *Tectona grandis* Linn. F.

However, the addition of vermicompost in greater quantity (50%) itself did not produce differentiated growth, demonstrating that the composition of the substrate interferes in the growth. According to [23], high concentrations of vermicompost induce a lower dry mass of the aerial part, result of a greater availability of nutrients in the substrate, slowing down the expansion of the root system, and hampering the development of the plant, which was observed in T6 treatment.

[26], comparing the organic substrate found that the treatment with bovine manure presented the high levels of organic matter, and the lowest values of phosphorus, potassium, calcium, and magnesium. The authors concluded that the addition of humus to the soil itself would not be sufficient to produce a differentiated growth in the plants, due to the immobilization of the nutrients in the organic matter.

On the other hand, the commercial substrate had the lowest growth results, demonstrating that it is not suitable for the production of seedlings of the species. [8], evaluating the height growth, stem diameter, dry mass of the aerial part, roots, and total of seedlings of *Sesbania virgata* (Cav.) Pers. 150 days after sowing, also found the lowest growth rates while using commercial substrate, when compared to substrate using sewage sludge, coconut fiber, vermiculite, and rice husk. [17], evaluating seedlings of forest species, also demonstrated that the addition of commercial substrate to the sandy soil produced the lowest growth of the seedlings.

The lower development in T2, T5, and T8, when added 40% of rock dust, is probably related to the fact that a higher proportion of this element may cause a process of substrate compaction, hindering the processes of gas exchange, and absorption of nutrients.

The results obtained also demonstrated that most of the substrates (except for T6, T7, T8, and T9) produced seedlings capable of surviving in the field, only taking the diameter of the stem into account. However, for T1, T3, and T4 the QID presented an average over 0.20, value that corresponds to what was recommended, and demonstrates that the seedlings produced in these different treatments present satisfactory quality for planting.

This way, the addition of organic fertilizer and/or dust rock is beneficial for the formation of seedlings with higher probability of survival. Once more, it can be emphasized that the worst diameters found were observed in the presence of commercial substrate (T7 and T8).

The main component analysis demonstrated the existence of a correlation between root weight and stem diameter, where a greater weight of the root system was followed by the larger diameter. [14] consider stem diameter, easily measurable, one of the most important characteristics to estimate seedling survival; the height is also an important morphological variable to guarantee a good development after the definitive planting in the field.

Thus, two important parameters (root and collection) for the survival of the seedlings in the field presented significant results in T1, T2, T3, T4, and T5. In T3, without any addition of rock powder, 50% of organic substrate was adequate to the growth of these parameters; on the other hand, in T6, the addition of 50% vermicompost did not provide a better growth. Only T3 and T4 stood out in terms of height, demonstrating the positive effect of the addition of organic substrate or vermicompost associated with rock dust.

[12] evaluating the growth of the same species in Dystrophic Red Latosol and different concentrations of nitrogen, indicated that the height did not exceed 21 cm, the diameter of the collection, 5.2 mm and, 8 g of total dry weight at 150 days of cultivation. The use of different organic substrates with the addition of rock dust was more adequate for the production of seedlings, especially the vermicompost.

[3], while evaluating the growth of the species using fertilization with sewage sludge and silicate after 265 days, found a maximum growth of 54.2 cm in height and 19.9 mm of stem, being these values lower than those found by this research at 150 days of evaluation.

Nonetheless, the success of the use of vermicompost and commercial substrate for the production of seedlings of forest species is dependent on the species tested, as it was reported by [23], who assessed the growth of *Eucalyptus grandis* Hill ex Maiden and *Pinus elliottii* var. *elliottii* Engelm. In this case, the addition of vermicompost to the commercial substrate promoted greater development for eucalyptus, in relation to the pure commercial substrate. On the other hand, the

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pine seedlings were not favored by the addition of vermicompost, developing better in pure commercial substrate.

This situation occurs because the forest species have specific requirements for their best growth, and each type of substrate provides different conditions of nutrition for the plant, besides different physical characteristics [2].

Considering the characteristics of the plant as root system, aerial part, height, and stem, the organ that had the greatest benefit from the addition of rock dust was the root system, which changed from 0.8 g to 1.4 g; but the addition of 40% affected it negatively (Table 2). This fact is also verified in the multivariate analysis (Figure 1), where the addition of 20% of rock powder provided an increase in root length (CR), in the separation from the other variables. However, in the addition of 40% of rock dust, the variables attached to the root system, such as CR, MFR, and MSR were separated from the variables of the aerial part, indicating that in this proportion the plant should spend more energy in the root system, in detriment to the aerial part, possibly due to the proportion of rock dust creating a more compacted environment for the seedlings.

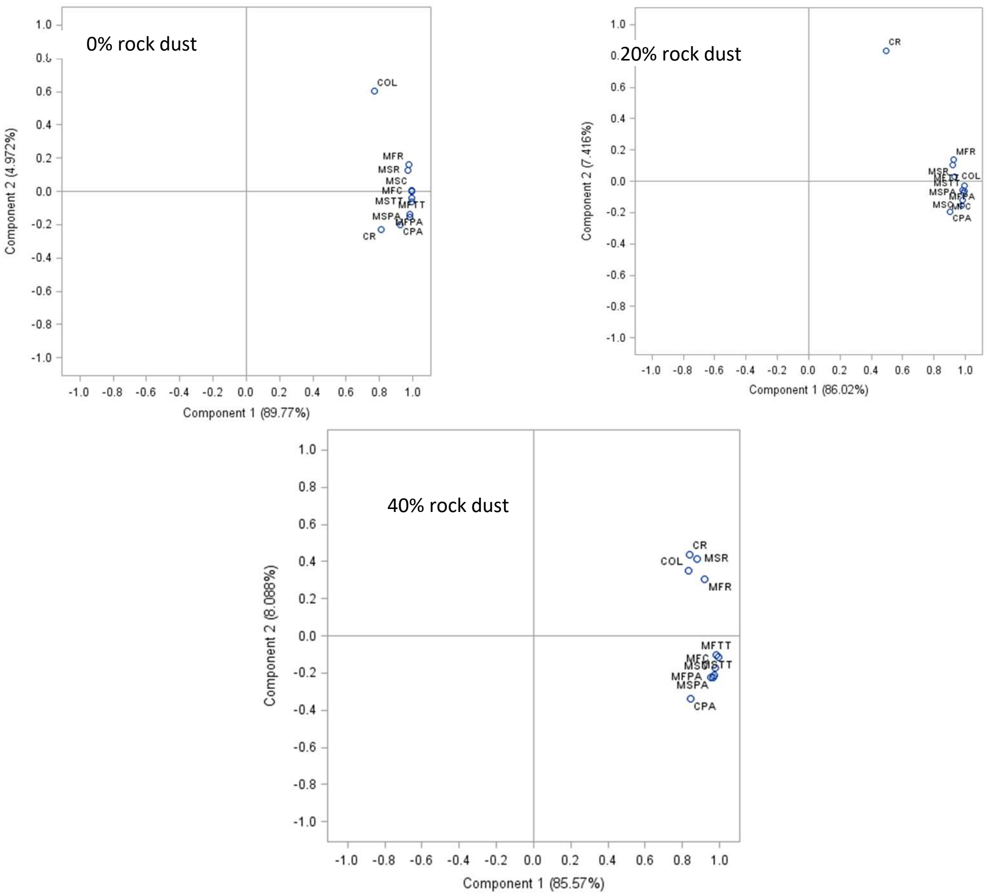

Figure 1 - Principal component analysis for variable of CR (root length), CPA (aerial length), COL (stem diameter), MFR (fresh root), MSR (dry root), MFC (fresh stem), MFTT (total fresh), MSTT (total dry), MFPA (fresh aerial), and MSPA (dry aerial) for seedlings of aroeira.

Testing ground basalt dust with seedlings of *Eucalyptus benthamii* and checking the chemical attributes of the soil, [20] explained that the pH of the soil increased as a function of the application of the basalt dust. This fact deserves special attention, since the elevation of the pH favors the microbiological activity, being these microorganisms responsible for the solubilization of the inorganic P through the process called biological weathering. This way, biological activity

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should be emphasized when rock dust is used, as mentioned by [22], while applying the dust of rock in an area with objective of remineralization of the soil, they verified that a better microbiological repopulation occurred in the place when the rock dust was applied alongside with organic residues.

Regarding the production of secondary metabolites (Figure 2), although the T4 treatment was prominent in all analyzed parameters, the phytochemical characterization of leaf extracts indicated that the treatments T2 and T9 presented a greater diversity of metabolites (9 class), followed by treatments T1, T4, and T5, eight class; the other treatments, seven class. The treatments did not interfere in the frequency of phenolic derivatives (flavonoids and anthraquinones 100%, and anthocyanins 50%). However, for the phenolic compounds, T1 was superior (100%) to the other treatments; the coumarins, lower frequency in T1.

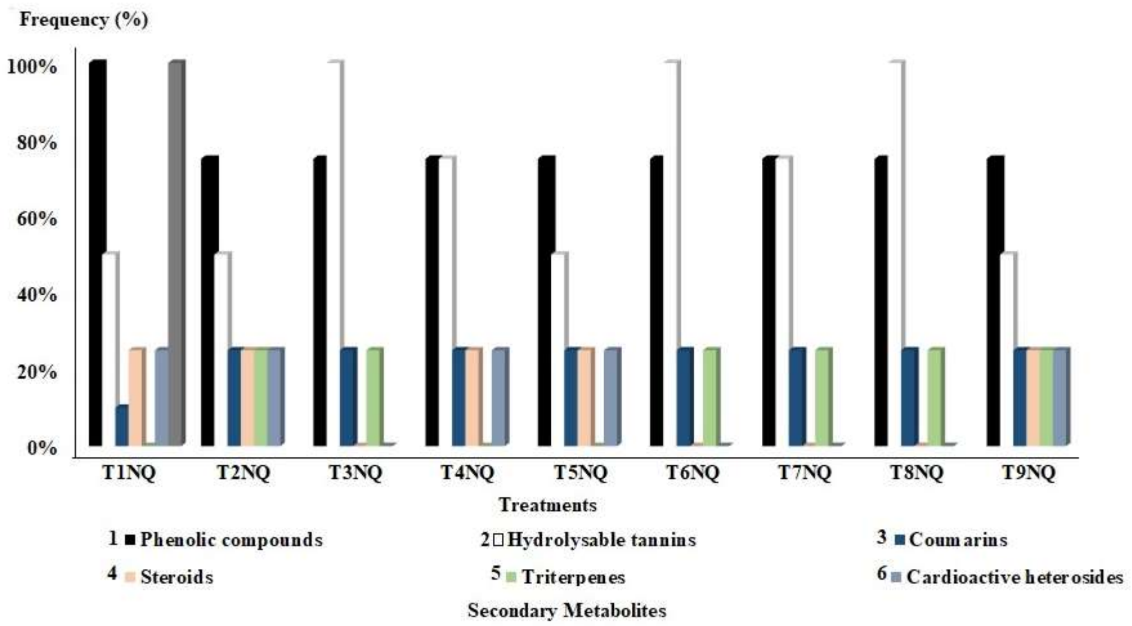

Figure 2 - Class and frequency (%) of secondary metabolites of extract of *Myracrodruon urundeuva* cultivated on substrates containing different percentages of dust rock, organic substrate, vermicompost or commercial substrate, and sandy soil.

The addition of rock dust, in different proportions, or their absence, did not lead to a differentiated production of metabolites, demonstrating the adaptation of the species to different cultivation environments, explaining its wide dispersion in several phytoecological regions. The production of these metabolites can provide competitive advantages, for example, since certain groups act in the defense of plants against pathogens, and/or insect predation, favoring the growth of the seedlings and also justifying its use as a medicinal plant. Thus, although the seedlings present a growth preference related to the type of substrate, the production of metabolites is diversified in all situations evaluated.

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CONCLUSIONS

The addition of rock dust at 20% of concentration, together witht he presence of vermicompost has provided the best growth rates, being it the most appropriate for the species, under the cultivation conditions assessed.

The organ that was mostly benefited from the addition of rock dust was the root system; but the addition of 40% affected it negatively.

The addition of rock dust, at different proportions or their absence, did not lead to a differentiated production of metabolites, demonstrating the adaptation of the species to different cultivation environments.

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REFERENCES

[1] ABREU, M.F.; ANDRADE, J.C.; FALCÃO, A.A. Protocolos de análises químicas. In: ANDRADE, J.C.; ABREU, M.F. **Análise química de resíduos sólidos para monitoramento e estudos agroambientais**. Campinas: Instituto Agronômico, 2006. p. 121-158.

[2] ANDRADE, A.P.; BRITO, C.C.; SILVA JÚNIOR, J.; COCOZZA, F.D.M.; SILVA, M.A.V. Estabelecimento inicial de plântulas de *Myracrodruon urundeuva* Allemão em diferentes substratos. **Revista Árvore**, v.37, n.4, p.737-745, 2013. https://doi.org/10.1590/S0100-67622013000400017

[3] CALDEIRA JÚNIOR, C.F.; SOUZA, R.A.; MARTINS, E.R.; SAMPAIO, R.A. Capacidade de recuperação de área degradada pelo gonçalo-alves (*Astronium fraxinifolium* Schott) sob adubação com lodo de esgoto e silicato. **Revista Brasileira de Biociências**, v.5, supl.1, p.480-482, 2007.

[4] CAMARGO, C.K.; RESENDE, J.T.V.; CAMARGO, L.K.C.; FIGUEIREDO, A.S.T.; ZANIN, D.S. Produtividade do morangueiro em função da adubação orgânica e com pó de basalto no plantio. Semina: **Ciências Agrárias**, v.33, suplemento1, p.2985-2994, 2012. https://doi.org/10.5777/ambiencia.2012.01.02

[5] CARVALHO, P.E.R. **Espécies arbóreas brasileiras**. Brasília: Embrapa Informação Tecnológica; Colombo: Embrapa Florestas, 2003. v. 1.

[6] CLAESSEN, M.E.C. (Org.). **Manual de métodos de análise de solo**. 2. ed. Rio de Janeiro: Embrapa-CNPS, 1997.

[7] DALMORA, A.C.; RAMOS, C.G.; OLIVEIRA, M.L.S.; OLIVEIRA, L.F.S.; SCHNEIDER, I.A.H.; KAUTZMANN, R.M. Application of andesite rock as a clean source of fertilizer for eucalyptus crop: Evidence of sustainability. **Journal of Cleaner Production**, v.256, p.120432, 2020. https://doi.org/10.1016/j.jclepro.2020.120432

[8] DELARMELINA, W.M.; CALDEIRA, M.V.W.; FARIA, J.C.T.; GONÇALVES, E.O.; ROCHA, R.L.F. Diferentes substratos para a produção de mudas de *Sesbania virgata*. **Floresta e Ambiente**, v.21, n.2, p.224-233, 2014. https://doi.org/10.4322/floram.2014.027

[9] DONAGEMA, G.K.; CAMPOS, D.V.B.; CALDERANO, S.B.; TEIXEIRA, W.G.; VIANA, J.H.M. (Orgs.). **Manual de métodos de análise de solos**. 2. ed. Rio de Janeiro: Embrapa Solos, 2011.

[10] EHLERS, T.; ARRUDA, G.O.S.F. Efeitos do pó de rocha basáltica adicionado em substratos para mudas de *Pinus elliottii*. **Revista de Ciências Agroveterinárias**, v.13, p.310-317, 2014a.

[11] EHLERS, T.; ARRUDA, G.O.S.F. Utilização do pó de basalto em substratos para mudas de *Eucalyptus grandis*. **Floresta e Ambiente**, v.21, n.1, p.37-44, 2014b. https://doi.org/10.4322/floram.2014.002

[12] FEITOSA, D.G.; MALTONI, K.L.; CASSIOLATO, A.M.R.; PAIANO, M.O. Crescimento de mudas de Gonçalo-Alves (*Astronium fraxinifolium*) sob diferentes fontes e doses de nitrogênio. **Revista Árvore**, v.35, n.3, p.401-411, 2011. https://doi.org/10.1590/S0100-67622011000300004

[13] FONTOURA, F.M.; MATIAS, R.; LUDWIG, J.; OLIVEIRA, A.K.M.; BONO, J.A.M.; MARTINS, P.F.R.B.; CORSINO, J.; GUEDES, N.M.R. Seasonal effects and antifungal activity from bark chemical constituents of *Sterculia apetala* (Malvaceae) at Pantanal of Miranda, Mato Grosso do Sul, Brazil. **Acta Amazonica**, v.45, n.3, p.283-292, 2015. https://doi.org/10.1590/1809-4392201500011

[14] GOMES, J.M.; PAIVA, H.N. **Viveiros florestais: propagação sexuada**. Viçosa: UFV, 2011.

[15] MATOS, F.J.A. **Introdução a fitoquímica experimental**. 3. ed. Fortaleza: UFC, 2009.

[16] MELO, V.F.; UCHÔA, S.C.P.; DIAS, F.O.; BARBOSA, G.F. Doses de basalto moído nas propriedades químicas de um Latossolo Amarelo distrófico da savana de Roraima. **Acta Amazonica**, v.42, n.4, p.471-476, 2012.

[17] OLIVEIRA, R.B.; LIMA, J.S.S.; SOUZA, C.A.M.; SILVA, S.A.; MARTINS FILHO, S. Produção de mudas de essências florestais em diferentes substratos e acompanhamento do desenvolvimento em campo. **Ciência e Agrotecnologia**, v.32, n.1, p.122-128, 2008.

[18] PEREIRA, A.S.; SHITSUKA, D.M.; PARREIRA, F.J.; SHITSUKA, R. **Metodologia da pesquisa científica**. Santa Maria: UAB/NTE/UFSM, 2018.

[19] PRATES, F.B.S.; LUCAS, C.S.G.; SAMPAIO, R.A.; BRANDÃO JÚNIOR, D.S.; FERNANDES, L.A.; JUNIO, G.R.Z. Crescimento de mudas de pinhão-manso em resposta a adubação com superfosfato simples e pó-de-rocha. **Revista Ciência Agronômica**, v.43, n.2, p.207-213, 2012.

[20] SILVA, A.; ALMEIDA, J.A.; SCHMITT, C.; COELHO, C.M.M. Avaliação dos efeitos da aplicação de basalto moído na fertilidade do solo e nutrição de *Eucalyptus benthamii*. **Floresta**, v.42, n.1, p.69-76, 2012a. https://doi.org/10.5380/rf.v42i1.26300

[21] SILVA, D.R.G.; MARCHI, G.; SPEHAR, C.R.; GUILHERME, L.R.G.; REIN, T.A.; SOARES, D.A.; ÁVILA, F.W. Characterization and nutrient release from silicate rocks and influence on chemical changes in soil. **Revista Brasileira de Ciência do Solo**, v.36, n.3, p.951-962, 2012b. https://doi.org/10.1590/S0100-06832012000300025

[22] SILVA, E.A.; CASSIOLATO, A.M.R.; MALTONI, K.L.; SCABORA, M.H. Efeitos da rochagem e de resíduos orgânicos sobre aspectos químicos e microbiológicos de um subsolo exposto e sobre o crescimento de *Astronium fraxinifolium* Schott. **Revista Árvore**, v.32, n.2, p.323-333, 2008. https://doi.org/10.1590/S0100-67622008000200015

[23] SILVA, R.F.; MARCO, R.; ROS, C.O.; ALMEIDA, H.S.; ANTONIOLLI, Z.I. Influência de diferentes concentrações de vermicomposto no desenvolvimento de mudas de eucalipto e pinus. **Floresta e Ambiente**, n.24, e20160269, 2017. https://doi.org/10.1590/2179-8087.026916

[24] STEFFEN, G.P.K.; ANTONIOLLI, Z.I.; STEFFEN, R.B.; SCHIEDECK, G. Utilização de vermicomposto como substrato na produção de mudas de *Eucalyptus grandis* e *Corymbia citriodora*. **Pesquisa Florestal Brasileira**, v.31, n.66, p.75-82, 2011. https://doi.org/10.4336/2011.pfb.31.66.75

[25] SUGUINO, E.; JACOMINI, A.E.; LAZARINI, A.P.; MARTINS, N.A.; FARIA, A.M.; PERDONÁ, M.J. Utilização do pó de basalto na agricultura. **Pesquisa & Tecnologia**, v.8, n.60, p.1-5, 2011.

[26] TRAZZI, P.A.; CALDEIRA, M.V.W.; PASSOS, R.R.; GONÇALVES, E.O. Substratos de origem orgânica para produção de mudas de teca (*Tectona grandis* Linn. F.). **Ciência Florestal**, v.23, n.3, p.401-409, 2013. https://doi.org/10.5902/1980509810551

[27] WELTER, M.K.; MELO, V.F.; BRUCKNER, C.H.; GOES, H.T.P.; CHAGAS, E.A.; UCHÔA, S.C.P. 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. https://doi.org/10.1590/S0100-29452011000300028

[28] ZORZETO, T.Q.; DECHEN, S.C.F.; ABREU, M.F.; FERNANDES JÚNIOR, F. Caracterização física de substratos para plantas. **Bragantia**, v.73, n.3, p.300-311, 2014. https://doi.org/10.1590/1678-4499.0086