Agronomic performance of strawberry cultivated in substrate with rock powder

Desempenho agronômico de morangueiro cultivado em substrato com pó-de-rocha

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José Luís Trevizan Chiomento
Doutor em Agronomia e professor do Curso de Agronomia
Faculdade de Agronomia e Medicina Veterinária, Universidade de Passo Fundo
Avenida Brasil Leste, BR 285, Bairro São José, Passo Fundo, RS, 99052-900
E-mail: jose-trevizan@hotmail.com

Jackson Korchagin
Doutor em Agronomia e professor do Curso de Agronomia
Centro de Ensino Superior Riograndense
Avenida Brasil Leste, BR 285, Bairro São José, Passo Fundo, RS, 99052-900
E-mail: jackson.korchagin@gmail.com

Michele Fornari
Doutoranda em Engenharia Agrícola pelo Programa de Pós-Graduação em Engenharia Agrícola (PPGEA) da Universidade Federal de Santa Maria e professora do Curso de Agronomia
Faculdade de Agronomia e Medicina Veterinária, Universidade de Passo Fundo
Avenida Brasil Leste, BR 285, Bairro São José, Passo Fundo, RS, 99052-900
E-mail: michelefornari@gmail.com

Leandro Pazzin Brugnera
Acadêmico do Curso de Agronomia
Faculdade de Agronomia e Medicina Veterinária, Universidade de Passo Fundo
Avenida Brasil Leste, BR 285, Bairro São José, Passo Fundo, RS, 99052-900
E-mail: 153473@upf.br

Thomas dos Santos Trentin
Acadêmico do Curso de Agronomia
Faculdade de Agronomia e Medicina Veterinária, Universidade de Passo Fundo
Avenida Brasil Leste, BR 285, Bairro São José, Passo Fundo, RS, 99052-900
E-mail: tstrentin@gmail.com

Alana Grando Dornelles
Acadêmica do Curso de Agronomia
Faculdade de Agronomia e Medicina Veterinária, Universidade de Passo Fundo
Avenida Brasil Leste, BR 285, Bairro São José, Passo Fundo, RS, 99052-900
E-mail: alanagrando5@gmail.com

Eduardo Zanin
Acadêmico do Curso de Agronomia
Faculdade de Agronomia e Medicina Veterinária, Universidade de Passo Fundo
Avenida Brasil Leste, BR 285, Bairro São José, Passo Fundo, RS, 99052-900
E-mail: eduardozanin96@gmail.com

Larissa Macedo Borges
Acadêmica do Curso de Agronomia
Faculdade de Agronomia e Medicina Veterinária, Universidade de Passo Fundo
Avenida Brasil Leste, BR 285, Bairro São José, Passo Fundo, RS, 99052-900
E-mail: lahryssa.borges@hotmail.com

ABSTRACT
Although different studies have shown beneficial effects of using rock powder on plants, no research has been done to determine the influence of adding this input to the strawberry growing substrate (*Fragaria* X *ananassa* Duch.). Thus, we investigated whether proportions of rock powder added to the cultivation substrate interfere in the agronomic performance of strawberry. The treatments tested were five proportions of rock powder (0%, 15%, 30%, 45% and 60% of the volume of the container). The experiment was designed in randomized blocks, with four replications. The supply of fertigation was reduced by half in order to verify whether the rock powder would be able to supply part of the nutrient demand required by the strawberry. The determination coefficient obtained was 0.83, indicating that the total production of fruits (TP) was explained in 83% by the proportions of rock powder added. We also observed that TP decreased linearly with the increase in the proportion of rock powder added to the cultivation substrate. TP was also negatively associated with the increase in the density of the culture media. In conclusion, increasing amounts of rock powder added to the cultivation substrate create a denser environment, not providing the necessary quantities for the development of the strawberry and this reduces its productive potential.

Keywords: *Fragaria* X *ananassa* Duch., remineralizer, production, quality.

RESUMO
Apesar de diferentes estudos mostrarem efeitos benéficos do uso de pó-de-rocha às plantas, nenhuma pesquisa foi feita para determinar a influência da adição desse insumo ao substrato de cultivo do morangueiro (*Fragaria* X *ananassa* Duch.). Assim, investigamos se proporções de pó-de-rocha adicionadas no substrato de cultivo interferem no desempenho agronômico do morangueiro. Os tratamentos testados foram cinco proporções de pó-de-rocha (0%, 15%, 30%, 45% e 60% do volume do recipiente de cultivo). O experimento foi delineado em blocos casualizados, com quatro repetições. O fornecimento de fertirrigação foi reduzido à metade buscando verificar se o pó-de-rocha seria capaz de suprir uma parte da demanda de nutrientes requerida pelo morangueiro. O coeficiente de determinação obtido foi de 0.83, indicando que a produção total de frutos (PT) foi explicada em 83% pelas proporções de pó-de-rocha adicionadas. A PT diminuiu linearmente com o aumento da proporção do pó-de-rocha adicionada ao substrato de cultivo. A PT se associou negativamente com o aumento da densidade dos meios de cultivo. Conclui-se que quantidades crescentes de pó-de-rocha adicionadas ao substrato

de cultivo criam um ambiente mais denso, não fornecendo as quantidades necessárias para o desenvolvimento do morangueiro e isso reduz seu potencial produtivo.

Palavras-chave: *Fragaria* X *ananassa* Duch., remineralizador, produção, qualidade.

1 INTRODUCTION

Strawberry (*Fragaria* X *ananassa* Duch.) production in Brazil is still concentrated in the conventional cultivation system (in soil, in open sky), with low productivity when compared to the countries considered the largest producers (CHIOMENTO et al., 2021). One of the initiatives observed in southern Brazil, to reduce the productivity gap between the most developed countries, is the migration of most producers from traditional cultivation in the soil to substrate cultivation.

The substrate cultivation profile is characterized by requiring many chemical fertilizers (ANDRADE et al., 2017). In addition, most producers who grow on substrate adhere to open systems, where the drained and surplus nutrient solution is released into the environment, which in the long run can cause agroecosystem contamination. An alternative to minimize these inconveniences is to use tools that reduce the amount of fertilizers applied during the production cycle of this horticultural crop, such as remineralizers, as is the case with rock powder. However, this tool is unknown to most strawberry growers.

The use of rockfall is a viable and sustainable alternative (ALMEIDA JÚNIOR et al., 2020). As conventional agriculture is characterized by the large-scale use of chemical fertilizers and biocides to provide good conditions for the development of cultivated plants (KORCHAGIN et al., 2019), the possibility of reducing the use of these inputs is one of the main factors that justifies the application of rock powder as a soil remineralizer (RAMOS et al., 2015). The use of rock powders in soil fertilization was initially proposed by Hensel (1894), highlighting the benefits of using ground rocks in agriculture, known as stone flour or soil remineralizers (LOPES et al., 2014).

Unlike most formulated fertilizers, rock powder has a slower solubility, making nutrients available for a longer period compared to conventional inputs (THEODORO & LEONARDOS, 2006). The addition of rock powder to the growth medium promotes an increase in the cation exchange capacity, provides macro and micronutrients not available in soluble chemical fertilizers and acts in the correction and conditioning of the growth medium (MELAMED et al., 2007). Despite the beneficial effects of rock powder on plants, no research has been done to determine the influence of proportions of this remineralizer added to the strawberry cultivation substrate in relation to the agronomic performance of this horticultural crop.

Therefore, the objective of the work was to investigate whether proportions of rock powder added to the cultivation substrate interfere in the agronomic performance of strawberry.

2 MATERIAL AND METHODS

2.1 PLANT MATERIAL AND EXPERIMENT LOCATION

The research was carried out in the municipality of Soledade (29º 03' 14" S, 51º 26' 00" W), Rio Grande do Sul (RS), Brazil, in a greenhouse, from April (autumn) to November (spring) 2020.

Strawberry mother plants, of the 'Monterey' cultivar, classified as neutral days (ND) regarding flowering, from the Llahuén/Chilean Patagonia nursery, were transplanted into the soil, in a commercial nursery in Brazil, with the purpose of producing bare-root plants. Afterwards, these bare-root plants obtained were transplanted in trays filled with commercial substrate to obtain daughter plants rooted in clod, which constituted the plant material of the research. These rooted daughter plants were supplied by the company Bioagro Comercial Agropecuária Ltda.

2.2 EXPERIMENTAL DESIGN

Treatments tested were five proportions of rock powder (0%, 15%, 30%, 45% and 60% of the volume of the container). The experiment was designed in randomized blocks, with four replications. Rock powder (Britagem Soledade Ltda.) was obtained by cone grinding in a vertical shaft impact.

2.3 CULTIVATION TECHNIQUES

In April 2020, the rooted daughter plants were transplanted in containers (32 L), filled with commercial substrate and with the treatments related to rock powder proportions. The substrate consists of carbonized rice husks, humus, acidity correctives and fertilizers (nitrogen, phosphorus and potassium) in quantities not provided by the manufacturer. Rock powder was mixed with the cultivation substrate. A 500 g sample of the substrate containing the treatments for rock powder was analyzed to obtain its physical attributes, according to Brazil (2007) (Table 1), and a 200 g sample of rock powder was analyzed to determine its chemical properties, according to Brazil (2014) (Table 2).

Table 1. Physical properties of the cultivation substrate in the absence and presence of rock powder proportions.

Substrate[1]	D[2]	TP	AS	RAW	BW	RW
	(kg.m^{-3})	(m^3.m^{-3})				
0%	245	0.861	0.448	0.128	0.029	0.256
15%	635	0.732	0.196	0.254	0.038	0.244
30%	863	0.659	0.180	0.209	0.043	0.227
45%	1029	0.591	0.137	0.187	0.045	0.222
60%	1255	0.513	0.123	0.122	0.045	0.223

Source: author's data.
[1]0%: cultivation substrate only; 15%: 85% of substrate + 15% rock powder; 30%: 70% of substrate + 30% rock powder; 45%: 55% of substrate + 45% of rock powder; 60%: 40% of substrate + 60% of rock powder.
[2]D: density; TP = total porosity; AS: aeration space; RAW: readily available water; BW: buffer water; RW: remaining water.

Table 2. Chemical properties of rock powder.

Substance	Formula	Concentration (%)
Silicon dioxide	SiO_2	64.41
Aluminum oxide	Al_2O_3	15.09
Iron (III) oxide	Fe_2O_3	5.62
Potassium oxide	K_2O	5.29
Sodium oxide	Na_2O	3.60
Calcium oxide	CaO	2.54
Magnesium oxide	MgO	1.80
Titanium dioxide	TiO_2	0.81
Phosphorus pentoxide	P_2O_5	0.29
Manganese monoxide	MnO	0.16
Barium oxide	BaO	010
Zirconium dioxide	ZrO_2	0.07
Chlorine	Cl	0.06

Source: author's data.

Containers were kept on benches, of 0.85 m height, in a greenhouse of 30m^2, with a semicircular roof, installed in the northwest-southeast direction. The galvanized steel structure is covered with low density polyethylene film, with anti-UV additive and 100 microns thick. Drip irrigation was used (flow rate of 2.4 L.h^{-1} per dripper) applied four times a day, with a total watering of eight minutes daily. Unlike the nutritional management that producers traditionally carry out (supplying nutrient solution once or twice a week), the nutrient solution supplied to the plants occurred biweekly according to Furlani & Fernandes Júnior (2004).

The evaluations started after the fruiting of the plants, in August (winter) of 2020. Attributes referring to the production and quality of fruits were evaluated.

2.4 FRUIT PRODUCTION

From fruiting, the total number of fruits per plant (TN, number.plant^{-1}) and the total production of fruits per plant (TP, g.plant^{-1}), harvested when 3/4 to fully ripe, were evaluated. The fruits were weighed on a digital scale. In addition, we determined the average fresh fruit mass (AFFM, g) by dividing TP by TN. The harvests took place until November 2020.

2.5 CHEMICAL QUALITY OF FRUITS

Analyses of fruit quality were carried out in November of 2020. Twenty fruits of each treatment per replication were used to characterize the content of total soluble solids (TSS, ºBrix), and total titratable acidity (TTA, % of citric acid). TSS content was determined using an analog refractometer, while TTA was performed according to the methodology used by the Instituto Adolfo Lutz (ZENEBON et al., 2008). To assess the flavor of the fruits, the TSS/TTA ratio was calculated.

2.6 STATISTICAL ANALYSIS

The data obtained were submitted to analysis of variance of regression, with the aid of the Costat® program. In addition, we used Pearson correlation analysis to assess the degree of association between dependent variables.

3 RESULTS

3.1 FRUIT PRODUCTION

The analysis of variance of the regression showed statistical differences for the linear regression model only for the TP attribute (Table 3).

Table 3. Synthesis of the analysis of variance of the regression regarding the proportions of rock powder for the fruit production.

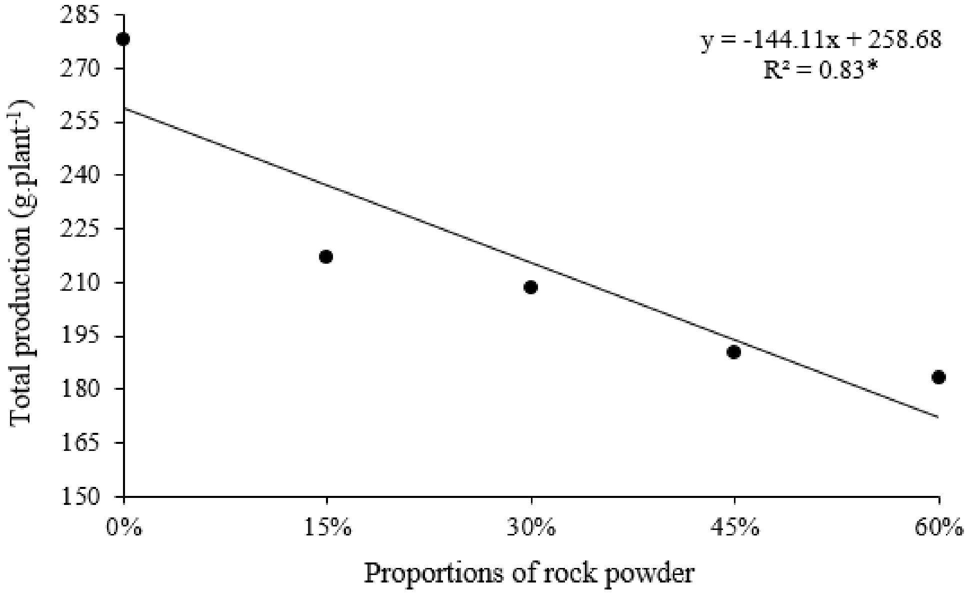
Causes of variation[1]	DF[2]	Medium square		
		TN (number.plant^{-1})[3]	TP (g.plant^{-1})	AFFM (g)
x^1	1	18.53^{ns}	17246.57*	12.35^{ns}
x^2	1	6.72^{ns}	2236.26^{ns}	0.78^{ns}
Residue	17	3.44	2689.66	6.09
Total	19			
R^2		0.30	0.83	0.11
Mean		10.54	215.45	20.22

Source: author's data.
[1]x^1: linear regression; x^2: second order polynomial regression.
[2]DF: Degrees of freedom.

[3]TN: total number of fruits; TP: total production of fruits; AFFM: average fresh fruit mass.
[ns]Not significant ($p \geq 0.05$).
*Significant at the probability level of 5% ($0.01 \leq p < 0.05$).

The regression analysis was carried out between the proportions of rock powder and TP. The determination coefficient (R^2) obtained was 0.83, indicating that TP was explained in 83% by the proportions of rock powder (Figure 1). Furthermore, it was observed that the TP decreased linearly with the increase in the proportion of rock powder added to the cultivation substrate (Figure 1).

Figure 1. Total production of strawberries ($g.plant^{-1}$) as a function of proportions of rock powder added to the cultivation substrate.



Source: author's data.
*Significant at the probability level of 5% ($0.01 \leq p < 0.05$).

3.2 CHEMICAL QUALITY OF FRUITS

We did not observe any statistical difference for the attributes of fruit quality among the treatments studied (Table 4).

Table 4. Synthesis of the analysis of variance of the regression regarding the proportions of rock powder for the fruit quality.

Causes of variation[1]	DF[2]	Medium square		
		TSS (ºBrix)[3]	TTA (%)	TSS/TTA
x^1	1	0.01[ns]	0.001[ns]	0.50[ns]
x^2	1	1.68[ns]	0.09[ns]	1.52[ns]
Residue	17	2.72	0.03	2.23
Total	19			
R^2		0.03	0.13	0.05

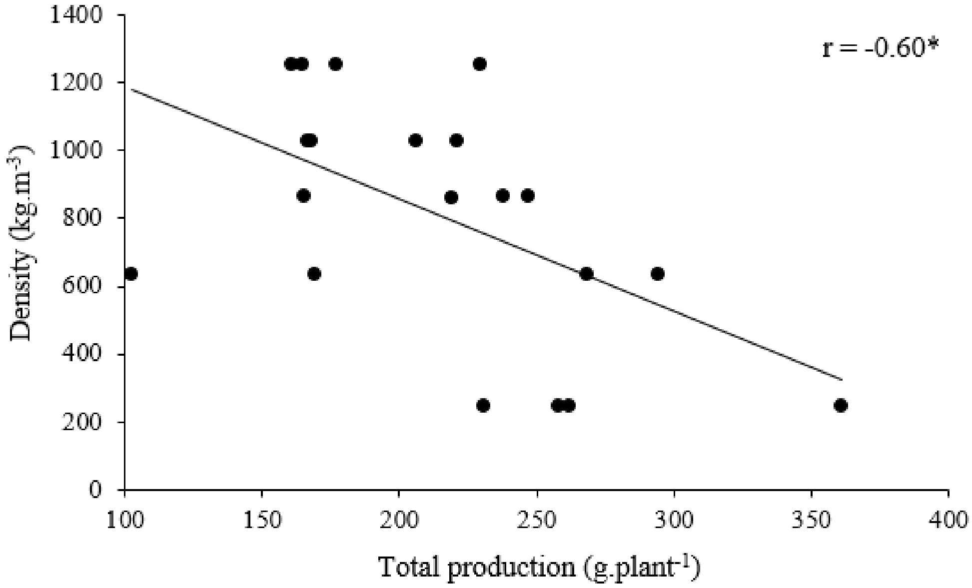
Mean	8.23	1.14	7.31

Source: author's data.
[1]x^1: linear regression; x^2: second order polynomial regression.
[2]DF: Degrees of freedom.
[3]TSS: total soluble solids; TTA: total titratable acidity; TSS/TTA: flavor of the fruits.
[ns]Not significant ($p \geq 0.05$).

3.3 CORRELATION ANALYSIS

Regarding the correlation analysis between the dependent variables, we observed that TP was negatively associated with the density of the proportions of rock powder added to the cultivation substrate (r = -0.60), that is, the increase in the density of the substrates significantly reduced the TP of strawberries (Figure 2).

Figure 2. Association between total production of strawberries (g.plant^{-1}) and density (kg.m^{-3}) of proportions of rock powder added to the cultivation substrate.



Source: author's data.
*Significant at the probability level of 5% ($0.01 \leq p < 0.05$).

4 DISCUSSION

These results are unprecedented when determining the action of rock powder on the production cycle of strawberry cultivated in substrate. When producing plants from 'Monterey' cultivar on a substrate that received the addition of different proportions of rock powder, we sought to understand whether this alternative would be viable in fruit production and quality. The cultivation for six months indicated that the proportions of rock powder added to the cultivation substrate reduced the productive potential of the strawberry and did not improve the quality of fruits.

We did not observe statistical differences regarding the quality of the fruits produced by plants grown with different proportions of rock powder (Table 4). The main attribute that has been used as an indicator of fruit quality is the content of total soluble solids (TSS). It should be noted that the sour or acid flavor of the fruit is determined by the total titratable acidity (ATT). The relationship between TSS content and TTA is the most important attribute in terms of fruit palatability, so this relationship gives the fruits a better balance between sweet and acidic and thus generates a more pleasant and attractive flavor (KROLOW & SCHWENGBER, 2007). The values of this relationship considered ideal are between 8.5 and 14 (OSC, 2006). In our study, the average value obtained for the TSS/TTA ratio was 7.31 (Table 4), indicating that the fruits produced, regardless of the proportions of rock powder used, did not have the desirable characteristics for consumption due to their greater acidity.

Contrary to what was expected, increasing proportions of rock powder added to the cultivation substrate did not benefit the production of strawberries (Figure 1). The physical evaluation of the materials used as a growth medium (Table 1) showed that the addition of rock powder to the cultivation substrate increased the density of the materials. The densities (kg.m^{-3}) were 635, 863, 1029 and 1255 for the proportions of 15%, 30%, 45% and 60% of rock powder, respectively (Table 1). By correlation analysis, we showed that strawberry production decreased significantly as the density of the substrates increased (Figure 2). Very dense substrates (> 300 kg.m^{-3}) impair the plant's radical growth by mechanical impediment (FERMINO & KÄMPF, 2012). The ideal characteristics of a substrate that enhance the development of the strawberry root system include water and nutrient retention, good aeration and light weight (WEI et al., 2020). Thus, the use of proportions greater than 15% of rock powder added to the cultivation substrate may have compromised the development of the root system of the plants, reducing the productive potential of the strawberry (Figure 1).

We emphasize that during the conduct of our research, the application of soluble nutrients via fertigation was reduced from one to two times a week for biweekly applications. This study strategy aimed to verify whether the rock powder would be able to complement the nutritional needs of the strawberry. However, as the solubility of the different minerals that make up a rock is variable and dependent on the conditions of the environment (HARLEY & GILKES, 2000) and as the strawberry culture has a relatively short cycle, requiring high amounts of nutrients in solution to obtain high productivity, the results obtained in this work showed that the rock powder was not able to supply the needs of the strawberry culture, providing less fruit quantity and quality.

Although we do not see any beneficial effect of rock powder on the horticultural performance of the strawberry (Figure 1 and Table 4), the use of this input in certain crops can offer economic advantages over mineral fertilizers that are considered to be highly soluble, being example of alternatives to importing fertilizers and the low cost of using regionalized rocks (ALMEIDA JÚNIOR et al., 2020). Still, the use of rock powder in agriculture meets the nutritional needs that must be provided for organic crops, which have restrictions on the use of synthetic fertilizers (CARVALHO, 2013).

The next studies should focus on the use of smaller proportions of rock powder mixed with the cultivation substrate (<15%) in order to enhance the horticultural performance of the strawberry. Thus, it is expected that these smaller proportions of rock powder will not drastically modify the physical characteristics of the plant growth medium. Among the most important physical properties of a substrate are density, total porosity, aeration space and water holding capacity (KÄMPF, 2000). Hardly does a material bring together all the characteristics appropriate to the needs of the plants, with frequent use of mixtures that allow obtaining the desired properties (DAMIANI & SCHUCH, 2009). In addition, it is important to ensure that the substrate used is free of elements/substance in phytotoxic concentration, phytopathogens, pests and undesirable plants (VAVRINA et al., 2002).

5 CONCLUSIONS

It is concluded that proportions of rock powder added to the cultivation substrate interfere in the productive potential of the strawberry. Increasing the proportion of this input added to the growth medium linearly reduces the total strawberry production.

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