Rock dust as a source of nutrients for upland rice crop

Pó de rocha como fonte de nutrientes para a cultura do arroz de sequeiro

El polvo de roca como fuente de nutrientes para el cultivo de arroz de secano

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ABSTRACT
Some farmers use rock dust as a cheap and efficient alternative to supply nutrients to plants. It is known that rock dust has the potential to replace chemical fertilization in organic production or it may complement chemical fertilization in other production systems. Thereby, the aim of this research was to evaluate the response of upland rice under different doses of rock dust. The experiment was carried out at Fazenda Cachoeira, Raul Soares city, Minas Gerais (MG), Brazil with an altitude corresponding to 360 m, sandy-clay soil. It was used BRSMG Caravera cultivar. Analysis of rock dust and soil before and after fertilization were performed to check nutrients levels present in them. It was used randomized blocks as the experimental design with five replications and four doses of rock dust: 1100, 1300, 1500, 1700 kg ha$^{-1}$, with an additional treatment consisting of NPK mineral fertilization without rock dust. Yield, weight of 1000 grains and the percentage of full and empty grains did not differ between treatments. Therefore, rock dust is a promising strategy to replace chemical fertilizer in rice crops providing equivalent yield to conventional fertilization with remarkable reduction of crop costs as well as the reduction of environmental impacts caused by the excessive use of chemical fertilizers.

Keywords: *Oryza sativa* L., soil fertility, rock, sustainability.

RESUMO
Alguns agricultores utilizam o pó de rocha como alternativa barata e eficiente para fornecer nutrientes às plantas. Sabe-se que o pó de rocha tem potencial para substituir a adubação química na produção orgânica ou pode complementar a adubação química em outros sistemas de produção. Com isso, objetivou-se avaliar a resposta da cultura do arroz de sequeiro sob diferentes doses do pó de rocha. O experimento foi conduzido na Fazenda Cachoeira, município de Raul Soares, Minas Gerais (MG), Brasil com altitude correspondente a 360 m, solo do tipo areno-argiloso. A cultivar utilizada foi a BRSMG Caravera. Realizou-se análise do pó de rocha, e do solo antes e depois da adubação para verificar os níveis de nutrientes presentes nos mesmos. O delineamento experimental utilizado foi em blocos casualizados, com cinco repetições e quatro doses de pó de rocha: 1100, 1300, 1500, 1700 kg/ha, com um tratamento adicional constituído por adubação mineral NPK sem pó de rocha. A produtividade, peso de 1000 grãos e a porcentagem de grãos cheios e vazios não diferiram entre os tratamentos. Portanto, o pó de rocha é uma estratégia promissora para substituir o adubo químico na cultura do arroz, proporcionando produtividade equivalente à adubação convencional com redução dos custos da cultura bem como a diminuição dos impactos ambientais causados pela utilização excessiva de adubos químicos.
Palavras-chave: Oryza sativa L., fertilidade, rochagem, sustentabilidade.

RESUMEN
Algunos agricultores utilizan el polvo de roca como alternativa barata y eficaz para suministrar nutrientes a las plantas. Se sabe que el polvo de roca tiene el potencial de reemplazar la fertilización química en la producción orgánica o puede complementar la fertilización química en otros sistemas de producción. Por ello, el objetivo de esta investigación fue evaluar la respuesta del arroz de secano bajo diferentes dosis de polvo de roca. El experimento se realizó en la Fazenda Cachoeira, ciudad de Raul Soares, Minas Gerais (MG), Brasil, con una altitud correspondiente a 360 m, suelo arenoso. Se utilizó el cultivar BRSMG Caravera. Se realizaron análisis del polvo de roca y del suelo antes y después de la fertilización para verificar los niveles de nutrientes presentes en ellos. Se utilizó como diseño experimental bloques al azar con cinco repeticiones y cuatro dosis de polvo de roca: 1100, 1300, 1500, 1700 kg ha-1, con un tratamiento adicional consistente en fertilización mineral NPK sin polvo de roca. El rendimiento, el peso de 1000 granos y el porcentaje de granos llenos y vacíos no difirieron entre tratamientos. Por lo tanto, el polvo de roca es una estrategia prometedora para sustituir a los fertilizantes químicos en los cultivos de arroz, proporcionando un rendimiento equivalente a la fertilización convencional con una notable reducción de los costes de cultivo, así como la reducción de los impactos ambientales causados por el uso excesivo de fertilizantes químicos.

Palabras clave: Oryza sativa L., fertilidad del suelo, roca, sostenibilidad.

1 INTRODUCTION

Rice is an essential food in the diet of most Brazilians and the national production approaches domestic consumption due to the technologies used as well as high productivities (CONAB, 2020). It is a crop grown in two different types of ecosystems in lowland or upland areas (Guimarães et al., 2006). Species that stands out the most in all regions of the world is Oryza sativa. Most of irrigated rice varieties belongs to the subspecies Oryza indica whereas in the tropical Japanese subspecies are those of upland rice (Fonseca et al., 2006).

It is known that a large amount of mineral fertilizers are applied to soils to obtain high productivity (Nascimento; Loureiro, 2004). The yields obtained are the answer to the efficient and fast application of conventional fertilizers. However, fertilizers used in Brazilian agriculture are derived from imported sources of NPK of high solubility and concentration. Therewith, Brazil is highly dependent on external agricultural inputs (Rodrigues, 2008; Rodrigues et al., 2010).

Weathered soils are generally deficient in nutrients and they present a high capacity for nutrient losses and immobilization due to the processes of volatilization, adsorption and leaching.
For these reasons, high doses of fertilizers are usually used above crops necessity to compensate for the expected loss that occurs in the production systems as well as to adjust the rates of nutrient recovery by the plants. Thus, studies on alternative sources of nutrients that are able to increase soil fertility, to satisfy plant needs, to reduce costs and to increase productivity without causing damage to the environment are of great importance (Martins et al., 2010).

The use of rock dust as a source of nutrients is a promising alternative and it has been successful in several crops (Theodoro; Leonardos 2006; Batista, 2013; Alovisi et al., 2017; Pádua, 2012; Castro et al., 2006, Rezende et al., 2011). According to Van Straaten (2006) rock dust may provide to plants sufficient amounts of macro and micronutrients, in addition to having favorable chemical properties to raise soils pH to adequate values and release nutrients slowly and gradually according to plants necessity. Therewith, the aim of this research was to evaluate the response of upland rice under different doses of rock dust.

2 MATERIAL AND METHODS

Experiment was carried out at Cachoeira Farm, located in the city of Raul Soares - MG, in a soil of sandy-clay texture, in the year of 2016. Raul Soares is at a latitude of 19º 58 '26" S, longitude 42º 27 '46" W and 360 meters of altitude. BRSMG Caravera was the cultivar used which presents a high quality of grains, good productivity and it is adapted to the climatic conditions of Minas Gerais State (Soares et al., 2008). Crop irrigation was implemented according to crop requirements.

Rock dust mixture used in the experiment came from igneous rock (granite) and metamorphic rock (gneiss), in the proportion of 1: 1. That material was collected in the city of Manhuaçu - MG and it constitutes waste from the extraction of stones with a granulometry of less than 3 mm.

Sampling of soil and rock dust were carried out and subsequently subjected to chemical analysis to determine soil fertility and material composition (Table 1 e 2).
Table 1. Chemical characteristics of soil and rock dust used in the experiment.

<table>
<thead>
<tr>
<th>Depth</th>
<th>pH</th>
<th>P</th>
<th>K</th>
<th>B</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Zn</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>0 - 20</td>
<td>6.26</td>
<td>6.27</td>
<td>117.4</td>
<td>0.27</td>
<td>120.51</td>
<td>2.18</td>
<td>9.16</td>
<td>7.37</td>
</tr>
<tr>
<td>Rock dust</td>
<td>0 - 20</td>
<td>7</td>
<td>100.7</td>
<td>124</td>
<td>0.17</td>
<td>634</td>
<td>1.6</td>
<td>90.4</td>
<td>7.4</td>
</tr>
</tbody>
</table>

pH in water, P; K; Fe; Cu; Mn and Zn – Mehlich-1 extractor Ca; Mg; Al – KCl-mol/L extractor, H+Al – SMP, S – acetic acid mono-calcium extractor, B – hot water extractor.
Source: Labsolo Laboratory, Manhuaçu, MG.

Table 2. Chemical characteristics of soil and rock dust used in the experiment.

<table>
<thead>
<tr>
<th>Al</th>
<th>Ca</th>
<th>Mg</th>
<th>H+Al</th>
<th>CTC</th>
<th>V</th>
<th>MO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cmol₂.dm⁻¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>3.88</td>
<td>1.51</td>
<td>2.1</td>
<td>7.94</td>
<td>73.55</td>
<td>3.96</td>
</tr>
<tr>
<td>Rock dust</td>
<td>1.53</td>
<td>1.92</td>
<td>1.3</td>
<td>5.07</td>
<td>74.4</td>
<td>0.71</td>
</tr>
</tbody>
</table>

pH in water, P; K; Fe; Cu; Mn and Zn – Mehlich-1 extractor Ca; Mg; Al – KCl-mol/L extractor, H+Al – SMP, S – acetic acid mono-calcium extractor.
Source: Labsolo Laboratory, Manhuaçu, MG.

Randomized block was used as experimental design with four doses of rock dust (1100, 1300, 1500 and 1700 kg ha⁻¹) plus a control with NPK mineral fertilization. Rock dust was applied in a planting furrow in a single dose 20 days before sowing. Conventional fertilization was applied with 55 kg. ha⁻¹ of N; 75 kg. ha⁻¹ P₂O₅ and 20 kg. ha⁻¹ of K₂O in the control treatment according to the recommendation for the crop (Paula et al., 1999). Nitrogen fertilization was performed in two applications: the first one at the time of planting and the second one 30 days after planting. Each experimental plot consisted of five rows spaced 0.40 m apart with three meters in length and density of 70 seeds per linear meter. Useful area of each plot corresponded to the three central lines, 0.5 m from each end of the lines being discarded. Management of irrigation, weeds, pests and diseases were carried out according to crop requirements.

At harvest time, grain yield, percentage of full grains, weight of 1000 grains and number of panicles per square meter were evaluated. Data obtained were subjected to analysis of variance and the means compared by Dunnet test at level of 5% probability.

3 RESULTS AND DISCUSSION

According to the soil analysis it is observed that there was an impoverishment of the soil in terms of P levels (Table 3 e 4).
Table 3. Soil chemical analysis at the end of the experiment.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Depth</th>
<th>pH</th>
<th>P</th>
<th>K</th>
<th>B</th>
<th>Fe</th>
<th>Cu (mg dm⁻³)</th>
<th>Mn</th>
<th>Zn</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100 Kg</td>
<td>0–20</td>
<td>5.9</td>
<td>3.9</td>
<td>40</td>
<td>0.26</td>
<td>17.2</td>
<td>0.7</td>
<td>70</td>
<td>4.8</td>
<td>3.43</td>
</tr>
<tr>
<td>1300 Kg</td>
<td>0–20</td>
<td>6</td>
<td>6.3</td>
<td>47</td>
<td>0.19</td>
<td>17.7</td>
<td>0.6</td>
<td>80.3</td>
<td>5.9</td>
<td>3.43</td>
</tr>
<tr>
<td>1500 Kg</td>
<td>0–20</td>
<td>6.1</td>
<td>8.9</td>
<td>63</td>
<td>0.28</td>
<td>19.8</td>
<td>0.7</td>
<td>69.5</td>
<td>7.13</td>
<td>3.76</td>
</tr>
<tr>
<td>1700 Kg</td>
<td>0–20</td>
<td>6.1</td>
<td>6.5</td>
<td>49</td>
<td>0.19</td>
<td>24.7</td>
<td>1</td>
<td>61.5</td>
<td>5.1</td>
<td>3.65</td>
</tr>
<tr>
<td>Cont.NPK</td>
<td>0–20</td>
<td>6.1</td>
<td>11.8</td>
<td>84</td>
<td>0.29</td>
<td>35</td>
<td>1</td>
<td>111.2</td>
<td>9</td>
<td>3.43</td>
</tr>
</tbody>
</table>

Source: Authors (2017)

Table 4. Soil chemical analysis at the end of the experiment.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Al (cmol₂ dm⁻³)</th>
<th>Ca</th>
<th>Mg</th>
<th>H⁺Al</th>
<th>CTC</th>
<th>V</th>
<th>MO (dag kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100 Kg</td>
<td>0</td>
<td>1.92</td>
<td>0.64</td>
<td>2.2</td>
<td>4.86</td>
<td>54.7</td>
<td>1.88</td>
</tr>
<tr>
<td>1300 Kg</td>
<td>0</td>
<td>2.17</td>
<td>0.72</td>
<td>2.1</td>
<td>5.1</td>
<td>58.9</td>
<td>2.32</td>
</tr>
<tr>
<td>1500 Kg</td>
<td>0</td>
<td>1.75</td>
<td>0.71</td>
<td>2.1</td>
<td>4.72</td>
<td>55.5</td>
<td>2.45</td>
</tr>
<tr>
<td>1700 Kg</td>
<td>0</td>
<td>1.48</td>
<td>0.56</td>
<td>2.3</td>
<td>4.47</td>
<td>48.5</td>
<td>1.72</td>
</tr>
<tr>
<td>Cont.NPK</td>
<td>0</td>
<td>2.17</td>
<td>0.53</td>
<td>2.1</td>
<td>5.31</td>
<td>60.5</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Source: Authors (2017)

There were no significant differences in rice yield among treatments (Figure 1).

Figure 1. Productivity of rice plants in response to the application of rock dust and mineral fertilizer (NPK). Averages followed by the same letter do not differ by Dunnet test at 5% probability level.

Produtividade Kg/ha
There was no significant difference in the percentage of full grains and number of panicles. m² with treatments application (Table 5).

Table 5. Percentage of full grains and number of panicles per square meter of rice in response to the application of rock dust and mineral NPK.

<table>
<thead>
<tr>
<th>Mineral Source (kg ha⁻¹)</th>
<th>Full grains (%)</th>
<th>Number of panicles. m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100</td>
<td>84.6 ± 3.87</td>
<td>326.2 ± 7.46</td>
</tr>
<tr>
<td>1200</td>
<td>83.0 ± 4.56</td>
<td>354 ± 26.06</td>
</tr>
<tr>
<td>1500</td>
<td>74.0 ± 7.23</td>
<td>398.2 ± 25.18</td>
</tr>
<tr>
<td>1700</td>
<td>86.0 ± 4.18</td>
<td>346 ± 13.04</td>
</tr>
<tr>
<td>Cont. NPK</td>
<td>83.25 ± 6.48</td>
<td>365 ± 21.04</td>
</tr>
</tbody>
</table>

Source: Authors (2017)

According to CONAB (2018) in the harvest years 2016/2017 average rice productivity in Minas Gerais was 2.534 t ha⁻¹ and upland rice productivity was 1.563 t ha⁻¹. Productivity with the use of rock dust was higher than the State average in upland areas as adopted in the experiment. It is observed that the use of rock dust was sufficient to guarantee similar productivity to mineral fertilization.

Theodoro et al. (2006) studied the nutritional efficiency of rock dust in relation to conventional fertilization in sugarcane, cassava, corn and rice crops, where they were able to observe that productivity was equivalent to or higher than the plots in which conventional fertilization was used, something around 40% higher. According to these authors, long-cycle crops such as sugar cane and cassava present better productive performance with the application of rock dust since the release of nutrients present in rock dust is slow. For short-cycle crops such as rice and corn, there is a similar performance or slightly superior to conventional fertilization; thus, from a productive point of view the results show the efficiency of rock dust in agriculture which may be a possible replacement for conventional fertilization (Theodoro et al. 2006). It is evident from the work presented earlier that the benefits of rock dust will be seen in subsequent harvests.

Barbosa Filho et al. (2006) observed that productivity of upland rice was significantly influenced by the addition of rock sources as a substitute for commercial KCl and also that rock material influences the crops response to the replacement of commercial fertilizer. The use of rock dust occurs in a complementary way to mineral fertilization or it substitutes conventional fertilization resulting in equivalent productivities as found in this research and in other experiments (Barbosa Filho et al., 2006; Rezende et al., 2011; Brito et al., 2019).
Effects of rock dust on soil fertility and the availability of nutrients for plants must be evaluated for a long period unlike conventional fertilization that provides nutrients quickly. In short-cycle crops, rock dust may show a better performance from the second harvest due to possible residual effect on the soil. Thus, it is suggested that studies on rock dust should also be evaluated in the medium to long term (Pádua, 2012).

Rock dust may reduce the cost of production specially because it is usually considered waste (Bertoldo et al., 2015). In addition, it is an environmentally friendly technique for using materials considered waste and for balancing the use of synthetic products (Theodoro et al., 2006) as well as an accepted technique in organic agriculture (Lapido-Loureiro; Nascimento, 2009). Moreover, it is expected that there will be a consolidation of this technique in agriculture because besides being an economically and ecologically viable alternative it also reduces the dependence on external inputs.

4 CONCLUSION

Rock dust being used in upland rice crop nutrition provided productivity equivalent to conventional chemical fertilization in different doses of the mineral fertilizer. Additional studies are needed to confirm benefits of using rock dust in the long term as the release of nutrients with this technique is slow.

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