Phosphate fertilization in sequeiro rice cropping

Adubação fosfatada na cultura do arroz de sequeiro

Fertilización fosfatada en el cultivo de arroz de secano

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ABSTRACT
Rice farming has great importance in Brazil and around the world as the grain is a vital source of carbohydrates, proteins, vitamins and minerals. With an increasing productive demand, there is need to search for sustainable and more efficient means of production. A promising alternative is fertilization with organomineral fertilizers, however, its application and efficiency is little explored by the literature. The objective of the study was to evaluate the effect of varying doses of phosphorus (P) from organomineral fertilizer on the productivity and nutritional status of rice plants. The design was completely randomized with 3 replications. The rice plants were treated with doses of 0, 75, 150 and 225 kg/ha of P$_2$O$_5$ from organic-mineral fertilizer and doses of 75 and 150 kg/ha of P$_2$O$_5$ from high solubility mineral fertilizer. The macro and micronutrient contents of fresh grain mass, total dry grain mass, dry grain mass and mass of 100 grains of rice were evaluated. The organomineral phosphate fertilizer showed similar behaviour to the high-solubility mineral fertilizer.

Keywords: agriculture, Oryza sativa L., soil fertility, sustainability, rice cultivation.

RESUMO
A cultura do arroz tem grande importância no Brasil e no mundo, pois o grão é uma fonte vital de carboidratos, proteínas, vitaminas e minerais. Com o aumento da demanda produtiva, há necessidade de busca por meios de produção sustentáveis e mais eficientes. Uma alternativa promissora é a adubação com fertilizantes organominerais, porém sua aplicação e eficiência são pouco exploradas pela literatura. O objetivo do estudo foi avaliar o efeito de diferentes doses de fósforo (P) proveniente de fertilizante organomineral sobre a produtividade e o estado nutricional de plantas de arroz. O delineamento foi inteiramente casualizado com 3 repetições. As plantas de arroz foram tratadas com doses de 0, 75, 150 e 225 kg/ha de P$_2$O$_5$ proveniente de fertilizante orgânico-mineral e doses de 75 e 150 kg/ha de P$_2$O$_5$ proveniente de fertilizante mineral de alta solubilidade. Foram avaliados os teores de macro e micronutrientes da massa fresca de grãos, massa seca total de grãos, massa seca de grãos e massa de 100 grãos de arroz. O fertilizante fosfatado organomineral apresentou comportamento semelhante ao fertilizante mineral de alta solubilidade.

Palavras-chave: agricultura, Oryza sativa L., fertilidade do solo, sustentabilidade, cultivo de arroz.
RESUMEN
El cultivo de arroz es de gran importancia en Brasil y en todo el mundo, ya que el grano es una fuente vital de carbohidratos, proteínas, vitaminas y minerales. Con el aumento de la demanda de producción, es necesario buscar medios de producción sostenibles y más eficientes. Una alternativa prometedora es la fertilización con abonos organominerales, pero su aplicación y eficacia están poco estudiadas en la bibliografía. El objetivo del estudio era evaluar el efecto de distintas dosis de fósforo (P) procedente de fertilizantes organominerales sobre la productividad y el estado nutricional de las plantas de arroz. El diseño fue totalmente aleatorizado con 3 repeticiones. Las plantas de arroz se trataron con dosis de 0, 75, 150 y 225 kg/ha de P2O5 procedente de abono orgánico-mineral y dosis de 75 y 150 kg/ha de P2O5 procedente de abono mineral de alta solubilidad. Se evaluó el contenido en macro y micronutrientes de la masa fresca de los granos, la masa seca total de los granos, la masa seca de los granos y la masa de 100 granos de arroz. El rendimiento del abono organomineral fosfatado fue similar al del abono mineral de alta solubilidad.

Palabras clave: agricultura, Oryza sativa L., fertilidad del suelo, sostenibilidad, cultivo de arroz.

1 INTRODUCTION

The cultivation of rice (Oryza sativa L.) plays a crucial role in the global agricultural scenario, being the second most cultivated cereal and serving as food for billions of people. It is expected that by 2030, its production will increase by 58 million tons (Mt), totaling 567 Mt (OECD/FAO, 2021). In Brazil, the trend is for a decrease in the cultivated area and an increase in productivity to meet growing internal demand (Oliveira Neto et al., 2015).

With the constant need to increase production, there is a search for new alternatives that can contribute and at the same time mitigate some impacts caused by the production system. Constructed fertility is a growing and relevant trend that proposes conditioning the soil over time, in addition to measures to improve the physical and biological attributes of the soil, increasing its use and reducing the need for fertilization (De Resende et al., 2016). Therefore, the possibility of using slower-release fertilizers, together with animal residues that will contribute to the soil microbiota, becomes interesting.

Annually, 105 million tons of pig manure and around 8 million tons of poultry litter are produced in Brazil (Corrêa et al., 2011). Although animal residues are an important source of nutrients for plants, their application to the soil faces limitations, the ratio between Carbon and Nitrogen (C/N), if low, the amount of C is insufficient for the conversion of N to occur. in cellular material, on the other hand, if the ratio is high, a nitrogen deficiency may occur due to its
consumption by microorganisms (Brietzke, 2017). Therefore, the use of agricultural residues for the production of organomineral fertilizers, which are subsequently applied as soil fertility correctors, presents an excellent alternative (Garcia et al., 2022).

Organomineral fertilizers contain a wide range of macronutrients and micronutrients essential for plant growth. In addition, organomineral fertilizers improve the structure, moisture retention and the ability of soil to slowly release nutrients over time (Smith et al., 2020).

Although, findings from several research suggest that the application of organomineral fertilizers in rice cultivation results in positive yields and improved grain quality, Positive results with organomineral fertilization in rice have already been obtained, improving the quality of grains and the plant and the use of residues, however, these studies were research focused in on flooded irrigated rice (Egbuchua & Enujeke, 2013). Given the lack of precise academic information related to the knowledge gap in the area of organomineral fertilization in upland rice cultivation, and the growing interest in the use of alternative fertilizers in rice farming, the experiment becomes crucial to identify possible interactions related to phosphate fertilization in the vegetable cereal.

The practice of organomineral fertilization in crop cultivation is incipient but promising. relatively recent in the agricultural market, however it shows quite promising, when carrying out a comparison between an organomineral and inorganic fertilizer, it was observed that the organomineral fertilizer presented a significant reduction in the losses of Phosphorus and Nitrogen due to eutrophication (Tejada et al., 2005). Organomineral fertilizers when applied in large quantities can have adverse effects on the soil biota and the environment, and thus must be applied within permissible limits. However, there is still no literature with recommendations on the permissible limits for the application of organomineral fertilizers on crops. Therefore, this study becomes necessary in order to fill the lacunae in the work has great applicability for rainfed rice producers in Brazil and around the world and for everyone interested in this type of fertilization. The objective of the study was to evaluate the effect of varying doses of phosphorus in organomineral fertilizer on the productivity and nutritional status of rice grains.
2 MATERIAL AND METHODS

The experiment was carried out in the greenhouse at the Educational Teaching, Research and Extension Unit – Airport (20° 45’ 17” S, 42° 52’ 57” W; altitude 663 m) of the Federal University of Viçosa from November 2022 to May 2023. The climate, according to Köppen-Geiger, is classified as Cwa, high-altitude tropical with hot, rainy summers and cold, dry winters.

Rice cultivar BRS-Esmeralda was sown in 45 dm³ pots, containing clayey soil, which has chemical characteristics shown in Table 1.

<table>
<thead>
<tr>
<th>pH</th>
<th>P kg/ha</th>
<th>K</th>
<th>Ca cmol/dm³</th>
<th>Mg cmol/dm³</th>
<th>Al</th>
<th>H+Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.71</td>
<td>2</td>
<td>68</td>
<td>1.08</td>
<td>0.25</td>
<td>0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SB</th>
<th>t</th>
<th>V</th>
<th>m</th>
<th>MO</th>
<th>Prem</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>3</td>
<td>50</td>
<td>0</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Table 1 - Chemical characterization of the soil before carrying out the experiment

The experimental design was completely randomized, with 3 replications per treatment in which each replication was represented by a pot consisting of two rice plants. The treatments consisted of the application of increasing doses of P (0, 75, 150 and 225) kg/ha in the form of P₂O₅ contained in the organomineral fertilizer and doses of 75 and 150 kg/ha in the form of P₂O₅ contained in the highly soluble mineral fertilizer, Super Simples. The doses of P were applied in full dose at the time of rice sowing. Also, during planting, doses of N were applied as ammonium sulfate (12 kg/ha of N) and K as of KCl (45 kg/ha of K₂O), according to the expected productivity for the cultivar and soil analysis (Ribeiro et al., 1999). Top dressing consisted of the application of N as ammonium sulfate (48 kg/ha of N) in the full tillering and flowering phase. Micronutrients were supplied via foliar spraying during the tillering phase.

At the end of the experiment (170 days after planting – DAP), the nutritional contents of N, P, K, Ca, Mg, Mn, Zn and Cu in grains were evaluated according to the methodology described by Malavolta (1997), for plant tissue. Fresh mass of grains, dry mass of grains, mass of 100 grains and mass of hatched grains were also evaluated.
The data obtained for increasing doses of P of the organomineral fertilizer, were subjected to analysis of variance and regression analysis. The models were chosen based on the significance of betas, biological sense and correlation coefficient. To compare organomineral and mineral fertilizers, the means of treatments that received a dose of 75 kg/ha of both fertilizers and the control treatment (without phosphorus) were compared using the Tukey test at a 5% probability level.

3 RESULTS AND DISCUSSION

3.1 ORGANOMINERAL FERTILIZER

The mass of total fresh matter, dry mass of grains, dry mass of hatched grains and mass of 100 grains with means 37.47, 36.45, 32.42 and 2.48, respectively did not vary with the doses of phosphorus in organomineral fertilizer (Figure 2).

![Figure 1 - Total fresh matter mass (MFT), dry mass of grains (MSG), dry mass of hatched grains (MSGc) and mass of 100 grains (M100) of rice in response to increasing doses of P, via organomineral fertilizer.](image)

Phosphorus is an essential element for plant growth and is found in every living plant cell. It is involved in numerous plant functions such as energy transfer involving ATP, ADP, and NADP molecules, essential for photosynthesis, sugar metabolism, assimilation of CO₂ in the...
Calvin Cycle, being important in plant metabolism and nutrient movement within plant. Furthermore, phosphorus is part of the composition of DNA and RNA, and plays an important role in the translation transfer of genetic information (Marschner et al., 1996).

Similar experiments with organomineral phosphate sources in rice (Egbuchua & Enujeke, 2013) and other crops such as corn (Loiola et al., 2020), soybeans (Almeida Júnior et al., 2021) and sugar cane (Borges et al., 2019) obtained yields like mineral fertilization, demonstrating organomineral as a viable alternative to replace or complement the mineral source. Therefore, this result shows the importance of future long-term studies with more cycles, considering that organomineral fertilizer has a slower release of phosphorus into the soil, which can generate better results in successions.

The P content did not vary with the doses of P applied through organomineral fertilizer and the general average was 0.17g/kg. The K and Mg contents showed quadratic behavior and the doses that guaranteed the highest levels were 182.3 and 117.1 kg/ha of P2O5, respectively. On the other hand, N showed a decreasing quadratic behavior and the minimum point was at a dose of 128.5 kg/ha of P2O5. Ca levels increased linearly with increasing P2O5 doses (Figure 2).

Figure 2 - N, P, K and Ca contents in response to doses of P applied via organomineral fertilizer.

Phosphorus plays an important role in root development (Guimarães, Fageria and Barbosa Filho, 2002) and its deficiency results in less absorption of all other mineral elements. Phosphorus is a structural constituent of important molecules related to the energy metabolism...
of plants, such as ATP, and in the case of a lack of P, there is a reduction in the size of leaves, the formation of a greater quantity of flat grains, small plants and consequently low productivity. As P is an essential element for plant growth, the constant behaviour with increasing doses of P is certainly related to the dilution effect of the element concentration.

Plants that received higher doses grew more and the absorbed nutrient was diluted in a larger aerial part of dry matter. The same effect was probably observed for N, which increased levels after reaching a minimum point. The soil analysis presented in Table 1 reinforces the argument of the effect of dilution and concentration, as the P levels were considered low according to the official fertilizer recommendation table of the state of Minas Gerais.

The rice plant demonstrates great affinity with the NO$_3^-$ molecule due to its gene expression and is directly related to the joint activity of H$^+$ pumps and NO$_3^-$ transporters (Sperandio, 2011). In aerated soils with high O$_2$ activity and pH close to 6, as is the case in the experiment, the activity of nitrifying bacteria is favoured (Buapet et al., 2008).

The soil used presented satisfactory pH values of 5.7, an ideal range for most crops, including rice (Sobral et al., 2015), and a very low Al$^{3+}$ content, which enabled good absorption of the nutrient by the plant, which in very weathered soils with low pH tend to be leached (Pavinato and Rosolem, 2008).

The ability of Mg to be absorbed by the plant is influenced not only by its concentration but also by its relationship with other cations, such as Ca and K. In the case of the experiment, the Ca:Mg ratio is 4:1, considered ideal for crops in general (Pavinato and Rosolem, 2008).

For all micronutrients evaluated, the levels showed a decreasing quadratic behavior and the doses that guaranteed the minimum levels are 108.5, 127, 116.3 and 101 kg/ha of P$_2$O$_5$ for Fe, Zn, Mn and Cu, respectively (Figure 3).
Cu deficiency is often associated with flooded soils with high levels of soil organic matter (SOM), as highly stable Cu chelates are formed with SOM (Pavinato and Rosolem, 2008). Mn deficiency usually occurs in situations involving flooded soil or very alkaline conditions (Pavinato and Rosolem, 2008). As the experiment was carried out in aerated soil with a pH tending to neutrality, Mn moved efficiently to the grains. The lower values can be explained by the neutral pH of the soil used for planting, 5.7. Zn, being a cationic nutrient, has reduced availability in neutral and alkaline soils (Pavinato and Rosolem, 2008).

The mass of 100 grains of rice of the treatment that received simple superphosphate was significantly different to the control and the treatment that received P through organomineral fertilizer. The fresh mass, total dry mass and mass of hatched grains of rice in the control set-up differed significantly from the treatment that received P in the form of simple superphosphate, but they did not differ significantly from the treatment that received P through organomineral fertilizer (Table 2).
Table 2 – Fresh mass, total dry mass, mass of hatched grains and mass of 100 grains of rice harvested from plants that received P via organomineral and mineral fertilizer at a dose of 75 kg/ha of P₂O₅.

<table>
<thead>
<tr>
<th></th>
<th>Fresh mass</th>
<th>Total dry mass</th>
<th>Dry pasta made from grains</th>
<th>100 grains rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>29.92 b</td>
<td>29.22 b</td>
<td>26.13 b</td>
<td>2.46 b</td>
</tr>
<tr>
<td>Simple superphosphate</td>
<td>52.97 a</td>
<td>51.77 a</td>
<td>45.97 a</td>
<td>2.60 a</td>
</tr>
<tr>
<td>Organomineral</td>
<td>39.85 ab</td>
<td>39.09 ab</td>
<td>34.72 ab</td>
<td>2.46 b</td>
</tr>
</tbody>
</table>

CV (%) 25.03 25.05 24.98 3.52

Means with the same superscripts in the column do not differ from each other using the Tukey test at a 5% probability level.

Source: Authors (2023)

P contents did not differ significantly between treatments. The N contents were statistically higher in the control treatment without the application of P. Probably, the dilution and concentration effect were observed for the P and N contents.

Only Ca levels did not vary between treatments. For the organomineral fertilizer, lower levels were observed than the treatment with high solubility fertilizer for the contents of Fe, Zn, Mn and Cu, all micronutrients, which possibly suffered a complexation effect by the organic matter component of the organomineral fertilizer. The K content was statistically higher in the treatment with organomineral fertilizer; however, it did not differ significantly from the treatment with simple superphosphate (Table 3).

Table 3 – Macro and micronutrient contents in rice grains that received P via organomineral (Org) and mineral (SS) fertilizers at a dose of 75 kg/ha of P₂O₅.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Fe</th>
<th>Zn</th>
<th>Mn</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.9 a</td>
<td>0.248 a</td>
<td>2.47 b</td>
<td>5.56 a</td>
<td>0.254 b</td>
<td>0.187  b</td>
<td>0.137 a</td>
<td>0.197 a</td>
<td>0.043 a</td>
</tr>
<tr>
<td>SS</td>
<td>1.3b</td>
<td>0.164 a</td>
<td>2.54 ab</td>
<td>6.22 a</td>
<td>0.225 b</td>
<td>0.198 a</td>
<td>0.095 b</td>
<td>0.177 ab</td>
<td>0.040 ab</td>
</tr>
<tr>
<td>Org</td>
<td>1.3b</td>
<td>0.131 a</td>
<td>2.82 a</td>
<td>5.91 a</td>
<td>0.328 a</td>
<td>0.145 b</td>
<td>0.095 b</td>
<td>0.152 b</td>
<td>0.032 b</td>
</tr>
</tbody>
</table>

CV (%) 22.46 35 7.98 12.35 15.06 18.5 10.25 14.93 19.92

Means with the same superscripts in the column do not differ from each other using the Tukey test at a 5% probability level.

Source: Authors (2023)

4 CONCLUSION

The organomineral phosphate fertilizer showed similar behaviour to the high-solubility mineral fertilizer. Although no increases were observed with increasing doses of phosphorus through the application of organomineral, in the growth and productivity components of rice plants, such fertilizer has a significant effect on the nutritional status of the grains.
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