

Article title	Characterization and Greenhouse Evaluation of Brazilian Calcined Nonapatite Phosphate Rocks for Rice
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Abstract	<p>Little information is available on the agronomic effectiveness of calcined nonapatite phosphate rock (PR) sources containing crandallite minerals in the form of Ca–Fe–Al–P for flooded and upland rice (<i>Oryza sativa</i> L.). We conducted laboratory and greenhouse studies to (i) characterize the mineralogical composition, (ii) investigate the solubility and dissolution behavior, and (iii) evaluate the agronomic effectiveness of two nonapatite PR sources (Juquia and Sapucaia) from Brazil and compared them with (i) a highly reactive Gafsa PR (Tunisia) containing apatite in the form of Ca–P and (ii) a reference water-soluble triple superphosphate (TSP) for flooded and upland rice. After calcination at 500°C for 4 h, the solubility of Juquia PR and Sapucaia PR in neutral ammonium citrate (NAC) significantly increased from almost nil to a maximum of 39.3 and 114 g P kg⁻¹, respectively. X-ray diffraction showed that crystalline crandallite mineral was transformed to an amorphous form after calcination. The solubility behavior of the two calcined PR sources followed the same trend as Gafsa PR, that is, P release decreased with increasing equilibrium pH in the 0.01 M KCl solution (pH 3.0–8.0). At pH 3, the solubility followed: Gafsa PR > calcined Sapucaia PR > calcined Juquia PR. No P release was detected from any of the PR sources at pH ≥ 5.0 in the solution, indicating the Ca–P characteristic of the Ca–Fe–Al–P mineral controlled P dissolution of the calcined PR. Without calcination, both Juquia PR and Sapucaia PR were totally ineffective for upland rice grown on a Hiwassee clay loam (fine, kaolinitic, thermic Rhodic Kanhapludult) with pH 5.4 whereas a significant P response was observed with the calcined PR samples. For flooded rice grown on Hiwassee soil, the calcined Juquia PR and Sapucaia PR were 66 and 72%, respectively, as effective as TSP in increasing rice grain yield whereas Gafsa PR was ineffective. For upland rice grown on the unlimed soil, Gafsa PR was as effective as TSP in increasing rice grain yield whereas calcined Juquia PR and Sapucaia PR were 89 and 83% of TSP. The effectiveness of Gafsa PR was reduced to 0% after the soil was limed to pH 7.0 whereas the two calcined PR sources were reduced to 49% of TSP. Soil available P extracted by iron oxide impregnated filter paper (Pi test) or anion-exchange resin after rice harvest correlated well with P uptake by rice grain for flooded and upland rice.</p>
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