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Assessing phosphorus availability to paddy rice: soil testing and plant responses

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The optimization of P fertilization in paddy rice fields requires an accurate estimation of soil P availability to balance rice productivity and ecosystem preservation. While there are several generally accepted methods to evaluate P availability to crops grown in aerobic soils, the available P pool in paddy soils cannot be so easily assessed. Phosphorus cycle in paddy soils is closely linked to Fe redox wheel and conditioned by the complex interactions between soil characteristics and plant strategies to promote P uptake. The aim of this study was the identification of the method that best estimates P availability for rice plants while taking into account the complex interactions between soil (bio)geochemistry and plant responses.

Twelve representative paddy soils have been selected and analyzed for available P with different methods (calcium chloride, Olsen, Mehlich-3, anion exchanging resins, EDTA, citrate/ascorbate and oxalate). In the same soils, rice plants were grown for 60 days; during this period temporal variation of soluble P and Fe(II) in the soil solution was monitored. The plants were then harvested and the roots and shoots biomass, the P content in plant tissues, the expression of the root phosphate transporter encoding genes and the root activity of phytase and phosphatase were determined.

During the growing period, the soluble P concentration in the soil solution increased during the first 3-4 weeks, following the same trend of Fe(II), then it decreased, probably due to plant uptake and P-Fe co-precipitation. Both biomass and P concentration in the tissues were affected by soil P content. The extraction with resins was the best predictor for plant productivity and P uptake, followed by $CaCl_2$ and Olsen extraction. The extractants involving the partial dissolution of the sorbing minerals (i.e., oxalate and citrate/ascorbate) showed a poorer, although still significant correlation with P concentration in rice plants, but a higher performance in terms of organic P. Phosphatase activity was greater than phytase in all cases; the former did not significantly differ among soils, while the latter was higher in those soils releasing more P in solution during the growing period and was correlated with P concentration in plants. In low P soils a higher expression of root transporter encoding genes was observed, particularly those at high-affinity.

Although resins, $CaCl_2$ and Olsen extractions are confirmed as useful tools for the prediction of P availability even for paddy rice cultivation, in P-deficient soils the enhancement of enzymatic activity and the overexpression of root P-transporters increased the capacity of plant P uptake

above the prediction of the chemical extractants.