Increase of rice yield in response to phosphorus fertilizer application can be predicted by soil phosphorus retention capacity

Phosphorus (P) fertilizer application is essential for increasing crop productivity in tropical agroecosystems in sub-Saharan Africa (SSA), where P-deficient weathered soils are dominant. Farmers in SSA generally have limited capacity to purchase expensive chemical fertilizers. Therefore, P fertilizer should be efficiently applied to croplands with high response to P fertilizer application based on soil diagnosis. Soils have the capacity to fix soluble P (P retention capacity). It causes the immobilization of applied P soon after fertilizer application and decreases P availability for crops. However, there is little quantitative information on the relationship between soil P retention capacity and crop response to P fertilizer application in P-deficient soils in SSA. In this study, we clarified the relationship between soil P retention capacity and rice yield when P fertilizer was applied in the central highlands of Madagascar. Furthermore, soil physicochemical properties were investigated to verify whether our finding can be applied to other regions in SSA.

Multi-site field trials were conducted to evaluate the response of rice yield to the application of P fertilizer (ΔYield) at farmers' P-deficient paddy fields in two communes (A and B) in the central highlands of Madagascar. The ΔYield ranged from −0.4 to 2.1 t ha^{-1} among the fields and it was better predicted by soil P retention capacity than by soil available P content of the fields (Fig. 1). The ΔYield decreased with increasing soil P retention capacity. There was no response of rice yield to P fertilizer application when soil P retention capacity was higher than 35% in Commune A with mean temperature of 22.2°C during the cultivation period. On the other hand, the increase in rice yield by P fertilizer application was not observed when soil P retention capacity exceeded 53% in Commune B with mean temperature of 20.8°C. Multiple regression analysis revealed that active aluminum (oxalate-extractable Al, Alox) content was the most important factor of soil P retention across all the soils collected from 213 paddy fields in the central highlands of Madagascar (Table 1). This indicates that rice plants grown on soils with higher Alox and P retention capacity are less sensitive to P fertilizer application.

We found that the increase in rice yield in response to P fertilizer application can be predicted by soil P retention capacity. Our finding can help farmers facing P deficiency to identify the most responsive fields to P fertilizer prior to its application and, thus, to utilize efficiently a limited amount of P fertilizer in their fields. Since soils with Alox and low available P content are often seen in SSA, our finding is applicable to wide regions in SSA other than Madagascar. Further study should verify its applicability on different crops.

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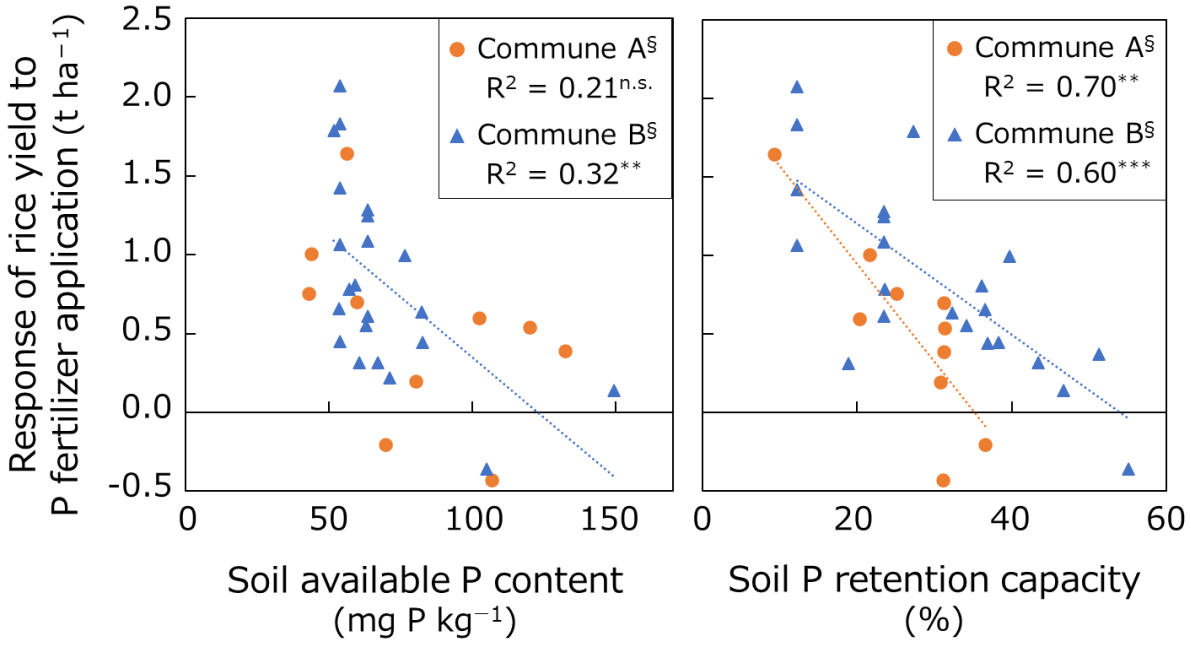

Fig. 1. Relationship between response of rice yield to P fertilizer application and soil available P content and soil P retention capacity

Yield increase in response to P fertilizer application was calculated by the difference between the rice yields of N fertilizer plot and N+P fertilizer plot in the field trials. N fertilizer was applied at 80 kg N ha^{-1} as urea, while P fertilizer was applied at 50 kg P ha^{-1} as triple super phosphate. Soil available P content was determined by acid ammonium oxalate extraction method. §Mean temperature during the cropping period was 22.2℃ and 20.8℃ at Communes A and B, respectively. ***$p < 0.001$, **$p < 0.01$, n.s. $p > 0.1$.

Table 1. Standard partial regression coefficients for soil P retention capacity and soil physicochemical properties

Alox¶	Clay	Feox¶	Base saturation
0.646***	0.305***	0.184***	0.173***

Multiple regression analysis detected soil physicochemical properties which significantly controlled soil P retention capacity for soils collected from 213 paddy rice fields in the central highlands of Madagascar. ¶Oxalate-extractable Al and Fe content. ***$p < 0.001$.

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