A simple method for estimating phosphorus (P) retention capacity in paddy soils based on soil moisture content: An effective approach for P fertilization diagnosis

Soils possess the inherent ability to adsorb phosphorus (P), known as P retention capacity. When this capacity is high, the effectiveness of P fertilizer application diminishes. This issue is particularly pertinent in sub-Saharan African (SSA) farmlands, where soil P content is low and farmers have limited access to fertilizers. Effective application of P fertilizers becomes crucial to increasing crop yields in such contexts. Understanding the variability of soil P retention capacity, even among neighboring fields, is essential before fertilizer application. However, analyzing soil P retention capacity typically involves hazardous reagents and expensive equipment, making widespread implementation challenging especially in SSA research institutions with insufficient analytical facilities. In a previous study, we found a significant correlation between the active aluminum content, which determines soil P retention capacity, and the moisture content of air-dried soil in neutral to acidic soils. Yet, the instability of moisture content due to changes in humidity during air drying caused measurement errors. Hence, this study aimed to develop a method to estimate soil P retention capacity accurately and easily by employing saturated salt solution as a moisture conditioning agent to regulate soil moisture content.

The study examined 306 surface soil samples from lowland rice fields in Madagascar, representing diverse soil properties with soil P retention capacity ranging from 10.1% to 96.1%. The results demonstrate that P retention capacity can be accurately estimated based on soil moisture content (Fig. 1). Soil moisture content was measured based on the weight changes before and after exposure to saturated salt solution for one week, which requires no chemical analysis (Fig. 2). By placing saturated salt solution (wherein at least 36 g of sodium chloride is dissolved in 100 g of water) as a moisture conditioning agent inside a closed container for soil placement, regardless of variations in the initial dryness before placement and the relative humidity outside the closed container, soil moisture content can be measured with high reproducibility (Fig. 3).These findings provide practical utility for agricultural extension officers to identify fields responsive to P fertilization with low P retention capacity, facilitating prioritized P fertilizer application for optimal crop yield. While this method is applicable to common lowland rice fields in tropical and subtropical regions, caution is advised for soils with high pH and exchangeable cation content, necessitating thorough validation before implementation.

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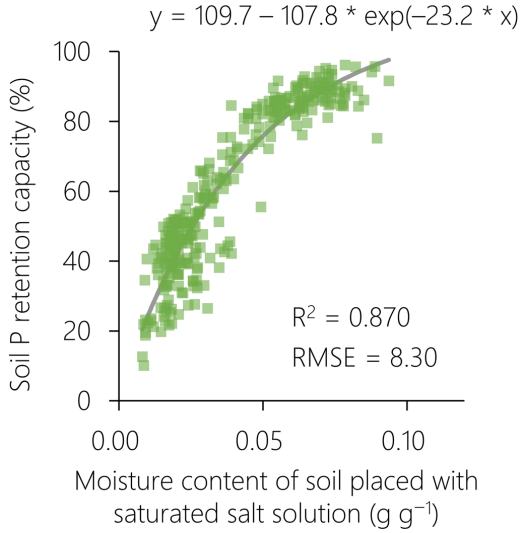
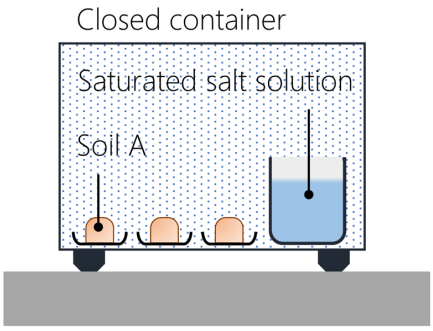


Fig. 1. Relationship between moisture content and P retention capacity of soils placed with saturated salt solution

Coefficient of determination (R^2): It indicates how closely the predicted values match the actual values, with a value closer to 1 indicating higher accuracy.

Root Mean Square Error (RMSE): It represents the average square root of the squared differences between predicted values and actual values, indicating that smaller values suggest a model with lower error.



$$\text{Moisture content of Soil A (g g}^{-1}\text{)} = \frac{\text{Weight of Soil A after placing with saturated salt solution (g)} - \text{Weight of Soil A after oven-drying (g)}}{\text{Weight of Soil A after oven-drying (g)}}$$

Fig. 2. Overview of placing soil with saturated salt solution in a closed container and the formula for calculating soil moisture content

Saturated salt solution (saturated sodium chloride (NaCl) solution) is used as a moisture conditioning agent. Saturated NaCl solution is known to maintain relative humidity nearly constant within the range of room temperature with minimal influence from temperature. When using approximately one cup of soil (about 200 g), weight is measured using an electronic balance capable of measuring up to 0.1 g.

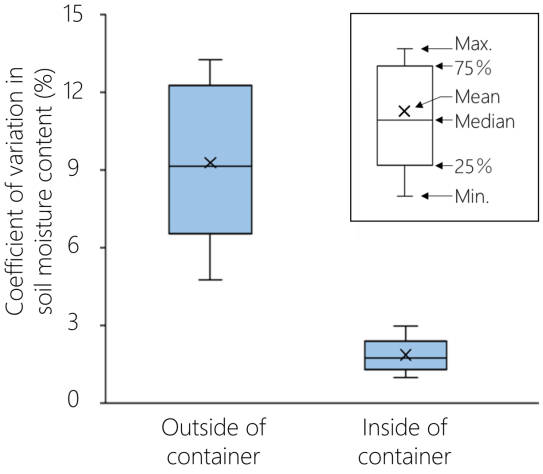


Fig. 3. The coefficient of variation of soil moisture content after placing various soils outside and inside of closed container under different relative humidity conditions

A box plot of the coefficient of variation of soil moisture content after one week of placement of various soils (n = 20, P retention capacity 19.6–94.1%) outside and inside of a closed container at relative humidities of 41%, 52%, and 64% (all at 20°C).

Reference: Nishigaki et al. (2023) *Soil Science and Plant Nutrition* 69: 337–345.