Field Assessment of Humic Substance Effect on Phosphate Rock Solubilization

O.O. Adesanwo, M.T. Adetunji, and S. Diatta

Abstract In the face of rapidly declining food production as a result of soil degradation, use of mineral fertilizers to maintain soil fertility is gradually fading away due to scarcity and high cost, and attention is now shifted to direct application of phosphate rock as an alternative phosphorus (P) fertilizer. Its direct application competes favorably well with mineral P fertilizers on acidic soils but needs to test how to make its use viable on slightly acidic to slightly alkaline soils in Nigeria. Effectiveness of humic substances on phosphate rock solubilization on slightly acidic soils was tested on two experimental sites in southwestern Nigeria. The fertilizer treatments consisted of four rates of Ogun phosphate rock (0, 30, 60, and 90 kg ha^{-1}) and triple superphosphate (TSP) at 40 kg ha^{-1}. The legume treatments consisted of cowpea (Vigna *unguiculata L.*) and mucuna (Mucuna *pruriens L.*). Legumes were grown to maturity as pre-rice crop, and the biomass was incorporated into the soil with Ogun phosphate rock treatments 10 weeks before planting rice. The experiments were laid out on the field as a randomized complete block design with three replicates. Combination of Ogun phosphate rock at 30 kg ha^{-1} increased soil available P by 233% over plots treated with legume alone before planting rice, but no significant effect was observed after harvesting. Rice grain yield increased by 275.0 and 272.0% over OPR alone when OPR at 90 kg ha^{-1} was combined with mucuna and cowpea biomass, respectively, in 2004 at Ibadan.

Keywords Phosphorus • Phosphate rock • Humic substances

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Introduction

Phosphates are a limited nonrenewable resource, which cannot be replaced by other substances, as an essential plant nutrient (Franz 2008). Its deficiency is one of the major factors limiting productivity of many tropical soils. Nigerian soil is a low-activity clay soil with very low organic matter, and presence of aluminum and iron oxides that fix P in the soil reduces its uptake by plants. Therefore, maintenance of high-level soil phosphorus in soil solution is a major challenge. Several studies have shown that addition of indigenous phosphate rock increases the soil P appreciably on acid soils. Various methods have been used to improve the solubility of PR and thus increase its widespread implementation. These include (1) partial acidulation with H_2SO_4 or H_3PO_4, (2) mechanical activation, (3) biological means such as composting organic wastes with phosphate rocks (phospho-composts), and (4) thermal treatment (Rautaray et al. 1995); capital-intensive nature of the technology involved in adopting some of these methods of PR amendments reduces the widespread implementation for direct application especially on slightly acidic soils, but application of humic substances from decomposition of plant residues with PR is thought to be cheaper and safe if adopted.

Specifically, the objective of this study was to determine the impact of humic substances from legume decomposition on phosphate rock solubilization and rice grain yield.

Field Experiment

The field experiments were conducted at two sites (Ibadan (IITA) and Ikenne (IAR&T)) between 2003 and 2005. The treatments were five rates of phosphorus from two sources (OPR at 0, 30, 60, and 90 kg ha^{-1} and TSP at 40 kg ha^{-1}) and two legume crops mucuna and cowpea (IT98K-356-1). It was a factorial experiment arranged in split-plot design, with legume as the main plot and P fertilizer rates as the subplot, and replicated three times. Two seeds of mucuna and four seeds of cowpea were sown at a spacing of 25 cm by 50 cm, and the crops grown to maturity as pre-rice crop in 2003. Cowpea seeds were harvested in 2004, and the biomass of both legumes remained on the field. The OPR was ground and sieved through 0.1-mm sieve, broadcast, and immediately mixed with legume biomass mechanically. Triple superphosphate (TSP) at 40 kg ha^{-1} was applied after planting rice (NERICA-1). Six seeds of rice were dribbled along the rows at spacing of 25 cm by 25 cm. Preemergence herbicide Ronstar was used to control weeds. In addition, plots were hand weeded at 4 and 8 weeks after emergence of the crop. All the treatment plots received basal 60 kg ha^{-1} as urea which was applied in three split doses (1/2 after planting, 1/4 at tillering, and 1/4 at booting stages of rice crop). Harvesting was done, and grain yield per plot at 14% moisture was taken. The experiment was repeated to determine residual effect of applied phosphate rock on soil properties and rice grain yield.

Laboratory Analysis

Soil samples collected from the experimental sites (Ibadan, Ikenne, and Abeokuta) were dried, sieved using 2-mm sieve, and subjected to physical and chemical analysis.

Results and Discussion

Field experiment was conducted to evaluate the effect of humic substances and phosphate rock on soil, plant, and growth parameters of rice. In Ibadan, little or no response of the treatment was observed on soil properties (Figs. 1 and 2). The effect of added legume biomass on soil pH before planting rice and after harvesting was not significant; similarly, OPR application did not affect soil pH significantly, but combined use of legume biomass and OPR affected soil pH before planting. A decrease in soil pH ranging from 1 to 7% was obtained after harvest. Addition of legume biomass increased soil organic carbon compared to no legume treatment but not significantly. Increases in soil organic carbon in the range of 2–20% were obtained as a result of OPR application before planting. Effect of legume biomass on soil available P and exchangeable calcium was not significant before planting. Plots treated with TSP gave the highest value (11.33 mg kg^{-1}) in soil available P, and it differed significantly from other treatments. Application of OPR increased soil available P significantly over control, but improvement on soil available P was higher when OPR was combined with legume biomass confirming positive impact of humic substances, for example, mucuna biomass combined with 30 kg ha^{-1} OPR increased soil available P before planting by 233% over plots treated with mucuna biomass alone. Similarly, plots receiving combination of cowpea biomass with 30 kg ha^{-1} gave 221% increase over no legume plot, but the effect was not significant after harvest. Significant increases in exchangeable calcium were obtained with treatment combination before planting and after harvest. The field experiment was repeated between October 2004 and September 2005. Effect of the treatments during the second field trial without fresh application of fertilizer on soil properties and growth parameters was similar. Agronomic effectiveness (RAE) of OPR on rice grain yield was higher with mucuna biomass treatments than cowpea at Ibadan, for instance, combination of mucuna biomass with 90 kg ha^{-1} OPR had RAE of 102.27% over plots treated with only mucuna biomass whereas. The RAE value with combination of cowpea biomass and 90 kg ha^{-1} was 86.73% over plots treated with only cowpea biomass in 2004 (Figs. 3 and 4). In 2005, agronomic effectiveness of OPR on grain yield in Ibadan increased significantly with both legume biomass though cowpea had exceedingly higher RAE than mucuna, for instance, cowpea treatment combined with 30 kg ha^{-1} had RAE of 700% in 2005 against 22.12% in 2004; similarly, OPR treatment in combination with mucuna biomass gave 480% RAE value in 2005 against 17.05% in 2004. In 2004, RAE

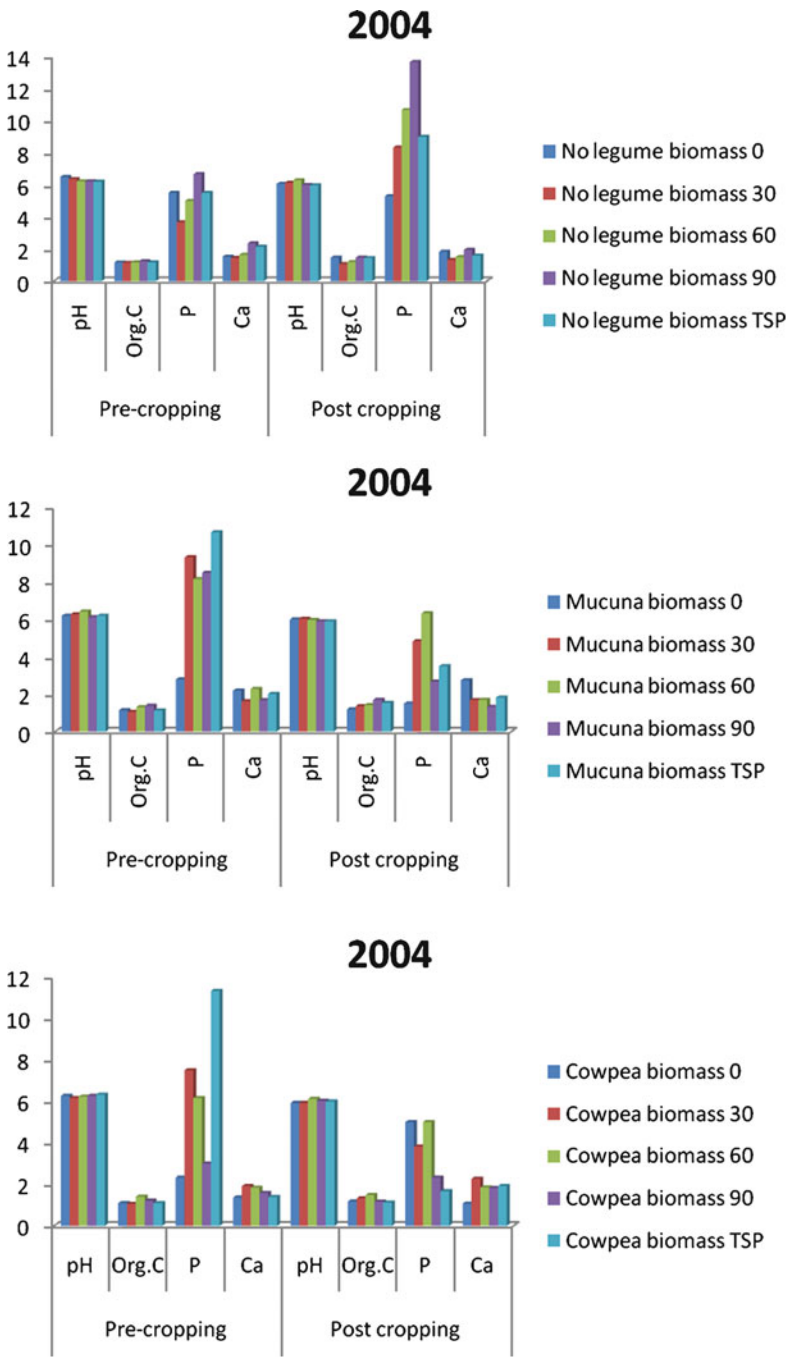

Fig. 1 Evaluation of the effect of humic substances and phosphate rock on soil during pre-cropping and post-cropping in 2004

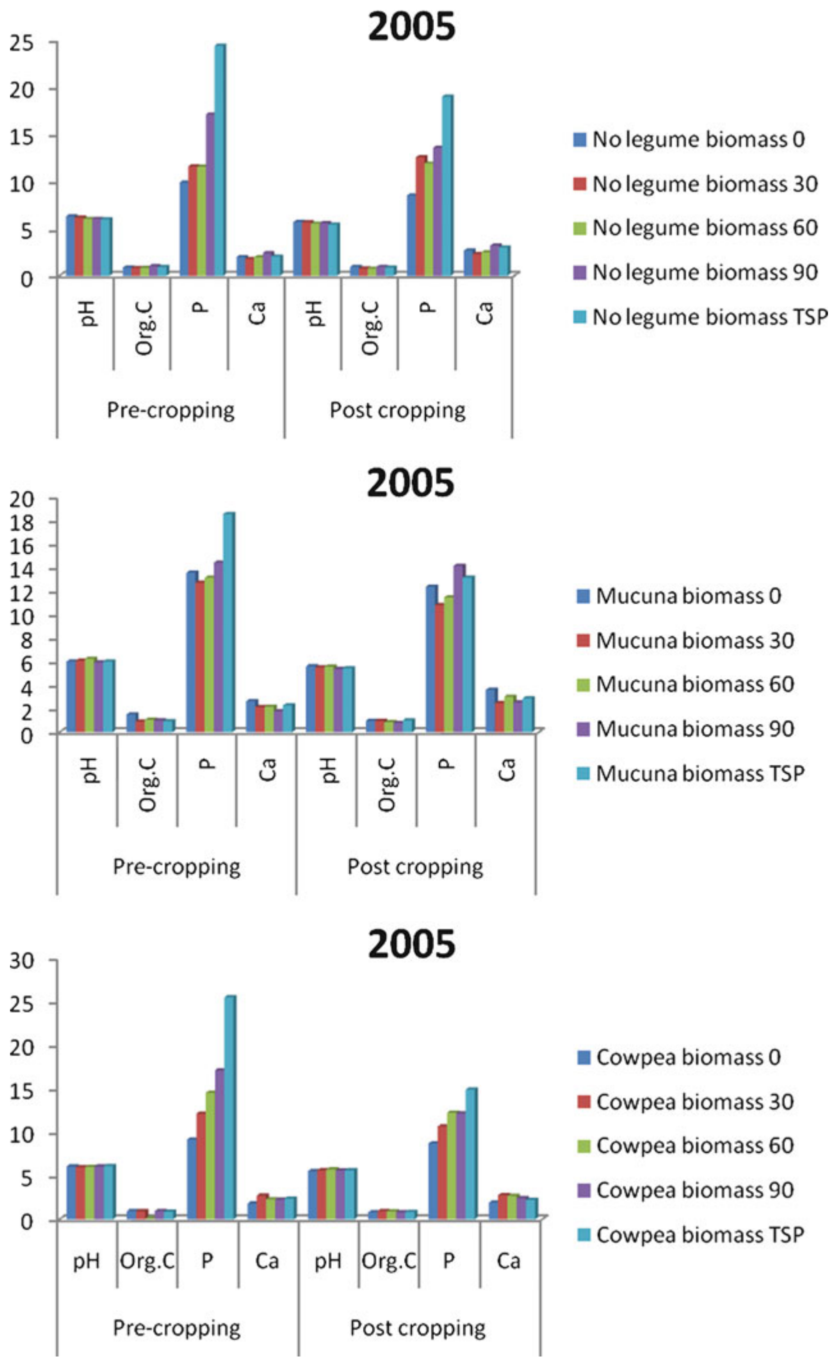

Fig. 2 Evaluation of the effect of humic substances and phosphate rock on soil during pre-cropping and post-cropping in 2005

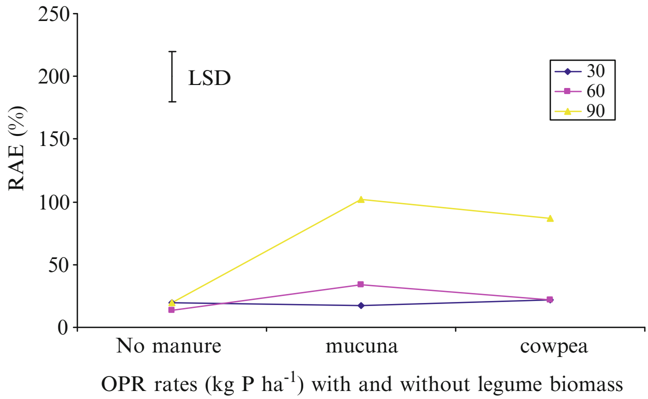

Fig. 3 Relative agronomic effectiveness OPR application with and without legume on rice grain yield in 2004 at IITA Ibadan

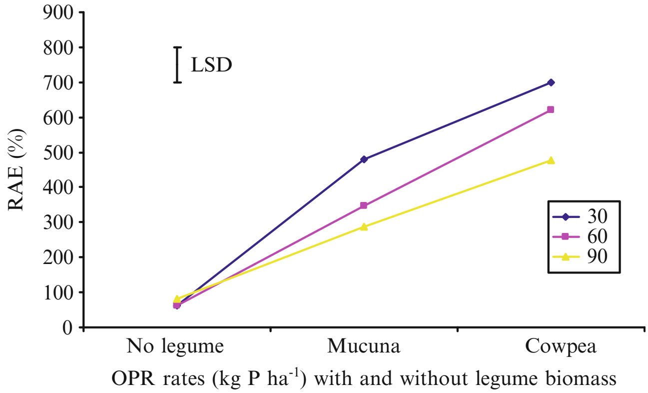

Fig. 4 Relative agronomic effectiveness OPR application with and without legume on rice grain yield in 2005 at IITA Ibadan

values increase as rate of P application increases, but the reverse was the case in 2005 (Fig. 4). It is glaring that application of legume significantly improved the effect of OPR even on soils that are slightly acidic. Positive results obtained from OPR treatment when combined with legume on soils that are not acidic could have been as a result of modification of soil the decomposition of legume which releases organic acids and nutrients. Evidences confirmed so far suggest that these acids can enhance the dissolution of elements from minerals due to their acidity and to a greater extent by a complex formation. Consequently, the increased solubility of less reactive OPR could be attributed to the action of the products of decomposition of legume biomass. Chelation of Ca from OPR resulting in increased P release (Chien 1992) which will contribute to grain yield could be another probable reason for the significant positive effect observed on rice grain. Still more of the organic acids could increase or reduce the availability of P by adsorption and fixation of P (Yang et al. 1994). A significant difference observed with the two legume crops could be attributed to differences in their chemical properties as confirmed by Tian et al. (1992).

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