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Topic 4 - Innovation in Organic farming: "thinking out of the Box"

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IMPROVING PHOSPHATE ROCK USE EFFICIENCY IN ORGANIC FARMING

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Abstract: Between 45 to 81% of the total phosphorus (P) fertilizer applied to soils in sub-Saharan Africa is absorbed in the soil, which among other factors reduce crop yield and contributes to high poverty in the region. The objective of the study was to assess the effect of different phosphorus rock (PR) management on carrot yields, P recovery and use efficiency. Different volumes (100, 200, 300, 400, and 500 mLs) of organic (lemon and pineapple) juices and water were used to dissolve 100 g of PR. The available P concentration in the solution was determined using a standard protocol. The solution with the high P concentration as well as powdered PR was each composted with manure and crop residues. Thereafter, a field experiment was set up on Humic andosols and Orthic acrisols to compare the effect of the dissolved PR applied directly with compost, to dissolved PR composted, powder PR composted, powdered PR applied directly with compost, Triple supper phosphate applied directly with compost, compost and the soil alone (as a control). Our findings showed that lemon juice could release over 65% of the available P from PR and the combined application of the dissolved PR and compost at planting increased P recovery and use efficiency, and carrot yields on both soils as compared to the other treatments.

Introduction: Phosphorus (P) is one of the essential elements required by plants, although its availability to plants is highly influenced by aluminum and iron and their oxides in acidic soils and calcium and magnesium in alkaline soils (Yadav et al. 2017). Due to the high sorption capacities of most of the soils in sub-Saharan Africa including Kenya, only 10-25% of P applied from fertilizer and 5-10% of P applied from PR is recovered and utilized by plants (Kisinyo et al., 2014); thereby limiting crop growth and reducing yields especially in organic farming. The sorption also increases rate of fertilizer P applied to soils which accrued a high cost of about USD 327 to 1483 on every hectare of land cultivated to the farmer (Mwangi et al. 2019).

Information on the use of natural acids from organic materials to dissolve PR dissolution is limited (if available at all). Furthermore, studies on the solubilization of PR have not assessed the impact of dissolved PR on the efficiency of P recovery and crop yields (Roy et al., 2016). The objective of this study was to assess the efficiency of using organic juices in the dissolution of PR; and to assess the effect of different management of PR on carrot yields, P recovery and use efficiency.

Material and methods: Efficiency of organic juices in PR dissolution

Organic juices were extracted from lemon and pineapple fruits. A hundred (100) grams of Minjingu phosphate rock (MPR) was dissolved in five different volumes of lemon, pineapple juice, and distilled water (100, 200, 300, 400, and 500 mls). The mixtures were stirred daily to enhance homogeneity. Ten (10) mls of the solutions were sampled on days 0 (immediately after mixing), 7, 14, 21, and 28 days after mixing for analysis of available phosphorus and pH. Available P was extracted following the Olsen method and determined by the molybdenum blue method as described by Okalebo et al. (2002). The lemon juice dissolved more PR compared to pineapple juice and distilled water.

Field experiment

A field experiment was conducted in both Humic andosols and Orthic acrisols in the long and short rain seasons. Composts were prepared, each with 250 kg boma manure, 26 kg fresh plant and crop residues, and 70 kg dry grass materials. Two of the composts were fortified with 8.67 kg of PR each, with the aim of raising total P content from 0.34% to approximately 3%. The first compost received PR dissolved in lemon juice at a ratio of 1:5 grams PR to mls of lemon juice; the second received PR in powder form. In the field experimental trials, treatments (Table 1, footnote) were applied at a rate of 52.00 kg N ha^{-1} and 40.15 kg P ha^{-1} based on the N and P requirements for carrots. *Daucus carota* (cv. Nantes) was planted as a test crop at a spacing of 15cm × 7cm in an experimental plot of 2m × 2m, spaced 1m apart. Treatments were replicated three times in a Randomized Complete Block Design. Fresh root yield data was collected for all the plants from each treatment. Twenty plants were selected from each treatment and used for determination of P recovery and use efficiency.

Results: Dissolution of PR with organic juices

The available P released in lemon juice at volume 500 mls immediately after mixing was 2 to 26 times higher ($p<0.001$) compared to the amount released in 400 to 100 mls on the same day (Figure 1). In lemon juice, pineapple juice and water, 63, 12, and 6% of total P applied respectively were released to available P.

Insert Figure 1

Effects of different PR management treatments on carrot yields, P recovery and use efficiency

Carrot fresh root yield was higher ($p<0.001$) in Humic andosols compared to Orthic acrisols and in long rain (LR) season compared to short rain (SR) season (Table 1). In Humic andosols, the yields were high in DPR + compost in both long and short rain seasons. In Orthic acrisols, DPR composted had the highest root yields in LR season, while DPR + compost had higher yields in SR season. P recovery efficiency was similar for DPR + compost, PPR + compost, and TSP + compost in both sites except in LR and SR seasons in the Humic andosols, respectively (Table 1). Agronomic PUE was high in DPR + compost in both sites and seasons except the LR season in Orthic acrisols.

Insert Table 1

Discussion: The high dissolution of PR by lemon juice was attributed to a high proportion of citric acid that lowered the solution pH significantly increasing solubilization of P compounds by the dissolution of adsorbents, competition for P adsorption sites, and change of surface charge of the adsorbents. The abundance of hydrogen ions in the organic acids enhanced solubilization of PR ($Ca_{10}(PO_4)_6F_2$) by substituting Ca^{2-} and F^- to form available P ($H_2PO_4^-$) (Osman, 2015). Increased availability of P resulted in high yields, P recovery efficiency, and agronomic P use efficiency in DPR + compost in both sites and seasons. High P recovery and yield in DPR + compost compared to other treatments can be attributed to increased uptake of P associated with the increased availability of solution P in the root medium (Yadav et al., 2017). The study concluded that dissolution of PR with organic acids and combination with composts increases concentration of solution P for plant uptake and utilization. This mechanism can enhance offset P deficiency problems faced by small scale farmers in organic farming systems.

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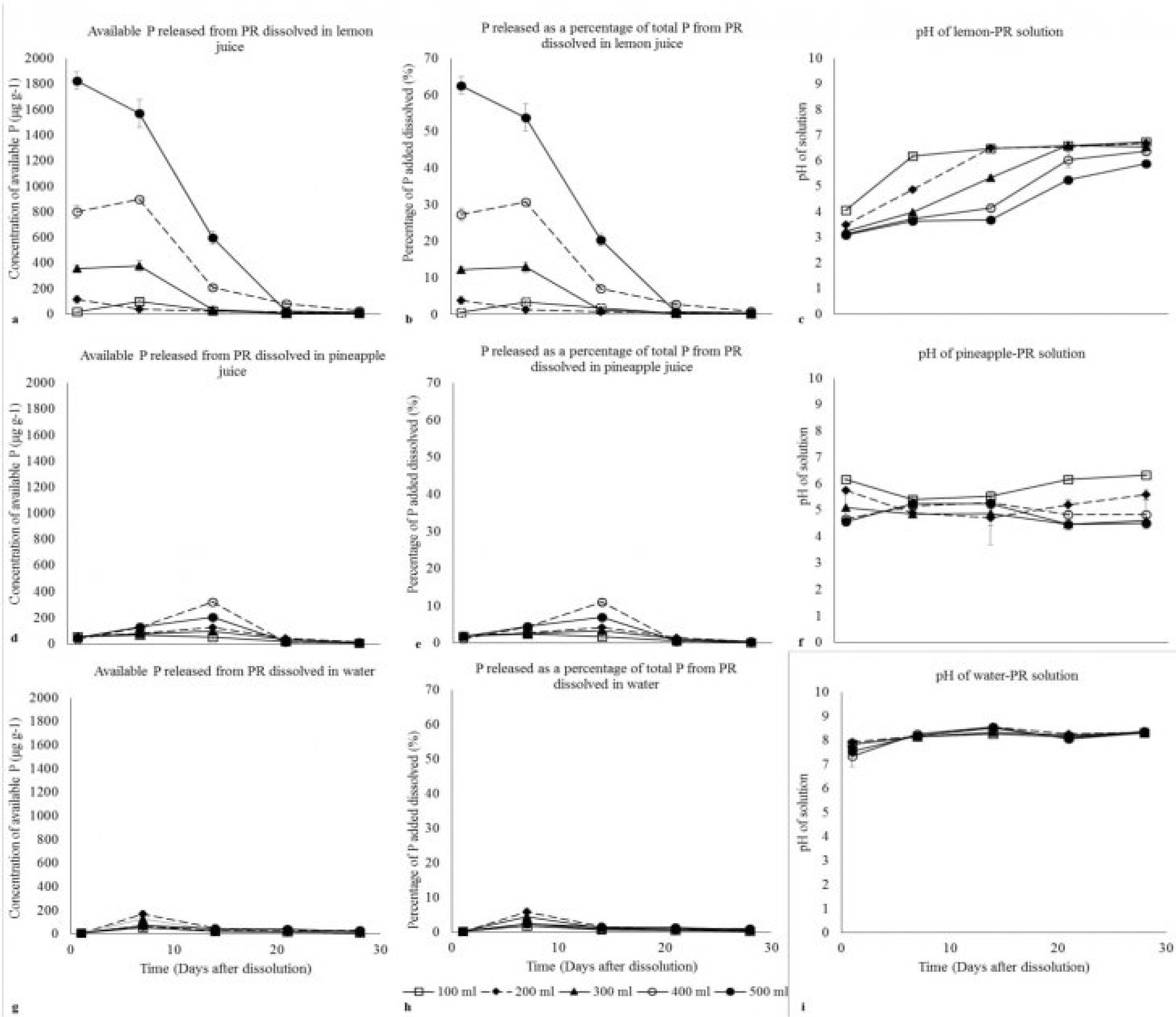
Image:



Source: Mwangi et al. (under review)

Figure 1: Effect of organic juices (lemon and pineapple) and water, and their volume and time on the dissolution of PR to release available P;

Day 0 refers to the time immediately after mixing

Image 2:

Table 1: The effects of different PR management on carrot yield, P recovery efficiency and P use efficiency in the field trials at Kangari and Kianjugu, Kenya

Treatment	Fresh root yield (tons ha^{-1})				P recovery efficiency (%)				P use efficiency (kg ha^{-1})			
Site	Humic andosols		Orthic acrisols		Humic andosols		Orthic acrisols		Humic andosols		Orthic acrisols	
Season	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR
DPR composted	39.31^{c}	10.12^{f}	17.58^{a}	4.48^{b}	26.50^{bc}	6.70^{e}	17.47^{b}	15.33^{c}	38.48^{f}	9.98^{f}	17.43^{a}	4.40^{b}
PPR composted	48.60^{b}	12.04^{e}	8.93^{e}	3.38^{e}	22.20^{cd}	10.13^{bc}	16.80^{b}	6.27^{d}	47.78^{b}	11.89^{e}	8.77^{f}	3.30^{d}
DPR + compost	54.54^{a}	22.94^{a}	14.83^{b}	5.63^{a}	39.20^{a}	18.57^{a}	25.27^{a}	25.87^{a}	53.72^{a}	22.80^{a}	14.67^{b}	5.55^{a}
PPR + compost	46.26^{c}	13.74^{d}	12.10^{cd}	3.84^{bc}	29.33^{b}	20.13^{a}	24.30^{a}	20.83^{abc}	45.33^{c}	13.60^{d}	11.94^{d}	3.76^{cd}
TSP + compost	45.37^{c}	17.50^{b}	13.76^{bc}	4.75^{ab}	37.30^{a}	10.47^{bc}	19.73^{ab}	21.80^{ab}	44.54^{d}	17.36^{b}	13.60^{c}	4.67^{b}
Compost	46.68^{c}	16.04^{c}	10.89^{d}	4.16^{bc}	20.67^{d}	18.27^{b}	8.17^{e}	19.63^{bc}	45.86^{c}	15.90^{c}	10.73^{e}	4.08^{bc}
TSP + Tithonia	43.64^{d}	9.11^{f}	7.38^{ef}	3.36^{e}	26.50^{bc}	9.63^{bc}	17.97^{b}	5.10^{d}	42.82^{e}	8.97^{g}	7.23^{g}	3.28^{d}
Un-amended soil	33.08^{f}	5.65^{g}	6.34^{f}	3.23^{e}								
Season	44.69^{a}	13.39^{b}	11.48^{b}	4.10^{c}	28.82^{a}	13.41^{d}	18.53^{b}	16.40^{c}	45.50^{a}	14.36^{b}	12.05^{c}	4.15^{d}
Site	29.04^{a}		7.79^{b}		7.12^{b}		7.38^{a}		21.11^{a}		17.47^{b}	
Season	***				***				***			
Site	***				***				***			
Treatment	**				***				***			
Site x Treatment	ns				***				***			
Season x Treatment	ns				***				***			
Season x Site	***				***				***			
Season x Site x Treatment	ns				***				***			

Source: Mwangi et al. (under review)

Where: Values followed by different alphabets (a, b, c, d) show significant differences among treatments at (ns; not significant; ** $p < 0.01$, ***$p < 0.001$); Mean comparison in for treatments is by column; mean comparison for season and site is by row;

LR, long rain season; SR, short rain season

DPR Composted = dissolved phosphate rock composted with manure and plant residues; PPR Composted = powdered phosphate rock composted with manure and plant residues; DPR + Compost = dissolved phosphate rock applied directly with compost from manure and plant residues; PPR + Compost = powdered phosphate rock applied directly with compost from manure and plant residues; TSP + Compost = Triple Super Phosphate applied directly with compost from manure and plant residues; compost alone = compost from manure and plant residues; TSP + Tithonia = Triple Super Phosphate applied directly with Tithonia

Disclosure of Interest: None Declared

Keywords: Compost, Organic juices, Phosphate rock dissolution, Phosphorus recovery