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Effect of phosphorus fortified compost on growth and yield of maize (*Zea mays* L.) and Lablab (*Lablab purpureus* L.) intercropped maize in acidic soils of Western Kenya

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Phosphorus deficiency majorly constrains maize (*Zea mays* L.) production in acidic soils of western Kenya. This requires high doses of expensive inorganic P fertilizers to correct. Recommended rock phosphates and manures are lowly adopted because of low solubility and P content respectively. A Randomized Complete Block Design experiment was conducted for two seasons to assess effect of a cheaper alternative P source, Phosphorus fortified *Tithonia* compost (PCM), on growth and yield of maize and lablab-intercropped maize on two sites with different soil fertility. The experiment was set up on seven farms per site in Kapkerer (low fertility) and Koibem (higher fertility). Three P source treatments of *Minjingu* rock phosphate (MRP), Phosphorus fortified *Tithonia* compost and Triple Super Phosphate (TSP) were applied at an equivalent rate of 26 kg P/ha for maize and maize-lablab intercrop. Data on plant height, Leaf Area Index (LAI), aboveground biomass, leaf P concentration and grain yield were collected. PCM treatment significantly ($p \leq 0.05$) increased maize height, LAI, aboveground biomass and grain yield compared to TSP in Kapkerer. No significant differences were noted in leaf P concentrations. PCM is a good alternative to expensive inorganic P fertilizers in acidic soils of western Kenya.

Key words: *Tithonia* P-fortified compost, Rock phosphate, intercropping, lablab.

INTRODUCTION

The agricultural productivity of the densely populated humid regions of western Kenya is commonly limited by low phosphorus availability. Continuous land cultivation coupled with low fertilizer use has often resulted in soil degradation and low crop yield averaging less than one ton of maize per hectare compared to a potential yield of 8 to 10 t/ha.

P deficiency in South Nandi Sub-county in western Kenya is attributed to the acidic nature of the soils which fix P, use of inappropriate types and amounts of fertilizers and continuous crop mining. Although this deficiency can be mitigated by use of P fertilizers, this strategy has not

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been effective among the smallholder farmers mainly because of their high cost (Odendo et al., 2007). Use of low cost yet effective P source alternative is thus critical to contributing to sustainable food production in the region.

Amelioration of soil P deficiency has largely focused on P enhancement using readily soluble but more expensive sources such as Diammonium Phosphate (DAP) and Triple Super Phosphate (TSP) that most smallholder farmers in the area cannot afford. In addition, inorganic fertilizers have low phosphorus use efficiency in acidic soils due to fixation (Kisinyo, 2011). Alternative low cost locally available fertilizer types for soil P amendment including Rock Phosphate (RP), compost and farm yard manure (FYM) among others, have been tried with limited success. Composts and farm yard manures are lowly adopted because of their low P content per unit weight (Nziguheba et al., 2016). *Minjingu* Rock phosphate, a biogenic phosphate rock obtained from Northern Tanzania, has low solubility at the time of application. Although its dissolution increases with time, low initial solubility coupled with fixation of solubilized P in acidic soils (Nekesa et al., 2005) limits its use. Therefore enhancement of its low solubility and reduction of fixation of its available P is thus required for successful use in building up soil fertility. Although liming has been tried to overcome the soil acidity problem, its adoption is low because it is expensive to the local farmers, requires technical skills to apply and is labor intensive.

Integrated soil fertility management (ISFM), narrowly defined as combination of organic and inorganic fertilizers, has been recommended as one of the most sustainable methods for crop production (Vanlauwe et al., 2010). However, direct combination of RP and organics has often shown low crop yield because the Ca^{2+} in the latter reverses the dissolution process (Karanja et al., 2004). Phosphorus fortification of the low-cost compost is one of the strategies for enhancing its quality for plant P nutrition. A study aimed at assessing the agronomic effectiveness of a cheaper alternative P source, phosphorus fortified *Tithonia* compost (PCM), on growth and yield of maize (*Zea mays*) grown either as a monocrop or as commonly practiced in this area, intercropped with a legume was carried out for two seasons at two sites of different soil fertility status. In this study, lablab (*Lablab purpureus*) that was recently introduced in the area was used as the intercrop.

MATERIALS AND METHODS

Site and soils

The study was carried out in Nandi South sub-county at two different sites, Kapkerer and Koibem. The two sites are located on a fertility gradient determined by how long the land has been under cultivation since conversion from forest land. Koibem site is more fertile compared to Kapkerer, having been cultivated for a shorter period since conversion from forest land. Kapkerer is located on a latitude of 00 00’ 319” N, 034 48’14.6” E with an altitude of 1530 m above sea level while Koibem is located on 00 09’28.2” N 034 54’31.9” E with an altitude of 1770 m above sea level. The trial was in the short rain (SR) and long rain (LR) seasons. The average annual temperature for Kapkerer was 23.9°C while that of Koibem was 22.3°C. In the SR season, Kapkerer site received an average of 1403 mm of rain whereas Koibem site received an average of 2001 mm of rain per season. In the long rain (LR) season, Kapkerer site received rainfall of 2122.2 mm and Koibem 1889.0 mm. In this area, long rains begin in March up to August and short rains follow from September to January. The predominant soils are classified as *Humic Acrisols* (Jaetzold et al., 2005). A composite soil sample was collected from each of the seven farms in each site, air dried and ground to pass through a 2 mm sieve. The samples were analyzed to determine soil pH (glass electrode), soil texture (mechanical method), exchangeable bases, total organic carbon (Walkey-Black) and the initial levels of available phosphorus (Bray2) (Table 1) using the standard procedures described in Okalebo et al. (2002).

Experimental design and treatments

A factorial experiment in a Randomized Complete Block Design (RCBD) was carried out for two seasons (short rains in 2014 and long rains in 2015) in two sites, Kapkerer and Koibem on seven farms at each site. Three different P source fertilizers applied at a rate of 26 kg P/ha were used namely Triple Super Phosphate (TSP), *Minjingu* Rock Phosphate (MRP) and phosphorus fortified *Tithonia* Compost (PCM). TSP was included as a positive control as it is the recommended fertilizer in the area and is the one commonly used by farmers. The treatments were: maize treated with TSP, maize treated with MRP, maize treated with phosphorus fortified *Tithonia* compost, maize-lablab intercrop treated with TSP, maize-lablab intercrop treated with MRP and maize-lablab intercrop treated with phosphorus fortified *Tithonia* compost.

PCM composting

Three compost heaps were set at the same time for the two seasons with phosphorus fortification done using rock phosphate (*Minjingu* Organic Hyper Phosphate with 12% P). Composting organic materials were layered to a height of 1.5 m. The compost trenches were 2½ m long × 1½ m wide with the heaps layered with maize stover, *Tithonia diversifolia* (Mexican sunflower), green vegetation, cattle manure, topsoil and the determined amount of *Minjingu* Rock Phosphate. *Tithonia* was harvested from a roadside where it naturally grows. The layers were sparingly watered and the last layer of the heaps was covered with dry grass to reduce loss of moisture during the composting period. Turning of the compost heaps was done periodically until fully composted after which uncomposted materials were removed and the compost from the three heaps thoroughly mixed, dried under shade and stored in a cool dry place. Two samples of the harvested compost were taken for nutrient analysis.

Experiment management and data collection

The land was manually prepared to produce a favorable seed bed. Maize variety, *Pioneer 30 G 19*, was planted in the short rain season and *H 517* in the long rain season at an inter-row spacing of 75 cm and intra-row spacing of 30 cm. In the intercrop the maize spacing was maintained at 75 cm by 30 cm and one lablab (*Rongai* variety) row grown between the maize rows at an intra-row spacing of 30 cm. The lablab was allowed to grow and produce seed. Each experimental unit measured 4 m by 3 m and had 5 rows of sole maize while the intercrop had 5 rows of monocrop maize and 4 rows of lablab. The plots were weeded twice, first at 3 weeks after

Table 1. Soil characterization.

Soil characteristic	Site	
	Kapkerer	Koibem
pH	5.09	4.97
Soil texture	Sandy clay loam	Sandy clay loam
Exchangeable bases (ppm)		
Ca	1.57	2.75
Mg	51.31	66.56
K	1.9	2.07
Total organic carbon %	0.78	2.47
Available P (ppm)	34.29	21.32

Table 2. Chemical composition of the phosphorus fortified Tithonia compost.

Parameter	Sample 1	Sample 2	Average
Citrate soluble P (%)	1.07	1.1	1.09
Water soluble P (%)	1.33	1.24	1.29
pH	8.62	8.66	8.64
Nitrogen (%)	3.34	2.98	3.16
Organic carbon (%)	7.31	6.74	7.03

Table 3. Available phosphorus content of *Minjingu* Rock phosphate.

Parameter	Sample 1	Sample 2	Average
Citrate soluble P (%)	1.06	1.08	1.07
Water soluble P (%)	2.29	2.11	2.20

emergence and later at 7 weeks after emergence. All the plots received starter nitrogen of 20 kg N/ha at planting time and 40 kg N/ha at knee height as top dress using Calcium Ammonium Nitrate (26% N).

Maize parameters measured included height, leaf area index, aboveground biomass, leaf P concentration and maize grain yield. Maize heights of two randomly selected plants of the harvestable rows at onset of tasseling were measured from the base to the last leaf of the plant. Three maize plants were randomly selected at onset of flowering and the length and breadth at the widest part of all the leaves measured to determine leaf area index. Maize flag leaves from six randomly selected plants from the harvestable rows were harvested for P concentration analysis. During harvesting, all the maize in the three harvestable lines was harvested and fresh weight of the cobs taken. Four cobs were weighed, shelled and grain weight determined. The fresh maize grain's moisture content was measured using a moisture meter and yield calculated to 13% moisture content equivalent and expressed on per hectare basis.

Phosphorus fortified *Tithonia* compost and rock phosphate analysis

Phosphorus fortified *Tithonia* compost was analyzed to determine pH, organic carbon, total nitrogen and available forms of P (water soluble P and citrate soluble P). The pH of the compost was determined using a pH meter (Monedero et al., 2001). Organic carbon was determined by the modified Walkley-Black method as described by Ryan et al. (2001). Total nitrogen was determined by the micro-Kjeldhal method and plant available P by modified Mehlich II method (Okalebo et al., 2002). *Minjingu* Rock Phosphate was analyzed for the available forms of P namely water soluble P and citrate soluble P.

Data analysis

Analysis of variance was conducted using the general linear model procedure of the Statistical Analyses Software (SAS) program (SAS Institute, version 8.2). Mean separation was done at 5% probability level using Least Significant Difference (LSD).

RESULTS AND DISCUSSION

The analysis results showed that the available forms of P (water soluble P and citrate soluble P) between phosphorus fortified *Tithonia* compost (PCM) and *Minjingu* Rock Phosphate (MRP) were similar. This means there was no particular advantage on P availability between PCM and *MRP* (Tables 2 and 3).

Table 4. Effect of P source on maize height (cm), Leaf Area Index, Biomass (tons/ha) leaf P concentration (ppm) and Grain Yield (kg/ha) of maize and maize intercropped with lablab in Kapkerer and Koibem during SR season.

Site	Cropping System	P source	Parameter				
			Height (cm)	LAI	Biomass (tons/ha)	Leaf P concentration (ppm)	Grain Yield(Kg/ha)
Kapkerer	Maize	PCM	198^{Aa}	2.50^{Aa}	9.35^{Aa}	555^{Aa}	2730^{Aa}
		TSP	174^{Ba}	2.14^{Aa}	8.53^{Aa}	561^{Aa}	1750^{Ba}
		MRP	187^{Aa}	2.21^{Aa}	8.63^{Aa}	480^{Aa}	2280^{Aa}
	Intercrop	PCM	202^{Aa}	2.54^{Aa}	10.1^{Aa}	708^{Aa}	2620^{Aa}
		TSP	185^{Aa}	2.37^{Aa}	8.56^{Ba}	514^{Aa}	2050^{Aa}
		MRP	191^{Aa}	2.29^{Aa}	7.52^{Ba}	561^{Aa}	2340^{Aa}
Koibem	Maize	PCM	188^{Ab}	3.17^{Aa}	18.2^{Aa}	608^{Aa}	-
		TSP	191^{Aa}	2.97^{Aa}	14.9^{ABa}	656^{Aa}	-
		MRP	186^{Aa}	3.32^{Aa}	13.1^{Ba}	504^{Aa}	-
	Intercrop	PCM	206^{Aa}	3.48^{Aa}	17.1^{Aa}	698^{Aa}	-
		TSP	194^{Aa}	2.77^{Ba}	17.1^{Aa}	592^{Aa}	-
		MRP	193^{Aa}	3.08^{ABa}	16.9^{Aa}	694^{Aa}	-

[‡]Means followed by the different capital letter within the column for different P sources and different small letter for same P source for maize and intercrop are significantly different at $p \leq 0.05$ according to LSD. PCM-Phosphorus fortified *Tithonia* compost TSP- Triple super phosphate MRP-*Minjingu* Rock Phosphate.

Maize height

In Kapkerer site, PCM treatment significantly increased monocrop maize height over TSP both in the short rain and long rain seasons by 13.5 and 9.8% respectively. No treatment differences were noted between PCM and MRP in the short rain season though in the long rain season, a significant difference in height of 6.2% was noted in monocrop maize. MRP treatment in the short rain season was 7.5% taller compared to TSP treatment with no difference noted in the long rain season. No significant differences were noted in height of maize grown in intercrop using the three different P sources in both seasons (Tables 4 and 5). In Koibem, there were no significant differences in height of maize resulting from the three P source treatments in both seasons. PCM performed similar as TSP in both seasons (Tables 4 and 5). PCM may have provided maize with more available P for growth. Enrichment of the compost in the presence of organic materials significantly increased P availability in the compost for plant use. The composting process of *Minjingu* rock phosphate with organic materials produced organic acids like citric acid, oxalic acid, acetic acid among others that may have increased the dissolution of the rock phosphate leading to presence of more available P in the PCM (Nwoke et al., 2008). Basic cations known to be released from mineralization of the P fortified composts (Opala et al., 2010) exchanged with acidic cations (H^+, Al^{3+} and Mn^+) on soil exchange sites thus encouraging reduction of Al and Mn toxicity. This may have improved the soil pH reducing P fixation. Further, complexion of Al and Fe oxides by organic anions in PCM may have protected P from fixation making it more available.

TSP with its readily available P did not perform as well as PCM and MRP. This may have been because the soluble P from TSP was quickly fixed in the acidic soil upon application and therefore becoming unavailable for plant uptake (Kisinyo et al., 2013). The low soil pH was advantageous for MRP for it is relatively more soluble in acidic soils than in neutral and alkaline soils. The relatively better solubility of MRP in acidic soils reduces exchangeable aluminium (Al) levels in the soil compared to TSP leading to its superior performance (Opala et al., 2010). Laboratory analysis of PCM and MRP showed that the available forms of P (water soluble P and citrate soluble P) between them were not significantly different (Tables 2 and 3). This means that there was no particular advantage on P availability between PCM and MRP. The organic form of P in PCM was more easily released making it more accessible to plants than the less soluble MRP (Waigwa et al., 2003). The results further showed that intercropping did not affect maize height especially in the long rains when maize had enough water (Table 5). The findings of Thwala and Ossom (2004) corroborated this finding. The similarity in performance between maize and intercropped maize may be due to minimal competition between the legume and the maize crop. Massawe et al. (2017) however, reported increased maize height in maize-lablab intercrops over maize while Thobatsi (2009) reported reduced maize height when

Table 5. Effect of P source on maize height (cm), Leaf Area Index, Biomass (tons/ha) leaf P concentration (ppm) and Grain Yield (kg/ha) of maize and maize intercropped with lablab in Kapkerer and Koibem during LR season.

Site	Cropping system	P source	Parameter				
			Height (cm)	LAI	Biomass (tons/ha)	Leaf P concentration (ppm)	Grain Yield(Kg/ha)
Kapkerer	Maize	PCM	245^{Aa}	3.45^{Aa}	24.6^{Aa}	509^{Aa}	4040^{Aa}
		TSP	223^{Ba}	2.83^{Ba}	22.0^{Aa}	590^{Aa}	3560^{Aa}
		MRP	231^{Ba}	3.07^{Ba}	25.6^{Aa}	389^{Aa}	4230^{Aa}
	Intercrop	PCM	240^{Aa}	3.13^{Aa}	26.0^{Aa}	425^{Aa}	4550^{Aa}
		TSP	235^{Aa}	2.74^{Ba}	20.0^{Ba}	330^{Ab}	3530^{Ba}
		MRP	232^{Aa}	2.69^{Bb}	22.0^{ABa}	564^{Aa}	3600^{Ba}
Koibem	Maize	PCM	242^{Aa}	3.24^{Aa}	42.0^{Aa}	354^{Aba}	4620^{Aa}
		TSP	245^{Aa}	3.22^{Aa}	44.7^{Aa}	253^{Ba}	5130^{Aa}
		MRP	240^{Aa}	3.25^{Aa}	46.3^{Aa}	486^{Aa}	5130^{Aa}
	Intercrop	PCM	248^{Aa}	3.39^{Aa}	45.7^{Aa}	370^{Aa}	5000^{Aa}
		TSP	242^{Aa}	3.26^{Aa}	44.7^{Aa}	372^{Aa}	4820^{Aa}
		MRP	237^{Aa}	3.25^{Aa}	42.43^{Aa}	405.99^{Aa}	5290^{Aa}

[‡]Means followed by the different capital letter within the column for different P sources and different small letter for same P source for maize and intercrop are significantly different at p≤0.05 according to LSD. [†]PCM- Phosphorus fortified *Tithonia* compost TSP- Triple super phosphate, MRP- *Minjingu* Rock Phosphate.

intercropped with legumes.

Leaf area index (LAI)

In Kapkerer site, P source did not significantly affect the leaf area index of maize plants grown as monocrop or intercrops in the short rain season. However, in the long rain season, PCM treatment produced significantly higher LAI compared to TSP and MRP both in maize and intercropped maize. PCM treatment in maize resulted into 21.9 and 12.4% higher LAI compared to TSP and MRP treatments respectively. In the intercropped maize, PCM treatment resulted into 14.2 and 16.4% higher LAI compared to TSP and MRP treatments respectively (Table 5). This indicates probably a higher available P in PCM for leaf expansion of maize. Composting organic materials and fortifying them with P increased the available P in them for better plant growth (Odongo et al., 2007). The multinutrient content in the P fortified *Tithonia* compost especially Ca, Mg and other nutrients resulting from decomposition together with phosphorus might have also contributed to its better performance (Oyeyiola et al., 2014). Due to its possible effects of reducing aluminium toxicity and increasing soil pH, phosphorus fortified *Tithonia* compost was a better fertilizer. No significant differences in LAI in monocrop and intercropped maize between TSP and MRP treatments in both seasons were noted (Tables 4 and 5).

The cropping system did not have a significant effect in LAI measurement except for MRP treatment in the long rain season where maize's LAI was significantly higher compared to intercropped maize receiving the same treatment (Table 5). This observation contradicted what Nuruzzaman et al. (2005) reported that MRP performed better in intercrops due to exudates by legume roots for increased MRP dissolution, hence higher available P for crops. Seemingly, interspecific competition between maize and lablab may have limited maize's leaf expansion.

In Koibem, no significant differences were noted in LAI in both seasons and cropping systems except for short rain season when PCM treatments for intercrop resulted into significantly higher LAI compared to TSP treatment (Table 4). MRP treatment was as good as PCM's. The low pH noted in Koibem may have been responsible for fixation of readily available P from TSP resulting into its low performance.

Maize leaf P concentration

There were no significant differences in maize leaf P concentration due to either P source or cropping system in both seasons in Kapkerer and Koibem (Tables 4 and 5). This indicates that PCM is as good as TSP and MRP in supplying maize with P. The acidic soils may have led to fixation of P from more soluble TSP but conversely increased the dissolution of MRP explaining the similarity in P uptake between TSP and MRP treatments. Findings by Kalala (2011) reporting no difference in maize leaf P concentration treated with TSP and MRP corroborated this finding. These findings however, contradicted Msolla et al. (2005) who reported higher P concentration when applying 80 kg/ha of P to a maize crop using TSP and MRP in an acidic soil in Tanzania. There were significant differences in leaf P concentration only in monocrop maize in the LR season in Koibem where PCM treatment resulted into significantly higher leaf P concentration compared to TSP treatment (Table 5). This may be due to higher availability of P from PCM compared to the lower availability of P from TSP due to its higher fixation in soils of Koibem.

Maize aboveground biomass

PCM treatment in the intercrop plots significantly increased aboveground maize biomass compared to TSP and MRP in the SR season in Kapkerer. In Koibem, PCM treatment in maize plots in the SR season resulted into significantly higher aboveground biomass compared to MRP treatment (Table 4). This corroborates findings by Odongo et al. (2007) who carried a greenhouse experiment comparing compost made from wheat straw and manure from animals fed on MRP and TSP and reported a higher biomass yield of maize in compost compared to TSP and Oyeyiola et al. (2014) who assessed the liming potentials of phosphate-compost and synthetic fertilizers in an acidic *Alfisol* and observed a higher biomass in compost treated cow pea compared to TSP treated one. In the LR season in Kapkerer, PCM treatment in the intercrop resulted into a significantly higher aboveground biomass compared to TSP treatment but showed no variance with MRP treatment. TSP and MRP showed no statistical differences in performance (Table 5). The superior performance of PCM may also be explained by the more available P, N and K it may have provided that was not provided by the inorganic TSP and MRP. PCM may have improved soil pH because of its liming effect due to the release of basic cations from its mineralization that went into exchange reaction with the acidic cations such as Al^{3+} and H^{+} on soil exchange sites (Oyeyiola et al., 2014). This thus reduces toxicity of Al and H ions in the soil and increases concentration of essential nutrients. The multinutrient content in the PCM especially Ca and Mg resulting from decomposition together with phosphorus might have contributed to its better performance. Fixation of P from TSP in acidic soil and low solubility of MRP may have led to their lower performance compared to PCM. The cropping system had no significant effect on above ground maize biomass (Tables 4 and 5). This observation is contrary to that of Lemlem (2013) who reported that maize monocrop had a significantly higher biomass compared to maize intercropped with lablab due to reduced interspecific competition. Lelei et al. (2009) in their studies reported increased maize biomass with legume intercropping attributed to the legume potentially fixing N which is available for maize uptake leading to enhanced biomass.

Maize grain yield

P source significantly affected maize grain yield in Kapkerer in the SR season. PCM treatment in maize resulted into a significantly higher grain yield (2.73 tons/ha) which was 55.9% higher than TSP (1.75 tons/ha). There were however, no differences in grain yield between PCM and MRP treatments (Table 4). In the LR season, PCM treatment in intercropped maize resulted into significantly higher grain yield by 29.1 and 26.6% compared to TSP and MRP respectively. The cropping system did not significantly affect maize grain yield in either seasons. No grain yield was obtained in Koibem in the short rain season due to maize lethal necrosis disease (MLND) that affected many regions of the country that season. However, in the LR season, there were no significant differences noted in PCM, TSP and MRP treatments both in maize and intercropped plots (Table 5). Treatment with PCM may have improved soil pH, added more P and encouraged multiplication and activities of soil micro and macro fauna in mineralization of alkaline radicals from the compost for easy plant uptake (Oyeyiola et al., 2014). The increased performance of PCM in the intercrop in the LR season may be explained by lablab roots releasing exudates to mobilize P in excess of their own demands which could subsequently be used by maize (Nuruzzaman et al., 2005). The increased available P for maize in the intercrop may have contributed to the higher yield. The higher level of available P from quick dissolution of TSP may have been fixed in the acidic soil leading to its low performance. The ability of MRP to slightly increase soil pH and therefore reducing the exchangeable Al compared to TSP may also have contributed to MRP's better performance compared to TSP (Opala et al., 2010).

Cropping system did not significantly affect maize grain yield. Probably, the effect of interspecific competition between component crops may have balanced with the benefits of N and biomass supply by the legume for the cropping system to have no significant effect. These findings are corroborated by Njeru et al. (2007) who concluded that maize grain yield was not affected by maize-common bean intercrop in western Kenya. The findings however, disagree with findings by Lelei et al. *(*2009) who reported increased maize grain yield in a maize-lablab intercrop which they attributed to the deep root system of lablab for nutrient capture and ability to fix nitrogen. Kimaro et al. (2009) observed reduced maize yield in intercrops that they attributed to competition for P and interspecific competition among component crops.

Interactions between P source and cropping system were investigated in all the trials both in Season 1 (short rain season) of 2014 and Season 2 (long rain season of 2015) in the two sites. All the interactions between P source and cropping system were found to be non-significant. The cost of preparing phosphorus fortified compost is minimal. Materials used are maize stover (obtained free after harvesting), *Tithonia. diversifolia* (obtained free from nearby roadside), cattle manure (obtained free from the cowshed within homesteads), Minjingu Rock Phosphate (purchased locally at a cost of Kenya shillings 2100 (approximately 21 US dollars). Labor cost to chop maize and *Tithonia. diversifolia* into small pieces, set up the compost and manage it until harvesting is minimal as cheap family labor is used.

Conclusions

From this study, phosphorus fortified *Tithonia* compost (PCM) performed better than or as well as Triple Super Phosphate (TSP) and *Minjingu* Rock Phosphate (MRP) in maize growth and yield whether planted as monocrop or intercropped with lablab. Therefore, PCM use can provide a low cost alternative to farmers with composting know-how and access to *Tithonia*. MRP outperformed TSP in a number of parameters measured probably due to increased solubilization of MRP in acidic soils. Being relatively cheaper, and in the absence of PCM, it can be a better substitute to use than the expensive TSP in acidic soils. Intercropping lablab with maize did not negatively affect maize performance and is thus advantageous since the farmers get same yield and extra lablab biomass to enhance soil fertility. Furthermore, the intercrop while not depressing maize yield, and being a legume, has a positive effect on soil nitrogen fertility enrichment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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