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EFFECT OF PHOSPHATE FERTILIZER APPLICATION METHODS AND NITROGEN SOURCES ON MAIZE IN WESTERN KENYA: AN AGRONOMIC AND ECONOMIC EVALUATION

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SUMMARY

Simultaneous deficiencies of nitrogen (N) and phosphorus (P) which limit crop production in western Kenya can be overcome through a combined application of organic and inorganic fertilizers. An experiment was conducted with maize (*Zea mays*) for two seasons to compare two methods of applying inorganic P fertilizer (broadcast versus spot) in a factorial combination with three N sources, i.e. farmyard manure (FYM), *Tithonia diversifolia* green manure (tithonia) and urea. Net financial benefits of the tested practices were computed using partial budgeting. Maize yield was not significantly affected by the P fertilizer application method in the first season, but the broadcast method was generally superior to spot application in the second season. The three N sources produced maize yields that were comparable in both seasons. FYM integrated with P fertilizer applied using the broadcast method, however, had the highest cumulative net benefit and was therefore the most economically attractive input combination.

INTRODUCTION

Phosphorus deficiency is a major constraint to crop production in many parts of western Kenya. Correction of P deficiency in these soils requires the application of mineral P fertilizers because most of the commonly available organic materials are low in P. However, P in most of the P fertilizers applied to these soils is rapidly fixed and this may impact negatively on the profitability (Buresh *et al.*, 1997). The method of application can significantly influence the availability of added P fertilizer to the crop. Broadcasting (BR) of P fertilizer at low rates enhances P fixation by bringing the fertilizer into close contact with the soil (Sanchez and Salinas, 1981). Therefore spot application (SP) which minimizes contact between the fertilizer and the soil has been recommended for smallholder farmers in western Kenya. However, SP is laborious and hence less attractive to the farmers especially where labour is limiting. Moreover, there are conflicting reports on the superiority of SP over BR in increasing crop yields with some results suggesting that BR could in fact be superior to SP in P-fixing soils (Warren, 1992).

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Phosphorus deficiency often occurs simultaneously with that of N in western Kenya and efforts are currently directed towards evaluating the agronomic effectiveness of what are thought to be cheap locally available organic materials as sources of N. The strategy being employed is to have these organic materials supply all the N needs for the crop and supplement them with inorganic P fertilizers because they are low in P. It is known that some of these organic materials can reduce P-fixation and enhance the availability and use efficiency of P by plants (Guppy *et al.*, 2005). Therefore, when organic materials with the capacity to reduce P-fixation are integrated with mineral P fertilizers, BR and SP methods may be equally effective. The choice of the fertilizer application method and the organic material to be used should, therefore, be based on economic considerations. However, economic analyses in the studies evaluating the use of organic inputs in combination with inorganic fertilizers are rare, thus limiting the farmers' ability to make informed choices. This study is an attempt to extend and develop these evaluations by linking agronomic performance to financial returns. The specific objectives of this study were: (i) to compare the effects on maize yield and financial benefits of two phosphate fertilizer application methods, BR and SP, when P fertilizer is combined with urea, tithonia and FYM; and (ii) to determine the influence of urea, tithonia and FYM on the availability of P in a P-fixing soil.

MATERIALS AND METHODS

The experiment was conducted on a smallholder farm in Siaya District of western Kenya (0°7′N, 34°24′E) at an altitude of 1400 m asl and with a mean annual rainfall of 1800 mm with two growing seasons per year: the long rainy season from March to August and short rainy season from September to January. The soil was an Orthic Ferralsol (FAO/UNESCO, 1990) with the following characteristics: pH 5.4, exchangeable acidity 0.3 $cmol_c\ kg^{-1}$, total soil organic carbon 15.9 $g\ kg^{-1}$, exchangeable Mg 1.9 $cmol_c\ kg^{-1}$, exchangeable Ca 4.7 $cmol_c\ kg^{-1}$ and resin extractable P 3.2 $mg\ kg^{-1}$. It had a moderate P-fixing capacity with a soil P concentration of 0.2 $mg\ l^{-1}$ corresponding to 355 $mg\ P\ kg^{-1}$ adsorbed by the soil.

The experimental treatments (see Table 4) were selected to allow the following comparisons:

1. Treatments 3 and 4, 5 and 6, and 10 and 11 compared the effects of P fertilizer application method when tithonia (3 and 4), urea (5 and 6) or FYM (10 and 11) were used as the sources of N at equal N (60 $kg\ N\ ha^{-1}$) and P (20 $kg\ P\ ha^{-1}$) levels.
2. Treatment 2 was compared with treatment 7 or 8 to determine the agronomic effectiveness of tithonia alone when compared to inorganic fertilizers at the same N (60 $kg\ N\ ha^{-1}$) and P (6 $kg\ P\ ha^{-1}$) levels. A similar comparison for FYM was provided by treatments 9 vs 12 or 13 (60 $kg\ N\ ha^{-1}$ and 14 $kg\ P\ ha^{-1}$). Plots measuring 5 m × 3 m were demarcated and prepared manually.

A randomized complete block design with four replications was used. Nutrient inputs were applied in the first season only. In the SP method, triple superphosphate (TSP) was put in the planting holes and mixed with soil before two maize seeds were placed in each hole and covered with soil. In the BR method, TSP was broadcast by hand and then incorporated into top soil (0–15 cm depth). Urea, tithonia and FYM were applied to provide the area recommendation of 60 kg N ha^{-1} (FURP, 1987). The tithonia biomass had 3.3 % N, 0.3 % P and 4.1 % K, and the FYM had 1.0 % N, 0.3 % P and 1.2 % K. Urea, FYM and tithonia were evenly spread within the appropriate experimental plots and incorporated to a depth of 0–15 cm at the time of planting. However, urea was applied at only one-third of the full rate and the rest was applied five weeks after planting (WAP). Muriate of potash (KCl) was applied at a rate of 100 kg K ha^{-1} to all plots at the time of planting maize. Hybrid maize (HB 512 variety) was grown for two consecutive cropping seasons, October 1998–February 1999 (short rains) and April–August 1999 (long rains), using the recommended agronomic practices of the area.

Soil sampling and analysis

Composite soil samples were collected from the inter-rows of all BR treatments and the control at 3, 9 and 16 WAP of the first crop. Sampling was not done for the SP treatments because the fertilizer was within the planting holes and attempts to sample the holes would damage the maize roots. All the soil samples were analyzed for resin extractable P, while P sorption characteristics were determined for soils sampled from treatments 1, 2, 7, 9 and 12 at 16 WAP (Table 4) using standard procedures (ICRAF, 1995). The adsorption data obtained were fitted in the Langmuir equation, the linear form of which is expressed as follows: $c/q = 1/kb + c/b$, where c (mg P l^{-1}) is the equilibrium concentration, q is the amount of P adsorbed per unit mass of soil, b is the P adsorption maximum and k is a constant related to the energy of adsorption. The P adsorption capacity of treatment 2 (tithonia alone) and treatment 7 (urea + TSP, 6 kg P ha^{-1} BR) were measured to assess whether tithonia alone reduced P adsorption capacity in comparison to TSP which provided an equivalent amount of P to tithonia. Similarly, treatments 9 (FYM only) and 12 (urea + TSP, 14 kg P ha^{-1} BR) allowed comparison of the reduction in P adsorption capacity due to FYM alone with TSP that provided an equivalent amount of P to FYM. No soil sampling was done in the second season. All the grain yield and extractable soil P data were subjected to analysis of variance (ANOVA) using the Genstat statistical package (GENSTAT, 1993). The standard error of the differences (*s.e.d.*) was used to compare the treatment means at $p < 0.05$.

Economic analysis

Costs and benefits of each treatment were compared using partial budgeting, which included only those that varied from the control (Table 1). The prices of maize, TSP, urea and fertilizer transport costs were determined through a market survey of the area. Amounts of labour for the application of fertilizer, FYM and tithonia were determined from ICRAF (1996) and Jama *et al.* (1997). The discount rate of capital was estimated at 10 % per season (20 % per year) and applied only to cash costs. This discount rate reflects a farmer's preference to receive benefits as early as possible and

Table 1. Values used for cost benefit analysis.

Parameter	Value†
Price of TSP	0.48 USD kg^{-1} fertilizer
Price of urea	0.53 USD kg^{-1} fertilizer
Transport of TSP and urea to the homestead	1.75 USD 100 kg^{-1}
Labour cost	0.22 USD $hour^{-1}$
Baseline labour cost for fertilizer application‡	
BR	1.37 USD ha^{-1}
SP	4.11 USD ha^{-1}
Labour cost for application of additional fertilizer§	
BR	0.28 USD kg^{-1}
Price of FYM¶	70 USD 100 kg^{-1}
Baseline labour cost for FYM application††	5.88 USD ha^{-1}
Cost of cutting and application of 1.82 t ha^{-1} of tithonia¶	82 USD
Price of maize	16.44 USD 100 kg^{-1}
Opportunity cost of capital	20 %

TSP: triple superphosphate; BR: broadcast application; SP: spot placement; FYM: farmyard manure.
†Exchange rate of 70 Kenya shillings = 1 US dollar (USD) (1999).
‡Cost of application of 10 kg ha^{-1} as TSP and 60 kg ha^{-1} as urea. Includes cost of transport of fertilizer within the homestead.
§Values of FYM and tithonia are expressed on dry weight basis.
¶Cost of application of fertilizer above or below the baseline rate of 10 kg ha^{-1} as TSP Calculated at 0.2 % of the baseline cost per additional kg or lesser of fertilizer.
††Cost of application of 10 kg P ha^{-1} includes cost for collection and transport of materials within the homestead. Cost for application of rates above or below 10 kg P ha^{-1} was directly proportional to the quantity of material applied.

to postpone costs. All monetary values were converted to US dollars (USD) at the mean exchange rate of the Kenya shilling in 1999 (70 Kenya shillings = 1 USD).

RESULTS

Phosphorus sorption and extractable soil phosphorus

None of the applied nutrient sources, whether organic or inorganic reduced the P adsorption capacity of the soil compared to the control as shown by the Langmuir sorption parameters (Table 2). It is worth noting, however, that although statistical significance was not attained, less P was adsorbed by soil treated with tithonia (326 mg P kg^{-1}) and FYM (331 mg P kg^{-1}) than that treated with similar amounts of P from TSP (350 and 346 mg P kg^{-1}respectively). This apparent reduction in P adsorption by the organic materials was accompanied by a reduction in P adsorption affinity, k, but not in the P adsorption maximum, b.

The extractable soil P generally increased with increasing rates of P application at all three sampling times (Table 3). At 3 WAP the extractable P from urea + TSP BR (7.0 mg kg^{-1}) was significantly higher than FYM + TSP BR (5.2 mg kg^{-1}) but similar to tithonia (6.2 mg kg^{-1}) at the same P rate. There was a general decline in extractable P from 3 WAP to 16 WAP. This was however more pronounced where the

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Table 2. Effect of organic and inorganic sources of nutrients on phosphorus adsorption characteristics.

Treatment	Total P added (kg ha^{-1})	k (l mg^{-1})	b (mg P kg^{-1})	q (mg P kg^{-1})
Control	0	6.7	620.5	355.3
Urea + TSP BR	6	6.7	620.3	350.4
Tithonia	6	5.4	636.6	326.1
FYM	14	6.1	632.2	330.6
Urea + TSP BR	14	6.9	603.8	346.0
s.e.d.	14	0.7	24.1	16.2

k: adsorption affinity; b: adsorption maximum; q: P adsorbed at an equilibrium solution of 0.2 mg P kg^{-1}.
TSP: triple superphosphate; BR: broadcast application of phosphate fertilizer.

Table 3. Effect of organic and inorganic sources of nutrients on extractable soil P.

Treatment	Total P added (kg ha^{-1})	Extractable P (mg kg^{-1}) 3 WAP	9 WAP	16 WAP
Control	0	3.2	3.2	2.7
Tithonia	6	3.5	3.9	3.0
Urea + TSP BR	6	3.6	3.8	3.6
Tithonia + TSP BR	20	6.2	5.4	5.2
Urea + TSP BR	20	7.0	4.7	4.3
FYM + TSP BR	20	5.2	5.0	4.2
FYM	14	4.2	4.9	3.1
Urea + TSP BR	14	5.4	4.4	3.3
s.e.d.		0.6	0.7	0.5

WAP: weeks after planting; SP: spot placement; BR: broadcast application of phosphate fertilizer;
TSP: triple superphosphate; FYM = farmyard manure.

treatment combination consisted of only inorganic fertilizers (e.g. urea + TSP BR, at 20 kg P ha^{-1}, declined from 7.0 mg kg^{-1} at 3 WAP to 4.7 mg kg^{-1} at 16 WAP).

Maize grain yield

Maize grain yields for all the treatments in the first season were generally low and ranged from 0.5 to 1.8 t ha^{-1} but improved considerably in the second season when they were between 1.3 and 2.8 t ha^{-1} (Table 4). At the low P rate (6 kg P ha^{-1}, Treatments 2, 7 and 8), the grain yields were similar to the control in both seasons. They, however, generally increased with increasing rates of total applied P with most of the treatments that received the highest P rate (20 kg P ha^{-1}) having significantly higher yields than the control. There were substantial residual responses in the second season at the highest P rate but not at lower rates. Treatment 10 (FYM + TSP BR at 20 kg P ha^{-1}) had the highest increase in yield above the control (87 %) in the second season while treatment 8 (Urea + TSP BR at 6 kg P ha^{-1}) had the least (−13 %). The organic materials when applied alone had comparable yields to inorganic fertilizers applied at similar N and P levels in both seasons (Treatments 2 vs 7 or 8 and treatment 9 vs 12 or 13).

Table 4. Effect of nutrient sources and phosphate fertilizer application methods on maize grain yields.

	Nutrient rate (kg ha^{-1})						Grain yield (t ha^{-1})	
	From organics		From inorganics		Total		Season	
Treatment	N	P	N	P	P	N	1	2
1. Control	0	0	0	0	0	0	0.8	1.5
2. Tithonia	60	6	0	0	6	60	0.8	1.6
3. Tithonia + TSP BR	60	6	0	14	20	60	1.8	2.4
4. Tithonia + TSP SP	60	6	0	14	20	60	1.8	2.2
5. Urea + TSP BR	0	0	60	20	20	60	1.8	2.7
6. Urea + TSP SP	0	0	60	20	20	60	1.4	1.9
7. Urea + TSP BR	0	0	60	6	6	60	0.6	1.4
8. Urea + TSP SP	0	0	60	6	6	60	0.5	1.3
9. FYM	60	14	0	0	14	60	1.3	1.9
10. FYM + TSP BR	60	14	0	6	0	60	1.5	2.8
11. FYM + TSP SP	60	14	0	6	20	60	1.4	2.3
12. Urea + TSP BR	0	0	60	14	20	60	1.2	2.2
13. Urea + TSP SP	0	0	60	14	14	60	1.0	1.9
s.e.d.							0.40	0.36

N: nitrogen; P: phosphorus; TSP: triple superphosphate; SP: spot placement; BR: broadcast application of phosphate fertilizer; FYM: farmyard manure.

Table 5. Effect of nitrogen sources and phosphate fertilizer application methods on grain yields (t ha^{-1}).

	P fertilizer application method					
	Season 1			Season 2		
N source	BR	SP	Mean	BR	SP	Mean
Tithonia	1.8	1.8	1.8	2.4	2.2	2.3
FYM	1.5	1.4	1.5	2.8	2.3	2.6
Urea	1.8	1.4	1.6	2.7	1.9	2.3
Mean	1.7	1.5	1.6	2.6	2.1	2.4
s.e.d. N source	0.32			0.21		
s.e.d. P source	0.27			0.71		

N: Nitrogen; P: Phosphorus; SP: spot placement; BR: broadcast application of phosphate fertilizer; FYM: farmyard manure; P fertilizer was applied at 20 kg P ha^{-1} and N at 60 kg N ha^{-1} to all the treatments. *S.e.d.* is the standard error of difference between means.

Analysis for the factorial combination of two application methods (BR vs SP) and three N sources (tithonia, FYM and urea) indicated no significant interaction between the phosphate fertilizer application method and the N source in either season. No significant effects of P application method on grain yields in the first season were observed (Table 5). However, in the second season BR was generally superior to SP at the comparable rate of 20 kg P ha^{-1}. There were no significant differences in grain yields due to the three N sources in either season at comparable P fertilizer

Table 6. Effect of nitrogen sources and phosphate fertilizer application methods on added costs and net benefits.

Treatment	Total P	Added cost (USD ha^{-1})	Net benefits (USD ha^{-1}) Season 1	Net benefits (USD ha^{-1}) Season 1 and 2
1. Control	0	–	–	–
2. Tithonia	6	164	−179	−163
3. Tithonia + TSP BR	20	200	−28	130
4. Tithonia + TSP SP	20	205	−33	95
5. Urea + TSP BR	20	121	71	293
6. Urea + TSP SP	20	127	−14	44
7. Urea + TSP BR	6	86	−106	−127
8. Urea + TSP SP	6	92	−138	−193
9. FYM	14	104	31	97
10. FYM + TSP BR	20	123	51	302
11. FYM + TSP SP	20	128	22	173
12. Urea + TSP BR	14	105	−45	77
13. Urea + TSP SP	14	111	−57	20

P: phosphorus; TSP: triple superphosphate; SP: spot placement; BR: broadcast application of phosphate fertilizer; FYM: farmyard manure; USD: United States Dollar. Nitrogen was applied at 60 kg ha^{-1} to all the treatments except the control.

application methods. Averaged over the two application methods at the highest P rate (20 kg P ha^{-1}), the cumulative grain yield for the two seasons as affected by urea (3.9 t ha^{-1}), FYM (4.1 t ha^{-1}) and tithonia (4.1 t ha^{-1}) were comparable.

Economic analyses

Added costs were higher for treatments associated with tithonia than FYM and urea mainly due to labour costs (Table 6). The net benefits for BR were higher than SP at the same P rate and N source. Apart from the three treatments associated with FYM (9, 10 and 11) and treatment 5 (urea + TSP BR), which had positive net benefits, all the other nine treatments had negative net benefits in the first season. The highest (71 USD ha^{-1}) were obtained with urea + TSP BR at a P rate of 20 kg ha^{-1} while tithonia applied alone at a rate of 6 kg ha^{-1} had the least (−179 USD ha^{-1}) in the first season. A comparison of the N sources averaged over the two P fertilizer application methods, at the same P rate, showed that FYM had the highest net benefit (238 USD ha^{-1}) followed by urea (169 USD ha^{-1}) and tithonia (113 USD ha^{-1}) for the two seasons. The best treatment was FYM + TSP BR with a cumulative net benefit of 302 USD ha^{-1}.

DISCUSSION

The initial extractable soil P levels at the site were low and therefore maize grain yields were expected to increase with increasing rates of P application. The failure of maize to respond to an application of 60 kg N ha^{-1} at low P rates indicates that P was more limiting than N at this site. The application of organic materials (FYM and tithonia) integrated with small amounts of TSP did not significantly increase the availability of P in this soil when compared to sole application of inorganic fertilizers (TSP + urea), at the same P rate, as would have been expected. This is likely to be due to the low rates of organic inputs applied in this study (e.g. 1.82 t ha^{-1} of tithonia). Palm *et al.* (1997) reported that increased availability of soil P and reduction in P adsorption can be achieved only at high rates of application of high quality organic inputs. This was confirmed by Nziguheba *et al.* (1998) who used 5 t ha^{-1} of tithonia to effect a reduction in P-fixation capacity in the study area. This rate of application is, however, impractical under normal smallholder farming conditions where availability of the organic inputs is often limited. Although our results showed non significant ($p < 0.05$) reductions in P adsorption by the organic materials, it is likely that repeated seasonal applications of these materials at the low rates could eventually reduce P adsorption.

The generally higher extractable P at 3 WAP for urea + TSP than for tithonia + TSP and FYM + TSP at the same P rate is attributed to the greater solubility of TSP than P in organic material which is mostly in the organic form and must mineralize before it becomes available. In the urea + TSP treatment, all of the 20 kg P ha^{-1} were provided by TSP compared with 14 and 6 kg ha^{-1} for tithonia and FYM respectively. The organic materials, however, seem to have mineralized within a short time because at 9 WAP, the extractable P levels from these treatments were similar to those from the inorganic fertilizers. At the end of the first season (16 WAP), there were still significant amounts of extractable P above the control in treatments where P was applied at higher rates. This appears to be the residual P that contributed to increases in grain yields above the control in the second season.

In both seasons, the grain yields were lowest in the control and the treatments where P was applied at the lowest rates (Table 4). The grain yields were higher in the second than the first season although nutrient inputs were not applied in the second season. This was largely due to differences in rainfall during the two cropping seasons with 1120 mm recorded for the second crop and 660 mm for the first crop. Apart from the unreliable rain, the short rainy season in western Kenya is often characterized by increased incidences of pests and the maize streak virus disease, which often lead to poor yields and negative financial benefits as was found in the first season. This may partly explain why many farmers in the area practice fallowing in the short rains despite their small land sizes.

The lack of significant differences in grain yields between the BR and SP methods of P fertilizer application in the first season is consistent with findings by Okalebo *et al.* (1990). Other agronomic studies in Africa indicate occasional but not consistent superiority of SP compared to BR of P fertilizers (Buresh *et al.*, 1997). The rate of P application seems to be an important factor in determining which of the two methods is superior. Kang and Yunusa (1977) found BR to be better at high rates (> 100 kg P ha^{-1}) while at moderate rates (20–40 kg P ha^{-1}), similar to those used in some of our treatments, the two methods were equally effective. At suboptimal rates (8–16 kg P ha^{-1}), Fox and Kang (1978) found SP to be superior to BR, which contrasts with our results. The generally inferior performance of SP in the second season in our

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study is attributed to possible non-uniform redistribution of the P fertilizer that was applied in the planting hole in the first season, as a result of tillage of the plots for the second crop. It is likely that during planting of the second season crop, some plants in the SP treatments were established in spots where there was little or no fertilizer P. This may not have been the case for BR where fertilizer was evenly spread within the plots.

Elsewhere, in tropical America Yost *et al.* (1979) found BR to be superior to localized placement (banding) of P fertilizer for the first crop. They attributed this to the fact that banding of P concentrated maize root development around the area of application. When a temporary drought struck, these plants suffered more than those in BR plots, which showed more extensive root development. These experiences led to the recommendation of an initial BR followed by annual localized applications of soluble P on soils with high P-fixation capacity and low available P (Sanchez and Salinas, 1981).

The extractable soil P and grain yield data suggest that the organic materials, i.e. FYM and tithonia, were as effective as TSP and urea in providing P and N respectively to maize. This confirms findings by Buresh and Niang (1997) and Lekasi *et al.* (2003) which indicated that tithonia and FYM were effective sources of nutrients and could substitute for commercial fertilizers on smallholder farms. Although earlier studies in Kenya treated FYM as a source of P to be augmented by N fertilizers (Probert *et al.*, 1995), our study demonstrates that FYM can also be treated as an N source to be supplemented with P fertilizers.

Farming practices that are economically profitable in the short-run usually attract farmers' interest and are therefore more likely to be adopted. In our study, the FYM treatments had relatively higher net benefits than the tithonia treatments at comparable N and P rates. This is mainly attributed to the lower labour costs for FYM and its high N/P ratio (10:3) compared to tithonia (10:1). Less TSP was therefore purchased (reducing costs) for the FYM treatments than for the tithonia treatments to make the total of 20 kg P ha^{-1}. This seems to have compensated for the generally high labour requirements for handling FYM, as the added costs for the FYM treatments were comparable to those of using inorganic fertilizers alone (TSP + urea). Consequently the net benefits for the best FYM and urea treatments for the two seasons, i.e. FYM + TSP BR (302 USD ha^{-1}) and urea + TSP BR (293 USD ha^{-1}), were comparable. As for tithonia, the costs involved in cutting, carrying and incorporating it into the soil were very high. This coupled with its low P content makes it an unattractive source of nutrients for maize. It is worth noting, however, that in the first season when nutrient inputs were applied, only the FYM treatments were consistently economically attractive. This appears to vindicate the widespread use of FYM by farmers in the area. Attempts to promote the use of tithonia as a source of nutrients for maize have failed probably because the socio-economic aspects of this technology had not been adequately considered before it was presented to farmers. The farmers, however, appreciate the importance of tithonia as a nutrient source and prefer to use it on high value crops such as kale or as an amendment to compost manures (Buresh and Niang, 1997).

CONCLUSIONS

Our study revealed no added agronomic benefit of SP as compared to the BR method of P fertilizer application. There may be, therefore, no merit in the current agricultural extension recommendation that smallholder farmers apply P fertilizers in the planting holes instead of broadcasting. FYM and tithonia were as effective as urea in increasing maize yields and can therefore be used as substitutes for urea as nitrogen sources for maize. Economic analyses, however, indicated that use of BR as the P fertilizer placement method and FYM as the source of N, supplemented with small amounts of TSP, was the most economically attractive combination.

This study highlights the importance of economic analyses in agronomy studies as practices that appear to be technically sound such as tithonia biomass transfer can be economically unattractive leading to their rejection by farmers. Since FYM was beneficial from both the agronomic and economic viewpoints, agricultural extension efforts should be directed towards assisting smallholder farmers in western Kenya to manage FYM properly on their farms with a view to increasing both its quantity and quality, which are currently low. This will reduce the need for purchased inorganic fertilizers and hence make farming more profitable.

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