Effects of organic and mineral sources of nutrients on maize yields in three districts of central Kenya

Kimani S.K.[1*], Esilaba A.O.[1], Odera M.M.[1], Kimenye L.[2], Vanlauwe B.[3] and Bationo A.[3]
[1]*Kenya Agricultural Research Institute, Muguga South, P.O. Box 30148, Nairobi, Kenya.*
[2]*Department of Agricultural Economics, University of Nairobi, P.O. Box 29053, Nairobi, Kenya.*
[3]*Tropical Soil Biology and Fertility Institute of CIAT, P.O. Box 30677, Nairobi, Kenya.*
[*]*Corresponding author. Kenya Agricultural Research Institute, Muguga South, PO Box 30148 Nairobi, Email: skimani@africaonline.co.ke*

Abstract

Trials were set up in three districts of central Kenya to evaluate organic and mineral sources of nutrients and their effects on maize yields. The experiments were set up during the long rains 2004 with fifteen different soil fertility management treatments. The treatments included cattle manure, green manures, maize stover, *Tithonia*, and mineral fertilizer. The test crop was maize (*Zea mays*), intercropped with beans (*Phaseolus vulgaris*). The experimental design was a Randomized Complete Block with three replicates. At final harvest at maturity, grain yield data were recorded. In general the yields were low ($\leq$1t ha^{-1}) in the unfertilized control, in plots intercropped with green manure cover crops, and where maize stover alone was applied. In Kirinyaga, and Maragwa, the highest maize grain yields (6.5t ha^{-1}) were obtained when manure was combined with mineral fertilizer. The responses were not as clear in the Kiambu site, possibly due to soil acidity at the site. There were no significant difference ($p = 0.05$) in grain yields between the green manure cover crops (0.4–1.5t ha^{-1}), maize stover (0.3–0.9t ha^{-1}) and the unfertilized control (0.4–1t ha^{-1}) across treatments and sites during this first season. The work confirms the efficiency of combining mineral sources of nutrients with organic inputs.

Introduction

Maize (*Zea mays*) is the staple food crop in Kenya and is grown over a wide range of agro-ecological zones. The area under maize production is estimated has presently stagnated at 1.5 million hectares, with an expected national production of 2.52 million tonnes and a national consumption of 3 million tonnes (Government of Kenya, 2002), indicating a production deficit. Soil fertility depletion in smallholder farms is the major cause for declining per-capita food production in most of sub-Saharan Africa (Sanchez et al., 1997). The central Kenya Highlands, where this study was carried out, covers approximately 18% of the land area of the country but contains around 64% of the population, with population densities in excess of 1,000 people per square kilometre in many areas (Braun et. al., 1997). In this highly populated region, maize yields can decline by about 30% in the absence of fertilizer and/or manure application (Quereshi, 1987). The use of inorganic fertilizers can overcome most of this soil fertility decline. A survey in Kiambu district, central Kenya showed high cost and unavailability of fertilizer as major constraints to fertilizer use in maize production (Makokha et al., 2001). An alternative to this, is the utilization of farm-derived sources of crop nutrients such as crop residues, composts and farmyard manure (Delve et al., 2001; Lekasi, 2000; Kihanda, 1996).

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Legume cover crops and biomass transfer from trees and shrubs growing along farm borders have also been used as alternative sources of nutrients (Jama et al., 2000; Mafongoya and Nair, 1997).

In central Kenya, manure is the most widely used organic fertilizer, by approximately 80% of households (Makokha et al., 2001). Of these about 90% of farmers use manure from their farms, while 10% either purchase it or are given free. However, in the majority of farms, the available manure is not enough to fertilize the farms (Makokha et al., 2001; Lekasi et al., 1998; Kihanda, 1996; Kagwanja, 1996). Most manures from farmers fields have less than 1% N and therefore do not contain enough nutrients to sustain crop production (Giller et al., 1997). In comparison, legume cover crops can have over 3% N (Palm et al., 2001). In addition, manures can have beneficial effects on other factors, for example, improvement in soil physical conditions such as improved moisture retention and addition of micronutrients, other than N and therefore play an important role in production systems (Kihanda and Gichuru, 1999). The best option would be to overcome the nutrient deficiencies through the combined use of cattle manures with modest amounts of inorganic fertilizers as a strategy to maintain and enhance soil fertility.

To date there are no recommended guidelines for combining organic and inorganic nutrients because of inadequate experimental design and little information on the quality of organic inputs used (Palm et al., 1997). However, recent studies to better define manure quality, and possible combinations with mineral fertilizers have been useful in furthering the hypothesis of manure and mineral fertilizer combinations (Kimani and Lekasi, 2004; Kimani et al., 2004).

The objectives of this study were therefore to compare the effects of different sources of organic nutrients on maize production.

Materials and methods

Experimental sites: The study sites were three districts of central Kenya, namely Kirinyaga, Maragwa and Kiambu. These districts differ in socio-economic conditions and also in soil fertility management.

On-farm trials were conducted at one site in each of the three districts that were identified to be N deficient. The trials were set up at Mukanduini area of Kirinyaga (0°35" S, 37° 17"E 1000 m a.s.l.), Kariti (0°52' S, 37° 01' E, 2000 m a.s.l.) in Maragwa and Githunguri (0° 56'S 37° 05' E, 2200 m.a.s.l) in Kiambu. At Kariti, mean annual rainfall is 1300–1600 mm and annual mean temperatures of 19.7–18.0°C. Githunguri has a mean annual rainfall of 1200–1400 mm and annual mean temperature of 18.4–19.5°C, while Mukanduini has a mean annual rainfall of 1000–1200 mm and annual mean temperatures of 21–22°C. The soils for the three sites are well-drained, extremely deep, dusky red to dark reddish brown, friable clay (Humic Nitisol). Surface soils were sampled (0–15cm), air-dried and ground to pass a 2 mm sieve and characterized for pH (in water), total C (Walkley-Black), total N (Kjeldahl), total P, Ca, Mg and K (extracted in NH4OAc). Details of the analytical methods are described by Anderson and Ingram (1996).

Three field trials with 15 different soil fertility treatments were established in each of the study Districts. Plots sizes were 4 by 6m with three replicates in a randomized complete block design. Maize was sown at a spacing of 90 by 30 cm during 4th April at Kirinyaga, 24th April at Kandara and during 25th April at Githunguri. Beans were also planted in plots where leguminous green manures were not included. The varieties of maize planted were H13 in both sites. Rose coco beans were used for the inter-planting. The maize was harvested at maturity on 3rd, 10th and 19th September 2003 for Mukandu-ini, Kariti, and Githunguri respectively. This paper only reports on the maize yield data.

The 15 soil fertility management technologies included unfertilized control, manure + mineral fertilizer (5t ha^{-1}; 20kg N ha^{-1}), manure + mineral fertilizer (5t ha^{-1}; 40 kg N ha^{-1}), manure + mineral fertilizer (5t ha^{-1}; + 60kg N ha^{-1}), and manure + mineral fertilizer (5t ha^{-1}; +80kg N ha^{-1}). Other treatments included compost (10t ha^{-1}), maize stover (5t ha^{-1} + decomposing bacteria, EM1), maize stover alone (5t ha^{-1}), tithonia (5t ha^{-1}) and the green manure cover crops mucuna (*Mucuna pruriens*), crotalaria (*Clotalaria ochlereuca*) and Dolichos (*Dolicos lablab*). The rest of the treatments comprised mineral fertilizer (100 kg N ha^{-1}), manure (5t ha^{-1}) and manure (10t ha^{-1}).

Grain yield data were collected at final harvest, which was done on 3rd, 10th, and 19th September respectively for Mukanduini, Kariti and Githunguri respectively.

Statistical analysis

Data were analyzed using SAS (SAS Institute Inc. 1988). Significant differences between treatments are reported at the $p \leq 0.05$ level.

Table 1. Three-site characterization in Central Kenya.

Site	Depth	PH	% C	Mineral N ppm	% N	ppm P	ppm K	ppm Ca	ppm Mg	ppm Na	CEC (cmol/Kg)
Kariti	0–20	4.98	1.06	14.65	0.19	81.073	376.699	1217.800	93.56	9.087	4.440
	20–40	5.01	1.22	12.69	0.20	50.631	327.132	1422.467	125.56	9.087	4.958
	40–60	5.32	1.10	10.18	0.18	22.275	354.040	1566.267	157.56	9.769	5.522
Kirinyaga	0–20	5.63	1.07	41.11	0.13	505.547	98.073	965.533	588.22	12.803	4.139
	20–40	5.60	0.80	37.85	0.11	429.991	61.067	915.400	515.11	12.291	4.105
	40–60	5.70	0.82	12.78	0.06	357.547	51.816	867.067	371.00	11.779	3.450
Kiambu	0–20	4.61	1.92	37.92	0.20	33.020	210.712	394.633	131.67	20.279	2.164
	20–40	4.56	2.23	27.77	0.21	20.843	162.774	373.300	106.44	15.228	1.860
	40–60	4.67	1.83	24.65	0.19	13.287	128.532	441.433	133.89	11.187	2.040

Results and discussion

Table 1 shows the general characteristics of the soils based on some selected parameters. Soil pH was around 5 for Kariti and 4.6 for Githunguri. The Kariti soil could be described as moderately acidic, whilst the Githunguri soil is strongly acidic. The carbon content was higher for Kiambu at 2% compared to Kariti at 1.1%. The higher C levels may have contributed to the relatively higher mineral N at Githunguri. P levels were lower in Kiambu at 30 ppm compared with Kariti at 80 ppm for surface soils and highest in Kirinyaga. The cation exchange capacity was much lower in Kiambu at 2 cmol kg^{-1}, compared with Kandara at 5 cmol kg^{-1}, which could be attributed to lower levels of Ca and K at Githunguri. From the soils data, it appeared that the Githunguri soil was less fertile compared to Kariti. Soil fertility at the Kirinyaga site could be described as in between the other two sites, with more favorable soil pH >5.5, but with exceptionally high values of available P at 500 ppm for surface soils.

Table 2. Mean maize yields during the long rains, 2003 in three sites in Central Kenya.

Treatments	SITE		
	Mukanduini	Kariti	Githunguri
Manure 5t ha^{-1}	3.996	2.83	2.30
Manure 10 t ha^{-1}	4.460	4.36	3.04
Manure 5t+20Kg N	3.222	4.28	3.17
Manure 5t+40Kg N	5.378	5.89	2.61
Manure 5t+60Kg N	6.507	6.14	2.61
Manure 5t+80Kg N	6.542	6.82	1.79
100Kg N	3.348	5.24	2.84
Tithonia 5 t ha^{-1}	4.682	4.02	1.36
Compost 10 t ha^{-1}	2.980	3.08	2.22
Maize stover 5t ha^{-1}	0.824	0.78	0.32
Maize stover 5t ha^{-1} +EM1	0.853	0.92	0.33
Crotalaria	1.404	1.45	0.73
Dolichos	1.018	1.40	0.56
Mucuna	0.492	1.03	0.73
Unfertilized control	0.944	1.07	0.37
LSD $_{(0.05)}$	**2.16**	**1.24**	**1.40**

Maize grain yields

Overall, grain yields were higher at Kariti, followed by Mukanduini and lowest in Githunguri (Table 2).

Manure alone when applied at 5 t ha^{-1} increased grain yields by 300%, 164%, and 500% at Mukanduini, Kariti and Githunguri respectively. Increasing the applied manure to 10 t ha^{-1} resulted in an increase in grain yield of 370%, 300% and 700% respectively for Mukanduini, Kariti, and Githunguri respectively. The results indicate only a slight increase in grain yields at Kariti on increasing the manure rate, from 5–10t ha^{-1}, but twofold increase at Mukanduini. The greater response Mukanduini and Githunguri could be attributed to the water shortages, due to lower total rainfall, particularly at Githunguri (Data not shown) which could have been alleviated by the increase in water holding capacity associated with manure application. Combining manures with mineral fertilizers resulted in high yields at Mukanduini and Kariti. This response was not observed for Githunguri possibly due to the high levels of soil acidity. Similarly for the Githunguri site, the response for the mineral fertilizer was not as pronounced as in the other two sites (Table 2). The combinations resulted in higher yields with the increase in the level of mineral fertilizer application. Combining manure with 40 kg N ha^{-1} or more mineral fertilizer resulted in higher yield than using a high rate of mineral fertilizer (100 kg N ha^{-1}).

Tithonia addition increased maize yields significantly at all sites. However the increase was most pronounced at Mukanduini (400%), and Kariti (275%) and less at Githunguri (70%). Maize stover suppressed yields at all sites during this growing season. This is attributable to immobilization of nutrients particularly nitrogen by the stover addition (Delve et al., 2001). Application of bacteria, EM1, on the incorporated maize stover had no effect on maize yield, suggesting that its ability to decompose the maize stover may require further study.

The green manure cover crops were not effective during this season since they had just been introduced. The normal practice is to grow them for the first season, then incorporate them during the subsequent season. Consequently, this paper may not discuss the effects of these amendments.

Conclusions and implications

Soil fertility can be ameliorated by application of manures singly or in combination with mineral fertilizers. Singular application of manure resulted in an increased relative maize yields of 3.5, 3.3, and 2.7t ha^{-1} for Mukanduini, Kariti, and Githunguri, respectively. The combinations of manure and fertilizer resulted in higher maize yields, compared with the singular application of either manure or mineral fertilizer. This integration, however, may be more feasible, as an option for farmers, considering the high costs of mineral fertilizers, and the level of resource endowment of most farmers in the study areas. Variability in soil fertility across the sites as shown by the carbon and cation exchange capacity levels indicate that formulation of recommendation domains may need to consider this variability. While biomass transfer resulted in more than a fourfold maize yield increase, availability of the materials remains a problem. Finally, it is important to perform economic analysis for the various technologies, in order to develop feasible recommendations for farmers.

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