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LOW COST SOIL FERTILITY MANAGEMENT STRATEGIES FOR IMPROVING MAIZE PRODUCTION IN THE CENTRAL HIGHLANDS OF KENYA

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ABSTRACT

Continuous decline in soil productivity is a major constraint to the improvement of livelihoods of smallholder farmers of Kenya. In highlands, levels of soil nitrogen, phosphorus and sometimes potassium are low and the situation is worsened by the methods of cultivation that results in nutrient mining rather than nutrient build up. Low soil fertility contributes to one of the greatest challenges currently facing Kenya; inadequate food production for the rapidly growing population. There is a need to seek for environmentally friendly and economically viable technologies to assist in soil fertility improvement and hence high and sustainable crop yields. To this end, a multidisciplinary research team of scientist and farmers implemented a participatory trial in Meru South district, one of the main maize growing areas of central Kenya. The trial was farmer-researcher managed with a general objective of offering small scale resource poor farmers with feasible soil nutrient management techniques for combating soil nutrient depletion caused by continuous cropping without adequate additions of external soil fertility inputs. Preliminary results indicate that maize performance may be improved by combining fast decomposing plant biomass (e.g. Tithonia diversifolia) with half the recommended rate of nitrogen fertilizer.

Key words: Low cost soil fertility management strategies

INTRODUCTION

The central highlands of Kenya are characterised by complex farming systems dominated by perennial cash crops, food crops and livestock. The soils are deep, well drained, weathered humic nitisols with moderate to high inherent fertility. Over time, soil fertility has declined due to continuous cropping with little nutrient replenishment (Ikombo, 1984). The use of inorganic fertilizers is generally low, less than 20 kg N and 10 kg P ha^{-1} $season^{-1}$ (Murithi, *et al.* 1994). This amount is inadequate to meet crop nutritional requirements for optimum crop yields at farm level. Due to the high cost of inorganic fertilisers and low prices of farm produce, over 80% of farmers use farmyard manure (FYM) to improve soil fertility and crop productivity (Maize Data Base, 1993). The usefulness of FYM is however limited mainly due to its variability and often-low nutrient concentrations. In addition, the large quantities (5–10 Mg ha^{-1}) needed to supply adequate nutrients (Kihanda, 1996; Nzuma, *et al.*, 1998), may not be available on-farm.

Research by Gachengo (1996), Nziguheba *et al* (1998), Mugendi, *et al.* (1999), and Mutuo, *et al.* (2000) reported positive results with the application the use of biomass from *Tithonia*, *Calliandra* and *Leucaena* for soil fertility replenishment. These materials are supplementary components in soil fertility improvement and need to be evaluated on-farm by farmers and other stakeholders in agricultural production processes. This paper reports information from a participatory on-farm trial conducted in the predominantly maize growing zones (UM_2/UM_3) of Meru South District with the aim of evaluating and providing integrated soil fertility management strategies for increased agricultural production by smallholder farmers.

METHODOLOGY

The site was in the predominantly maize growing zone or upper midlands (UM_2/UM_3) with an altitude of approximately 1500m asl and annual mean temperature of about 20^0C. The annual rainfall varies from 1,000 to 1,400mm and falls in two seasons, the long rains (LR) lasting from March through June and short rains (SR) from October through December (Jaetzold and Schmidt 1983). The soils are deep, well drained, weathered humic *Nitisols* with moderate to high inherent fertility. Over time, the soil fertility has declined due to continuous cropping with little nutrient replenishment.

The trial was laid out in a randomised complete block design (RCBD) with 3 replicates. Maize (*Zea mays* L, var. H513) was the test crop and planted at the onset of rains in plots measuring 6 m x 4.5 m and spacing of 0.75m and 0.5m inter- and intra-row, respectively. Three (3) seeds were sown and thinned to 2 plants per hole after four weeks to make approximately 53,300 plants ha^{-1}. Soil fertility amendment external inputs consisting of farm yard manure (FYM), *Tithonia diversifolia, Calliandra calothyrsus* and *Leucaena diversifolia* biomasses and combinations of each of these organic materials with half the recommended rate of inorganic fertilizer (30 kg ha^{-1} of both N and P) formed the first eight treatments. The ninth treatment consisted of inorganic fertilizer at the recommended rate (30kg ha^{-1} of both N and P). Lastly, the tenth treatment was the unfertilised control. The applied treatments are shown in Table 1.

All, except FYM organic materials were applied while fresh and incorporated into the soil to a depth of 15cm during land preparation. This was done one week before the onset of the rains. Samples of each material were collected and analysed for N and P concentrations (Table 1). The compound fertiliser (23:23:0) was the source of inorganic P and N and was applied at maize sowing. Routine agronomic procedures for maize production were appropriately followed. Two hand weedings were done the first within four weeks after the onset of rains and the second at maize flowering. Stalk borers were controlled by use of borercide. At harvest, one row on either side of the plot and the first and the last plants of each row were removed to make the net plot where data (biophysical, economic and farmers' evaluation) were collected and synthesised. Biophysical data was analysed using SAS computer programme, while the economic data were computed to provide the most beneficial technology on net-benefit and benefit/cost ratio basis.

Farmers around the site (Kirege primary school) were encouraged to visit the trials and make comments on various soil fertility management strategies based on the availability of the materials and the general crop performance. This was particularly done during various field operations and farmers open-day conducted at seed filling stage. The trial was on-going by the time of this write up and therefore the results reported herewith are preliminaries of what had already been achieved. Plant response to P deficiency was visually scored 50 days after the crop emergence using a scale of 1-4 (Table 2). A score of 1 was used in cases where no plant P-deficiency was observed while 4 was used where severe P-deficiency response was

Table 1. Applied organic soil amendments and their nutrient concentrations (%) values

Treatment	N	P	Ca	Mg	K	Ash
FYM	1.4	0.2	1.0	0.4	1.8	46.1
Tithonia	3.0	0.2	2.2	0.6	2.9	13.2
Calliandra	3.3	0.2	1.0	0.4	1.1	5.8
Leucaena	3.8	0.2	1.4	0.4	1.8	8.7

observed. Plant height is an important parameter in determining the final plant yields. The maize plant height was recorded 70 days after emergence, just before flowering and when the crop was supposed to be at its optimal vigour (Table 2).

RESULTS AND DISCUSSIONS

Biophysical

The total rainfall within the growing season was 126 mm and most of it recorded within the first 20 days of the season. The phenomena differed significantly (P = 0.05) between treatments and had an average mean of 2.3. Plants under *Tithonia* with 30 kg N and P ha^{-1} had an average value score of 1.0 while those planted with 60kg ha^{-1} of both N and P and FYM with 30kg ha^{-1} of both N and P had a score of 1.3 and 1.6, respectively. Table 2 shows that high P-deficiency was observed in plants grown under *Tithonia, Calliandra, Calliandra* + 30kg ha^{-1} of both N and P and control with an average score value of 3.0. This could have been as a result of the low P concentration in the organic materials compared to the recommended rate of 60kg ha^{-1} P application in the area.

The low moisture in the soil during the season could have worsened the situation as this could have meant that most of the organic materials did not fully decompose in time, thus P was not released for the plants. This shows that the organic inputs cannot by themselves be options to curbing P deficiency in the soil but should be integrated with inorganic sources of P as reported by Palm (1995). This was well illustrated in the case of *Tithonia*, which showed high P deficiency (3.0) with sole *Tithonia* application but showed a low (1.0) P deficiency when integrated with the inorganic fertilizer. Nziguheba, *et al.* (1998) reported that *Tithonia* biomass could slightly reduce P adsorption and increase soil biological activities, which might enhance availability of P and other nutrients by cycling through labile soil organic pools. Table 2 shows that treatments that received inorganic fertilizer plus organic inputs had significantly higher maize height than all other treatments. Plant heights were lower than normal (120cm) for 70 days old medium maturity cultivars. This was associated inadequate precipitation received during the growing season. As a result, reduced maize grain yields were obtained at the end of the season (Table 2).

The average maize grain yields across the treatments was 1.9Mg ha^{-1} (Table 2). Application of recommended rate of inorganic fertilizer (60kg ha^{-1} of both N and P $season^{-1}$) gave an average grain yield of 2.8Mg ha^{-1}. This was closely followed by organic inputs with half recommended rate that ranged from 2.0 Mg ha^{-1} for *Leucaena* with 30kg ha^{-1} of both N and P $season^{-1}$ to 2.5 Mg ha^{-1} for *Tithonia* with 30kg ha^{-1} of both N and P $season^{-1}$. *Calliandra* and unfertilised control gave the lowest maize grain yields of 1.0 – 1.3Mg ha^{-1}, respectively. The average maize grain yield during the season was far below the expected potential yield of 6Mg ha^{-1} for (*Var.* H513) for the area. Yields obtained were 68% less than expected. This was associated to low rainfall (average 126 mm) recorded during the season. A general conclusion drawn from the results is that application of the recommended rate of inorganic fertilizer and a combination of any of the organic soil amendment inputs with 30 kg N and P ha^{-1} gave the best yields under the harsh conditions.

SOCIO-ECONOMICS

One of the reasons that lead to the acceptance of a new technology by farmers is its profitability. For example, a farmer would like to know the monetary gains by adopting an agricultural option. In most situations farmers only adopt technologies that have higher net benefits than the current practices. However, socio-cultural considerations may influence farmers to adopt other technologies rather than those with the highest net benefits. The information used for socio-economic analysis were collected at different times of the season. For instance, the cost of seeds, weed control and crop removal from the field were recorded during planting, weeding and harvesting time, respectively. The main source of the data was

Table 2. Maize performance under different soil fertility amendment

Treatment	Scored plant P deficiency (50 days after emergence	Plant Height (70 days after emergence (cm)	Grain weight (Mg ha^{-1})
Cattle manure	2.3b	30b	1.7b
Tithonia biomass	3.0a	40b	1.8b
Calliandra biomass	3.0a	31b	1.0c
Leucaena biomass	2.0a	32b	1.9b
Cattle manure + 30 kg N & P ha^{-1}	1.6c	50a	2.4a
Tithonia + 30 kg N & P ha^{-1}	1.0d	59a	2.5a
Calliandra + 30 kg N & P ha^{-1}	3.0a	46a	2.1a
Leucaena + 30 kg N & P ha^{-1}	2.3b	46a	2.0ab
60 kg N & P ha^{-1}	1.3c	53a	2.8a
Unfertilised control	3.0a	30b	1.3c
Mean	2.3	41.7	1.9
CV%	31.9	17.8	35.4

Note: Values followed by the same letter are not significantly (p=0.05) different.

farmers, extensionists and agro-input stockists. Table 3 gives benefit-cost and cost benefit ratio of growing maize under various soil fertility management strategies. The socio-economic data collection and analysis assumed that labour for carrying out various farm activities was always hired and tools were brought to the farm by the labourers. An other assumption was that the average annual interest rate for money in a bank savings account was 12% and that maize (H513) took 5 months from planting to harvesting/selling. Hence, the interest rate was computed for 5 months (Table 3).

The inorganic input of N and P at the rate of 60 kg ha^{-1} gave the highest net benefit of Ksh. 74,899.00 and net benefit cost ratio (BCR) of 3.4 (Table 3). This means that a farmer would get Ksh 3.40 for every shilling used in maize production. The second and third best were cattle manure + 30 kg N and P ha^{-1} and tithonia + 30 kg N and P ha^{-1} treatments with Ksh 57,345.00 and Ksh 52,824.00, and a BCR values of 2.2 and 1.6, respectively.

Figure 1 shows that although some treatments had a higher net benefit (NB), they had respectively lower benefit cost ratio (BCR). For example, *Leucaena* had NB of Ksh. 30,577 and BCR of 0.8 compared to the control that had an NB of Ksh. 28,099 and BCR of 1.7 or manure treatment with NB of 37,821 and BCR of 1.7 compared to tithonia with NB of 38,766 and BCR of 1.4. Therefore, considering NB alone may be misleading for BCR seems to be the most appropriate economic tool for determining the most economical soil fertility amendment technologies.

TRIAL EVALUATION BY FARMERS

The trial evaluation by farmers was based on general field or crop performance such as plant height, cob size and plant vigour. The evaluation was qualitative and results are summarized in Table 4. Plant height was recorded at grain filling stage where farmers used visual judgement to describe the height based on the position of cobs from the ground.

Table 3. Cost-benefit ratio of maize production under different soil fertility management.

Variable activities/ input (Ksh ha^{-1})	Soil fertility management options (Treatments)									
	FYM	Tithonia biomass	Calliandra biomass	Leucaena biomass	FYM + 30kg N & P ha^{-1}	Tithonia + 30 kg N & P ha^{-1}	calliandra + 30kg N & P ha^{-1}	Leucaena + 30kg N & P ha^{-1}	60kg N & P ha^{-1}	Unfertilised control
Fixed cost (FC)[2]	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,000
Organic and Inorganic fertilisers[3]	3,333	7,500	15,000	15,000	5,083	10,750	18,250	18,250	6,500	0
Harvesting	1,900	2,100	1,100	2,100	2,700	2,800	2,300	2,200	3,100	1,400
Empty bags (@ 25/=)	472	500	278	528	667	694	583	556	778	361
Purchase & application of storage dust @ 10/ = bag^{-1}	190	200	110	210	270	280	230	220	310	140
Total variable cost (TVC)	5,895	10,300	16,488	17,838	8,720	14,524	21,363	21,226	10,688	1902
TVC adjusted at 33% loss due to drought	7,840	13,699	21,929	23,725	11,598	19,317	28,413	28,231	14,215	2,530
Total cost (TC) = Adjusted [4]TVC + FC	20,840	26,699	34,929	36,725	24,598	32,317	41,413	41,231	20,715	15,530
Cost of capital	1,042	1,335	1,746	1,836	1,223	1,616	2,071	2,062	1,036	777
Final TC	21,882	28,034	36,675	38,561	25,821	33,933	43,484	43,293	21,751	16,307
Maize grain (tons ha^{-1})	1.7	1.8	1	1.9	2.4	2.5	2.1	2	2.8	1.3
Stovers	6.1	8	5.2	8	8	8.5	8	7.5	10.3	5.2
Grain sales (@ Ksh 1400 per 90kg bag)[5]	26,600	28,000	15,400	29,400	37,800	39,200	32,200	30,800	42,400	20,000
Stover (@ Ksh ton^{-1})	9,150	12,000	7,800	12,000	12	12,750	12,000	11,250	15,450	7,800
Total sales	35,750	40,000	23,200	41,400	49,800	51,950	44,200	42,050	57,850	26,800
Total sales (adj at 67% loss due to drought)	59,703	66,80	38,744	69,138	83,166	86,757	73,814	70,224	96,610	44,756
Net Benefit (NB)	37,821	38,766	2,069	30,577	57,345	52,824	30,330	26,931	74,859	28,099
Benefit/cost ratio (BCR)	1.7	1.4	0.06	0.8	2.2	1.6	0.7	0.6	3.4	1.7

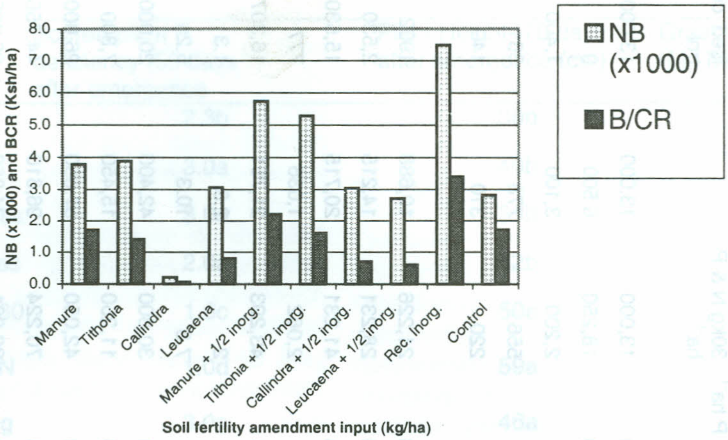

Figure 1. Comparison of net benefit (NB) and benefit cost ratio (BCR)

Table 4. Maize evaluation results by farmers, on basis of soil fertility management inputs

Treatment	Plant height	Cob size	Plant vigour
Cattle manure (CM))	Short	Small	Poor
Tithonia *(T)*	Medium	Medium	Good
Calliandra *(Cc)*	Short	small	Poor
Leucaena *(Ld)*	Short	Small	Poor
CM + 30 kg N and P ha^{-1}	Medium	Medium	Good
T + 30 kg N and P ha^{-1}	Tall	Medium	Good
Cc + 30 kg N and P ha^{-1}	Medium	Medium	Good
Ld + 30 kg N and P ha^{-1}	Medium	Medium	Good
60 kg N and P ha^{-1}	Tall	Medium	Good
Unfertilised control	Short	Small	Poor

Plants planted with [60 kg ha^{-1} of both N and P] and those with [*Tithonia* +30 kg ha^{-1}of both N and P] were tall while the ones with cattle manure; *Calliandra*, *Leucaena* biomass and unfertilised control treatments were short. The rest of the treatments had medium plant height. The farmers recorded medium cobs in all treatments except under FYM, *Calliandra*, *Leucaena* and control treatments, which had small cobs. Plant vigour was recorded 50 days after crop emergency. Good plant vigour was recorded in all treatments except those under FYM, *Calliandra*, *Leucaena* and control, which had poor plant vigour.

A general comment from farmers' evaluation was that the *Tithonia* biomass + 30 kg N and P had almost the same performance with the recommended rate (60kg ha^{-1} of both N and P ha^{-1}) of inorganic plant nutrients. Hence, a recommendation by farmers to use *Tithonia* biomass in soil fertility improvement and crop production in the maize growing zones where *Tithonia* is commonly available at farm level planted as a boundary hedge and on the road reserves. The farmer evaluation compared well with the biophysical data analysis which indicated that inorganic fertilisers have to be integrated with organics for better maize yields.

CONCLUSION

Low maize yields in central highlands of Kenya are a common phenomena due to low soil nutrients. The situation may be arrested through use inorganic and organic fertilizers, but more feasibly when organic and inorganic inputs are combined. The recommended rate (60 kg ha^{-1} of both N and P) of inorganic fertilizer gave the highest maize yields, thus farmers with high resource endowment may adopt it while those with low resource endowment may be encouraged to grow maize under organic and inorganic combination soil management strategies.

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