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Soil microbial biomass changes with application of organic and inorganic in acid soil in Embu County, Kenya

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Declining in soil fertility continues to affect food production by affecting soil and crop productivity in the Central Highlands of Kenyan (CHK). One of the major components and drivers of soil fertility is the soil microbial biomass which contributes nutrients released through organic matter decomposition. Soil acidity contributes for reduced microbial biomass, fertility and crop yields. To evaluate the influence of manure, lime, P fertilizer and their combination on the soil microbial biomass an experiment was conducted in Embu-ATC comprising 8 treatments. The study included manure (0, 5 and 10 t ha\(^{-1}\)), Lime (0 and 2 t ha\(^{-1}\)) and P fertilizer (0, 30 and 60 kg P ha\(^{-1}\)). The experiment was laid out as RCBD with 4 replicates in plots of 4x4.5m. Soil samples were collected at harvest and subjected to microbial biomass analysis. The microbial biomass was analyzed by the chloroform fumigation and extraction method. Data generated was analyzed by use of SAS and LSD was used to separate means at 95% of confidence level. The results showed that application of manure, lime or their combination plus P fertilizer contributed to increased soil conditions and supplied nutrients for microorganism's survival enhancing therefore soil microbial biomass N. Subsequently it was concluded that application of manure and lime are required in the CHK to promote microorganism’s development.

Keywords: Manure, Lime, P fertilizer, soil microbial biomass.

INTRODUCTION

Most studies are focused on fertilizer either organic or inorganic to improve soil fertility, health and crop yields in most of the farming systems worldwide. But less is addressed in regard to microorganisms in the soil and its role to promote soil fertility. However organic resources are the primary source of plant nutrient which are made available through microorganism decomposition. The Soil Microbial Biomass (SMB) is the active component of the soil organic pool, playing an important role in nutrient cycling, plant nutrition and functioning of different ecosystems (Logah et al., 2010; Lin et al., 2010). It is responsible for organic matter decomposition thus affecting soil nutrient content (Onwonga et al., 2010). As such, the biomass is both a source and sink of the nutrients C, N, P and S contained in the organic matter (Lin et al., 2010; Basu et al., 2011). Soil microorganisms are significant determinants of organic matter decomposition, soil nutrient status, crop health, and overall crop productivity (Basu et al., 2011). Soil MB is undoubtedly a valuable tool for understanding and predicting changes in soil fertility management and associated soil conditions such as nutrient dynamics and soil reactions (Sharma et al., 2004). However changes in soil conditions (plant or animal residues) will determine how fast the microbial biomass responds (Onwonga et al., 2010). In the Central Highlands of Kenya (CHK) the

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soils are mainly acidic humic nitisols. The prevalence of soil acidity is responsible for the lower soil microbial community which results in the low organic matter as a consequence of reduced poor turnover of organic residues. The low soil organic matter also contributes for low levels of nitrogen (N), phosphorus (P), carbon (C) and other nutrients. These disadvantageous conditions contribute for poor soil fertility and crop performance. Therefore, understanding soil microbial biomass dynamics is particularly critical in the management of acid soils, to reverse declining soil organic matter content and restores soil fertility. Several researchers have reported the positive influence of soil amendments on soil microbial biomass (Onwonga et al., 2010; Basu et al., 2011; Bhadoria et al., 2011; Fuentes et al., 2006). In order to study the microbial biomass dynamics in the soil of CHK a study was conducted to evaluate the effects of applied manure, lime and P fertilizer on soil microbial biomass.

## MATERIAL AND METHODS

### Site description

The experiment was carried out at Embu Agricultural Training College (Embu-ATC); located in Embu West district (0°35’ 25.58”S and 37° 25’ 31.84”E); in Central Highlands of Kenya at an elevation of 1494 m above sea level. Embu West district is in Upper Midland 2 and 3 (UM 2 -UM 3) agro ecological zones having an altitude of about 1440 m a.s.l with annual temperature of about 20°C and annual rainfall of 909 - 1230 mm (Jaetzold et al., 2006). The rainfall is bimodal with two seasons; long rains (LR) in March through to June and Short Rains (SR) from October through to January. Over 65% of the rains occur in the LR season (Jaetzold et al., 2006).The soils are mainly humic Nitisols (Jaetzold et al., 2006), which are deep, well weathered with moderate to high inherent fertility but over time soil fertility has declined due to continuous mining of nutrients without adequate replenishment. Recent studies have reported that they have generally low levels of organic carbon (< 2.0%), nitrogen (<0.2 %), phosphorus (< 10 ppm) and are moderately acidic (pH ranges from 4.8 – 5.4), conditions that result in low crop production (Mugwe, 2007). The district is a predominantly maize growing zone with small land holdings ranging from 0.1 to 2 ha with an average of 1.2 ha per household.

The area is characterized by rapid population growth, low agricultural productivity, increasing demands on agricultural resources and low soil fertility. The farming systems are complex consisting of an integration of crops trees and livestock, and smallholder farms that are intensively managed (Mairura et al., 2007). Livestock production is a major enterprise, especially dairy cattle that is of improved breeds. Other livestock in the area include sheep, goats and poultry.

### Experiment design and field management

The experiment was conducted for 2 seasons (2012 short rain season (2012SR) and 2013 long rain season (2013LR)), and set as a Randomized Complete Block Design (RCBD) in plots measuring 4.0x4.5 m and replicated four times. The experiment had 8 treatments with the following factors; manure (M) (0, 5 and 10 t ha⁻¹ as goat manure); Lime (0, 2 t ha⁻¹ as CaO) and P fertilizer (0, 30 and 60 kg P ha⁻¹) as Triple Super Phosphate (TSP). The treatments were:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Factor</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Manure</td>
<td>(M)</td>
<td>10 t ha⁻¹ M</td>
</tr>
<tr>
<td>2. Lime</td>
<td>(L)</td>
<td>2 t ha⁻¹ CaO</td>
</tr>
<tr>
<td>3. TSP</td>
<td>(P)</td>
<td>60 kg ha⁻¹ P₂O₅</td>
</tr>
<tr>
<td>4. Manure+Lime</td>
<td>(ML)</td>
<td>5 t ha⁻¹ M + 2 t ha⁻¹ CaO</td>
</tr>
<tr>
<td>5. Manure+TSP</td>
<td>(MP)</td>
<td>5 t ha⁻¹ M + 30 kg ha⁻¹ P₂O₅</td>
</tr>
<tr>
<td>6. Manure+Lime+TSP</td>
<td>(MLP)</td>
<td>5 t ha⁻¹ M + 2 t ha⁻¹ CaO + 30 kg ha⁻¹ P₂O₅</td>
</tr>
<tr>
<td>7. Lime+TSP</td>
<td>(LP)</td>
<td>2 t ha⁻¹ CaO + 30 kg ha⁻¹ P₂O₅</td>
</tr>
<tr>
<td>8. Control</td>
<td>(C)</td>
<td>No inputs</td>
</tr>
</tbody>
</table>

Land was ploughed manually using a hand hoe followed by leveling 2 weeks before planting. Manure and lime, with regard to required rate, were broadcasted and then incorporated in the soil within 15 cm depth, using hand hoe also 2 weeks before planting. TSP was the source of P and was applied per furrow and well mixed with the soil at planting.

### Soil sampling and determination of Microbial Biomass (MB)

Soil samples were collected at harvest of 2012 SR and 2013 LR season at 15 cm depth, using soil auger. Fresh soil samples were packed in cooler box and transported to the laboratory. Soil microbial biomass N was determined by chloroform fumigation-extraction method (Okalebo et al. 2002; Sark and Hader, 2005). Three subsamples of 10 grams each were obtained from each subsample. For the first subsample was determined gravimetric moisture content by drying it for 48hr at 105°C (Okalebo et al., 2002), to enable express MB in a soil dry weight basis. The remaining 2 samples were analyzed for total N after subjecting one of the subsamples (10g) to chloroform fumigation. Thereafter the subsamples were extracted using 0.5M K₂SO₄. Total
N was determined by Kjeldahl method whereby N was determined colorimetrically after acid digestion (Okalebo et al., 2002; Sark and Hader, 2005; Ryan et al., 2001). The microbial biomass nitrogen was estimated as the difference in total N content between fumigated and control (non-fumigated) samples.

\[
\text{Microbial Biomass N} = N_{\text{fumigated}} - N_{\text{control}} \quad (1)
\]

Data analysis

Data generated was subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS) version 8. The means were subjected to \( t \)-test at 95% of confidence to test means difference. Least Significance Difference (LSD) at 95% of significance level was used to separate means.

RESULTS

During 2012 SR there was observed significant differences in soil microbial biomass among the treatments \((p = 0.0335)\) as result of treatment application (Table 1). The application of sole lime treatment recorded the highest value of 48.59 mg kg\(^{-1}\) soil therefore increasing microbial biomass by 2.1 folds against the control. These was not statistically different from the application of 5 t. ha\(^{-1}\) of manure combined with 30 kg P ha\(^{-1}\), sole manure and combination of 5 t. ha\(^{-1}\) of manure with lime plus 30 kg P ha\(^{-1}\) which recorded 41.4 mg kg\(^{-1}\), 39.23 mg kg\(^{-1}\) and 30.44 mg kg\(^{-1}\), thus increased microbial biomass by 1.8, 1.7 and 1.3 folds respectively. In the other hand the lowest microbial biomass increase was observed under combined application of 5 t. ha\(^{-1}\) of manure with lime and sole application of 60 kg P ha\(^{-1}\) by 1.2 folds over the control.

In the 2013 LR season the microbial biomass values showed significant differences \((p = 0.0308)\) as a result of treatment application. During the same period the application of 10 t. ha\(^{-1}\) of manure treatment recorded the highest value of 74.99 mg kg\(^{-1}\) soil which corresponded to an increase of 75.55% over the control. This was followed by the application of 5 t. ha\(^{-1}\) combined with lime plus 30 kg P ha\(^{-1}\) (68.85 mg kg\(^{-1}\) soil) and lime alone (66.89 mg kg\(^{-1}\) soil) treatments which increased by 59.34% and 54.80% respectively. Though, there were not significant differences amongst them and against sole manure. Contrary, the application of 5 t.ha\(^{-1}\) of manure plus 30 kg P ha\(^{-1}\) and 60 kg P ha\(^{-1}\) less increased on microbial biomass by 31.36% and 35.76% respectively and against the control.

DISCUSSION

Soil microbial biomass, a living part of soil organic matter, is an agent of transformation for added and native organic matter and acts as a labile reservoir for plant-available nitrogen, phosphorus and sulphur (Logah et al., 2010), therefore it can be used as an indicator of the soil microbial status characterization (Nannipieri et al., 1990). The application of L, MP and MP treatments respectively most increased significantly microbial biomass. The application of lime alone increased significantly microbial biomass in both seasons and this may be a result of increased soil pH and nutrient availability which in turn improved soil conditions for microorganism’s development. However, when lime was combined with either manure or both manure plus P fertilizer increased microbial biomass in the 2012 SR, but not significantly. Meanwhile in 2013 LR the same treatments increased significantly microbial biomass, and this fact may be explained by the lime effect on reducing soil acidity over the time. The results are in similarity with those of Filep.

Table 1: Effects of manure, lime and P fertilizer on SMB during 2012 SR and 2013 LR (0 - 15 cm depth) at Embu, Kenya.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>2012 SR</th>
<th>2013 LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>39.23(^{ab})</td>
<td>74.99(^{a})</td>
</tr>
<tr>
<td>Lime</td>
<td>48.59(^{a})</td>
<td>66.89(^{ab})</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>28.41(^{bc})</td>
<td>58.66(^{abc})</td>
</tr>
<tr>
<td>Manure+Lime</td>
<td>27.09(^{bc})</td>
<td>65.13(^{ab})</td>
</tr>
<tr>
<td>Manure+Phosphorus</td>
<td>41.40(^{ab})</td>
<td>56.76(^{bc})</td>
</tr>
<tr>
<td>Manure+Lime+Phosphorus</td>
<td>30.44(^{bc})</td>
<td>68.85(^{ab})</td>
</tr>
<tr>
<td>Lime+Phosphorus</td>
<td>27.48(^{bc})</td>
<td>64.31(^{ab})</td>
</tr>
<tr>
<td>Control</td>
<td>23.26(^{c})</td>
<td>43.21(^{c})</td>
</tr>
<tr>
<td>(p)-value</td>
<td>0.0335(^*)</td>
<td>0.0308(^*)</td>
</tr>
<tr>
<td>LSD((0.05))</td>
<td>15.54</td>
<td>16.81</td>
</tr>
</tbody>
</table>

\(\text{LSD}\) (Least Significant Difference) at 95% of significance level.

\(\text{ab}\) indicating differences significant at 95% confidence level.
and Szili-Kovács (2010), Fuentes et al. (2006) who also reported increased soil microbial biomass when lime was applied. Furthermore, the soil pH was strongly and significantly correlated ($R^2 = 0.74$; $p = 0.0065$) with microbial biomass in 2013 LR (Figure 1), therefore it suggested that the soil acidity plays an important role on microorganism’s survival. Several other researchers have reported decreased microbial biomass due to application of lime (He et al. 1997; Lorenz et al., 2001). This probably explains the poor response in plots that received lime combined with manure and P fertilizer in the 2012 SR, although this was not expected, and can be associated with short period of time of which lime was exposed.

Application of manure alone and when combined with P fertilizer increased significantly microbial biomass during the 2012 SR, while M, ML and MLP increased significantly in the 2013 LR. It seemed that the application of lime affected positively on microbial biomass but its effect was relatively slow. These results are similar to those of Tennekoon (1990), Mohammadi (2011), Onwonga et al. (2010), Cerny et al. (2008) who had also reported significant effects of manure on SMB. The positive effect of full rate of manure can be due to the rate of manure which contributed to increased soil pH and supply of nutrients in relatively high amount than when it was combined. Additionally it can be stated that when manure was applied in combination with P fertilizer and lime there was a synergetic effect in providing nutrient P which is much vital for microorganism survival and development which in return contributed for significant increase on microbial biomass. The increase can also be a result of greater amounts of biogenic materials like mineralizable nitrogen (Mohammadi, 2011), soil moisture, temperature and availability of substrate provided by application of manure (Logah et al., 2010; Onwonga et al., 2010). In other hand application of P fertilizer alone increased but numerically SMB and this maybe associated to poor labile N and other nutrients present in the soil which may be also related to the lower soil pH which hindered microorganism’s survival and activity as well as the rate of organic material applied to the soil.

**CONCLUSION**

Soil Microbial Biomass N responded better and significantly to lime, manure and the combination of manure, lime and P fertilizer. The application of manure, lime or their combination plus P fertilizer contributed to increased soil conditions and supplies nutrients for microorganism’s survival and enhanced organic matter decomposition, mineralization and partly crop yields.

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**REFERENCES**


