Effect of Mavuno and farmyard manure and fertilizer application on soil properties in western Kenya

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Abstract

The study was undertaken to evaluate the effect of organic and inorganic fertilizer application on soil chemical and biological properties in Siaya and Vihiga districts of Kenya. The experiment was set up in a completely randomized block design with a split plot arrangement with the fertility gradients (high and low) as the main plots and the treatments (IR maize control, manure only and mavuno + manure) as the sub plots. IR maize was the test crop. Soil pH, organic C, P and total N were analyzed at initial, flowering and at maturity maize growth stages. Organic carbon respiration was recorded at 3, 7 and 14 days of incubation. There were significant differences in P levels between treatment means with mavuno + manure treatment recording the highest mean P levels (11.78) at crop maturity. Soil organic C and total N showed significant differences across sites and treatments prior to planting and at harvest (P<.001). There were significant differences in soil pH across sites prior to planting. Soil respiration showed significant differences across fertility gradients after 7 and 14 days of incubation. A combination of both organic and inorganic fertilizers potentially enhanced both soil biological and chemical properties. Further studies are recommended on dynamics of soil microbial biomass across fertility gradients in smallholder farms.

Key words: fertility gradients, inorganic fertilizer, organic fertilizer, soil respiration.

Introduction

Soil fertility management practices by small holder farmers mainly depend on application of farmyard manure (FYM) since it is cheap and readily available in their fields (Sanginga and Woomer, 2009). Sufficient mineral fertilizers are not available at the right times during the year due to high transaction costs and inefficiencies throughout the production-consumption chain (Nyamangara et al., 2009). Mavuno (10-26-00) is a mineral fertilizer being advanced in western Kenya and the use of local minerals in its production makes mavuno blends less expensive than other mineral fertilizers and hence an alternative option for small holder farmers. However continual use of mineral fertilizers has led to the development of fertility gradients in a single farm. On the other hand Western Kenya is heavily infested with striga weed that strives greatly in low fertile soils. The existence of the fertility gradients therefore enhances the occurrence of this weed. Farmers in Siaya and Vihiga use IR maize in their fields to minimize the effects of striga on their crops. IR maize is a herbicide coated maize that makes it resistant to attacks by striga. Fertilizer manufacturing and blending is shifting to ensure that fertilizers not only have the major macronutrients but also the secondary and micro-nutrients (Sanginga and Woomer, 2009). It is therefore important to carry out research not focusing only on NPK but other elements and their effects of soil properties since soil properties act as possible early-warning indicators of changes in plant and microbial community and changes in nutrient cycling and energy flow processes (Chiurazzi, 2008). This allows us to come up with better management strategies aimed at maximizing the available resources whilst maintaining or improving the soil health and quality. The study was therefore conducted to assess the effects of application of mavuno and manure fertilizers on soil biological and chemical properties in small holder farmer fields in Siaya and Vihiga.
Materials and methods

Fertility trials were conducted on-farm in Siaya (Nyalgunga and Nyabeda) and Vihiga (Emusutswi) in Western Kenya. Mean annual rainfall and temperatures in Vihiga and Siaya are 2000 mm, 24 °C and 1450 mm, 21.75 °C respectively (Cheserem, 2012). Humic nitosols, Nitisols and ferralsols (Emusutswi) and ferralsols and acrisols (Nyabeda, Nyalgunga) are the main soil types (Gachene and Kimaru, 2003). From the three sites, 12 farmers were selected, using Y frame sampling procedure and farms were demarcated into fertility gradients as perceived by farm owners (Tittonell et al., 2010). A randomized complete block design with a split plot arrangement replicated 4 times was used and the main plots were the fertility gradients (high and low) and the subplots were the fertilizer treatments; control, manure and manure+ mavuno. IR maize was used as the test crop and mavuno was applied at a rate of 20 kg P per ha whilst FYM was applied as a projection of 2 tons per ha. IR maize was planted at a spacing of 30 x 75 cm in a plot of size 6 x 4.2 m.

Soil samples were collected at a depth of 0-20 cm using W-sampling (Peters et al., 2008). Soil pH was measured using a soil to water ratio of 1:2.5. Organic carbon and total N were determined using wet digestion method and the Kjedahl method. The Mehlich 1 method was used to determine soil P (Okalebo et al., 2002). Organic carbon respiration was measured using passive CO2 absorption in an alkali trap incubated for 3, 7 and 14 days (Jensen et al., 1996). Analysis of variance was conducted using GENSTAT 14th Edition and the Least Significant Difference (LSD) was used to separate means of significant differences.

Results

There were significant (P<0.001) differences in soil pH across sites at the initial soil sampling (Figure 1). The pH ranged from 5.1-6.0 in all the fields before the maize crop was planted. During the flowering stage there was a slight increase in pH ranging from 5.6-6.1 and at maturity pH ranged from 5.2 to 5.7 (Figure 1). The results showed higher decreases in soil pH in the mavuno+ manure treatment when compared to the manure alone treatment. Does it mean significant?

![Figure 1: pH in different treatments](image)
There were significant differences in P levels between treatment means (p<0.01) at all stages of crop growth. The P levels across sites and treatments were highest at the flowering stage and reduced at maturity (Figure 2).

![Figure 2: Soil P at different growing stages](image)

Soil organic C showed significant differences across sites at the initial soil sampling (P<0.001). The highest mean (2.19%) in Nyabeda which was significantly different from the other sites (Figure 3).

There were no significant differences across sites, treatments or fertility gradients in %OC at the flowering stage. %C was higher at the flowering stage across several treatments than at initial and final sampling stages of maize. The mavuno+ manure treatment had the largest P (11.78 ppm) at maturity stage (Figure 2). The sites and fertility gradients were not significantly different in P content.

![Figure 3: Soil organic C at different growing stages](image)
Figure 3: % OC in across sites, fertility gradients and treatments
Percent C showed significant ($P < 0.001$) differences at crop maturity across sites and treatments (Figure 3). % N showed significant ($P < 0.001$) differences in the sites at the initial stages of the season (Figure 4).

![Figure 3: % OC in across sites, fertility gradients and treatments](image)

Figure 4: % Nitrogen at different levels of maize crop maturity
There were no significant differences in %N across treatments, sites and fertility gradients at flowering and maturity stages as hypothesized. There was however a decrease in %N in most of treatments across the three sampling stages in the order initial < flowering < maturity stages (Figure 7). Soil Respiration showed no significant differences ($P < 0.001$) in treatments means after 3 days of incubation but higher respiration rates were noted from the mavuno+ manure treatment (Figure 8). After 7 days and 14 days of incubation, fertility gradients were significantly different ($p < 0.001$) with higher $C_{org}$ respiration occurring in fields of lower fertility. The soil respiration rates across treatments and sites were generally below 9.5 mgCO2/kg/day (Figure 9) indicating that there was very low soil activity.
Discussion

The differences in pH across sites at initial sampling are attributed to the variations in soil types and rainfall distribution across sites. Emusutswi receives higher rainfall than Nyabeda and Nyalgunga resulting in leaching of cations and accumulation of Al\(^+\) and H\(^+\) ions hence making the soils more acidic. Basu et al. (2011) also found that soil types influenced the pH across different sites. When microbes decompose FYM they produce acids in the process and if these acids are in large amounts, a significant decrease in pH is observed as observed from initial to maturity sampling. These results are similar to those of Nalatwadmath et al. (2003) who recorded that there was a production of acids on decomposition of organic manure (FYM) that resulted to decreases in soil pH.

The decrease in P at the flowering stage is due to crop nutrient uptake as P is a critical element in crop development. The mavuno + manure treatment had the highest P and this is because Mavuno is a P fertilizer and contains 26% P\(_2\)O\(_5\) that improved the soil’s mineral components and on the other hand FYM may have improved the soil’s structure and hence its ability to hold nutrients. Thus the mavuno+ manure treatment created an ideal environment for nutrient uptake by the plant and retention in the soil matrix. These results indicate that a combination of both organic and inorganic fertilizers is better at improving soil P compared to their sole applications. These results are in agreement with those reported by Kathuku et al. (2011) that there was an increase in yield and soil nutrient availability in soil that was added mineral N fertilizer combined with manure when compared to their sole applications. The manure only treatment showed a decrease in P and this could have resulted from the reaction of P with organics in manure to form more stable compounds making it unavailable for plant uptake. Waldrip et al. (2012) supports these findings and observed that manure C content influenced P cycling and reduced P availability in soils amended with manure. Stabilization of P due to low pH may have also resulted in its unavailability for plant uptake (Abaye et al., 2006).

The OC increased during the flowering stage and this may be due to high precipitation during the growing season. The moist environment and moderate temperatures created when it rains, allow soil microbes to become active and hence breakdown organic residues thus increase the soil carbon. This is also suggested by Alvarez and Lavado (1998) that OC in the top 0–50 cm soil layer is positively correlated with the precipitation/temperature ratio. The differences across sites may be attributed to the clay content in the soils of the different sites. The higher the clay content a soil has the higher the %OC it contains due to the stability of clay colloids (Feller and Beare1997). The treatments had an
influence on the %OC as hypothesized when a combination of organic and inorganic amendments were added and not sole application.

Total N showed significant differences at initial sampling and this can be attributed to growing of legumes by farmers in Siaya prior to the experiment which may have fixed nitrogen and hence resulted in a significant differences being observed across sites. Oriola and Bamidele (2012) supported the findings in that cropping systems have effects on soil elements, fertility status and have implications for agricultural productivity. No significant differences were observed in total N across treatments and this is due to the low N content of the FYM (P<10ppm and %OC <5%) added and Mavuno which contains 10% N and also to manure’s slow release of nutrients. Johnson, et al.(1987) further elaborates these findings in that a substrate with low N and high C:N ratio results in a disappearance of nitrates from the soil due to great demand from microbes for reproduction. Nutrient leaching is also evident as the treatments showed no significant differences. N losses can be attributed to leaching down the soil profile due to heavy rains, microbial immobilization and or denitrification. Hoeft et al. (2000) supports the findings and reports that excessive rainfall is an effective agent for removing basic cations resulting in losses in agricultural nutrients.

The higher respiration rates observed in the mavuno+manure treatments could be attributed to higher organic matter present in fertilizer amended plots hence a higher microbial activity as compared to the control plots. These findings are in line with Yuste et al. (2007) who reports that the higher the carbon inputs added to the soil the higher the soil respiration. Soils in this treatment have a medium soil activity indicating that the soil could be approaching or declining from an ideal state of biological activity (United States Department of Agriculture, 2001).This could be due to exposure of organic matter to organisms and oxygen following tillage as suggested by Stoyan et al.(2000).

Conclusions

The pH levels highly affected availability of nutrients to plants causing a general decrease in soil chemical and biological properties in all fields not shown in the results. Soil fertility gradients were not significant across most of the properties but sites and treatments were significant with the mavuno + manure treatment superior over the control and manure only treatments. A combined application of mavuno and FYM therefore has the potential to improve soil properties over their sole application.

Recommendations

- pH levels highly affected the availability of nutrients to plants hence liming should be done in the study area. Not valid – did not evaluate liming
- Farmers can benefit from the integrated use of both FYM and mavuno as this will enable them to save money in procurement of inorganic fertilizers. Not valid.. did not evaluate economics
- Improvement of the management of the FYM is encouraged in order to improve its quality. Does not emanate from the study

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References


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