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REGULAR ARTICLE

Short-term influence of compost application on maize yield, soil macrofauna diversity and abundance in nutrient deficient soils of Kakamega County, Kenya

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Abstract
Background and aims Degradation of physical, chemical and biological properties of soils in sub-Saharan Africa mainly results from little or no organic resource application coupled with sub-optimal fertilizer application. A study was conducted over three seasons, from March 2010 to August 2011, to evaluate potential of six organic materials (bagasse, cow manure, filtermud, maize stover, sugarcane straw and *Tithonia diversifolia*) for compost production and their influence on maize yield and soil fauna diversity.
Methods Treatments comprised of the six composts, commercial fertilizer and no-input control, laid out in randomized complete block design in four replicates. Soil macrofauna were collected using soil monolith method. Data obtained were subjected to analysis of variance (ANOVA) using GENSTAT whereas differences were evaluated using Fisher's least significant difference (LSD). Correlation between macrofauna and soil chemical properties was done using CANOCO 3.1.
Results The ANOVA showed significantly higher N and P on filtermud (10.0 g N kg^{-1} and 979 mg P kg^{-1}) and *T. diversifolia* (9.6 g N kg^{-1} and 614 mg P kg^{-1}) composts. Generally, amending soils with composts increased C, N and P of the soil by 90 %, 29 % and 20 %, respectively, while fertilizer treated plots recorded 42 %, 4 % and 110 % increase in C, N and P, respectively. Control plots recorded 25 % increase in C, but 15 % and 50 % decline in N and P, respectively. Maize yields were highest in fertilizer (4.4 Mg ha^{-1}), followed by composts (2.8 Mg ha^{-1}) and lowest in control plots (1.4 Mg ha^{-1}). Soil macrofauna responded positively to addition of composts. Isopterans, Oligochaeta and Hymenopterans dominated the sites constituting 44 %, 26 % and 17 %, respectively of all the macrofauna. Relationships between macrofauna and soil chemical properties were positively significant.
Conclusions Results of this study demonstrate the potential of composts in improving soil biodiversity and crop productivity.

Keywords Filtermud compost · Soil macrofauna · Soil organic carbon · Soil health · Maize yield

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Introduction

Soil fauna are essential components of soil health as they exert vital ecosystem functions such as organic material decomposition and nutrient cycling, soil structure modification, and biological control of soil borne pests and diseases (Brussaard et al. 2007; Ayuke et al. 2009). The various components of soil health are therefore an expression of the impact soil biota have in an ecosystem. Soil health however, is often associated with management practices applied to the soil. In this regard, soil macrofauna such as earthworms have been recognized as potential bio-indicators of soil disturbance, nutrient enrichment or soil pollution since they relate to various physical and chemical characteristics of the soil (Karanja et al. 2010). Within agroecosystems, soil management practices adopted by the farmers could therefore have positive or negative effects on soil fauna abundance and diversity and the effects may be short-term or long-term depending on the magnitude of soil organic matter changes and the level of soil disturbance (Eggleton et al. 1997; Lavelle et al. 2001; Brussaard et al. 2007). Intensive tillage practices without application of sufficient organic and inorganic inputs, for example, has been reported to diminish soil organic matter which in turn negatively affects soil aggregate stability and soil biota (Saggar et al. 2001; Paul et al. 2013). It has been demonstrated that soil organic matter plays a great role in stimulating soil biota through detoxification of chemical substances that inhibit their growth, direct or indirect supply of energy, and creation of conducive environment that favour their survival (Woomer et al. 1994; Craswell and Lefroy 2001). Maintenance of high levels of soil organic matter through proper management of organic resources therefore remains one of the most viable means of enhancing soil fertility and managing soil biodiversity (Six et al. 2002; Brussaard et al. 2007; Karunditu et al. 2007). Soil macrofauna such as earthworms and termites have been shown to depend on soil organic inputs and therefore their feeding dynamics in the soil could be affected by soil management practices (Mando et al. 1999; Lavelle et al. 2001). This may directly affect their activities in the soil such as burrowing, casting and nesting habits and therefore their influence on physico-chemical properties of the soil (Ayuke 2010). For instance, soil fauna induced decomposition of organic materials and consequently redistribution of soil organic matter through their excretions contributes to aggregation of soil structural units. Such activities improve soil structure and associated functions in aeration regulation, root penetration, water and nutrient availability and ease of uptake of these nutrients by plants (Mando et al. 1999; Ayuke et al. 2009). In addition, some macrofauna such as earthworms also modify soil environment through ingestion of soil together with organic matter thus creating organo-mineral structural units which form micro-habitats for microorganisms to colonize (Lavelle 1997; Lavelle et al. 2001; Sileshi and Mafongoya 2006). The soil structural units are also resistant to erosion forces caused by the increased bonding strength between mineral constituents (Ayuke 2010).

Farmers' efforts to restore and maintain soil fertility have been met by various challenges, the major one being to access and/or using right quantities of inorganic fertilizers (Van Straaten 2002; Karanja et al. 2006). Moreover, little or no agricultural residues are ploughed back to the farms since materials are either burned or field-disposed to facilitate land preparation (Karanja et al. 2006; Achieng et al. 2010). This has led to persistent loss of fertility and eventually degradation of soil, which not only negatively affects crop productivity, but also has long-term devastating effects on soil biodiversity. In western Kenya where small-scale crop-livestock farming system is dominant, use of livestock manure and crop residues as soil amendments is a common practice (Waithaka et al. 2007). However, these organic resources are not sufficient to meet crop nutrient requirements since most of the crop residues are of low quality while livestock manure is handled and stored poorly leading to nutrient losses (Gichangi et al. 2007). Majority of these farmers are also faced with the challenge of converting these materials into quality soil amendments which could arise from limited knowledge and inadequate supportive policies that encourage recycling and utilization of these wastes (Chianu and Mairura 2012). Composting is one of the management practices that can be used to convert these low quality organic resources to stable, nutrient-rich materials for crop production, and also act as a good substrate for soil biota (Lekasi et al. 2003).

In this study, therefore, we assessed soil fauna diversity and abundance in soils amended with composts arising from various feedstocks in two farms at Ivakale and Buyangu in Kakamega County, Kenya. We also assessed correlation between soil macrofauna and soil chemical properties as affected by the composts. The two sites were part of a chronosequence experiment that was designed to investigate soil fauna community structure across land-use management systems in Kenya and Tanzania since 2005 (Ayuke et al. 2007).

Materials and methods

Description of the study site

The study was conducted in Ivakale and Buyangu villages, Kakamega County, western Kenya. The two sites are approximately 20 Km North of Kakamega town. The region lies between latitude 0° 10' N and 0° 21' N; Longitude: 34° 47' E and 34° 58' E, with an elevation of between 1,500 and 1,600 m above sea level. The area receives bimodal rains, with an annual total of about 2,000 mm. The long rains occur between February and July while short rains between August and December. The reliability growth period for cereals and legumes lies between 330 and 340 days (Jaetzold et al. 2005). Temperatures are fairly constant throughout the year with mean daily minimum and maximum of about 11 and 26 °C respectively, while mean annual temperature range between 18 and 27 °C, respectively (Althof 2005). The soils are predominantly luvisols and lixisols (FAO-UNESCO 1987), with moderately to slightly acidic conditions (pH 5.3–5.9), and low inherent fertility as shown by low amounts of nitrogen, soil organic carbon and exchangeable bases (Ayuke et al. 2007). The study sites encompass farmlands adjacent to Kakamega forest. The area was originally occupied by a sparse population of former forest dwelling communities who practiced shifting cultivation, hunting and gathering. The sites have a settlement history dating 100 years with relatively intensive sedentary subsistence mixed agriculture over the last 60 years (Kimetu et al. 2008). High population growth rate and immigration into the area has reduced average land holding to about 0.5 ha per household (Place et al. 2006). Most of the farmlands are therefore characterized by low soil fertility, low crop yields and low on-farm income (Ayuke et al. 2007). Maize, beans and sugarcane are the predominant crops, with most of the fields being through maize/sugarcane rotation over the years (Place et al. 2006). Most farmers also rear livestock comprising mainly of cattle and poultry which supply manure for farming. However, the quantity and quality of these manures are low. Tillage is largely by hand hoeing for low income earners, and oxen plough for those who can afford it.

Selection and composting of organic feedstocks

Six agro-organic wastes that are commonly found in the study area were selected for the purpose of our study. Selection criterion was based on availability of materials. These organic wastes included: *Tithonia diversifolia* trimmings, maize stover, bagasse, filtermud, sugarcane straw and cow manure. Cow manure, maize stover and sugarcane straw were obtained from Buyangu farm; filtermud and bagasse were collected from West Kenya Sugar Company while *Tithonia diversifolia* was obtained from Ivakale farm and transported to composting site. Composting was done at Buyangu using pit method (Inckel et al. 2005). Pits measuring 4×3×2 m were dug in preparation of composting. Large and bulky materials were shredded to smaller pieces, about 3 cm long, to enhance the rate of decomposition. Layering within each pit was done to a thickness of 20 cm, where two liters of water was sprinkled at the top to moisten the materials. This process was repeated till there were about ten layers. Pits were covered with dry grass to ensure aeration and reduce moisture loss. The heaps were composted for eight weeks; turning of decaying materials being done every two weeks to facilitate even decomposition. During turning, about five liters of water was sprinkled to maintain the moisture. Composts were cured for another four weeks and then sieved using a 5 mm sieve in preparation for planting.

Chemical characterization of composts

Samples of all the composts were taken to laboratory for analysis before planting commenced. The samples were analyzed for macro-elements (N, P and K), organic carbon and pH. Organic carbon (C) was determined by wet oxidation using modified Walkley-Black method as described by Nelson and Sommers (1982); total nitrogen (N) by wet oxidation using Kjeldahl digestion and distillation procedures (Parkinson and Allen, 1975) while Phosphorus (P) and potassium (K) were extracted using the dry ashing method and analyzed by an Atomic Emission Spectrophotometer (Kalra and Maynard, 1991). The analysis was done at the Crop Nutrition Laboratory, Nairobi.

Experimental design and treatment combinations

Field trials were carried out on the two farms in plots measuring 5 m by 4 m using maize (variety H-512) as the test crop. There were eight treatments comprising the six composts, fertilizer treatment (Mavuno fertilizer – 10 % N, 26 % P and 4 % MgO) and no-input control.

In each site, treatments were replicated four times in a randomized complete block design. Composts were applied at a rate of 5 Mg ha^{-1} each season based on small-scale manure and compost application rates as recommended by Ncube et al. (2006) and Mapfumo and Giller (2001), while fertilizer was applied at the recommended rate of 26 kg P ha^{-1} and 60 kg N ha^{-1} (Okalebo et al. 2007). Maize was harvested after drying in the farms by cutting the stalks at the base and gathering the crop together within each plot. The cobs were then separated from the stalks and the grains shelled from cobs. The grain yield was determined as Mg ha^{-1}. Finally, after separating the cobs, stalks were removed from the plots in order to retain integrity of applied treatments in preparation for subsequent seasons. However, the stubbles left were incorporated into the soil during land preparation. Broken pegs marking edges of the plots were also replaced.

Soil sampling and analysis

Soil samples were randomly taken from four points on each plot using soil augers to a depth of 20 cm. The soil was mixed well and two composite samples taken for laboratory analysis. The soil properties analysed included; soil pH, available phosphorous (P) and potassium (K), total and available nitrogen (N) and organic carbon (C). Organic C was determined by wet oxidation using modified Walkley-Black (Nelson and Sommers 1982); total N by wet oxidation using Kjeldahl digestion and distillation procedures (Parkinson and Allen 1975), while P and K were extracted by Mehlich-3 procedure (Mehlich 1984) and measured by automated colorimetry using an Atomic Emission Spectrophotometer (Kalra and Maynard 1991). Available N (NO_3^- and NH_4^+) was extracted using 2 M potassium chloride (KCl) and determined using steam distillation method (Bremner and Keeney 1965). The analysis was also done at the Crop Nutrition Laboratory, Nairobi, Kenya.

Macrofauna sampling protocol

Collection of earthworms and other macrofauna was done eight weeks after sowing maize using monolith method. Two soil monoliths (25×25×30 cm) were randomly excavated on each plot using the standard TSBF method as described by Anderson and Ingram (1993). The soil samples were placed in plastic trays and large clods broken-up to enable hand picking of earthworms and other macrofauna. Earthworms were placed in 75 % alcohol after which they were fixed in 4 % formaldehyde and stored in sealed vials. Insects and other arthropods were preserved in 75 % alcohol before being transported in sealed vials to the laboratory for identification, enumeration and biomass determination. Identification was carried out at the Department of Invertebrate Zoology of the National Museums of Kenya, Nairobi. The soil macrofauna abundance was calculated as number of individuals per square meters.

Statistical analysis and data management

Soil fauna data as well as that of soil chemical properties was entered into Excel spreadsheets and subjected to analysis of variance (ANOVA) using GENSTAT statistical software (GENSTAT 11.1 2009) and treatment differences evaluated using Fisher's least significant difference (LSD). Multivariate analysis on macrofauna data was done using CANOCO 3.1 (Ter Braak and Verdonschot 1995; Ter Braak and Smilauer 1998). A preliminary detrended correspondence analysis (DCA) was performed to determine the length of gradient of the first axis, and to decide on the ordination analysis to be used on the macrofauna data. Since the length of gradient of the first axis determined by DCA was <4, linear ordination technique, Redundancy Analysis (RDA), was chosen to assess the correlation between soil chemical parameters and macrofauna abundance. The overall contribution of soil chemical properties to the variation in macrofauna data was assessed using Monte-Carlo test based on 999 random permutations under reduced model.

Results

Initial soil chemical properties from the two farms

Soils from the two sites were found to be moderately acidic with very low P content; 11.0 mg P kg^{-1} in Buyangu and 8.6 mg P kg^{-1} in Ivakale (Table 1). Total N was found to be 1.3 and 1.4 g kg^{-1} while organic C, 14.0 and 16.4 g kg^{-1} in Buyangu and Ivakale, respectively. Based on the rating by Landon (1984), all the elements could be considered to be low.

Table 1 Initial soil chemical properties of the two sites

Characteristics	Site		Summary of statistical analysis		
	Buyangu	Ivakale	SED	$LSD_{5\%}$	ANOVA *p*-value
$pH_{(water)}$ (1 : 2.5)	5.40	5.50	0.02	0.08	*
Exchangeable K (mg kg^{-1})	170.0	90.0	10.0	30.0	**
Available P (mg kg^{-1})	11.0	8.6	0.79	3.40	**
Total N (g kg^{-1})	1.3	1.4	0.10	0.40	ns
Organic C (g kg^{-1})	14.0	16.4	0.30	1.30	*
NO_3^- – N (mg kg^{-1})	1.36	1.67	0.05	0.19	*
NH_4^+ – N (mg kg^{-1})	8.05	4.51	0.54	2.34	*

*, ** significant at $p<0.05$ and $p<0.01$ respectively; ns = not significant

Chemical properties of organic resources used in composting

The chemical properties of organic materials used in composting varied considerably (Table 2). The highest N content was recorded in *T. diversifolia* (4.0 %) and filtermud (3.5 %). Cow manure had slightly higher N content (1.4 %) than bagasse, sugarcane straw and maize stover which recorded the lowest values of 0.4, 0.6 and 0.8 % N, respectively. Filtermud and *T. diversifolia* also had highest P content of 3.8 and 4.3 g kg^{-1}, respectively, compared to other organic materials such as bagasse, sugarcane straw and maize stover which had relatively low values of 0.1, 0.5 and 0.6 g kg^{-1}, respectively. On the other hand, cow manure had slightly higher amount of P (2.50 g kg^{-1}) compared to the three materials: bagasse, sugarcane straw and maize stover, but slightly lower than that of filtermud and *T. diversifolia*. Bagasse showed a very high C:N ratio of 144:1 compared to other materials such as maize stover and sugarcane straw which had ratios of 65:1 and 80:1, respectively. *Tithonia diversifolia*, filtermud and cow manure had very low ratios of 12:1, 13:1 and 18:1, respectively. Although total carbon content of all the materials were within close range (46.3 to 53.1 %), total N varied greatly leading to the sharp differences in C:N ratios.

Chemical characteristics of the composts

Table 3 shows the chemical properties of composts prepared from the six organic materials. Total N was highest in composts made from filtermud (10.0 g kg^{-1}) and *T. diversifolia* (9.6 g kg^{-1}) with the rest of composts within a range of 6.3 g and 7.3 g N kg^{-1}. The highest available P (979 mg kg^{-1}) was also observed in composts prepared from filtermud while it was lowest in bagasse composts (563 mg P kg^{-1}). Sugarcane straw, cow manure and maize stover composts had a range of 574–614 mg P kg^{-1}. Organic C was highest on compost made from maize stover (80 g kg^{-1}) and lowest on filtermud composts (62 g kg^{-1}).

Table 2 Chemical characteristics of organic biomasses used in making composts

Characteristics	Organic biomasses [a]						Summary of statistical analysis		
	CM	MS	SS	BG	FM	TD	SED	$LSD_{5\%}$	ANOVA *p*-value
P (g kg^{-1})	2.50	0.60	0.50	0.10	3.80	4.30	0.24	0.57	***
K (g kg^{-1})	1.50	6.70	1.20	0.70	1.00	47.0	0.64	1.56	***
% DM content	95.4	89.5	92.6	93.3	92.9	89.3	0.52	1.27	***
C:N (ratio)	18.0	65.0	80.0	144	13.0	12.0	1.31	1.85	***
Total N (%)	1.37	0.79	0.58	0.37	3.47	4.04	0.32	0.78	***
Organic C (%)	25.2	51.6	46.4	53.1	46.3	46.8	1.79	4.38	***

[a] BG = Bagasse; CM = Cow Manure; FM = Filtermud; MS = Maize Stover; SS = Sugarcane Straw; TD = *Tithonia diversifolia*

*** Significant at $p<0.001$

Table 3 Chemical characteristics of composts made from six organic biomasses

Characteristics	Compost Type [a]						Summary of statistical analysis		
	T3	T4	T5	T6	T7	T8	SED	$LSD_{5\%}$	ANOVA *p*-value
pH $_{(water)}$ (1 : 2.5)	7.3	7.2	7.1	7.1	7.3	6.9	0.13	0.29	ns
Avail. P (mg kg^{-1})	574	570	571	979	614	563	57.2	123.2	*
Exc. K (mg kg^{-1})	760	660	640	600	720	430	53.3	119.6	ns
C:N (ratio)	9.9	11.6	10.0	9.4	10.7	7.0	-	-	-
Total N (g kg^{-1})	7.3	6.9	7.0	10.0	9.6	6.3	0.76	1.58	*
Organic C (g kg^{-1})	72.5	80.1	70.0	61.8	67.6	69.5	5.49	12.14	*

[a] T3 = Cow manure compost; T4 = Maize stover compost; T5 = Sugarcane straw compost; T6 = Filtermud compost; T7 = *Tithonia diversifolia* compost; T8 = Bagasse compost; Avail. = available; Exc. = exchangeable

[*] Significant at $p<0.05$; ns = not significant

Soil chemical properties after application of composts

Application of all compost types led to increase in soil total N except on plots amended with bagasse compost, a case in which total N remained constant (Table 4). The highest N in Buyangu was obtained on plots treated with filtermud (2.2 g kg^{-1}) and cow manure composts (2.0 g kg^{-1}), representing 69 % and 54 % increase from the baseline. Sugarcane straw, maize stover and *T. diversifolia* composts led to 46 %, 31 % and 23 % increase, respectively, whereas fertilizer an increase of 8 %. Control plots recorded a 15 % reduction in N. In Ivakale, soils amended with filtermud compost also gave the highest N (1.8 g kg^{-1}), a 29 % increase, while *T. diversifolia* compost (1.6 g kg^{-1}) a 14 %

Table 4 Chemical properties of soils treated with different soil amendments

Characteristics	Treatment type [a]								Summary of statistical analysis		
Buyangu Site											
	T1	T2	T3	T4	T5	T6	T7	T8	SED	$LSD_{5\%}$	ANOVA *p*-value
pH $_{(water)}$ (1 : 2.5)	5.44	5.23	5.68	5.63	5.63	5.59	5.58	5.60	0.036	0.071	***
Extr. P (mg kg^{-1})	7.23	22.17	11.33	12.49	11.73	18.53	14.76	11.12	1.543	3.037	***
Exc. K (mg kg^{-1})	50.0	40.0	60.0	60.0	60.0	50.0	50.0	60.0	5.30	11.34	***
Total N (g kg^{-1})	1.10	1.40	2.00	1.70	1.90	2.20	1.60	1.30	0.130	0.250	***
Organic C (g kg^{-1})	18.0	22.4	29.2	28.4	29.0	30.3	26.0	27.2	2.190	4.310	***
NH_4^+ - N (mg kg^{-1})	18.75	24.23	34.69	32.36	33.75	37.45	24.42	27.95	3.358	6.629	**
NO_3^- - N (mg kg^{-1})	4.98	12.24	10.12	8.81	11.23	14.39	6.23	5.21	1.437	2.835	***
Ivakale Site											
pH $_{(water)}$ (1 : 2.5)	5.49	5.21	5.59	5.53	5.56	5.59	5.50	5.60	0.035	0.068	***
Avail. P (mg kg^{-1})	3.30	18.81	9.92	9.84	9.32	12.15	10.84	9.21	1.472	2.897	***
Exc. K (mg kg^{-1})	40.0	40.0	40.0	50.0	50.0	50.0	30.0	50.0	3.00	6.71	***
Total N (g kg^{-1})	1.20	1.50	1.50	1.50	1.50	1.80	1.60	1.40	0.120	0.270	***
Organic C (g kg^{-1})	19.9	20.3	29.0	29.6	32.2	28.7	26.8	27.3	2.110	4.160	***
NH_4^+ - N (mg kg^{-1})	18.63	34.81	26.98	29.08	31.05	36.8	29.64	25.32	3.277	6.469	**
NO_3^- - N (mg kg^{-1})	4.41	18.03	5.16	6.12	6.10	5.52	8.20	4.63	1.042	2.767	***

[a] T1 = Control; T2 = Fertilizer; T3 = Cow manure compost; T4 = Maize stover compost; T5 = Sugarcane straw compost; T6 = Filtermud compost; T7 = *Tithonia diversifolia* compost; T8 = Bagasse compost; Avail. = available; Exc. = exchangeable

[**, ***] significant at $p<0.01$ and $p<0.001$ respectively; ns = not significant

increase in N. Soils amended with cow manure, maize stover and sugarcane straw composts and inorganic fertilizer gave the least increments of 7 % each. Control plots recorded a 14 % decline in soil N. Available N showed similar trend to that of total N. Soil P increased in all the treatments in Buyangu except in control plots where decline was recorded. The highest amount (22.2 mg kg^{-1}) was obtained on soils treated with fertilizer; a 103 % increase from the baseline. Soils treated with composts had their P values within a marginal range of 11.1–18.5 mg kg^{-1} which was 2–69 % increase from the baseline. Control plots recorded a 34 % reduction in P. similar trends were observed in Ivakale, with the highest P recorded in fertilizer treated plots (18.8 mg kg^{-1}) which was a 118 % increase. Soil P on plots treated with composts ranged between 9.21 and 12.2 mg kg^{-1}, translating to 7–41 % increase. Control plots recorded a decline of 62 %. Soil organic C increased in all the treatments. In Buyangu, the highest value of 30.3 g kg^{-1} was obtained from soils amended with filtermud compost, which was 116 % increase. Plots treated with *T. diversifolia*, bagasse, cow manure, sugarcane straw and maize stover composts ranged between 26.0 and 29.0 g kg^{-1} representing 90–109 % increase in soil C from the baseline. Fertilizer and control treatments recorded a 60 % and 29 % increase, respectively. In Ivakale, the highest value of 32.2 g kg^{-1} was obtained from soil amended with sugarcane straw compost, which was 96 % increase from the baseline. Soil treated with bagasse *T. diversifolia*, filtermud, cow manure and maize stover compost recorded slightly lower values ranging from 26.8 to 29.6 g C kg^{-1}, which represented increases of between 66 and 85 %. Inorganic fertilizer treatment and control plots recorded a 23 % and 21 % increase in soil C, respectively.

Agronomic effectiveness of different compost types on maize performance

Addition of composts and inorganic fertilizer increased yields significantly ($p<0.001$) compared to the control (Table 5). Fertilizer treated plots produced the highest maize grain yields in both sites over the three seasons. In the first season, fertilizer treated plots recorded 5.9 Mg ha^{-1} of maize grain yield in Buyangu and 5.8 Mg ha^{-1} in Ivakale, which were 320 % and 350 %, respectively above the control plots. Compost treated plots recorded maize grain yields ranging from 2.1 to 2.7 Mg ha^{-1} in Buyangu and 2.3–2.6 Mg ha^{-1} in Ivakale, representing an increase ranging from 50 to 93 % in Buyangu and 77–100 % in Ivakale above the control. In the second season, maize yields were severely affected by inadequate rainfall in the month of November 2010 (Fig. 1). Fertilizer treated plots gave only 1.0 Mg ha^{-1} of grain yield in Buyangu and 1.1 Mg ha^{-1} in Ivakale which were 230–270 % increases, respectively, above control plots. Compost treated plots gave maize grain yields ranging from 0.6 to 0.7 Mg ha^{-1} in both sites, which was a 100–190 % increase above control plots. During the third season, fertilizer treated plots gave 6.4 Mg ha^{-1} of maize grain yields in both farms, an increase of 150 % in Buyangu and 140 % in Ivakale above control plots. Compost treated plots recorded maize grain yields ranging from 4.5–5.6 Mg ha^{-1} in Buyangu and 4.5–5.5 Mg ha^{-1} in Ivakale, a 75–115 % increase in Buyangu and 70–100 % in Ivakale relative to control.

Effects of compost application on soil fauna diversity and abundance

a) Effects on soil macrofauna diversity and taxonomic richness

Table 6a and 6b shows macrofauna diversity in Buyangu and Ivakale. A total of 21 macrofauna genera belonging to five classes were identified across the two sites. Class insecta dominated the macrofauna sampled. Taxonomic richness varied across different treatments as well as between the sites. In Buyangu, soils amended with filtermud composts had the highest taxonomic richness (17 taxa), followed by soils amended with bagasse (16 taxa) and sugarcane straw composts (14 taxa). Cow manure, maize stover and *Tithonia diversifolia* composts all had 13 taxa each while the lowest taxonomic richness was recorded in control plots and those treated with fertilizer; 9 and 10 taxa, respectively. In Ivakale, soils amended with filtermud composts were also taxonomically richest with 18 taxa, followed by *Tithonia diversifolia* (13 taxa) and bagasse composts (12 taxa). As in Buyangu, control plots and those treated with fertilizer had the lowest taxonomic richness; 7 and 9 taxa, respectively.

b) Effects on abundance of soil macrofauna

The ANOVA showed significant treatment differences on Oligochaeta, Isoptera and Hymenoptera groups only (Table 7). Isopterans were the most dominant group of the macrofauna, constituting 52 % of the total in

Table 5 Maize grain yield (Mg ha^{-1}) over the three seasons on the two study sites

Treatment [a]	Yields (Mg ha^{-1}) [b]							
	April–July (2010)		Oct.–Dec.(2010)		April–July (2011)		3-Seasons Mean	
	Buyangu	Ivakale	Buyangu	Ivakale	Buyangu	Ivakale	Buyangu	Ivakale
T1	1.4	1.3	0.3	0.3	2.6	2.7	1.5	1.4
T2	5.9	5.8	1.0	1.1	6.4	6.4	4.6	4.5
T3	2.6	2.5	0.6	0.6	4.9	4.9	2.7	2.6
T4	2.4	2.3	0.6	0.6	5.0	4.6	2.7	2.5
T5	2.1	2.5	0.6	0.7	4.9	4.6	2.5	2.6
T6	2.7	2.5	0.7	0.7	5.6	5.5	3.0	2.9
T7	2.1	2.6	0.6	0.6	4.5	5.3	2.4	2.8
T8	2.2	2.6	0.7	0.7	5.0	4.5	2.6	2.6
SED	0.158	0.233	0.054	0.061	0.428	0.412	0.816	0.795
$LSD_{5\%}$	0.329	0.484	0.113	0.139	0.889	0.857	1.623	1.581
p-value	***	***	***	***	***	***	*	*

[a] T1 = Control; T2 = Fertilizer; T3 = Cow manure compost; T4 = Maize stover compost; T5 = Sugarcane straw compost; T6 = Filtermud compost; T7 = *Tithonia diversifolia* compost; T8 = Bagasse compost

[b] 1 megagram (Mg) = 10^6 grams (g)

*, *** significant at $p<0.05$ and $p<0.001$ respectively

Buyangu and 35 % in Ivakale, followed by Oligochaeta, (18 % and 34 %), Hymenopterans (12 % and 23 %) and Coleoptera (13 % and 5 %), respectively. Other macrofauna groups such as, Orthoptera, Blattodea, Chilopoda, Diplopoda and Arenae, each constituted less than 5 % of the total macrofauna. *Macrotermes sp*. was the most numerous genera within the Isopteran group, representing 29 % of the total macrofauna in Buyangu and 20 % in Ivakale while *Microtermes pusillas* represented 23 % and 9 % of macrofauna found in Buyangu and Ivakale, respectively. *Pseudacanthotermes sp.* was found only in Ivakale. Five genera of Oligochaeta group belonging to three families (Ocnerodrilidae, Acathodrilidae and Eudrilidae) were obtained from the two sites. *Nematogenia lacuum* of the family Ocnerodrilidae dominated the Oligochaeta group representing 17 % of the total

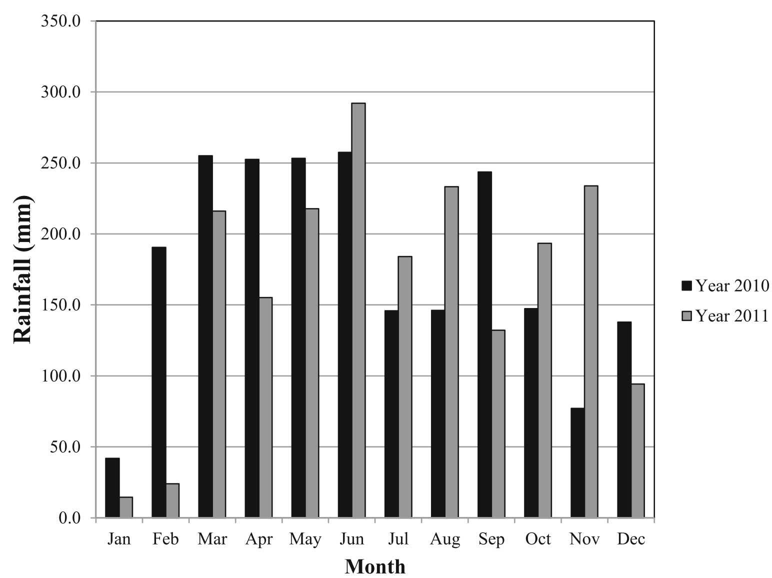

Fig. 1 Monthly rainfall performance in Kakamega County over the duration of the study (with permission from Kenya Meteorological Department)

Table 6a Macrofauna diversity and taxonomic richness across different treatments in Buyangu

Macrofauna description			Treatment [a]								Summary of analysis	
Macrofauna group	Family	Genera/Species	T1	T2	T3	T4	T5	T6	T7	T8	Total	% Total
Oligochaeta	Acathodrilidae	*Dichogaster bolaui*	0	0	1	1	0	8	0	0	10	0.9
		Dichogaster affinis	0	1	0	0	1	0	3	1	6	0.5
		Dichogaster saliens	0	0	0	0	2	2	0	1	5	0.4
	Ocnerodrilidae	*Nematogenia lacuum*	11	13	23	20	20	41	32	34	194	16.6
	Eudrilidae	*Eminoscolex violaceus*	0	0	0	0	0	0	0	0	0	0.0
Isoptera	Termitidae	*Microtermes pusillas*	13	2	28	39	11	51	29	95	268	23.0
		Macrotermes sp.	6	6	31	19	43	123	100	12	340	29.2
		Pseudacanthotermes sp.	0	0	0	0	0	0	0	0	0	0.0
Coleoptera	Staphylinidae	*Philonthus sp.*	2	1	4	3	1	4	0	3	18	1.5
		Leptacinus sp.	2	12	11	9	14	12	11	13	84	7.2
	Scarabidae	*Phyllopertha sp.*	1	3	4	7	4	6	2	6	33	2.8
		Aphodius lividus	0	0	0	1	0	0	0	0	1	0.1
	Carabidae	*Harpalus sp.*	3	1	0	1	1	6	4	0	16	1.4
Hymenoptera	Formicidae	*Ponera sp.*	9	2	5	5	5	25	7	22	80	6.9
		Carebara sp.	1	7	4	11	6	13	6	3	51	4.4
		Bothroponera sp.	0	0	4	1	0	1	1	1	8	0.7
Orthoptera	Gryllidae	*Gryllus bimaculatas*	0	0	6	0	3	3	2	2	16	1.4
Blattodea	Blattoidea	*Blatella sp.*	0	0	0	0	0	2	0	1	3	0.3
Chilopoda	Scolopendridae	*Scolopendra sp.*	0	0	5	5	2	8	2	1	23	2.0
Diplopoda	?	?	0	0	0	0	0	1	0	1	2	0.2
Araneae	?	?	0	0	1	0	1	2	2	2	8	0.7
Taxonomic richness (number of genera or species)			9	10	13	13	14	17	13	16	-	-

[a] T1 = Control; T2 = Fertilizer; T3 = Cow manure compost; T4 = Maize stover compost; T5 = Sugarcane straw compost; T6 = Filtermud compost; T7 = *Tithonia diversifolia* compost; T8 = Bagasse compost Macrofauna groups represented by the symbol (?) could not be identified beyond the Order because they were too juvenile hence no identification key could be appropriately used

macrofauna sampled in Buyangu and 20 % in Ivakale. However, *Dichogaster saliens* of Acathodrilidae family were also numerous in Ivakale constituting 13 % of the total macrofauna obtained. *Dichogaster affinis* and *D. bolaui* from the same family occurred in low numbers, recording a population below 1 % of the total macrofauna sampled from both sites. *Eminoscolex violaceus* from Eudrilidae family were found only in Ivakale, representing about 1 % of the total macrofauna sampled.

Relationship between soil macrofauna and selected soil chemical properties

The Redundancy Analysis (RDA) biplots between soil macrofauna and soil chemical properties showed significant trends (Fig. 2). The eigenvalues of the first and second RDA axis constrained to the soil chemical properties were 0.165 and 0.035, respectively and the two axes explained 20 % of the observed variation in macrofauna abundance. The sum of all RDA canonical eigenvalues showed that soil chemical properties explained 25 % of the total variation observed in macrofauna abundance and that the correlation was highly significant ($p=0.007$). The first axis is a total N/pH gradient ($r=0.67$ and −0.37, respectively), while second axis is an organic carbon/pH gradient ($r=0.43$ and −0.20, respectively). The two axes separate soil which had higher carbon and nitrogen content to those with lower amounts of these elements. Most of macrofauna groups were found to be positively correlated with N, C and P along the first and second axes. Notably, Oligochaeta (earthworms), Isoptera (termites) Blattodea (cockroaches), Diplopoda (millipedes) and Chilopoda (centipedes) were strongly and positively correlated with the three soil

Table 6b Macrofauna diversity and taxonomic richness across different treatments in Ivakale

Macrofauna description			Treatment type [a]								Summary of analysis	
Macrofauna group	Family	Genera/Species	T1	T2	T3	T4	T5	T6	T7	T8	Total	% Total
Oligochaeta	Acathodrilidae	*Dichogaster bolaui*	0	0	0	0	0	3	2	0	5	0.6
		Dichogaster affinis	0	0	0	0	0	1	0	0	1	0.1
		Dichogaster saliens	3	3	10	10	21	27	8	21	102	12.7
	Ocnerodrilidae	*Nematogenia lacuum*	8	9	19	26	20	26	28	20	157	19.5
	Eudrilidae	*Eminoscolex violaceus*	0	2	0	0	0	3	0	0	5	0.6
Isoptera	Termitidae	*Microtermes pusillas*	8	12	1	8	8	4	10	24	75	9.3
		Macrotermes sp.	0	5	1	27	33	57	2	36	161	20.0
		Pseudacanthotermes sp.	1	0	25	0	3	13	2	3	47	5.8
Coleoptera	Staphylinidae	*Philonthus sp.*	0	0	0	0	0	1	0	0	1	0.1
		Leptacinus sp.	1	2	8	1	2	3	1	4	22	2.7
	Scarabidae	*Phyllopertha sp.*	0	2	3	5	2	3	1	2	18	2.2
		Aphodius lividus	0	0	0	0	0	0	0	0	0	0.0
	Carabidae	*Harpalus sp.*	0	0	0	0	0	0	0	0	0	0.0
Hymenoptera	Formicidae	*Ponera sp.*	2	2	6	6	4	8	8	4	40	5.0
		Carebara sp.	4	2	14	4	10	11	5	44	94	11.7
		Bothroponera sp.	0	0	0	1	1	2	45	0	49	6.1
Orthoptera	Gryllidae	*Gryllus bimaculatas*	0	0	0	3	5	2	3	1	14	1.7
Blattodea	Blattoidea	*Blatella sp.*	0	0	0	0	0	1	0	0	1	0.1
Chilopoda	Scolopendridae	*Scolopendra sp.*	0	0	0	0	0	1	0	1	2	0.1
Diplopoda	?	?	0	0	0	0	0	0	0	0	0	0.0
Araneae	?	?	0	0	4	1	0	1	2	4	12	1.6
Taxonomic richness (number of genera or species)			7	9	10	11	11	18	13	12	-	-

[a] T1 = Control; T2 = Fertilizer; T3 = Cow manure compost; T4 = Maize stover compost; T5 = Sugarcane straw compost; T6 = Filtermud compost; T7 = *Tithonia diversifolia* compost; T8 = Bagasse compost Macrofauna groups represented by the symbol (?) could not be identified beyond the Order because they were too juvenile hence no identification key could be appropriately used

chemical properties. The correlation between Araneae (spiders) and Hymenoptera (ants) with the three parameters along two axes, though positive, was not very strong. Coleoptera (beetles) and Orthoptera (crickets) had no correlation with the three parameters along first axis but only weak correlation along second.

Discussion

Initial soil chemical properties

Soils of the two study sites were found to be low in the most essential crop nutrients (C, N and P). This could be associated with continuous cropping coupled with low inorganic and organic fertilizer application which is common to that area. Crop residues which otherwise should be returned to soil, are also burned or field-disposed during land preparation (Karanja et al. 2006; Achieng et al. 2010; Ayuke 2010). This practice results in continuous removal (with little or no replenishment) of C, N and P as well as other macro and micronutrients taken up by the crops. The three elements have been classified as the most limiting in sub-Saharan Africa and their deficiency have often been linked to low the crop yields recorded in this region (Jama et al. 2000; Okalebo et al. 2007; Achieng et al. 2010). In addition, depletion of soil organic C has been shown to affect water and nutrient retention capacity negatively (Bationo and Bürkert 2001; Bationo et al. 2007). Since application of small amounts of P has been shown to have significant responses in crops, proper management of organic and inorganic nutrient resources is required in optimizing crop production (Bationo 2008).

Table 7 Soil Macrofauna abundance (number m^{-2}) identified across the two sites

Macrofauna group	Treatment type [a]								Summary of statistical analysis				
	T1	T2	T3	T4	T5	T6	T7	T8	Total	%Total	$LSD_{5\%}$	SED	*p*-value
Buyangu site													
Oligochaeta	11	14	24	21	23	51	35	36	215	18.4	1.935	0.922	***
Isoptera	19	8	59	58	54	174	129	107	608	52.1	59.68	28.18	*
Coleoptera	8	17	19	21	20	28	17	22	152	13	7.742	3.687	ns
Hymenoptera	10	9	13	17	11	39	14	26	139	11.9	10.32	5.007	*
Orthoptera	0	0	6	0	3	3	2	2	16	1.4	2.903	1.382	ns
Blattodea	0	0	0	0	0	2	0	1	3	0.3	0.653	0.241	ns
Chilopoda	0	0	5	5	2	8	2	1	23	2	5.391	2.230	ns
Diplopoda	0	0	0	0	0	1	0	1	2	0.2	0.762	0.317	ns
Araneae	0	0	1	0	1	2	2	2	8	0.7	1.935	0.922	ns
Total	48	48	127	122	114	308	201	198	1,166	100	-	-	-
Ivakale site													
Oligochaeta	11	14	29	36	41	60	38	41	270	33.5	3.346	1.542	***
Isoptera	9	17	27	35	44	74	14	63	283	35.1	29.03	13.82	*
Coleoptera	1	4	11	6	4	7	2	6	41	5.1	4.839	2.304	ns
Hymenoptera	6	4	20	11	15	21	58	48	183	22.7	15.35	8.217	*
Orthoptera	0	0	0	3	5	2	3	1	14	1.7	3.871	1.843	ns
Blattodea	0	0	0	0	0	1	0	0	1	0.1	0.968	0.461	ns
Chilopoda	0	0	0	0	0	1	0	1	2	0.1	1.935	0.922	ns
Diplopoda	0	0	0	0	0	0	0	0	0	0	1.935	0.922	ns
Araneae	0	1	4	1	0	1	2	4	13	1.6	0.968	0.461	ns
Total	27	40	91	92	109	167	117	164	806	100	-	-	-

[a] T1 = Control; T2 = Fertilizer; T3 = Cow manure compost; T4 = Maize stover compost; T5 = Sugarcane straw compost; T6 = Filtermud compost; T7 = *Tithonia diversifolia* compost; T8 = Bagasse compost

[*, ***] significant at $p<0.05$ and $p<0.001$ respectively; ns = not significant

Chemical characteristics of organic resources used in composting

Within cereal-based cropping systems, the bulk of residues available at harvest are relatively low in nutrients but high in lignin and polyphenols and thus may be classified as low quality materials. The C:N ratio has also been widely used to measure quality of organic resources (Tian et al. 1997; Vanlauwe et al. 2005). It was evident in this study that maize stover and sugarcane residues (bagasse and sugarcane straw) had considerably high C:N ratio compared to other organic residues such as filtermud and cow manure. Therefore composts produced from maize stover and sugarcane residues could be categorized as low quality composts. However, filtermud contained exceptionally high available P content compared to the other two sugarcane residues, perhaps due to the higher amounts of ash, soil sediments and other impurities that are released during processing of canes. *Tithonia diversifolia*, a perennial shrub, has been recognized as effective source of crop nutrients due to high nutrient content in its biomass. Jama et al. (2000) reported that the green leaf biomass of *T. diversifolia* contained 3.5 % N, 0.37 % P and 4.1 % K on a dry matter basis, which qualifies it as a potential source of crop nutrients. Analysis of *T. diversifolia* in our study showed consistent results with those reported by Jama et al. (2000) and the content of these elements was higher compared to all other organic residues used in composting, with exception of filtermud which contained almost equal amounts of N and P. Utilizing available organic materials in the

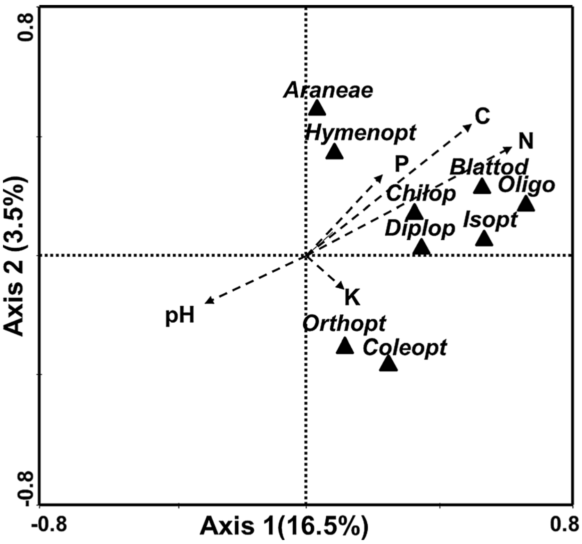

Fig. 2 RDA biplot showing correlation between soil macrofauna groups and soil chemical properties. Soil macrofauna are represented by triangles while soil chemical properties represented by dotted lines. Macrofauna abbreviations; Blattod=Blattodea, Chilop=Chilopoda, Coleopt=Coloeptera, Diplop=Diplopoda, Hymenopt=Hymenoptera, Isopt=Isoptera, Oligo=Oligochaeta and Orthopt=Orthoptera

form of livestock manures and/or composts could therefore be an important step in supplying crop nutrients. Besides, returning organic residues to agricultural soils has additional benefits such as improving soil structure, soil moisture storage and increase soil microbial activities among other soil functions (Nziguheba et al. 2000; Fankem et al. 2008).

Chemical characteristics of the composts

Organic feedstocks used in composting influenced the quality of composts as demonstrated by the chemical properties of individual composts. This was manifested by the higher quantities of N, P in composts made from filtermud and *T. diversifolia*, compared to compost made from sugarcane straw, maize stover and bagasse. Due to the fact that most of the available organic materials within cereal-based farming systems are of low quality, addition of high quality materials such as green leaves as N-source or incorporation of inorganic sources of nutrients such as rock phosphate during composting could enhance the quality of composts (Lekasi et al. 2003). This could enhance the content of these two most essential macronutrients which are considered the most limiting in sub-Saharan soils. Negassa et al. (2001) reported that 5 t ha^{-1} of high quality compost could contribute up to 171 kg N and 41 kg P ha^{-1} in addition to other macro and micronutrients. It is estimated that 60 % N and 10 % P in manure are lost due to poor handling (Mafongoya et al. 2003). Through composting and appropriate storage of the composts, these losses could be minimized. These high quality composts could effectively enhance recycling of the nutrients within small-scale farming systems of western Kenya where soils are characterized by low levels of available N and P, high soil acidity and low organic matter content (Okalebo et al. 2005). This would not only increase crop yield, but also build soil nutrient hence improve soil productivity.

Effects of compost application on soil chemical properties

Application of compost increased soil macronutrients, especially C and N compared to inorganic fertilized plots and control. This was in agreement with Melero et al. (2007) and Courtney and Mullen (2008) who reported higher total organic C and Kjeldahl-N on soil amended with composts. An increase in C in control plots could perhaps be linked to contribution of stubble which was left after harvesting. However, this trend may be unsustainable in the long run since intensive tillage without replenishing soil with external organic matter sources has been shown to increase the rate of soil C degradation, especially in tropical conditions (Ayuke 2010). Soil P was higher on plots treated with inorganic fertilizer than those which received composts. This ought to be expected since the fertilizer used in our study was P-based. This trend may nonetheless diminish over time since increase in soil acidity observed in fertilizer treated plots could render P unavailable to crops. According to Gyaneshwar et al. (2002) soil acidity lowers availability soil P through precipitation into insoluble compounds. Soil pH tended to be higher on compost treated plots, which concur with the findings by Adeniyan et al. (2011) who similarly observed an increase in soil pH on addition of composts and other types of organic manures. Soumaré et al. (2003) and Courtney and Mullen (2008) also reported higher soil pH on soil treated with compost compared to those under inorganic fertilizer. Besides supplying readily available soil nutrients at short-term scale, composts can also be important in building long-term soil nutrient reserves as well as soil organic matter. For instance, Eghball et al. (2004) observed significant residual concentrations of plant-available P and NO_3-N several years after the last compost application. Hepperly et al. (2009) also reported that composts were superior in building levels of soil C and N compared to synthetic fertilizer treatments. In addition, composts and other organic amendments are known to increase soil organic matter, an important agent in regulating soil nutrients (Smith 1994). Incorporating quality organic amendments into soil nutrient fertility budgets is thus important if steady and long-term supply of soil nutrients is to be realized.

Agronomic effectiveness of composts on maize performance

The over 2 Mg ha^{-1} maize grain yield obtained from plots that were amended with composts is a reflection of their potential as fertilizers. Among compost treated plots, the highest grain yields across the three seasons were obtained in plots under filtermud compost. The higher N and P content recorded in filtermud composts could have contributed to the difference seen in maize grain yields compared to other compost types. The yield differences between inorganic fertilizer treated plots and the plots treated with composts decreased with time, with the least difference recorded in the third season. This could be attributed to residual effects due to compost addition, which as a slow nutrient release organic fertilizer, enhanced soil fertility. The nutrients retained in soil could therefore have contributed to over 4.5 Mg ha^{-1} of maize yield recorded in plots treated with composts in the third season. This concurs with Eghball et al. (2004) who observed residual effects of composts on corn grain yield which lasted for at least one growing season. The authors attributed the effects to the increased concentration of plant-available P and NO_3-N in the soil. In another study, Courtney and Mullen (2008) reported higher barley grain yield on compost treated plots compared to those treated with mineral fertilizer. Though compost application rates were quite high (25, 50 and 100 Mg ha^{-1}), their study emphasizes the superiority of composts in building soil nutrients reserves. Therefore, organic amendments offer potential alternative to improving crop productivity where socio-economic conditions limit the farmers from accessing and using the right quantities of inorganic fertilizers (Van Straaten 2002).

Effects of composts application on soil macrofauna

Results of this study show soil macrofauna, especially earthworm, termites and beetles, were numerous on soil treated with composts compared to that of the control and inorganic fertilizer treatments. In addition, crickets, centipedes, millipedes and cockroaches, though occurred in low numbers, the few were also mainly obtained from plots treated with composts. This could perhaps be attributed to increased substrates provided by the composts to the soil macrofauna. Most surface litter from the study region are usually burned in preparation for the next season's crop (Karanja et al. 2006; Achieng et al. 2010), therefore, eliminating vital substrate for soil invertebrates to utilize. As such, application of composts probably contributed to such significant increase in soil macrofauna through provision of food resources. Studies conducted in long-term trials by Ayuke et al. (2011) reported significantly higher earthworms' and termites' diversity on sites where management practices increased soil carbon. Ayuke et al. (2004), Fonte et al. (2009) and Riley et al. (2008) also reported significantly higher earthworm abundance and biomass on soil where large amounts of organic materials were incorporated than on conventionally managed plots. The authors linked these findings to increased soil organic matter inputs. Since soil organic matter remains an important source of energy to most soil organisms, farm management practices that encourage its increase therefore enhances the great role soil organisms play in the soil. Besides nourishment, organic matter is also said to have positive benefits in ameliorating soil environment for soil macrofauna to thrive (Lavelle et al. 2001; Karanja et al. 2009). This could also explain the higher number of macrofauna observed on plots treated with composts.

The sum of all RDA canonical eigenvalues showed that the soil chemical properties explained 25 % of the total variation observed in soil macrofauna abundance. Though the variation explained by the soil chemical properties could have been low, the correlative relationship between soil chemical properties and soil macrofauna was highly significant. The results concurs with Ayuke et al. (2009) and Karanja et al. (2009) who observed strong and significant correlations between soil chemical properties with selected macrofauna groups under different land use systems in Taita and Embu. Therefore, soil chemical properties may partly be used to explain the trends of abundance, diversity and distribution of soil macrofauna communities. The unexplained variation could perhaps be attributed to other factors that directly regulate population of soil macrofauna, such as soil disturbance arising from cultivation (Ayuke et al. 2009). Cole et al. (2008) showed that physical soil disturbance could, to some extent, be of more importance in regulating population of some soil fauna than food availability. Soil tillage is one of the most common forms of soil disturbance in agroecosystems (Cole et al. 2008; Ayuke 2010). This has been shown to negatively affect soil dwelling organisms mainly through reduction or redistribution of food substrates and destruction of their nests and burrows (Ayuke et al. 2009; Karanja et al. 2009; Ayuke 2010). Such modifications may be unfavourable to these organisms. This could therefore explain why despite addition of composts, some macrofauna groups such as cockroaches and millipedes occurred in low numbers in all the treatments.

Conclusions

The results of this study demonstrate potential of recycling locally available organic resources through composting; an important practice as it stabilizes these materials hence reducing nutrients losses. This could be a starting point towards increasing cereal and legume grain yield; the most important crops in small-scale farming systems of Kakamega County, Kenya, given that the soils are severely deficient in N and P and low in organic matter. The findings also suggest that composts could be of great importance in enhancing abundance and diversity of beneficial soil fauna such as earthworms which are essential components in nutrient cycling and soil structure improvement. Future research with long-term application of composts could be of great benefit in expounding the impacts of composts on soil fauna at longer periods since seasonal variations could affect the observed results at short-term scales. Furthermore, the studies involving interaction of composts and different kinds of soil disturbance could help to expound the unexplained variation.

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