

Evaluation of Chicken Blood and Maize Stover Compost as a Nitrogen Source for

Maize

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ABSTRACT

Organic materials are an important source of nutrients for many smallholder farmers. The use of composted organic amendments is constrained by their variability and maturity. The aim of this study was to evaluate the potential of aerobically composted chicken blood and maize stover mixtures on maize N uptake and to determine the effect on seed emergence in a greenhouse pot experiment. Four composts with proportions of 10%, 30%, 70% and 100% maize stover were used as soil amendments and compared against an unamended soil (control). The greenhouse pot experiment involved planting 10 maize seeds in each pot. Seed emergence percent was determined a week after sowing to ascertain whether the composts had phytotoxic effects. Percent emergence did not differ significantly among treatments ($p = 0.26$). Two plants were allowed to grow in the pots for five weeks after which maize dry matter yield and foliar analysis followed.

The foliar samples were analysed for total nitrogen, dry matter yield and cations (Mg, Ca, K and Na). Nitrogen uptake differed significantly among treatments and ranged from 0.27% to 0.75%. Nitrogen uptake was higher in soils amended with 10% and 30% maize stover compost treatments. Dry matter yield also differed significantly ranging from 1.09g to 2.2g per pot). Uptake of all cations did not differ ($p > 0.05$) significantly among treatments. The 10% and 30% maize stover composts had greater potential to support maize growth as shown by the dry matter yield and total N concentrations in the plant samples.

Key words: Compost, emergence, maize, nitrogen.

1. INTRODUCTION

Organic materials are an important source of nutrients for many smallholder farmers who lack financial resources to purchase mineral fertilisers (Masunga et al., 2016; Steinfield et al., 2006; Rufino et al., 2007). The use of organic amendments is however constrained by their heterogeneity, variability and benefits are not realized immediately after incorporation hence most organic resources show limited increases in crop growth (Vanlauwe, 2004). Organic materials and compost use in crop production is gaining popularity due to the increased appreciation that conventional and intense tillage cropping systems

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result in soil organic matter loss (Chivenge et al., 2009). Incorporation of compost can result in organic matter build up and an increase in organic matter results in an increase in cation exchange capacity (CEC) of soils and also adsorption of soil contaminants (Mando et al., 2005; Vanlauwe, 2004). Nutrients become available to plant roots at a slower rate with compost compared to inorganic fertilisers thus nutrients are retained for longer in soils. In order to develop efficient systems to improve soil nutrient dynamics a balance must be established between crop demands and nutrient supply from the decomposition of organic materials (Munthali et al., 2015). Organic matter decomposition releases these nutrients and is affected by a wide range of factors including soil nutrient content, moisture content, biological activity and organic residue quality. A good quality compost is one that has the capacity to function within natural or managed ecosystem boundaries by restoring and enhancing the potential of the soil to sustain plant and animal productivity (Brinton 2012; Bera et al., 2013; Pisa and Wuta 2013)

Though compost applications have a number of benefits, there have been cases in which composts have had negative impacts on crop growth. Tiquia (2010) reported delayed seedling emergence and reduced crop growth after the incorporation of some compost products. These negative impacts were attributed to the use of unstable or immature compost. Compost maturity determines whether compost can be used in crop production without negative effects due to N immobilisation, oxygen depletion or the presence of phytotoxic compounds, such as the organic acids; propionic, acetic and butyric acid. Low molecular weight organic acids such as phenolic compounds are responsible for phytotoxic effects of composts on seed germination, emergence and plant growth (Gómez-

Brandón et al., 2008). Monspart-S'enyi (2012) demonstrated that volatile low molecular weight organic acids decreased with composting duration and are associated with early stages of decomposition. Various parameters have been used as compost maturity indices (Gómez-Brandón et al., 2008; Mangkoedihardjo, 2006). Carbon to nitrogen ratio and $\text{NH}_4^+:\text{NO}_3^-$ ratio can be used to determine compost maturity (Chukwujindu et al., 2006; Mangkoedihardjo, 2006). Electrical conductivity of less than 2.0 mmho, pH between 6 and 7.5, absence of phytotoxic substances and an $\text{NH}_4^+:\text{NO}_3^-$ ratio of less than 1:1 (Pant et al., 2011; Radovich et al., 2011), are indices used to determine compost maturity.

Nitrogen is the most limiting nutrient to crop growth in most Zimbabwean soils (Agren et al., 2012; Mapfumo and Giller, 2001) requiring the use of soil amendments. Nitrogen in organic amendments, such as compost, is in organic form (Bremmer, 1996) therefore the fertilising value of the compost is evaluated on the basis of its ability to release mineral N to meet crop requirements. It is therefore necessary to determine the content as well as the potential of the compost to release mineral N (Pisa and Wuta, 2013). The ability to release N has to be balanced against contribution of the stable soil organic matter pool which contributes more to long-term soil fertility. Handayanto, et al. (1997) explored the possibility of synchronising nutrient release and plant uptake through composting and mixing residues of different quality. The intention is to increase N release from low quality organics by mixing them with high quality organic to meet plant requirements. There is thus a possibility of using mature composts along with mineral fertilisers or mixtures of raw waste in proportions which

moderate the nutrient release pattern of the mixture favourably.

In Zimbabwe, there has been limited research on composting and the ability of the compost products to supply nutrients. Research done include composting of household wastes as soil amendments for peri-urban farming systems (Mhindu et al., 2013) and composting of poultry wastes to produce an organic fertilizer for maize and horticultural crops (Pisa, 2007; Pisa and Wuta, 2013). However, there has been no study that has evaluated the potential of chicken blood and maize stover compost as a nitrogen source in crops. Large quantities of blood are produced in Zimbabwe's small abattoirs and slaughterhouses. The blood is held in lagoons and holding tanks for a long time before disposal (Pisa, 2007; Pisa and Wuta, 2013) as fresh blood cannot be spread over land. Blood is rich in N and other essential plant nutrients (Mittal, 2007) and therefore can be used as a source of plants nutrients. It cannot be however applied directly to land due to associated environmental pollution problems such as the presence of pathogens, eutrophication, groundwater pollution, acid deposition, and high ammonia and nitrate concentration in the soil (Akinro et al., 2009, Singh et al., 2014). To avoid pollution composting a mixture of blood and maize stover was found to produce stable compost with little or no environmental problems. Pisa and Wuta 2013 determined the composting performance of chicken blood and maize stover but the potential of the finished compost to support plant growth was however not done. The compost produced was assumed to be stable and environmentally friendly with no pathogens, a C:N ratio less than the critical 20:1 (Marthur et al., 1993, Kokkora et al., 2010) and an $\text{NH}_4\text{-N}:\text{NO}_3\text{-N}$ ratio of less than 0.16 (Pant et al., 2011; Radovich et al., 2011). The aim of this

study was to evaluate the potential of aerobically composted chicken blood and maize stover mixtures as sources of nitrogen and also determine their effect on maize seed emergence.

2. MATERIALS AND METHODS

Chicken blood and maize stover were aerobically composted (Pisa and Wuta, 2013) and the finished product was used in this study. Chicken blood from slaughter houses was mixed with maize stover at different proportions of 10%, 30%, 70% and 100% maize stover by weight and composted in composting bins measuring 1 m³ over 72 days (Pisa, 2007; Pisa and Wuta, 2013). The final composts were tested in a greenhouse pot experiment at the University of Zimbabwe using sandy soils from Churu farm (1390 masl; 30° 55'E & 17° 56"S) in Harare. The finished composts and the soil were characterised before use.

2.1 Soil sampling and analysis

Soils were collected from Churu farm by randomly taking five representative soil sub samples from a depth of 0 to 20 cm using a soil auger. Bulk soil samples were also collected and mixed to make a total of 50 kg of soil for use in the greenhouse experiment. The composite auger sample was air dried and sieved to pass through a 2 mm sieve. Soils were analysed for texture, pH, organic carbon, available P and N. Soil texture was determined using the hydrometer method after dispersing the soil using sodium hexa-meta-phosphate (Anderson and Ingram, 1993). Soil pH was measured using the CaCl_2 method (Okalebo et al., 2002) using a Jenway model 3510 pH meter.

Soil organic carbon was determined using the modified Walkley-Black method (Anderson and Ingram, 1993) with external heating. Total N was

extracted from a soil sample by wet digestion using concentrated sulphuric acid, selenium powder, lithium sulphate and hydrogen peroxide mixture (Anderson and Ingram, 1996). Total soil N was measured colorimetrically at a wavelength of 650 nm (Okalebo et al., 2002).

2.2 Compost sampling and analysis

Composite samples were collected from respective compost bins by pooling 5 sub-samples from random positions of each bin at the end of the composting period. Before collecting samples, compost in each bin was thoroughly mixed. The compost samples were oven dried at 60°C for 48 hours before grinding them to pass through a 2 mm sieve. Composts were analysed for total N, mineral N, total nutrients (Ca Mg Na and K), organic carbon, pH, electrical conductivity and ash after oven drying using standard methods described in Okalebo, et al., 2002).

Mineral N (ammonium-N and nitrate-N) was extracted from compost samples by shaking 10 g of fresh compost in 100 ml of 0.5 M K₂SO₄ on a reciprocal shaker for one hour. The mixture was filtered through a Whatman's No 42 filter paper. Ammonium-N was determined in an aliquot (0.2 ml) of the filtrate after colour development with sodium nitro-prusside and nitrate-N was determined in a separate aliquot (0.5 ml) after colour development with 5% salicylic acid using a spectrophotometer (Okalebo, et al., 2002).

Total N, total nutrients (Ca Mg Na and K), organic carbon, pH, electrical conductivity and ash content were determined on ground oven dried compost samples. Total N was extracted from compost sample by wet digestion using concentrated sulphuric acid, selenium powder, lithium sulphate and hydrogen peroxide mixture (Anderson and

Ingram, 1996). The hydrogen peroxide oxidises the organic matter while selenium powder acts as the catalyst for the process. Sulphuric acid completed the oxidation at elevated temperatures. Total N was determined in an aliquot of the digest after colour development with sodium nitroprusside using a spectrophotometer (Okalebo et al., 2002).

Electrical conductivity and pH were determined on water extracts (1:10 air-dried compost raw material: water) as outlined by Smith and Hughes (2002). The ground samples were shaken in distilled water on a reciprocal shaker for 30 minutes and left to stand overnight. pH was measured using a Jenway model 3510 pH meter and EC was read on an EcoScan Con 5 electrical conductivity meter. Ash and organic matter content were determined as residual mass and weight loss respectively on ignition at 550°C for 12 hours in a muffle furnace. Organic carbon was calculated from weight loss on ignition using equation 1:

$$\%C = (\text{weight loss on ignition} \times 100) / 1.8$$

(Haug, 1980) **Equation 1**

Total cations (Ca, Mg, Na and K) were determined in ash by adding 2 to 3 drops of distilled water. Hydrochloric acid (50%; 2.0 ml) was added to the sample and the sample heated to dryness on a block heater. Nitric acid (25%; 5.0 ml) was added to dissolve the sample. The dissolved sample was transferred to a 50 ml volumetric flask and the volume made to the mark. After settling a clear supernatant (1.0 ml) was pipetted into a 50 ml volumetric flask. Strontium chloride (1%; 25 ml) was added followed by distilled water (24 ml) and the mixture was thoroughly mixed. Calcium and magnesium were read on an atomic absorption spectrophotometer (AAS) at wavelengths of 422.7 nm and 285.2 nm respectively. Sodium and

potassium was determined using flame emission spectrophotometry.

2.3 Green house experiment layout and procedure

A green house pot experiment was established using air dried Churu farm soil to test the maturity of the finished compost derived from chicken blood and maize stover. The compost was used as a soil amendment. Maize variety SC 513, an early maturing variety was grown in pots filled with amended sandy soil. The pots used measured 23 cm in diameter and 23 cm depth. The soil was first sieved to pass through a 2 mm sieve before use. The soil was amended with an equivalent rate of 100kg of N per hectare. Maize N requirement ranges from 90 -120 kg N/Ha (FAO, 2006). Treatments used are shown in Table 1.

Composts were ground to pass through a 2 mm sieve before mixing with 3 kg of soil. The treatments were replicated three times and pots were placed in the greenhouse in a completely randomised design. A total of 15 pots were used. The soil and the composts were thoroughly mixed and ten maize seeds placed into each pot. After determining percent emergence by counting the number of emerged seeds two weeks after sowing, two plants were left in each pot. The remaining plants were allowed to grow for five weeks because at between four and five weeks plant nutrients are well distributed in the plant and this is when optimum nutrient uptake from the soil takes place. Soil moisture was adjusted regularly according to plant requirements to avoid moisture stress and leaching the soils. The above ground plant parts were harvested at five weeks and oven dried at 60°C for 48 hours. Oven-dried maize samples were

ground and analysed for total N, Mg, Ca and K using the same methods outlined for the compost samples (Okalebo et al., 2002).

2.4 Statistical analysis

Statistical analysis was done using Genstat 6 package, (Genstat, 2003). Treatment means were calculated and a general ANOVA was used to determine whether there were significant differences among treatments at a confidence interval of 95%. Least significant difference (LSD) was used to determine treatments that were significantly different.

RESULTS

3.1 Characterisation of soil and the final compost

Tables 2 and 3 show the different chemical properties of the composts and the soil used for the greenhouse pot experiment. Total and mineral N content decreased in the order 10% > 30% > 70% > 100% in the maize stover compost treatments. The C:N ratio of the 10% and 30% maize stover compost treatments were below the critical 20:1 ratio while the 70% and 100% were higher.

Percent Seed emergence

Seed emergence percentage did not significantly differ among treatments ($P = 0.260$, Table 4). Most of the planted seeds germinated and emerged well indicating that there were no problems.

Table 1. The treatments used in the greenhouse pot experiment

Treatment	Proportions of chicken blood and maize stover in the finished compost
1	10% maize stover + 90% chicken blood
2	30% maize stover + 70% chicken blood
3	70% maize stover + 30% chicken blood
4	100% maize stover + 0% chicken blood
5	No amendment (control)

Table 2. Chemical properties of soil amendments

Chemical properties	10% stover	30% stover	70% stover	100% stover
Total N (%)	3.75	3.43	2.41	0.98
Ammonium –N ppm	146.9	62.36	55.9	35.4
Nitrate – N ppm	1.52	0.94	0.44	0.37
Total cations (ppm)	43.99	40.78	33.60	30.40
Organic Matter (%)	50.6	47.7	55.0	59.00
pH	6.03	6.52	6.49	7.74
EC (mScm ⁻¹)	4.05	3.46	2.88	2.14
Ash Content (%)	16.38	14.54	15.04	15.06
C/N ratio	13.52	13.92	22.84	60.20

Table 3. Selected chemical soil properties

Chemical properties	
% Clay	5
% Silt	3
% Sand	92
Texture	Sandy
pH (CaCl ₂)	5.2
OC (%)	1.6
Available P (ppm)	11
Available N (ppm)	23

Table 4. Percent seed emergence for each soil amendment

Percent maize stover in compost amendment	% Seed emergence
10% Maize stover	96.7
30% Maize stover	100
70% Maize stover	93.3
100% Maize stover	86.7
Control	100
Least significance difference	14.09

Maize dry matter yield

Maize dry matter yield differed significantly among treatments ($p < 0.05$) and was in the order 10% > 30% > 70% > 100% > control (Figure 1). The plants grown in the soil amended with 10% and 30%

Foliar analysis

Total Nitrogen

Mean N concentration in plant samples increased with a decrease in the proportion of maize stover in the compost. Nitrogen values were in the order 10% > 30% > 70% > 100% > control (Figure 2). There were significant differences ($p < 0.001$) among treatments in terms of N concentration with the plants growing in the soil amended with compost derived from 10% maize stover treatment having the greatest N concentration (0.75%) and those in the control the least (0.27%).

However, there was no significant difference in N concentration between the soils amended with the 70% and 100% maize stover compost and the

maize stover final compost had greater biomass. These were significantly different from the 70%, 100% and control treatments.

Nutrient content in maize plant samples

control. Total cation (Mg, Ca, K and Na) uptake did not differ significantly among treatments ($p > 0.05$) (Figure 4). The control, however, had the highest total cation content and was significantly different from the soils amended with compost.

4. DISCUSSION

Maize seed emerged well for all the treatment indicating that the amendments did not have phytotoxic organic compounds, such as the propionic, acetic and butyric acid which hinder germination and seed emergence. Baziramakenga and Simard (1998) demonstrated that volatile low molecular weight organic acids decreased with composting duration and are associated with early stages of decomposition.

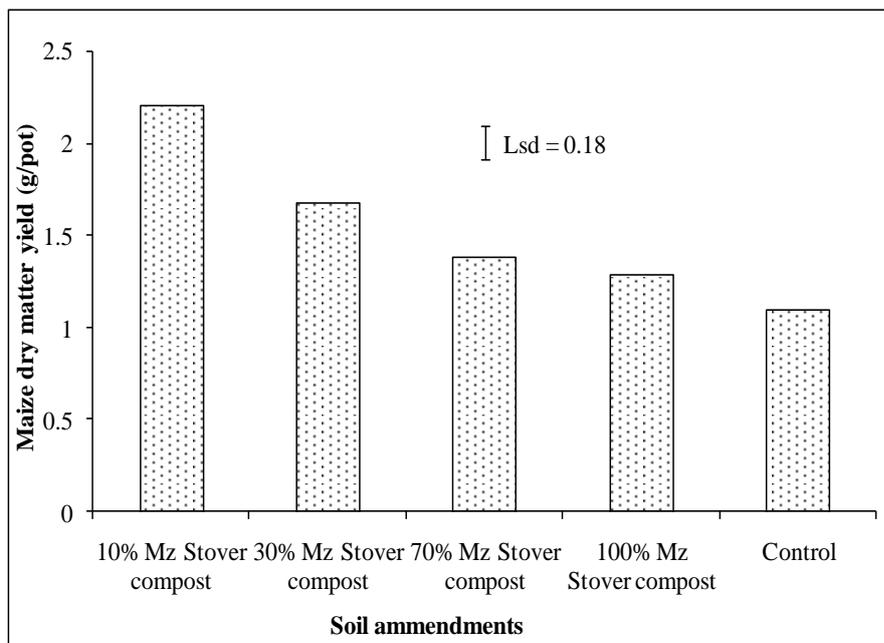


Figure 1: Effects of final composts on maize dry matter yield at five weeks after emergence in the greenhouse pot.

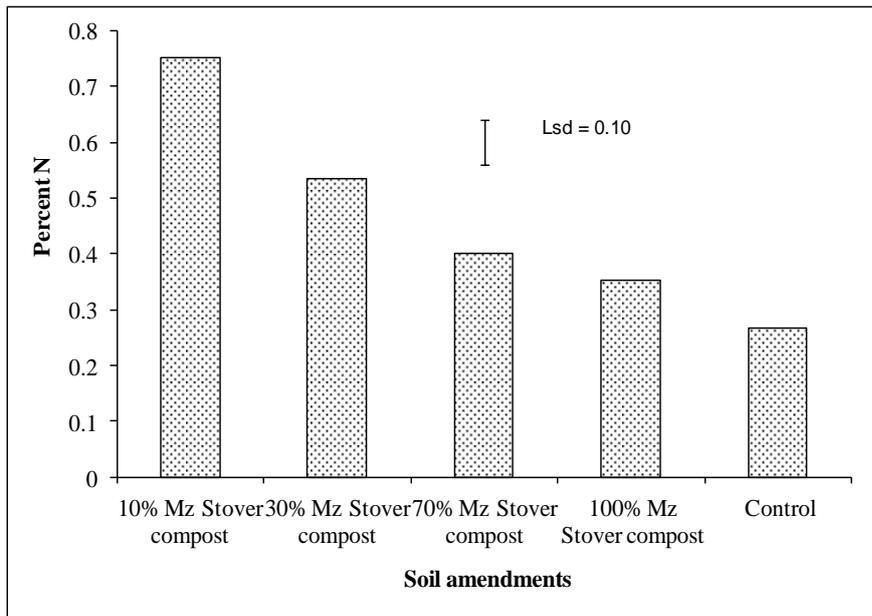


Figure 2: Total nitrogen uptake by plants grown in soils amended with different chicken blood finished compost. (Data points are the mean of the three replicates)

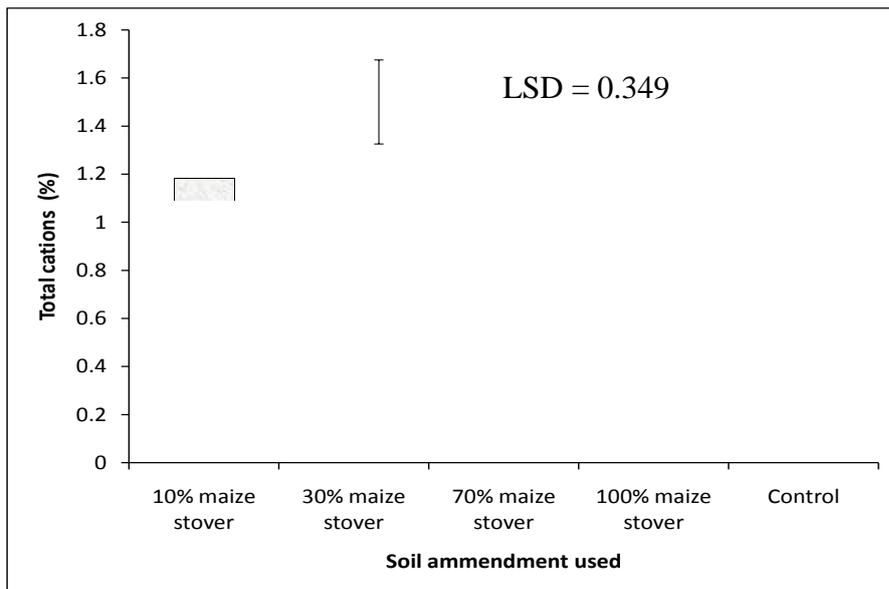


Figure . Total cation uptake by plants grown in soils amended with different chicken blood finished compost. (Data points are the mean of the three replicates)

Tiquia and Tam (1998), Tiquia et al., (1996) and Terman et al., (1973), reported that the application of immature composts inhibited seed germination, emergence and plant growth due to phytotoxic compounds. Nitrogen availability in the soils

amended using the 70% and 100% treatments was low compared to the 10% and 30% treatments. This could have been due to differences in N mineralization as C:N ratios differed significantly, $P < 0.05$). Rate of nitrogen mineralization is

affected mainly by the C:N ratio of the organic amendment. Residues with low C:N ratios tend to exhibit net N mineralization, while residues with high C:N ratio exhibit immobilization (Mohanty et al., 2010;). The 10% and 30% treatments had C:N ratios of 13.52 and 13.92 respectively. These were below the critical C:N ratio of 20:1 (Mupondi et al., 2006) and thus mineralised better and faster than the other treatments making more N available for uptake. The initial C:N ratios of the 70% and 100% maize stover treatments were 22.84 and 60.20 respectively. The 10% and 30% composts also had more available $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ (Table 2). However, the concentrations of N for all the treatments were lower than the adequate plant N tissue concentration reported by Okalebo et al., (1999). Nitrogen should range from 3.5 to 5% at 5 weeks for maize (Okalebo et al., 1999), in fields after the application of organic amendments. Research has also shown that mineralisation occurs in multiple phases after compost application depending on the decomposability of the composts (Hargreaves et al., 2008; Kokkora et al., 2010). This means there is a non-steady N release rate even if compost is expected to result in net N mineralisation at C:N ratio below 15. Nyamangara and Giller, (2003), reported N deficiency in maize during early plant growth (6 weeks after planting). For this study the maize crop could have been left to grow over a longer period. Most studies on compost mineralisation have been done over longer periods. Murillo et al., (1995) found 22% mineralisation over a 22 week period of incubation while Iglesias and Alvarez, (1993) found 21% mineralisation over a 6 month pot study.

The low N recoveries suggest slow mineralisation rates. Large compost applications would be required to significantly increase short term soil N supply (Hartz et al., 2000) or combine with

Composting reduces N mineralisation rates of organic waste. It stabilises C and N in the organic soil amendment (Nyamangara et al., 1999). Kokkora et al., (2010), Hargreaves et al., (2008ab), and Hartz et al. (2000), however, reported that mineralisation rates of composts vary nearly as widely as those of uncomposted manure. Castellanos and Pratt (1981) found N mineralisation rates ranging from 4 to 35% in a 10 month assay for manure composts, while Douglas and Magdoff (1991) reported that three manure composts had net N immobilization over 67 day incubation period.

The maize plants were stunted and yellow in colour and this could have been due to the inadequate N concentration in the soil. Short term immobilisation could be attributed to the deficiency symptoms observed. This could explain crop N deficiencies inorganic fertiliser (Nyamangara et al., 2003). Compost and manure amendment trials can indicate the value of organic amendments in long term soil building and their limitations in enhancing short term N availability.

5. CONCLUSION

From the study, the composts derived from mixtures of chicken blood and maize stover with initial proportions of 10% and 30% maize stover had greater potential to support maize growth as shown by the dry matter yield and total N concentrations in the plant samples. Total cations (Mg, Ca, K and Na) did not show significant difference among treatments. Further studies where the composts are combined with mineral nitrogen fertilizer to enhance the supply of N are recommended because the N from the composts were inadequate. Maize seed emerged well for all the treatments indicating that the amendments did not have phytotoxic organic compounds.

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