

## Efficacy of chicken manure on the growth, yield and profitability of maize in the upland and inland valley swamp of Sierra Leone

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**Abstract:** An experiment was conducted to investigate the effect of chicken manure on the growth, yield and profitability of maize at the School of Agriculture Experimental Site, Njala University, during 2014 and 2015 cropping seasons. A total of eight treatment combinations comprising two plant densities (26,666 and 53,333 plants.ha<sup>-1</sup>) and four chicken manure levels (0, 2, 4 and 8 t.ha<sup>-1</sup>) were established in split plot design with three replicates. Results revealed that plant height, stem diameter, leaf area index (LAI) and chlorophyll content of leaves significantly increased with time and increasing chicken manure (CM) rate. Seed yield and yield attributes of populations one and two significantly increased with increasing CM rates. Application of CM at 2.0 t.ha<sup>-1</sup> increased yields by more than 100% in the second and third seasons; and in populations one compared to the control. Findings of the economic analysis revealed that the 2.0 t.ha<sup>-1</sup> CM point application is the most profitable maize production system for populations 1 and 2 in the upland and IVS ecologies. Results suggest that optimum application and adequate supply of plant nutrient from chicken manure is important for the success of conservation and sustainable farming systems. Findings in this study could be used as guide for improving nutrient use efficiency of CM in crop management rotation systems and commercial production of the crop.

### INTRODUCTION

Maize (*Zea mays* L) is the third most important cereal of the world after wheat and rice (FAO, 2011). It is an important cereal crop that provides staple food to large number of human population in the world (Farhad *et al.*, 2007). In developing countries, maize is a major source of income to many farmers (Tagne *et al.*, 2008). The crop is commonly cultivated in the tropics and warm sub tropics for food, livestock feed, and other industrial uses. In Sierra Leone, maize is the second most important cereal crop grown after rice which is the country's staple food (NARCC/MAFFS, 2005). Maize is eaten fresh or milled into flour and serves as a valuable ingredient for baby food, cookies, biscuits, ice-cream, pancake mixes, livestock feed and a variety of traditional beverages (NARCC/MAFFS, 2005).

Despite its importance, the mean grain yield of maize for 10 years on infertile soils in West Africa was

estimated at 1.6 t.ha<sup>-1</sup> (FAO, 2012). The decreased productivity of the crop in the sub-region, including Sierra Leone, is partly attributable to yield limiting factors such as low soil fertility, poor agronomic practices, reduced bush fallow periods due to intensive use of land for non-agricultural activities, erratic climatic changes during growth and development, pests and diseases and limited value addition (Kamara *et al.*, 2004; SLARI, 2011).

The application of fertilizer from organic and inorganic sources have been well established as one of the critical ways of effectively improving growth and yield of maize (Iken and Amusa, 2004; Dauda *et al.*, 2008; Boateng *et al.*, 2006). Chemical fertilizers are often expensive, unaffordable, inaccessible and unavailable to resource poor farmers in Sierra Leone. Comparatively, organic fertilizers such as poultry manure are readily available to and affordable by farmers as cheap source of nitrogen for sustainable

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maize production. Poultry manure is a natural fertilizer that contains higher nitrogen content and other essential plant nutrients, and serves as soil amendment by adding organic matter (Hussein, 1997). These fertilizers supply both essential macro and micro nutrient elements to plants as well as improve the soil physico chemical condition for better maize growth and yield in various agro ecological zones (Martin *et al.*, 1998; Enwezor *et al.*, 2008). Moreover, information on economic analysis of poultry manure serves as useful guide for maize producers. Development of appropriate, sound and affordable soil management strategies contribute to maximizing the yield potential of the crop. This study was therefore designed to investigate the effect of poultry manure on the growth, yield and profitability of maize under the upland and inland valley swamp ecologies.

## MATERIALS AND METHODS

### Description of experimental site

An experiment was conducted on the upland and inland valley swamp of the School of Agriculture Experimental Site, Njala University, Njala, Southern Sierra Leone, during early September, 2014 and early February, 2015. Njala is situated at an elevation of 50 m above sea level on longitude 12° 05' W and latitude 8° 07' N. The annual rainfall of Njala range between 2000 and 2900 mm per annum. The mean monthly air temperature ranges from 21 to 28°C for the greater part of the day and night especially during the rainy season. Mean monthly minimum temperatures in December, January and February are 14 to 20°C. During the remainder of the year, minimum temperatures vary little from 20 to 23°C. Sunshine varies substantially with the amount of cloudiness averaging 6-8 h per day during the rainy period. Relative humidity is usually very high (95-100%) especially during the rainy season.

### Soil and chicken manure sample collections and analyses

Soil samples were randomly collected in three positions per replicate at each site at 0-20 cm soil depth before planting using a Jarret T-handle soil auger (100 mm head diameter). All samples were then bulked into one composite sample. Fresh subsamples were first sieved using 8 mm grid size to remove plant residues, roots and stones and air dried. Dried samples were crushed and sieved using 2 mm grid size mesh for the chemical and mechanical analyses. Selected physical and chemical data for both the upland and inland valley swamp soils are presented in Table 1. Soils from experimental sites are well to moderately well-drained and very low in plant nutrients. The cation-exchange capacities are low and generally less than 10 cmol(+)/kg of soil. Exchangeable contents of Ca, Mg, K, and Na are low.

Soil analyses were carried out using methods described jointly by the International Soil Reference and Information Center (ISRIC) and the FAO (ISRIC/FAO, 2002). Soil colour was visually compared with the Munsell Chart while pH was determined on 1:1 soil: water extracts. Texture was determined using the hydrometer method. Organic carbon was determined by titration using the Walkley-Black procedure while total nitrogen was determined by Kjeldahl distillation. Available P was determined using the Bray 1 procedure while exchangeable cations (K, Ca and Mg) were measured on neutral 1N ammonium acetate extracts. Exchangeable K and Na were read on a Flame Photometer, while exchangeable Ca and Mg were determined by titration. Exchangeable Acidity (Al + H) was extracted by 1M KCl and titrated with 0.025 M NaOH. Effective CEC was calculated as the sum of exchangeable cations and exchangeable acidity.

Chicken manure sample was analyzed using standard procedures (ISRIC/FAO, 2002). The CM consisted of the following chemical composition: 12.37% C, 24.72% organic matter, slightly acidic pH of 6.61.

**Table 1:** Physical and chemical properties of soil samples from the experimental sites at 0– 20 cm

Composition	Upland soil	Inland valley swamp soil
	<b>Physical properties (%)</b>	
Sand	81.0	78.8
Silt	8.0	8.2
Clay	11.0	13.0
	<b>Chemical properties</b>	
pH in H <sub>2</sub> O	5.0	4.7
Organic carbon (g/kg)	5.41	6.16
Total nitrogen (g/kg)	0.14	0.07
Available exchangeable P (mg/kg)	5.43	4.00
Exchangeable base (cmol/kg)		
Ca	0.21	0.55
Mg	0.13	0.27
K	0.08	0.12
Na	0.02	0.08

CEC	5.0	5.7
Exchangeable acidity H (cmol/kg)	4.0	4.2
Exchangeable Aluminum (cmol/kg)	2.0	2.2

### Planting material, treatments, design and cultural practices

An improved maize variety (cv. DMR-ESR Yellow), obtained from the International Institute of Tropical Agriculture, Ibadan, Nigeria, was used as the experimental planting material. A total of eight treatment combinations consisting of two plant populations (i.e. population 1=one plant per stand=26,666 and population 2=two plants per stand=53,333 plants.ha<sup>-1</sup>) with each population amended at 0, 2, 4 and 8 t.ha<sup>-1</sup> of chicken manure (CM). Three months old chicken manure from layer birds in deep litter system at the Animal Production Department (APD) commercial farm was used. Prior to planting, the upland was ploughed and harrowed using the disc plough whilst the inland valley swamp (IVS) was manually prepared using digging hoe. Both sites were laid out in a split plot design with the two populations in the main plots and the four chicken manure amendments in the sub-plots.

The chicken manure was applied in the planting holes and well incorporated in the soil using hand trowel a week prior to planting. The maize seeds were planted at 0.75 m x 0.50 m. In both ecologies, three hand and hoe weeding was done at three, five and eight weeks after planting.

### Data collection and analysis

A total of fourteen agronomic data were collected during experimental periods of both seasons. At two weeks after planting, five plants were randomly selected and tagged in each plot for growth parameter collection. Data collected included plant height (cm), number of leaves, stem girth (at 10 cm above the base of each stem); leaf length and width for determination of leaf area (cm<sup>2</sup>) and leaf area index (LAI). The leaf area was measured using a nondestructive method (Stoppani *et al.*, 2003). The LAI was calculated as the sum of green leaf area per plant multiplied by number of plants per plot (Stoppani *et al.*, 2003).

LAI= LA (cm<sup>2</sup>)\*plant number per plot\*leaf number per plant/ plot area.

Leaf chlorophyll content was measured at 3, 6 and 9 WAP using SPAD-index meter (SPAD-502, Konica Minolta, Osaka, Japan) on 5 completely opened leaves as described by Markwell *et al.* (1995). Days to tasseling and silking were also recorded from date planted to date five plants tasseled and silked.

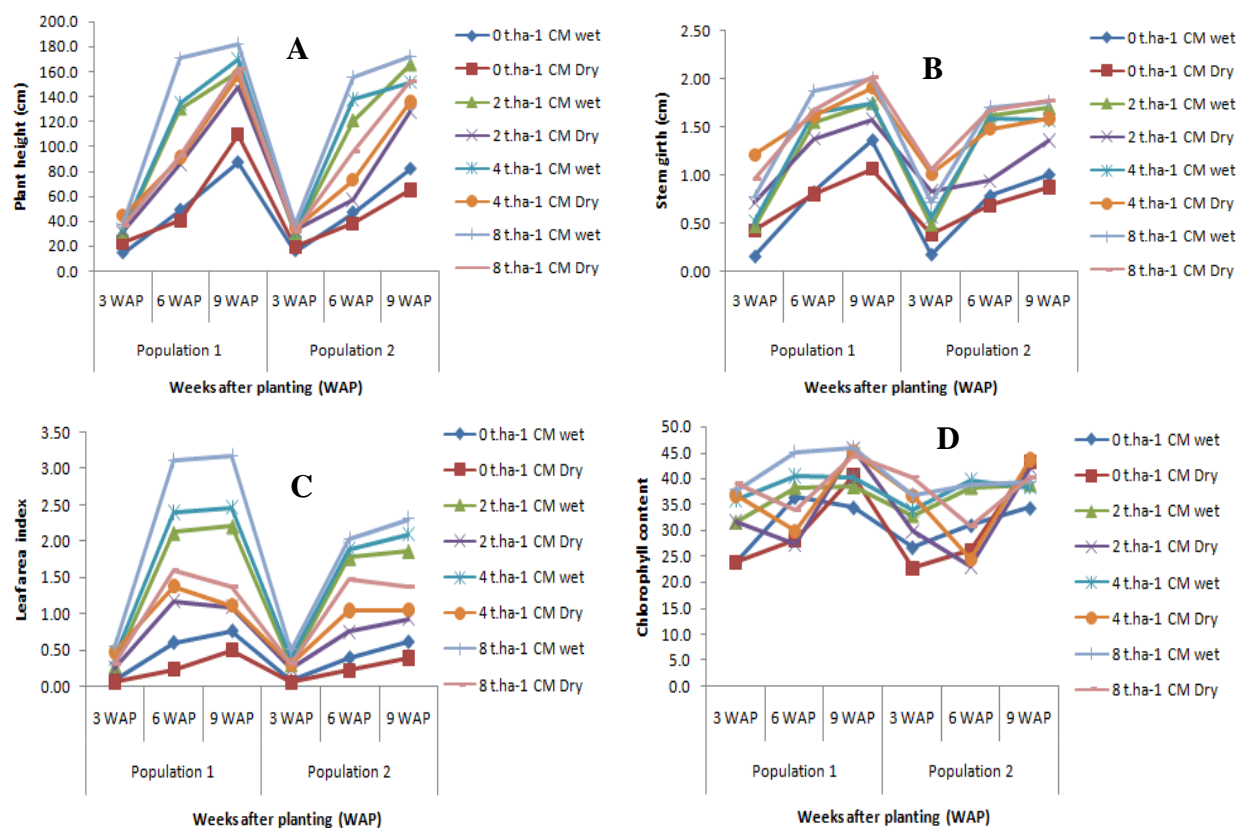
At harvest, the following yield components and yield data were collected. ear length (cm), ear diameter (cm), cob length (cm), cob diameter (cm), kernel length (cm), kernel diameter (cm), yield (t.ha<sup>-1</sup>). The harvested and shelled grains were sun-dried to 12% moisture level for determination of grain yield. Vernier caliper and meter rule were used for all diameter and length measurements, respectively.

Data were subjected to analysis of variance (ANOVA) using the GENSTAT statistical programme (GENSTAT, 15<sup>th</sup> release, Rothampstead, UK). The Least Significance Difference (LSD) was used to compare between treatment means using a significance level of  $\alpha = 0.05$ . The residuals of data for the parameters used were first checked for normality and homogeneity using the Shapiro-Wilk test and Bartlett's test to ensure that data were normally distributed.

## RESULTS AND DISCUSSION

### Growth parameters

Mean plant height, stem girth and leaf area index significantly increased with increasing CM rates from 3-9 WAP (Figure 1 A, B and C). The plant height, stem girth and leaf area index of CM mended plants out-grew the control at 2-8 t.ha<sup>-1</sup> rates, while the control had the lowest in populations one and two during both growing seasons.



**Figure 1:** Effect of CM rate on (a) plant height, (b) stem girth, (c) leaf area index, and (d) chlorophyll content of maize at various sampling regimes

Chicken manure application at 8 t.ha<sup>-1</sup> rates significantly exhibited tallest, biggest and largest plant height, stem girth and leaf area index, respectively, during the wet season compared to the control plots. Chlorophyll content increased with increasing CM application with the highest value (46.0) obtained at 8 t.ha<sup>-1</sup> CM rate (Figure 2 D). The significantly taller plant heights in CM amended plots could be possibly attributed to increased organic matter content and decomposition that may have contributed to higher initial N-mobilization compared to non-amended plots. These results agree with those of other researchers (Obi and Ebo, 1995; Boateng *et al.*, 2006; Beah *et al.*, 2014). The reduced leaf area index in the non-amended plots was also probably attributed to the reduced leaf area, leaf number and low mobilization of available mineral N. The slight increase and decreasing LAI in later stages of growth partly corroborates with the phenomenon of decreasing returns reported by other researchers (Boateng *et al.*, 2006). The higher chlorophyll content in CM amended plants is indicative of higher N mineralization during plant growth, which may have increased available soil N and higher crop uptake, thereby producing greater chlorophyll concentration in plant tissues. The results confirmed earlier observations that available nutrients in manures enhanced higher nutrient uptake and development of photosynthetic sites, thereby aiding

yield increase (Amujoyegbe *et al.*, 2007).

#### Yield and yield attributes of maize

Generally, rates of chicken manure (CM) applied, season and interaction between both highly significantly ( $P < 0.001$ ) affected seed yields of maize (Table 2). Seed yield and yield attributes of populations one and two significantly increased with increasing CM rates compared to the control. In the second season (upland ecology), the highest yields of populations one and two were 3.09 and 2.44 t.ha<sup>-1</sup>, respectively, both at the 8.0 t.ha<sup>-1</sup> rate, while the control (0.50 - 0.71 t.ha<sup>-1</sup>) had the lowest. Similar trends were also noted in the third season (IVS) ecology with regards treatments used. However, the mean second (wet) season yield (1.95 t.ha<sup>-1</sup>) was significantly higher than the third (dry) season yield (1.08 t.ha<sup>-1</sup>). Results agree with earlier work by Boateng *et al.* (2006) who noted that CM significantly enhanced maize grain yield with the 4.0 t.ha<sup>-1</sup> CM rate statistically similar to 6.0 t.ha<sup>-1</sup> CM and NPK fertilization at 2.29 t.ha<sup>-1</sup>; but different from the 8.0 t.ha<sup>-1</sup> CM rate. In the present study, however, the yields of both rates were only different for the one and two plants per stand (populations) during the wet (second cropping) season compared to the dry season. The variation could be partly attributed to the varying ecological environment used and the high damage by grasshoppers observed in the IVS.

Rates of CM, season and their interaction significantly affected ear length and diameter of maize. Ear length and diameter increased with increasing rates of CM application in both populations one and two during the second and third cropping seasons. Cob length and diameter were significantly influenced by plant population, rate of CM application and season. In both seasons and populations, the longest and widest cobs were obtained in plots amended with 8.0 t.ha<sup>-1</sup> CM, whereas the control (0 t.ha<sup>-1</sup> CM) plots exhibited shortest and smallest cobs. Rate of CM and season significantly influenced maize kernel size. Unlike kernel length which exhibited significant interaction between CM and season, all other interactions in both kernel length and diameter were non-significant.

#### Economic analysis of various chicken manure rates

The partial budget and cost benefit analysis of maize grown under 0, 2, 4 and 8 t.ha<sup>-1</sup> chicken manure rates is shown in Tables 3 and 4. Results generally indicated that benefit-cost-ratios of all manure regimes of the upland second season maize were

higher than their corresponding IVS third season plants. In the second upland cropping season, point application of 2 t.ha<sup>-1</sup> CM exhibited the highest benefit-cost-ratio in both population 1 (1.75:1) and population 2 (1.70:1), whereas the non-amended plants had the lowest benefit-cost ratios of 0.77:1 and 0.58:1, respectively. Thus, for Le 1.0/ha invested by the farmer to cultivate maize using point application of 2 t.ha<sup>-1</sup> CM, he/she accrues Le 1.0 plus additional Le 1.75 and 1.70, for populations 1 and 2, respectively. However, in the third IVS cropping season, point application of 2 t.ha<sup>-1</sup> CM was only highest for population 1 (0.75:1), followed by 4 t.ha<sup>-1</sup> CM rate in population 2 (0.70:1), whereas the non-amended plants had the lowest benefit-cost ratios of 0.36:1 and 0.54:1, respectively. Thus, for Le 1.0/ha invested by the farmer to cultivate maize using point application of 2 t.ha<sup>-1</sup> CM, he/she accrues Le 1.0 plus additional Le 0.75 using population 1, whereas for the same money he/she will accrue Le 1.0 plus additional Le 0.70 using 4 t.ha<sup>-1</sup> CM rate in population 2. The study demonstrated the importance of economic analysis of different production systems for sound recommendation of profitable technologies or innovations developed.

**Table 2:** Seed yield (t.ha<sup>-1</sup>) and yield attributes of maize as affected by plant population and chicken manure during the second and third cropping seasons at Njala

Population	Nutrient rate (t.ha <sup>-1</sup> )	Seed yield (t.ha <sup>-1</sup> )		Ear length (cm)		Ear diameter (cm)		Cob length (cm)		Cob diameter (cm)		Kernel length (cm)		Kernel diameter (cm)	
		Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	0	0.71	0.50	20.4	15.8	3.5	2.9	9.5	8.5	3.1	2.4	0.9	0.5	0.7	0.6
	2	2.20	1.11	23.1	21.2	4.4	3.8	14.4	11.9	3.8	3.4	1.0	0.7	0.8	0.7
	4	2.19	1.38	22.1	18.9	4.5	3.9	15.9	11.7	3.9	3.7	1.1	0.8	0.8	0.8
	8	3.09	1.45	25.5	19.1	4.9	4.1	16.6	13.2	4.1	4.0	1.1	0.8	0.9	0.9
2	0	0.61	0.59	19.1	18.9	3.8	2.9	9.4	8.8	2.9	2.7	0.8	0.5	0.6	0.5
	2	2.14	0.81	20.8	17.5	4.2	3.4	12.5	9.3	3.6	3.1	1.0	0.6	0.8	0.7
	4	2.17	1.33	21.1	19.1	4.3	3.9	12.9	10.4	3.7	3.6	1.0	0.8	0.8	0.8
	8	2.44	1.44	21.2	20.2	4.4	4.0	13.6	12.5	3.9	3.8	1.0	0.9	0.8	0.9
<b>Mean</b>		<b>1.95</b>	<b>1.08</b>	<b>21.7</b>	<b>18.8</b>	<b>4.3</b>	<b>3.6</b>	<b>13.1</b>	<b>10.8</b>	<b>3.6</b>	<b>3.3</b>	<b>1.0</b>	<b>0.7</b>	<b>0.8</b>	<b>0.7</b>
LSD(5%)P		0.14 <sup>ns</sup>		0.61 <sup>*</sup>		0.18 <sup>ns</sup>		0.16 <sup>*</sup>		0.11 <sup>*</sup>		0.08 <sup>ns</sup>		0.05 <sup>ns</sup>	
LSD(5%)T		0.14 <sup>***</sup>		0.87 <sup>***</sup>		0.17 <sup>***</sup>		0.62 <sup>***</sup>		0.24 <sup>***</sup>		0.06 <sup>***</sup>		0.06 <sup>***</sup>	
LSD(5%)S		0.17 <sup>***</sup>		0.80 <sup>***</sup>		0.14 <sup>***</sup>		0.43 <sup>***</sup>		0.16 <sup>***</sup>		0.05 <sup>***</sup>		0.04 <sup>*</sup>	
LSD(5%)PxT		0.19 <sup>ns</sup>		1.10 <sup>**</sup>		0.22 <sup>*</sup>		0.97 <sup>**</sup>		0.29 <sup>ns</sup>		0.09 <sup>ns</sup>		0.07 <sup>ns</sup>	
LSD(5%)PxS		0.18 <sup>ns</sup>		0.85 <sup>**</sup>		0.17 <sup>ns</sup>		0.85 <sup>*</sup>		0.17 <sup>ns</sup>		0.06 <sup>*</sup>		0.05 <sup>ns</sup>	
LSD(5%)TxS		0.27 <sup>***</sup>		1.37 <sup>ns</sup>		0.24 <sup>ns</sup>		0.83 <sup>**</sup>		0.32 <sup>ns</sup>		0.09 <sup>ns</sup>		0.07 <sup>ns</sup>	
LSD(5%)PxTxS		0.38 <sup>ns</sup>		1.87 <sup>*</sup>		0.34 <sup>ns</sup>		1.23 <sup>ns</sup>		0.42 <sup>ns</sup>		0.12 <sup>ns</sup>		0.10 <sup>ns</sup>	
CV(%)		7.5		3.4		3.3		4.1		5.4		6.1		6.0	

P=population, T=chicken manure treatment, S=season, ns=non-significant, \*=significant at p<0.05, \*\*=significant at p<0.01, \*\*\*=p<0.001



**Table 3: Partial budget and cost benefit analysis of maize grown under different chicken manure rates (0, 2, 4 and 8 t.ha<sup>-1</sup>) in the upland ecology of Njala**

Population	1				2			
CM rates (t.ha <sup>-1</sup> )	0	2	4	8	0	2	4	8
Average yields (t.ha <sup>-1</sup> )	0.71	2.2	2.19	3.09	0.61	2.14	2.17	2.44
Adjusted yields (t.ha <sup>-1</sup> )*	0.639	1.98	1.971	2.781	0.549	1.926	1.953	2.196
Gross benefit (Le/ha)	4153500	12870000	12811500	18076500	3568500	12519000	12694500	14274000
Cost of chicken manure (CM) (Le/ha)	0	800000	1600000	3200000	0	800000	1600000	3200000
Labour cost of applying CM (Le/ha)	0	200000	200000	200000	0	200000	200000	200000
Machine hire for 1 day (Le/ha)	350000	350000	350000	350000	350000	350000	350000	350000
Ploughing and harrowing cost (Le/ha)	181500	181500	181500	181500	181500	181500	181500	181500
Cost of maize seed (Le/ha)	172500	172500	172500	172500	172500	172500	172500	172500
Labour cost of planting (Le/ha)	200000	200000	200000	200000	200000	200000	200000	200000
Cost of weeding (Le/ha)	600000	600000	600000	600000	600000	600000	600000	600000
Harvesting cost (Le/ha)	200000	200000	200000	200000	200000	200000	200000	200000
Cost of processing of cobs	639000	1980000	1971000	2781000	549000	1926000	1953000	2196000
Total variable cost	2343000	4684000	5475000	7885000	2253000	4630000	5457000	7300000
Net benefit	1810500	8186000	7336500	10191500	1315500	7889000	7237500	6974000
<b>Benefit cost ratio</b>	<b>0.77</b>	<b>1.75</b>	<b>1.34</b>	<b>1.29</b>	<b>0.58</b>	<b>1.70</b>	<b>1.33</b>	<b>0.96</b>

\*Average yield adjusted 10%, farm gate price per kg of maize in 2014=Le 6,500; USD 1 = Le 5,500

**Table 4: Partial budget and cost benefit analysis of maize grown under different chicken manure rates (0, 2, 4 and 8 t.ha<sup>-1</sup>) in the lowland (IVS) ecology of Njala**

Population	1				2			
CM rates (t.ha <sup>-1</sup> )	0	2	4	8	0	2	4	8
Average yields (t.ha <sup>-1</sup> )	0.5	1.11	1.38	1.45	0.59	0.81	1.33	1.44
Adjusted yields (t.ha <sup>-1</sup> )*	0.45	0.999	1.242	1.305	0.531	0.729	1.197	1.296
Gross benefit (Le/ha)	2925000	6493500	8073000	8482500	3451500	4738500	7780500	8424000
Cost of chicken manure (CM) (Le/ha)	0	800000	1600000	3200000	0	800000	1600000	3200000
Labour cost of applying CM (Le/ha)	0	200000	200000	200000	0	200000	200000	200000
Machine hire for 1 day (Le/ha)	350000	350000	350000	350000	350000	350000	350000	350000
Ploughing and harrowing cost (Le/ha)	181500	181500	181500	181500	181500	181500	181500	181500
Cost of maize seed (Le/ha)	172500	172500	172500	172500	172500	172500	172500	172500
Labour cost of planting (Le/ha)	200000	200000	200000	200000	200000	200000	200000	200000
Cost of weeding (Le/ha)	600000	600000	600000	600000	600000	600000	600000	600000
Harvesting cost (Le/ha)	200000	200000	200000	200000	200000	200000	200000	200000
Cost of processing of cobs	450000	999000	1242000	1305000	531000	729000	1197000	1296000
Total variable cost	2154000	3703000	4746000	6409000	2235000	3433000	4701000	6400000
Net benefit	771000	2790500	3327000	2073500	1216500	1305500	3079500	2024000
<b>Benefit cost ratio</b>	<b>0.36</b>	<b>0.75</b>	<b>0.70</b>	<b>0.32</b>	<b>0.54</b>	<b>0.38</b>	<b>0.66</b>	<b>0.32</b>

\*Average yield adjusted 10%, farm gate price per kg of maize in 2015=Le 6,500; USD 1 = Le 5,500

## CONCLUSIONS

This study demonstrated that chicken manure is a valuable organic fertilizer whose use should be encouraged. Based on the results obtained in the two cropping seasons' experiment, it was evident that: (i) point or pocket application of chicken manure minimized manure wastage thereby facilitating the effective use of manure by the maize plants. (ii) The growth attributes of maize, which included plant height, stem girth, leaf area index and chlorophyll content increased with time and increasing CM rates. (iii) Days to tasseling and silking decreased significantly with increasing CM rates. (iv) Seed yield and yield attributes of populations one and two significantly increased with increasing CM rates compared to the control. (v) An application rate of 2 t.ha<sup>-1</sup> was capable of increasing yields by more than 100% in both the second and third seasons and in populations one over the control. (vi) Chicken manure application at 8.0 t.ha<sup>-1</sup> exhibited the highest yields of 3.09 and 2.44 t.ha<sup>-1</sup>, respectively, for populations one and two, while the control which ranged between 0.50 and 0.71 t.ha<sup>-1</sup>, respectively, had the lowest. (vii) It was most profitable amending maize at 2 t.ha<sup>-1</sup> chicken manure point application in the upland and

IVS ecologies. Future studies shall target the nutrient release pattern and residual effect of chicken manure in these two ecologies.

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