EFFECT OF DIFFERENT FORMS OF BIOSLURRY ON PERFORMANCE OF CROPS IN WESTERN UGANDA

END OF PROJECT REPORT

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Acronyms

ABPP	Africa Biogas Partnership Program
CBOs	Community Based Organizations
CEC	Cation Exchange Capacity
CFU/G	Colony forming units per gram;
DGIS	Dutch Government Ministry of Foreign Affairs
FICA	Farm Inputs Care Centre LTD
FYM	Farm Yard Manure
HIVOS	Humanistic Institute for Cooperation with developing countries
LSD	Least Significant Difference
MBAZARDI	Mbarara Zonal Agriculture Research and Development Institute
NARO	National Agriculture Research Organization
NPK	Fertilizers providing Nitrogen, Phosphorus, and Potassium
RCBD	Randomized Complete Block Design
SNV	The Netherlands Development Organization
UDBP	Uganda Domestic Biogas Program

SUMMARY

The increasing global population, estimated to reach nine billion people in 2050 requires increased efficiency in agricultural production for food security and household income. With increasing decline in soil fertility, use of fertilizers becomes a requirement for crop production. In Uganda, the use of inorganic fertilizers remains below one kg per hectare per year. Besides, inorganic fertilizers are unfriendly to the environment and users, and are short lived in the soil requiring regular application. The use of bioslurry in increasing crop productivity is therefore the best alternative to inorganic fertilizers but its effectiveness to improve yield in crops is not known. The use of bio-slurry in increasing crops productivity has been reported in other countries but little research has been done in Uganda to establish the importance of bio-slurry on improvement of soil and increased performance of crops. National Agriculture Research Organization (NARO), together with SNV Uganda, established trials to evaluate the use of bioslurry in production of annual crops using maize, cabbages and perennial crops using coffee as a test crop. The study aimed at determining the effect of different forms of bioslurry (composted bioslurry, liquid bio slurry and dried bio slurry) on the performance of crops. Studies were also conducted to determine how bioslurry affects soil quality. For all the crops, the experiments were conducted over the two seasons. For annual crops, experimental fields were established on station at Mbarara Zonal Agriculture Research and Development Institute in Mbarara district while for coffee; the experiments were conducted on four farmers' fields in Isingiro district in western Uganda and were managed by farmers following their farming practices, with project team advising them on good coffee management practices.

For annual crops (maize and cabbages), the results from this study indicate that compost bioslurry applied at rate of 10 t/ha is the most effective form of bio-slurry and increased yield of cabbage by 70% (139 t/ha) compared to the control (82 t/ha) and the yield of maize to more than 4 t/ha compared to 2.7 t/ha for the control (59% increase). The experiment was affected by heavy drought and this could explain the poor performance of both cabbages and maize in both seasons. The profitability analysis indicated that application of bioslurry increased crop revenue per hectare by 65% over control and 33% over NPK for cabbages, and 44% over control and 18% over NPK for maize. This is high revenue that remains untapped by farmers to reduce household poverty. An additional advantage bioslurry over NPK is that it is not easily faked and can retain fertility in the soil for over two years.

For coffee, the overall results indicate that composted bio slurry applied at a rate of 10 t/ha was the most cost effective form of bioslurry and increased the yield of coffee by 65.6% compared to control (the least performance). Composted bioslurry applied at 10 t/ha (10 kg/tree) resulted in actual yield of 2.29 t/ha compared to 0.79 t/ha that was produced in control plots. However, in all seasons the experiment was affected by heavy drought, pests and diseases and this could explain the overall poor performance of coffee. Though there was no significant difference between compost bioslurry applied at 10 t/ha and 15 t/ha (10 kg/tree and 15 kg/tree), it would be a wastage to apply 15 t/ha since it does not result in any advantage over 10t/ha.

Generally the results indicated that the use of bioslurry improves the productivity of crops under field conditions and the findings are a breakthrough for small scale farmers to improve their productivity cheaply since bio slurry is cheaper about $5.0 per ton) than the inorganic fertilizer (about $860 per ton)and can be easily accessible in the communities than inorganic fertilizers. The application of bioslurry improved the Nitrogen content of the soil, the major limiting nutrient for most crops.

Although the liquid bioslurry also improved the yield of coffee, cabbages and maize, but its use is limited by its labour intensity especially if the fields are far since it requires special transport mechanisms such as tank truck, which are expensive. The tedious nature of liquid application is more challenging to women who are majority of the labour force engaged in agriculture. Besides, liquid bioslurry was found to contain health threatening microorganisms and should be handled cautiously. Research should develop innovative ways of effectively processing and packaging bioslurry for easy transport and availability to farmers. Further studies are also recommended to determine the effect of bioslurry on beneficial soil microorganisms and whether the microorganisms detected in the liquid bioslurry could be harmful to consumers of fresh vegetables harvested from plots treated with bioslurry.

Key words: Head weight, Head circumference, Nutrient content analysis, soil fertility, actual yield, potential yield, bioslurry, NPK

CHAPTER 1: INTRODUCTION

Bio-slurry is a by-product of anaerobic biogas production process. It is rich in humus and other plant nutrients and therefore can be utilized to increase plant productivity as potent fertilizer. Bioslurry, a form of organic manure contains nitrogen, phosphorus, and other nutrients that plants need to grow. In addition to slowly releasing plant nutrients over time, the bioslurry improves soil structure and the soil's ability to hold water. Healthier soils improve crop yields and reduce soil loss from both wind and water erosion, and protect water quality by reducing contaminated runoff. Bioslurry can also be a source of income to farmers by saving money that could have been otherwise used to buy fertilizer but also can also sell bioslurry or bioslurry products to gardeners, landscapers, golf courses, and others who use nutrients to grow plants. Previous reports indicate that it is rich in Nitrogen (0.25% wet matter), the major limiting plant nutrient component (UDBP, 2010). It also contains potassium and phosphorus, zinc, iron, manganese and copper, the last of which has become a limited factor in many soils (Warnars and Oppenoorth, 2014). Bioslurry can thus be used to build healthy fertile soil for crop production. Indeed, bioslurry form and content stabilises with double nitrogen content, which is different from Farmyard Manure (FYM). Bioslurry contains readily-available plant nutrients and it contains higher amounts of nutrients and micronutrients than FYM and composted manure do (Warnars and Oppenoorth, 2014). The effects of bioslurry application have been comparable to the effects of the application of chemical fertilisers. As such, bioslurry can be a serious alternative to chemical fertilisers (Warnars and Oppenoorth, 2014).The importance of bioslurry to improve soil fertility, soil structure, and crop productivity, is an interesting link between the biogas use for cooking and lighting, and sustainable agriculture (Warnars and Oppenoorth, 2014).

Studies carried out elsewhere, (Dhussa, 1985) indicate that biogas effluent increases the yield of rice and maize (cereals) by 9% and 7% respectively and yield of cotton 16%. Besides, bio-slurry is reported to enhance cation exchange capacity (CEC), soils aggregation, and water holding capacity, stabilization of soil humid content and prevention of leaching of nutrients (Swift and Woomer. 1993; Dudal and Decker. 1993). However, no study has been done in Uganda, to qualify and quantify the bio slurry´s advantages in agriculture under climate conditions and farmers' practices in Uganda. Limited numbers of farmers in Uganda are familiar with this advantage since there is no data evidence on the importance of bioslurry in agriculture. For this reason, SNV has sought consultancy to undertake scientific study to provide information to convince farmers to increase and take advantage of bioslurry in their farms. This coupled with the initial benefit of cooking and lighting, in effect will create, increase and sustain the demand for biodigesters. Financial institutions will thus be convinced that bio digesters increase people's income and their ability to pay which will increase their willingness to lend for bio digester construction. The purpose of the research was to determine the effect of application and use of bio-slurry on the performance of three selected crops namely; maize to represent cereals, coffee to represent perennial crops and cabbage to represent vegetable crops. These crops were selected due to their importance to the communities of western Uganda and source of food security and household income. The report highlights results on the effect of bioslurry on the soil fertility and performance of the three crops under different bioslurry forms and rates of application. The effect of bioslurry on the quality of soil fertility was also determined. This report covers the results on cabbage, maize and coffees trials. The report also highlights results on the effect of bioslurry on the soil fertility.

1.1 Justification: The need for evaluation of bio slurry as a green fertilizer

The global population is estimated to reach 9 billion people in 2050, a 50% increase since 2007. These people need food and therefore agricultural production and efficiency must be increased. However, unpredictability of climate variability has a significant impact on agriculture production and productivity. Intensive agriculture then becomes necessary and use of fertilizers becomes a requirement since soil infertility remains one of the major challenges to crop production. In Uganda, this problem is compounded by high population density that has resulted in over utilization of land and thus soil exhaustion. Studies have shown that inorganic fertilizer use in Uganda is below 1 kg per hectare and this has been attributed to farmers' inability to access quality fertilizers due to high costs involved. The inorganic fertilizers are either unavailable or unaffordable to small holder farmers. Besides, inorganic fertilizers are healthy unfriendly to the environment and users, and are short lived in the soil requiring regular application. Organic fertilizers are safe and easy to use and their effects are comparable to those of inorganic fertilizers (Warnars and Oppenoorth, 2014). One such example of an inorganic fertilizer that has been recommended is bioslurry, the biogas by-product. Unconfirmed reports (PDBPPakistan-unpublished 2012) suggest that bioslurry is rich in plant nutrients and can improve soil fertility. The number of bio-digesters (thus increase in bio slurry) has been rapidly increasing in Uganda, thanks to development agencies particularly SNV Uganda and Biogas Solutions Uganda (BSU). Therefore, once the advantage of use of bio-slurry in agriculture is scientifically proved, it will be promoted and this will reduce on the use of synthetic fertilizers, improving environmental health. It will also make it easy to promote the biogas program among farmers since the benefits of having biogas will not only be for energy for lighting and cooking but also to increase on food production for food security and income. Farmers hosting the biogas plants will also get income from sale of surplus bioslurry.

1.2 Objectives

The main objective was to conduct the research to determine the effect of different forms of bioslurry (liquid, dried and composted) on soil quality and the performance of crops. This study compared results from bioslurry with that of the inorganic fertilizers.

More specifically, the study addressed the following areas:

1. Compared use of bioslurry with inorganic fertilizers in enhancing crop productivity
2. Determined the effect of bioslurry on crop productivity (harvestable yield, growth rate,) and soil quality
3. Compared the effect of different forms of the bioslurry (liquid, dried and composted) on crop yield and soil quality (soil organic matter and soil nutrient)
4. Determined the bioslurry safety, nutrient contents and their availability to plants,

CHAPTER 2: BIOSLURRY SAFETY AND ITS EFFECTS ON SOIL QUALITY

2.1 The three Bioslurry forms used

Three different forms of bio slurry (liquid, dried and composted) were prepared at Mbarara ZARDI.

Dry Bioslurry: Dry bio slurry was prepared at MBAZARDI by drying liquid bio-slurry under a makeshift shelter. This was to prevent direct sunlight on the bioslurry that may result in vaporization of nutrients from the bioslurry. The shade would also prevent the bio slurry from rain that may result in its movement in runoff (Figure 1).

Figure 1: Dry Bio slurry being prepared under the shade

Compost Bioslurry: The compost bioslurry was made by mixing liquid bio slurry in a bio-slurry pit with organic matter especially grass and green vegetation collected as weed from on-station crops. These would be mixed-up until they decompose (Figure 2).

Figure 2: Compost Bio slurry being prepared under the shade in the slurry pit

Liquid Bioslurry: samples were collected from Simba Farm in Ibanda district, Kalitani's Farm in Mbarara and on-station biogas plant at MBAZARDI Mbarara (Figure 3).

Figure 3: Liquid Bio slurry being offloaded from the tank

2.2 Is fresh Liquid safe to the user?

Liquid Bio-slurry samples were collected from three different sources (Simba Farm in Ibanda district, Kalitani's Farm in Mbarara and on-station biogas plant at MBAZARDI Mbarara) and analysed for presence of coliforms, entropathogenic E. coli, helminth ova and cysts, salmonella, shigella and other parasites. Simba Farm is located in Ibanda district and contains Friesian dairy cattle which feed on natural grass, Silage and Hay. The Kalitani's farm found at 6 miles from Mbarara Town on Kasese Road and consists of Friesian cows, cross breeds and local cows; and feed entirely on natural grass in paddocks. On the other hand, the MBAZARDI bio-digester is fed with cow dung from Friesian dairy cattle which feed on natural grass and some feed supplements. The fresh bioslurry was collected into plastic bottles and taken to for Bio-slurry safety analysis at Makerere University, school of veterinary Sciences from where they were analysed for the parasites and micro-organisms.

The results indicate that in all the three samples, no faecal parasites (ascarid eggs) were found. However, all the samples contained Coliforms, E. coli, Salmonella spps and Shigella spps. This suggests that the liquid bio-slurry have the potential to cause human infection and should be handled with care such as using protective gloves and other protective gears. The amount of E.coli ranked from 3.0 x 103 in samples collected at MBAZARDI to 4 x 105 in samples collected form Simba Farm in Ibanda district (Table 1). It should be noted however, that the results reported here about the safety of bio-slurry are specific to these samples and may be different from samples collected from other sources. For example no faecal parasites were found in these samples but previous reports indicate that liquid bio-slurry may contain ascari eggs (Wang Qinsheng and Juing 1992). What is noteworthy, however, is that the liquid bio-slurry has potential risk for human infection and protective gears should be used during their handling and /or people handling liquid bioslurry should thoroughly wash their hands with soap after handling the slurry.

Table 1: The Micro-organisms from bio-slurry as indicated by biosafety analysis

Sample	***source***	***Faecal parasites***	***Total aerobic count (37°C) CFU/G***	***Total coliform count CFU/G***	***Total E. coli count CFU/G***	***Salmonella spps (ISO)***	***Shigella spps***
1	Simba	A	1x106	9x105	4x105	p	p
2	Mbarara	A	5x106	4x105	3x104	p	p
3	MBAZRDI	A	4x106	3x105	3x103	p	p

CFU/G=Colony forming units per gram; NA=Not analysed; P= Present; A absent

2.3 Bioslurry nutrient content and effects on soil quality in maize and cabbage fields

Before conducting the trial, the representative samples of the soils and bioslurry manures were sampled for analysis to obtain first-hand information on the soil properties and quality of bioslurry. The soil were analysed for properties like pH, organic matter, Nitrogen, phosphorus, potassium and its texture. After harvesting the crops, soil samples were collected from the harvested plots for soil nutrient analysis. Nutrient analysis for soil and bioslurry was carried out at Makerere University soil laboratory. For each treatment, soil samples were collected (Figure 4) from all replications and pooled and mixed together before quartering. The quartering was then done to get at least 0.5 kg of soil sample for each treated and control plots. Soil nutrient analysis before application of treatments and after harvesting would help to establish the effect of bioslurry on soil quality. All the three forms of bioslurry samples (liquid, dried and composited forms) were analysed for nutrient content, especially the available and total Nitrogen (N), phosphorus (P), Potassium (K), calcium (Ca) and other micro-nutrients and elements. Dry bioslurry was prepared at MBAZARDI by drying liquid bioslurry under makeshift shade. This was to prevent direct sunlight on the bioslurry that may result in vaporization of nutrients from the bioslurry.

Figure 4: Soil sampling was done before and at end of the experiment

Soil analysis indicates that the bioslurry (except for dry bioslurry) samples contain more nitrogen content (the crucial plant nutrient) than soil samples (Table 2),

Table 2: Results from soil and bioslurry nutrient analysis for samples collected before bioslurry application in cabbage and maize trials for 2014B

Source of soil/ bioslurry sample	**PH**	**% N**	**% OM**	**P (ppm)**	**K**	**Ca**	**Mg**	**Na**	**% Sand**	**% Clay**	**% Silt**
S1 (Maize field)	5.24	0.105	1.739	3.4	0.369	3.75	0.81	0.315	77	28	5
C1 (Cabbage field)	4.42	0.117	1.729	11.59	0.449	3.75	0.82	0.196	71	22	7
Liquid Bioslurry 1 (simba Farm)		4.48		1.133	1.15	1.5					
Liquid Bioslurry 2 (Mbarara Farm)		1.4		0.433	1.02	1.63					
Liquid Bioslurry 3 (MBAZARDI)		2.1		0.599	1.15	1.5					
Dry bioslurry (MBAZARDI)		0.7		0.433	0.701	1.125					
Compost bioslurry (MBAZARDI)		1.26		0.658	0.701	1.25					

Table 3: Nutrient analysis of soil samples after harvesting of season one cabbage and maize planted at MBAZRDI during 2014B

Treatment*	**PH**	**%N**	**% OM**	**P (ppm)**	**K**	**Ca**	**Mg**	**Na**
Compost bio cabbage 10t/ha	5.120	0.163	1.640	15.710	0.503	2.500	0.620	0.220
Compost Maize 10t/ha	5.570	0.117	1.640	3.060	0.264	1.250	0.350	0.160
Control cabbage	4.800	0.163	4.910	8.430	0.441	2.500	0.630	0.140
Control maize	4.630	0.105	1.400	4.580	0.264	1.880	0.480	0.050
Dry cabbage	5.580	0.200	1.870	10.660	0.377	2.500	0.630	0.140
Dry bio maize 10t/ha	4.980	0.140	1.360	3.300	0.232	2.500	0.610	0.140
NPK cabbage	4.650	0.222	1.920	8.130	0.513	2.500	0.630	0.160
NPK maize	4.620	0.117	1.640	4.390	0.200	1.880	0.450	0.150
Wet bio cabbage 10t/ha	5.060	0.163	2.570	17.100	0.377	2.500	0.650	0.080
Wet maize bio 2L/m2	5.000	0.117	1.640	11.200	0.264	2.500	0.390	0.160

**Note; the soil samples were not analysed for % clay, %sand and %silt as these physical parameters are not affected by treatments*

Table 4: Percentage change (comparison) in soil nutrient content before application of soil amendments and after harvesting of season one cabbage and maize during 2014B

Treatment/crop harvested	**%N Before**	**%N after**	**% Diff**	**OM Before**	**% OM After**	**% Diff**	**P (ppm) before**	**P (ppm) After**	**% Diff**	**K Before**	**K After**	**% Diff**
Compost bio 10t/ha-cabbage	0.12	0.16	39.32	1.73	1.64	-5.15	11.59	15.71	35.55	0.45	0.50	12.03
Control- cabbage	0.12	0.16	39.32	1.73	4.91	183.98	11.59	8.43	-27.3	0.45	0.44	-1.78
Dry Bio -cabbage	0.12	0.20	70.94	1.73	1.87	8.16	11.59	10.66	-8.02	0.45	0.38	-16.04
NPK- cabbage	0.12	0.22	89.74	1.73	1.92	11.05	11.59	8.13	-29.9	0.45	0.51	14.25
Wet bio 2L/m2-cabbage	0.12	0.16	39.32	1.73	2.57	48.64	11.59	17.10	47.54	0.45	0.38	-16.04
Compost bio 10t/ha- Maize	0.11	0.12	11.43	1.74	1.64	-5.69	3.40	3.06	-10.0	0.37	0.26	-28.46
Control- maize	0.11	0.11	0.00	1.74	1.40	-19.49	3.40	4.58	34.71	0.37	0.26	-28.46
Dry bio 10t/ha- maize	0.11	0.14	33.33	1.74	1.36	-21.79	3.40	3.30	-2.94	0.37	0.23	-37.13
NPK -maize	0.11	0.12	11.43	1.74	1.64	-5.69	3.40	4.39	29.12	0.37	0.20	-45.80
Wet bio 2l/m2-maize	0.11	0.12	11.43	1.74	1.64	-5.69	3.40	11.20	229.4	0.37	0.26	-28.46

%Diff= percentage increase/change between the soil nutrients after and before application of soil amendments

Table 5: Results from soil nutrient analysis for samples collected before bioslurry application for 2015A

Plot*	PH	%N	%OM	P bray (ppm)	K	Ca	Mg	Na	% Sand	%Clay	%Silt
Maize field	6.34	0.187	3.92	77	0.107	6.25	1.38	0.38	74	19	7
Cabbage field	6.74	0.187	4.72	46.5	0.978	7.5	1.55	0.33	78	19	3

**Nutrient analysis for bioslurry was not necessary for the season 2015A since similar bioslurry was used*

Table 6: Nutrient analysis of soil samples after harvesting of season two cabbage and maize during 2015A

Treatment	PH	%N	%OM	P (ppm)	K	Ca	Mg	Na	% Sand	%Clay	%Silt
Compost bio cabbage 10/ha	5.980	0.210	2.058	65.564	0.881	3.625	0.720	0.380	76	16	8
Compost Maize 10/ha	6.450	0.241	1.750	77.520	1.070	3.750	0.610	0.333	74	18	8
Control cabbage	5.840	0.187	1.853	51.386	0.881	3.625	0.620	0.313	66	4	30
Control maize	6.350	0.163	1.750	77.874	1.074	3.375	0.620	0.353	71	18	11
Dry cabbage	6.710	0.210	2.264	73.655	1.282	4.125	0.830	0.380	71	18	11
Dry bio maize 10/ha	6.060	0.187	1.647	77.459	0.986	3.500	0.640	0.380	72	14	14
NPK cabbage	5.890	0.210	2.058	72.293	1.226	3.750	0.710	0.394	75	16	9
NPK maize	6.460	0.187	1.853	83.407	1.282	4.000	0.710	0.421	74	18	8
Wet bio cabbage 10/ha	6.120	0.187	1.853	59.270	1.010	3.750	0.810	0.353	76	12	12
Wet maize bio 2l/m2	6.46	0.21	1.695	78.565	1.074	3.625	0.66	0.353	73	18	9

Table 7: Percentage change in nutrient content of the soil before application of soil amendments and after harvesting of season one cabbage and maize during 2015A

Treatment	%N after	%N before	% diff	%OM after	%OM before	% diff	P after	P before	% diff	K after	K before	% diff
Cabbage Compost	0.21	0.19	10.53	2.06	4.72	-56.36	65.56	46.5	40.99	0.88	0.98	-10.20
cabbage Dry	0.21	0.19	10.53	2.26	4.72	-52.12	73.66	46.5	58.41	1.28	0.98	30.61
cabbage NPK	0.21	0.19	10.53	2.06	4.72	-56.36	72.29	46.5	55.46	1.23	0.98	25.51
Cabbage Control	0.19	0.19	0.00	1.85	4.72	-60.81	51.39	46.5	10.52	0.88	0.98	-10.20
Cabbage Wet	0.19	0.19	0.00	1.85	4.72	-60.81	59.27	46.5	27.46	1.01	0.98	3.06
Compost maize	0.24	0.19	26.32	1.75	3.92	-55.36	77.52	77	0.68	1.07	0.11	872.73
Control maize	0.16	0.19	-15.79	1.75	3.92	-55.36	77.87	77	1.13	1.07	1.07	0.00
Dry bio maize	0.19	0.19	0.00	1.65	3.92	-57.91	77.46	77	0.60	0.99	1.07	-7.48
NPK maize	0.19	0.19	0.00	1.85	3.92	-52.81	83.41	77	8.32	1.28	1.07	19.63
Wet maize	0.21	0.19	10.53	1.7	3.92	-56.63	78.57	77	2.04	1.07	1.07	0.00

The nutrient content of the soil samples collected after harvesting cabbages and maize for the two seasons (Tables3 and 6) were compared with nutrient content of the soil samples collected before application of bioslurry (Table 2 and 5). The major striking difference between the soil analysis before and after use of treatments is that all the fertilizers improved soil Nitrogen content, the major limiting nutrient for most crops (Table 4 and 7). The results also indicated that fields from where cabbages were harvested had more nutrients than from fields where maize was harvested suggesting that maize might be a heavy nutrient miner than cabbages.

2.4 Effect of bioslurry on the soil quality in coffee fields

Before conducting the trial, the representative samples of the soils were analysed to obtain first-hand information on the soil properties and quality. The soil were analysed for properties like pH, organic matter, Nitrogen, phosphorus, potassium and its texture. The results below show the initial data from soil nutrient analysis before application of bioslurry and fertilizer (Table 8). For comparison to determine the effect of bioslurry and fertilizer on soil quality after one season (about 10 months), soil samples were collected and analysed from Makerere soil Science Laboratory and results are presented in Table 9. The nutrient content of the soil samples collected before application of bioslurry was compared with nutrient content of the soil samples collected after harvesting coffee (Table 10).

The major striking difference between the soil analysis before and after use of treatments is that all the fertilizers improved soil Nitrogen content, the major limiting nutrient for most crops (Table 10). On average, all treatments increased soil Nitrogen and Potassium content but there was no specific trend for potassium, calcium, magnesium and Sodium elements (Tables 10).

Table 8: Showing results from soil nutrient analysis of soil before application of treatments

SOURCE OF SOIL/ BIOSLURRY SAMPLE	PH	% N	% OM	P (PPM)	K	CA	MG	NA	% SAND	% CLAY	% SILT
KWESIGABO LUKE	6.33	0.175	3.85	14.36	0.833	14.38	3.1	0.533	46	24	30
KATABAZI HASSAN	5.63	0.128	1.862	4.11	0.721	7.5	1.4	0.467	63	26	11
AYOREKIRE FRED	6.4	0.117	2.793	11.47	1.67	11.25	2.1	0.717	46	24	30
BAMPISAKI PULINARI	3.94	0.082	1.993	3.72	0.224	3.13	0.59	0.283	69	20	11

Table 9: Showing results from soil nutrient analysis of soil after application of treatments

Farmer	Treatment	PH	%N	%OM	P (ppm)	K	Ca	Mg	Na	% Sand	%Clay	%Silt
Hassan	Liquid	6.43	0.163	1.853	5.325	0.641	3.125	51	0.258	65	20	15
Hassan	NPK	6.32	0.163	1.695	7.538	0.625	3.125	0.53	0.217	60	21	19
Hassan	Dry	6.22	0.163	1.853	13.832	0.705	3.125	0.5	0.258	70	20	10
Hassan	Compost	5.96	0.163	2.882	12.587	0.954	3.375	0.56	0.326	67	20	13
Hassan	Control	6.23	0.175	1.647	3.251	0.617	3	0.5	0.245	65	12	23
Ayorekire	Liquid	6.54	0.21	2.47	12.172	1.282	5.25	0.91	0.201	69	20	11
Ayorekire	NPK	6.82	0.187	1.853	6.985	1.282	5	0.93	0.421	54	20	26
Ayorekire	Dry	6.51	0.093	2.264	10.028	1.715	5.25	0.85	0.571	60	19	21
Ayorekire	Compost	7.04	0.187	2.264	22.754	1.394	4.75	0.82	0.421	60	17	23
Ayorekire	Control	7.1	0.187	2.264	6.639	0.603	5.625	0.91	0.205	60	19	21
Purinari	Liquid	4.84	0.163	1.235	8.783	0.433	1	0.25	0.163	70	24	6
Purinari	NPK	5.2	0.187	1.853	6.294	0.697	1.87	0.34	0.231	64	23	13
Purinari	Dry	4.86	0.117	1.44	7.193	0.625	1.375	0.27	0.231	66	20	14
Purinari	Compost	5.33	0.14	1.695	36.516	0.657	2.125	0.43	0.122	67	22	11
Purinari	Control	4.75	0.14	1.029	6.224	0.625	1.25	0.3	0.258	66	20	14
Luka	Liquid	6.38	0.233	3.088	17.774	0.825	6.25	0.9	0.245	47	21	32
Luka	NPK	6.74	0.233	2.882	12.864	0.801	5.875	0.97	0.231	56	24	20
Luka	Dry	6.49	0.233	3.293	20.817	0.954	6.375	0.99	0.326	50	22	28
Luka	Compost	4.75	0.175	3.293	39.42	0.737	5.51	0.93	0.299	45	17	38
Luka	Control	6.41	0.233	3.293	17.359	1.266	6.125	0.98	0.408	45	20	35

Table 10: Percentage change in nutrient content of the soil before application of soil amendments and after harvesting of coffee by treatment and farmer for season 2015

		After	*Before*	*% increase*	*After*	*Before*	*% increase*	*After*	*Before*	*% increase*
Farmer	*Treatment*	*%N*	*%N*	*%N*	*P (ppm)*	*P(ppm)*	*P(ppm)*	*K*	*K*	*K*
Hassan	Liquid	0.163	0.128	21.472	5.325	4.110	22.817	0.641	0.721	-12.480
Hassan	NPK	0.163	0.128	21.472	7.538	4.110	45.476	0.625	0.721	-15.360
Hassan	Dry	0.163	0.128	21.472	13.832	4.110	70.286	0.705	0.721	-2.270
Hassan	Compost	0.163	0.128	21.472	12.587	4.110	67.347	0.954	0.721	24.423
Hassan	Control	0.175	0.128	26.857	3.251	4.110	-26.423	0.617	0.721	-16.856
Ayorekire	Liquid	0.210	0.117	44.286	12.172	11.470	5.767	1.282	1.670	-30.265
Ayorekire	NPK	0.187	0.117	37.433	6.985	11.470	-64.209	1.282	1.670	-30.265
Ayorekire	Dry	0.093	0.117	-25.806	10.028	11.470	-14.380	1.715	1.670	2.624
Ayorekire	Compost	0.187	0.117	37.433	22.754	11.470	49.591	1.394	1.670	-19.799
Ayorekire	Control	0.187	0.117	37.433	6.639	11.470	-72.767	0.603	1.670	-176.949
Purinari	Liquid	0.163	0.082	49.693	8.783	3.720	57.645	0.433	0.224	48.268
Purinari	NPK	0.187	0.082	56.150	6.294	3.720	40.896	0.697	0.224	67.862
Purinari	Dry	0.117	0.082	29.915	7.193	3.720	48.283	0.625	0.224	64.160
Purinari	Compost	0.140	0.082	41.429	36.516	3.720	89.813	0.657	0.224	65.906
Purinari	Control	0.140	0.082	41.429	6.224	3.720	40.231	0.625	0.224	64.160
Luka	Liquid	0.233	0.175	24.893	17.774	14.360	19.208	0.825	0.833	-0.970
Luka	NPK	0.233	0.175	24.893	12.864	14.360	-11.629	0.801	0.833	-3.995
Luka	Dry	0.233	0.175	24.893	20.817	14.360	31.018	0.954	0.833	12.683
Luka	Compost	0.175	0.175	0.000	39.420	14.360	63.572	0.737	0.833	-13.026
Luka	Control	0.233	0.175	24.893	17.359	14.360	17.276	1.266	0.833	34.202

CHAPTER 3: EFFECT OF BIOSLURRY ON PERFORMANCE OF CABBAGE

The main objective was to conduct research to determine the effect of different forms of bioslurry (liquid, dried and composted) on the performance of cabbages and maize. This study compared results from bioslurry with that of the inorganic fertilizers. More specifically, the study Compared use of different bioslurry forms with inorganic fertilizers in enhancing cabbage and maize productivity

3.1 Effect of different forms of bio slurry on the performance of cabbages

The commonly grown and preferred hybrid cabbage variety known as Hybrid Gloria was used in this study. One seedling was planted per hole at spacing of 70 cm X 25 cm. The field trials were established on station at MBAZARDI in replicated Randomized Complete Block Design (RCBD).

The three replicates had the following treatments;

- T1=compost slurry applied at rate of 5t/ha
- T2=compost slurry applied at rate of 10 t/ha
- T3=dry slurry applied at rate of 5t/ha,
- T4=dry Bio-slurry applied at rate of 10t/ha,
- T5=NPK (50N: 25P2O5: 25 K2O) at 90kgN/acre
- T6=Liquid slurry 1.5 litres per square metre
- T7=Liquid slurry 2.0 litres per square metre
- T8=Control

3.2 Fertilizer application

Fertilizers were applied one week before planting. Shallow channels were dug along the line (Figure 5) and the fertilizer applied at the described rates above (Figure 6). After application of the bioslurry/fertilizer, a layer of soil was used to cover up the slurry/fertilizer to avoid direct contact of bioslurry/fertilizer with seed/seedling and avoid exposure to the sun or rain runoff. After one week of fertilizer application, planting was done. No top dressing was done.

Figure 5: Preparing shallow channels to apply bioslurry

Figure 6: Application of liquid bioslurry using a watering can

3.3 Data analysis

Data was collected on vegetative and yield parameters including plant height, number of ears/combs, ear height and grain yield for maize, and head size or circumference and weight for cabbages. Data collected from the trials were analysed by analysis of variance using statistical packages including Microsoft Excel and GeneStat software. The means were separated by Least Significant Difference (LSD) at 5%.

3.4 Results and discussion

Results indicate that there was significant difference (≤0.05) between treatments in affecting the performance of cabbage (Table 11). The head weight and the head size (circumference) were both influenced by the treatment applied (Figure 7). For both the head size and circumference, there was no significantly different between replications for all seasons indicating that the only source of variation was treatments. Across the seasons and treatments, the performance of cabbages was higher (head circumference of 57.4±0.3 and head weight of 2.3±0.03) in season two (2015A) than in season one (2014B) (mean head circumference of 53.9±0.3 and mead head weight of 1.8±0.03).

Figure 7: Cabbages under compost bio slurry more than doubled the yield of control plots

Table 11: Analysis of variance (P ≤0.05) for head weight and head circumference of cabbages planted at MBAZARDI in 2014

SOV	DF	SS	MS	VR	Fpr
Head circumference					
Season	1	2035.75	2035.75	45.25	<.001
Treatment	7	6700.99	957.28	21.28	<.001
Season X Treatment	7	3253.39	464.77	10.33	<.001
Residual	912	41028.48	44.99		
Total	927.00	53018.60	57.19		
Head weight					
Season	1	58.5465	58.5465	137.11	<.001
Treatment	7	64.5507	9.2215	21.6	<.001
Season X Treatment	7	23.7507	3.393	7.95	<.001
Residual	912.00	389.42	0.43		
Total	927.00	536.26	0.58		

SOV= Source of variation; DF= Degree of freedom; SS=Sum squares; MS= Mean square value; VR= Variation; FRpr.=Probablity

During the two seasons (2014B and 2015A), plots treated with compost bioslurry applied at rate of 10 t/ha recorded the highest head weight (mean of 2.28±0.08 kg per head in 2014B and 2.59±0.08 kg per head in 2015A). The same treatment recorded the highest head size estimated by head circumference (mean of 59.45±0.87 in 2014B and 60.55±0.87 in 2015A). Across the two seasons, the highest mean head weight was recorded in plots treated with compost bioslurry applied at rate of 10 t/ha with mean of 2.44±0.06 kg per head translating into about 139 t/ha), followed with Dry bioslurry applied at rate of 10 t/ha (2. 33 kg per cabbage) or about a total yield of 133 t/ha. The least yield was obtained in plots with no any soil amendment (the control) with the mean head weight of 1.43 kg per cabbage or 82 t/ha (Table 12). These results suggest that compost bioslurry improves the yield of cassava by 69.5% compared to when no fertilizer is added. The results records higher increase than previously reported by (Warnars and Oppenoorth, 2014) who reported an increase of 20% The results in this study also indicate that compost bioslurry improved yield of cabbages more than the NPK fertilizer by 30% and 15% applied at 10 t/ha and 5 t/ha, respectively. Since Compost bioslurry is both user and environmental health friendly, it should be recommended and promoted for use by farmers. Bioslurry can be used to build healthy fertile soil for crop production. The bioslurry can be used in liquid, compost, and dry form and is a very good fertiliser/composting substance for agricultural crops (Warnars and Oppenoorth, 2014).

Table 12: The mean performance of cabbages across the two seasons

Variate/treatment	Circumference	Head weight	Estimated yield (t/ha)
Compost Bio-slurry 10t/ha	60.02±0.61	2.44±0.06	139.30
Compost Bio-slurry 5t/ha	56.43±0.61	2.15±0.06	122.73
Control	49.15±0.75	1.43±0.07	81.77
Dry Bio-slurry 10t/ha	57.93±0.61	2.33±0.06	133.08
Dry Bio-slurry 5t/ha	54.18±0.61	1.87±0.06	106.83
NPK 60 kgN/ha	53.44±0.62	1.87±0.06	106.74
Wet Bio-slurry 1.5 L/m2	57.18±0.61	2.20±0.06	125.53
Wet Bio-slurry 2.0 L/m2	55.65±0.61	2.04±0.06	116.34
LSD	1.69	0.16	

Table 13: The mean (± standard error) of cabbage head weight (kg) and circumference and yield estimates for cabbages planted under different soil amendments during 2014B and 2015A

Variate/ treatment	**Circumference**		**Weight**	
	Season 2014B	Season 2015A	Season 2014B	Season 2015A
Compost Bio-slurry 10t/ha	59.45±0.87	60.55±0.87	2.28±0.08	2.59±0.08
Compost Bio-slurry 5t/ha	55.72±0.87	57.08±0.87	1.93±0.08	2.35±0.08
Control	43.75±1.25	54.20±0.87	0.88±0.12	1.95±0.08
Dry Bio-slurry 10t/ha	57.91±0.87	57.95±0.87	2.21±0.08	2.44±0.08
Dry Bio-slurry 5t/ha	51.58±0.87	56.60±0.87	1.51±0.08	2.21±0.08
NPK 90 kgN/ha	48.54±0.90	58.02±0.87	1.34±0.08	2.36±0.08
Wet Bio-slurry 1.5 L/m^2	55.70±0.85	58.57±0.87	1.85±0.08	2.52±0.08
Wet Bio-slurry 2.0 L/m^2	56.01±0.87	55.32±0.87	1.97±0.08	2.10±0.08
LSD	*2.38*		*0.23*	
%cv	*12.01±6.71*		*31.56±0.65*	

The performance of cabbages was better in season 2015A than in 2014B (Table 13). This improved performance of cabbages in season 2015A is attributed to adequate rainfall that occurred during this season. Season 2014B was characterised by early severe drought. This implies that besides fertilizers, adequate soil moisture is one of the critical requirements for crop yield.

CHAPTER 4: EFFECT OF BIOSLURRY ON PERFORMANCE OF MAIZE

4.1 Effect of different forms of bio slurry on the performance of Maize

The commonly grown maize variety known as LONGE 5 was used in the study. This variety was obtained from FICA seeds LTD, a seed company in Kawempe-Kampala. Maize field trials were established on station at MBAZARDI in replicated Randomized Complete Block Design (RCBD) with seed rate of 2 seeds per hole at a spacing of 70cm X 30cm. The two replicates had the following treatments;

- T1=compost slurry applied at rate of 5t/ha
- T2=compost slurry applied at rate of 10 t/ha
- T3=dry slurry applied at rate of 5t/ha,
- T4=dry Bio-slurry applied at rate of 10t/ha,
- T5=NPK (50N: 25P2O5: 25 K2O) at 90kgN/acre
- T6=Liquid slurry 1.5 litres per square metre
- T7=Liquid slurry 2.0 litres per square metre
- T8=Control

4.2 Fertilizer application

Fertilizers were applied one week before planting. Shallow channels were dug along the line and the fertilizer applied at the described rates above. After application of the bioslurry/fertilizer, a layer of soil was used to cover up the slurry/fertilizer to avoid direct contact of bioslurry/fertilizer with seed/seedling and avoid exposure to the sun or rain runoff. After one week of fertilizer application, planting was done. No top dressing was done.

4.3 Results and discussion

4.3.1 Vegetative/Qualitative parameters

The differences between treatments were visible even during early stages of growth. There was poor germination and growth vigour in plots treated with NPK and those with control plots. In the first season (season 2014B), NPK treated plots delayed to germinate and had low vigour compared to those in season two (2015A) and this may be attributed to low moisture content in the soil during planting as there was early drought during season 2014B. Due to low soil moisture content, NPK could not easily be mineralised for absorption and utilization. Secondary, undissolved NPK raises soil temperatures that may be unfavourable for seed germination. During season two there was early rainfall that facilitated germination and early growth rate.

Figure 8: Comparison of bioslurry and control plots of maize during 2014B

4.3.2 Quantitative parameters

Yield, ear height and plant height, were significantly different (≤0.05) for different treatments (Table 14). The plant height and yield were significantly different between seasons.

Table 14: Analysis of variance for yield, ear height and plant height for LONGE 5 maize variety planted at MBAZARDI in 2014A

SOV	DF	SS	MS	VR	Fpr
Ear height					
Season	1.00	23.50	23.50	0.04	0.84
Treatment	7.00	8390.30	1198.60	2.06	0.05
Season X Treatment	6.00	14204.10	2367.40	4.07	<.001
Residual	346.00	201167.50	581.40		
Total	360.00	223785.40	621.60		
Height					
Season	1	988064.1	988064.1	1157.18	<.001
Treatment	7	31838.4	4548.3	5.33	<.001
Season X Treatment	6	18216.6	3036.1	3.56	0.002
Residual	346	295435.2	853.9		
Total	360	1333554	3704.3		
Yield (t/ha)					
Season	1.00	520.76	520.76	469.13	<.001
Treatment	7.00	78.84	11.26	10.15	<.001
Season X Treatment	6.00	87.53	14.59	13.14	<.001
Residual	346.00	384.08	1.11		
Total	360.00	1071.21	2.98		

SOV= Source of variation; DF= Degree of freedom; SS=Sum squares; MS= Mean square value; VR= Variation; FRpr.=Probablity

Across the two seasons, compost bio-slurry applied at rate of 5 t/ha resulted in the highest maize yield (4.6 t/ha) (70% higher than the control plots) followed by plots treated with compost bioslurry applied at 10 t/ha (4.3 t/ha) (about 60% higher than control plots). The least was recorded in plots with no soil amendment (control) with the mean yield of 2.7 t/ha (Table 15). Maize treated with Dry bioslurry applied at 5t/ha grow taller than all treatments but heir yield has relatively poor, only yielding higher than the maize in non-treated plots (control). Basing on the Least significant difference (LSD), across the seasons the performance of treatments can be grouped into four groups; the best performing which are compost bioslurry (5t/ha not significantly from 10t/ha), followed by liquid bioslurry (1.5 L/m^2 not significantly from 2.0 L/m^2), followed by plots treated with dry bioslurry and NPK (not significantly from each other), the least the control plots (Table 15). Previous reports have also indicated that dry bioslurry is least efficient form (Warnars and Oppenoorth, 2014) as a result of nutrient loss especially ammonia during the drying process. On the other hand, Warnars and Oppenoorth, (2014) reported that liquid bioslurry is very difficult to transport if the farm is far away from the bio digester. The composted form of bioslurry is the best way to overcome the transportation issue related to liquid bioslurry and the nutrient loss of the dried form. The yield from plots treated with compost bio-slurry applied more than doubled the control. These results are higher than previously reported increase of 32% of maize yield under bio-slurry compared with control (Quang and Trung Kien, 2010) but lower than 92% reported by (Warnars and Oppenoorth, 2014). The differences observed between these two studies may be attributed to different soil fertility levels between the sites used and environmental conditions, since the previous work was done in Vietnam.

There was season by treatment interaction where some treatments performed better in first season but poor in the second season. Although the plots treated with compost bioslurry at 5 t/ha outperformed all other treatments in season one (2014B), their performance was lower than plots treated with compost bioslurry at 10 t/ha in season two (Table 16). Plots treated with NPK had performed better in the first season but performed least during season two. Generally, the maize in season two did not perform well due to terminal drought that affected the maize during the flowering period.

Table 15: The mean (± standard error) of yield for maize variety LONGE 5 planted under different soil amendments during 2014B and 2015A

Treatment	Height	Ear	Yield (t/ha)
Compost Bio-slurry 10t/ha	192.90±4.07	130.60±3.36	4.31±0.15
Compost Bio-slurry 5t/ha	205.40±4.31	134.20±3.56	4.56±0.16
Control	188.70±4.96	120.10±4.09	2.72±0.18
Dry Bio-slurry 10t/ha	185.70±4.82	118.60±3.98	3.42±0.17
Dry Bio-slurry 5t/ha	225.90±5.34	120.40±4.40	3.27±0.19
NPK 90 kgN/ha	170.80±4.31	127.70±3.56	3.48±0.16
Wet Bio-slurry 1.5 L/m^2	197.80±4.07	127.80±3.36	4.00±0.15
Wet Bio-slurry 2.0 L/m^2	196.60±4.07	132.30±3.36	3.76±0.15
LSD	11.32	9.35	0.41

Table 16: The mean (± standard error) of yield for maize variety LONGE 5 planted under different soil amendments during 2014B and 2015A

	Ear height		Height		Yield	
Treatment	Season A	Season B	Season A	Season B	Season A	Season B
Compost Bioslurry 10t/ha	127.00±4.92	132.40±4.40	115.60±5.97	231.90±5.34	5.49±0.22	3.71±0.19
Compost Bioslurry 5t/ha	151.90±6.03	125.30±4.40	143.80±7.31	236.50±5.34	7.52±0.26	3.06±0.19
Control	101.50±8.53	129.50±4.40	99.90±10.33	233.50±5.34	3.46±0.37	2.35±0.19
Dry Bio-slurry 10t/ha	108.90±8.04	123.50±4.40	104.10±9.74	226.90±5.34	4.12±0.35	3.06±0.19
Dry Bio-slurry 5t/ha	*	120.40±4.40	*	225.90±5.34	*	3.27±0.19
NPK 90 kgN/ha	124.30±6.03	129.30±4.40	114.90±7.31	198.90±5.34	5.86±0.26	2.27±0.19
Wet Bio-slurry 1.5 L/m^2	126.30±4.92	128.50±4.40	116.10±5.97	239.00±5.34	5.45±0.22	3.27±0.19
Wet Bio-slurry 2.0 L/m^2	129.70±4.92	133.70±4.40	117.50±5.97	236.40±5.34	5.37±0.22	2.95±0.19
LSD	*12.25*		*14.84*		*0.54*	
CV%	*18.89±24.11*		*15.26±29.22*		*27.39±1.05*	

Figure 9: Stakeholders discussing the possible causes of poor germination in NPK treated plot during 2014B

Figure 10: High maize yield were obtained with compost bio slurry applied at rate of 5t/ha

4.4 Profitability of use of bioslurry in maize and cabbage production

Although this study did not carry out detailed economic analysis for bioslurry application, it should be noted from differences in yield performance of maize and cabbage, that bioslurry has numerous advantages and is of great financial value for farming and crop yields. In Western Uganda, one kilogramme of bioslurry is UGX 20 (estimating from 7 tonne truck costs 140,000 UGX). Applying at 10 t/ha requires UGX 200, 000 for each hectare (less than 57 USD). The same area would require over 200 Kg of Nitrogen fertilizer applied at rate of 90kgN/acre. The average cost of fertilizer is UGX 2500-3000 per kilogramme translating to over 500,000 UGX (about 143 USD). Whereas chemical fertilizer requires application every season, bioslurry has longer term effects and may need replacement after two years (four planting seasons in Uganda). This makes the bioslurry ten times (X10) cheaper than chemical fertilizer. Besides, getting quality chemical fertilizer is very difficult due to limited availability and also faking.

In this study, cabbage yield in compost bioslurry treated plots, was estimated at 139 tons per hectare and sold at 500 UGX per kg of cabbage (Farm gate price), it translates into 69,500,000 UGX (about 20,000 USD) compared to control 41,000,000 UGX (about 12,000 USD) and 53,500,000 UGX (15,000 USD) from plots treated with NPK. On average, the application of bioslurry (including cost and transport) was 500,000 UGX (143 USD) per hectare and the cost application of NPK was about 30% of the cost of applying bioslurry (43 USD). Therefore the profit margin for bioslurry over control would $7,857 per hectare (65% profit) and $ 4,900 per hectare of cabbage (33% profit) over NPK assuming that other than labour for application, the other operations were the same for all the plots.

Similarly for maize, estimating the cost of maize grain at farm gate price of 700 UGX (0.2 USD) per kilogramme, from the compost treated plots, the farmer would get 3,220,000 UGX (920 USD) compare to the control 1,890,000 UGX (540 USD) and 2,436,000 (696 USD) for NPK treated plots. On average, the application of bioslurry (including cost and transport) was 500,000 UGX (143 USD) per hectare and the cost application of NPK was about 30% of the cost of applying bioslurry (43 USD). Since other operations were uniform, the profitability from bioslurry was high ($124 per hectare of maze) about 18% profit margin above NPK ($237 per hectare) about 44% profit margin above control. Previous reports from Tanzania indicate that farmers using bioslurry as a fertilizer increased their crop revenues by 25 per cent (Warnars and Oppenoorth, 2014), and this is not far different from the results obtained in this study. However, it’s recommended that detailed economic analysis be carried out to calculate the actual profitability of use of bioslurry.

CHAPTER 5: EFFECT OF BIOSLURRY ON PERFORMANCE OF COFFEE

5.1 Abstract

This report highlights the results of data obtained from the study carried out over the two coffee harvesting seasons (2015 and 2016) of the experiments carried out on four farms in Isingiro district in Western Uganda. The study aimed at determining the effect of different forms of bioslurry (composted bio slurry, liquid bio slurry and dried bio slurry) on the performance of coffee. The experiment was conducted on-farm in four farms and was managed by farmers following their farming practices, with project team advising them on good coffee management practices. The overall results indicate that composted bio slurry applied at a rate of 10 t/ha was the most cost effective form of bioslurry and increased the yield of coffee by 65.6% compared to control (the least performance). Composted bioslurry applied at 10 t/ha (10 kg/tree) resulted in actual yield of 2.29 t/ha compared to 0.79 t/ha that was produced in control plots. However, in all seasons the experiment was affected by heavy drought, pests and diseases and this could explain the overall poor performance of coffee. Though there was no significant difference between compost bioslurry applied at 10 t/ha and 15 t/ha (10 kg/tree and 15 kg/tree), it would be a wastage to apply 15 t/ha since it does not result in any advantage over 10t/ha. Generally the results indicated that the use of bioslurry improves the productivity of coffee under field conditions and the findings are a breakthrough for small scale farmers to improve their productivity cheaply since bio slurry is cheaper about $5.0 per ton) than the inorganic fertilizer (about $860 per ton)and can be easily accessible in the communities than inorganic fertilizers.

5.2 Materials and methodology

5.2.1 Site selection and materials

Four farmers who had coffee fields with relatively uniform coffee trees were selected in the two sub-counties (Kaberebere TC and Isingiro TC) of Isingiro district. Only farmers who were not applying any soil fertility amendment options were selected to avoid farmers interfering with the trials with their own soil fertility amendments during the implementation. The fields selected were of relatively the same age of establishment (4-5 years of age). Three different forms of bio slurry (liquid, dried and composted forms) and NPK fertilizer were used in this study (prepared as in Chapter 2). Control plots had neither fertilizer nor bio slurry.

5.2.2 Bio slurry application

A ring of a shallow trench/channel was made around the coffee tree about 50-60 cm from the tree. Then a measured amount of bio slurry was applied in the trench and then covered with a layer of soil to protect it from direct sunlight, runoff and animals/birds. For comparison, NPK fertilizer was also used on the same farms.

Figure 11: Measuring Bio slurry before application; wet on left and dry on right

Figure 12: Wet Bio slurry application (left) and Dry one (right)

Eight following treatments were adopted:

- Dry bioslurry (5 t/ha) approximately 5 kg per tree,
- Dry bio slurry (10 t/ha i.e. about 10 kg per tree),
- Wet bio slurry (10 kg/plant),
- Composited bioslurry (5 t/ha i.e. 5 kg per tree),
- Composited bio slurry (10 t/ha i.e. 10 kg/tree),
- Composited bio slurry (15 t/ha about 15kg/tree),
- Inorganic fertilizer (90 kg N/ha about 8-10 g/tree) and
- Control plots.

The plots were established in randomized complete Block Design (RCBD) and replicated on a number of trees. Each treatment was applied on ten trees per farm on four farms, two from each of the two sub-counties (Kaberebere Town council and Isingiro town council). These farms were selected to host the trials due to relatively uniform trees which were relatively of the same age.

5.2.3 Data collection and analysis

Of the ten trees per treatment, per farm, five coffee trees with uniform size were selected and tagged for data collection and subsequent monitoring (Figure 6). Data was collected on total number of primaries per tree, number of primaries bearing the berries, number of berries on nodes and yield of berries (weight of fresh berries per tree in grams) using a sensitive scale (Figure 7). Data collected from the trials were analysed by analysis of variance using statistical packages including Microsoft Excel and GeneStat software. The means were separated by Least Significant Difference (LSD) at 5%. Actual yield per tree was calculated from the weight of fresh berries collected at harvesting from all primaries bearing the ripe berries and potential yield of the tree was estimated from the total number of primaries on each tree (assuming all berries produced ripe berries at harvesting).

Figure 13: Tagging coffee trees for data collection

Figure 14: data collection from fresh berry

5.3 Results and discussion

Results from 2015 harvesting season, indicate that there was significant difference (≤0.05) between treatments in affecting the performance of coffee (Table 17). All the three important parameter (actual yield, potential yield and number of primaries possessing the coffee berries) were significantly influenced by the treatment applied. Actual yield, potential yield and number of primaries possessing the coffee berries were also significantly different between farmers and treatments between farmers indicating that field management by farmers was also a source of variation in addition to treatments. The interaction between the farmer's field and the treatments (Table 5) suggests that the results could have been affected by farmer's management practices (timing of weeding, pest and disease control, and intercropping with annual crops), and environmental micro conditions occurring at different farms.

Table 17: Analysis of variance for actual yield, potential yield and number of primaries possessing the coffee berries for coffee fields in Isingiro in 2015

SOV	D.F.	S.S.	M.S.	V.R.	Fpr.
Potential yield					
Farmer	3	311258968	103752989	24.25	<.001
Treatment	7	127065830	18152261	4.24	<.001
Farmer by treatment	21	329515780	15691228	3.67	<.001
Residual	201	860004231	4278628		
Total	232	1627844809	7016572		
Actual yield					
Farmer	3	42565381	14188460	20.61	<.001
Treatment	7	21004443	3000635	4.36	<.001
Farmer by treatment	21	61104640	2909745	4.23	<.001
Residual	201	138384768	688481		
Total	232	263059232	1133876		
Bearing Primaries					
Farmer	3	5361.86	1787.29	38.65	<.001
Treatment	7	1460.54	208.65	4.51	<.001
Farmer by treatment	21	4421.24	210.54	4.55	<.001
Residual	194	8972.22	46.25		
Total	225	20215.86	89.85		

SOV= Source of variation; DF= Degree of freedom; SS=Sum squares; MS= Mean square value; VR= Variation; Fpr=Probability

During the 2015 season, the highest coffee yield was recorded in plots treated with compost bioslurry at rate of 10 kg/tree with mean of 1.2 kg/tree translating into estimated yield of 1.3 t/ha per season (assuming recommended spacing of 3 m X 3 m is followed resulting in the total number of trees of 1110 in a hectare). The lowest yield was obtained in plots with no soil amendment (the control) with the mean flesh weight of 0.202 kg/tree equivalent to 0.22 t/ha per season (Table 18). Therefore, the application of bioslurry at 10 kg/tree improved coffee yield by 83.2% compared to control. The high yield recorded in plots with compost bioslurry applied at rate of 10 kg per tree is attributed to the high number of primaries (21.14±1.29) on trees having coffee berries.

Table 18: The mean (± standard error) of actual yield, potential yield and number of primaries possessing the coffee berries for coffee fields in Isingiro in 2015

Treatment	Actual (g/tree)	Potential (g/tree)	Bearing primaries
Compost bioslurry (10 t/ha)	1200±191.6	3152±477.7	15.122±1.649
Compost bioslurry (15 t/ha)	546.3±148.5	1989±370.1	10.528±1.244
Compost bioslurry (5 t/ha)	710±151.6	2098±377.9	11.149±1.243
Control	202.4±161.7	753±403.2	7.95±1.581
Dry bioslurry (10 t/ha)	687.2±164.6	2484±410.4	9.608±1.373
Dry bioslurry (5 t/ha)	405±145	1490±361.4	6.724±1.189
Liquid bioslurry (10L/plant)	246.1±164.5	1053±410	6.861±1.347
NPK	960.2±158.7	2324±395.6	11.644±1.283
LSD	***207.5***	***517.3***	***1.72***
%cv	***154.66±829.7***	***119.52±2068***	***74.75±6.801***

Similarly, the results from 2016 season indicate that there was significant difference (≤0.05) between treatments in affecting the performance of coffee (Table 19). All the three important parameters (actual yield, potential yield and number of primaries possessing the coffee berries) were significantly influenced by the treatment applied. They were also significantly different between farmers and treatments indicating that there was genotype by environment interaction as an extra source of variation.

Table 19: Analysis of variance for actual yield, potential yield and number of primaries possessing the coffee berries for coffee fields in Isingiro in 2016

SOV	D.F.	S.S.	M.S.	V.R.	Fpr.
Actual Yield					
Treatment	7	124982876.	17854697.	5.49	<.001
Farmer	3	415826712.	138608904.	42.64	<.001
Treatment By Farmer	21	163348571.	7778503.	2.39	<.001
Residual	211	685958517.	3250988.		
Total	242	1390116676.	5744284.		
Potential Yield					
Treatment	7	478885889.	68412270.	5.56	<.001
Farmer	3	1861279685.	620426562.	50.43	<.001
Treatment By Farmer	21	571869050.	27231860.	2.21	0.002
Residual	211	2595728440.	12302031.		
Total	242	5507763064.	22759352.		
Primaries					
Treatment	7	2286.93	326.70	3.68	<.001
Farmer	3	4834.04	1611.35	18.13	<.001
Treatment By Farmer	21	5849.42	278.54	3.13	<.001
Residual	209	18576.44	88.88		
Total	240	31546.83	131.45		

SOV= Source of variation; DF= Degree of freedom; SS=Sum squares; MS= Mean square value; VR= Variation; Fpr=Probability

During the 2016 season, the highest coffee yield was recorded in plots treated with compost bioslurry at rate of 15 kg/tree with mean of 3.38 kg/tree translating into estimated yield of approximately 3.8 t/ha per season (assuming recommended spacing of 3 m X 3 m is followed resulting in the total number of trees of 1110 in a hectare). This was followed by plots treated with compost bioslurry applied at rate of 10 kg/tree with mean of 3.2 kg/tree translating to 3.6 t/ha. The lowest yield was obtained in plots treated with NPK with the mean flesh weight of 0.99 kg/tree equivalent to 1.0 t/ha per season (Table 20), though this was not significantly different from the control plots. The low performance for plots treated with NPK could be a result of severe drought that affected the trial and therefore the fertilizer could have failed to dissolve for utilization by trees, perhaps , a reason why not significantly different from control plots. Although the coffee yield in plots treated with 15 kg/tree of compost bioslurry was higher than in plots treated with 10 kg/tree of compost bioslurry, basing on least significant difference at P≥0.05, this yield is not significant and therefore could have been by chance but not by treatment, unlike in 2015 harvesting season when the coffee yield in plots treated with 10 kg/tree was significantly higher than in plots treated at 15 kg/ha. Therefore, application of compost bioslurry at rate of 10 kg/tree, like in 2015 season, remains the cost effective rate, since 15 kg/tree does not result in significant yield advantage. Application of compost bioslurry at rate of 10 kg/tree improved coffee yield by 57.3% compared to control during 2016 harvesting season.

*T*able 20: The mean (± standard error) of actual yield, potential yield and number of primaries possessing the coffee berries for coffee fields in Isingiro in 2016

Treatment	Actual yield (g/tree)	Potential yield (g/tree)	Number of Primaries
Compost bioslurry (10 t/ha)	3176±345.0	6757±671.1	25.95±1.803
Compost bioslurry (15 t/ha)	3383±340.9	7640±663.1	24.00±1.781
Compost bioslurry (5 t/ha)	1596±326.6	3837±635.3	19.92±1.750
Control	1356±368.9	3389±717.6	15.00±1.961
Dry bioslurry (10 t/ha)	2449±408.2	5844±794.0	23.64±2.136
Dry bioslurry (5 t/ha)	1559±294.4	3930±572.6	20.29±1.543
Liquid bioslurry (10L/plant)	1941±350.4	3999±681.6	21.34±1.838
NPK	993±323.2	2821±628.7	15.86±1.684
LSD	*437.2*	*850.4*	*2.284*
CV%	*92.59*	*77.16*	*46.16*

Overall across the two harvesting seasons, the best performing treatment was compost bioslurry applied at rate of 10 kg/tree (2.29 kg/tree) translating into 2.54 t/ha, followed by compost bioslurry applied at 15 kg/tree (2.05 kg/tree) or 2.3 t/ha though the difference was not significant. The poorest yield of less than one kilogram per tree (0.79 kg/tree) was recorded in trees in plots with no soil amendment (control). Therefore, compost bioslurry applied at 10 kg/tree improved the yield of coffee by 65.6% compared to control. Although NPK improved yield of coffee by 18.8% compared to control, basing on the statistic LSD at P≥0.05, this increase was not significant (Table 21). Therefore, NPK may not be a good fertilizer for perennial crop like coffee since it may not stay long in the soil for long. Besides, the severe drought during experiment could have resulted in less dissolution and utilization of NPK. Further studies to verify this are recommended. What is important though is that the composted bioslurry resulted in higher yields and should be recommended.

Table 21: The mean (± standard error) of actual yield, potential yield and number of primaries possessing the coffee berries for coffee fields in Isingiro in15- 2016 combined

Treatment	Actual yield (g/tree)	Potential yield (g/tree)	Number of Primaries
Compost bioslurry (10 t/ha)	2290±215.3	4175±434.5	21.14±1.286
Compost bioslurry (15 t/ha)	2050±185.4	4990±374.2	17.69±1.102
Compost bioslurry (5 t/ha)	1146±185.0	2959±373.3	15.31±1.098
Control	788±200.3	2100±404.3	11.55±1.392
Dry bioslurry (10 t/ha)	1632±219.0	4256±441.9	17.11±1.299
Dry bioslurry (5 t/ha)	1017±169.3	2760±341.7	13.79±0.988
Liquid bioslurry (10L/plant)	1136±192.7	2585±388.9	14.49±1.120
NPK	970±189.9	2566±383.2	13.65±1.101
LSD	250.8	506.1	1.477
CV%	112.56	92.45	55.33

There was significant interaction between field management practices and treatment. Across the two seasons, the highest yield was recorded on Purinari's farm. This high coffee yield was consistent even for 2015 and 2016 harvesting seasons (Tables 22, 23 and 24). The differences between farms could be explained by differences in field management, pest and disease control and soil moisture availability and age of trees. Overall, the performance of coffee was low and drought could have been devastating factor. There was a lot of flower abortion and drying of coffee berries before maturity. Generally, Isingiro district is a drought prone area whose crop performance is heavily affected by long dry spell. Other factors that could have resulted in low coffee yields could be pests and diseases, and poor farmers' management of the fields. What is important, however, is that the effect of treatments on the performance of trees was pronounced.

Table 22: The mean (± standard error) of actual yield of coffee (g/tree) at different farmers' fields in Isingiro as influenced by different treatments in 2015

Treatment	***Farmers plots***			
	Ayorekire	Hassan	Luka	Purinari
Compost bioslurry (10 t/ha)	1460.7±479.1	45.3±313.6	1717±414.9	2102.6±371.1
Compost bioslurry (15 t/ha)	185.8±293.4	293.6±239.5	800.5±338.7	885.8±313.6
Compost bioslurry (5 t/ha)	0±371.1	278.4±230.1	1620±338.7	854.4±313.6
Control	29.1±414.9	4.5±313.6	84.1±230.1	727±338.7
Dry bioslurry (10 t/ha)	0±313.6	109.6±313.6	2223.3±338.7	362.2±313.6
Dry bioslurry (5 t/ha)	0±371.1	75.9±276.6	1049.2±230.1	472.4±293.4
Liquid bioslurry (10L/plant)	52.1±414.9	119.9±293.4	92.8±338.7	720.5±293.4
NPK	32.1±479.1	37.1±207.4	3586.8±371.1	141.6±293.4
LSE	***309.8***			

LSE=Least standard error of mean

Table 23: The mean (± standard error) of actual yield of coffee at different farmers' fields in Isingiro as influenced by different treatments in 2016

Treatment	Ayorekire	Hassan	Luka	Purinari
Compost bioslurry (10 t/ha)	1249±601.0	3345±736.1	1734±736.1	6784±681.5
Compost bioslurry (15 t/ha)	1295±570.2	3440±637.5	1802±736.1	7462±806.3
Compost bioslurry (5 t/ha)	1144±570.2	641±637.5	858±736.1	4031±681.5
Control	775±806.3	57±736.1	590±681.5	4383±681.5
Dry bioslurry (10 t/ha)	630±520.5	2856±1041	1231±806.3	5414±806.3
Dry bioslurry (5 t/ha)	805±637.5	2188±570.2	991±520.5	2307±601.0
Liquid bioslurry (10L/plant)	832±901.5	1666±543.6	973±570.2	4602±681.5
NPK	622±637.5	902±500.1	1460±806.3	1063±637.5
LSD	334.9			

Table 24: The mean (± standard error) of actual yield of coffee at different farmers' fields in Isingiro as influenced by different treatments in 2015-16 combined

Treatment	Ayorekire	Hassan	Luka	Purinari
Compost bioslurry (10 t/ha)	1353±466.6	1730±394.2	1726±454.7	4492±412.8
Compost bioslurry (15 t/ha)	752±334.8	1900±324.2	1312±408.4	4243±415.7
Compost bioslurry (5 t/ha)	584±384.7	463±319.5	1231±408.4	2476±378.1
Control	410±473.4	31±394.2	342±333. 7	2593±392.9
Dry bioslurry (10 t/ha)	322±334.6	1511±492.2	1717±429.2	2941±415.7
Dry bioslurry (5 t/ha)	411±401.3	1154±324.7	1020±283.4	1409±343.3
Liquid bioslurry (10L/plant)	450±500.2	909±327.6	542±363.4	2702±366.6
NPK	333±474.3	479±264.7	2501±447.4	612±353.7
LSD	762			

The overall results indicate that composted bioslurry applied at a rate of 10 t/ha was the most cost effective form of bioslurry and increased the yield of coffee by 66% compared to control (the least performance). It resulted in an actual yield of 2.54 t/ha compared to 0.98 t/ha that was produced in control plots. The percentage increase of 66% of yield in bioslurry treated plots compared to control plots is comparable to earlier reports by Warnars Oppenoorth (2014) who reported that bioslurry increased the yield of coffee by 50%. However, the experiment was affected by heavy drought and pests and this could explain the overall poor performance. The yield potetntial of coffee in Uganda is about 4 t/ha per season (about 4 kg/tree per seson). Though there was no significant difference between compost bioslurry applied at 10 t/ha and 15 t/ha (10 kg/tree and 15 kg/tree), it would be a wastage to apply 15 t/ha since it does not result in any advantage over 10t/ha. Therefore, it is recommended that 10 kg/tree of compost bioslurry is the most effective rate for bioslurry application. Generally the results indicated that the use of bioslurry improves the productivity of coffee under field conditions and the findings are a breakthrough for small scale farmers to improve their productivity cheaply since bioslurry is cheaper than the inorganic fertilizer and can be easily accessible in the communities.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions and Recommendations

The results indicated that the use of bioslurry enhances the availability of Nitrogen in the soil which is the most common nutrient limiting element for crops. This was further evidenced by the improved yields of coffee, cabbages and maize in plots treated with bioslurry compared to control plots. The study also suggests that compost bioslurry applied at rate of 10 t/ha (10 kg/tree for coffee) is a good source of fertilizer for crops and resulted in better performance in all crops than the commonly used inorganic fertilizer NPK. Since the bioslurry is cheaper than NPK and cannot easily be faked, its use is hereby recommended for small holder farmers to enhance their crop productivity. Besides, bioslurry being organic fertilizer, it could result in prolonged retention of soil fertility in the soil than mineral organic fertilizer which need to be applied every planting season. An additional advantage of organic bioslurry is that it environment and user healthy friendly. . Generally the the findings are a breakthrough for small scale farmers to improve their crop productivity cheaply since bioslurry is cheaper than the inorganic fertilizer and can be easily accessible in the communities.

Although Liquid bioslurry improved soil fertility and crop productivity, its use in distant fields may be limited due the cost of transporting it requires expensive special transport mechanisms such as use of tank trucks and heavy large drums. This may be particularly challenging for women, who do most of crop production activities in the Ugandan agriculture. Besides, it should be handled with care since it may contain health threatening microorganisms.

Furthers studies are recommended to determine the effect of bioslurry, especially liquid bioslurry that was found to contain microorganisms, on the beneficial soil microorganisms. Whether these microorganisms found in the liquid bioslurry can be detected in the harvested crops from bioslurry treated plots, especially vegetables such as cabbages? Studies to compare the presence and the concentration of microrganims in the composted and dry bioslurry are recommended.

6.2 Challenges during experimentation

1) Frequent and prolonged affected the trials especially coffee. The coffee plants wilted and flower abortion was common on most of the coffee plants. This could have affected the quality of data collected and yield of coffee.
2) There was heavy infestation of pests especially scales and mealy bugs in coffee and this could have also affected the yield in the experiments.
3) This was a community based research with possibility of a lot of interference. However the study was done to understand the actual situation of what happens at farm level despite the fact that objective of understanding the impact of all forms of bio slurry on coffee was embedded in this.

6.3 Lessons Learnt

a) On-farm trials, though, can help answer questions important to farmers, require adequate planning and farmers' involvement from planning process to implementation. If not properly planned, background “noise” or farmer interference can play destruction to detect true treatment effects. Due to inadequate funding, farmer participation in planning and designing trials was not adequate

b) For rapid adoption of the technology, evaluating the new or not well understood technology like use of bioslurry to improve productivity should be done in farmer's fields, under farmers’ conditions and management, by using farmer's own practice as control. This helps in developing innovations consistent with farmer's circumstances, compatible with the actual farming system and corresponding to farmer's goals and preferences.

c) There must be balance between the preference of farmer and researcher for larger plots on the basis of realism or ease of treatment application, and the statistical benefit of improved precision from more, smaller plots.

d) Effective and frequent communications with farm owners, workers, and other decision makers are crucial.

e) It is important to have few rather than more treatments. Whereas on station experiments can be complex, and scientists may evaluate multiple treatments, it was difficult for farmers to adequately follow our experiments on farm due to many treatments. What is important however, is that farmers were able to observe the differences in performance in plots treated with different forms of bioslurry, though it was difficult to distinguish between performance of different levels of each bioslurry form

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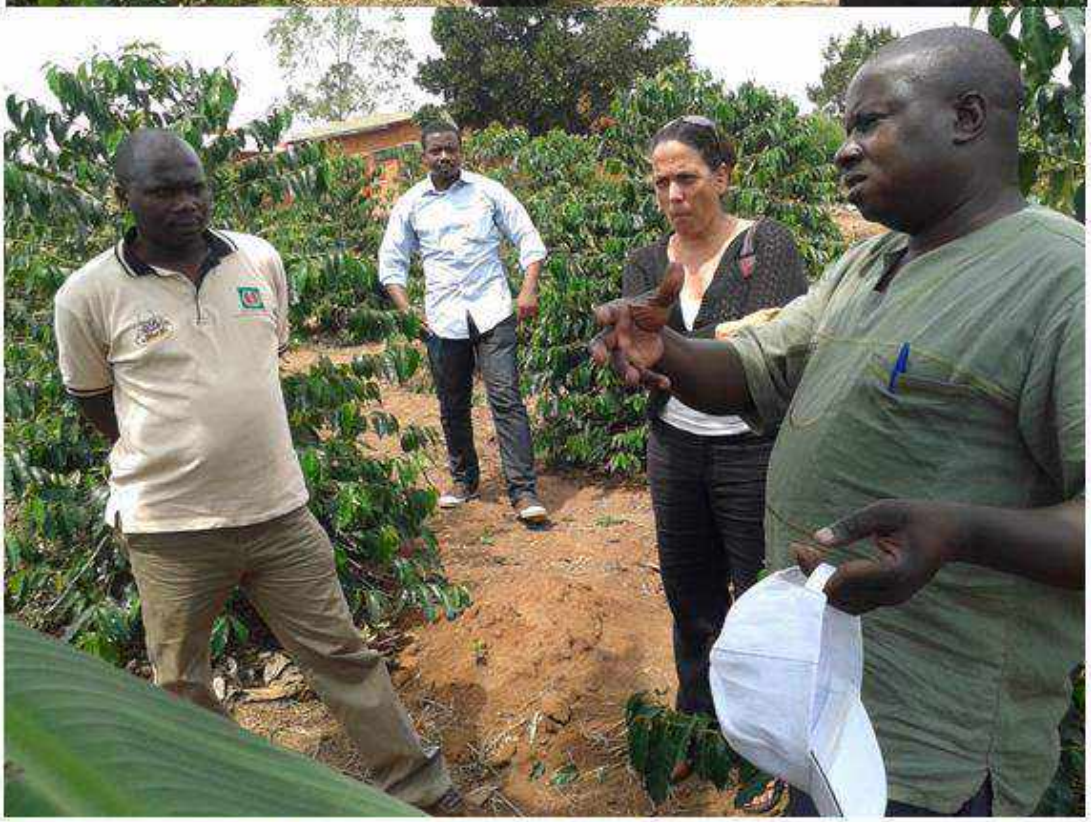
ANNEX: PICTORIAL PRESENTATION OF PROCESSES DURING EXPERIMENTATION

A: Participatory Monitoring and Evaluation of cabbage trials

B: Data collection from cabbage trials



C: Participatory Monitoring and evaluation of coffee trials

D: Host farmers participated in evaluation and data collection

E: Bioslurry improved flowering and fruiting in coffee

F: Severe drought caused wilting and flower abortion in coffee

G: Liquid Bioslurry is expensive to transport to far fields

H: Proper application of liquid Nitrogen using watering can