EFFECTS OF BIO-SLURRY AND FARM YARD MANURE ON SOIL AMELIORATION AND CHINESE CABBAGE (*BRASSICA RAPA VAR. CHINENSIS*) YIELDS IN NJOMBE REGION, TANZANIA

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ABSTRACT

The study was carried out to assess the effects of bio- slurry and farm yard manure on soil amelioration and yields of Chinese cabbage in Nyumbanitu and Itulike villages in Njombe Tanzania. Chinese cabbage is a very important crop for human nutrition as a source of vitamins, minerals and dietary fiber. However, soil acidity and nutrient deficiencies limit Chinese cabbage production in many tropical soils. The overall objective was to quantify the effects of bio- slurry and farm yard manure on soil amelioration and yields of Chinese cabbage (*Brassica rapa var. chinensis*). A randomized Complete Block Design (RCBD) experiment with 10 treatments and three replications was laid in a field. Liquid bio-slurry, Composted bio-slurry, Farmyard manure and Di-ammonium phosphate (DAP) were applied at planting in a hole. Chinese cabbage seeds were sown at a spacing of 30 cm x 30 cm in plots of 3 m × 1.5 m. Manures were characterized for their nutrient contents. Results showed that soil pH at Nyumbanitu and Itulike changed from medium acidic to slightly acidic after the addition of bio-slurry and manure. On the other hand, soils in all plots which received manures plus DAP had significant increase in NPK. Organic fertilizers are very effective in increasing soil nutrients availability. A combination of composted bio-slurry, farmyard manure and DAP gave a higher value of organic matter as compared to other treatments. DAP, manures and their combination increased Chinese cabbage fresh weight of leaves from 44.3 to 83.3 g/plant significantly at $P \leq 0.05$ according to Duncan Multiple Range Test. There was a significant increase in fresh weight of Chinese cabbage among treatments throughout the ten weeks at Nyumbanitu village which was also the case for Itulike village. Therefore, integrated application of organic and inorganic fertilizers is necessary for soil fertility improvement and sustainable crop production.

DECLARATION

I, Kinaghi Everesty Mwanga, do hereby declare to the Senate of Sokoine University of Agriculture, that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
°C	Degrees Centigrade
Al^{3+}	Aluminium ion
ANOVA	Analysis of variance
B	Boron
C/N	Carbon, Nitrogen ratio or carbon/nitrogen
Ca	Calcium
CBS	Composted Bio-slurry
Cd	Cadmium
CEC	Cation Exchange Capacity
cm	Centimetre
cm^2	Centimetre squared
cm^3	Cubic centimetre
Co	Cobalt
Cr	Chromium
CV	Coefficient of variation
DAP	Di-ammonium phosphate
DMRT	Duncan's Multiple Range Test
e.g.	For example
FAO	Food and Agriculture Organization of the United Nations
Fe	Iron
FYM	Farmyard Manure
g	Gram
g/cm^3	Gram per cubic centimetre
H^+	Hydrogen ion
Ha	Hectare

IFPRI	International Food Policy Research Institute
K	Potassium
L	Litre
LA	Leaf Area
LAI	Leaf Area Index
LBS	Liquid Bio-slurry
m	metre
Mg	Magnesium
Ml	Millilitre
mm	Millimetre
N	Nitrogen
N/P	Nitrogen to Phosphorous ratio
Na	Sodium
NH_4	Ammonium
Ni	Nickel
OC	Organic Carbon
OM	Organic Matter
P	Phosphorous
P_2O_5	Di-phosphorus Pentoxide
RSPN	Royal Society for Protection of Nature
SNV	Stichting Nederlandse Vrijwilligers (Foundation of Netherlands Volunteers)
SUA	Sokoine University of Agriculture
t ha^{-1}	Tonnes per hectare
TN	Total nitrogen
Zn	Zinc

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

1.1.1 Bio-slurry

Bio-slurry is an anaerobically fermented organic material released as a byproduct from a biogas plant after production of combustible methane gas. The fermentation process in a biogas digester is brought about anaerobically by *methanogenic* bacteria. It may be considered as an effective source of organic fertilizer as it contains considerable amounts of primary nutrients, namely nitrogen, phosphorus and potassium (NPK) and organic matter that are readily absorbed by plants and soil micro-flora (Islam, 2006; SNV, 2009). Cow dung is among the organic materials used to produce the bio-slurry. The cow dung is fermented for 50 days after which the slurry is discarded (South Netherlands Volunteers Royal Society for Protection of Nature, 2012). It is said to be a good source of nutrients for most plants, especially for fruit bearing trees, vegetables and other horticultural crops (Mohabbat *et al*., 2008). Bio-slurry improves the physical, chemical, and biological quality of soil, including soil structure, water holding capacity, CEC, lowering soil bulk density, protection against soil erosion, preventing the leaching of nutrients and it also provides nutrients to soil micro-flora and fauna (Fentaw, 2010). Therefore, bio-slurry is a good organic fertilizer that can be used together with inorganic nitrogenous fertilizers to improve soil fertility (Satyanarayana *et al.,* 2002; Garg *et al.,* 2005).

1.1.2 Farmyard manure

Farmyard manure is a heterogeneous decomposed organic material consisting of dung and urine of farm animals along with litter and left over crop material from fodder fed to cattle. Farmyard manure is an important organic resource for crop production in livestock-based farming systems. Thus, there is a potential use of farmyard manure as an inorganic fertilizer to reduce total dependence on inorganic fertilizers which are expensive and not safe environmentally. Farmyard manure plays an important role in improving soil aggregates stability, soil physical and chemical properties, air and water movement (Satyanarayana *et al.,* 2002). These improvements in soil physical, chemical and microbial properties lead to better crop growth and increased yields (Satyanarayana *et al.,* 2002).

1.1.3 Soil characteristics

Soil acidity and nutrient deficiencies limit crop production in many tropical soils and it has been found to retard plant growth through H^+ and Al^{3+} ionic toxicity effects to root hairs or by indirectly interfering with mineral availability (Onyango *et al*., 1997). Research findings indicate that most of the soils in Njombe district are highly acidic (http://www.umb.no/statisk/noragric/EPINAV/njombe.pdf). For example, at Lunyanywi site, soils are strongly acidic with pH ranging from 4.1 to 4.8 (Mtengeti *et al.,* 2012). This indicates that the problem of low crop productivity in Njombe is due to, among other factors, soil acidity hence liming or the use of manure such as bio-slurry and farmyard manure will neutralize (buffer) the soil acidity.

1.1.4 Chinese cabbage

Vegetables play a very important role in the human nutrition especially as sources of vitamins such as vitamin C, minerals and dietary fiber (Craig and Beck, 1999). All over the world, vegetables are used either as a whole meal or as a complement to the main meal (Craig and Beck, 1999).

As the name suggests, Chinese cabbage originated in China. The earliest records in Chinese literature date to the fifth century, where the plant occurred naturally as a cross between Pak choi (*Brassica rapa var. chinensis*) and turnip (*B. rapa var. rapifera*) (Paul and Bruce, 1995). Chinese cabbage is currently popular in almost all areas of the world and in Tanzania, including Njombe. Little has been done in Njombe and Tanzania at large on improving the yields of the Chinese cabbage through use of organic or inorganic fertilizers (Larkcom, 1991). This proposed research will fill this gap.

1.2 Justification

The study is important because organic fertilizers such as bio-slurry and farm yard manure are alternative cheap locally available materials used in soil acidity neutralization, and are used for improving Chinese cabbage yield in Njombe; and are affordable by most resource-poor small scale growers. However, crops' yield responses to bio-slurry and farm yard manure application have not been studied especially the Chinese cabbage yield responses to bio-slurry and farm yard manure application in Njombe.

1.3 Objectives

1.3.1 Overall objective

To quantify the effects of bio- slurry and farm yard manure on soil amelioration and yields of Chinese cabbage (*Brassica rapa var. chinensis*).

1.3.2 Specific objectives

i. To determine improvements in soil pH, soil organic carbon, bulk density and soil texture resulting from bio-slurry, farm yard manure and DAP use.

ii. To determine the availability of N, P and K in soils under different fertilizer treatments.

iii. To determine the effects of bio-slurry and farmyard manure on yields of Chinese cabbage.

1.4 Hypotheses

i. Liquid bio-slurry, composted bio-slurry and farmyard manure do not increase soil pH in acidic soils

ii. Liquid bio-slurry, composted bio-slurry, farmyard manure and DAP do not improve soil fertility in poor soil fertility areas

iii. There are no differences among the liquid bio-slurry, composted bio-slurry, farmyard manure and DAP on growth, development and yield of Chinese cabbage

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General

Chinese cabbage requires deep, fertile, well-drained soils because it is susceptible to root rot. However, it will not tolerate excessive water stress due to its shallow root system (Anon, 1984). Therefore, addition of organic materials is recommended to improve water retention (Nguyen, 1992). Chinese cabbage has been successfully grown on a range of soil types from sandy soils to heavier textured Western Australia loams (McKay and Phillips, 1990). In general, a soil pH of 5.5 to 7.0 is considered ideal for the growth of Chinese cabbage (Waters *et al.,* 1992).

2.1.1 Nutrients requirements of chinese cabbage

The quantities of nutrients needed to increase yields depend on soil type, nutrient status, previous cropping practices (Waters *et al.*, 1992) and irrigation efficiency (Phillips, 1990). Large amounts of potassium, nitrogen and phosphorous are needed to increase yields of Chinese cabbage (Waters *et al.*, 1992). Nguyen (1992) recommended that fertilizer with an NPK ratio of 5:5:5 should be broadcast at the rate of 1.5 t/ha before planting. In addition, regular applications of nitrogenous and potassium fertilizers after crop establishment are desirable. Organic fertilizers can serve as a substitute for expensive mineral fertilizers. Manures supply the required nutrients, improve soil structure, increase microbial population and at the same time maintain the quality of crop produce (Dauda *et al*., 2008). Bio-slurry and farmyard manure improve the physical and biological quality of soil by adding organic matter to the soil in addition to providing both macro and micro-nutrients to crops (Mohabbat *et al.,* 2008).

2.2 Beneficial Use of Organic Fertilizers

In traditional agricultural systems where very little or no inorganic fertilizers are used, breakdown of organic materials supplies the dominant portion of nitrogen and Sulphur needed by plants and as much as half of the phosphorous (Bernard, 1985 in Gurung,1997).

Organic matter (OM) considerably enhances the cation exchange capacity (CEC) of the soil - that is, its ability to bind positively charged ions such as magnesium (Mg), calcium (Ca), potassium (K) and ammonium (NH_4^+). Without this binding effect, these nutrients would be rapidly leached away when it rained. CEC of the OM is particularly important in acid soils, and especially those with low clay content since such soils have low cation retention capacity.

Organic matter also forms complexes with micro-nutrients such as iron, manganese, boron and copper and through binding prevents them from being lost through leaching. Phosphorous availability is increased with the presence of organic matter. This occurs when organic matter forms complexes with amorphous iron in the soil thus preventing them from binding and immobilizing phosphate ions (Gurung, 1997).

Yield responses of vegetable crops to bio-slurry application have been reported in different crops including Okra (Shahbaz, 2011) and maize and cabbage (Karki, 2001). However, not much has been reported much for other vegetable crops, including Chinese cabbage.

2.2.1 Effects of manure on soil pH

The pH range of the soil is an important condition for many chemical reactions and microbial activities in soil (Gurung, 1997). Organic matter helps to buffer the soil pH by keeping it towards the neutral range. This increases the availability of phosphorous, molybdate, borate, and a number of other nutrients (Gurung, 1997). Bio-slurry and farmyard manure are especially suitable and cheap sources of soil nutrients; they have considerable liming effect hence very suitable for acidic soils. They reduce the acidity of the soils and thereby protect crops from aluminium toxicity (Bhuiyan, 1991). Bio-slurry application on saline soil can reduce the salinity of soil by 30 to 40 percent (Abdul *et al.*, 2012).

2.3 Bio-slurry as a fertilizer

Bio-slurry is anaerobic digested manure released as by-product from bio-gas plant after production of combustible methane gas for cooking lighting, and/or running machineries (Aminul, 2013). About 25 to 30% of the organic matter in dung is converted into biogas during the anaerobic fermentation process, while the rest becomes available as bio-slurry. This bio-slurry is normally rich in macro and micro nutrients (Islam, 2006).The composition of bio-slurry depends upon several factors: the kind of dung (animal or human), water, breed and age of animals, types of feed and feeding rate (Warnars and Oppenoorth, 2014).

As with other organic sources, bio-slurry improves the physical, chemical, and biological quality of soil, including improvement in soil structure, water holding capacity and providing crop nutrients (Fentaw, 2010). Bio-slurry can be used in liquid, dried or composted form (Dhobighat and Painyapani, 2006; Minale *et al.,* 2008).

The beneficial effect of bio-slurry in crops production has been demonstrated by many workers e.g. (Mohabbat *et al.*, 2008). Maintenance of soil fertility is a prerequisite for long term sustainable crop production and organic fertilizers. A very good example is that cow dung and poultry manure or their slurry can play a vital role in the sustainability of soil fertility and crop production (Mohabbat *et al*., 2008).

Bio-slurry can be used to fertilize crops directly or added to composting of other organic materials. Bio-slurry is an already-digested source of animal waste and if urine (animal and/or human) is added, more nitrogen is added to the bio slurry which can speed up the compost making process (Warnars and Oppenoorth, 2014). This improves the carbon/nitrogen (C/N) ratio in the compost. But this also depends on the kind of digester. With the right amounts of materials, the composition of the bio slurry can be 93% water and 7% of dry matter, of which 4.5% is organic matter and 2.5% inorganic matter (Warnars and Oppenoorth, 2014).

The bio-slurry coming out of the digester has the following characteristics:

- When fully digested, effluent is odorless and does not attract insects or flies in the open.
- The effluent repels termites whereas raw dung attracts them and they can harm plants fertilized with farmyard manure (FYM).
- Effluent used as fertilizer reduces weed growth with about 50%. When FYM is used the undigested weed seeds cause an increased weed growth.
- Composted effluent and effluent used as liquid fertilizers have a greater fertilizing value than FYM or fresh dung. This is because nitrogen is available in a form that can be immediately absorbed, for some crops it is superior to chemical fertilizer (Aminul, 2013).

Bio-slurry is used to improve soil fertility, soil structure and crop productivity. Bio slurry has so many advantages that have been referred to as 'bio-gold' (Warnars and Oppenoorth, 2014). The percentage of NPK (Nitrogen, Phosphorus and Potassium) of slurry on wet basis is 0.25, 0.13 and 0.12 while in dry basis it is 3.6, 1.8 and 3.6 respectively (Aminul, 2013).

2.3.1 Effects of bio-slurry on crop yield

Yield is the most important parameter in the production of any crop. It has a direct relationship with the amount of available nutrients in the soil. Resources or inputs injected into a farming system to realize the yield thereof, including issues pertaining to accessibility of the said inputs, are cardinal as they can otherwise seriously affect the yield (Mueller, 2005).

Bio-slurry organic fertilizer is more effective than traditional organic fertilizer as it contains 20-30% more nutrient than commonly used organic fertilizer (Aminul, 2013). In the Ethiopian town of Debre Zeit with Andosol soils, the use of bio-slurry in liquid or composted form alone at the rate of 20 t/ha, or together with full doses of mineral fertilizer with bio-slurry at the rate of 10 t/ha increased the yields of maize, soybean, wheat, sun flower, cotton, ground nut, cabbage and potato as compared to yields in the controls (Mohabbat *et al.,* 2008; International Food Policy Research Institute (IFPRI, 2010). Dhobighat and Painyapani (2006) indicated that the use of bio-slurry increased the yields of rice and maize by 34 percent and yields of wheat by 25 percent.

The use of bio-slurry in different forms improved not only the quantity but also the quality of yield of the crops, vegetables and fruits (Krishna, 2001). Joshi *et al.* (1994) reported that application of bio-slurry gave significantly higher yields of vegetables in Bangladesh. Batsai *et al*. (1979) reported that mineral fertilizer together with organic fertilizer produced the highest cabbage yields. Because bio-slurry is very rich in nutritive elements including nitrogen (N), phosphorous (P), potassium (K) and trace elements as zinc (Zn), nickel (Ni), iron (Fe), cobalt (Co), cadmium (Cd), chromium (Cr), boron (B), calcium (Ca) and sodium (Na) (Gupta, 2007).

It is also reported that variation in dry matter accumulation by different varieties may be related to Leaf Area (LA), Leaf Area Index (LAI) and other growth parameters (Muleya, 2009). Several environmental factors affect leaf area (Wilson, 2004). Size of leaves has been reported to be largely determined by the nutritional status of the soil in which the plant grows (Wilson, 2004).

Nitrogen is an important soil nutrient and it increases total leaf area per plant and per unit area by increasing number and size of leaves (Sompongse and Pushparajah, 1994). It is also an integral part of chlorophyll, which is the primary absorber of light energy needed for photosynthesis (Muleya, 2009). An adequate supply of nitrogen is associated with vigorous vegetative growth and the green color (Sompongse and Pushparajah, 1994). An imbalance of nitrogen or an excess of this nutrient in relation to other nutrients such as phosphorus and potassium can prolong the growing period and delay crop maturity (Vanlauwe *et al.,* 1999).

2.3.2 Application and forms of bio slurry

During digestion nutrients are transformed from organic states to inorganic states, making them more useful for plant uptake. From experience, it is generally recommended to apply the bio-slurry at a rate of 10 to 20 tons/ha in irrigated areas and 5 tons/ha in dry farming in order to achieve a significant increase in yield (Warnars and Oppenoorth, 2014). Applying more is sometimes suggested by other literature, but the additional increase in yield is not so significant after around 25 t/ha. The appropriate rate may depend on the crop and soil type (sand, clay, loam) (Warnars and Oppenoorth, 2014). For instance, with a banana plant growing on a loamy soil, a jerrycan (20 litres) is applied every cropping season, which is equivalent to two jerrycans (40 litres) per tree per year (Warnars and Oppenoorth, 2014).

The bio-slurry can be applied: (1) as a foliar fertiliser, being sprayed onto the crops; (2) in liquid form (diluted) onto the roots, or; (3) in dry and composted form (combined with irrigation techniques so that crops have sufficient water). With regards to tillage, note that immediate incorporation of pig bio-slurry through tillage would increase the N value and favour greater N/P fertiliser value (Warnars and Oppenoorth, 2014).

Bio-slurry can be found in different forms and varies according to the digester and feeding substances. The fully-digested bio slurry can be easily identified (like regular compost: smells good, is black or dark brown in colour, can contain small living organisms, and no substances can be identified) and can be used as manure to improve soil fertility and increase crop yields and production (Warnars and Oppenoorth, 2014). The bio-slurry can be used in liquid, compost, and dry form and is a very good fertiliser/composting substance for agricultural crops (Warnars and Oppenoorth, 2014). If the dung is available in dry form, more water needs to be added (Warnars and Oppenoorth, 2014).

2.4 Farmyard Manure

Manures or simply manures are materials largely of plant or animal origin in different stages of decomposition that are added to the soil like other manures to supply plant nutrients and improve the soil's physical, chemical and biological properties (Prasad and Power, 1997). This in turn improves nutrient uptake resulting into improved plant growth, yields and yield components. Farmyard manure is a heterogeneous composted organic material consisting of dung, crop residue, and / or household sweepings in various stages of decomposition (Satyanarayana *et al.*, 2002). When livestock excrement, urine and bedding materials are allowed to fully decompose, the resulting product is a composted farmyard manure which contains nearly all the nutrient elements, both macro and micro-nutrients required for plant growth (Saidia, 2013).

2.4.1 Farmyard manure as a fertilizer

Manures play important roles in improving the physical, chemical and biological properties of soils. Therefore, application of farmyard manure considerably improves plant nutrient uptake, resulting into increased growth, yields and yield components in crops (Pandey *et al.*, 1999). This is because farmyard manure increases organic matter in the soil which increase porosity, reduces bulky density and improve rooting environment for upland rice (Gupta and O'Toole, 1986; Hesse, 1984 in Saidia, 2013) with subsequent increase for the roots' capacity to scavenge for nutrients in the soil. Khan *et al.* (2010) found that application of farmyard manure increased soil organic matter by about 29.9%, and improved the soil's physical and chemical properties like soil structure, moisture retention capacity and plant nutrient retention. Organic matter positively contributes to soils' aggregate stability and aeration (Khan *et al.*, 2010; Prasad and Power, 1997 in Saidia 2013).

2.4.2 Quality of farmyard manure

The value of manure in improving soil quality and enhancing plant growth can be termed as manure quality (Kimani and Lekasi, 2004). Laboratory analyses are employed in the determination of the quality of manure (Jackson and Mtengeti, 2005). Farmers have their own traditional ways of determining the qualities of manures. For example, in central Kenya farmers use texture, longevity of composting, homogeneity, presence of fungi spores or hyphae as some of the quality characteristics or indicators (Kimani and Lekasi, 2004). In Ethiopia, farmers determine manure quality based on the degree of decomposition, where well decomposed manure is rich in nutrient content than less decomposed manure (Kimani and Lekasi, 2004). Kimani and Lekasi (2004) reported that fine soil texture, black-grey colour, presence of white caterpillars and longer time of composting and lack of heat in manure are good indicators used by farmers to assess the quality of farmyard manure.

Nutrient contents of farmyard manures are highly variable depending on the ages of the animals, feeds given to the animals as well as the manure storage and handling methods employed (Snijders *et al.*, 2009). Based on animal species, nutrient contents differ from cattle, goat, pig, poultry, rabbit and sheep (Prasad and Power, 1997; Sanginga and Woomer, 2009). It has been reported that indoor manure contain more nutrients than outdoor manures, like kraal manures because of significant leaching and volatilization of nutrient and nutrient components in the latter (Sanginga and Woomer, 2009; Jackson and Mtengeti, 2005).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site Description

The study was carried out in Nyumbanitu and Itulike villages, Njombe district in Njombe region, Tanzania. The Nyumbanitu village is located at an elevation of 1996 m above sea level and latitude of 9^{o} 18'412'' South and longitude 34^{o} 40'812'' East while Itulike village is located at an elevation of 1968 m above sea level and latitude of 9^{o} 18'449'' South and longitude 34^{o} 44'292'' East. The annual mean temperature is 13.2 to 18 ^{o}C and the annual rainfall is 1,200 to 1,600 mm as reported by EBM and NEMC (2012).

3.2 Materials

In this study, materials needed and used were Chinese cabbage seeds, liquid bio-slurry, composted bio-slurry, FyM and DAP fertilizer. Chinese cabbage seeds from Kibo Seed Company Limited were purchased from Agro-shops in Njombe town. Liquid and composted bio-slurry was obtained from two farmers having a bio-gas plant at home in Nyumbanitu and Itulike villages. Composted bio-slurry was obtained from farmers with a bio-gas plant constructed at home where crop residues were placed in a pit before and after placement of liquid bio-slurry and allowed to decompose for two months. Farmyard manure was obtained from a farmer keeping livestock in-door in each village. The FyM used was collected and stored under a shade for decomposition for about six months. DAP was bought from Agro-dealers in Njombe town, this is an inorganic fertilizer containing 46% P_2O_5 and 18%N (FAO, 2000).

3.3. Analysis of Soils, Bio-slurry, Composted Bio-slurry and Farmyard manure

3.3.1 Soils

Soil analysis was done before the beginning and at the end of the experiment. Before experimental layout, a composite soil sample was collected from each site (Nyumbanitu and Itulike) at a depth of 0 - 30 cm. Samples were collected at random from ten spots within the experimental site and the quartering method was used to get one composite sample as described by Pleysier (1995) and Saidia (2013). Then, the composite soil sample was dried, ground and sieved through a 2 mm sieve for laboratory analyses. Soil physical properties analyzed include particles size distribution for textural class determination and bulk density. While, chemical properties analyzed were pH, N, OC, P and K. At the end of the experiment, soil samples from each site in each treatment were again collected for laboratory analyses of physical and chemical properties.

Soil texture was determined by the hydrometer method whereby soil particles were dispersed with sodium hexametaphosphate (Calgon) and then agitated. After dispersion, the amount of each particle size (sand, silt, clay) was determined by using a hydrometer (Day, 1965).

Bulk density was determined following the method of Grossman and Reinsch (2002). Steel cores of known volume were hammered gently into the soil. The soil core was then excavated, ensuring that the cylinder is full of soil. Soil at the ends of the cylinder was trimmed using a knife so that the soil fitted into the volume of the cores. In the laboratory, the cores containing soils were oven dried at 105 ^{0}C for twenty four hours; samples were left to cool for three hours and then weighed. Weights of the oven dried soil were obtained by determining the difference between the weight of the core sampler + sample and core sampler alone. The bulk density of soils was then calculated as recommended by Okalebo *et al.* (1993):

Bulk density (g/cm^3), = Weight of oven dry soil (g)/ Volume of dry soil (cm^3)……………………………………………..……………………………… (1)

Soil pH was measured potentiometrically in water using 1:2.5 soils: solution ratio, using a pH meter (Maclean, 1982). Total nitrogen was determined by the micro-Kjeldahl method as described by Bremmer and Mulvaney (1982). Soil organic carbon was determined by the Walkley and Black method (Nelson and Sommer, 1982). Extractable phosphorus was determined by the Bray-1 procedure (Bray and Kurtz, 1945) and colour developed by the ascorbic acid method of Murphy and Riley (1962). Exchangeable potassium was determined in the NH_4-acetate filtrates by Ammonium Acetate Solution (Sumner and Miller, 1996)

3.3.2 Manure analysis

Bio-slurry, Composted Bio-slurry and Farmyard Manure samples were collected and analyzed in the soil laboratory at SUA. Soil pH and nutrients composition were analyzed in each sample basing on procedures proposed by Okalebo *et al.* (1993) which included the determination of pH, organic carbon, total nitrogen, phosphorus and potassium.

Bio-slurry was first mixed thoroughly in order to obtain a uniform suspension. About 1,000 ml of bio-slurry was collected for laboratory analysis of nitrogen, phosphorus, potassium and pH. A representative sample of 100 ml of bio- slurry was measured, filtered and dried to get the dry weight in order to obtain the relationship between the slurry suspension and the dry slurry.

Composted bio-slurry was analyzed by taking 1,000 g of a well decomposed sample for laboratory analysis for nitrogen, phosphorus, potassium and pH. A 50 g sample of composted bio-slurry was dried at 70^{0}C to constant weight to get the dry bio-slurry in order to establish the relation between liquid bio-slurry and composted bio-slurry.

Farm yard manure was sampled by taking 1,000 g of a well decomposed sample for laboratory analysis for nitrogen, phosphorus, potassium and pH. A 50 g sample of manure was oven dried at 60 ^{0}C to constant weight to obtain dry manure so as to establish the relation between raw and dry manure.

3.4 Field Experiment

3.4.1 Experimental layout, treatment application and management

Land preparation was done thoroughly using a hand hoe and rack before experimental layout. The experiment was laid in a Randomized Complete Block Design (RCBD) with ten treatments in plots of 3 m × 1.5 m, with 1m path between plots, in three replications (Gomez and Gomez, 1984). These treatments were applied as: 1. Control, 2. Liquid Bio-slurry = 3 L/ plot (0.06 L/ plant or 6666.7L/ha), 3. Composted Bio-slurry = 9 kg/plot (180 g/ plant or 20 t/ha), 4. Farmyard manure = 9 kg/ plot (180 g / plant or 20t/ha), 5. DAP = 0.1 kg/ plot (2 g / plant), 6. Liquid Bio-slurry + DAP = 1.5 L + 0.05 kg/ plot, 7. Composted Bio-slurry + DAP = 4.5 kg + 0.05 kg/plot, 8. FyM + DAP = 4.5 kg + 0.05 kg/ plot, 9. Liquid Bio-slurry + FyM + DAP = 1.5 L + 4.5 kg + 0.05 kg/ plot, 10. Composted Bio-slurry + Farmyard manure + DAP = 4.5 kg + 4.5 kg + 0.05 kg/ plot. Bio-slurry, Farmyard Manure and DAP were applied around individual planting holes incorporated into the soil and moistened a day before sowing. Chinese cabbage seeds were sown at a spacing of 30 cm between rows and 30 cm between planting holes (Waters *et al*., 1992). Thinning to one plant per hill was done two weeks after seedling emergence. Other agronomic management practices like weeding was done to keep the plots clean as recommended by Kanyeka *et al.* (2007) for vegetable crops.

3.4.2 Data collection

Data was collected in a net plot of 2.4 m × 1m. Height (cm) of ten Chinese cabbage plants adjacent to the net plot from each treatment was measured using a ruler from ground level to the top of the shoot one month after emergency and weekly thereafter. Then, the average plant height per treatment was calculated at each measuring time.

The number of leaves per plant were counted and recorded from the randomly selected ten Chinese cabbage plants adjacent to the net plot. Then, average number of leaves per plant was calculated in each treatment.

Leaf area was obtained by measuring the length and width (cm) of selected ten plants adjacent to the net plot using a ruler. The average leaf length and width were used to calculate leaf area using the formula:

Leaf area (cm^2) = Leaf length (cm) x leaf width (cm) x factor (0.75) x number of leaves ………………………………………………………………………….…………………..…….. (2)

Leaf Area Index (LAI) was calculated as the relationship between leaf area and ground area of ten plants sampled.

Fresh weights of Chinese cabbage were obtained by harvesting leaves on a weekly basis from week 5 to 14 weeks (i.e. 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 weeks). At each harvesting time, four leaves were detached from the base of each of the selected ten plants and combined to give one sample. These samples were then weighed to obtain fresh weight and the average weight was calculated and expressed in gram per plant.

Nutrient concentrations in Chinese cabbage leaves were done at 7^{th} week after planting by sampling six leaves per treatment, and then these leaves were sent to the Soils Laboratory at Sokoine University of Agriculture for preparation and plant tissue analysis as described by Okalebo *et al.* (1993). Nutrients analyzed were nitrogen (N), phosphorus (P) and potassium (K) because they are the primary macro-nutrients.

3.5 Statistical Analysis

Crop growth, development and yield data collected such as plant height, number of leaves, leaf area, leaf area index and plant weight were subjected to Analysis of Variance (ANOVA) under the following statistical model.

The statistical model is: $Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$ .... (3)

where: Y_{ij} = Treatment effects, μ = Overall mean, α_i = the effect of i^{th} treatment, β_j = the effects of j^{th} replicate, ε_{ij} = Error term.

Then, treatment means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of significant ($P \leq 0.05$) as described by Gomez and Gomez (1984). The Gen Stat software, fifteenth edition, was used for data analysis.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Quality of Manures

Characteristics of organic materials used in the study are presented in Table 1. The value of OC, N and P were 7.9 – 17%, 0.7 – 1.83% and 0.06 – 0.55%, respectively. Saidia (2013) rated 6.91% OC and 0.94% total N as low and P above 3% as high in farmyard manure. Accordingly, it appears that except for LBS and FYM, which had low values of N and P, all materials were of high quality.

However, a more frequently used indicator of the quality of organic matter is C/N ratio, percentage of total nitrogen and phosphorus (Palm *et al.*, 2001). According to Saidia (2013), manures like LBS, CBS and FYM are considered to be of high quality if the ratio is 8 – 13, where net mineralization of N would be expected to occur. Okorogbona *et al.* (2013) further suggested that when the C/N ratio of manure is less than 20, its application results in a net increase of N in the soil. Results of this study (Table 2) show that the C/N ratio of the organic materials used in this study was 9 -11, suggesting that they were of high quality. Regarding P content, Palm *et al.* (2001) suggested that manure with P > 0.25% influences net P mineralization, indicating that LBS used in this study was of poor quality in that respect.

Table 1: Biochemical properties of organic soil amendment materials at Nyumbanitu and Itulike villages Njombe Region Tanzania

Site	Treatment	pH	OC	N	P	K	C/N ratio
			%	%	%	%	
A	LBS	7.79	17.00	1.79	0.08	0.07	9.50
	CBS	7.90	15.20	1.52	0.20	1.25	10.00
	FYM	7.99	9.15	0.92	0.40	2.74	9.95
B	LBS	7.64	16.30	1.83	0.06	0.04	8.91
	CBS	8.80	14.36	1.65	0.55	2.65	8.70
	FYM	7.73	7.89	0.70	0.12	1.11	11.27

Key: A: Nyumbanitu, B: Itulike village

4.2 Characteristics of Soils at Nyumbanitu and Itulike Villages

4.2.1 Soil characteristics before the application of treatments

Some key properties of composite soil samples in selected areas before field experimentation at Nyumbanitu and Itulike villages are presented in Table 2. The results show that soil texture in both villages is sandy clay. Soil chemical characteristics of the two villages were also similar, except for total N which was much lower at Itulike. Soil pH at both villages was medium acid; soil total N is low at Nyumbanitu and very low at Itulike. The soils of the two villages were very low in organic carbon and extractable P, but had high exchangeable K (Table 2 and Appendix 1.)

The low soil organic carbon and hence organic matter implies that the soils have poor water storage and nutrient retention capacity. The low total N and available P probably are mainly due to continuous cultivation without application of fertilizers or manures. Other factors affecting soil nutrients concentrations, include crop cultivar, soil type, season, crop management and fertilizer treatment (Kozai, 1994; Martin-Prevel *et. al*., 1984 in Muleya, 2009). Moreover, soil nutrients are influenced by rainfall and under high precipitation, large amounts of soil nutrients may be lost through leaching; which might be the case for Njombe which receives high rainfall. Other studies reported that soils with low organic matter also have low nitrogen (Saidia, 2013). Therefore, application of manures and inorganic fertilizers is an important strategy to improve soil fertility status and crop production.

4.2.2 Soil characteristics after the application of treatments at Nyumbanitu and Itulike villages

Some physical and chemical characteristics of soils after application of manures at Nyumbanitu and Itulike villages are shown in Table 3a and 3b. Soil pH in all experimental plots at both villages varied with treatment and increased from 5.4 to 6.3 at Nyumbanitu and from 5.5 to a maximum of 6.27 at Itulike. This improvement from medium acidic to slightly acidic soil conditions, indicates that some of the applied treatments neutralized soil acidity, hence improving nutrients availability.

Total N was low in most of soils except in plot 8 in Nyumbanitu village whereby application of FYM and DAP raised nitrogen level from low to medium. However, at Itulike village, five plots that received DAP and organic soil amendments had medium soil N (Table 3b). Soil organic carbon in all plots was rated as high, and on average higher levels at Itulike than at Nyumbanyitu. Soil extractable P in both villages varied from medium to high in all treatments except when liquid bio-slurry alone or with DAP were applied resulting in low available P. In general, of particular interest was that the application of LBS+ FYM+ DAP resulted in high P levels (41.0 mg g^{-1}) in both villages. Exchangeable K^+ in all plots ranged from high and very high in soils at both villages (Appendix 1.)

Di-ammonium phosphate (DAP) is an inorganic fertilizer which contains 46% P_2O_5 and 18%N (FAO, 2000). FYM, CBS and LBS contain both macro-nutrients (e.g. N, P, and K) and micronutrients including Zn (Saidia, 2013). Since manure contains organic matter which improves soil structure, water and nutrient retention capacity, application of DAP + manure such as FYM, CBS and LBS is likely to enhance nutrient release and improve soil fertility status. The failure of DAP and organic amendments to improve N availability at Nyumbanyitu village was thus not expected. However, total N is not a good indicator of N availability. Similarly, the inability of LBS to improve P availability in both villages was not surprising given its low P concentration (Table 1). However addition of DAP ameliorated this deficiency.

Table 2: Soil characteristics before experimentation at Nyumbanitu and Itulike villages Njombe Region Tanzania

Soil No.	Particle size distribution (PSD)			Textural Class	BD	OC	TN	C/N	pH (1:2.5) in H_2O	Ext. P	Exch. K
	% Clay	% Silt	% Sand		(mg cm^{-3})	(%)	%	ratio		mg/kg^{-1}	Cmol(+)kg^{-1}
A	40	10	50	Sandy clay	1.03	1.71	0.16	10.68	5.40	5.98	1.66
B	42	7	51	Sandy clay	1.02	1.69	0.10	16.90	5.50	5.84	1.71

%Key: A is Nyumbanitu, B is Itulike village, respectively

Overall, the results from this study show that soils in most plots which received manures (amendments) and inorganic fertilizer particularly DAP had improved NPK levels, suggesting that organic fertilizers were effective in releasing nutrients in the soil. This is in agreement with the findings of Nasir *et al*. (2010) who reported that bio-slurry improves NPK contents in maize crop. Furthermore, Islam (2006) reported that bio-slurry is an excellent organic fertilizer and a good source of plant macro and micro nutrients. This is in broad agreement with the observation noted in this study.

At Nyumbanitu village, a combination of composted bio-slurry, FyM and DAP gave a higher value of organic carbon as compared to the other treatments. In both villages DAP alone and DAP+ CBS gave the second highest amount of extractable P. In contrast to the lowest extractable P resulting from LBS alone, addition of FYM and with DAP gave the highest extractable P in both villages. This is in contrast to the application of CBS with FYM and DAP which was 73% as effective as where LBS replaced CBS. These results are line with those of Nasri (2012) who reported that bio-slurry and a combination of bio-slurry and inorganic fertilizer gave high values of organic matter 1.53% and 1.27%, respectively, as compared to control with 0.87%. High organic matter in the soil implies that the soil will have high water retention and storage capacity, high nutrient retention capacity, high soil buffering capacity, good soil structure and high microbial population and activities in the soil. Hence the soils are likely to provide good conditions for crop growth and yield.

Table 3a: Soil Characteristics after experimentation at Nyumbanitu Njombe Region Tanzania

Treatment No.	Particle size distribution (PSD)			Textural Class	BD	pH (1:2.5) in H_2O	OC	TN	C/N	Ext. P	Exch. K
	% Clay	% Silt	% Sand		g/cm^3		%	%	ratio	mg/kg^{-1}	Cmol(+)/kg^{-1}
1	43	7	50	Sandy clay	1.02	5.6	1.78 (H)	0.17(L)	11.17	6.66 (L)	1.79 (H)
2	43	9	48	Sandy clay	1.14	5.87	2.97 (H)	0.20(L)	14.85	13.25(M)	2.09 (VH)
3	35	13	52	Sandy clay	1.11	5.99	2.89 (H)	0.18(L)	16.06	14.29(M)	2.25 (VH)
4	43	5	52	Sandy clay	1.08	5.95	3.20 (H)	0.19(L)	16.84	10.82(M)	2.04 (VH)
5	41	9	50	Sandy clay	1.08	5.42	2.51 (H)	0.18(L)	13.94	29.55(H)	1.49 (H)
6	41	11	48	Sandy clay	1.04	5.56	2.89 (H)	0.20(L)	14.45	11.86(M)	1.59 (H)
7	41	7	52	Sandy clay	1.02	5.65	2.66 (H)	0.20(L)	13.30	29.90(H)	1.54 (H)
8	35	15	50	Sandy clay	1.06	5.70	2.69 (H)	0.21(M)	12.81	18.80(M)	1.29 (H)
9	33	13	54	Sandy clay loam	1.04	5.95	2.93 (H)	0.20(L)	14.65	41.00(H)	1.74 (H)
10	43	9	48	Sandy clay	1.09	6.30	3.47 (H)	0.19(L)	18.26	27.47(H)	2.4 (VH)

Key: VL= Very low, L= Low, M= Medium, H= High, and VH= Very high according to the ratings by Landon (1991).

Table 3b: Soil properties after experimentation at Itulike villages Njombe Region Tanzania

Soil No.	Particle size distribution (PSD)			Textural Class	BD	pH (1:2.5) in H_2O	OC	TN	C/N	Ext. P	Exch. K
	% Clay	% Silt	% Sand		g/cm^3		%	%	ratio	mg/kg^{-1}	Cmol(+)/kg^{-1}
1	42	8	50	Sandy clay	1.01	5.52	1.74 (H)	0.11(L)	15.82	6.68 (L)	1.82 (H)
2	41	9	50	Sandy clay	1.13	5.80	2.99 (H)	0.21(L)	14.24	13.27 (M)	2.13 (VH)
3	38	10	52	Sandy clay	1.11	5.95	2.92 (H)	0.18(L)	16.22	14.31 (M)	2.28 (VH)
4	44	6	50	Sandy clay	1.07	5.99	3.24 (H)	0.20(L)	16.20	10.87 (M)	2.07 (VH)
5	40	8	52	Sandy clay	1.07	5.54	2.58 (H)	0.15(L)	17.20	29.59 (H)	1.52 (H)
6	40	11	49	Sandy clay	1.04	5.60	2.91 (H)	0.21(M)	13.86	11.88 (M)	1.63 (H)
7	42	7	51	Sandy clay	1.02	5.85	2.69 (H)	0.21(M)	12.81	29.92 (H)	1.59 (H)
8	36	14	50	Sandy clay	1.05	6.15	2.73 (H)	0.22(M)	12.41	18.84 (M)	1.34 (H)
9	34	12	54	Sandy clay loam	1.04	6.05	2.97 (H)	0.24(M)	12.38	41.04 (H)	1.77 (H)
10	41	13	46	Sandy clay	1.09	6.27	3.54 (H)	0.23(M)	15.39	27.49 (H)	2.46 (VH)

Key: VL= Very low, L= Low, M= Medium, H= High, and VH= Very high according to the ratings by Landon (1991)

4.3 Influence of Manures on Growth and Development of Chinese cabbage at Nyumbanitu and Itulike Villages

4.3.1 Nutrient concentration in Chinese cabbage

The concentrations of nutrients mainly total nitrogen, phosphorus and potassium in Chinese cabbage plants are as shown in Table 4.

At Nyumbanitu village, N and P concentrations in control plots were inadequate, while K was sufficient (Table 4a). However, all treatments increased N to sufficiency level. Similarly, plant P concentrations were increased from low to sufficiency levels by all amendments except in LBS and FYM+DAP-treated plots which had P-deficient plants, and decreased P concentrations to insufficiency level - even below the control, suggesting P immobilisation.

Table 4a: Nutrient content of Chinese cabbage at Nyumbanitu village Njombe Region Tanzania

Plant Sample No.	Treatment	Foliar nutrient concentration		
		N (%)	P (%)	K (%)
1	Control	3.26	0.34	3.88
2	LBS	3.89	0.22	5.58
3	CBS	3.78	0.60	5.43
4	FYM	3.89	0.53	5.38
5	DAP	4.48	0.33	3.05
6	LBS+ DAP	4.55	0.71	4.45
7	CBS + DAP	4.52	0.45	4.40
8	FYM + DAP	4.73	0.22	4.09
9	LBS+ FYM+ DAP	4.83	0.55	4.19
10	CBS+ FYM+ DAP	4.31	0.48	5.43

Horticultural/ Vegetable Leaf Crops: 3.5 to 6.0% N is sufficient, 0.4 to 1.0% P is sufficient and 3.5 to 8.0% K is sufficient (Agronomy Handbook- MidWest Laboratories)

Similar results were observed at Itulike village (Table 4b).

Table 4b: Nutrient content of Chinese cabbage at Itulike village Njombe Region Tanzania

Plant Sample No.	Treatment	Foliar nutrient concentration		
		N (%)	P (%)	K (%)
1	Control	3.24	0.34	3.89
2	LBS	3.87	0.25	5.56
3	CBS	3.75	0.62	5.49
4	FYM	3.86	0.55	5.37
5	DAP	4.44	0.39	3.25
6	LBS+ DAP	4.57	0.72	4.47
7	CBS + DAP	4.51	0.41	4.37
8	FYM + DAP	4.76	0.22	4.19
9	LBS+ FYM+ DAP	4.85	0.55	4.19
10	CBS+ FYM+ DAP	4.33	0.47	5.45

Horticultural/ Vegetable Leaf Crops: 3.5 to 6.0% N is sufficient, 0.4 to 1.0% P is sufficient and 3.5 to 8.0% K is sufficient (Agronomy Handbook- MidWest Laboratories)

Soils at Nyumbanitu and Itulike sites with low OC content had high K, low N and P. Application of manures usually increase soil organic matter as well as plant nutrients; and in addition, increased organic matter that increases water holding and nutrient retention capacity, as well as improving nutrient availability and uptake by plants, thus contributing to increased plant nutrient contents in Chinese cabbage plant. Although DAP fertilizer contains N and P in large quantities, yet P concentration in plant tissues was inadequate in the plot applied with DAP alone. Since P availability and uptake to plants is highly dependent on soil pH, thus may have contributed to low P concentration in plant tissues. It is widely accepted that application of both inorganic and manure in integrated manner improves soil physical and chemical properties which enhances availability and uptake of plant nutrients and increases nutrient concentration in plants (Satyanarayana *et al.,* 2002; Garg *et al.,* 2005).

4.3.2 Growth response of Chinese cabbage to organic and inorganic fertilizers at Nyumbanitu and Itulike villages

The influence of manures on Chinese cabbage was investigated in terms of plant height, number of leaves, leaf area, leaf area index and live weight of leaves in both Nyumbanitu and Itulike villages.During the first nine weeks after initial harvesting, the importance of organic amendments at Nyumbanitu village was very clear (Appendix 3a). The results indicated that at five weeks, plants were significantly taller in all treatments than in control. However, plants treated with DAP combined with FYM and either LBS or CBS gave significantly taller plants than those treated with DAP alone. Thereafter, except in week 8, plant height did not differ significantly among amendments. In contrast, in week 8, soil treated with DAP alone had significantly shorter plants than those in treatments with FYM alone or with DAP combined FYM, CBS and LBS indicating the importance of FYM.

Figure1a shows height growth in control plot increased from the fifth week to seventh week and dropped thereafter due to high precipitation which hindered nutrient uptake and growth. However, from the tenth week the trend increased progressively unlike in plots with DAP and manure which had very high plant height for first three weeks only and the trend was decreasing from fourth week.

Plant height at Itulike differed significantly between control and all other treatments throughout the 10 weeks of harvesting. The lowest plant height (cm) was observed in control while the highest height was observed in plots where both DAP and manures were applied in an integrated manner (Appendix 3b). Plants in the first three weeks of harvesting were tall compared with the last three weeks. Generally, the trend started to decrease from the seventh week till the last fourteenth week.

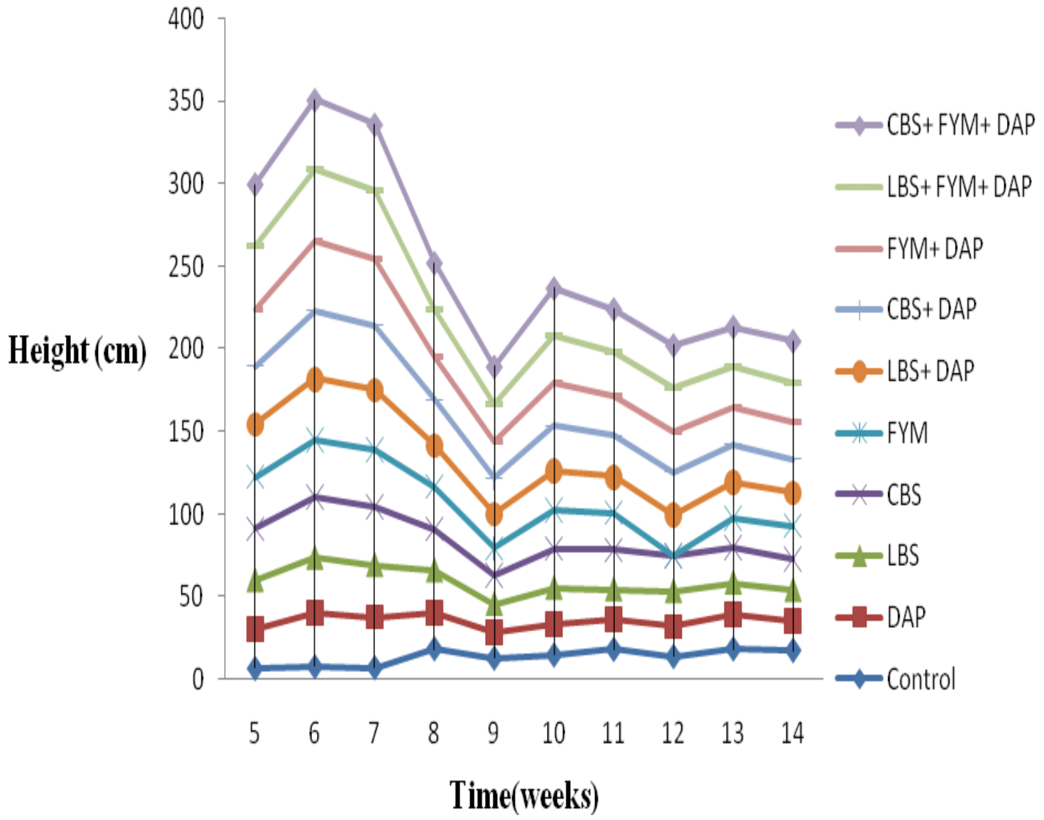

Figure 1a: Plant height in Chinese cabbage at Nyumbanitu village Njombe Region Tanzania **from 5th to 14th week of harvesting**

Plant nutrients such as N, P and others play a key role in plant development. DAP provides N and P for plant nutrition while manure provides macronutrients and micronutrients although in small quantity (FAO, 2000). Hence, application of both mineral fertilizers like DAP and manures like LBS, CBS and FYM provides an ideal condition for plant development. This finding is in agreement with Sangiga and Woomer (2009) who reported that a combination of organic and inorganic fertilizers provides ideal conditions for plant growth, development and yield. However, it was observed that continuous harvesting of Chinese cabbage leaves on a weekly basis may affect plant growth and development especially plant height which normally the length of leaves are taken into account to determine plant height.

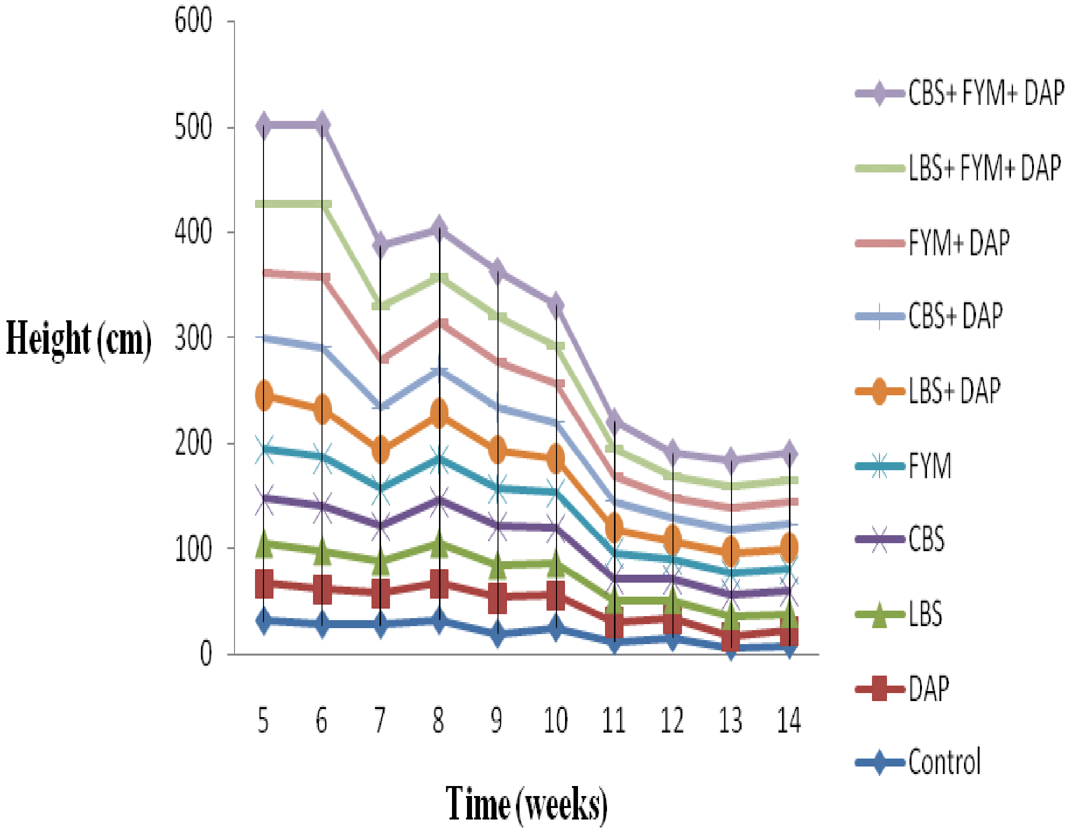

Figure1b: Plant height in Chinese cabbage at Itulike village Njombe Region Tanzania from 5th to 14th week of harvesting

The number of leaves in Chinese cabbage at Nyumbanitu village was significantly different among treatments applied in all ten weeks of harvesting (Table 5a). The number of leaves was low in control plots while in the combined application of DAP and manure plots had large number of leaves. However, there was no significant difference in number of leaves between control and DAP in week 7,8,9,10, 13 and 14, and also no significant difference between control and LBS in week 7,10,13 and 14. The trend was decreasing from week 5 to week 14.

Table 5a: Number of leaves in Chinese cabbage at Nyumbanitu Njombe Region Tanzania from 5th - 14th week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	6a	6a	5a	5a	5a	4a	4a	3a	3a	3a
DAP	7b	7ab	6a	5a	5a	4a	5ab	4ab	3a	3a
LBS	9d	8bc	6a	6b	6b	4a	5ab	4ab	3a	3a
CBS	8c	7ab	7b	8d	6b	6c	5ab	4ab	4b	3a
FYM	10e	8bc	8c	7c	7c	8e	5ab	5b	3a	3a
LBS+ DAP	11f	9cd	8c	7c	7c	5.b	6b	5b	4b	3a
CBS+ DAP	11f	9cd	9c	10f	8d	6c	5ab	6c	4b	3a
FYM+ DAP	12g	10d	9c	9e	8d	7d	6b	5b	5c	4b
LBS+ FYM+ DAP	10e	9cd	10d	10f	9e	6c	7c	6c	4b	4b
CBS+ FYM+ DAP	12g	10d	10d	10f	9e	8e	7c	7d	5c	4b
Mean	10	8	8	8	7	6	6	5	4	3
CV (%)	3.3	10.3	4.8	4.8	10.7	4.5	7.5	6.4	18.3	19.9

Number(s) in columns followed by same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test

The number of leaves at Itulike was significantly different among the treatments applied. However, the difference was not significant between control and DAP in week 8, 9, 10, 12 and 14. In week 9 and 14 the difference was not significant among the treatments applied. The lowest number of leaves was observed in control plots while the highest was in plots which were treated with both DAP and manures (Table 5b). During the first three weeks plants had more leaves than in subsequent weeks.

The average leaf area per plant in Chinese cabbage differed significantly among the treatments applied. In some scenarios though, the differences were not significant between control and DAP in week 5, 7, 10, 13 and 14. The smallest leaf area was observed in control plots, while applications of both DAP and manures significantly increased the size of leaves as shown in Table 6a. Leaf area was very high during the first weeks and decreased for the last four weeks.

Formation of leaves is influenced by nutrient availability in the soil as well as uptake and utilization by plants. Plant nutrients such as nitrogen and phosphorus are very important in leaves formation and growth of plants (FAO, 2000). Application of DAP and manure such as FYM, LBS and CBS influenced the formation of more leaves and increased the number of Chinese cabbage plant leaves. However, harvesting of this crop once a week on weekly basis might lead to decreasing in number of leaves from the first week to the last week since the harvest was done continuously for ten weeks.

Leaf area at Itulike was significantly different among the control and DAP except for week 5, 8, 11, 12 and 13, while the difference was significant in control and manure treatments applied in all ten weeks of harvesting (Table 6b). The performance of control plots was very low in terms of leaf area compared with plots where DAP and manures were combined. Leaf size was increasing with time up to week 6 and thereafter, decreased with the last two weeks having very low canopy size.

Table 5b: Number of leaves in Chinese cabbage at Itulike Njombe Region Tanzania from 5th - 14th week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	4a	4a	3a	1a	4a	3a	1a	2a	1a	2a
DAP	6bc	5ab	4ab	2a	5a	3a	3b	2a	2ab	2a
LBS	6bc	6ab	4ab	5bc	5a	4b	4cd	2a	3bcd	3a
CBS	6bc	5ab	4ab	5bc	5a	3a	3b	3b	2ab	3a
FYM	6bc	5ab	4ab	4b	5a	4b	3b	3b	2ab	2a
LBS+ DAP	6bc	6ab	4ab	5bc	5a	4b	4cd	3b	3bcd	3a
CBS+ DAP	7c	6ab	5ab	5bc	6a	4b	4cd	3b	3bcd	3a
FYM+ DAP	7c	6ab	5ab	5bc	6a	4b	4cd	3b	3bcd	3a
LBS+ FYM+ DAP	7c	6ab	6b	6c	6a	5c	5d	3b	3bcd	3a
CBS+ FYM+ DAP	7c	6ab	6b	6c	6a	4b	5d	4c	3bcd	3a
Mean	6	5	5	4	5	4	4	3	3	3
CV (%)	10.8	16.9	30.4	19.0	18.2	5.0	19.1	21.8	16.8	16.0

Number(s) in columns followed by same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test

Table 6a: Leaf area (LA (cm^2)/ plant) in Chinese cabbage at Nyumbanitu Njombe Region Tanzania from 5th - 14th week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	743.00a	1786.00a	1174.00a	347.00a	270.30a	331.90a	234.90a	105.00a	116.2a	136.80a
DAP	916.00a	2390.00ab	1515.00a	730.00ab	424.90b	363.50a	365.20b	160.70b	159.2a	155.40a
LBS	1778.00b	2506.00ab	1908.00ab	1041.00abc	431.90b	638.60c	654.70de	185.50b	185.9ab	217.70a
CBS	2346.00c	2972.00abc	2444.00abc	1132.00bcd	757.90c	834.90d	507.80c	262.50c	251.0bc	229.50ab
FYM	2635.00d	3471.00bcd	3062.00bc	1105.00bc	940.40de	496.90b	585.20cd	345.80d	263.1bc	345.20bc
LBS+ DAP	4291.00ef	3925.00cde	3285.00c	1265.00bcde	824.10cd	833.00d	693.20e	541.70f	255.50bc	399.70c
CBS+ DAP	4188.00e	3731.00cde	3331.00c	1872.00def	1016.20e	1374.80e	724.80ef	478.10e	267.80bc	385.60c
FYM+ DAP	5388.00g	4078.00cde	3749.00c	1784.00cdef	1236.30f	1543.80f	918.30g	545.10f	287.70c	637.00d
LBS+ FYM+ DAP	4514.00f	4724.00e	3818.00c	2117.00f	1420.20g	1814.00h	1077.10h	647.50g	322.80c	466.40c
CBS+ FYM+ DAP	5477.00g	4271.00de	3464.00c	1991.00ef	1454.40g	1712.00g	810.10f	727.80h	337.80c	717.40d
Mean	3227.44	3385.46	2775.08	1338.47	877.65	994.33	657.13	399.96	244.71	369.07
CV (%)	5.10	19.10	25.80	29.80	8.70	5.00	7.60	8.10	18.70	18.90

Number(s) in columns followed by same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test

Leaf area in Chinese cabbage plants was low in control plots due to poor soil fertility especially low N and P in the study areas as the soils had low organic matter hence poor water and nutrient holding capacity, resulting into poor size of leaves in unfertilized plots. In plots where DAP and manure like LBS, CBS and FYM were applied, the size of leaves increased. This is because of nutrients supplied from the fertilizer DAP and manure increases leaf length and width, hence leaf size.

Leaf area index (LAI) in Chinese cabbage at Nyumbanitu study site was significantly different among the treatments applied in all ten harvesting weeks (Table 7a). The control plots had very low leaf area index while plots with both DAP and manures had high area leaf index except for week 5, 6, 10, 13 and 14 where there was no significant difference between control and DAP.

The leaf area index in Chinese cabbage at Itulike village was significantly different in control and DAP except for week 5, 11 and 14, while the difference was significant between control and manures for the ten harvesting weeks except at week 11 (Table 7b). Control plots had the lowest leaf area coverage on the ground while the highest leaf area coverage was recorded in plots applied with both DAP and manures. Saidia (2003) reported that combination of organic and inorganic N fertilizers increases nutrient availability and balance hence, increases nutrient use efficiency. The first four weeks were found to have a very high leaf area index and the trend decreased towards the last two weeks.

Table 6b: Leaf area (LA (cm^2)/ plant)) in Chinese cabbage at Itulike Njombe Region Tanzania from 5^{th} - 14^{th} week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	543.00a	1179.00a	1215.00a	269.00a	457.00a	221.60a	291.90a	1468.00a	103.00a	32.60a
DAP	576.00a	1710.00b	1507.00ab	468.00a	625.00ab	354.80b	330.10a	1506.00a	156.10a	83.60ab
LBS	1668.00b	1993.00bc	1545.00ab	1070.00bc	1389.00bc	471.60bcd	342.70a	2427.00bc	523.50bc	138.20bcd
CBS	779.00a	2157.00bc	1575.00ab	907.00b	1322.00abc	420.20bc	362.70a	2491.00bc	528.9bc	120.00bc
FYM	1545.00b	2201.00c	1835.00b	1097.00bc	1363.00bc	534.50cde	348.90a	2127.00b	441.20b	144.80cd
LBS+ DAP	2147.00c	2113.00bc	1831.00b	1309.00cde	1444.00bc	622.70e	458.20ab	2496.00bc	534.80bc	193.20de
CBS+ DAP	2244.00c	2368.00cd	1963.00b	1258.00bcd	1675.00cd	593.60de	562.00bc	3551.00d	550.20bc	218.90e
FYM+ DAP	2362.00c	2210.00c	1855.00b	1487.00def	1483.00bc	747.00f	560.40bc	2829.00c	600.30bc	241.40ef
LBS+ FYM+ DAP	2442.00cd	2651.00de	1978.00b	1624.00ef	2018.00cd	1355.30h	638.90c	4163.00e	611.20bc	277.90fg
CBS+ FYM+ DAP	2824.00d	2963.00e	1994.00b	1737.00f	2422.00d	1018.50g	659.90c	4880.00f	641.20c	302.70g
Mean	1712.96	2154.47	1729.83	1122.71	1419.89	633.98	455.55	2793.83	469.03	175.32
CV (%)	14.60	11.20	17.80	17.00	34.40	11.30	19.20	11.60	19.70	18.10

Number(s) in columns followed by same letter(s) are not significantly different at P≤0.05 according to Duncan Multiple Range Test

Table 7a: Leaf area index (LAI) in Chinese cabbage at Nyumbanitu Njombe Region Tanzania from 5th - 14th week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	0.19a	0.46a	0.32a	0.09a	0.07a	0.13a	0.08a	0.05a	0.07a	0.09a
DAP	0.21a	0.47a	0.39ab	0.17ab	0.09b	0.11a	0.10b	0.07b	0.07a	0.09a
LBS	0.29b	0.51ab	0.47abc	0.24bc	0.11c	0.15b	0.14c	0.08b	0.08b	0.10b
CBS	0.42d	0.60abc	0.52abc	0.23bc	0.17d	0.20d	0.16d	0.10c	0.08b	0.12c
FYM	0.39c	0.56ab	0.49abc	0.25bc	0.18de	0.17c	0.17e	0.12d	0.09c	0.15d
LBS+ DAP	0.58e	0.61abc	0.55abc	0.21bc	0.19e	0.21d	0.18e	0.13e	0.09c	0.16e
CBS+ DAP	0.61e	0.62abc	0.59bc	0.28bc	0.21f	0.28e	0.21f	0.15ef	0.10d	0.19f
FYM+ DAP	0.60e	0.64abc	0.57abc	0.26bc	0.21f	0.29e	0.22f	0.16fg	0.11e	0.26h
LBS+ FYM+ DAP	0.69f	0.78c	0.65c	0.32c	0.22f	0.32f	0.24g	0.15ef	0.11e	0.23g
CBS+ FYM+ DAP	0.68f	0.68b c	0.61bc	0.32c	0.22f	0.33f	0.26h	0.170h	0.12h	0.27i
Mean	0.47	0.59	0.52	0.24	0.17	0.21	0.18	0.12	0.09	0.17
CV (%)	4.40	17.90	25.00	27.20	4.30	3.40	2.80	4.90	2.80	3.00

Number(s) in columns followed by same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test

The coverage of Chinese cabbage plants on a ground was low in control plots due to poor soil fertility and low ability to supply nutrients needed for plant growth and development. Soils had low organic matter, nitrogen and phosphorus hence poor water and nutrient retention and storage capacity resulting into poor canopy size and ground coverage when fertilizers and organic soil amendments are not applied. All plots which DAP and manures like LBS, CBS and FYM were applied had higher leaf area coverage in relation to ground area due to nutrients added in the soils and physical soil properties improved to support nutrient availability and uptake by plants. FAO (2000) recommended that application of both mineral fertilizers and manure are very important to improve soil physical and chemical conditions and enhance nutrient uptake and use by plants.

Fresh weight of Chinese cabbage at Nyumbanitu was significantly different among the treatments applied throughout the ten weeks. Control plots had the lowest weight while the highest fresh weight was observed in treatment combination of DAP and organic fertilizers as shown in Figure 2a, Appendix 4. Results like these were reported by Sangiga and Woomer (2009) that a combination of organic and inorganic fertilizers provides ideal conditions for improved plant yield, it was also reported by Saidia (2013) that combined application of both organic and inorganic fertilizers increased upland rice yield from 1.35t to 5.34 t/ha. The first two weeks have the highest trend of plant weight while the lowest trend is in the last two weeks.

Plant fresh weight of Chinese cabbage at Itulike was significantly different among the treatments applied such as control, DAP, manures and combination of both DAP and manures. The lowest weight was observed in control plots while higher fresh weight was in plots applied with both DAP and manures (Figure 2b, Appendix 4). Application of DAP and manure provides nutrients in the soil which are essential for plant growth, development and increased weight of Chinese cabbage under the study.

Table 7b: Leaf area index (LAI) in Chinese cabbage at Itulike village Njombe Region Tanzania from 5th - 14th week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	0.18a	0.42a	0.40a	0.29a	0.07a	0.11a	0.18a	0.17a	0.14a	0.04a
DAP	0.19a	0.47b	0.43ab	0.37b	0.09b	0.17b	0.19a	0.19b	0.15b	0.04a
LBS	0.43c	0.49c	0.43ab	0.61c	0.11c	0.19bc	0.21a	0.19b	0.15b	0.05b
CBS	0.24b	0.49c	0.45abc	0.69d	0.17d	0.19bc	0.22ab	0.21c	0.15b	0.05b
FYM	0.47d	0.43a	0.46abc	0.70d	0.18de	0.20bc	0.21a	0.23d	0.19g	0.06c
LBS+ DAP	0.59e	0.52d	0.49bcd	0.73e	0.19e	0.22c	0.28bc	0.28e	0.16d	0.07d
CBS+ DAP	0.59e	0.52d	0.48abcd	0.75f	0.23f	0.21bc	0.33cd	0.28e	0.16d	0.07d
FYM+ DAP	0.61f	0.55e	0.49bcd	0.76g	0.21f	0.26d	0.31c	0.29f	0.17e	0.08e
LBS+ FYM+ DAP	0.69g	0.56f	0.52cd	0.76g	0.22f	0.36e	0.31c	0.28e	0.18f	0.08e
CBS+ FYM+ DAP	0.69g	0.59g	0.54d	0.77h	0.22f	0.39e	0.38d	0.31g	0.18f	0.09f
Mean	0.47	0.50	0.47	0.64	0.17	0.23	0.26	0.24	0.16	0.07
CV (%)	1.30	1.10	8.80	0.70	4.30	9.90	13.10	1.90	2.00	4.40

Number(s) in columns followed by same letter(s) are not significantly different at P≤0.05 according to Duncan Multiple Range Test

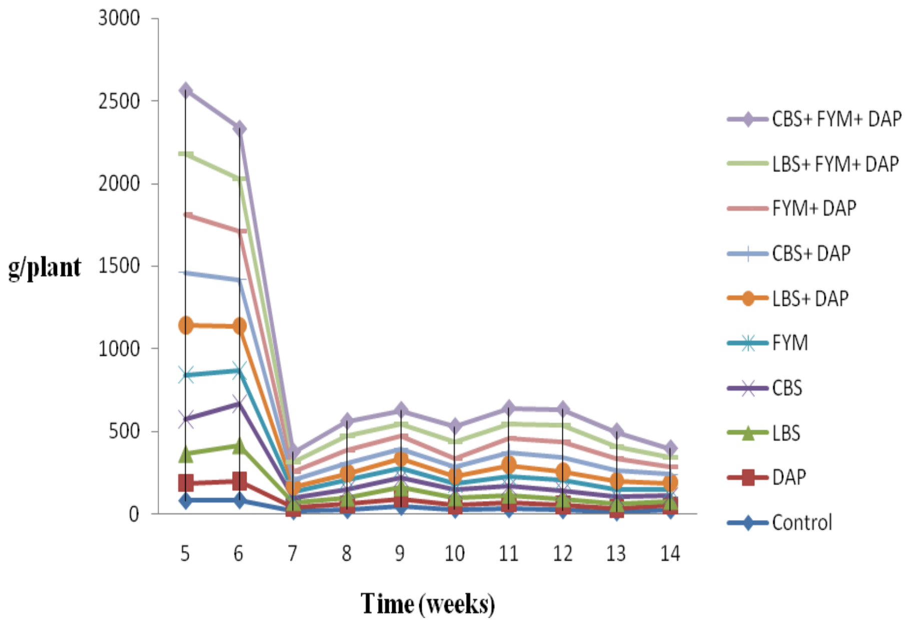

Figure 2a: Fresh Weight of Chinese cabbage (g/plant) at Nyumbanitu village Njombe Region Tanzania from 5th to 14th week of harvesting

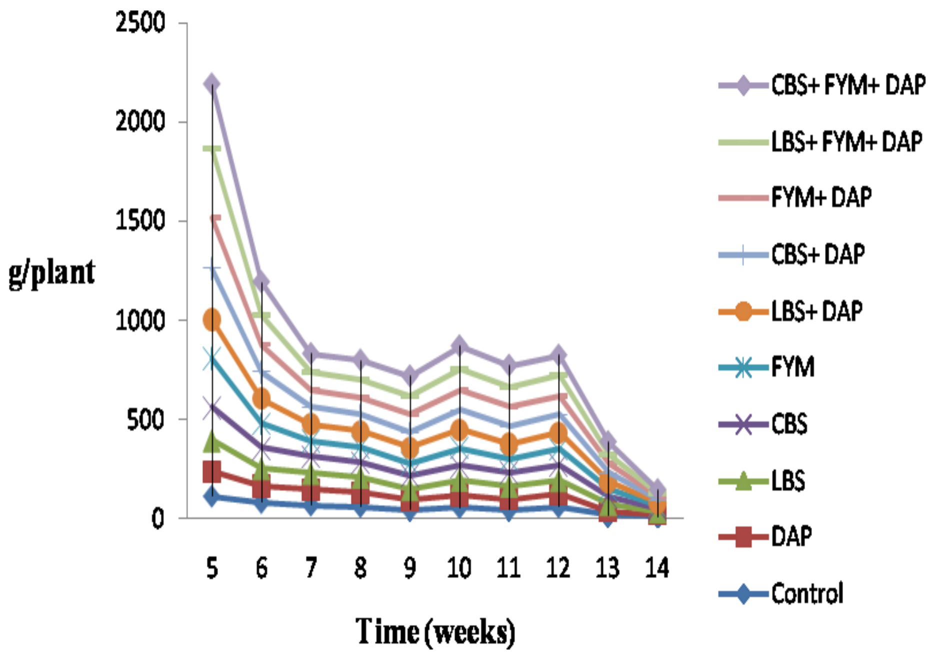

Figure 2b: Fresh Weight of Chinese cabbage (g/plant) at) Itulike village Njombe Region Tanzania from 5th - 14th week of harvesting

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Soil conditions in Nyumbanitu and Itulike villages where this study was conducted were limited in organic matter, nitrogen and phosphorus while potassium was not limiting. Such soil with low organic matter and having limitations in some nutrients requires application of fertilizers and organic soil amendments such as CBS, LBS and FYM in order to improve physical, chemical and biological characteristics. Most of inorganic or mineral fertilizers available commercially do supply only few nutrients such as N, P and K alone but some supply two macronutrients like DAP. Unlike mineral fertilizers, manures have ability to supply both macro and micronutrients in the soil for plant growth however in small proportions (Saidia, 2013). Combination of both mineral and manure known as integrated plant nutrient management provides favourable conditions for proper plant growth and yield.

5.2 Recommendations

- It is recommended to apply fertilizers and other soil ameliorants in all soils with low fertility status so as to maximize yield.
- There is a need to integrate organic and inorganic fertilizers especially in acidic soils so as to improve crop growth and yields sustainably.
- Chinese cabbage growers are advised to harvest leaves at the interval of two weeks in order to give enough time for sprouting and growth of new leaves.
- To quantify the residual effects of composted bio-slurry and liquid bio-slurry in acidic soils.

REFFERENCES

Achieng, J. O., Ouma, G., Odhiambo, G. and Muyekho, F. (2010). Effect of farmyard manure and inorganic fertilizers on maize production on Alfisols and Ultisols in Kakamega, western Kenya. *Agriculture and Biology Journal of North America*, 1(4): 430-439.

Aminul, H. A. B. M. (2013). Bio slurry Ultimate Choice of Bio fertilizer. 2: 738 doi: 10.4172/scientific reports.738 and land management research. http://www.agnet.org. 17, July 2015

Anonymous, (1984). *Chinese cabbage.* Ministry of Agriculture, Fisheries and Food Booklet No.2336, 32pp.

Arisha, H.M. and Bardisi, A. (1999). Effect of mineral fertilizers and organic fertilizers on growth, yield and quality of potato under sandy soil conditions. *Journal of Agricultural Resource,* 26, 391-405.

Batsai, S.T., Polyakev, A. A. and Nedbal. R. F. (1979). Effect of organic and mineral fertilizers on the yield and quality of irrigated late white cabbage in the steppe region of the Crimea. *Horticulture Journal,* 49 (11): 730pp.

Bhuiyan, N. I. (1991). Issues concerning declining/stagnating productivity *in* Bangladesh Agriculture. *A* paper presented at the National Workshop *on* Risk Management *in* Bangladesh Agriculture, held at BARC, Dhaka. August, 1991. Pp. 8.

Bonten, L.T.C., Zwart, K.B., Rietra, R.P.J.J., Postma, R. and de Haas, M.J.G. (2014). *Bio-slurry as fertilizer, literature review on the value of digested manure as fertilizer for crops and aquaculture in developing countries*. Wageningen, Altera Wageningen UR, Altera Report. 45p.

Bray, R. H., and Kurtz, L. T. (1945). Determination of total, organic and available forms of Phosphorus in soils. *Journal of Soil Science* 59:39-45.

Craig, W. and Beck, L. (1999). Phyto-chemicals: health protective effects, *Canadian Journal of Dietetic Practice and Research* 60: 78-84.

Dauda, S. N., Ajayi, F. A. and Ndor, E. (2008). Growth and yield of water melon (*Citrulluslanatus*) as affected by poultry manure application. *Journal of Agriculture and Social Science* 4: 121-124.

Dhobighat, C. and Painyapani, T. (2006). Physico-chemical Analysis of Bio-slurry and Farm Yard Manure for Comparison of Nutrient Contents and other Benefits so as to Better Promote Bio-slurry, Yashoda Sustainable Development (P) Ltd, Final Report, Nepal pp. 30 -31.

EMB and NEMC (2012). *Tanzania National Roads Agency, Transport sector support project phase two (TSSP 2)*. National Environment Management Council, Dar Es Salaam, Tanzania. 13p.

FAO (2000). *Fertilizers and their use: a pocket guide for extension officers.* Food and Agriculture Organizations (FAO), International Fertilizer Industry Associaton (IFA). 4th Edition. 34p.

Fentaw, E. (2010). Bio-slurry in Ethiopia: what is it and how to use it, Institute for Sustainable Development (ISD) and National Biogas Program Ethiopia Coordination Office, Addis Ababa. 23 pp.

Garg, R.N., Pathak, H., Das, D.K. and Tomar, R.K. (2005). Use of fly ash and biogas slurry for improving wheat yield and physical properties of soils. *Environmental Monitoring and Assessment* 107: 1-9.

Gomez, A.K. and Gomez, A.A. (1984). *Statistical Procedure for Agricultural Research.* John Wiley and Sons, Inc. 680 pp.

Grossman, R.B. and Reinsch, T.G. (2002) SSSA Book Series: *5 Methods of Soil Analysis.* 2nd Ed. Dane J.H, Clarke Topp G. Soil Science Society of America Inc.Madison, Wisconsin,USA. Pp 201–228.

Gupta, M. K, (2007). *Handbook of Organic Farming and Biofertilizers* 1st edition ABD Publishers, Jaipur, India. 220pp.

http://www.umb.no/statisk/noragric/EPINAV/borge_integrated_farming_system_fordairy _farm ers_in_njombe.pdf.

IFPRI (2010). Fertilizer and soil fertility potential in Ethiopia, constraints and opportunities for enhancing the system, sustainable solution for enduring hunger and poverty. Skype: ifprihomeoffice, Washington, DC, USA. Pp 10-15.

Islam, M.S. (2006). Use of Bio-slurry as Organic Fertilizer in Bangladesh Agriculture. Bangkok, Thailand. pp. 27-28

Jackson, H.L. and Mtengeti, E.J. (2005). Assessment of animal manure production, management and utilization in Southern Highlands of Tanzania. *Livestock Rsearch for Rural Development* 17 (10): 19 Available at [http: //www.cipav.org.co/lrrd/lrrd17/10/jack17110.htm.] 19, July 2015

Joshi, J.R., Moncrief, J.F., Swan, J.B. and Malzer, G.L. (1994). *Soil and Tillage Research* 31: 225pp

Kanyeka, E., Kamala, R and Kasuga, R. (2007). Improved Agricultural Technologies Recommended in Tanzania. 1st edition. Published by the Department of Research and Training, Ministry of Agriculture Food Security and Cooperatives, Dar es Salaam, Tanzania. 144 pp.

Karki, K. B. (2001). Response to bio-slurry Application on Maize and cabbage in Laliptur district. Final Field Research Report Submitted to Alternative Energy Promotion Centre of Ministry of Science and Technology, Pulchok. Nepal. 20 pp.

Khan, N.I., Malik, A.U, Umer, F. and Bodla, M.I. (2010). Effect of tillage and farmyard manure on the physical properties of soil. *International Research Journal of Plant Science* 1 (4): 75- 82.

Kimani, S.K. and Lekasi, J.K. (2004). Managing manures throughout their production cycle enhances their usefulness as fertilizers: A review. In: *Managing nutrient cycles to sustain soil fertility in Sub-Saharan Africa*. (*edited by Bationo, A*.). CIAT. Pp 187- 198.

Larkcom, J. and John M. (1991). *Oriental vegetables:* The complete guide for garden and kitchen. Ltd. London. 232pp.

McKay, A. and Phillips, D. (1990). *Chinese cabbage.* Department of Agriculture, Western Australia Bulletin No. 4197, 13 pp.

Mohabbat, U., Ranjit, S. K. H. and BadirulIsalm, M., Shahabuddin, K. (2008). *Bio-slurry Management and its Effect on Soil Fertility and Crop Production in Bangladesh,* Bangladesh Agricultural Research Institutute Soil Science Division and On-Farm Research Division Gazipur 1701:8-22.

Mtengeti, E., West, J., Mahonge, C., Eik, L.O., Bentrup, F. and Chambuya, R. R. (2012). Public-Private Partnership collaboration in environmental climate compatible agricultural growth. Preliminary observation, Proceedings of the first Climate Change Impacts, Mitigation and Adaptation Programme Scientific Conference. Sokoine University of Agriculture, Morogoro, Tanzania

Mueller, A. (2005). Food miles and sustainability. FAO promotes organic agriculture. http://www.organica /FAO 17 July, 2015

Muleya, M. P. (2009). Performance of rape (*brassica napus*) grown under organic farming compared to conventional practices. A dissertation submitted in partial fulfillment of the degree of Master of Science in Agronomy. University of Zambia pp 1-33.

Murphy, J. and Riley, J.P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* 27:31-36.

Nasir, A., Usman, M. K., Anwar, S., Arslan, C., Akhtar, M. J. and Sultan, M. (2012).Evaluation of bio-fertilizer application to ameliorate the environment and crop production. *Pakistan Journal of Agricultural Science* 49(4): 527-53.

Nelson, D. W. and Sommer, L. E. (1982). Total carbon, organic carbon, and organic matter Phosphprus 539-579. In: *Methods of Soil Analysis*. 2nd Edition ASA Monograph. 9(2). American Society of Agronomy. Madison, WI.

Nguyen, V.Q. (1992). *Growing Asian vegetables*. N.S.W. Agriculture Agfact H8.1.37, 16pp.

Okalebo, J.R., Gathua, K.W. and Woommer, P.L. (1993). *Laboratory methods of soil and plant analysis*. A Working Manual. KARI and Rost. 88pp.

Okorogbona, A.O.M., Van Averbeke, W. and Ramusandiwa, T.D. (2011). Growth and yield response of Chinese cabbage (*Brassica rapa* L subsp. *Chinensis*) as affected by nutrient availability in air-dried and pulverized different types of animal manure using low biological activity soil. *World Journal of Agricultural Sciences* 7 (1): 01- 12.

Onyango, M.A., Njue, E.K., Ogecha, J.O., Nzabi, A.W., Tana, P.O., Makworo, S. and Kuaya, F. (1997). RRC- Kisii on-farm research experience with soil fertility management. In: *Focus on Agricultural Research for Sustainable Development in a Changing Economic Environment:* Proceedings of the 5th KARI Scientific Conference. Fungo, P.O. and Mbadi, G.C.O. (Eds) Kenya Agricultural Research Institute, Nairobi. pp 421-435.

Pandey, N., Sarawgi, A.K., Rastogi, N.K. and Triphathi, R.S. (1999). Effect of farmyard manure and chemical N fertilizer on grain yield and quality of scented rice (*Oryza sativa*) varieties. *Indian Journal of Agricultural Science* 69(9): 621-623.

Paul, D. and Bruce, T. (1995). *Production and postharvest handling of Chinese cabbage* (B*rassica rapa var. pekinensis*). A review of literature prepared for the Rural Industries Research and Development Corporation. Institute for Horticultural Development Private Bag 15, South Eastern Mail Centre Vic 3176. RIRDC Publication No. 97/1. Pp 5-8.

Phillips, D. (1990). Chinese cabbage research pays off. *Good Fruit and Vegetables*, September 26, 1990: 20-21.

Pleysier, J.L. (1995). Soil sampling and sample preparation. IITA Research Guide 2. Training Program, International Institute of Tropical Agriculture (IITA). Third edition. Ibadan, Nigeria. 27 pp.

Prasad, R. and Power, J.F. (1997). *Soil Fertility Management for Sustainable Agriculture*. CRC Press Lewis Publishers, New York. 356pp.

Saidia, P. (2013). Response of upland rice to activated effective microorganisms (EMA), farmyard manure and nitrogen at Ukiriguru Mwanza Tanzania. Dissertation submitted in partial fulfillment of the degree of MSC in Crop Science at Sokoine University of Agriculture, Morogoro Tanzania. 94pp.

Satyanarayana, V., Prasad, P. V., Murthy, V. R. K. and Boote, K. J. (2002). Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. *Journal of Plant Nutrition* 25(10): 2081–2090.

Shahabz, M. (2011). Potential of bio-slurry and compost at different levels of inorganic Nitrogen to improve growth and yield of okra (*Hibiscus esculetus* L.). Msc.Thesis, University of Agriculture Faisalabad, Pakistan. *Slurry Management and its Effect on Soil Fertility and Crop Production in Bangladesh,* Bangladesh Agricultural Research Institutute Soil Science Division and On-Farm Research Division Gazipur 1701. Pp 8-22.

Sompongse, D. and Pushparajah, E. (1994). The use of soil and plant analysis in soil and land management research. http://www.agnet.org. 17, July 2015

South Netherlands Volunteers, (2009). Domestic Biogas Compact Course on Technology and Mass-Dissemination Experiences from Asia, hand-out for students, Postgraduate Programme Renewable Energy, University of Oldenburg, Jan Lam, Felix ter Heegde, BastiaanTeune, pp 6-30.

South Netherlands Volunteers, Royal Society for Protection of Nature (2012). Integrated use of bio-slurry and chemical fertilizer for vegetable production, pp. 8.

Steel, R. G. D. and Torrie, J. H. 1984. *Principles and Procedures of Statistics*. McGraw Hill Book Co. Inc., New York. *pp: 336–6.*

Snijders, P., Onduru, D., Wouters, B., Gachimbi, L., Zake, J., Ebanyat, P., Ergano, K., Abduke, M. and Keulen, H. (2009). Cattle Manure Management in East Africa: Review of manure quality and nutrient losses and scenarios for cattle and manure management. Wageningen UR Livestock Research, Report 258. 39 pp. [http://www.livestockresearch.wur.nl] site visited on 18/8/2012.

Vanlauwe, B. J., Diels, K., Lyasse, O. N., Sanginga, K., Aihou, I. N. O. and Merckx, R. (1999). Balanced nutrient management systems for Maize-based systems in the moist savanna and humid forest zone of West Africa. Annual Report 1998. IITA, Ibadan, Nigeria.

Waters, C.T., Morgan, W.C. and D.J. McGeary (1992). How to identify, grow and use oriental vegetables. Department of Food and Agriculture, 128pp.

Warnars, L. and Oppenoorth, H. (2014). Bioslurry: A supreme fertilizer, a study on bioslurry results and uses. [http://www.laviniaes.com/files/6113/9576/2986/Bioslurry book .pdf] site visited on 16/2/2016.

Wilson, D. R. (2004). A potential yield model for forage brassicas. [http://www.cropscience.org.au/ics2004/poster/2/8/1087-Wilsondr.htm] 17, July 2015.

APPENDECES

Appendix 1: Guide to general evaluation of some soil chemical and physical properties

(Source: Baize (1993), ILACO (1991), Hazelton and Murphy (2007) and Landon (1991))

1. Organic matter and total nitrogen

	Very low	Low	Medium	High	Very high
Organic matter %	< 1.0	1.0-2.0	2.1-4.2	4.3-6.0	>6.0
Organic carbon %	<0.60	0.60-1.25	1.26-2.50	2.51-3.50	>3.50
Total nitrogen %	<0.10	0.10-0.20	0.21-0.50	>0.50	

C/N ratios give an indication of the quality of the organic matter:

C/N ratio 8-13: good quality

C/N ratio 14-20: moderate quality

C/N ratio >20: poor quality

2. Soil reaction

Soil reaction (pH H_2O) is classified as follows

Extremely acid	pH < 4.5	Neutral	pH 6.6-7.3
Very strongly acid	pH 4.5-5.0	Mildly alkaline	ph 7.4-7.8
Strongly acid	pH 5.1-5.5	Moderately alkaline	pH 7.9-8.4
Medium acid	pH 5.6-6.0	Strongly alkaline	pH 8.5-9.0
Slightly acid	pH 6.1-6.5	Very strongly alkaline	pH> 9.0

3. Available phosphorus

mgP/Kg soil	Low	Medium	High
Available P (Bray-Kurtz 1)	< 7	7-20	> 20
Available P (Olsen)	< 5	5-10	> 10

Available P is determined by the Bray-Kurtz 1 method if the pH H_2O of the soil is less than 7.0. In soils with a pH H_2O more than 7.0 the Olsen method is used.

Appendix 2: Nutrient contents of the farmyard manure

Compiled from Sanginga and Woomer (2009), Kimani and Lekasi (2004) and Jackson and Mtengeti (2005).

1: Animal manure from different species

	Nutrient content (%)				
Animal species	N	P	K	Ca	Mg
Cattle manure dry	0.98	0.22	0.85	0.40	0.23
Cattle manure fresh	1.50	0.54	0.64		
Goat composite	1.50	0.40	0.53		
Pig composite	0.20	1.19	0.49		
Poultry composite	2.88	1.58	2.25	3.20	0.69
Rabbit composite	1.60	0.40	0.50		
Sheep composite	1.28	0.47	5.77	1.10	1.45

2: Nutrient contents of farmyard manure samples collected from different countries

	Nutrient content (%)				
Country	N	P	K	Ca	Mg
UK	1.76	0.24	1.29	0.74	0.34
Kenya	1.62	0.50	1.34	0.26	0.26
Zimbabwe	0.80	0.20	0.85	0.25	0.15
Madagascar	1.10	0.80	0.86	0.85	0.40

3: Cattle manure nutrient composition with respect to handling techniques in Tanzania

	Manure nutrient composition, %DM			
Handling techniques	N	P	K	C/N ratio
Indoor	1.96	0.36	1.75	10.00
Kraal	1.13	0.19	1.16	19.04
Earth pit	1.58	0.27	0.94	10.57

Appendix 3a: Plant height in Chinese cabbage at Nyumbanitu village Njombe Region Tanzania from 5th - 14th week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	6.67a	7.70a	7.10a	18.33a	12.73a	14.60a	17.97a	13.77a	18.27a	17.40a
DAP	23.50b	32.20b	30.67b	22.00b	15.80ab	18.87ab	18.10a	18.30ab	20.77a	18.07a
LBS	29.77bc	33.80b	31.43b	25.57bc	16.97ab	21.87bc	18.33a	21.17bc	19.57a	18.50a
CBS	30.97bc	36.43b	34.83b	24.87bc	17.27ab	23.63bcd	23.67a	21.63bc	20.90a	19.07a
FYM	31.83bc	34.93b	34.70b	26.07c	16.60ab	23.37bcd	22.87a	23.77bc	17.90a	20.10ab
LBS+ DAP	31.77bc	36.87b	36.47b	25.00bc	20.60ab	23.80bcd	21.70a	24.53c	22.13a	19.90ab
CBS+ DAP	34.63bc	41.07b	38.83b	27.40c	21.67ab	26.93cd	24.90a	25.53c	22.37a	19.97ab
FYM+ DAP	34.70bc	42.20b	40.27b	26.23c	22.03b	26.27cd	24.13a	24.70c	22.50a	22.33ab
LBS+ FYM+ DAP	37.90c	43.20b	41.57b	28.20c	22.47b	28.70d	26.23a	26.47c	24.20a	23.47ab
CBS+ FYM+ DAP	38.07c	42.33b	40.03b	28.53c	23.37b	28.87d	26.40a	26.37c	24.97a	26.10b
Grand Mean	29.98	35.07	33.59	25.22	18.95	23.69	22.43	22.62	21.36	20.49
CV (%)	21.20	16.30	16.60	8.50	24.40	13.30	22.43	14.30	16.80	16.30

Number(s) in columns followed by same letter(s) are not significantly different at P≤0.05 according to Duncan Multiple Range Test

Appendix 3b: Plant height in Chinese cabbage at Itulike village Njombe Region Tanzania **from 5th - 14th week of harvesting**

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	31.69a	28.06a	28.22a	15.63a	25.12a	32.17a	19.13a	12.67a	6.83a	8.89a
DAP	35.17ab	29.74ab	33.24ab	17.60ab	30.71b	34.67ab	33.80b	17.44b	9.83b	13.47b
LBS	38.98bc	31.13bc	37.28abc	18.81ab	31.39bc	39.10bc	32.20b	22.34d	20.11c	16.62c
CBS	41.35c	32.50cd	40.53bc	19.05ab	31.91bc	38.89bc	36.43b	19.40c	19.44c	20.41d
FYM	46.78d	34.55d	46.39c	18.24ab	33.41bc	40.47bc	34.93b	23.56de	19.94c	20.50d
LBS+ DAP	50.83de	37.03e	45.78c	18.98ab	32.27bc	41.77c	36.87b	24.14e	20.28c	21.00de
CBS+ DAP	55.32e	40.42f	60.00d	20.64b	35.00bc	43.13c	41.07b	24.65ef	20.90cd	21.67de
FYM+ DAP	61.03f	45.40g	65.85de	19.50ab	36.78c	43.41c	42.20b	24.37e	21.06cd	21.39de
LBS+ FYM+ DAP	65.92g	50.81h	69.73de	20.11ab	36.15bc	44.20c	43.20b	26.02f	21.39cd	22.28de
CBS+ FYM+ DAP	72.89h	57.17i	73.82e	22.05b	37.03c	44.73c	42.33b	24.98ef	23.22d	23.33e
GM	50.00	38.68	50.08	19.06	32.98	40.25	36.22	21.96	18.30	18.96
CV (%)	5.70	3.60	12.50	12.60	9.20	8.10	17.40	3.50	7.60	6.80

Number(s) in columns followed by same letter(s) are not significantly different at P≤0.05 according to Duncan Multiple Range Test

Appendix 4a: Fresh Weight of Chinese cabbage (g/plant) at Nyumbanitu village Njombe Region Tanzania from 5th - 14th week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	80.20a	83.30a	18.33a	25.00a	44.33a	27.33a	29.44a	24.31a	10.76a	22.50a
DAP	108.60a	116.70a	21.72a	33.33b	50.00ab	27.67a	36.00b	32.22b	21.73b	29.00c
LBS	175.20b	216.70bc	30.00b	39.00bc	66.67bcd	42.67b	49.67c	34.77b	30.30b	25.00b
CBS	208.90c	250.00bcd	28.57b	52.67d	58.33abc	50.00c	53.00cd	52.48c	41.83c	34.00d
FYM	266.80d	200.00b	32.09b	52.33d	58.33abc	34.33a	58.33d	60.79d	41.60c	35.00d
LBS+ DAP	300.10e	266.70cde	34.07bc	43.33c	58.33abc	47.67bc	68.67e	50.10c	53.83 d	41.33e
CBS+ DAP	321.70e	283.30de	38.74c	62.67e	58.33abc	52.00c	76.00f	83.33e	62.50de	49.67f
FYM+ DAP	353.70f	300.00de	51.80d	76.00f	75.00cd	50.67c	83.67g	94.96f	70.47e	51.00f
LBS+ FYM+ DAP	367.00f	316.700e	54.68d	84.67g	75.00cd	100.00d	87.00g	99.78g	74.50def	53.15g
CBS+ FYM+ DAP	383.50f	300.00de	63.55e	90.67g	83.33d	96.33d	96.67h	98.89g	90.00g	54.00g
GM	256.56	233.33	37.35	55.97	62.77	52.87	63.84	63.16	5.25	39.47
CV (%)	6.7	13.80	8.00	7.70	15.40	7.70	4.90	2.80	10.70	2.90

Number(s) in columns followed by same letter(s) are not significantly different at P≤0.05 according to Duncan Multiple Range Test

Appendix 4b: Fresh Weight of Chinese cabbage (g/plant) at) Itulike village Njombe Region Tanzania from 5th - 14th week of harvesting

Treat	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
Control	113.40a	81.80a	68.28a	61.44a	43.21a	56.15a	43.67a	60.21a	10.24a	14.89 a
DAP	123.10b	83.20a	78.42b	69.00ab	49.81b	61.50b	52.83b	65.67b	11.70b	25.39b
LBS	159.00c	89.20b	83.11bcd	79.89cd	54.88bc	77.67d	68.33c	68.33b	13.31c	32.81c
CBS	165.10d	100.30c	81.42bc	72.78bc	69.15d	69.98c	67.50c	75.33c	14.22d	40.25d
FYM	248.40f	124.40d	81.89bc	75.76bcd	60.08c	90.50e	63.83c	80.33d	14.96de	31.34c
LBS+ DAP	196.80e	127.30d	84.11cd	81.78de	81.30f	92.67e	81.00d	83.67d	15.14e	42.60de
CBS+ DAP	254.90g	134.30e	84.22cd	82.33de	74.90e	98.83f	87.67e	90.33e	15.63ef	43.45de
FYM+ DAP	256.00g	137.40e	86.75cd	89.42ef	91.90g	102.33f	96.17f	96.50f	15.82ef	46.41e
LBS+ FYM+ DAP	348.90i	147.90 f	88.22d	92.89f	96.48g	106.50g	103.33g	101.67g	16.22f	46.47e
CBS+ FYM+ DAP	324.00h	166.10g	93.33e	92.62f	95.48g	113.00h	107.00g	100.17fg	16.54f	62.37f
GM	218.97	119.20	82.98	79.79	71.72	86.91	77.13	82.22	14.38	38.60
CV (%)	1.50	2.30	3.50	5.60	4.70	2.80	4.60	2.70	3.50	5.70

Number(s) in columns followed by same letter(s) are not significantly different at P≤0.05 according to Duncan Multiple Range Test