ASSESSMENT OF THE EFFECT OF AMMONIUM SULPHATE PROCESSED FROM ANAEROBIC PASTEURIZATION DIGESTER LATRINES EFFLUENT ON SOIL pH AND YIELDS OF PEAS (*Pisum sativum*)

BY

MUSABWA EDITH

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DECLARATION

Declaration by student

This is to certify that this thesis report is my original work towards the Masters of Philosophy Degree and has not been presented for award of any degree in any other institution and due acknowledgement has been made in the text to all other sources of information or materials used. No part of this work should be reproduced without prior permission of the authors and / or University of Eldoret.

MUSABWA EDITH

Reg. No.: SES/PGH/002/13

Signature ______________________________Date _____________________

Declaration by supervisors

We declare that this thesis is submitted with our approval as the university supervisors

Dr. G. SIMIYU **Signature_________________** **Date _____________**

Department Biology and Health,
University of Eldoret,
P.O. Box 1125,
ELDORET.

Dr. K. KIPTOO **Signature________________** **Date _____________**

Department Biology and Health,
University of Eldoret,
P.O. Box 1125,
ELDORET.

DEDICATION

This work is dedicated to my husband (Edward), father (Felician), Mother (Agnes) who have been there for me and sacrificed their interests for my academic benefit.

ABSTRACT

Improper disposal of human waste is one of the developing world's most serious health problems due to pollution of the environment. Food production is also dwindling due to soils' nutrients loss to leaching caused by continued use of chemical fertilizers, which acidify soils. This study was aimed to assess the potential of using ammonium sulphate processed from anaerobic pasteurization digesters latrines (APDLS) effluent to stabilize soil pH and enhance yields of peas (*Pisum sativum*). The experiment was laid out in a completely randomized design with four treatments replicated four times. The treatments were Ammonium sulphate, Compost manure, Di-ammonium Phosphate (DAP) and control. The growth attributes measured, were plant height, fresh weight, dry weight, seed diameter and chlorophyll content in leaves. The peas yield and soil data were statistically analyzed by Genstat version 14. The organic and inorganic fertilizers as well as the interaction between the fertilizer and time did not have significant effect on soil pH ($p > 0.05$). Application of ammonium sulphate improved dry weight (6.45g), number of seeds (40) and seed diameter (0.62), However the highest fresh weight was recorded in crops treated with DAP (11.70g)). DAP showed the greatest plant at the initial stage (9.8cm-42cm), while ammonium sulphate showed gradual increase in the plant height (8.9cm-41cm). Highest total chlorophyll was observed in peas treated with DAP(0.0184mg) and compost at vegetative stage(0.0167mg), which reversed at flowering stage with chlorophyll content in plants treated with ammonium sulphate being higher(0.0265mg) than compost. From this study it is possible to infer that ammonium sulphate extracted from digester effluent increase plants productivity comparable to DAP without any harmful effects in the soil and the environment as observed in the relative increase of soil Ph therefore recommendation is made for application of Ammonium sulphate in crop production.

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LIST OF ABBREVIATIONS

AD	Anaerobic Digester
APDL	Anaerobic Pasteurization Digester Latrine
AS	Ammonium sulphate
DAP	Diammonium phosphate
MDG	Millennium Development Goals
N	Nitrogen
UNICEF	The United Nations Children’s Fund
UNWFP	United Nation World Food Program
WHO	World Health Organization

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CHAPTER ONE

INTRODUCTION

1.1 Background information

Human waste removal is an important part of daily life, and it is an important factor in human health (Esrey *et al*, 2001). According to Esrey (2001), a sustainable sanitation system is a system that prevents disease and promotes health, protects the environment and conserves water, and recycles recovered nutrients and organic matter. However, inadequate sanitation is still a major problem in low income countries and infectious diarrhea accounts for more deaths than AIDS, malaria and measles combined (UNICEF/WHO, 2009). The number of people lacking 'improved' sanitation in 2004 was estimated to be 2.6 billion, that is to say 42% of the world's population. These people mainly live in low and middle income countries (Rockström *et al.*, 2005). On the global scale, only 330 million people, that is to say approximately 5%, are connected to an advanced sewage treatment facility (Ecosanres, 2005). However, even advanced secondary treatment is in many cases still a source of environmental pollution and water recipients are eutrophied with plant nutrients, even in high income countries such as Sweden (Nordin, 2010).

Human excreta contain millions of tons of fertilizer equivalents, 20 to 30% of what the global fertilizer industry produces annually, which to a large extent end up in water bodies via wastewater and surface runoff (Koné *et al.*, 2010; Winker *et al.*, 2009). Such misuse of plant nutrients from human excreta is currently a neglected aspect of health in relation to sanitation. In low and middle income countries malnutrition constituted approximately 14% of the 2001 contribution to global burden of disease, the use of plant nutrients from human excreta offers great potential to increase crop production and nutritional status in countries with limited use of other fertilizers (Winker *et al.*, 2009).

The recovery and use of human urine and faeces have been practiced over millennia by almost all cultures and the practice has not been limited to agricultural production, but this has been the main application (Muskolus, 2008). Excreta are a rich source of inorganic plant nutrients such as nitrogen, phosphorus and potassium, and of organic matter. Each day, humans excrete in the order of 30 g of carbon (90 g of organic matter), 10-12 g of nitrogen, 2 g of phosphorus and 3 g of potassium. Most of the organic matter is contained in the faeces, while most of the nitrogen (70-80 %) and potassium are contained in urine. Phosphorus is equally distributed between urine and faeces (Drangert, 1998). Excreta are not only a fertilizer its organic matter content which serves as a soil conditioner and humus replenisher is an asset not shared by chemical fertilizers, is of equal importance the traditional practices of recycling faecal sludges to agriculture or aquaculture have for centuries made use of this resource (Winblad 1997; Esrey et al. 1998). In China, where excreta reuse has long been widely practiced, soil fertility has been maintained over millennia, despite high population densities (Bracken *et al.*, 2007).

In Japan the recycling of urine and faeces was introduced in the 12th Century and in China human and animal excreta have been composted for thousands of years (Esrey *et* *al.* 1998). In Swedish cities, organized collection and transportation of latrine products to farmers started in the 18th Century (Tingsten 1911). As the population grew, quantities increased and treatment alternatives to facilitate the handling of excreta were developed. Soil structure in agricultural productivity are very important and it is regarded as an indicator of quality and productivity, To maintain agricultural yields at high levels over the years, the nutrients removed by crops have to obe replaced. Otherwise, there is an annual net loss of nutrients from the soil (Vinnerås *et al.*, 2008).Today, there is mainly an outflow of nutrients from farms to society. For a sustainable society, it is necessary to recycle these excreta back to the farms (Vinneras, 2002).

However, artificial fertilizers account for the largest share of these nutrients, but the materials to create them are becoming increasingly more difficult to obtain. The nitrogen, phosphorus, and potassium that make up the majority of these fertilizers come from finite resource pools (Vaccari, 2009). And excessive use of chemical fertilizer in agriculture causes environmental problems including soil, physical destruction and nutrient imbalance (Wang *et al*., 1999). More so, inorganic fertilizers lead to accumulation of heavy metals in soil and plant system. Plants absorb the fertilizers through the soil and they can enter the food chain. Thus, inorganic fertilization leads to water, soil and air pollution. Nevertheless the cost of making and buying fertilizer is further worsening. From 2006 to 2008, spikes in petroleum prices helped cause fertilizer costs to nearly triple and food transportation costs doubled (FAO, 2008). Buying fertilizers and/or importing foods from outside the community is expected to become more and more expensive as these resources become less available.

Anaerobic pasteurization digester offers an alternative treatment of waste and wastewater while allowing recovery of nutrients. Anaerobic pasteurized digester is based on the systematic implementation of reuse and recycling of nutrients and water as a hygienically safe. Previous studies have shown that anaerobic pasteurization digester systems enable the recovery of nutrients for example Ammonium sulphate (mugo el al., 2016). The nutrient so recovered from human faeces and urine may benefit agriculture, thus helping to preserve soil fertility, assure food security, minimize water pollution ,recover bio energy and to renounce or minimize the purchase of chemical fertilizer.

The main objectives of Anaerobic pasteurized digester consist of reduction of health risks related to sanitation, contaminated water and waste, prevention of pollution of surface and ground water. Furthermore, anaerobic process generates ammonia which contributes significantly to the nutritional needs of terrestrial organisms by serving as a fertilizer, therefore this study is aimed at assessing the effect of ammonium sulphate processed from anaerobic pasteurization digester effluent on soil pH and yield of peas.

1.2 Problem Statement

Improper disposal of human waste is one of the developing world's most serious health problems. The number of people lacking 'improved' sanitation in 2004 was estimated to be 2.6 billion, that is to say 42% of the world's population (Rockström *et al.*, 2005). They defecate in open fields, behind bushes, in buckets, or in latrines suspended over water sources or open pits. These practices contribute to the spread of disease and degrade the quality of water resources. Globally, diarrhoeal diseases attributable to a lack of safe water and basic sanitation cause 1.6 million deaths each year (UNICEF, 2006) the situation is growing worse with population increase and rapid urbanization and there will be need for safe, sustainable and affordable sanitation technology or system. Although the currently onsite treatment can prevent pollution in some places it is not often feasible in urban crowded communities due to lack of space and scarcity of water.

At the same time soils are losing nutrients and are declining in crop yields at a high rate due to insufficient organic matter inputs which provide organic acids that help dissolve soil nutrients and make them available for the plants (Connor,2006). Continuous use of inorganic fertilizers affects soil structure (Naeem *et al*., 2006) and how well water is able to move through soil, even though chemical fertilizers of many kinds are widely used, the materials to create them are becoming increasingly more difficult to obtain. The farmers use mostly chemical fertilizers indiscriminately without adequate information on actual soil/plant requirement. This results in over application of some nutrients, under application of others and general inefficiency of the costly fertilizer input. The cost of chemical fertilizers in the international market has gone up. Environmental pollution due to use of chemical fertilizers has also become an international issue. Proper processing of organic wastes such as ammonium sulphate and residues for use in agriculture appears to be promising and this can reduce the environmental pollution to a great extent.

The ongoing study on organic stabilization and nutrients production with resource recovery from anaerobic pasteurisation digester latrine has proven that ammonium sulphate can be processed from the final effluent of APDLs, APDL is a new technology for human waste disposal is based on the systematic implementation of reuse and recycling of nutrients and water as a hygienically safe. Anaerobic pasteurization digester systems enable the recovery of nutrients from human faeces and urine for the benefit of agriculture, thus helping to preserve soil fertility, assure food security, minimize water pollution and recover bio energy.

1.3 Study Objectives

1.3.1 Overall objective

To assess the effect of ammonium sulphate processed from anaerobic pasteurization digester latrines effluent on soil pH and yields of peas (*pisum sativum*)

1.3.2 Specific objectives

1. To determine the effects of ammonium sulphate recovered from APDLs on soil pH compared to other inorganic and organic fertilizers.

2. To determine the effects of ammonium sulphate recovered from APDLs on growth and yield of peas (*Pisum sativum*) compared to other organic and inorganic fertilizers.
3. To determine the role of ammonium sulphate recovered from APDLs in chlorophyll synthesis compared to other organic and inorganic fertilizers.

1.3.3 Hypotheses

Ho: Ammonium sulphate recovered from APDLs has no significant effect on soil acidity compared to other inorganic and organic fertilizers.

Ho: Effect of Ammonium sulphate recovered from APDLs on growth and yield of peas is not significantly different compared to other organic and inorganic fertilizers.

Ho: Ammonium sulphate recovered from APDLs has no significant effect on chlorophyll synthesis compared to other organic and inorganic fertilizers.

1.4 Justification of the study

Human excreta is a resource to be recycled, rather than a waste to be disposed off. Anaerobic digestion contributes to the hygienic management of human waste by collecting and isolating the untreated waste from the environment and preventing human contact with pathogens present in the waste. During the digestion process pathogens are destroyed and several economically valuable byproducts are formed, including biogas and nutrient rich effluent and sludge. (Winblad, 2000)

Peas is an important crop grown in most parts of the world and a major source of protein in eastern Africa beside beans, Low agricultural productivity is one cause of hunger and malnutrition in many low and middle income countries, in spite of the fact that the climate would allow several cropping seasons. This is attributable to the fact that almost no fertilizers are used, in combination with many working days lost due to hunger and enteric disease, the latter resulting from failure to treat human faeces properly (Heinonen-Tanski *et al.*, 2010). The use of nutrients from treated human excreta and their subsequent use as fertilizer can give a more sanitary environment and more sustainable food production and hence contribute to poverty reduction and nutritional status among communities with limited access to other fertilizers.

Despite the development of several technologies on pit latrines, there exists several sanitation and health limitations, in their use especially in densely populated areas.Hence,APDLs can be viable solution to densely populated settlements where pit latrines are difficult to construct .APDLs may be a breakthrough to proper sanitation and economically affordable, to operate and maintain (Thye.et al., 2009)

CHAPTER TWO

LITERATURE REVIEW

2.1 Nutrients and Organic Matter

Excreta are a rich source of inorganic nutrients such as nitrogen, phosphorus and potassium, and of organic matter. Each day, humans excrete in the order of 30 g of carbon (90 g of organic matter), 10-12 g of nitrogen, 2 g of phosphorus and 3 g of potassium. Most of the organic matter is contained in the faeces, while most of the nitrogen (70-80 %) and potassium are contained in urine. Phosphorus is equally distributed between urine and faeces (SANDEC, 2000).

Excreta is a fertilizer and as well, its organic matter content serves as a soil conditioner and humus replenisher, which is an attribute not shared by chemical fertilizers. The traditional practices of recycling faecal sludges to agriculture or aquaculture (e.g. in Southeast Asia) have for centuries made use of this resource (Winblad 1997; Esrey *et al*. 1998). For the same reason, urban farmers in arid or semi-arid zones or during dry seasons, in addition to procuring water for irrigation are endeavoring to get access to wastewater, raw or treated. This allows them to renounce or minimize the purchase of chemical fertilizer.

It is now being postulated that sanitation systems should, whenever feasible, be conceived and managed such as to enable and maximize the recycling of organic matter and nutrients contained in human excreta (EAWAG/SANDEC 2000). A change in the sanitation management paradigm from flush-and-discharge to recycling of urine and faeces is gaining ground in Europe (Larsen and Guyer 1996; Otterpohl *et al*., 1997, 1999; Otterpohl, 2000). As a consequence, treatment strategies and technological options for faecal sludges and wastewater will have to be developed which allow the optimum recycling of nutrients and organic matter to peri-urban agriculture, while being adapted to the local situation and needs.

2.2 Human waste as a resource in agriculture

The use of human excreta as a source of plant nutrients has existed since ancient times. Below are some of the examples of agricultural utilization of human excreta: Burkina Faso has organized groups of young people who collect urine which they use to apply in fields in Burkina Faso (Makaya *et al*., 2014). This is used in planting of onions, Maize and others. In Mexico, farmers use urine as fertilizers for planting cabbage and spinach after 2 months treatment with diluted urine. When the two fields are compared one that was fertilized using urine with one without urine fertilizer, it was noticed that the one with urine application produces more yield and healthy looking crops (Guadarrama *et al*., 2001) Youth groups also used urine to enrich the compost, which they produced from feaces and organic waste.

Experiments in the USA found that maize which was grown using substantial quantities of urine grew 50% taller than control corn not applied with urine nor any other fertilizer (Malkki, 1999). Further, pilot trials for the agricultural use of urine on growing spinach (Swiss chard) conducted in Nigeria gave best results with plot applied with compost and urine together. This resulted in participants starting to use urine after the demonstration, and even those without toilets started to collect urine for further use (Hanke, 2003) other African countries like Republic of South Africa, Ghana, Mali, and Senegal, human excreta is currently gaining more attention as an agricultural input (Müllegger *et al*., 2010).

However nutrient content and hygienic quality of composted toilet waste have been sparsely studied , which makes such waste more difficult to use. The usual way to utilize composted toilet waste is to spread it in the yard under bushes or on wasteland. Owing to biased attitudes towards composted faeces, people rarely use it as soil conditioner or fertilizer for vegetables (Malkki *et al*. 1997).

At present, composted toilet waste is of little significance as fertilizer or soil conditioner for households (Malkki *et al*. 1997). This fact is also supported by Hagalund and Olofsson (1997) in their research, according to which utilization of the nutrients in sludge, urine, and toilet manure still functions poorly.

2.3 Ammonia from fecal waste

Ammonia as fertilizer from fecal waste for reuse in agriculture has been a normal practice, but there is lack of concrete information on the subject, particularly on farmer's needs, preferences, health and environmental risks (Ogola *et al.*,2011). Ammonia (NH_3) is the foundation for the nitrogen (N) fertilizer industry. It can be directly applied to soil as a plant nutrient or converted into a variety of common N fertilizers (LUC, 2004).

Most fertilizers used in food crop production (58%) in Kenya are various fertilizer types; di-ammonium phosphate (DAP), triple super phosphate (TSP), mono ammonium phosphate (MAP), single phosphate and top dressers such as calcium ammonium nitrate (CAN) and urea. Decision by farmers to use particular type of fertilizer is usually influenced mainly by demand (94%), fertilizer stock available (78%) and affordability (21%) (Kazungu, 2010).

On the production side of the fertilizer market, the input costs usually put upward pressure on fertilizer prices. Chemical fertilizer production is an energy intensive process and requires large amounts of energy. Ammonia used to produce urea and nitrate is particularly energy dependent. Nitrogen as a raw material (78% volume in the atmosphere) is available almost without limit but its transformation into ammonia

(Haber-Bosch process) is highly demanding in terms of energy, particularly natural gas. Natural gas accounts for 72-85% of ammonia production costs (Ulmann, 2001).

Nutrients such as nitrogen, phosphorus and potassium contained in human excreta are very suitable as fertilizer, because they meet most of the plant nutrient needs and the organics function as soil conditioner. Biogas sanitation contributes to closing the nutrient cycle which is a target of sustainable agriculture. Each day, one adult excretes about 30g of carbon (90g of organic matter), 10-12g of nitrogen, 2g of phosphorus and 3g of potassium (Drangert 1998).

Nitrogen (N) is the motor of plant growth - it makes up 1 to 4 percent of dry matter of the plant. It is taken up from the soil in the form of nitrate (NO_3^-) or ammonium (NH_4^+). In the plant it combines with compounds produced by carbohydrate metabolism to form amino acids and proteins. Being the essential constituent of proteins, it is involved in all the major processes of plant development and yield formation. A good supply of nitrogen for the plant is important also for the uptake of the other nutrients, thus is required in the largest amount from soil (Nasim *et al.,* 2012).

In Africa, closing the gap between actual and potential agricultural yields, which could mitigate food insecurity, depends heavily on improved access to readily available and cheap sources of fertilizers (Ott, 2012).

2.4 Anaerobic pasteurization digester latrine (APDL)

This is new a technology facility for human waste disposal that is very different from other facilities that have been used to dispose human waste. In fact this is a technology that is under piloting. It is a further improved, or “advanced,” sanitation system under field test at upcoming market at Sogomo next to University of Eldoret, Kenya coordinated by a research group from Duke University, Department of Civil & Environmental Engineering. The effluent leaving the ADPL system is sterilized, making it safe for environmental discharge. (Forbis-stokes & Colón 2012).

The new approach recognizes the need and benefit of protecting environmental health and promoting human well-being, recovering and recycling nutrients, and conserving and protecting natural resources. Nutrients and organic matter in human excreta are considered a resource, food for a healthy ecology of beneficial soil organisms that eventually produce food or other benefits for people (SA Esrey, 2000).

2.5 Pit Latrines and Sanitation

A pit latrine is used to retain resources in form of feaces and urine underground for approximately two years making which requires space and with densely populated regions such as slum areas and in high sprouting centre‘s, there are usually cost implications of repeated construction and emptying (Alabaster,2008).

Sanitation systems worldwide can be classified into two major categories, namely: offsite and on-site sanitation systems. The off-site systems include: the conventional sewerage system with proper treatment and disposal, and small-bore sewers. The on-site systems include a number of technology options: dry pit latrines, borehole latrines, ventilated improved pit latrines, eco-san latrines, and pour-flush latrines with single or twin pits, aqua privies, composting latrines, and septic tanks (Drangert, 2008).

Sanitation levels are categorized by the MDGs as open defecation, unimproved facilities, and improved facilities. In order for a facility to be considered ―improved,waste should either be removed by a flushing mechanism or be a pit latrine with concrete slab and pit ventilation as a minimum requirement (Nwaneri, 2009).

Municipal sewer systems are the standard of wastewater treatment that is most desired. Human exposure to waste is removed through flush toilets that transport waste to a centralized wastewater treatment facility through piping infrastructure.

Users hardly have direct contact with waste in any way during the process. Though these systems are highly desired, high costs for wastewater infrastructure are a major limitation. Additionally, those not living within range of a municipality‘s services do not have this option. In low-income countries (with a gross national income per capita of $1,025 or less), a large portion of households use improved or unimproved pit latrines due to their low cost and availability (Mallery *et al.*,2012).

Improved pit latrines are the most basic and inexpensive form of improved sanitation and typically consist of a pit – circular, rectangular or square – dug into the ground and covered with a concrete slab or floor with a hole through which excreta falls. Often, the lack of available space or costs of constructing a new latrine superstructure and this means that pit latrine emptying may be the only practical alternative (Thye, et al, 2009).

Urine and feaces are considered as a resource, the nutrient so recovered from human faeces and urine may benefit agriculture, In this regard its reuse has an advantage of it being used as nitrogen source organic fertilizer in food production industry (Jana *et al*., 2012).

2.6 Inorganic fertilizer

Inorganic fertilizers are fertilizers mined from mineral deposits with little processing (e.g. lime, potash or phosphate rock), or industrially manufactured through chemical processes (e.g. urea) Inorganic fertilizers vary in appearance depending on the process of manufacture. The particles can be of many different sizes and shapes (crystals, pellets, granules or dust) and the fertilizer can include straight fertilizers (containing one nutrient element only), compound fertilizers (containing two or more nutrients usually combined in homogeneous mixture by chemical interaction) and fertilizer blends (formed by physical blending mineral fertilizers to obtain desired nutrient ratios).

Low use efficiencies of inorganic fertilizers coupled with their rising costs and the need for organically produced foods has directed the attention of farmers towards organic sources. Organic manures may increase soil fertility and thus the crop production potential possibly by changes in soils physical and chemical properties including nutrient bioavailability, soil structure, water holding capacity, cation exchange capacity, soil pH, microbial community &activity etc (Marschner, H. **1986**)

2.7 Organic fertilizers

Natural organic fertilizers are commonly made from waste products of various sources ranging from chicken feathers and manures to treated sewage sludge. These materials have very slow release rates, requiring soil bacterial action to convert the organic matter into forms usable by plants. Nutrients released will be excessively slow when cool soil temperatures reduce bacterial activity. Higher application rates may be applied and the fertilizer will last over a longer period of time (Khatib and Al-khateeb, 2009).

Home owners recognize the need for timely nutrient applications to promote vigorous plant growth in landscapes and gardens. These nutrients may be supplied by either organic or inorganic fertilizers, or a combination of materials. Many nursery and garden supply stores now stock a wide variety of organic fertilizers. In addition, many organic materials are produced around the home, or can be obtained at little or no cost from livestock operations, municipal green waste collection centers, and local landfills. Virtually any organic material can be used as a fertilizer; however, materials vary considerably in the concentration of plant nutrients they contain and the rate at which these nutrients are released for plant use. Therefore, some organic fertilizers are better for certain situations than others, and different materials need to be applied at different rates to supply the correct amount of plant nutrients (Osorio & Neill,2005)

Many farmers have an interest in using organic fertilizers for vegetable transplant production. There are no general recommendations for using organic fertilizers, because historically, organic fertilizers are generally insoluble in water, and nutrients are slowly available. Because of their insolubility, organic fertilizers have not been applied with the use of injectors in a typical greenhouse transplant production system fertilizers. (Antonini *et al*., 2000)

2.8 Ammonium sulphate

Ammonium sulphate $(NH_4)SO4$ is a granular or crystalline, in general white nitrogen fertilizer, containing 21% nitrogen and 24% sulphur. Because ammonium sulphate contains 100% ammonium nitrogen it guarantees a long-term and sustainable nitrogen supply. Furthermore it prevents the nitrogen from being washed out of the soil. In addition, ammonium sulphate supports the availability of secondary nutrients like manganese, iron, and boron in the soil. AS is generated as a by-product from the caprolactam production. Western Europe represents the biggest production region worldwide (www.helmag.com,accessed *June 2015)*

Gaseous ammonia is directly neutralized with H_2SO_4 to produce $(NH4)_2SO_4.2NH_3$ + H_2SO_4 $(NH_4)_2SO_4$ the neutralizer reactor and the crystallizer are interconnected so that the heat released during neutralization is used to evaporate water in the slurry. The crystallizer is designed to produce uniformly sized crystals. Amorphous $(NH_4)_2SO_4$ is prepared by reacting gaseous NH_3 and H_2SO_4 in spray towers. The heat of reaction removes all the water present and the dry, fine product is continuously removed from the base of the tower. This product is suitable for making dry –mixed and granular fertilizers (Klasen, 2002).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

The experiment was conducted at University of Eldoret farm, in Uasin Gishu District of Kenya. The university is located approximately 9 km from Eldoret town in western Kenya. Latitude 0.31° North, Longitude 35.17° East and at an Elevation of between 2110 m and 2140 m above sea level (Figure 3.1). The annual precipitation average 1103mm. The soils are of igneous origin, acidic (pH:4.5-5.0) and low in fertility and moisture storage. It is classified as rhodic ferralsol classification and oxisols classification (Osundwa *et al.*, 2013).

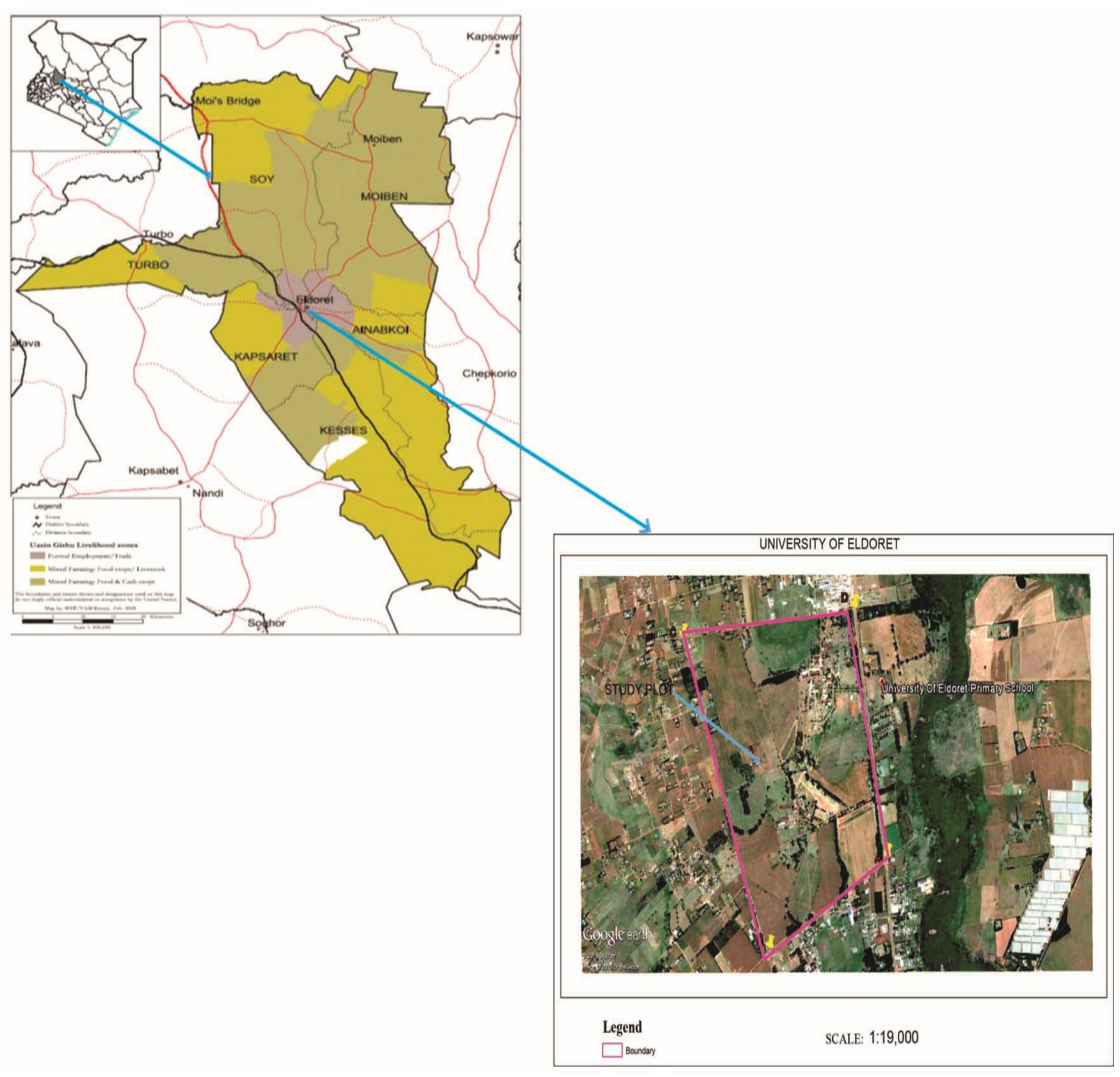

FIGURE 3.1: Map of the study area (Source: University of Eldoret, GIS Laboratory, 2016)

3.2 Materials

Materials for the experiment consisted of compost collected from the farm, DAP purchased from authorized fertilizer stores in Eldoret town, Peas (*Pisum sativum*) seeds purchased from Kenya Seed Company shop in Eldoret town, ammonium sulphate extracted from effluent from ADPL and Ridomil Gold pesticide (mostly used pesticide at agriculture farm and it was recommended by the farm manager) to control pests purchased from Agro vet shop in Eldoret town .

3.3 Field Methods

3.3.1 Extraction of ammonia

The requirements for total ammonia determination are ammonium sulphate, zinc granules, 10% sodium hydroxide, methyl red indicator and 0.1 M sodium hydroxide. Final effluent was collected from APDL in pre-cleaned and labeled 50.0 ml plastic containers, the sample was transported to the laboratory for treatment and extraction of ammonium sulphate. 50.0 ml of the final effluent was accurately measured into a volumetric flask. Two hundred milliliters of distilled water was added and thoroughly shaken. 25.0 ml of aliquot of the solution was transferred into a 250.0 ml distillation flask and diluted with 100.0 ml of distilled water. 1.0 g of granulated zinc was added to the content in order to promote regular abolition in the subsequent distillation. Exactly 50.0 ml of standard 0.1M of acid (sulphiric) was placed in receiver and the flask was adjusted such that the end of the condenser just dipped into the acid while making sure that all the corks were tightly fitted.

Fifty milliliters of 10% sodium hydroxide was placed in the separating funnel and the sodium hydroxide run into the distillation flask by opening the tap. The tap was later closed as soon as the alkali had entered. The flask was heated so that the contents boiled gently and the distillation process continued for 60.0 minutes until half or a third of the original volume remained. By this time it was assumed that all the total ammonium had passed over into the receiver contents**.**

3.3.1.1 Anaerobic Pasteurization Digester Latrine system

A sketch of an improved sanitation system used in this study referred to as Anaerobic Digestion-Pasteurization Latrine developed by the Deshusses research group in the Civil and Environmental Engineering Department of Duke University is shown in figure 2. The system operates by using an anaerobic digestion tank to receive human excreta from the latrine. Microorganisms living in the anaerobic (lacking oxygen) environment metabolize influent wastes and produce biogas. Biogas is a combustible gas comprised of approximately 65% methane, 35% carbon dioxide, and trace levels of other gases. Digested liquid leaving the digester enters a heating tank that is powered by burning the biogas produced.

The effluent is heated to temperatures of 75°C to remove all pathogens. The process is made more efficient by adding a counter-flow heat-exchanger between the anaerobic digestion tank and the heating tank in the heat exchanger. The effluent leaving the system is sterilized, making it safe for environmental discharge (Forbis-stokes & Colón 2012)

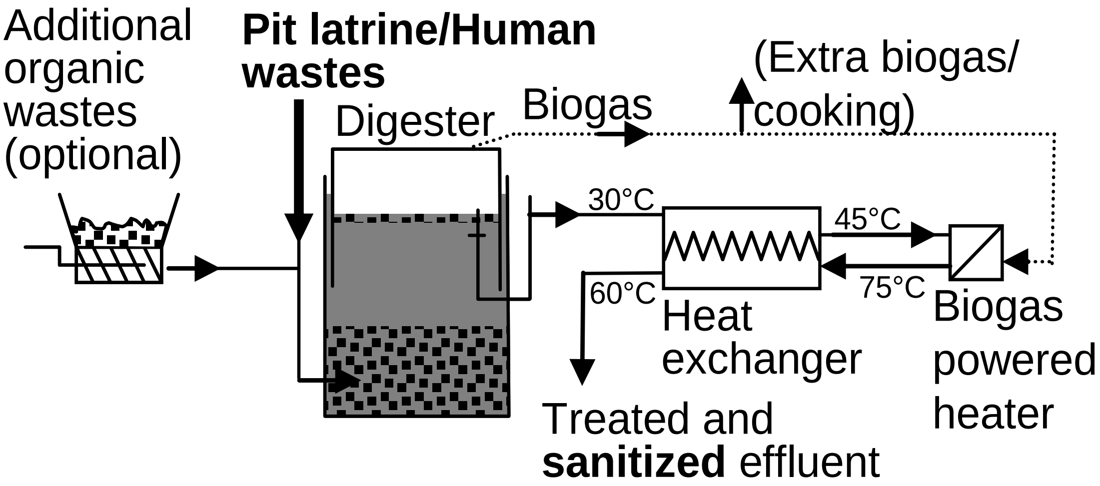

FIGURE 3.2: Flow Sheet and Concept of the Anaerobic Latrine

3.3.2 Experimental design in the field

Planting of this experiment was done in March, 2015 using four treatments and one variety of green peas as the test crop under field conditions. The experiment was laid out in a completely randomized design with each treatment replicated four times with each plot measuring 2 m by 2 m. at a spacing of 50cm between rows and within row spacing of 20 cm was used per plot. The treatments consisted of inorganic fertilizers (DAP), decomposed organic material (Compost), processed fertilizer from the digester (ammonium sulphate) and a control experiment (no fertilizer) the experimental layout and statistical model is as shown in Table 3.1.

TABLE 3.1: A REPRESENTATION OF THE LAY OUT IN THE EXPERIMENTAL FIELDS

BLOCK I	BLOCK II	BLOCK III	BLOCK IV
A	B	D	D
D	C	C	A
C	D	A	B
B	A	B	C

KEY

A = DAP

B = COMPOST

C = AMMONIUM SULPHATE

D = CONTROL

3.3.3 Treatment application

The application of the treatment was done once and were applied at planting by spreading over the plot (ammonium sulphate was top-dressed in two applications, three weeks after planting and 2 months after planting following the farmers' top dressing regime.

3.3.4 Disease and pest control

To prevent or control different diseases and pests, spraying was done twice, the pesticide used was Ridomil Gold at a mixing ration of 50g in 20 litres of water.

3.3.5 Data collection

a) Growth parameters

Plant height was measured using a tape measure by taking the height of 6 randomly selected plants after every two weeks up to maturity in 4 months.fresh leaves were taken for chlorophyll determination during vegetative stage, flowering and maturity stage.

b) Pod and Seed count

A total of 20 pods were plucked from mature plants from each treatment plots and transferred to a labeled paper bag. The pods for each plot were shelled and the seeds were counted and weighed using single pan electrical balance before drying. The seeds were dried for 3 days to constant weight and the weight was recorded in each case.

3.3.6 Soil chemical parameter and analysis

Soil pH was tested before planting and after harvesting to determine the effect of treatments on the soil acidity. Soils samples were taken from each block to a depth of 0.20cm just before the start of the experiment, the samples were bulked and mixed to obtain composite samples per block. Another soil sampling from each plot was done to the same depth soon after harvesting and the samples were bulked together. The soil was spread over a polythene sheet and mixed thoroughly by hand, after which a sub-sample was taken from each sample and placed in proper bags labeled with plot descriptions. The soils were spread on trays in a well ventilated room to dry for 4 days after which they were gently crushed to break soil lumps and then sieved through a 2mm mesh and placed in labeled paper bags ready for chemical analysis.

Soil pH analysis (1:2:5)

During soil pH analysis, soil sample was collected in a plastic container and 25 ml distilled water was added to 20 g of soil. The mixture was stirred for 10 minutes and allowed to stand for 30 min and then stir again for 2 minutes. Before measuring the pH, the pH meter was calibrated using pH 4 and pH 7 buffer solutions. The pH reading was done using a pH meter.

3.3.5 Determination of chlorophyll concentration in the leaves

One gram (1 gm) of chopped leaves of green peas were accurately weighed into a pre-cleaned mortar. 40 ml of the 80 %acetone was added and Ground to a fine pulp. The green liquid was decanted into a Buchner funnel lined with 2 layers of the filter paper discs size No.1 and filtered into a 100 ml volumetric flask (Plate 3.1). Extraction of chlorophyll from the pulp in mortar was repeated by addition of 30 ml of the 80 % acetone, mixed and ground for another 4 minutes. The extract was transferred into the funnel and filter into the volumetric flask. 20 ml of the 80 % acetone was added and extraction process repeated to ensure that no more chlorophyll remained in the pulp. The flak was then filled to the mark with fresh 80 % acetone (Plate 3.2).

80% acetone was used to calibrate the spectrophotometer and read and record the optical density (OD), absorbance, with a 10ml glass cuvette at 645,663 and 652 mm.

Chlorophyll concentration was calculated according to the following equations (Aron et al., 1949).

mg chlorophyll a/g tissue = $\frac{12.7\ (^{D}663) - 2.69\ (^{D}645) \times V}{1000 \times W}$

mg chlorophyll b/g tissue = $\frac{22.9\ (^{D}645) - 4.68\ (^{D}645) \times V}{1000 \times W}$

Mg total chlorophyll mg/g = $\frac{8.02\ (D663) + 20.20\ (D645) \times V}{1000 \times W}$

OR total chlorophyll/g tissue = $\frac{D652 \times 1000 \times V}{34.5 \times 1000 \times W}$

Where D represents the optical density reading at the specific indicated wavelengths,V is the final volume of the extract and W is the fresh weight in grams.

Plate 3.1 Showing Extraction Of Chlorophyll In Progress

(Source :Author,2015)

Plate3. 2: Showing the extract produced from leaves treated with different fertilizers.(source: Author 2015)

3.3.6 Statistical data analysis

The data collected was subjected to analysis of variance (ANOVA), using Genstat Software Version 14, to find out whether there were significant differences in various Fertilizer application and peas yield. Significant differences were tested at 5% level of significance and means were separated by contrast comparison by carrying – post hoc tests to help in answering specific questions relating to the different fertilizers.

CHAPTER FOUR

RESULTS

4.1 Effects of organic and inorganic fertilizer on soil Ph

Soil pH before and after treatment of various fertilizers is summarized and presented in Table 4.1. pH before planting ranged from 4.7 to 4.9 while after planting it ranged from 5.6 to 5.7. Soil pH before and after was in the acidic range and application of the organic and inorganic fertilizers as well as the interaction between the fertilizer and time did not have significant effect on soil pH ($p > 0.05$).

TABLE 4.1: Effects of Various Inorganic and Organic Fertilizers on Soil pH

FERTILIZER	TIME		MEAN	DMRT
	Planting	Harvesting		
Ammonium sulphate	4.7	5.6	**5.2**	**a**
Compost	4.9	5.7	**5.3**	**a**
Control	4.8	5.7	**5.2**	**a**
DAP	4.9	5.6	**5.2**	**a**
MEAN	**4.8**	**5.6**	**5.2**	

Statistics	**Fertilizer**	**Time**	**Fertilizer x Time**
Probability	0.473	<.001	0.594
S.E	0.0656	0.0464	0.0928
S.E.D	0.0928	0.0656	0.1312
% C.V	3.5		

However, the pH increased in all plots irrespective of the fertilizer used and at the end of planting season, the average pH was 5.6. Additionally, time differences between planting and harvesting impacted significantly on pH ($p < 0.05$) despite the fact that fertilizers did not differ significantly in terms of their effect on soil pH (Table 4.1).

4.2 Effect of organic and inorganic fertilizers on growth and yield parameters

The statistical analysis of data revealed that dry weight, fresh weight, number of seeds and seed diameter were significantly influenced by different organic and inorganic fertilizer at different days of crop age ($p < 0.05$).

TABLE 4.2: Effects of Different Organic and Inorganic Fertilizers on Yield Parameters of Peas Under Field Conditions

FERTILIZER	YIELD PARAMETERS							
	Dry weight	DMRT	Fresh weight	DMRT	Number of seeds	DMRT	Seed diameter	DMRT
Ammonium sulphate	6.45	b	11.25	c	40	d	0.620	a
Compost	6.40	b	8.60	b	36	b	0.590	ab
Control	4.50	a	7.15	a	30	a	0.576	b
DAP	5.93	b	11.70	c	39	c	0.594	ab
MEAN	**5.80**		**9.70**		36		0.595	

Statistics				
Probability	0.004	< 0.001	< 0.001	0.05
S.E	0.3	0.415	0.25	0.01145
S.E.D	0.424	0.588	0.354	0.01619
% C.V	10.3	8.6	1.4	12.2

It was observed that dry weight (6.45g), number of seeds (40), seed diameter (0.62) was maximum in peas treated with ammonium sulphate followed by compost. During the yield analysis the highest mean fresh weight was recorded in crops treated with chemical fertilizer (DAP) followed by Ammonium sulphate. On the other hand, the lowest dry weight (4.50), fresh weight (7.15), number of seeds (30) and sees diameter (0.58) was observed in control (Table 4.2).

4.3 Effects of different fertilizers on height of peas under field condition

Regarding growth, application of Ammonium sulphate, Compost and DAP fertilizer had a significant varying effect on the performance of Peas (standard error bars) (Figure 4.1).

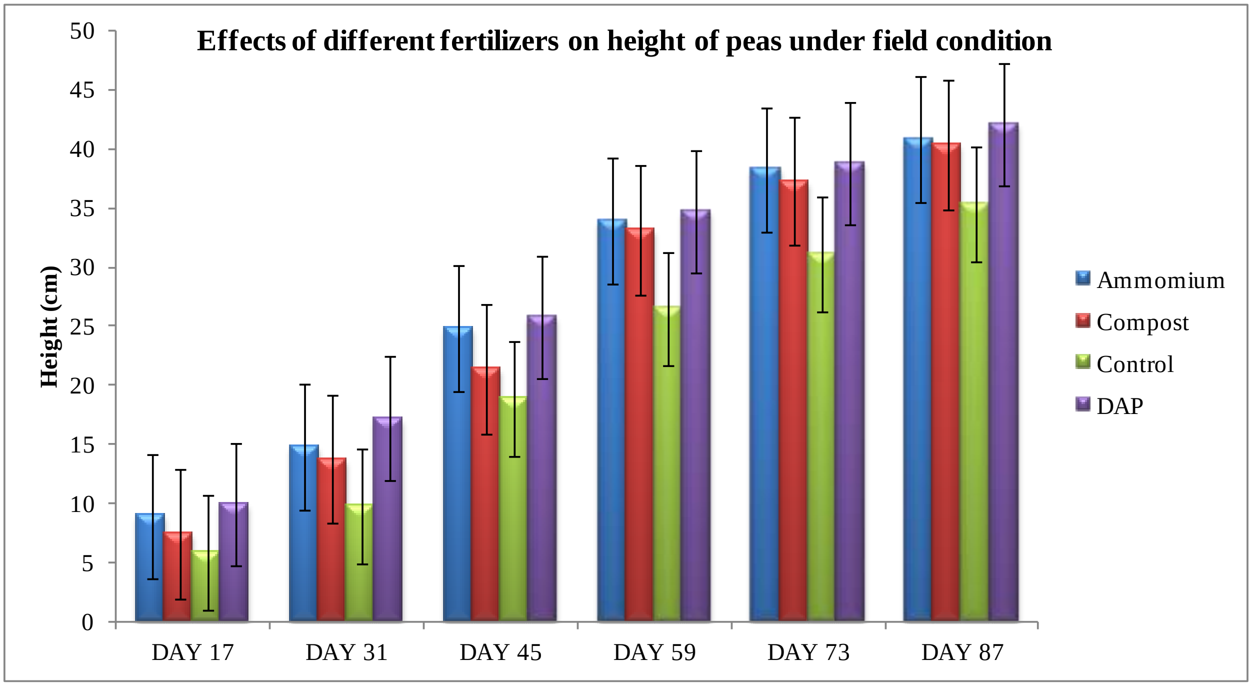

FIGURE 4. 1: Effects of Different Fertilizers On Growth Of Peas In The Field

At day 17 after sowing, the application of DAP produced the greatest plant height, followed by ammonium sulphate and Compost, while the lowest plant height was obtained from the control . The plant height difference was maintained up to maturity with DAP having tallest plant and control the least.

4.4 Effects of organic and inorganic nutrient sources on chlorophyll synthesis

Total chlorophyll, chlorophyll a and chlorophyll b of all plants were significantly affected by fertilizer application. The highest total chlorophyll was observed in peas treated with DAP and compost at vegetative stage. At flowering stage there was an increase in chlorophyll content in plants treated with ammonium sulphate and thereafter chlorophyll content declined in crops grown with fertilizers.

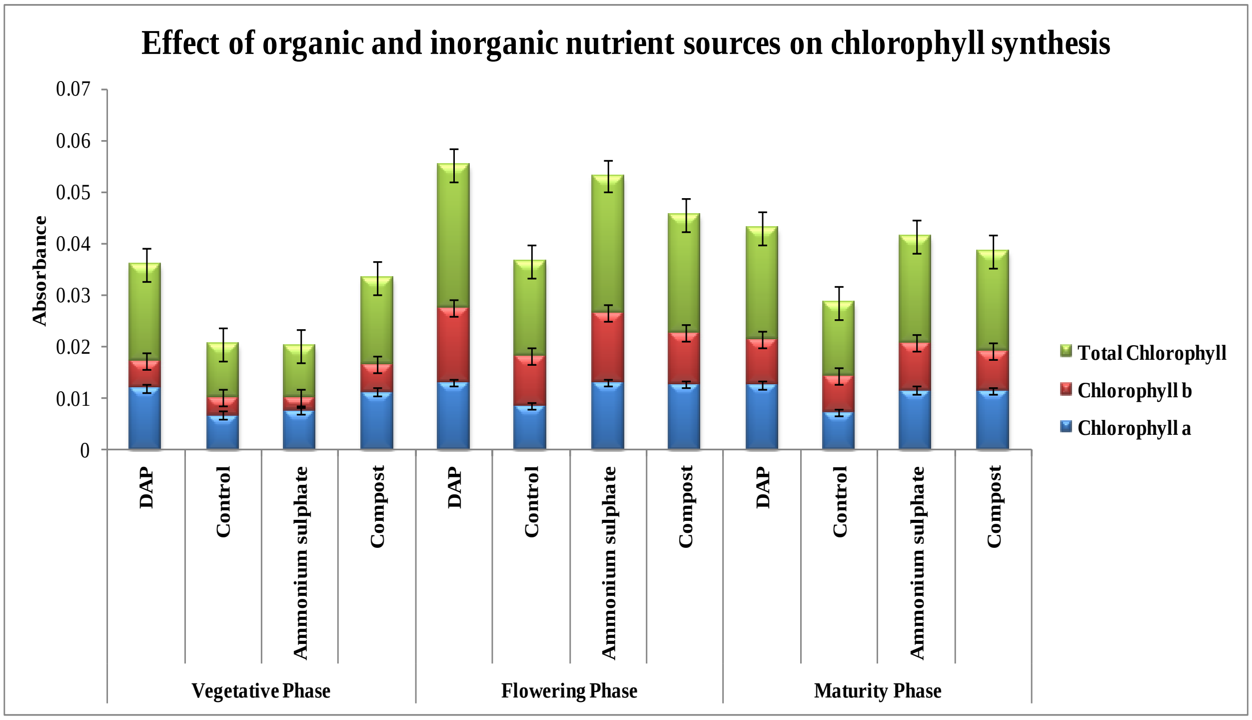

FIGURE 4. 2: Effect of Organic and Inorganic Nutrient Sources On Chlorophyll Synthesis

Crops grown without fertilizer obtained minimum chlorophyll. In contrast all plants the incremental rate of chlorophyll with fertilizer was more pronounced compared to the plants grown without fertilizer. All crops with fertilizer showed sharp increase at vegetative stage and reached peak at initiation of flowering stage and thereafter declined gradually**.**

CHAPTER FIVE

DISCUSSION

5.1 Effects of various inorganic and organic fertilizers on soil pH

The insignificant effect of fertilizers used on soil pH could imply that the nutrient compositions did not have much effect on the soil pH. Also, the lack of interaction effect between fertilizer and time and the significant effect of time may mean that both time and fertilizers acted independently without the additive effect of each factor. It is also possible that the increased pH could be due to the legume crop used rather than the fertilizers due to the ability of peas(legumes) to fix nitrogen through symbiotic relationship with the *Rhizobium* species, meaning they improve the nutrion of the soil they are in **.**

Under such conditions, the availability of the base forming cations is limited since the soil solution is mostly occupied by aluminium and hydrogen ions (Mutegi, 2012). The increment of soil pH may be attributed to the addition of organic residues from the legumes in form of leaf litter drops and probably from the decay of roots and nodules legumes have the potential to improve soil fertility through the release of nitrogen from decomposing leaf residues, roots and nodules which results to increased sward productivity after nitrogen uptake by the companion grasses (Guretzky *et al.*, 2004; Cherr *et al.,* 2006).

5.2 Effects of inorganic and organic fertilizers on yield of green peas

Nitrogen (N) is by far the most abundant nutrient element taken up from soils and subsequently removed by a vegetable crop (Brandenburg, 1980). An adequate supply of nitrogen can promote plant growth and increase crop production (Collins & McCoy, 1997).

The higher performance of ammonium sulphate and DAP compared to other fertilizers in terms of growth and development of peas is that Ammonium fertilizers contain nitrogen in the form of the ammonium ion, NH_4^+. When applied to soil, the ammonium ions in the fertilizer are absorbed by soil colloids and are not lost through leaching (Fertilizer & plant nutrition guide, 1984) Furthermore it prevents the nitrogen from being washed out of the soil. In addition, AS supports the availability of secondary nutrients like manganese, iron, and boron in the soil. Whereas Diammonium phosphate (DAP) is highly water-soluble nitrogen, Phosphates react with sulphuric acid to produce phosphoric acid, which in turn reacts with ammonia. This process converts the poorly water-soluble rock phosphate into a water-soluble phosphate fertilizer that is easily assimilated by plants. (Nieminen, 2010)

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5.3 Effects of inorganic and organic fertilizers on growth of green peas

The increase in plant height with DAP and Ammonium sulphate can be attributed to the fact that nitrogen promotes plant growth, increases the number and length of the internodes which results in progressive increase in plant height. Similar results were reported by Sharma (1973), Turkhede and Rajendra (1978), Koul (1997), Saigusa et al. (1999) and Gasim (2001). This may also be due to the fact that inorganic fertilizers provided early nutrient to the growing crops during the early vegetative growth stage, while the organic component provided nutrient at the later stage of the crop development.

It takes some time for the mineralization, in later stage, plant growth in organic fertilizer incorporated plants was almost similar to the growth rate of inorganic fertilizer treated plants, because of the availability of nutrients from the compost. Thus, inorganic fertilizers hasten early growth of peas, but that could recompense by the organic fertilizers in the later stages. Organic fertilizers activates many species of living organisms which release phytohormones and may stimulate the plant growth and absorption of nutrients (Arisha *et al*., 2003) and such organisms need nitrogen for multiplication (Ouda and Mahadeen, 2008).

5.4 Effects of organic and inorganic nutrient sources on chlorophyll synthesis

All crops possessed the highest chlorophyll content at the initiation of flowering stage and declined thereafter. At later stages, the chlorophyll content decreased and it might be due to source-sink relationship (Nursu, 2014). Crops grown with fertilizer obtained higher chlorophyll content than crops grown without fertilizer as a result of fertilizer application. Chlorophyll content is a particular significance in precision agriculture as an indicator of photosynthesis activity (Tranavicience *et al*., 2008). There is a strong linear relationship between nutrient availability and chlorophyll availability and chlorophyll content according to sabo *et al*.(2002).This indicated that better nutrients supply received by plants treated with DAP, ammonium sulphate and compost compared to control as chlorophyll is believed to take part in the process of organogenesis (Bojovic and Stojanovic 2005).

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study was aimed at determining the effects of ammonium sulphate recovered from APDLs on soil acidity compared to other inorganic and organic fertilizers, to determine the effects of ammonium sulphate recovered from APDLs on growth and yield of peas compared to other organic and inorganic fertilizers and to determine the role of ammonium sulphate recovered from APDLs in chlorophyll synthesis compared to other organic and inorganic fertilizers base on the results ammonium sulphate has no significant effect on soil pH ,it enhanced number of seeds, grain weight and seed diameter therefore it is concluded that Ammonium sulphate recovered from APDLs final effluent can act as effective as a chemical fertilizer without significant reduction in the yield. APDLs proved that there are sufficient nutrients for reuse for sustainable development in agriculture, for a sustainable society to be created, the nutrients from human waste and wastewater have to be recycled to agriculture. This will result to greater environmental protection because the use and dependency on fossil sources would go down and consequently would the negative effects rising from discharge of nutrients to water recipients.

6.2 Recommendations

1. It is recommended for optimum performance of crops, $(NH_4)_2SO_4$ from APDLs effluent could be used by the subsistence farmers without significant reduction in the yield. This will decrease dependency and cost on fossil sources and consequently would the negative effects rising from discharge of nutrients to water recipients.

2. Since the APDLs produce final effluent as organic fertilizer rich in nitrogen and ammonia, more APDLs should be installed for large quantities of organic fertilizer production.

Areas of Further Research

1. There is a need to study effect of ammonium sulphate on soil pH under non-leguminous crops and its residual effects over seasons.
2. There is a need to study the effect of applying the slurry directly from the APDLs compared with other organic and inorganic fertilizes and its residual effects over seasons.

3. Anaerobic digestion can play an important role in the improvement of sanitation and public health, there is need to study some of the cultural constraints (taboos) and attitudes associated with use fertilizer from APDLs.

4. Planting of long term food crops using ammonium sulphate from APDLs fertilizer and compare the yields with other types of inorganic and organic fertilizer.

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APPENDICES

APPENDIX I: Anova table for ph score

Analysis of variance **Variate: pH_score**					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Block stratum	3	0.20204	0.06735	1.96	
Fertilizer	3	0.08971	0.0299	0.87	0.473
Time	1	4.97701	4.97701	144.63	<.001
Fertilizer x Time	3	0.06676	0.02225	0.65	0.594
Residual	21	0.72266	0.03441		
Total	31	6.05819			

APPENDIX II: **Anova table for the dry weight of the peas**

Analysis of variance **Variate: DRY_WEIGHT**					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Block stratum	3	2.7269	0.909	2.53	
Fertilizer	3	9.9469	3.3156	9.24	0.004
Residual	9	3.2306	0.359		
Total	15	15.9044			

APPENDIX III: Anova table for the fresh weight of the peas

Analysis of variance **Variate: FRESH_WEIGHT**					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Block stratum	3	0.065	0.0217	0.03	
Fertilizer	3	56.45	18.8167	27.25	<.001
Residual	9	6.215	0.6906		
Total	15	62.73			

APPENDIX IV: Anova table for the number of seeds

Analysis of variance **Variate: NUMBER_OF_SEEDS**					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Block stratum	3	14.25	4.75	19	
Fertilizer	3	241.25	80.4167	321.67	<.001
Residual	9	2.25	0.25		
Total	15	257.75			

APPENDIX V: Anova table for the seed diameter

Analysis of variance **Variate: SEED DIAMETER**					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.001675	0.000558	0.11	
Fertilizer	3	0.041975	0.013992	2.67	0.05
Residual	153	0.80234	0.005244		
Total	159	0.84599			

APPENDIX VI: Anova table for the height of the plants

Analysis of variance **Variate: HEIGHT**					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	3.3204	1.1068	1.26	
TREATMENT	3	645.0613	215.0204	245.62	<.001
DAY	5	12987.653	2597.5307	2967.15	<.001
TREATMENT.DAY	15	58.02	3.868	4.42	<.001
Residual	69	60.4046	0.8754		
Total	95	13754.46			