SOIL FERTILITY AMENDEMENT USING MOLASSES WASTEWATER AND PIGWASTE AND THEIR INFLUENCE ON SOIL CHARACTERISTICS AND YIELD OF COWPEAS (*Vigna unguiculata*)

BY

KIPKOGEI EZEKIEL MARITIM

A THESIS SUBMITTED TO SCHOOL OF SCINCE IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE AWARD OF A DEGREE OF MASTERS OF SCIENCE IN ANALYTICAL CHEMISTRY OF UNIVERSITY OF ELDORET

NOVEMBER, 2014

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University. No part of this thesis may be reproduced without the prior permission of the author and/or University of Eldoret.

Candidate

Kipkogei Ezekiel Maritim

………………………………….. Date …………………………………..

SC/PGC/004/09

Declaration by Supervisors

This thesis has been submitted for examination with our approval as the University supervisors.

……………………………………… …………………………………..

Prof Paul K. Ndalut **Date**

University of Eldoret, Eldoret, Kenya

………………………………….. ... **…………………………………..**

Prof Caleb O. Othieno **Date**

University of Eldoret, Eldoret, Kenya

DEDICATION

This thesis is dedicated to my parents, all friends, relatives and the family of Mr. and Mrs. Joseph Ketter.

ABSTRACT

Soil fertility is the number-one natural resource in Africa. However, due to high soil acidity and low fertility, food production has declined over the last decade. A case in point is in Uasin Gishu County, where farmers continue to report continued decrease in farm production. This is mainly due to continuous use of soil acidifying inorganic fertilizers that include diammonium phosphate (DAP). Remedy for such reduced soil fertility may be done through soil fertility amendments. Large amounts of pig manure containing high concentrations of nutrients are generated on pig farms while factories generate large quantities of waste water. The aim of the current research was to determine the use of molasses fermentation wastewater and pig waste as an amendment to soil acidity and determine the impacts of such amendments on soil characteristics, plant nutrient characteristics and crop yields. This research was carried out under field and green house conditions in the University of Eldoret Farm. The treatments were pig waste, molasses fermentation wastewater and DAP on cowpea. The molasses fermentation wastewater used in the experiment was obtained from Muhoroni Agro-chemicals and Food Company (ACFC) while the pig waste used was obtained from University of Eldoret Farm. Chemical analysis for molasses fermentation wastewater and soils before and after treatment were carried out and also done on dry cowpea seeds. In the field, complete randomized division blocks each measuring 3 m x 3 m were used. Eight treatments were used and replicated to give a total of 72 plots. The fertilizer treatments were applied based on P requirement of the plant. The experiments were carried out in two seasons. After harvesting, the seeds were dried to 13% moisture content and grain yield (kg/ha), seed quality and economic analysis was done. From the study, Soil characteristics differed significantly between seasons 1 and 2 among all the analyzed parameters ($p < 0.05$) except in the control plots. In both seasons, the pH value was found to be highest in treatment using wastewater, combination of pig waste and wastewater and then pig waste alone. DAP had the lowest pH. The treatment combining DAP, PW and WW had the highest yield followed by those with PW + WW while treatment with only WW and DAP were lower, which were, however, higher than the control. Other parameters of yield such as, plant height, leaf height, leaf width, and number of pods, number and weight of seeds followed similar trend. The results in this research show that molasses fermentation wastewater and pig waste are suitable to amend soil acidity in the university of Eldoret farm. The results should be replicated outside the University of Eldoret especially in Uasin Gishu County farms. Data was analysed using SPSS.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACFC	Agro-Chemicals and Food Company
DAP	Diammonium phosphate
DAPPW	Combination of di-ammonium phosphate and pig waste
FAO	Food and agriculture organization
KEBS	Kenya bureau of standards
KNBS	Kenya National Bureau of Statistics
NA	Not applicable
NIL	Control
OC	Organic carbon
PW	Pig waste
PWDAPWW	Combination of pig waste, di-ammonium phosphate and waste water
WHO	World health organization
WW	Molasses fermentation wastewater
WWDAP	Combination of molasses waste water and di-ammonium phosphate
WWPW	Combination of molasses waste water and pig waste

ACKNOWLEDGEMENT

My heartfelt appreciation goes to my supervisors Prof. Paul K. Ndalut of Department of Chemistry and Biochemistry and Prof.Caleb O. Othieno of the Department of Soil Science both of the University of Eldoret for their immeasurable assistance, guidance, encouragement and supervision throughout field work and in the writing of my research thesis. Secondly, I sincerely thank the management of the University of Eldoret for giving me an opportunity to conduct this study. I thank Prof. F. Segor, the former HOD, Department of Chemistry and Biochemistry and other academic staff in the Department during the entire process of research and thesis development. Special thanks go to my parents for their moral, material and financial support. Lastly, i will not forget to thank Mr. E. Bore for his continuous guidance and pieces of advices during the entire research.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Concerns are growing about long-term sustainability of agriculture. Soil fertility is currently declining due to increased agricultural practices worldwide. Part of this decline is attributed to soil degradation, which has resulted in reduced agricultural productivity worldwide. It has been reported that intensification of agricultural practices and operations has become an issue of critical importance concerning the decline in soil fertility. Several pollutant sources also partly or wholly contribute to the problem of declining soil fertility with negative consequences for the crop production (Sanchez *et al*., 1998). Moreover, there is also increased loading of sediments, nutrients particularly phosphorus (P) and nitrogen (N), organic carbon (OC), pesticides, metals, pathogens, and salts which impair growth of crops (Palm *et al*, 1997; Rostagno and Sosebee, 2001; Swift, 2009; Eswaran and Beinroth, 2012).

Despite of the progress made in crop improvement, low soil fertility and nutrient depletion continue to present huge obstacles to agricultural production in Africa. Moreover, the drastic reduction in fallow periods and the almost continuous cropping without soil fertility restoration has depleted the nutrient base of most soils (Jayne *et al*., 2013). By the late 1990s, all Sub-Saharan Africa countries were demonstrating a negative annual nutrient balance. Countries that have the highest nutrient loss rates are the ones where fertilizer use is low and soil erosion is high. These areas include the East African highlands and a number of countries in West Africa (Kelly *et al*., 2011). The declining soil fertility poses higher threats to agricultural productivity than in some areas of the temperate. The declining soil is characterized by low pH, excessive metal (mainly Al^{3+}) toxicity, low soil mineral content such as deficiency of calcium (Ca^{2+}), and low organic matter (Kang and Juo (2007); Wallace, 2007).

Soils are also less productive because some of these soils are prone to strong phosphate and nitrate fixation (adsorption to oxides and clay minerals) that renders phosphorus and nitrogen unavailable to plant (Tisdale *et al*., 2009). The barren soils are a result of years of mining and insufficient replacement of nutrients by smallholder farmers, mostly practicing low-input agriculture. Although little production increase has taken place, this has been obtained by cultivation of poor and marginal lands while the productivity of most existing lands has been declining (Donovan and Casey, 1998).

In Kenya, agriculture is an important development vehicle for achieving the Millennium Development Goal (MDG) on halving the share of people suffering from extreme poverty and hunger by 2015, and for meeting the Kenyan 2030 vision on food security. Yet in the Kenyan agro systems, the continuous tillage, increasing population and the unsustainable soil management have contributed significantly to the problem of low soil fertility (Mochoge *et al*., 1997; Tejada *et al*., 2011). Such agricultural practices have led to progressive impoverishment in the organic matter contents in the soil horizon A. This leads to a remarkable decrease of the initial productivity of these soils, derived from their unsuitable chemical properties (Edmeades, 2009). To curb declining soil fertility and enhance crop production, best management practices and remediation techniques have been evaluated and recommended.

Soil amendment has been established to reverse the declining soil fertility in many conditions. Soil amendment using industrial waste have very complex effects on soil such as improving the air: water ratio, increasing the exchange capacity of the soil, detoxifying some heavy metals, releasing chemical compounds that stimulate root growth and the growth of soil micro and macro organisms (Campbell *et al*., 2006). Beside, the application of wastewater significantly increased the cation exchange capacity (CEC) indicating greater nutrient retention capacity of the soil (Mbah and Mbagwu, 2006). Therefore, the utilization of wastewater from local industries offers an alternative and a complementary source of plant nutrients.

In Kenya, molasses wastewater is abundant from various sugar industries such as Mumias, Muhoroni, Chemelil, and Sony among other factories. Yet, there is lack of research outputs on the use of molasses wastewater in agriculture. It has been established that molasses wastewater contains essential nutrients for plant growth like nitrogen (N), phosphorous (P), and potassium (K). Micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) and a considerable amount of organic matter (Cameron *et al*., 2007; Elliott and Stevenson, 2007).

The availability of wastewater as well as the nutrients it may contain makes it an attractive source for soil amendments and also as a good fertilizer that would increase crop yield and enhance soil fertility and productivity (Ouazzani *et al*., 2012; Elliott and Stevenson, 2007). The utilization of these industrial wastewaters for remediation purposes also offers the benefit of reducing the storage constraints associated with them. The organic matter in wastewater can improve soil aeration, increase water infiltration and soil moisture holding capacity, decrease soil erosion potential, increase soil cation exchange, buffer soil pH and promote the growth of beneficial soil organisms (Jamjoum and Khattari, 2003; Campbell *et al*., 2006). Other researchers found that micro nutrients can be accumulated in the soil and the plants after long term wastewater application (Schalscha *et al*., 2008).

Utilization of molasses wastewater in soil amendment may not prevent the loss of organic matter in the soils. To circumvent the loss of the organic matter, application of manure appears to be the best solution in solving the reduced organic matter content in the soil. Manures may increase soil organic matter, provides nutrients for plant growth, alleviate aluminum toxicity, and render phosphorus and nitrogen more available to crops (Brown *et al*., 2005). In addition, organic manure increases the organic carbon content of the soil. It exerts positive influence on soil nitrogen which is an important source of nitrogen supply for crop production and could have a long term effect on the soil nitrogen (Anikwe and Nwobodo, 2002; Eneje and Ukwuoma, 2005). Positive impact of organic manure on soil structure, stability; nitrogen and carbon content has been reported (Hudson, 2001; Diaz *et al*., 2008).

Various types and sources of organic wastes are utilized in agriculture but most of these materials remain unutilized, especially in resource poor countries. Pig wastes like pig dropping influence the level of soil ammonium nitrogen ($NH^{+}{}_{4}{}^{-}N$) and nitrate nitrogen ($NO^{-}{}_{3}$–N) which is the form of nitrogen that is absorbed by plants through their roots (Ano and Agwu 2010). The accumulation of pig wastes has been reported to cause an increase in the organic carbon content of the soil (Eneje and Ukwuoma, 2005).

Agricultural soils in Kenya especially in Uasin Gishu County have been reported to be reducing in fertility and at the same time, the soils are low in organic matter content. The amendment of the soils using a combination of wastewater and pig waste may remedy the situation. Simultaneous application of wastewater and pig waste for soil amendments has rarely been done in Kenya, especially for the fertility depleted soils of Uasin Gishu County. The response of crops to the application of wastewater and pig waste is not well known.

Cowpea (*Vigna ungulata*) is cultivated for both grain and green leaves (Shakoor *et al*., 1984). Potential cowpea grain yield of most improved Kenyan cowpea cultivars ranges from 1170 to 1800 kg ha^{-1} (Audi *et al*., 1996) in pure stands. However, cowpea yields are limited by low plant population, low yield potential of local cultivars, insect pests and diseases, shading by the cereals, drought stress and low soil fertility. Cowpea growth is retarded by low soil P (Bationo *et al*., 1991). A number of crop nutrients lack in such soils and therefore lower the yields of *V. ungulata* (Owolade *et al*., 2006). To remedy the situation and improve cowpeas yields, soil amendments are required. Currently, no study is available that has evaluated the yield of cowpeas when planted in soils amended with molasses wastewater pig waste.

1.2 Statement of the problem

Kenya relies on agriculture to support close to 70% of its economy (KNBS, 2010). Despite the increased agricultural production of the last five decades, the country face challenges of acute food crisis and insufficient food production for the growing population (Obada, 2012). Part of the reason for this food insecurity and reduced agricultural production has results from reducing soil fertility. The soils have low soil

P, low organic carbon and low soil pH of 4.5-5.0 (Ogola *et al*., 2011). The reduced soil fertility has resulted in reduced crop yields that expose the farmers to financial constraints and they cannot meet the ever growing demand for food due to the current rapid population growth. To increase agricultural activities to meet the needs of the growing population implies more dependence on soil remediation technologies in order to reduce the risks posed by pollutants generated from agricultural systems. Remedies for such include the use of alkaline substances including agricultural lime that is becoming expensive overtime. Besides, fertilizer prices are already very high above the threshold of affordability for many of the rural resource poor farmers. There is therefore a problem finding suitable materials to use in reducing acidity and improving the soil organic matter of the soils being cultivated.

Molasses wastewater is regularly produced by some of the industries in Kenya. Environmental pollution resulting from agro-industrial sources has become an issue of critical concern in recent years. Pollutant discharged from agro-industrial systems has been documented as one of the key non-point sources of pollution chiefly responsible for soil and water quality impairment if not well utilized. Most of this water contains substances such as organic chemicals, heavy metals, bacteria, suspended particles among others that are not useful for human consumption and are usually therefore disposed of after treatment in settling tanks. Treated molasses wastewater from food industries is utilized as irrigation water and thus suitable for amending soils such as those in Uasin Gishu County. Also the organic materials are available in bulk amounts as farm manure, pig manure and wastes from industry like food, sugar, cotton and rice. If these materials are accumulated, they may become a potential source of air, land and water pollution. The use of pig manure as a source of organic matter into the soils has been practiced since for a long time, it contains the required plant nutrients. However, few attempts have been made on utilization of molasses with pig manure and how it will impact the growth of plants. On the backdrop of the above, this study will seek solution to the utilization of wastewater and pig manure in soils amendment and its influence on the yield of cowpeas (*Vigna unguiculata*).

1.3 Objectives of the study

1.3.1 Main objective

To amend soil fertility using molasses wastewater and pig waste and evaluate its influence on soil characteristics and seed yield of cowpeas.

1.3.2 Specific objectives

The specific objectives of the study were:

1. To determine chemical composition of molasses wastewater and pig waste used in soil amendment.
2. To determine the soil chemical composition before and after amendment with molasses wastewater and pig waste.
3. To evaluate the nutrient characteristics of *V. unguiculata* seeds after amendment with molasses wastewater and pig waste.
4. To establish the seed yield of *V. unguiculata* after amendment with molasses wastewater and pig waste.

1.4 Research hypotheses

1. Soil nutrient characteristics are not affected by amendment with molasses wastewater and pig waste.

2. Nutrient characteristics of *V. unguiculata* seeds are not affected by amendment with molasses wastewater and pig waste.
3. Seed yield of *V. unguiculata* is not affected by amendment with molasses wastewater and pig waste.

1.5 Justification

Due to increase in population, there is overexploitation of resources such as land, forest and water. This has led to increased environmental concern and decline in food production in the country. Land as a resource especially agricultural land is reducing day by day. There is need to maximize production per unit area (Okalebo, 2009) to meet the growing demand for food. The cost of inorganic fertilizers is high and most middle income farmers cannot afford. These fertilizers also lead to decreased organic carbon and increased acidity in the soil which make production of acid sensitive crops to decline as experienced by farmers in Uasin-Gishu. This problem can be curbed by use of environment friendly fertilizer which supply the nutrients required by the plants, add organic carbon, reduce soil acidity and are locally available

A better understanding of the principal problems of soil fertility and the applicable remediation techniques is of great significance in enhancing agricultural production and soils improvements. To curb this environmental deterioration arising from agricultural production, best management practices and remediation techniques have been evaluated and recommended.

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil fertility problems in Africa

Declining agricultural productivity is a matter of concern in many sub-Saharan African countries, Kenya included. Productivity declines over the last two decades have resulted from soil erosion and degradation of agricultural land among other factors. Access to land has become increasingly constrained in smallholder agricultural areas that were formerly land abundant, while declining agricultural productivity has greatly contributed to rural poverty, which further exacerbates soil degradation (Kabubo-Mariara, 2007). A set of factors condition this vicious circle of declining productivity, poverty and degradation (Mäler, 1997).

With land abundance, many African farm households traditionally responded to declining land productivity by abandoning existing degraded pasture and cropland and moving into new lands (Kabubo-Mariara, 2007). Today, access to land in Kenya and many other African countries has become increasingly constrained in smallholder agricultural areas that were formerly land abundant (Byiringiro and Reardon, 1996). For land scarce countries, the long-term growth in food and cash crop production necessarily depends upon increased yields from land already under crops. Gebremedhin and Swinton (2003) argue that production will have to increase in such a way that future production capacity of natural resources is enhanced rather than diminished. The biggest challenge currently facing the Kenyan government is how to enhance soil fertility and improve food crop production so that food output can keep pace with population growth without increasing the land devoted to food crops. But in Kenya, available evidence indicates that poor farming practices and inadequate conservation measures, aggravated by rapidly increasing human and livestock populations have contributed to soil fertility degradation (Kabubo-Mariara, 2003, 2005a).

Under the hot and humid tropical environment, weathering of soils has been rapid; thus, large areas of Ultisols and Oxisols occur in African regions (Motavalli, 1997). The inherent poor chemical properties of Ultisols and Oxisols pose problems for agriculture in these regions. The fertility of these soils is often limited by the properties brought about by the high iron and aluminum contents, low activity clay, and low organic-matter content (Taluk and Medeiros, 1989, 2009). Much rain and high temperature in Africa is also influence organic matter decomposition, which may also release H^+ ions that acidify the soil and increase exchangeable Al to toxic levels that limit root growth in the subsoil. Another general problem with soils of the tropics is the deterioration of soil physical conditions. The degradation can take many forms, and has a variety of consequences including low fertility status due to poor soil quality (Lal and Pierce, 1991).

In addition to its slow release nutrient capability, organic matter is largely responsible for aggregation, soil moisture holding capacity and other improved physical properties of the soil. Thus, increasing soil organic matter content must be the first step in any farming practice (Alva *et al*., 2000). If productivity is to be maintained, an agricultural system able to preserve a satisfactory physical condition in the soil must also be developed. Kang and Juo (2007) stated that the continued productivity of the soils in the tropics depends largely upon the replenishment. Hence, a good supply of soil organic matter makes it safe to apply rather large applications of fertilizer at planting time and thus avoid the need for a second application. Nyamangara *et al*. (2003) reported that the organic waste (composted manure) application even enhanced the use efficiency of mineral N fertilizer by crops when the two were applied in combination.

Micronutrients may be satisfactorily supplied by decomposing organic matter. This is especially true during the production of crops that have specific micronutrient needs. For instance, it may be necessary to supply boron in the fertilizer for crops on a boron deficient soil, because its need for the element is quite high. Other micronutrients may be likewise furnished from decomposing organic matter. This is because decomposed organic matter (humus) possesses chelating properties. These properties bring about covalent bonding between the organic matter and ions of copper, zinc, manganese, and iron. In alkaline soils or in acid soils after liming, such metallic nutrients remain in solution and in a state of availability to plants. This is because composted organic matter has the potential to reduce the pH to an acceptable level where soils are alkaline (Rainbow *et. al*, 2002).

Among the practices recommended for improvement of the soil quality and soil fertility in tropical regions is the application of organic wastes, which slowly release significant amounts of nitrogen and phosphorus (Muse, 1993; Zibilske, 1987; Eghball, 2001). Frequently, the regular use of organic material (compost) is a prerequisite for sustained upland soils with inherent low natural fertility (Schoningh and Wichmann, 1990). As reported by Nyamangara *et al*, (2003), management of soil organic matter by using composted organic waste is the key for sustainable agriculture. Increasing soil organic matter has the added benefit of improving soil quality and thereby enhancing the long-term sustainability of agriculture (Laird *et al*, 2001).

Manure does several things to benefit the soil that synthetic fertilizer cannot do. First, it adds organic matter, which improves the way water interacts with the soil. In sandy soils, compost acts as sponge to help retain water in the soil that would otherwise drain down below the reach of plant roots, protecting the plant against drought. In clay soils, compost helps to add porosity to the soil, making it drain easily so that it does not stay waterlogged and does not dry out into a bricklike substance. Compost also inoculates the soil with vast numbers of beneficial microbes (bacteria and fungi) that promote biological activity of the soil (Muse, 1993; Zibilske, 1987). These microbes are able to extract nutrients from the mineral part of the soil and eventually pass the nutrients on to plant (Johnson, 1996). Furthermore, properly processed compost reduces soil borne diseases without the use of chemical control (Rynk *et.al*, 1992). The disease suppressing quality of compost is just beginning to be widely recognized and appreciated. Farm fields treated with compost are also less prone to erosion. High quality compost will do more for soil fertility and soil quality than commercial fertilizer.

The use of composted organic waste as fertilizer and soil amendment not only results in an economic benefit to the small-scale farmer but also reduces pollution due to reduced nutrient run-off, and N leaching (Nyamangara, 2003). Most farmers will be able to adopt the composting technology by participating in programs of research or demonstration of technologies. This provides them the means to accept the technology.

The above discussion indicates that a given waste material must be evaluated for both its beneficial components and negative impacts within the context of a specific land use and crop performance objective. Given the variety of waste material types available, it was desirable to conduct a side-by side comparison in order to evaluate each material's impact on crop performance under the same environmental and soil conditions. Multiple investigations have documented the impact of organic amendments in agricultural systems (Rynk *et al*, 1992). In many cases, poor quality soils represent a completely destroyed soil-plant ecosystem. Restoration of these sites provides a unique opportunity to study the development of newly placed soils and associated succession of plant communities as modified by organic amendments (Egball, 2001).

2.2 Amendment of degraded soils

Soil amendment is often undertaken on highly porous, leached soils. It may correct deficiencies in fertility and moisture retention, adsorb otherwise mobile contaminants such as phosphorus, improve soil structure by the addition of compost, alter soil pH or foster ion exchange (Acosta-Martinez and Harmel, 2006). Amendment materials are generally the by-products of activities such as water treatment, mineral processing, energy conversion, intensive animal holding or crop harvesting. The use of waste materials as soil amendments has received increased attention in recent years for agronomic applications as well as soil reclamation projects. Adding these materials to soils can be viewed as serving a dual purpose of disposal of solid waste from municipalities and agricultural operations and a means to improve chemical and physical soil properties. This in turn promotes improved crop performance (Acosta-Martinez and Harmel, 2006).

A variety of materials have been investigated for their suitability as soil amendments. For example, applications of composted municipal solid waste and composted crop residues were shown to increase soil fertility and improve structural stability in agricultural soils (Tejada *et al*., 2011). Similarly, municipal biosolids have been used to improve soil chemical and physical properties in numerous studies. Farmyard manures (FYM) can increase water holding capacity and porosity but have also been shown to reduce crop performance due to nitrogen immobilization (Campbell *et al*., 2006). For this reason, FYM can be used as a means to reduce C: N and maintain nitrogen availability (Brown *et al*., 2005). Others have utilized agricultural limestone or wood ash in biosolids mixtures to reduce metal bioavailability (Brown *et al*., 2005). The chemical properties of the waste material can also have significant impacts on crop performance. For example, high nitrogen content favors fast-growing grass species which is often desirable for reclamation and re-vegetation projects (Glanville *et al*, 2004).

The use of organic soil amendments has been associated with desirable soil properties. These include higher plant available water holding capacity, cation exchange capacity and lower bulk density. This can foster beneficial microorganisms (Doran, 1995; Drinkwater *et al*., 1995). Benefits of compost amendments to soil also include pH stabilization and faster water infiltration rate due to enhanced soil aggregation (Stamatiadis *et al*., 1999). Soil chemical characteristics are affected by soil amendment and production system. For example, at the Rodale Institute, long-term legume-based and organic production systems have resulted in an increase in soil organic matter and reduced nitrate runoff (Drinkwater *et al*., 1998). Soils in organic production systems lost less nitrogen into nearby water systems than did conventional production systems (Liebhardt *et al*., 1989). The amount of soil nitrogen in fields under conventional production systems has been negatively correlated with soil microbial components, whereas soil nitrogen in fields under organic production was positively correlated with soil microbial components (Gunapala and Scow, 1998). Yields of crops grown in organic and conventional production systems can be equivalent. Vegetable fields under organic production in California produced yields equal to those under conventional production (Drinkwater *et al*., 1995; Stamatiadis *et al*., 1999).

Long-term research in Pennsylvania has also demonstrated little difference in yields between conventional and organic production systems (Drinkwater *et al*., 1998). Limited field studies have been conducted to determine the impact of soil amendments on microbial communities in actual organic and conventional production systems in the fields (Drinkwater *et al*., 1995; Gunapala and Scow, 1998). However, it has been shown that microbial activity and biomass is higher in fields with organic amendments than fields with conventional fertilizers (Drinkwater *et al*., 1995). Many studies on soil microbial communities, as affected by organic amendments, have examined functional groups, or classes of organisms, while few studies have examined the impact on community composition and genera within these groups. One such study in organic tomato fields in California found that suppression of corky root disease was associated with increased actinomycete activity (Workneh *et al*., 1993; Workneh and van Bruggen, 1994).

2.2.1 Use of industrial wastewater in soil amendment

Wastewater contains large quantity of soluble organic matter and plant nutrients. It has very high biological oxygen demand, chemical oxygen demand and electrical conductivity. Wastewater management in the agro-industries has always been a complex problem. Even though direct application of wastewater to the soil would return the nutrients to the soil, its continuous application to the soil may be harmful. Suitable management system needs to be evolved for the application of effluent to the soil without causing deterioration in the quality of the environment. Muhoroni Agro-Chemical and Food Company (ACFC) is a sugar based industry which generate large volumes of wastewater which is rich in various elements.

One of the logical solutions for management of the industrial wastewater is bio-composting, besides applying directly to the fields. Bio-composting is therefore an eco-friendly process where wastewater are re-cycled and reused as a source of nutrients for crop production in sustainable manner. Scientists are concerned about how best these wastes could be disposed off on the agricultural land (Ensink *et al*, 2002). For proper utilization and/or disposal of wastewater, it is therefore necessary to understand their chemical composition and their effects on soil proiperties and crop production.

In Kenya, it is estimated that wastewater generated is directly used for irrigating negligible proportion of the land (Ensink *et al*., 2004). The crops grown in suburban areas while using wastewater include vegetables and fodder crops because they fetch high prices in nearby urban markets. The quantities of N and K are quite sufficient for any crop while that of P is low and would need to be supplemented in P deficient soils.

In another study conducted at Haroonabad (Pakistan), up to 2030, 1110 and 1580 kg ha^{-1} of N, P and K, respectively, per cropping season were added to the soils when crops were irrigated with wastewater (Ensink *et al*., 2002). Efficiencies of nutrients (excess of nutrient above the recommended rate) applied through wastewater irrigation ranged from 140 to 920 for N, 20 to 790 for P and 125 to 930% for K, depending upon the crop type and amount of wastewater (Ensink *et al*., 2002). This estimated pollution indicates that wastewater application to most of the crops may exceed N and P fertilizer needs over the growing. When plant nutrient needs do not coincide with irrigation needs, the presence of nutrients in irrigation water may be problematic. For example, ill-timed and over fertilization with N can cause excessive growth, encourage weed growth, increase chances of lodging and thus reduce crop yield (Asano and Pettygrove, 1987; Bouwer and Idelovitch, 1987). Yield and its quality have been harmed by excess N in many crops, including tomatoes, potatoes, citrus, and grapes (Bouwer and Idelovitch, 1987).

In Kenya, a large amount of wastewater generated from agro- industries is discharged either on land or into the running water. The wastewater is dark brown in colour having unpleasant odour with high chemical oxygen demand, biological oxygen demand and electrical conductivity besides appreciable quantities of plant nutrients. Its disposal without treatment would cause pollution of soil, water and air. Orlando *et al.* (1985) studied soil applied with wastewater for 20 years in Brazil and found beneficial effects in terms of pH, increased availability of K, Ca, and Mg contents along with increased cation exchange capacity of the soil.

Instances of large scale mortality of fish in river Gomti due to industrial effluent had been reported by Joshi (1994). Addition of wastewater leads to build up of salinity in clay loam and silty clay. Cruz *et al.* (1991) of Brazil studied the impact of wastewater application on soil and groundwater. Over 5 samples were collected at depths of 25, 75 and 150 cm. These results showed that the organic material added with wastewater mineralizes rapidly increasing N, P, Ca and S contents and increasing soil fertility. Nutrients reached the groundwater, but not at levels harmful to human health.

Wastewater from Muhoroni ACFC resulted in high concentration of organic matter and salts in River Nyando. This has been responsible for increased pH, biological oxygen demand, chemical oxygen demand and total dissolved solids in river water (Raburu, 2003). Impact of sugar mill and industrial effluents on water quality of River Nzoia, during the operational periods of the mill and also after its closure have been studied during the year 1990-91 by Achoka (1998). The effluent added high concentration of organic matter and was responsible for the deterioration of the river water quality. The same results were reported by Joshi *et al.* (1994).

Anilkumar *et al.* (2003) studied the effect of industrial wastewater on some soil characteristics and water. The effluent from Sri Sadilal Industrial situated at Mansurpur (Dist: Muzafarnagar) falls into the river Kali. Soil samples were collected very near to effluent channel and away from the channel. Comparison of the water and soil characteristics revealed that the wastewater was highly. As the wastewater along with river water moved down the stream, its organic load reduced substantially. Soil samples collected from effluent fed fields showed higher salinity and organic matter content compared to the soil without being fed with effluent.

2.2.2 Characterization of molasses industrial wastewater

Jadhav and Savant (1975) analyzed the wastewater from spentwash in India for its composition and reported as follows, pH - 8.00; EC - 31 dSm^{-1} and nutrients in percentage such as total N - 0.14, P - 0.12, K - 1.36, Ca - 0.01, Mg - 0.17 and COD - 1300 ppm. Kulkarni *et al.* (1987) stated that wastewater was major pollutant because of its high organic load. They considered wastewater as dilute liquid organic fertilizer with high K content and further reported that it contained about 90 to 93 per cent water and 7 to 9 percent solids. Seventy five percent of solids were organic and 25 percent were inorganic. Its N content was mostly in colloidal form which behaves as a slow release fertilizer and it was better than other inorganic N source. The two thirds of P were in organic form and the metabolic availability of which was more than any other important elements such as Ca, S and Mg as well as Cu, Mn and Zn. It contained in percentage, 29.1 reducing sugar, 90 protein, 1.5 volatile solids, 21.0 gums, 4.5 combined lactic acid, 1.5 combined organic acids, 5.5 glycerol and 15.0 wax and phenolic bodies.

Bhat (1994) analyzed the Industrial effluent of Ugar sugar works Ltd., Ugarkhurd and reported the pH of raw wastewater as acidic (4.03) which increased to 7.62 during lagooning. It also contained large amounts of suspended and dissolved solids having high concentration of BOD and COD. The contents of Ca, Mg and K were higher than Na. However, BOD and COD values of effluent were found to be drastically reduced by lagooning and diluting with Krishna river water. Joshi *et al.*, (1994) found that the industrial effluent contained large amounts of organic matter, N, P, K, S, Ca besides high salt load, sulfates and chlorides of K, Na and Ca. Rajukannu and Manickam (1996) reported that wastewater carried a huge organic load that is., BOD (45000 to 55000) mg/l), COD (90000 to 110000 mg/l) and total solids (80000 to 90000 mg/l).

The industrial effluent contains N, P, K, Ca, Mg and SO_4 (Devarajan *et al*., 1996). It is therefore a valuable fertilizer when applied to soil through irrigation water. The wastewater after the primary and secondary treatments can be diluted and disposed of on lands. Bio-methanated wastewater had a very high EC (29.00 dS/m) with neutral pH (7.20), sodium adsorption ratio of 4.17 and Ca, Mg, K, NO_3, HCO_3, SO_4 and Cl values were 58.88, 34.54, 170.87, 28.58, 35.00, 195.25 and 65.50 $mmoll^{-1}$, respectively. It had total N, P and K contents of 1200, 900 and 6681 mgl^{-1}, respectively. Fe, Mn, Zn and Cu contents were 61.26, 4.00, 1.17 and 0.78 mgl^{-1}, respectively. Pb^{+2}, Cd^{2+} and Ni^{2+} contents of wastewater were 0.68, 0.04, 0.70 mgl^{-1}, respectively. The wastewater had high organic load i.e., high BOD and COD 2500 mgl^{-1} and 6000 mgl^{-1}, respectively (Zalawadia *et al.*, 1997). Annadurai *et al.,* (1999) reviewed the data on characteristics of wastewater. It had a neutral reaction (6.9), alkalinity ($CaCO_3$: 491.3 mg/l), total dissolved solids (1280.0 mg/l), volatile suspended solids (113.0 mg/l) with high COD (2152 mg/l) and BOD at 200C (1002 mg/l). Wastewater contained almost all the elements and ions required by the plants such as SO_4^-, Cl, Na, K and Ca with amounts of 46.0, 18.5, 100.0, 91.0 and 438.0 mgl^1, respectively.

Analytical data of industrial effluent collected from the Coimbatore alcohols and chemicals Ltd., situated on the banks of river Bhavani were reviewed by Kailasam *et al.,* (2001). The parameters were pH (8.57), electrical conductivity (36 dS/m), total suspended solids (9200 ppm), total dissolved solids (10230 ppm), chlorides (6748 ppm), sulphates (80 ppm), BOD (1400 ppm), COD (1400 ppm), volatile suspended solids (2450 ppm) and potassium (4560 ppm). Sharma (2001) stated that potassium salts were mainly responsive for increasing the EC of the pre-treated Industrial effluent. It carries a huge organic load i.e., BOD (5600 ppm), COD (45000 ppm) and total solids (81000 ppm). The high COD of the effluent might be due to the presence of large quantity of chemicals.

Chemical composition of untreated industrial wastewater and primary treated industrial effluent was studied by Haroon and Bose (2004). There was a considerable change in chemical composition among them that is., pH: 3.8 and 8.0; EC: 30.0 and 32.5 dSm^{-1}. Total solids: 90,000 and 81,000 mg l^{-1}, nitrogen: 1500 and 1740 mgl^{-1}, phosphorus : 260 and 260 mg l^{-1}, potassium : 10000 and 11500 mgl^{-1}, calcium : 7000 and 1050 mgl^{-1}, magnesium : 3300 and 2200 mgl^{-1}, sodium : 400 and 510 mgl^{-1}, chloride : 5000 and 11200 mgl^{-1} and sulphate: 5000 and 2400 mgl^{-1} content in untreated and primary treated wastewater, respectively.

2.2.3 Use of pig waste in agricultural soil amendment

The pig industry is one of the largest and fastest growing agro-based industries in the world. Confined pig production is the major source of manure by-products in many countries. Pig litter (PL) has been traditionally applied to agricultural soils for decades as an organic fertilizer, because it is a good source of plant nutrients (Moore *et al*., 1995). The use of manure in agricultural land is beneficial to the soils properties (Olayinka, 2001) on account of their valuable ingredients and characteristics. Disposal of pig litter is one of the major concerns of pig farmers in the congested cities. Handling excess PL through burning would reduce the volume available for land application in areas of intensive pig production. The major components of PL include the bedding material, feather, manure and the spilt feed (Kelley *et al*., 1996; Tasistro *et al*., 2004). The litter contains plant nutrients, such as N, P and K, trace elements, such as Cu, Zn and As, pesticide residues, pharmaceuticals such as coccidiostats, endocrine disruptors and microorganisms. As with other organic wastes, the moisture content, pH, soluble salt level, and elemental composition of pig waste and litter have been shown to vary widely as a function of types of pig , diet and dietary supplements, litter type, and handling and storage operations. Pig litter ash (PLA) contains high level of calcium, phosphorus, potassium, and magnesium, which could be used as an effective P fertilizer for crops, although it had low levels of H_2O-extractable P (Codling, 2006). For safe and sustainable management of pig litter, it is important to evaluate and understand the concentrations of essential elements during treatments for disposal. However, the literature evaluating combusted pig litter as a source of P in sandy soil is scanty.

One of the major problems is the accumulation of large amount of wastes, especially manure and litter, generated by intensive production. It is estimated that about 44.4 million tons of pig waste was produced in 2009 year, containing 2.2 million tons of N, 0.7 million tons of P and 1.4 million tons of K (McDonald *et al*., 2009). Large-scale accumulation of these wastes may pose disposal and pollution problems unless environmentally and economically sustainable management technologies are evolved

(Power and Dick, 2000; Kelleher *et al*., 2002; Sharpley *et al*., 2007). Most of the manure and litter produced by the pig industry is currently applied to agricultural land. When managed correctly, land application is a viable way to recycle the nutrients such as nitrogen, phosphorus and potassium in manure.

However, pollution and nuisance problems can occur when manure is applied under environmental conditions that do not favour agronomic utilisation of the manure-borne nutrients (Sharpley *et al*., 1998; Casey *et al*., 2006; Kaiser *et al*., 2009). The continued productivity, profitability, and sustainability of the pig industry will likely be dependent on the formulation of best management practices to mitigate environmental consequences associated with air and water quality parameters that are impacted by land application, and the development of cost-effective innovative technologies that provide alternative to land application of pig wastes (Kelleher *et al*., 2002; Moore Jr., *et al*., 2006; Szogi and Vanotti, 2009).

Manure by-products have the potential for being recycled on agricultural land. Beneficial use through land application is based on their ability to favourably alter soil properties, such as plant nutrient availability, soil reaction (pH), organic matter content, cation exchange capacity, water holding capacity, and soil tilth. Pig waste contains all essential nutrients including micronutrients and it has been well documented that it provides a valuable source of plant nutrients (Kelley *et al*., 1996; Williams *et al*., 1999; Chan *et al*., 2008; Harmel *et al*., 2009), especially for organic growers (Preusch *et al*., 2002). Addition of pig waste to soils not only helps to overcome the disposal problems but also enhances the physical, chemical and biological fertility of soils (Friend *et al*., 2006; McGrath *et al*., 2009). For example, continuous cultivation of arable soils often results in the deterioration of soil structure leading to reduced crop yield. Addition of pig waste has been shown to improve the fertility of the cultivated soil by increasing the organic matter content, water holding capacity, oxygen diffusion rate and the aggregate stability of the soils (Mahimairaja *et al*., 1995a; Adeli *et al*., (2005).

Optimum use of manure by-products requires knowledge of their composition not only in relation to beneficial uses but also to environmental implications. Environmental concerns associated with the land application of manure by-products from intensive animal operations include leaching losses of N in sub-surface drainage and to groundwater, contamination of surface water with soluble and particulate P, reduced air quality by emission of greenhouse gases and volatile organic compounds, and increased metals input (Williams *et al*., (1999); Ribaudo *et al*., (2003); Harmel *et al*., (2004); Casey *et al*., (2006). Maintaining the quality of the environment is a major consideration when developing management practices to effectively use manure by-products as a nutrient resource and soil conditioner in agricultural and horticultural production systems, Sims and Wolf (1994); Moore *et al*., (1995); Moore Jr. *et al*., (2006). Most of the environmental problems associated with improper practices of land application of manure by-products have centered on the contamination of ground and/or surface water with two major nutrients, N and P, Sims *et al*., (2005).

Manure by-products may also contain other potentially toxic trace elements, such as arsenic, copper and zinc, which, to date; have received less attention, Bolan *et al*., (1992); Jackson *et al*., (2003); Epstein and Moss, (2006); Toor and Hunger, (2009). Edwards and Someshwar, (2000) pointed out that ‘to reduce the risk of offsite contamination, land application guidelines should be developed that consider the total composition of the manure by-products rather than only one component, that is, N and/or P concentration. On the other hand, the concentration of trace elements in pig litter and its by-products could be minimized by controlling the quality of raw feed materials and reducing mineral additives in pig diet, Van Ryssen, (2008).

The major plant nutrients in pig waste include N, P, and K, calcium, magnesium and sulphur. Some general observations on chemical composition of pig waste and litter include (i) the huge variability in nutrient concentration can be attributed to a number of factors including feed use efficiency, bedding material used, litter management practices etc; (ii) the total N and P contents of pig manures and litters are among the highest of organic amendments including manures and compost; (iii) the total N and P contents are usually lower for pig litter than for fresh manure, which is attributed to both the losses that occur following manure excretion and the dilution effect from combining manures with bedding materials that are low in nutrients; (iv) uric acid and ammonium are the significant N components of pig manures and litters; (v) the use of pig waste as a soil amendment for agricultural crops will provide appreciable quantities of essential major plant nutrients (N, P and K), secondary nutrients (Ca, Mg and S) and some of the trace elements (Cu, Zn and Mo); and (vi) application of pig waste based on crop N requirements is likely to provide more of other nutrients (especially P) than is required by the crops (Sims and Wolf, 1994; Toor *et al*., (2009); Guo and Song, (2009) .

Among these nutrients, N and P cause some environmental concerns. Four forms of N are identified in pig litter that include complex organic N, labile organic N, and ammonium and nitrate (Sims and Wolf, 1994; Diaz *et al*., 2008). Complex forms of organic N in pig litter include constituents of feathers, spilt and undigested feed, and bedding materials. Labile organic N is largely uric acid and urea. Uric acid in the fresh manure is rapidly hydrolyzed to urea by the uricase enzyme, and the urea is subsequently hydrolyzed to ammonium by urease enzyme. Nitrate is formed when the ammonium ions are oxidised during aerobic composting. Phosphorus in pig litter is about two thirds present as solid-phase organic P and one third as inorganic P (Sharpley *et al*., 2007). The amount of total P in pig litter varies with the diet and bedding material, and ranges from 0.3 to 2.4% of dry matter. Fractionation studies have shown that a large proportion of P in pig litter is in acid soluble fraction, indicating low bioavailability, Mahimairaja *et al*., (1995a). According to Turner and Leytem (2004), acid extractable P in raw broiler litter is dominated by inorganic (35 to 41%) and organic P forms (58 to 65%). Inorganic phosphate species in pig waste include dibasic calcium phosphate, amorphous calcium phosphate and weakly bound water-soluble phosphates (Sato *et al*., 2005), while organic P in pig litter is largely in form of phytic acid salts , Turner and Leytem, (2004).

Continuous cultivation of arable soils results in the deterioration of soil structure leading to reduced crop yield. For example, in the Manawatu region of New Zealand, continuous cultivation of maize has resulted in the deterioration of the physical conditions of the soils. A plant growth experiment was conducted in which the effects of pig waste on the physical fertility of the cultivated soil and the growth of maize crop were examined. A soil that has undergone continuous cultivation of maize for 34 years and a pasture soil were used in the study. Pig waste was compared with urea at an application level of 300 kg N/ha, Bolan *et al*., (1992). The addition of urea and pig waste increased the dry matter yields of the maize crop in both cultivated and the pasture soils. In the pasture soil, there was no significant difference in dry matter yields between the pig waste and the urea treatments. However, in the case of the cultivated soil, pig waste achieved greater yields than the urea treatment.

Addition of pig waste achieved similar dry matter yields in the pasture and the cultivated soils. The results indicated that improving the chemical fertility status of the cultivated soil alone through chemical fertilizer input is not enough to achieve the potential maximum yield of maize crop in these soils. Addition of pig waste decreased the bulk density, increased the organic matter content, water holding capacity, oxygen diffusion rate and the aggregate stability of the soils. The effect of pig waste on these physical properties was more pronounced in the cultivated soil than the pasture soil. These results indicate that the addition of pig waste improved the physical fertility of the cultivated soil leading to increased maize growth. Compost products, including pig litter, are used commonly as a mulching material for agricultural and horticultural crops to conserve soil moisture and to protect the surface feeding roots from drying during the summer periods Eneji *et al*., (2008); Agbede and Ojeniyi, (2008). Similarly the application of pig litter has been shown to improve the biological fertility of mine tailings. Organic manures, such as pig litter, are increasingly being used in the rehabilitation of disturbed land resulting from mining and other industrial activities, Franzluebbers and Doraiswamy, (2007).

2.3 Effect of amendment of wastewater on soil nutrient properties

Wastewater as an industrial waste is posing disposal problem. Wastewater contains many useful elements and can be profitably re-cycled to improve soil fertility, Bore

(2009). Wastewater treated optimally can be used as an effective fertilizer as well as irrigation source. Regular application of Industrial effluent may affect soil physical and chemical properties *viz*., infiltration rate, hydraulic conductivity, water retention capacity, electrical conductivity, pH, availability of nutrients and also results in adverse effects on microbial biomass and population which might alter the fertility status of the soil.

Nunes *et al.*, (1981) reported that increasing levels of wastewater application did not alter total N, organic carbon and exchangeable Na contents but exchangeable K, Ca, Mg contents were increased whereas, exchangeable aluminium, available phosphorus and nitrate nitrogen contents decreased.. The available nutrients were also increased with effluent irrigations, the available N from 276 to 412, available P from 21.0 to 34.0 and available K from 700 to 2400 kg ha^{-1}. The mineralization of organic materials and the nutrients present in the effluent were responsible for the increase in the availability of plant nutrients (Somashekar *et al.*, 1984). Mattiazo and Ada Gloria (1985) found that organic matter oxidation brought out by microbial activity was responsible for increased pH when soil was treated with industrial effluent. The electrical conductivity of the soils also increased significantly with effluent irrigation. The organic carbon content of the soils increased significantly with effluent irrigations which might be due to the fact that the effluent contains high organic load. The available N, P, K, Ca, Mg and micronutrient contents of the soils, in both the seasons, were significantly increased due to effluent irrigations. Scandaliaris *et al.*, (1987) pointed out that application of wastewater to soil increased soil NO_3--N availability, EC and interchangeable potassium.

Taluk and Medeiros (2009) also observed increased soil pH, available N, P, K, Ca and Mg due to the application of 80 m^3 substances to treat wastewater per hectare. Irrigation to cane field with industrial effluent had a tendency to increase exchangeable calcium. Mbagwu and Ekwealor (1990) stated that increased levels of Industrial effluent application resulted in increased mean weight diameter water stable aggregates (1.6 to 2.2 mm), moisture retention (17.2 to 20.3 per cent) as well as available water holding capacity of soil (14.7 to 18.3 per cent). Sweeney and Graetz (1991) reported that the digested industrial effluent application increased concentrations of most elements particularly K in soil. The decreasing trend of infiltration rate (IR) was noticed with effluent irrigations. However, the drop in IR was marginal at 50 and 40 times dilutions (33.4 and 31.2 cm/hr) when compared with water (33.8 cm/hr). The infiltration rate of the soils was significantly reduced with effluent irrigations, in both the seasons. The reduction was marginal (5.2 per cent) at 50 times dilution and appreciable (54.5 per cent) at 10 times dilution.

Shinde *et al.* (1993a) observed increased EC of saturation paste extract and available K in soil when applied with wastewater solids. Further, it increased available N, P and extractable Fe, Mn and Zn in the soil at the harvest of sorghum. Zalawadia and Raman (1994) studied the effect of effluent on changes in fertility status of clay soil of Gujarat. They recorded higher values of electrolyte conductivity, organic carbon, available N, P and K with the usage of effluent water than with normal water at the same level of fertilizer application. Irrigation with treated industrial effluent to molases soil under varying dilutions significantly altered the microbial load in the rhizosphere. The population varied with period under effluent irrigation and the peak was recorded in the fifth month. The microbial population was found to be high in the soil that was irrigated with 50 times diluted effluent, Zalawadia and Raman (1994)).

Singh *et al.*, (1997) stated that effluent irrigation decreased the rate of infiltration and bulk density of soils which are favorable traits for sandy soils. Whereas, Pathak *et al.*, (1999) noticed improved saturated hydraulic conductivity, bulk density and volumetric water content of soils with effluent application. Application of diluted industrial effluent in 1:10 and 1:20 ratio recorded higher cane yield of 129.5 and 122.3 tonnes per ha, respectively over 1:30, 1:40 and 1:50 dilutions at molasses research station, Cuddalore. There was general build up of organic carbon, soil available N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu nutrients including sodium. There was remarkable addition of 170 and 155 kg of K per ha due to the application of effluent 1:10 and 1:20 dilution, respectively. There was an increase in organic carbon (0.14 per cent), N (48 kg), SP (4.4 kg) and K (170 kg) in molasses crop receiving 1:10 diluted effluent irrigation (Pathak *et al.*, (1999)).

2.4 Response of crops to application of wastewater and manure

Field experiments were conducted by Devarajan *et al*. (1994) to study the effect of one time application of treated undiluted Industrial wastewater @ 25, 50, 125, 250 and 500 t ha^{-1} before planting. Results revealed that all the levels of wastewater addition recorded significantly higher cane yield than control. The highest cane yield of 155.8 t ha^{-1} was recorded with the application of 125 t ha^{-1} wastewater followed by 148.9 t ha^{-1} at 25 t ha-1 wastewater applications.

Similar results were reported by Mallika (2001) who found that the application of wastewater @ 150 t ha^{-1} produced higher grain yield of maize (5.85 t/ha) and sunflower (2.42 t/ha) than either higher or lower rates and these yield levels were significantly higher than recorded on addition of recommended dose of fertilizers. A field experiment conducted during the rainy season in Bhopal revealed that industrial effluents (bio-methanated and raw wastewater) did not affect the oil content, crude and true protein (percent) contents in groundnut but, increased the seed yield. Biomethanated wastewater produced the highest seed yield (619 kg/ha) followed by raw wastewater (557 kg/ha) and these yield levels were higher than the recommended level of NPK, Singh *et al*., (2004).

2.5 Botany and ecology of cowpea

2.5.1 Historical and current status

Vigna unguiculata is one of the highly appreciated species of African leafy vegetables. It is an important food legume, and its use as leafy vegetable is essential in many African countries. Its ability to withstand drought, short growing period and multi-purpose use make cowpea a very attractive alternative for farmers in marginal, drought-prone areas with low rainfall and less developed irrigation systems (Hallensleben *et al*., 2009). Cowpea an annual legume, is also commonly referred to as southern pea, blackeye pea, crowder pea, lubia, niebe, coupe or frijole. The country of origin is uncertain. Vavilov (1951) thought it might be India, with secondary centres in China and Ethiopia. Recent workers believe it to be of central African origin. It is widespread throughout the tropics and most subtropical areas. In the southern United States it is chiefly used as a grain crop, for animal fodder, or as a vegetable.

The history of cowpea dates to ancient West African cereal farming, 5 to 6 thousand years ago, where it was closely associated with the cultivation of sorghum and pearl millet. Worldwide cowpea production has increased dramatically in the last 25 years. United States production of dry cowpea has declined from 3/4 million acres to a few thousand over the same period. Dual-purpose cowpea production offers versatility by utilization of both foliage and seeds from the same crop (Bubenheim *et al*., 1990). Growing of dual-purpose cowpea can contribute greatly towards meeting food requirement of many people especially in areas where food security and malnutrition are a major challenge. Under such scenario, both cowpea leaves and grain can play an important role towards meeting the nutritional requirements of especially the resource poor families. In many areas, cowpea has been produced mainly for its protein-rich grains, popularly consumed with cereal foods. The production of cowpea as a leafy vegetable, however, appears to have increased markedly in many areas in recent years as farmers shift to more drought-tolerant vegetable crops in light of repeated droughts facing many parts of Africa (Saidi *et al*., 2007).

Despite its increasing importance, cowpea’s use as leafy vegetable in many African countries has been widely neglected in research (Barret, 1987).Although lately some research has been widely carried out on African leafy vegetables, cowpea research continued to focus on grain and/or the entire herbage for animal feed (Singh *et al*., 2003). There is paucity of information on factors that affect leaf vegetable yields, more so, on how leaf vegetable harvesting practices impact on grain yields and profitability of the different dual-purpose cowpea-based production systems. Few studies have been conducted on the effect of leaf harvesting on grain and biomass yields. Most of these studies, however, tended to focus on intensity of defoliation, hence targeting even leaves that were past the consumable (young/tender) stage as leafy vegetables in the defoliation intensities (Wien and Tayo, 1978), did not use germplasm selected for dual-purpose production (Karikari and Molatakgosi, 1999) or were conducted under protected environment Saidi *et al*. (2007). Results from such studies may thus not be relevant to understanding how frequency of harvesting young leaves intended for consumption as leaf vegetable would impact leaf vegetable and grain yield and the profitability of dual-purpose cowpea based production systems under field condition.

2.5.2 Botanical

The Common name for the plant is cowpea. It is occasionally referred to as southern pea in United States. Saidi *et al*., (2007) has divided cowpea species into three main groups: Var. sinensis, the common cultivated cowpea, with medium length, pendant pods, and medium-sized, kidney-shaped or roundish seeds, Var. sesquipedalis: the yard long or asparagus bean, which has long pendant pods which are inflated when green and shrivel when ripe, with elongate, kidney-shaped seeds; and Var. cylindrica or catjang (Vigna catjang, Burm. Walp.): which have short, erect pods with seeds which are small, either oblong or cylindrical.

2.5.3 Description

They are herbaceous annual with twining stems varying in erectness and bushiness. Leaves are trifoliate, petioles 2.5 to 12.5 cm long. The central leaflet hastate, 2.5 to 12 cm long, smooth, lateral leaflets are irregular. Flowers are in axillary racemes on stalks 15 to 30 cm long. Pod pendulous are, smooth, with 10 to 23 cm long with a thick de-curved beak and 10- to 15-seeded. Seeds are 4 to 8 mm long, 3 to 4 mm broad, variable in size and colour (Barnard, 1969).

2.5.4 Altitude range

Usually a low-altitude plant, but will grow quite well up to 1 500 m elevation (Barnard, 1969).

2.5.5 Rainfall and temperature requirements

For forage purposes, a rainfall of 750 to 1 100 mm are preferable. Cowpea tolerates lower rainfall, but in high rainfall areas disease and insect attacks increase. The crop responds positively to irrigation but will also produce well under dry land conditions. Cowpea is more drought resistant than common bean (Duke, 1981). The plant prefers warm moist conditions, with a hotter climate than for maize or soybeans. Dart and Mercer (1965) found that a day temperature of 27°C gave optimum growth. Cowpea is sensitive to cold conditions (Johnson, M and Minson (1968) found that cowpea dropped from 33 to 14 percent of its leaves in winter. The crop is very susceptible to frost, and in frost-susceptible subtropical areas seed harvesting is usually deferred until frosts have killed and dried the top growth.

2.5.6 Soil requirements

The crop is tolerant of a wide range of soil textures from sands to heavy, well-drained clays. Heavy clays tend to encourage vegetative growth at the expense of seed production. It adapts to a wide range of pH, but prefers slightly acid to slightly alkaline soils. It has little tolerance of salinity, Johnson and Minson (1968)). Cowpea performs well on a wide variety of soils and soil conditions, but performs best on well-drained sandy loams or sandy soils where soil pH is in the range of 5.5 to 6.5, McLeod (1982).

2.5.7 Nutrient requirements and fertilizer application rate

Cowpea grows well without fertilizer in the better soils. In soils of low fertility, it responds to phosphorus and potash and often some nitrogen. Up to 10 kg/ha of nitrogen and 40 to 70 kg/ha P_2O_5 and K_2O may be needed in low fertility soils, Johnson and Minson (1968). There is a response to calcium where the pH is low but this may be a response to the released molybdenum. The table below presents the recommended rate of fertilizer for cowpea production.

Table 2.1: Recommended fertilizer rate for cowpea

Fertilizer nutrient per hectare	**Quantity equivalent in bags per hectare**	**Time for application**	**Remarks**
15 kg N	2bags compound fertilizer (NPK 15:15:150)	Applied at planting or during land preparation	This supplies 15 kg each of N, P and K
30 Kg Single supper phosphate (SUPA)	2 Bags of single super phosphate	As above	This will supply 18 kg of phosphorus

Source: IITA (2005)

2.5.8 Uses

Cowpea seed is a nutritious component in the human diet, as well as a nutritious livestock feed (Duke, 1981). . The crude protein contents in cowpea hay are 13.01 and 12.8 percent, and the digestible crude protein 7.92 and 8.70 percent respectively. The seed contains 24 percent crude protein, 53 percent carbohydrates and 2 percent fat.

The protein in cowpea seed is rich in the amino acids, lysine and tryptophan, compared to cereal grains; however, it is deficient in methionine and cystine when compared to animal proteins. Therefore, cowpea seed is valued as a nutritional supplement to cereals and an extender of animal proteins (Duke, 1981). Cowpea can be used at all stages of growth as a vegetable crop. The tender green leaves are an important food source in Africa and are prepared as a pot herb, like spinach. Immature snapped pods are used in the same way as snap beans, often being mixed with other foods. Green cowpea seeds are boiled as a fresh vegetable, or may be canned or frozen. Dry mature seeds are also suitable for boiling and canning. In many areas of the world, the cowpea is the only available high quality legume hay for livestock feed. Cowpea may be used green or as dry fodder. It is also used as a green manure crop, a nitrogen fixing crop, or for erosion control. Similar to other grain legumes, cowpea contains trypsin inhibitors which limit protein utilization.

2.5.9 Cultural Practices

Seedbed Preparation**:** Cowpea performs best if treated as a crop sown on a well-prepared seed bed. The crop however, establish quite well on a roughly prepared seed bed from an initial ploughing or disc harrowing. The large seed helps in establishment.

Sowing methods: Cowpeas may be sown broadcast on rough seed beds or be drilled into well-prepared ground in rows 50 to 75 cm apart. Maize planters with cowpea plates are usually used. It is often sown in maize crops at the time of the last inter-row cultivation. Seed is sown at from >.5 to 7.5 cm, the latter being preferable, from spring to mid-summer where frosts are likely; it is sown later in frost-free areas. Early sowings give higher yields. Sow 17 to 39 kg/ha drilled or 45 to 95 kg/ha broadcast (Singh *et al*., 1997)

The table below show recommended seed rate for cowpea planting. It is based on recommended plant spacing which is determined by cowpea type.

Table 2.2: Seed rate/ha based on recommended plant spacing.

Cowpea type	**Maturity**	**Spacing (cm)**	**Quantity of seeds/ha**
Erect	Extra-early	50 × 20	25 Kg
Semi-erect	Early/medium	75 × 20	20Kg
Prostate (creeping)	Medium/late	75 × 30	16Kg
Prostate	Late	75 × 50	12Kg

Source: (Singh *et al*., 1997)

The criterion which is used to select a cowpea variety for a particular environment is shown in the table 2.3 below.

Table 2.3: The criteria used when selecting a cowpea variety for a particular environment

Production limitation	**Variety to use**
Drought	Drought tolerant and early maturing
Heat	Heat tolerant
Striga infestation	Striga resistant
Short rainfall	300-500 mm/yr
Extra-early and early maturing	Look out for varieties that have a maturity period that falls within 60-80 days
Pests and diseases	Resistant to some major pests and diseases

Source: (Onyibe *et al.*, 2006)

Weed control: adequate weed control was necessary for good growth and high yields. This was done mechanically and chemically. Cowpea can compete fairly with low growing weeds, but not with tall ones such as *Targetes minuta*. it is preferably given one or two inter row cultivations if seed has been rown-sown.

Diseases and their Control: Cowpea are affected mostly by stem and root rots and some pod infections. *Phytophthora vignae* is most important in Australia. Breeding programmes aim at resistance to this disease. Fusarium wilt, septoria leaf spot and mildew are common. The best way to prevent large yield losses from virus diseases is to grow tolerant varieties, Onyibe *et al.*, (2006).

Harvesting: Cowpea can be harvested at three different stages of maturity: green snaps, green-mature, and dry. Depending on temperature, fresh-market (green-mature) peas are ready for harvest 16 to 17 days after bloom (60 to 90 days after planting). Harvesting is usually done by direct heading after the tops of the plants have died, especially in erect growing crops. For prostrate or trailing varieties, the crop can be mown when two-thirds of the pods are dry and rattle when shaken (in some varieties). The vines should be thoroughly dried before threshing by stationary or pick-up harvesters. Hand picking of pods a number of times during the season gives the highest yields; they can be threshed by flailing in bags or by machine. Stored seeds must have a moisture content of 14% or less. Seed treatment with palm, groundnut, or coconut oil protects seeds during storage (CABI; 2000, 2004). Stored seeds are extremely susceptible to insect infestation.

2.5.10 Seed yield

Average yield is about 750 kg/ha but reaches as high as 2 800 kg/ha. Gill and Batra (1968) found that cowpeas gave the best seed yield with less than 200 to 250 mm rainfall during growth.

2.6 Summary

This review examines the composition of wastewater and pig litter in relation to nutrient content, its value as a nutrient source and soil amendment to improve soil fertility. It can be summarized from the review that wastewater and pig litter provides a major source of N, P and trace elements for crop production. It is very effective in improving the physical, chemical and biological fertility, indicating that land application remains as the main option for the utilization of this valuable resource. The review makes it clear that there is paucity of information on the combined role of wastewater and pig litter on the composition of soils, and on crop yield in acidic soils. More importantly, there is lack of information on the role of the wastewater and pig waste in Cowpea production in Kenya and in many other parts of the world making the current study useful.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Field experiments

3.1.1 Study area

The study was conducted at the University of Eldoret (0°34′13.8″N and 35°18′49.8″E) in Uasin- Gishu County, Kenya which lies at about 2140 m above the sea level. The county receives mean annual rainfall of about 900-1300 mm and has a mean annual temperature of 25^0C (Jaetzold and Schmidt, 1983). The soils are classified as rhodic ferrasol, (FAO/UNESCO, 1974) and are of igneous origin. They are acidic with pH value of 4.85, low fertility and low water holding capacity. The experiments were done in the field and under greenhouse conditions for two seasons. Season 1 plants were planted on April 2011 and harvested in August 2011. Season 2 planting was done on August 2012 and harvested on November, 2012.

3.1.2 Materials and treatments

One species of cowpea (M 66) was used. A total of eight treatments were used and each treatment was replicated three times in randomized complete block design to obtain 72 plots. The treatments used were pig waste (PW), molasses wastewater (WW), di-ammonium phosphate (DAP) and NIL (Control). The molasses wastewater which had undergone all stages of treatment and was obtained from Muhoroni Agrochemicals and Food Company (ACFC), pig waste was from University of Eldoret farm and DAP from an agro-vet shop.

The pig waste and molasses wastewater were analyzed for chemical composition prior to application. Various methods were used which included atomic absorption spectrometry (AAS) for heavy metals, flame photometer for potassium and sodium and colorimetry for nitrogen and phosphorous. The elements tested include nitrogen, phosphorous, potassium, magnesium, calcium and organic carbon. Heavy metals analyzed include Cu^{2+}, Zn^{2+}, Cd^{2+} and Cr^{3+} ions. DAP applied was 18: 46: 0 which is equivalent to 46% P_2O_5 .This was the source of phosphorous. The rate of P levels was maintained at the rate of 18 kg/ha which is the recommended rate for cowpeas. Cowpeas were chosen for the experiment because it is traditional vegetable and certified seeds can easily be found.

3.1.3 Land preparation

After site allocation, the land was first cleared to remove some weeds. It was then ploughed for the first time. After two weeks, second ploughing proceeded to attain the correct soil texture for planting. When the land was ready for planting, it was sub-divided into complete blocks each measuring 3 m by 3 m. A spacing of 1 m was left between one block and another while 0.5 m was left between the divisions in a block.

3.1.4 Treatment application and planting

When land preparation was complete, planting holes were dug using the recommended spacing of 50cm by 20cm (Singh, *et al.,* 1997). This spacing gave 90 plants per division. The fertilizers were applied at the rate of P requirement of the plant. This was done by weighing the 300g WW, 180g PW and1g DAP where they were used singly. In case of combinations of two, half the amounts were weighed and mixed and a third for three combinations. The weighed fertilizer was placed in the holes then mixed thoroughly with the soil. The cowpea seeds were planted in the holes.

3.1.5 Diseases, pest and their control

The cowpeas were affected by leaf rust which is a fungal disease and was prevalent during the cold weather. The disease was controlled by spraying with rindomil two times before flowering. There was no other disease which affected the cowpeas.

Apart from the leaf rust, the cowpeas were infested by aphids, especially during flowering in hot weather. They were controlled by spraying with dithane. Another pest though not serious was some type of birds which feed on cowpeas especially during the first two weeks of germination. The birds were controlled by use of scare crow and sometimes physically chasing them away.

3.1.6 Data collection

Rate of germination: The number of plants that germinated was determined by the formula;

$$\frac{x}{y} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. eqn\ [1]$$

x - Number of plants that germinated and y- Number of seeds sown.

Plant survival was determined using the formula;

$$\frac{z}{x} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ [2]$$

z - Number of plants per plot at harvest and x- number of plants that germinated

The plant height, leaf length and leaf width were determined by taking at random 10 plants in each plot. A 30cm ruler was used to take the measurements. The measurement for the above parameters was averaged and the averaged value recorded. The first measurements were done 2 weeks after germination and the subsequent ones after every 2 weeks. This was done for the 2 seasons. Six measurements were made in both season 1 and 2.

Pods and seeds: The number of pods per plant was determined by taking at random 10 plants per plot and the pods counted. This was done at harvest. After harvesting, 20 pods were picked at random from each plot, shelled and seeds counted and averaged to estimate the average number of seeds per pod in different treatments.

Seed yield: After harvesting the seeds were air dried to obtain moisture content of 13%. The weight of seeds was measured using electrical balance graduated in grams. The yields were calculated using the formula;

$$\frac{Y}{A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eqn}\ [\mathbf{3}]$$

Y - Yield in kg in 3m by 3m and A – area of the plot.

This gave yield per unit area. The yields can also be converted into yields per acre or hectare by multiplying the yields per unit area with the area of an acre or the area of a hectare.

After the seeds had been dried, 50 seeds from each plot were sampled at random and weighed using electrical balance graduated in grams.

3.2 Soil and seed sampling and preparation for laboratory analysis

The soil samples were taken from each plot using systematic quadrat method to depth of 20 cm using soil auger just before the start of the experiment. Another soil sample was taken immediately after harvesting .The pH of the soil samples in each case was determined immediately using pH meter. The pH of the soil receiving different treatments was determined 4 weeks after planting and immediately after harvesting. The soil samples were air dried and crushed to attain mesh size of 2mm.The soil samples where total N and OC were to be determined were crushed to attain size which could pass through 60 mesh screen (soil particle size less than or equal to 0.3 mm). The soil samples prepared were analyzed for total %N, OC%, available P, K%, Ca and Mg.

Dry harvested cowpea seeds were further dried to attain a moisture content of 13% by placing containers in forced-air oven and dry at 80^{o} C for 12 to 24 hours. After drying, samples were ground to pass a 1.0-mm screen (20 mesh). After grinding, the samples were thoroughly mixed and a 5g aliquot withdrawn for analyses and storage.

3.2.1 Soil pH (2.5:1 in H_2O)

Ten grams of soil sample was placed in a 60ml beaker and 25ml of distilled water was added. The mixture was stirred for 10 minutes and allowed to stand for 30 minutes and then stirred for 2 minutes. The pH meter was calibrated using pH4 and pH 7 buffer solutions before measuring the soil pH.

3.2.2 Colorimetric determination of N in soil and seed samples

Reagents used were, Stock Ammonium solution prepared by dissolving 3.819 grams of anhydrous ammonium chloride (NH_4Cl), dried at 100°C for 1 hour, in ammonia free water and diluted to 1 L. Standard Ammonium solution (100 mg/L) was prepared by diluting 10.0 mL of stock solution to 1 L with ammonia free water. Nessler reagent was prepared by dissolving 100 g of Mercury (II) iodide (HgI_2) and 70 g of Potassium iodide (KI) in a small amount of ammonia free water.

The mixture was added slowly, with stirring, to a cool solution of 160 g of Sodium hydroxide (NaOH) dissolved in 500 mL of ammonia free water and dilute to 1 L. This solution was stored in a rubber stoppered Pyrex bottle in the dark. Aliquot of 50 mL was Pipetted and diluted to 50 mL with ammonia free distilled water into a 125 mL Erlenmeyer flask. Boric acid absorbing solution was neutralized by adding Sodium hydroxide to pH near 7 followed by the addition of 1 mL of Nessler reagent. The Erlenmeyer flask was capped with a clean rubber stopper and mix thoroughly. The mixture was then allowed 10 minutes for color development. Sample, blank, and standards were maintained at the same temperature and color development time. Percent transmittance of the sample was measured using a distilled water blank as reference (%T = 100) at the selected wavelength of 500nm.

The concentration of nitrogen in the sample material expressed in % was calculated as;

$$N\% = (a-b) \times v \times \frac{100}{1000 \times w \times al \times 1000} \dots\dots\dots\dots\dots\dots.. eqn\ [4]$$

Where a= concentration of N in the solution, b= concentration of N in the blank, v= total volume at the end of analysis procedure, w = weight of the dried sample and al = aliquot of the solution taken.

3.2.3 Determination of total P without pH adjustment using ascorbic acid

Nitric acid (HNO_3) and Perchloric acid ($HClO_4$) was used for wet ashing.

Acid molybdate stock solution - In a 2 L volumetric flask, 125 g ammonium molybdate [$(NH_4)_6Mo.4H2O$] were dissolved in 400 mL distilled water by heating to 60^o C. The solution was then allowed to cool, then 2.9 g antimony potassium tartrate

[K(SbO)C_4H_4O.61/2H2O] dissolved in the molybdate solution. The flask was placed in an ice bath and slowly 1500 mL concentrated sulfuric acid (H_2SO_4) added. The mixture in the ice bath was slowly diluted to volume with distilled water. The solution was stored in a brown bottle at 4^o C. Ascorbic acid stock solution was prepared by dissolve 211.2 g ascorbic acid ($C_6H_8O_6$) in 1500 mL distilled water and diluted to 2 L with distilled water then stored in a brown bottle at 4 ^{o}C. Working solution was freshly prepared by adding 20 mL of the acid molybdate stock solution and 10 mL of the ascorbic acid stock solution to 800 mL distilled water, then diluted to 1 L with distilled water.

Standards solutions (1,000 ppm phosphorus stock solution) were made by dissolving 4.3937 g of dried monopotassium phosphate (KH_2PO_4) in distilled water then diluted to 1 L. Starndards of 20, 40, 60, and 80 mg P L^{-1} were made by pipetting 2, 4, 6, and 8 mL, respectively, of the 1000 mg L^{-1} stock solution into separate 100-mL volumetric flasks and diluted to volume with distilled water.

Procedure

Digestion was done by weighing 1.0000 g + 0.0005 g of dried and ground plant seeds into 150-mL beakers or 50-mL porcelain crucibles. The samples were digested using the wet oxidation procedure. The samples were quantitatively transferred into 100-mL volumetric flasks and diluted with distilled water. Color development was carried out using a dilutor-dispenser, to dilute the samples and the 20, 40, 60, and 80 mg P L^{-1} standards 1:100 with the working solution. Color was allowed to develop for 30 minutes before reading. The concentrations were read at 660 nm with a visible spectrophotometer.

Calibration and Standards

To calibrate the spectrophotometer for routine analysis, use the working solution as the blank and the developed 0.80 mg P L^{-1} standard to establish the slope of the line. To check for linearity, read the developed 0.20, 0.40, and 0.60 mg P L^{-1} standards. If the sample concentration lies above the linear working range, dilute the samples appropriately. The P in the sample was calculated as follows;

P in sample (%) = $c \times \frac{0.05}{w} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn$ [5]

Where c is corrected concentration for the sample solution, w is the weight of the sample taken.

3.2.4 Determination of K and Na in soil and seeds

K and Na ions were determined using flame test (Okalebo *et al.,* 2002). Potassium stock solution was prepared by weighing 238.35 g potassium chloride (KCl) into a 1L volumetric flask, dissolved and diluted to volume with deionized water.

Procedure

Digestion was done by weighing 1.000 g of dried ground seeds or soil into a 10-mL porcelain crucible. Place the crucible in a cool muffle furnace and ash for 4 hours at 500^oC. The crucible was removed from the furnace and allowed to cool. Five millilitres of buffer solution was added to the crucible and gently swirl to dissolve the ash. Analysis was done by transferring the digest to a teflon boat and analyzed on the direct reading arc-spark emission spectrograph.

3.2.5 Determination of organic carbon in soil and seed samples

A weigh of 0.5 to 1.0 g of dried (80^oC) seeds or soil that had been ground (0.5 to 1.0 mm) and thoroughly homogenized was made and placed in a tall-form beaker or digestion tube. Five milliliters of concentrated HNO_3 was added and the beaker covered with watch glass and allowed to stand. The covered beaker was placed on digestion tube in block digester and heated at 125^oC for 1hour then removed and allowed to cool. To the digest, 2 mL 30% H_2O_2 was added at the same temperature. Repeated heating was done and 30% H_2O_2 additions until digest was clear. Additional HNO_3 was added to maintain a wet digest. After sample digest was clear, watch glass was removed and temperature lowered to 80^oC. Continued heating was done until near dryness and a white residue left. Addition of dilute HNO_3, HCl and deionized water was done to dissolve digest residue and made to final volume. The digest solution was diluted with excess acidified $K_2Cr_2O_7$ and 0.3ml indicator added followed by titration of the excess dichromate with 0.2M ferrous ammonium sulphate (Nelson & Sommers, 1975). The end point was reached with a colour change from green to brown. The titre was then recorded and corrected for the mean of 2 reagent blanks (T). The percentage organic carbon was calculated using the formula;

Organic carbon (%) = $T \times 0.3 \times \frac{0.2}{sampleweight} \ldots\ldots\ldots\ldots\ldots..eqn$ [6]

3.2.6 Determination of heavy metals (Cu, Zn, Cd & Cr) in soils, wastewater, pig-waste and in cowpeas seeds

The analysis of the above heavy metals was done using AAS. Wet digestion was done. The standards were prepared as follows; 1000 mg Mn L^{-1} standard by weighing 1.000 g of Mn metal dissolved with a minimum of equal parts deionized water and nitric acid. Eight millimetres of 12 *M* HCl was added and brought to the final volume of 1L by addition of deionized water.

A standard of 1000 mg Fe L^{-1} was prepared by weighing 1.000 g of Fe wire and dissolved with approximately 8 mL deionized water and 8 mL of 12 *M* HCl. The final volume made to 1 L by adding deionized water. A standard of 1000 mg Cu L^{-1} was prepared by weighing 1.000 g Cu metal and dissolved with 8 mL deionized water and 8 mL of concentrated HCl. The final volume made to 1L with additional deionized water. A standard of 1000 mg Zn L^{-1} was prepared byweighing 1.000 g Zn metal ribbon and dissolved with 8 mL deionized water and 8 mL of concentrated HCl. The final volume made to 1 L with additional deionizedwater. The digests were then aspirated and subsequently introduced into an energy source. The source was anacetylene/air flame producing a temperature of about 2,300^{o}C. Absorption was calculated based upon the measured difference in light intensity passing around the flame and that passing through the flame and hence the concentration of the metals in the samples.

3.3 Greenhouse experiments

The experiments were carried out in the green house for yield comparison with those of the field. The same treatments were used as those used in the field. The soil used was dug from the field where field experiments were carried out. Two kilogram pots with diameter of 15 cm were used. The layout was the same as that of the field. A total of eight treatments were used and replicated three times. A plot was made of 8pots hence in one block there was 64 pots and when replicated 3times gave a total 192. A space of 30cm was left between the plots and 50cm between the blocks.

3.3.1 Seed yield

After harvesting the seeds were air dried to obtain moisture content of 13%. The weight of seeds was measured using weighing scale. The yields were calculated using the formula;

$$\frac{y1}{n1} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots eqn \text{ [7]}$$

Where y1 is yield per plot in kg, n1is number of plants in a block.

This gives yield per plant. The yield can also be converted into yield per acre or hectare by multiplying the yield per plant with the number of plants in an acre or the area of a hectare.

3.4 Data analysis

All statistical analyses were performed with a version of STATISTICA 10.0 (StaSoft, 2001) or Statistical Package for Social Sciences (SPSS 18.1) statistical packages. Normality and homoscedasticity of data distribution was checked by means of the skewness and kurtosis (Zar, 2001). In case where data was found not to follow normal distribution (heteroscedastic), log transformation was used to normalize all the biological data (Michael and Douglas, 2004). Difference between nutrient content of the wastewater and molasses was analyzed using independent sample t-test. Differences in the soil and nutrient characteristics among different treatments in season one and two were analyzed by One-Way ANOVA. Duncans Multiples Range Test (DMRT) was used for Post-hoc discrimination of significant means (Michael and Douglas, 2004).

CHAPTER FOUR

RESULTS

4.1 Nutrient characteristics of molasses wastewater and pig wastes used in soil amendment

The concentration of nutrients in molasses wastewater and pig wastes used in soil amendment are shown in Table 4.1. There were significant differences in the nutrient concentrations between molasses wastewater and pig wastes ($p < 0.05$) except for iron. The pH of molasses was (8.62) was significantly higher than that of pig waste (6.81). Mean Concentrations of nitrogen, phosphorus, organic carbon, and copper were found to be significantly higher in the pig waste as compared to molasses waste water. Nonetheless, wastewater had significantly higher concentration of potassium (30.63 meq), sodium (21.813 meq), magnesium (1.19 meq), and calcium (5.31 meq), iron (0.16 meq) and zinc (0.13 meq).

Table 4.1: Concentration of nutrients in molasses wastewater and pig wastes used in soil amendment.

	Molasses waste water	Pig waste	t	*p*-value
pH	8.62 ± 0.02	6.81 ± 0.07	15.642	0.001
N%	0.132 ± 0.007	0.193 ± 0.116	-12.100	0.000
P%	0.090 ± 0.001	0.141 ± 0.007	-6.545	0.015
OC%	2.781 ± 0.006	7.450 ± 0.142	-301.258	0.000
K (meq)	30.632 ± 0.024	2.360 ± 0.143	1103.730	0.000
Na (meq)	21.813 ± 0.24	7.054 ± 1.219	12.103	0.000
Mg (meq)	1.193 ± 0.113	0.118 ± 0.002	9.514	0.000
Ca (meq)	5.305 ± 0.306	1.462 ± 0.014	12.528	0.000
Fe (meq)	0.169 ± 0.111	0.057 ± 0.002	1.121	0.289
Zn (meq)	0.132 ± 0.001	0.078 ± 0.000	81.529	0.000
Cu (meq)	0.359 ± 0.004	1.031 ± 0.091	-7.449	0.000

4.2 Soil nutrient characteristics before amendment with molasses wastewater and pig waste

The initial soil nutrient characteristics before the experimental setup among the experimental plots are shown in Table 4.2. The pH ranged from 4.82 to 4.98, N(%) ranged between 0.11 to 0.15 while P(%) ranged between 0.01 to 0.06. The overall soil organic content ranged from 2.32 to 2.38 but was similar across the plots. Potassium levels ranged from 0.81 to 0.91 while sodium ranged from 0.40 to 0.45 mg. All parameters were significantly ($p > 0.05$) similar among the treatments plots.

Table 4.2: Initial soil nutrient characteristics before the experimental setup among the experimental plots

Treatments	pH	N %	P%	OC%	Kmeq	Nameq
CONTROL	4.88 ±0.01	0.11 ±0.003	0.04 ±0.001	2.33 ± 0.12	0.82 ± 0.01	0.42 ± 0.06
PW	4.83 ± 0.02	0.12±0.001	0.02 ±0.003	2.34 ± 0.13	0.88 ± 0.03	0.41 ± 0.05
WW	4.85 ± 0.03	0.15 ± 0.007	0.02 ± 0.005	2.33 ± 0.11	0.87 ± 0.02	0.42 ± 0.05
DAP	4.85 ± 0.04	0.14 ± 0.005	0.04 ± 0.004	2.35 ± 0.09	0.85 ± 0.07	0.42 ± 0.06
PWWW	4.85 ± 0.05	0.13 ± 0.007	0.05 ± 0.007	2.32 ± 0.11	0.87 ± 0.05	0.42 ± 0.04
PWDAP	4.85 ± 0.07	0.13 ± 0.006	0.04 ± 0.003	2.34 ± 0.09	0.88 ± 0.02	0.43 ± 0.03
DAPWW	4.82 ± 0.02	0.12 ± 0.009	0.04 ± 0.003	2.37 ± 0.10	0.89 ± 0.05	0.42 ± 0.02
DAPPWWW	4.97 ± 0.06	0.12 ± 0.012	0.06 ± 0.004	2.33 ± 0.09	0.89 ± 0.03	0.42 ± 0.02
F	0.797	1.179	2.214	2.071	0.072	0.786
P-value	0.601	0.986	0.102	0.108	0.994	0.609
CV(%)	2.525	2.525	4.561	9.561	5.126	11.654
Lsd	0.221	0.324	0.452	0.562	0.016	0.265

Key: The column for treatments means the soil samples were taken from the plots where those treatments were to be applied it is actually the control.

The soil nutrient characteristics in the experimental plots in season 1 and season 2 are shown in Table 4.3. An overall observation indicates that soil characteristics differed significantly between seasons 1 and 2 among all the analyzed parameters (p < 0.05) except in the control plots. In both seasons, the pH value was found to be highest in treatment WW followed by PWWW and then PW. Soil pH in both seasons after application of DAP, the levels being significantly lower in season 2 than in season 1. The N content in the soil in the two seasons was found to be highest in treatment PW followed by PWDAP, DAP and PWWW while the control had the lowest nitrogen among all the treatments. The P content of the soil in the two seasons was highest in DAP, followed by PW, then DAPPW, and DAPWW, but WW had low P (%). The trend in OC levels in the two seasons was similar albeit the higher values of P were recorded in the second season. In both seasons, highest OC was recorded in treatment PW, followed by WW, then combination DAPPWWW and then PWWW while among the treatments, OC in DAP was low, although higher than the control. Similar trends in the variation of micronutrients K and Na were observed in both seasons. The concentration of K and Na were highest in treatment WW followed by treatment WWDAP and DAPPWWW while WWPW had the fourth most abundant K and Na. Among the individual treatments, PW had the lowest K and Na which was significantly higher than the control treatment.

Table 4.3: Soil nutrient characteristics in the experimental plots in season 1 and season 2

Treatments	Season 1						Season 2					
	pH	N%	P%	OC%	Kmeq	Nameq	pH	N%	P%	OC%	Kmeq	Nameq
CONTROL	5.28 ± 0.06^{b}	0.12 ± 0.02^{a}	0.10 ± 0.03^{a}	1.81 ± 0.05^{a}	1.20 ± 0.06^{a}	0.31 ± 0.09^{a}	5.28 ± 0.06^{b}	0.13 ± 0.01^{a}	0.11 ± 0.01^{a}	2.43 ± 0.05^{a}	1.22 ± 0.29^{a}	0.32 ± 0.06^{a}
PW	6.66 ± 0.27^{d}	0.45 ± 0.02^{f}	0.25 ± 0.07^{e}	3.67 ± 0.08^{g}	1.26 ± 0.09	0.37 ± 0.08	6.14 ± 0.74^{d}	0.62 ± 0.08^{f}	0.48 ± 0.04^{f}	5.28 ± 0.29^{f}	1.46 ± 0.31^{b}	0.71 ± 0.07^{b}
WW	7.06 ± 0.03^{f}	0.23 ± 0.04^{b}	0.12 ± 0.07^{b}	3.43 ± 0.18^{f}	1.72 ± 0.09	0.94 ± 0.12	6.98 ± 0.05^{e}	0.29 ± 0.03^{b}	0.17 ± 0.04^{b}	5.15 ± 0.06^{e}	2.21 ± 0.45^{e}	1.87 ± 0.08^{i}
DAP	4.81 ± 0.06^{a}	0.35 ± 0.07^{d}	0.28 ± 0.05^{f}	2.26 ± 0.14^{b}	1.37 ± 0.16	0.49 ± 0.12	4.76 ± 0.81^{a}	0.36 ± 0.03^{d}	0.52 ± 0.02^{g}	3.23 ± 0.05^{b}	1.55 ± 0.15^{b}	1.01 ± 0.08^{c}
PWWW	6.74 ± 0.44^{e}	0.34 ± 0.04^{d}	0.15 ± 0.09^{b}	3.24 ± 0.15^{d}	1.51 ± 0.27	0.73 ± 0.16	6.93 ± 0.17^{e}	0.36 ± 0.08^{d}	0.23 ± 0.02^{c}	4.50 ± 0.13^{d}	1.89 ± 0.12^{c}	1.58 ± 0.07^{f}
PWDAP	5.85 ± 0.11^{c}	0.40 ± 0.03^{e}	0.23 ± 0.08^{d}	3.23 ± 0.05^{d}	1.42 ± 0.22	0.64 ± 0.12	6.07 ± 0.36^{d}	0.49 ± 0.01^{e}	0.36 ± 0.03^{e}	4.31 ± 0.23^{d}	1.74 ± 0.26^{c}	1.40 ± 0.07^{e}
DAPWW	6.48 ± 0.08^{d}	0.21 ± 0.06^{b}	0.21 ± 0.02^{d}	2.45 ± 0.05^{c}	1.29 ± 0.07	0.53 ± 0.13	5.91 ± 0.08^{c}	0.28 ± 0.06^{b}	0.27 ± 0.02^{d}	4.09 ± 0.12^{c}	2.08 ± 0.14^{d}	1.76 ± 0.08^{h}
DAPPWWW	6.03 ± 0.14^{c}	0.29 ± 0.03^{c}	0.17 ± 0.03^{c}	3.37 ± 0.11^{e}	1.58 ± 0.21	0.81 ± 0.18	5.98 ± 0.01^{c}	0.33 ± 0.05^{c}	0.24 ± 0.04^{c}	5.11 ± 0.17^{e}	2.02 ± 0.27^{d}	1.67 ± 0.05^{g}
F	12.7452	19.265	71.233	69.788	124.213	131.267	99.412	614.258	7854.235	511.248	235.871	301.221
P-value	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CV(%)	12.542	11.231	9.265	23.362	12.224	9.745	13.255	8.256	7.412	8.135	9.135	13.254
Lsd	1.254	0.954	2.144	0.985	0.854	1.023	1.254	1.745	1.234	1.025	0.998	2.125

Similar lettering represents concentrations that do not differ significantly ($p > 0.05$)

4.3 Nutrient characteristics of *V. unguiculata* seeds after amendment with molasses wastewater and pig waste

The seed nutrient characteristics in the experimental plots in the two seasons are shown in Table 4.4. An overall observation indicates that seed nutrient characteristics differed significantly between the seasons among all the analyzed crop nutrient parameters ($p < 0.05$) except in the control plots. In both seasons, the pH value was found to be highest in treatment WW followed by PWWW and then PW. Soil pH in the two seasons after application DAP, the levels being significantly lower in season 2 than in season 1. The N content in the soil in both seasons was found to be highest in treatment PW followed by PWDAP, DAP and PWWW while control had the lowest nitrogen among all the treatments. The P content of the crops in both seasons was highest in DAP, followed by PW, then DAPPW, and DAPWW, but WW had low P(%). The trend in OC levels in the seasons was similar albeit the higher values of P were recorded in the second season. In both seasons, highest OC was recorded in treatment PW, followed by WW, then combination DAPPWWW and then PWWW while among the treatments, OC in DAP was low, although higher than the control. Similar trends in the variation of micronutrients K and Na were observed in both seasons. The concentrations of K and Na were highest in treatment WW followed by treatment WWDAP and DAPPWWW while WWPW had the fourth most abundant K and Na. Among the individual treatments, PW had the lowest K and Na which were significantly higher than the control treatment.

Table 4.4: Nutrient characteristics of *V. unguiculata* seeds after amendment with molasses wastewater and pig waste. Readings were taken in seasons 1 and 2 and pooled.

Treatments	N	P	OC	Zn	Na	K	Cu
CONTROL	2.51 ± 0.03^{b}	0.13 ± 0.04^{a}	27.60 ± 4.67^{a}	0.20 ± 0.05^{b}	0.16 ± 0.07^{a}	0.17 ± 0.03^{a}	0.02 ± 0.005^{a}
PW	4.45 ± 0.05^{g}	0.56 ± 0.05^{e}	90.55 ± 8.87^{f}	0.22 ± 0.08^{b}	0.18 ± 0.05^{a}	0.20 ± 0.04^{b}	0.12 ± 0.006^{e}
WW	1.63 ± 0.04^{a}	0.20 ± 0.06^{b}	81.07 ± 5.44^{e}	0.57 ± 0.03^{e}	0.37 ± 0.09^{f}	0.42 ± 0.09^{f}	0.04 ± 0.006^{b}
DAP	3.93 ± 0.07^{e}	0.58 ± 0.09^{e}	39.67 ± 4.11^{b}	0.25 ± 0.02^{c}	0.21 ± 0.03^{b}	0.23 ± 0.06^{c}	0.03 ± 0.004^{b}
PWWW	3.67 ± 0.06^{d}	0.23 ± 0.06^{b}	71.60 ± 6.94^{d}	0.41 ± 0.02^{d}	0.25 ± 0.05^{c}	0.27 ± 0.05^{d}	0.09 ± 0.003^{d}
PWDAP	4.10 ± 0.01^{f}	0.51 ± 0.08^{d}	56.40 ± 4.99^{c}	0.32 ± 0.04^{c}	0.22 ± 0.08^{b}	0.24 ± 0.07^{c}	0.05 ± 0.004^{c}
DAPWW	3.53 ± 0.04^{d}	0.47 ± 0.07^{d}	53.60 ± 5.12^{c}	0.12 ± 0.01^{a}	0.33 ± 0.09^{e}	0.34 ± 0.03^{e}	0.03 ± 0.005^{b}
DAPPWWW	3.28 ± 0.09^{c}	0.42 ± 0.08^{c}	75.30 ± 5.66^{d}	0.45 ± 0.02^{d}	0.28 ± 0.08^{d}	0.31 ± 0.04^{e}	0.10 ± 0.011^{d}
F	8.211	7.273	11.788	12.213	6.265	15.871	7.258
P-value	0.0021	0.0011	0.0002	0.0000	0.0035	0.0001	0.0031
CV(%)	5.63	4.44	7.62	8.95	4.66	4.22	7.88
Lsd	3.73	0.28	0.22	1.22	1.44	1.16	1.33

Similar lettering represents concentrations that do not differ significantly ($p > 0.05$)

4.4 Seed yield of *V. unguiculata* after amendment with molasses wastewater and pig waste

The seed yield in seasons 1 and 2 are shown in Figure 4.1. Treatment combining DAP + PW + WW had the highest yield followed by those with PW + WW while treatment with only WW and DAP were the lowest, which were, however higher than control.

Parameters of growth measured are shown in Figure 4.2. Based on the figure, plant height, leaf height, leaf width, number of pods, number of seeds and mass of 50 kg seeds followed similar trend being highest in treatment combining DAP + PW + WW followed by those with PW + WW while treatment with only WW and DAP were the lowest, which were, however higher than control.

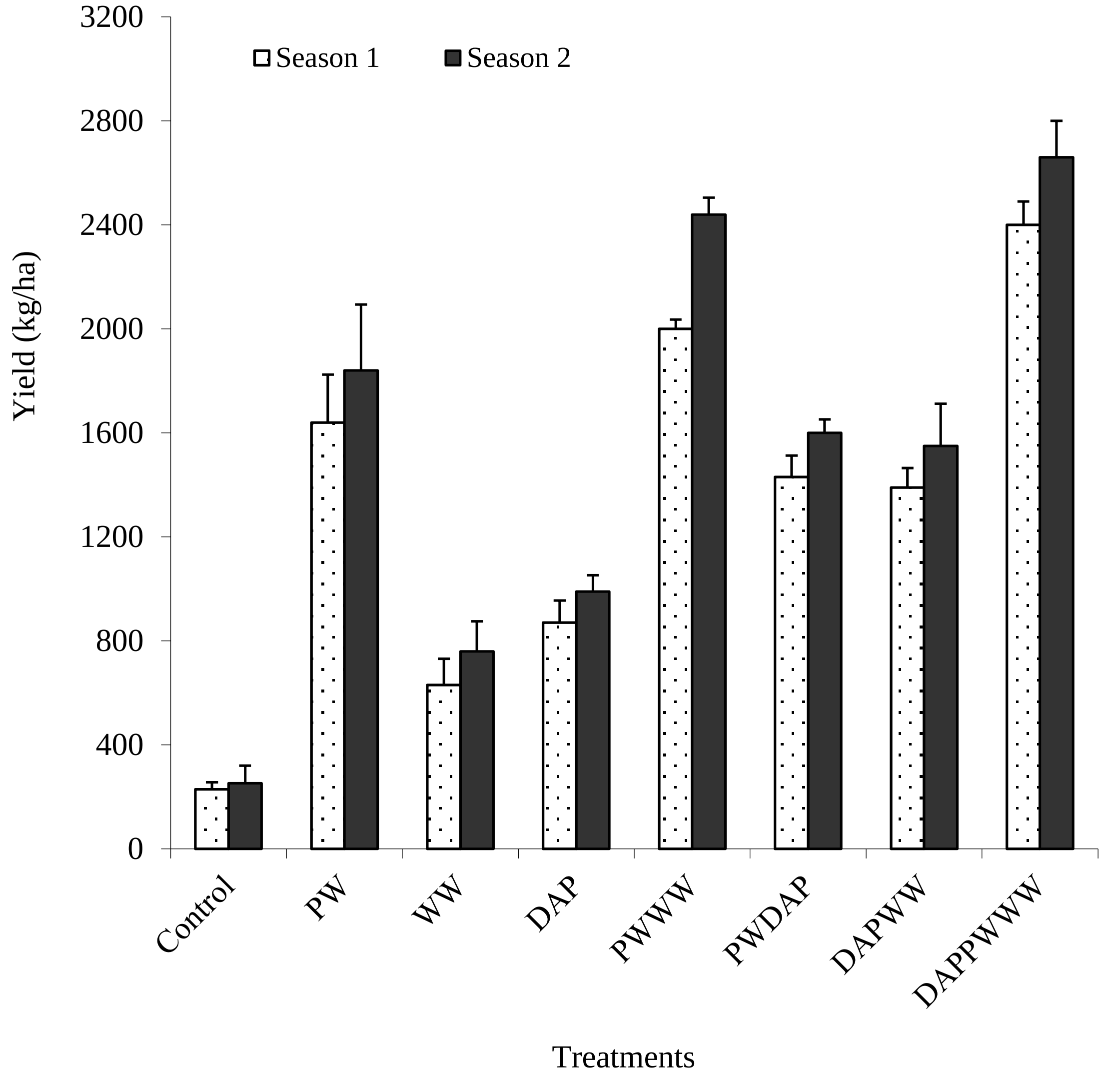

Figure 4.1: Seed yields of *V. unguiculata* in the experimental plots in season 1 and in season 2

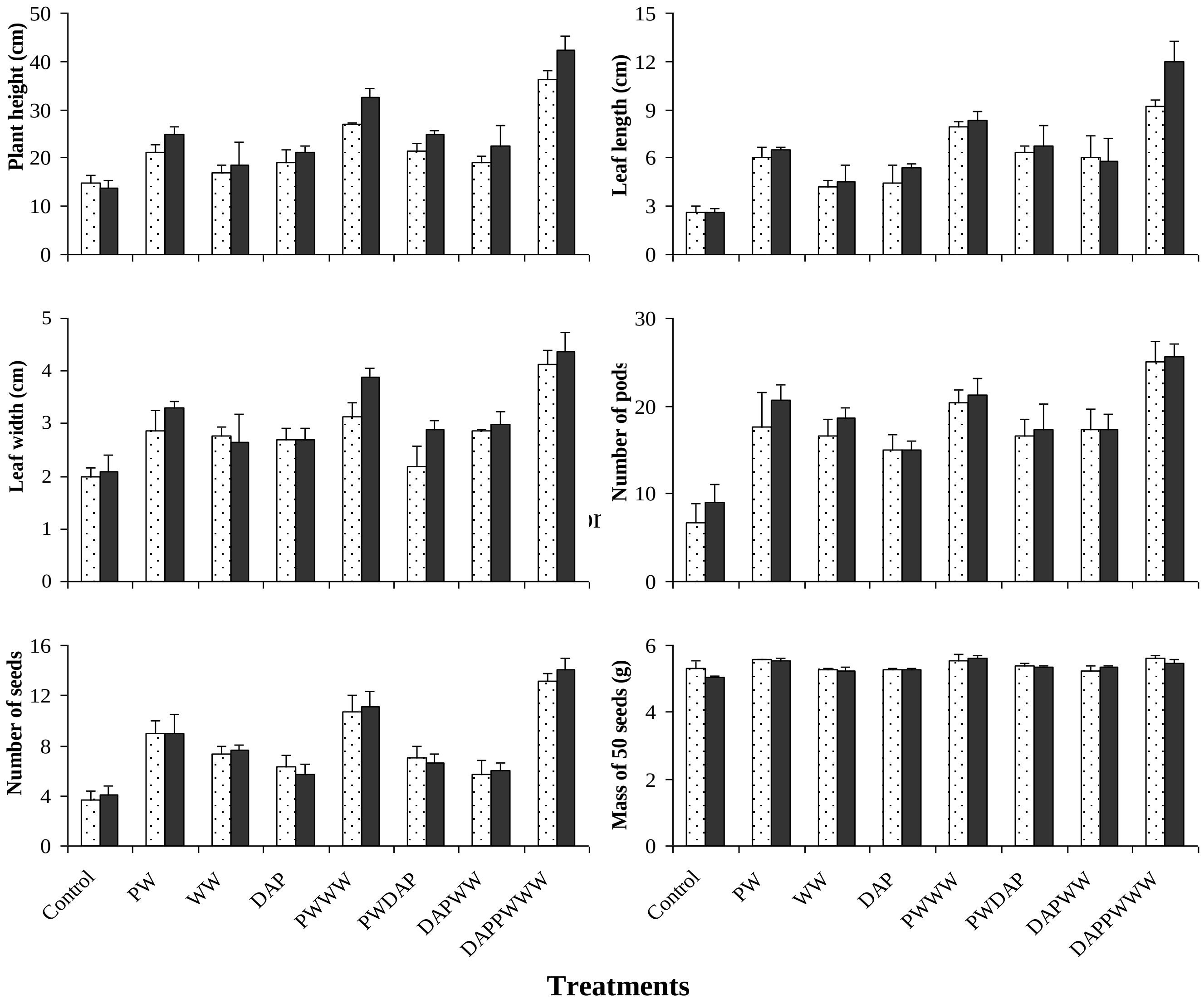

Fig 4.2: Parameters measured of *V. unguiculata* in the experimental plots in season 1 and 2

Key: Doted and shaded bars represent season 1 and 2 respectively

4.5.1 Green house yield results

The seed yield in greenhouse is shown in figure 4.3. From the figure, the yields showed that the plants in pots receiving PW, DAPPWWW and PWWW had higher seed yields compared to those receiving DAP and control. This trend is similar to the results obtained from the field.

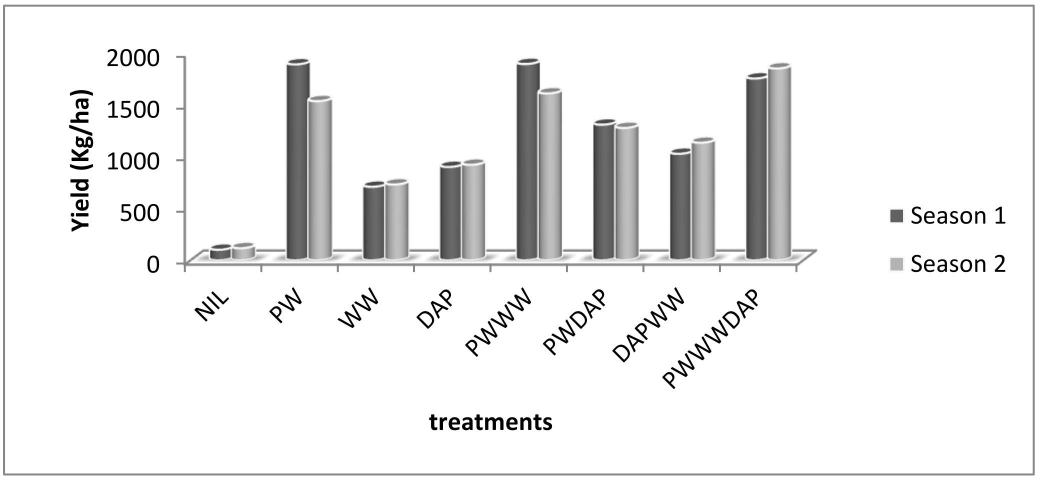

Fig 4.3: Green house seed yield of *V. unguiculata* in different treatments

4.5.2 Green house soil pH results

The pH of the soil which received different treatments is shown in figure 4.4. the results show that the soil in pots which received PW, WW and PWWW recorded the highest increase in soil pH of 6.99, 6.93 and 7.1 respectively compared to those receiving DAP which had an average of 4.765

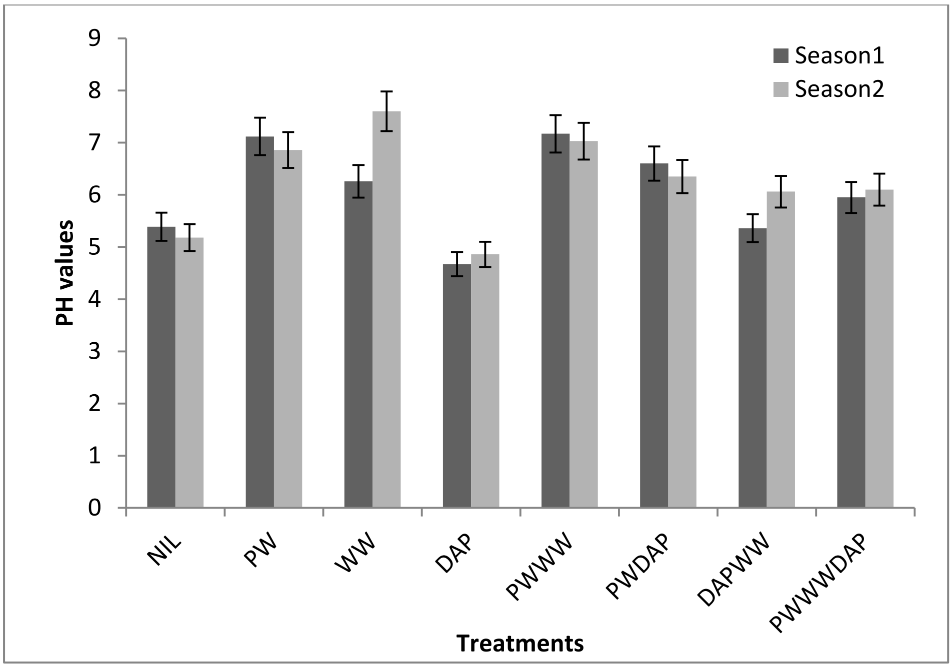

Fig 4.4: Green house soil pH after the experiments

4.6 Economic analysis

The table below was used to estimate the cost of the different inputs used.

Table 4.5: Estimated costs of inputs

	Cost	
Description	**KES**	**U.S $**
Land preparation	10,000	116.279
Planting seeds	5,000	58.14
Pest and disease control	2,000	23.256
Labour	10,000	116.279
DAP	10,000	116.279
WW Transportation	5,000	58.14
PW Transportation	2,000	23.256

Table 4.6: Averaged Profit margins for different treatments

	Input		Output		Profit margin	
Treatments	**KES**	**U.S $**	**KES**	**U.S $**	**KES**	**U.S $**
NIL	27,000	313.95	14,400	167.44	-12,600	-146.51
PW	29,000	337.21	104,400.00	1,213.95	75,400	876.74
WW	32,000	372.09	41,700.00	484.88	9,700	112.79
DAP	37,000	430.23	55,800.00	648.84	18,800	218.61
PWWW	30,500	354.65	133,200.00	1,548.84	102,700	1194.19
PWDAP	33,000	383.72	90,900.00	1056.98	57,900	673.26
DAPWW	34,500	401.16	88,200.00	1025.58	53,700	624.42
PWWWDAP	32,666.67	379.85	151,800.00	1765.12	119,133	1385.27

+ Sign means net profit

-Sign means net loss

CHAPTER FIVE

DISCUSSION

5.1 Nutrient characteristics of molasses wastewater and pig wastes used in soil amendment

Traditionally, manure has been applied to land, providing fertilizer elements and organic matter. Though the actual composition of wastewater may differ from community to community, all industrial wastewater contains the following broad groupings of constituents: organic matter, nutrients (N, P and K), inorganic matter (dissolved minerals), toxic chemicals and pathogens. Unfortunately, the change towards intensification in recent decades by agriculture through maximizing productivity from a minimal surface area, has reduced the use of manure as fertilizer. This has led to an increase of pollution risk and agricultural cost from inorganic fertilizers (Sangiorgi *et al*., 1996).

The process of molasses wastewater treatment generates substrates that can be used as fertilizer in agriculture while pig manure has several beneficial nutrients for crop production. All plants require nutrients to grow and a significant portion of these nutrients are removed from the soil and exported into the soil when a crop is harvested and left to decompose in the farm (Qian *et al.*, 2013). Generally, plant nutrients are divided into two groups, according to the amount of each nutrient required for plant growth: macronutrients which are required in large amounts (generally measured in several or many pounds per acre) and micronutrients which are required in relatively small amounts. This definition, based on requirement, does not always match up with the quantities actually found in soils for plants. For example, iron is the most abundant mineral nutrient present in soil and chlorine (Cl) is often found in large quantities in plant tissue. Soil fertility is adjudged due to nutrients that are removed to be replaced with synthetic fertilizers, manures, municipal wastes or, in a few cases, the atmosphere (Rawluk and Flaten, 2007).

In the current study, the concentrations of nitrogen, phosphorus, organic carbon, and copper were found to be significantly higher in the pig waste. Nonetheless, molasses wastewater had significantly higher concentration of potassium, sodium, magnesium, calcium iron and zinc. The pH of molasses fermentation wastewater was 8.62 which were higher than that of pig waste (6.81). Concentrations of nitrogen, phosphorus, organic carbon, and copper were found to be significantly higher in the pig waste as compared to molasses wastewater. N% ranged from 0.12 to 0.15 in molasses wastewater which was lower than that of pig waste (0.19 to 1.11). Also P% was higher in molasses waste water (0.09) which was lower than that of pig waste (0.14). OC was higher in pig waste (7.45) than molasses wastewater. Nonetheless molasses waste water had significantly higher concentration of potassium (30.63 meq), sodium (21.813 meq), magnesium (1.19 meq), and calcium (5.31 meq), iron (0.16 meq) and zinc (0.13 meq) but lower Cu (0.36 meq). These results are similar to those reported by Kailasam *et al*., (2001)

The fertilizer value of manures and slurries is highly variable from farm to farm and is dependent on factors such as type of livestock (species, breed and age), diet, type of production, housing system and waste handling system (Sommerfeldt and Chang, 2011). Normally, the effects of organic manure and wastewater may have a significant impact on the soil fertility and soil quality focuses primarily on the behaviour of nitrogen and phosphorus in soil because these two nutrients are the main nutrients that limit crop yields (Akinremi, 2005). This explains why the crop yield was high in treatment containing pig waste.

5.2 Nutrient characteristics of soils after amendment with molasses wastewater and pig wastes

Soil nutrient characteristics dictate the overall fertility of the soils and its ability to support crop production. In the current study, before soil fertility amendment, the initial soil nutrient characteristics indicated that pH ranged from 4.82 to 4.98. This is an acidic soil that does not support wide range of crops (Tarkalson and Mikkelsen, 2004). After amendments the pH significantly rose to 7.06 and 6.74 in soil which received WW and PWWW respectively. However, the soils which received DAP recorded a decrease in pH to 4.81 in season 1 and 4.76 in season 2. These results compare to those reported by Haroon and Bose (2004) where they found a considerable change in pH in soils which received wastewater from 3.8 to 8.0. The soil amendments therefore were necessary as it raised soil pH to levels where most crops grow best.

Acidic soils limit plant growth because most nutrients are chelated or are adsorbed hence not available to plants. Also acidic soils raise aluminium levels in the soil which leads to aluminium toxicity which is injurious to plant roots. Percentage nitrogen ranged between 0.10 and 0.16 before the amendments and after amendments the soil which received pw, DAP and combination of these two recorded the highest increase to 0.45 and 0.35 in season1 and 0.62 and 0.36 respectively. Percentage phosphorous ranged between 0.01 to 0.06 before amendments but after amendments, the soil which received DAP and PW and their combination recorded the highest levels of p. This could be associated with the high concentration of p in the two fertilizers. The overall soil organic content ranged from 2.32 to 2.38 but was similar across the plots. After amendments the soil which received PW and WW recorded the highest increase in OC in both seasons. The soil which received DAP alone recorded the least rise in oc. These results show that pig waste and wastewater are suitable in amending acidic soils. Similar results were reported by Drinkwater *et al.,* (1995) where they found out that use of organic manures improves OC in the soil and stabilize soil pH.

The use of organic soil amendments has been associated with desirable soil properties including higher plant available water holding capacity and CEC and lower bulk density, and can foster beneficial microorganisms Doran, (1995). Benefits of compost amendments to soil also include pH stabilization and faster water infiltration rate due to enhanced soil aggregation (Stamatiadis *et al.*, 1999). Soil chemical characteristics are affected by soil amendment and production system. This true because in the study the soils whjich received organic fertilizers led to improved chemical properties especially pH and oc. For example, at the Rodale Institute, long-term legume-based and organic production systems have resulted in an increase in soil organic matter and reduced nitrate runoff (Drinkwater *et al.*, 1998). Soils in organic production systems lost less nitrogen into nearby water systems than did conventional production systems (Liebhardt *et al.*, 1989). The amount of soil nitrogen in fields under conventional production systems has been negatively correlated with soil microbial components, whereas soil nitrogen in fields under organic production was positively correlated with soil microbial components (Gunapala and Scow, 1998).

The soil pH is a very important factor for optimal plant development and general agricultural crop production. Soil pH near neutral (6-7) is often the best for P availability. Soils with pH near neutral often have the smallest capacity to adsorb P, since these soils have lower concentrations of oxides or carbonates than acid soils or alkaline soils, respectively. Soils with a pH near neutral also have the smallest capacity to precipitate P. Phosphorus forms relatively insoluble precipitates with Al and Fe at low (acid) pH and Ca and Mg at high (alkaline) pH. Soil pH is influenced by many factors including soil type, soil structure, rainfall and agricultural production system. The pH of the soil will naturally tend to fall due to rainfall and the removal of elements by crop production and harvesting. Therefore there is an essential requirement to keep the pH of soils as it will naturally tend to decrease. The pH level of the soil can only be increased by the addition of basic elements such as calcium and magnesium. This is obtained by the regular application of basic elements to the soil as liming materials. In both seasons, the pH value was found to be highest in treatment WW followed by PWWW and then PW. Soil pH in seasons 1 and 2 after application of DAP, the levels being significantly lower in season 2 than in season 1.

The N content in the soil in season 1 and 2 was found to be highest in treatment PW followed by PWDAP, DAP and PWWW while control had the lowest nitrogen among all the treatments. This observations could be as a result of the high concentration of N in pw and DAP. The same results were obtained by Cruz *et al.,(*1991) who studied the impact of wastewater application on soil in Brazil.The P content of the soil in season 1 and season 2 was highest in DAP, followed by PW, then DAPPW, and DAPWW, but WW had low P(%). The trend in OC levels in seasons 1 and 2 were similar albeit the higher values of P were recorded in the second season. In both season, highest OC was recorded in treatment PW, followed by WW, then combination DAPPWWW and then PWWW while among the treatments, OC in DAP was low, although higher than control. Similar trends in the variation of micronutrients K and Na were observed in both season 1 and season 2. The concentration of K and Na were highest in treatment WW followed by treatment WWDAP and DAPPWWW while WWPW had the fourth most abundant K and Na. Among the individual treatments, PW had the lowest K and Na which was significantly higher than the control treatment.

Clark *et al.,* (1998) found that concentrations of organic carbon, phosphorus, potassium, calcium, and magnesium were greater in soils with incorporated manures and cover crops. Soil organic carbon, phosphorus, and potassium declined after manure applications ceased. Soils with alternative fertility amendments initially had a lower soil pH than soils with inorganic fertilizers. Over time, pH increased in soils with alternative amendments to higher levels than pH in soils with inorganic fertilizers. These findings are similar to the finding in the current study. Despite the soil pH-lowering mineralization that occurs upon addition of composted N-containing organic wastes to soil (Bevacqua and Mellano, 1994; Sikora and Yakovchenko, 1996), compost additions typically raise the pH of acid soils by complexing Al and increasing base saturation (Shiralipour *et al.,* 1992; Van den Berghe and Hue, 1999). This explains why there was rise in pH in the soils that received organic amendments, while the one which received DAP alone recorded decrease in soil pH.

5.3 Nutrient characteristics of *V. unguiculata* seeds after amendment with molasses wastewater and pig waste

The agronomic value of pig manures and wastewater depends on their nutrient, organic matter and trace element content. For example, slurry is very rich in ammoniacal nitrogen which can be rapidly assimilated by plants while solid manure has a slower release of nutrient and has beneficial effect on the soil structure. In most soils, the majority of the P is held very strongly by precipitation and adsorption reactions. Although the P retention capacity in most soils is large, it is never infinite.

The N content in the seeds of the crop was found to be highest in treatment PW followed by PWDAP, DAP and PWWW while control had the lowest nitrogen among all the treatments. The P content of the crop was highest in DAP, followed by PW, then DAPPW, and DAPWW, but WW had low P. This is due to the fact that DAP and PW had the highest N and P. Similar results were reported by Bore, (2009) while carrying out research on wastewater use in soil amendments in beans. Highest OC was recorded in treatment PW, followed by WW, then combination DAPPWWW and then PWWW while among the treatments, OC in DAP was low, although higher than control. This observation supports the findings of Clark *et al.,* (1998) who found out that OC increased in crops which received organic manures than those which received inorganic fertilizers. The concentration of K and Na were highest in treatment WW followed by treatment WWDAP and DAPPWWW while WWPW had the fourth most abundant K and Na. Among the individual treatments, PW had the lowest K and Na which was significantly higher than the control treatment. The seeds from the plants which received WW recorded highest concentration of Na and K because wastewater had high concentration of these elements. These results compare with those obtained by Joshi *et al.,* (1996) who found out that there was high concentrations of Na and K in plant that were grown in soils amended with industrial wastewater.

5.4 Seed yield of *V. unguiculata* after amendment with molasses wastewater and pig waste

In the current study, the treatment combining DAP + PW + WW had the highest seed yield followed by those with PW + WW while treatment with only WW and DAP were lower, which were however, higher than control. Also parameters of yield such as, plant height, leaf height, leaf width, number of pods, number of seeds and mass of 50 kg seeds followed similar trend being highest in treatment combining DAP + PW + WW followed by those with PW + WW while treatment with only WW and DAP were lower, which were however, higher than control. These results therefore show cowpea seed yield can be improved by amending soil with wastewater and pig waste.

Drinkwater *et al.,* (1995) and Stamatiadis *et al.,* (1999) reported similar results where yields of crops grown in organic and conventional production systems were high. Also, vegetable fields under organic fertilizers in California were reported to produce high yields by Audi *et al*., (1996) than those under conventional production. Long-term research in Pennsylvania has also demonstrated little difference in yields between conventional and organic production systems (Drinkwater *et al.,* 1998). Therefore cowpea growth can be improved by addition of organic fertilizers which provide better soil conditions essential for plant growth, Subarao *et al*., (1999). The ability of organic fertilizers to raise pH of acidic soil might have contributed to the high yields in crops that received WW, PW and their combination.

Organic amendments provide advantages beyond the benefits of increased organic matter content on soil physical and chemical properties since nutrients that are seldom applied by farmers for instance manganese, zinc, and sulfur are added as insurance against potential yield limitations. Furthermore, nutrients that are normally applied in commercial fertilizers like potassium and liming sources that is calcium and magnesium are supplemented in organic amendments and permitted to accrue in the soil. Yield increases in fields transitioning from conventional to organic production systems usually require 3–5 years to detect (Parr *et al*., 1992; Altieri, 1995). The sustainability of organic production systems has been questioned recently (Trewavas, 2001). Despite this, lower negative environmental impact, higher profitability, and higher apple fruit quality were demonstrated in the organic farming systems (Reganold *et al*., 2001).

No differences in the yields of tomato were observed between organic and conventional production in California (Drinkwater *et al*., 1995). Similarly, soybean yields were as high in fields undergoing transition from conventional to low-input production as in fields under conventional production practices (Liebhardt *et al*., 1989). From the research findings and work done by other researchers, it can be pointed out that field soils receiving organic fertilizers were more productive than conventional fields probably due to the beneficial effects on soil properties of long-term organic amendments. Therefore, the argument that organic farming is equivalent to low yield farming is not supported by our data (Avery, 1995).

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From this research, both molasses wastewater and pig wastes contain nutrients that are useful to plant growth despite the fact that the concentrations of these nutrients differed. The concentration of nitrogen, phosphorus, organic carbon, and copper were significantly higher in the pig waste as compared to molasses wastewater. Nonetheless wastewater had significantly higher concentration of potassium, sodium, magnesium, calcium, iron, zinc and pH.

The initial soil pH ranged from 4.82 to 4.98 which shows that the soils are acidic hence does not support a wide variety of crops. The soils therefore, required amendments to raise the pH to levels that support a variety of crops. The organic carbon of the soil ranged from 2.32 to 2.38%. Such soils require amendments which raises the OC content. Fertilizers of organic origin are known to raise OC in the soil. The level of OC in the soil is important as it determines the level of microbial activity which necessary for proper plant growth. Soil amendments using wastewater and pig waste singly or their combination was the best. This is because the amendments raised soil pH and OC. The combination of DAP with either WW or PW also gave good results because the DAP supplies high P while the organic manures raises the soil pH.

The nutrients in the seeds from crops which received organic fertilizers were comparable to those which received DAP. Phosphorus was high in seeds from plants which received DAP treatment. In both seasons, highest OC was recorded in seeds from plants grown under in pigwaste treatment. The concentration of K and Na were highest in seeds from plants which were grown in wastewater treatment. Therefore WW and PW is a good source of nutrients to plants and indirectly to humans.

Seed yield of cowpea which was also part of this research and is the interest of every farmer in Kenya was high in crops which were grown under treatment of DAP + PW + WW and treatment of PW + WW. The results from this research therefore, show that PW and WW can actually be used as a better alternative to conventional DAP. The combination of PWWW was the best amendment because it gave good results in all the parameters analysed.

6.2 Recommendations

This research therefore offers important agricultural and agro-industrial wastes composition information and their use in soil amendment. This is useful tool for farmers to amend the soils for improved crop yields. Present research findings may contribute to achieve a better management of pig manures and molasses wastewater to improve soils and crop yields. From the findings I recommend treatment combination PWWW.

6.3 Recommendations for further studies

This research was carried out only in one ecological zone therefore future research should aim at varying the ecological zones in order to come up with a general trend.

Future research should also use the amendments in other crops to ascertain whether these findings are applicable to different crops or not.

REFERENCES

Achoka, D.J. (1998). Levels of the physico-chemical parameters in the liquid effluents from Pan paper mills at Webuye and in river Nzoia. Doctoral thesis at SES Moi University Eldoret, Kenya.

Acosta-Martinez, V. and Harmel, R.D. (2006). Soil microbial communities andenzyme activities under various poultry litter application rates. Journal of Environmental Quality 35: 1309-1318.

Adeli, A J.J. Varco, K.R. Sistani, and Rowe D.E. (2005). "Effects of Swine Lagoon Effluent Relative to Commercial Fertilizer Applications on Warm Season Forage Nutritive Value." Agronomy Journal. 97:408–417.

Agbede, T. M, Ojeniyi, S. O and Adeyemo, A. J. (2008). Effect of poultry manure on soil physical and chemical properties, growth and grain yield of sorghum in southwest Nigeria. *American-Eurasian Journal of Sustainable Agriculture.* **2**(1):72-77.

Altieri, M.A. (1995). Agroecology. The Science of Sustainable Agriculture. Westview Press, Boulder, CO, p. 433.

Anikwe, M.A.N., Nwobodo, K.C.A. (2002). Long term effect of Municipal waste disposal on Soil Properties and Productivity of Sites used for Urban Agriculture in Abakaliki, Nigeria. Bioresource Technology. **83**: 241–250.

Anilkumar, Yashpal, S. Joshi, B. D. and Rai, J. P. N. (2003). Effect of distillery spentwash on some characteristics of soil and water. *Indian J. Ecol.,* **30** : 7-12.

Annadurai, K. Kavimani, R. and Masilamani, P. (1999), Effect of distillery effluent and organic amendment on rice yield and soil fertility status. *Madras Agric. J.,* **86** : 572-577.

Asano,T. and Pettygrove G.S. (1987). Using reclaimed municipal wastewater for irrigation. Calif. Agric. 41(3-4): 15-18.

Audi, P.O. Ngugi, C.K. Wandera, F.P. Ndengwa, R. (1996). Dryland farming research, extension and development project. Dryland farming: Recommendations for smallholder farmers. Proceedings of a workshop held in KARI-Katumani, Machakos, Kenya, pp. 47

Avery, D.T. (1995). Saving the Planet with Pesticides and Plastics: the Environmental Triumph of High-Yield Farming. Hudson Institute, Indianapolis, IN, p. 432.

Alva, A.K. Huang, B. and Paramasivam, S. (2000) Soil pH affects copper fractionation and phytotoxicity. Soil Science Society of America Journal 64: 955-962.

Barnard, C. (1969). Herbage Plant Species. p. 133 (Division of Plant Industry,CSIRO, Canberra).

Barrett, R.P. (1987). Integrating leaf and seed production strategies for cowpea [Vigna unguiculata (L.) Walp] MS thesis, (Michigan State Univ, East Lansing, MI).

Bationo, A. and Mokwunye, A.U. (1991). Role of manures and crop residues in alleviating soil fertility constraints to crop production: With special reference to the Sahelian and Sudanian zones of West Africa. Fertilizer Research 29:117–125.

Bevacqua, R.F. Mellano, V.J. (1994). Cumulative effects of sludge compost on crop yields and soil properties. Commun. Soil Sci. Plant Anal. 25, 395–406.

Bhat, S.N. (1994). Investigation on effect of lagoon spent wash on soil properties M. Sc., (Agri) Thesis, Univ. Agric. Sci., Dharwad, Karnataka (India). Biological Wastes, **34**: 242-249.

Bolan, N.S. Mahimairaja, S. and Hedley, M.J. (1992) Improving the fertilizer value of poultry manures. Proceedings of the Seminar on 'Eggs '92-winning in a deregulated environment,' Egg Producers Federation of New Zealand, pp. 1-15.

Bore, E.K. (2009). Soil fertility amendment using molasses wastewater homa-lime, biogas effluents and their effect on common pea (Phaseolus vulgaris) yields on acidic soils of Kenya. Moi university

Bouwer, H. and Idelovitch E. (1987). Quality requirements for irrigation with sewage water. *J. Irri. Drain. Div., ASCE* 113: 516-535.

Brown, S. Sprenger, M. Maxemchuk, A. and Compton, H. (2005). Ecosystem function in alluvial tailings after biosolids and lime addition. *Journal of Environmental Quality*. **34(1)**: 139–148.

Bubenheim, D.L. Mitchell, C.A. Nielsen, S.S. (1990) in Advances in new crops, Utility of cowpea foliage in crop production for space, eds Janick J., Simon J.E. (Timber Press, Portland, OR), pp 535–538.

Byiringiro, F. and Reardon, T. (1996). Farm productivity in Rwanda: effects of farm size, erosion and soil conservation investments. Agricultural Economics. **15**: 127–136.

CABI. (2000): Crop protection compendium. Global module, 2nd edition. CABI Publishing,WallingfordUK.

CABI. (2004): Crop protection compendium. 2004 Edition. CAB International PublishinmUK.

Cameron, K.C. Rate, A.W. Noonan, M.J. Moore, S. Smith, N.P. Kerr, L.E. and Lysimeter, L. (2007). Study of the fate of nutrients following subsurface injection and surface application of dairy pond sludge to pasture. Agricultural Ecosystems and Environment. **58**: 187–197.

Campbell, W.F. Miller, R.W. and Screeg, T.M. (2006). Alfalfa, sweet corn and wheat responses to long term application of municipal wastewater to crop land. *Journal of Environmental Quality*. **2**: 243-249.

Casey, K.D. Bicudo, J.R. Schmidt, D.R. Singh, A. Gay, S.W. Gates, R.S. Jacobsen, L.D. and Hoff, S.J. (2006). Air quality and emissions from livestock and poultry production/waste management systems, in: Rice, J.M., Caldwell, D.F. & Humenik, F.J. (Eds.) Animal Agriculture and the Environment: National Center for Manure and Animal Waste Management White Papers, Publication No 913C0306, pp. 1-40(St.Joseph, MI,ASABE).

Chan, K.Y. van zwieten, L. Meszaros, L. Downie, A. and Joseph, S. (2008). Using poultry litter BIOCHARS as soil amendments, *Australian Journal of Soil Research* 46:437-444.

Clark, M.S. Horwath, W.R. Shennan, C. Scow, K.M. (1998). Changes in soil chemical properties resulting from organic and low-input farming practices. *Agron. J.* 90, 662–671.

Codling, E.E. (2006). Effects of lime, phosphorus and iron amended orchard soils on vitro, water and 1n hno3 extractable lead.

Cruz, R. L. Righetto, A. M. and Nogueira, M. O. (1991). Experimental investigation of soil and ground water impacts caused by vinasse disposal. Water Sci. Technol. 24(11): 77-85

Dart, P. J. and Mercer , F. V. (1965). The effect of temperature, level of ammonium nitrate, and light intensity on the growth and nod-ulation ofcowpea (I'ignasinens. Endl. ex Hassk.). Austr. J. Agric. Res. 16:321-345.

Devarajan, L. and Oblisamy, G. (1994). Performance of banana (Poovan) under distillery effluent irrigation. *South Indian Hort.*,**32**: 324-326.

Devarajan, L. Rajanan, G. Ramanathan, G. and Oblisami, G. (1996). Performance of field crops under distillery effluent irrigations, Kisan world, 21: 48-50

Diaz, D.A.R. Sawyer, J.E. and Mallarino, A.P. (2008). Poultry manure supply of potentially available nitrogen with soil. *Agronomy journal* 100: 1310- 1317.

Doran, J. (1995). Building soil quality. In: Proceedings of the 1995 Conservation Workshop on Opportunities and Challenges in Sustainable Agriculture. Red Deer, Alta., Canada, Alberta Conservation Tillage Society and Alberta Agriculture Conservation, Development Branch, pp. 151–158.

Drinkwater, L.E. Letourneau, D.K. Workneh, F. Van-Bruggen, A.H.C. Shennan, C. (1995). Fundamental differences between conventional and organic tomato agroecosystems in California. Ecol. Appl. 5, 1098–1112.

Drinkwater, L.E. Wagoner, P. Sarrantonio, M. (1998). Legumebased cropping systems have reduced carbon and nitrogen losses. Nature 396, 262–265.

Duke, J. A. (1981). Handbook of Legumes of World Economic Importance. Plenum Press, N.Y.

Edmeades, G. (2009). Efficiency in the use of inorganic fertilizers for soil amendments in Africa. *Journal of Agriculture in the Tropics*. **12**: 18-26.

Edwards, J.H. and Someshwar, A.V. (2000). Chemical, physical, and biological characteristics of agricultural and forest by-products for land application, in: DICK, W.A. (Ed.) Land Application of Agricultural, Industrial, and Municipal By-products, pp. 1-62 (Madison, WI, Soil Science Society of America).

Eghball, B. (2001). Composting Manure and other organic residue. Cooperative Extension Publication (NebGuide), Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln

Elliott, L.F. and Stevenson, F.J. (2007). Soils for Management of Organic Wastes and Wastewaters; SSSA: Madison, WI.

Eneje, R.C. and Ukwuoma V.E. (2005). Plant and Animal organic Manure, effects on Vegetable and orchard farm Soils (Part 1). Effect on Soil Chemical properties. Journal of Agriculture, Agricultural Technology and Environment. **1**: 1-12.

Eneji, A.E. Inanaga, S. Li, X. An, P. Li, J. Duan, L. and Li, Z. (2008). Effectiveness of mulching vs. incorporation of composted cattle manure in soil water conservation for wheat based on eco-physiological parameters. *Journal of Agronomy and Crop Science* 194: 26-33.

Ensink, J.H.J.T. Mahmood, W. Van-der-hoek, L. Raschid-Sally and Amerasinghe F.P. (2004). A nationwide assessment of wastewater use in Pakistan: an obscure activity or a vitally important one? Water Policy 6: 197-206.

Ensink, J.H.J. W. Van der-hoek, Y. Matsuno, S. Munir, M.R. Aslam. (2002). Use of untreated wastewater in peri-urban agriculture in Pakistan: Risks and opportunities. IWMI Research Report No. 64. International Water Management Institute (IWMI), Colombo, Sri Lanka.

Epstein, E. and Moss, L.H. (2006). A comparison of characteristics of manures, biosolids, and mineral fertilizers. *Journal of Residuals Science and Technology* 3: 35-42.

Eswaran, H. and Beinroth, F.H. (2012). Land degradation: issues and challenges. Abstracts. International Land Degradation Conference, Adana, Turkey (10-14 June 1996) University of Cukurova, Department of Soil Science, Adana, Turkey

FAO-UNESCO (1974). Soil map of the world. Revised legend. World Resources. Report 60 (FAO, Rome, Italy).

Franzluebbers, A.J. Doraiswamy, P.C. (2007). Carbon sequestration and land degradation. In: Sivakumar, M.V.K., Ndiangui, N. (eds). Climate and Land Degradation, Springer Verlag, Berlin, Germany. p. 343-358.

Friend, A.L. Roberts, S.D. Schoenholtz, S.H. Mobley, J.A. and Gerard, P.D. (2006). Poultry under various poultry litter application rates. *Journal of Environmental Quality* 35: 1309-1318.

Gebremedhin, B. and Swinton, S.M. (2003). Investment in soil conservation in Northern Ethiopia: the role of land tenure security and public programs. Agricultural Economics. **29**: 69–84

Gill and Batra (1968) . Cowpea research and publications at IITA: Information about crop improvement and crop health ; The highs and lows of cowpea production.

Glanville, T.D. Persyn, R.A. Richard, T.L. Laflen, J.M. Dixon, P.M. (2004). Environmental effects of applying composted organics to new highway embankments: Part 1I. Water quality. American Society of Agricultural Engineers 47: 471-478.

Gunapala, N. Scow, K. (1998). Dynamics of soil microbial biomass and activity in conventional and organic farming systems. Soil Biol. Biochem. 30, 805–816.

Guo, M. and Song, W. (2009). Nutrient value of alum-treated poultry litter for land application. Poultry science 88: 1782-1792.

Hallensleben, M. Polreich, S. Hellee, J. Maass, B. L. (2009). Assessment of the importance and utilization of cowpea *(Vigna unguiculata L. Walp.)* as leafy vegetable in smallscale farm households in Tanzania – East Africa.

Harmel, R.D. Smith, D.R. Haney, R.L. and Dozier, M. (2009). Nitrogen and phosphorus runoff from cropland and pasture fields fertilized with poultry litter. *Journal of soil and water conservation* 64: 400-412.

Harmel, R.D. Torbert, H.A. Haggard, B.E. Haney, R. and Dozier, M. (2004). Water quality impacts of converting to a poultry litter fertilization strategy. *Journal of Environmental Quality* 33: 2229- 2242.

Haroon, A. Bose, M. (2004). Use of distillery spent wash for alkali soil reclamation, treated distillery effluent for ferti irrigation of crops. Indian Farm, March, 48-51

Hudson Institute. (2001). (A Futurist Perspective, Hudson Institute Annual Report.

IITA Annual Report. (2005). Lush cowpea field 74 Publications Nziguheba, G, ... Gilmer,Whitney & Williams, Proc. 1st IITA Grain LegumeImprovement Workshop, Ibadan, Nigeria, 325 pp., 1974.

Jadhav, H. D. and Sawant, N. K. (1975). Influence of added spentwash on chemical and physical properties of soil. *Indian J. Agri. Chem*., 8 : 73-84.

Jaetzold, R. Schmidt, H. (1983). Farm Management Handbook of Kenya, vol. II. Natural Conditions and Farm Management Information in East Kenya, Ministry of Agriculture, Nairobi, Kenya, 311 pp.

Jamjoum, K.I. and Khattari, S.K. (2003). Effect of wastewater and sludge application on soil, corn plant composition and production in Zizia Region. Dirasat. 15(11): 29-44.

Jayne, T.S. Kelly, V.A. and Crawford, E. (2013). Fertilizer consumption trends in Sub-Saharan Africa. Policy Synthesis, nos. 69. USAID, Bureau of Agriculture and Food Security and the Office of Sustainable Development.

Johnson, M. and Minson. (1968). Cowpea research and publications at IITA: ...

Joshi, H.C. Kalra, N. Chaudhary, A. and Deb, D.L. (1994). Environmental issues related with distillery effluent utilization in agriculture in India, *Asian Pac J. Env. Dev.*, 1: 92-103.

Kabubo-Mariara, J. (2005a). Herders response to acute land pressure under changing property rights: some insights from Kenya. Environment and Development Economics. 10(1): 67–85.

Kabubo-Mariara, J. (2007). Land conservation and tenure security in Kenya: Boserup's hypothesis revisited. Ecological Economics. 64: 25 – 35.

Kabubo-Mariara, J. (2003). The linkages between property rights, migration and productivity: the case of Kajiado district, Kenya. Environment and Development Economics. 8(4): 621–636.

Kailasam, N. Subramaniam, N. and Selvam, M. (2001). Analysis of distillery effluent and its effect on the mortality of earthworm (Megascolex pumilio). *Journal of Ecotox. Environ. Monit*., 12 : 21-25.

Kaiser, D.E. Mallarino, A.P. and Haq, M.U. (2009). Runoff phosphorus loss immediately after poultry manure application as influenced by the application rate and tillage. *Journal of Environmental Quality* 38: 299-308.

Kang, B.T. and Juo, A.S.R. (2007). Management of low activity clay soils in tropical Africa for food crops production pp129-133 In: Terry ER, KA.

Karikari, S.K. Molatakgosi, G. (1999). Response of cowpea [Vigna unguiculata (L.) Walp] varieties to leaf harvesting in Botswana. UNISWA J. Agr. 8:5–11.

Kelleher, B.P. Leahy, J.J. Henihan, A.M. O'dwyer, T.F. Sutton, D. and Leahy, M.J. (2002). Advances in poultry litter disposal technology – a review. Bioresource Technology 83: 27-36.

Kelley, T.R. Pancorbo, O.C. Merka, W.C. Thompson, S.A. Cabrera, M.L. and Brnhat, H.M. (1996). Elemental concentrations of stored whole and fractionated broiler litter. *Journal of Applied Poultry Research* 5: 276-281.

Kelly, V.A. Crawford, E.W. Howard, J.A. Jayne, T. Staatz, J. and Weber, M.T. (2011). Towards a Strategy for improving agricultural inputs markets in Africa. Policy Synthesis, no. 43 USAID Bureau of Agriculture and Food Security and the Office of Sustainable Development.

Kulkarni, A. D. Modak, H. M. and Jadhav, S. J. (1987). Fertilizer from spentwash- A review, Bhartiya Sugar. 12(9): 17.

Laird, D.A. Martens, D.A. and Kingery, W.L. (2001). Nature of Clay-Humic Complexes in an Agricultural Soil: I. Chemical, Biological, and Spectroscopic Analyses. Soil Sci. Soc. *Am. J.* 65: 1413-1418

Lal, R. and Pierce, F.J. (1991). Soil Management for Sustainability. A publication of Soil and Water Conservation Society and Soil Science Society of America.

Liebhardt, W.C. Andrews, R.W. Culik, M.N. Harwood, R.R. Janke, R.R. Radke, J.K. Rieger-Schwartz, S.L. (1989). Crop production during conversion from conventional to low-input methods. *Agron. J.* 81, 150–159.

Mahimairaja, S. Bolan, N.S. and Hedley, M.J. (1995a) Agronomic effectiveness of poultry manure composts. Communications in Soil Science and Plant Analysis 26: 1843-1861.

Mäler, K.G. (1997). Environment, poverty and economic growth. In: Pleskovic, B., Stiglitz, J.E. (Eds.), Proceedings of the Annual World Bank Conference on Development Economics. The World Bank, Washington, DC, pp. 251–270.

Mallika, K. (2001). Eco- friendly utilization of distillery spent wash for enhancing soil fertility and crop productivity. M.Sc (Env. Sci.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Mattiazo, M. E. and Ada-gloria, N. (1985). Effect of vinasses on soil activity. STAB (Portuguese). 4(2): 38-40.

Mbagwu, J.S.C. and Ekwealor, G.C. (1990). Agronomic potential of Brewer's spent grains.

Mbah, C.N. and Mbagwu, J.S.C. (2006). Effect of Animal Waste in Physico-chemical properties of a Dystric Leptosol and maize yield in South-eastern Nigeria. *Nigerian Journal of Soil Science.* **15**: 89-97.

McDonald, J.M. Ribaudo, M.O. Livingston, M.J. Beckman, J. and Wang, H. (2009). Manure Use for Fertilizer and for Energy – Report to Congress. Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

McGrath, S. Maguire, R.O. Kike, J.H. (2009). Tacy litter application to Loblolly pine forests: Growth and nutrient containment. Journal of Environmental Quality 35: 837-848., B.F. and Improving soil nutrition with poultry litter application in low input forage systems. *Agronomy Journal* 102: 48-54.

McLeod. (1982) . Cowpeas growing conditions and disease tolerance.

Milford and Minson. (1968). Cowpea research and publications at IITA.

Mochoge, B.O. Kanyanjua, S. and Obanyi, S. (1997). Response of maize, maize cowpea intercrop and pigeon pea to N and P fertilizers and farmyard manure. African crop science conference proceedings. **3**: 439-448.

Moore Jr, P.A. Joern, B.C. Edwards, D.R., Wood, C.W. and Daniel, T.C. (2006). Effects of manure amendments on environmental and production problems, in: RICE, J.M., CALDWELL, D.F., & HUMENIK, F.J. (Eds) Animal Agriculture and the Environment: National Center for Manure and Animal Waste Management White Papers, Publication No 913C0306, pp. 1-40 (St. Joseph, MI, ASABE).

Moore, P.A. Daniel, T.C. Sharpley, A.N. and wood, C.W. (1995). Poultry manure management environmentally sound options. *Journal of Soil and water Conservation* 50: 321-327.

Motavalli, P. P. (1997). Introduction to soil plant testing in the American Pacific region. Proceedings of the Workshop on Utilization of Soil and Plant Analysis for Sustainable Nutrient Management in the American pacific. College of Agriculture and Life Sciences, University of Guam, Mangilao, Guam

Murtaza, G. A. Ghafoor, M. Qadir, G. Owens, M.A. Aziz, M.H. Zia, and Saifullah. (2010). Disposal and Use of Sewage on Agricultural Lands in Pakistan: A Review. Pedosphere 20: 23-34.

Muse jr, J.K. (1993). Inventory and evaluation of paper mill by-products for land application. Master thesis, Auburn University. Pp 9-13

Nunes, M. R. Velloosa, A. C. X. and Lela, J. R., (1981). Effect of land disposal of vinasse on exchangeable cations and other nutrients in soil. Presqhia Agropecularia Barasilerias, **6** : 171-176.

Nyamangara, J. Bergstrom, L.F. Piha, M.I. and Giller. K.E. (2003). Fertilizer use efficiency and Nitrate Leaching in a Tropical Sandy Soil. *J. Eniviron. Qual.* 32:599-606

Ogola, J.B.O. Ayieko, M.W. Orawo, A.O. and Kimani, F.W. (2011). Analysis of fertiliser use in potato production in Nakuru district, Kenya. *African Journal of Agricultural Research Vol.* 6(16), pp. 3672-3677.

Okalebo, J.R. (2009). Recognising the constraint of soil fertility depletion and technologies to reverse it in Kenyan agriculture. Moi University inaugural lecture 6 series no. 1. Moi University Press, Eldoret, Kenya.

Okalebo, J.R, Gathua, K.W. Woomer, P.L. (2002). Laboratory methods of soil and plant analysis: A working Manual (Soil Science Society of East Africa Technical Publication No. 1, Marvel EPZ (Kenya) LTD, Nairobi, Kenya), 2nd Edition.

Olayinka, A. (2001). Environmentally-friendly means of managing poultry litter. Invited paper presented at the Workshop "Improving Poultry Feed Supply and Litter Management" organized by World‟s Poultry Science Association, Nigeria Branch in Partnership with the Department of Animal Science, Obafemi Awolowo University, Ile-Ife, Nigeria, February 15, 2001.

Onyibe, J.E. Kamara, A.Y. and Omoigui L.O. (2006). Guide to cowpea production in Borno State, Nigeria. Promoting Sustainable Agriculture in Borno State (PROSAB), Ibadan, Nigeria. 36 pp.

Orlando, J. Zambello, E. Agujara, R. And Rossetto, A.J. (1985). Effect of prolonged vinasse application on the chemical properties of sugarcane soils. Indian Sugars, **87**: 11A.

Parr, J.F. Pappendick, R.I. Hornick, S.B. Meyer, R.E. (1992). Soil quality: attributes and relationship to alternative and sustainable agriculture. *Am. J. Alt. Agric*. 7, 5–11.

Pathak, H. Joshi, H. C. Chaudhary, A. Chaudhary, R. Kalra, N. and Dwivedi, M. K. (1999). Soil amendment with distillery effluent for wheat and rice cultivation. Water Air Soil Poll., **113** : 133-140.

Power, J.F. and Dick, W.A. (2000). Land Application of Agricultural, Industrial, and Municipal Byproducts. Soil Science Society of America Inc., Madison, WI.

Preusch, P.L. Adler, P.R. Sikora, L.J. and Tworkoski, T.J. (2002). Nitrogen and phosphorus availability in composted and uncomposted poultry litter. *Journal of Environmental Quality* 31: 2051-2057.

Qian, P. Schoenau, J.J. King, T. and Japp, M. (2013). Effect of repeated manure application on potassium, calcium and magnesium in soil and cereal crops in Saskatchewan. *Canadian Journal of Soil Science*. 85:397–403.

Raburu, P.O. (2003). Water quality and the status of aquatic macroinvertebrates and ichthyofauna in River Nyando, Kenya. PhD thesis, Moi University, Kenya.

Rainbow, A. and F.N. Wilson. (2002). Composting for Soil Improvement in the United Kingdom. In: Proceedings of the 12th International Soil Conservation Organization Conference. May 26-31, 2002 Beijing, China. Pp63-67

Rajukkannu, K. and Manickam, T. S. (1996). Use of distillery and sugar industry waste in agriculture. In: Proc. of 6th national symposium on environment, Tamil Nadu Agricultural University (TNAU), Coimbatore, Jan. 7-9, pp. 286-290.

Rawluk, C. and Flaten, D. (2007). Manure nutrient management and water quality. Pages 13-105. In A report on current knowledge of key environmental issues related to hog production in Manitoba for the Clean Environment Commission Panel on the Sustainability of Manitoba’s Hog Industry. 92 pp.

Reganold, J.P.,Glover, J.D. Andrews, P.K. Hinman, H.R. (2001). Sustainability of three apple production systems. Nature 410, 926–930.

Ribaudo, M.O. Gollehon, N.R. and Agapoff, J. (2003). Land application of manure by animal feeding operations: Is more land needed? *Journal of Soil and Water Conservation* 58: 30-38.

Rostagno, C.M. Sosebee, R.E. (2001). Surface application of biosolids in the Chihuahuan Desert: effects on soil physical properties. Arid Land Research and Management. **15**: 233–244.

Rynk, R. M. van de Kamp, G.B. Wilson, M.E. Singley, T.L. Richard, J.J. Kolega, F.R. Gouin, L. Laliberty, Jr D. Kay, D.W. Murphy, H.A. J. Hoitink, and W.F. Brinton. (1992). On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service, Ithaca, N.Y.

Saidi, M. Ngouajio, M. Itulya, F.M. Ehler, J. (2007). Leaf harvesting initiation time and frequency affect biomass partitioning and yield of cowpea [Vigna unguiculata (L.) Walp] Crop Sci. 47:1159–1166.

Sanchez, P.A. Buresh, R.J. and Leakey, R.R.B. (1998). Trees, soils and food security. In D. J.Greenland, P. J. Gregory and P. H. Nye (eds.). Land resources: on the edge of the Malthusian precipice, CAB International, Wallingford, and The Royal Society, London.

Sangiorgi, F. Provolo, G. Carton, O.T. Comby, T.R. Lorenz, F. Huijsmans, J.F.M. Eftichidis, G. McGechan, M.B. Magette, W.L. (1996). Optimal use of animal slurries for input reduction and protection of the environment in sustainable agricultural systems (SWAMP), Proceedings of the International Scientific Conference "Faculty of Agronomy and Agricultural Development of Slovakia", Nitra, Slovakia, aprile 1996, 101-105.

Sato, S. Solomon, D. Hyland, C. Ketterings, Q.M. and Lehmann, J. (2005). Phosphorus speciation in manure and manure-amended soils using XANES spectroscopy. Environmental Science and Technology 39: 7485-7491.

Scandaliaris, T. Dantur, C.N. and Rancedo, M. (1987). Influence of vinasse on sugarcane production and soil properties. Review of Indian Agroforestry, Tucuman, **64**: 41- 44.

Schalscha, E.B. Escudero, P. Salgado, P. and Ahumada, L. (2008). Chemical forms and sorption of copper and zinc in soils of Central Chile. Communication in Soil Science Plant and Analysis. **30(3/4):** 497-507.

Schoningh. E. and Wichmann W. (1990). Organic manures – meeting expectations? Proceedings, FAO fertilizer conferences. April 1990. Rome

Shakoor, A. Rono, W.K. and Ngugi, E.C.K. (1984). Performance of early maturing determinate varieties of green gram in semi-arid areas. E. A. Agric. For. J., 44: 324-326.

Sharma, O. P. (2001). Use of distillery spentwash in agriculture and its impact on environment-North Indian experience. In: National Seminar on use of poor quality water and sugar industry effluent in agriculture. Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University (TNAU), Trichy, Feb 5, pp 50- 59.

Sharpley, A. N. (2007). Toward environmental and nutrient sustainability: Considering co-benefits and tradeoffs in a system-based approach. Oral presentation at 2007 Manure Management Conference. Adapting and Innovating for Sustainability, Winnipeg, MB.

Sharpley, A. Meisinger, J.J. Breeuwsma, A. Sims, J.T. Daniel, T.C. and Schepers, J. S. (1998). Impact of animal manure management on ground and surface water quality, in: Hatfield, J.L. & Stewart, B.A. (Eds) Animal Waste Utilisation: Effective Use of Manure as a Soil Resource, pp.173-242 (Chelsea, MI, Ann Arbor Press).

Shinde, B. N. Patil, J. D. and Patil, A. S. (1993a). A note on effect of spentwash (distillery effluent) solids and spentwash pressmud compost on soil properties. DSTA 43rd Ann. Conf., Part I, pp. 89-96.

Shiralipour, A. McConnell, D.B. Smith, W.H. (1992). Physical and chemical properties of soils as affected by municipal solid waste compost application. Biomass and Bioenergy 3, 261–266.

Sikora, L.J. Yakovchenko, V. (1996). Soil organic matter mineralization after compost amendment. Soil Sci. Soc., Am. J. 60, 1401–1404.

Sims, J.T. and Wolf. (1994). Environmental Issues. Advances in Agronomy 52: 1-83. D.C. Poultry Waste Management: Agricultural and waste management.

SIMS, J.T. Bergström, L. Bowman, B.T. and Oenema, O. (2005). Nutrient management for intensive animal agriculture: policies and practices for sustainability. Soil Use and Management 21: 141-151.

Singh, A. B. Biswas, A. K. and Ramana, S. (2004). Effect of distillery effluent on plant and soil enzymatic activities and groundnut quality. http : //www. interscience. wiley. com.

Singh, B.B. Mortimore, M.J. Harris, F. Blade, S.B. (1997). in Advances in cowpea research, Cowpea in traditional cropping systems, eds Singh B.B., Mohan Raj D.R., Dashiell K., Jackai L.E.N. (Co-publication of International Institute of Tropical agriculture (IITA) and Japan International Center for Agricultural Sciences (JIRCAS), IITA, Ibadan, Nigeria), pp 99–113.

Singh, B.B. Ajeigbe, H.A. Tarawali, S.A. Fernandez-Rivera, S. Abubakar, M. (2003). Improving the production and utilization of cowpea as food and fodder. Field Crops Res. 84:169–177.

Somashekar, R. K. Gowda, M. T. G. Shettigar, S. L. N. and Srinath, K. P. (1984). Effect of industrial effluents on crop plants. Indian J. Environ. Hlth. 26: 136 -146.

Sommerfeldt, T.G. and Chang, C. (2011). Changes in soil properties under annual applications of feedlot manure and different tillage practices. Soil Sci. Soc. *Am. J.* 49: 983-987.

Stamatiadis, S. Werner, M. Buchanan, M. (1999). Field assessment of soil quality as affected by compost and fertilizer application in a broccoli field (San Benito County, California). Appl. Soil Ecol. 12, 217–225.

Subarao, G.V. et al (1999). Alternative technologies for Sahelian crop production systems in West Africa. In: Faroda, AS, Joshi NL, Kattju S (eds) Recent advances in management of arid ecosystems. Arid zone research Association of India, Jodhpur, India, pp. 121-132.

Sweeney, D.W. and Graetz, D.A. (1991). Application of distillery waste anaerobic digester effluent to St. Augustine grass Agriculture, Ecosys. Environ. 33: 341-351.

Swift, M. (2009). Soil biodiversity principles, tropical soil and biology fertility programme.www.unep.org/bpsp/Agrobiodiversity/agrobiodiversity%20thematic/.pdf.

Szogi, A.A. and Vanotti, M.B. (2009). Prospects for phosphorus recovery from poultry litter. Bioresource Technology 100: 5461-5465.

Taluk, S.M. and Medeiros, A.M. (2009).Nutrient and enzymatic activity in red yellow medium textured latosol treated with vinasse under maize crop. Ecletica Quimica, **14**: 83- 93.

Tarkalson, D.D. and Mikkelsen, R.L. (2004). Runoff phosphorus losses as related to phosphorus source, application method, and application rate on a Piedmont soil. *Journal of Environmental Quality*. **33**: 1424-1430.

Tasistro, A.S. Kissel, D.E. and Bush, P.B. (2004). Spatial variability of broiler litter composition in a chicken house. *Journal of applied poultry research* 13: 29-43.

Tejada, M. Hernandez, M.T. and Garcia, C. (2011). Soil restoration using composted plant residues: effects on soil properties. Soil and Tillage Research. **102(1)**: 109–117.

Tisdale, S.L. Havlin, J.L. Beaton, J.D. Nelson, W.L. (2009). Soil Fertility and Fertilizers. An Introduction to Nutrient Management, 6th ed., Prentice-Hall, Upper Saddle River, New Jersey.

Toor, G.S. and Hunger, B.E. (2009). Phosphorus and trace metal dynamics in soils amended with poultry litter and granulates. Soil Use and Management 25: 409-418.

Trewavas, A. (2001). Urban myths of organic farming. Nature 410, 409–410.

Turner, B.L. Leytem, A.B. (2004). Phosphorus compounds in sequential extracts of animal manures: chemical speciation and a novel fractionation procedure. Environmental Science & Technology **38** (22), 6101-6108.

Van den Berghe, C.H. Hue, N.V. (1999). Limiting potential of composts applied to an acid oxisol in burundi. Compost Sci. Utiliz. 7, 40–46.

Van ryssen, J.B.J. (2008). Trace elements in poultry litter: prevalence and risks, in: Schlegel, P., Durosoy, S. & Jongbloed, A.W. (Eds) Trace Elements in Animal Production Systems, pp. 101 113 (The Netherlands, Wageningen Academic Publishers).

Vavilov N. I. (1951). Phytogeographic basis of plant breeding. The origin, variation, immunity and breeding of cultivated plants. *Chronica Botanica*. 13: 1-366

Wallace, M.B. (2007). Fertilizer use and environmental impacts - Positive and Negative: A review with Emphasis upon inorganic fertilizers in Africa. Winrock.

Wien, H. C. and Tayo T. O. (1978). The effect of defoliation and removal of reproductive structures on growth and yield of tropical grain legumes, pp. 241–252. In S. R. Singh, H. F. van Emden and T. A. Taylor [Eds.], Pests of grain legumes: ecology and control. Academy Press, New York, 454 pp.

Williams, C.M. Barker, J.C. and Sims, J.T. (1999). Management and utilisation of poultry wastes. Reviews of Environmental Contamination and Toxicology 162: 105-157.

Workneh, F. van Bruggen, A.H.C. (1994). Suppression of corky root of tomatoes in soils from organic farms associated with soil microbial activity and nitrogen status of soil and tomato tissue. Phytopathology 84, 688–694.

Workneh, F. van Bruggen, A.H.C. Drinkwater, L.E. Shennan, C. (1993). Variables associated with corky root and Phytophthora root rot of tomatoes in organic and conventional farms. Phytopathology 83, 581–589.

Zalawadia, N.M. Raman S. and Patil, R.G. (1997). ‘Influence of diluted spent wash of sugar industries application on yield and nutrient uptake of sugarcane and changes in soil properties’, *J. Indian Soc. Soil Sci.*, Vol. 45, No. 4, pp. 767 – 769.

Zalawadia, N. M. and Raman, S. J. (1994). Effect of distillery waste water with graded fertilizer levels on sorghum yield and soil properties. *J. Indian Soc. Soil Sci.*, **42** : 575- 579.

Zibilske, L.M. (1987). Dynamics of nitrogen and carbon in soil during paper mill sludge decomposition. *Soil Sci. J.* 143: 26-33

APPENDICES

Appendix i: Field layout for the second experiment

I	II	III
1 NIL	9 WW DAP	17 PW
2 WW	10 WW PW	18DAP PW WW
3 PW	11 WW	19 DAP PW
4 DAP	12 PW DAP WW	20 WW
5 WW DAP	13 NIL	21 WW PW
6 WW PW	14 DAP PW	22 WW DAP
7 PW DAP WW	15 PW	23 NIL
8 DAP PW	16 DAP	24 DAP

Appendix ii: Green house layout

I	**II**	**III**
NIL	PWDAP	DAP
PW	DAPWW	PWWW
WW	DAPPWWW	NIL
DAP	PWWW	DAPPWWW
PWWW	DAP	PW
PWDAP	WW	DAPWW
DAPWW	PW	WW
DAPPWWW	NIL	PWDAP

N/B 1.The spacing between blocks I, II and III was 1m while the spacing between sub-divisions was 0.5m.

2. The abbreviations used in the field and in green house were the same.

Appendix iii: WHO, FAO & KEBS recommended concentration limits of Pb, Cd, Cr, Cu, Zn and Fe in food stuffs and drinking water.

	W.H.O & F.A.O	KEBS
Metal	Maximum limits (ppm)	Maximum limits (ppm)
Pb	0.010	0.100
Cd	0.003	NA
Cu	1.000	0.100
Cr	0.050	NA
Zn	5.000	5.000
Fe	15.000	NA

Adopted from WHO & FAO Geneva (1993), WHO & FAO Netherlands,1998, KEBS (1996).

Appendix iv: Plates showing plant survival rate

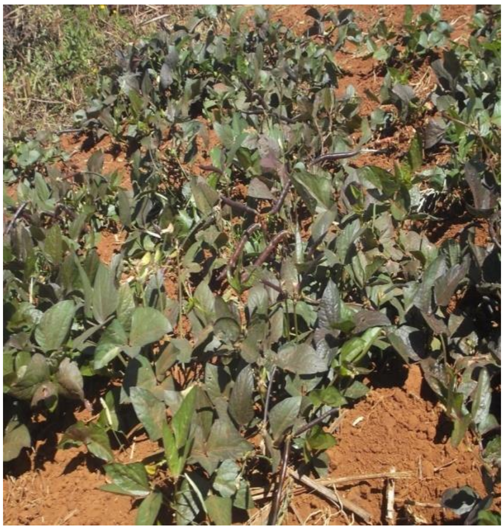

Plate 1 WW

Plate2 NIL

Plate3 PWWW

Plate4 PW

Plate 5 PWDAP

Plate 6 DAPWW

Plate 7 PWWWDAP

Plate 8 DAP

(Source: Author 2012)