A STUDY OF ECOLOGICAL SANITATION OF HUMAN URINE BY TUNNEL HARVEST AND RE-USE FOR PERI-URBAN VEGETABLE PRODUCTION IN BAYERO UNIVERSITY, KANO OLD CAMPUS: A PILOT SCHEME

BY

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BEING A DISSERTATION SUBMITTED TO THE DEPARTMENT OF BIOLOGICAL SCIENCES, FACULTY OF LIFE SCIENCES, BAYERO UNIVERSITY, KANO, IN PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE (M.Sc) IN APPLIED BIOLOGY (ECOLOGY AND ENVIRONMENTAL BIOLOGY).

SUPERVISED

BY

DR. IBRAHIM LAWAN ABDULLAHI

JANUARY, 2018

DECLARATION

I hereby declare that this research work titled **A Study of Ecological Sanitation of Human Urine by Tunnel Harvest and Re-Use For Peri-Urban Vegetable Production in Bayero University, Kano Old Campus**, is a product of my research efforts undertaken under the supervision of Dr. Ibrahim Lawan Abdullahi and has not been presented anywhere for the award of a degree or certificate. All sources have been duly acknowledged.

…….. ……

Rukayya Ahmed Habib Date / Sign

(SPS/14/MAB/00002)

CERTIFICATION

This is to certify that the research work for this dissertation titled **A Study of Ecological Sanitation of Human Urine by Tunnel Harvest and Re-Use for Peri-Urban Vegetable Production in Bayero University, Kano Old Site Campus-A Pilot Scheme,** and subsequent write-up conducted by (Rukayya Ahmed Habib SPS/14/MAB/00002) were carried out under my supervision.

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APPROVAL

This dissertation has been examined and approved for the award of Master degree in Biology (Ecology and Environmental Biology).

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DEDICATION

I have dedicated this work to my beloved Father Mallam Ahmad Habib and to those people around that show respect to humanity.

TABLE OF CONTENTS

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF PLATE

ABSTRACT

Urine used as a fertilizer can help in the mitigation of poverty and malnutrition, and improve the trade balance of countries importing chemical fertilizers if adopted at large scale. The main aim of the research is on urine harvest for vegetables production in Kano. The study employs Ecological sanitation approach by constructing a urine diversion toilet with urine collection facility attached for harvest. The urine sample collected was subjected to chemical analysis to determine spectrophotometrically its chemical composition by adopting different digestion procedures. The urine was sanitized through storage for maximum period of 4month, before field application to assess nutrients contained for the growth and yield of two vegetable species; *Amaranthus caudatus* and *Lactuca sativa*. The different urine and NPK fertilizer in solution concentration levels were prepared and the volume of urine were diluted in ratio per 100mls with water to make 100% volume. There were total of 9 treatments replicated 3 times in a completely randomized block design making 54 pots, and all the weekly data collected was analyzed using sigma stat software (version 3.0).The result indicated that urine contain varying concentrations of chemicals found to improve plant growth and yield including; pH (9.24), Urea (194.9 mg/dl), Chloride (2.96 mg/dl), Potassium (16.24 mg/dl), Uric Acid (2.96 mg/dl), Calcium (4.20 mg/dl), Bicarbonate (23.04mg/dl), Ammonia (0.3175 mg/dl), Sodium (90.63 mg/dl), Phosphate (9.17 mg/dl), and Sulphate (9.25 mg/dl). The growth and yield of *Amaranthus caudatus* with the use of 75% (1:3) water: urine level produced highest significant height ($p<0.05$) of 90.30cm±6.7 and highest yield of 14323Kg/ha. In the case of *Lactuca sativa*, 100% urine level produced most significant ($p<0.05$) number of 21.00±1.1 leaves per plant and also highest yield of 6957Kg/ha. It is envisaged that research output from the study would contribute to reduction of poverty and hunger of Millennium Development Goals (MDG) and attainment of Sustainable Development Goals (SDG) of the United Nations (2015) in areas such as the study area of urban Kano where the impact of the programme was limited by varying factors. It is therefore necessary to evolve better means of addressing environmental sanitation in urban Kano by assessing the practical value of a urine diversion toilets developed and tested elsewhere with modification to suit existing condition or situation in the area

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

The United Nation in year 2000 launched a global initiative on key development issue that concerns most nations in the world. The programe popularly known as UN Millennium Development Goal (MDG) set out eight targets expected to be achieved by 2015 (UNDP, 2016). However, these targets were not achieved by most countries across the globe based on assessment and for various reasons. In Nigeria, the MDG programme was introduced but fraught with several challenges. Issues such as reducing extreme poverty and hunger by half, reducing child mortality, eliminating gender disparity and ensuring environmental sustainability were poorly implemented (Ajiye, 2014). Thus, there was no visible impact of most set targets in many parts of the country. The MDG was subsequently reviewed and changed to Sustainable Development Goals (SDG) in 2012. The success of this new programme depends on a number of factors; namely partnership of government, private sectors, civil societies, and citizens. Out of the eight issues set-out to be covered by MDG, sanitation is perhaps one of the serious problem; poverty, lack of access to safe water, illiteracy and poor and inadequate housing have further worsen sanitation in almost every part of Nigeria (Ajao *et al*., 2011). In cities such as urban Kano, poor sanitation has compounded human health and health care in general.

The expansion in population particularly in urban centers such as urban Kano out-paced the capacity and resources of government both local and state level to provide the necessary sanitation infrastructures for the teeming population. In Kano over the years, monthly general sanitation of the urban Kano environment were implemented with very little impact. Participation is very low,

waste collected from homes and drainages are improperly disposed. This aspect of sanitation which focuses on environmental cleanliness and solid waste disposal excludes the most critical component of sanitation; that is urine and excreta. Access to safe and improved sanitation facility by population of urban Kano is remarkably poor. The population of Kano and Nigeria in general are no doubt among the over 2.4 billion people estimated by WHO/UNICEF (2003) with lack of access to improved sanitation facility. The lack of comprehensive strategy for sanitation in urban Kano has encourage individuals to use open defecation, pit latrines and septic tank system. The waste is usually not treated but collected and dumped on open landfills or farmlands outside the closed-settled zones.

Over the past decades mainly centralized systems have been built to serve the densely populated areas (Wilderer, 2001), these centralized systems result in large investment costs especially for the sewer lines required (Lettinga *et al.*, 2001). Now the focus of sanitation is gradually changing in some countries in Africa, south-America and Asia (Wilderer, 2001) because centralized sanitation system to serve the densely populated areas or cities requires huge investments on pipe network, treatment plants and others. However, a sustainable approach was developed based on decentralized system and it was built on the concept of ecological sanitation (Eco-san). Ecological sanitation is a new paradigm. Eco-san as it is often referred to by some is a system that permits the complete recovery of nutrients from faeces, urine and grey water for the benefits of agriculture and consequently minimizes water pollution. This approach closes the gap between sanitation and agriculture. Ganrot (2005), described Eco-sanitation approach as the economic use of water for maximum reuse particularly for the purpose of irrigation agriculture.

Eco-san has been employed in peri-urban cultivation with a number of benefits (Pasquini, 2006). In this study an Eco-san toilet was used for collection of urine and subsequently employed to raise vegetables in a pilot work.

1.2 Justification

The population of urban Kano now put at about 3million, pose a serious challenge to public health. Water supply is critical for most of the areas, and effective sanitation depends on adequate water supply. Public toilets in urban Kano are very rare and poorly maintained, hence it is very common to see people urinating openly along the streets, open spaces, drains, in water bodies, on buildings and in important places e.g. school premises. This widespread practice by people contributes greatly to the poor state of environmental hygiene in many parts of urban Kano. Any approach that enable the collection of urine separately and subsequently utilize in urban cultivation particularly vegetables would reduce the stench from urine, improve level of environmental sanitation, ensure adequate supply of vegetables for the population and income for the growers is necessary.

1.3 Aim

Assessment of urine by eco-sanitation approach as nutrient for the growth and yield of two vegetable species in field experiment.

1.4 Objectives

The specific objectives of the research includes;

1. Design and construction of a urine collector for harvesting urine
2. Determination of the chemical composition of the urine

3. Preparation and application of urine concentration levels for testing and preparation and application of varying concentrations of NPK fertilizer in solution on growth and yield of selected vegetable species.

1.5 Null Hypothesis

1. The composition of urine does not contain the necessary nutrients for plant growth.
2. Urine does not affect germination, growth and yield of vegetable plants.
3. Growth performance of selected plants treated with urine not better than conventional fertilizers (NPK fertilizer in solution) in the experiment.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Waste management and Environmental sanitation

The Federal Environmental Protection act (1988) of Nigeria does not define "waste", however according to Adewole (2009), waste as the term implies is any solid, liquid or gaseous substances or materials in a foam of scrap or being super flows, refuse or reject, is disposed of or required to be disposed as unwanted. With regard to this, United Kingdom's Environmental Protection Act 1990, re-enacting an earlier U.K statue, took this statutory definition a step further in section 75(2), it defines waste in these terms:

I.) Any substance which constitutes a scrap material or an effluent or other unwanted surplus substance arising from the application of any process or

II.) Any substance or article, which requires to be disposed of as being broken, worn out, contaminated or otherwise spoiled.

Demirbas (2010) defined waste management as the collection, transport, processing, recycling or disposal and monitoring of waste materials. He added that a typical waste management system comprises of collection, transportation, pre-treatment, processing, and final abatement of residues and that the waste management system must consists of the whole set of activities related to handling, treating, disposing or recycling of the waste materials.

Based on this Sharma *et al*., (1994) opined that the most important objective of waste management in developed countries is to protect the environment and that all other objectives are by far, less important. But for developing countries the regard is more complex as it includes environmental sanitation, environmental protection, productivity improvement, employment generation, resource recovery and welfare needs of the huge population among others. According to Pasha (2006)

practicing environmental protection against pollution due to excreta is much more prepared than to undertake expensive measures to reduce pollution that has already taken place. He further added that the approach to the sanitation challenge should be ecologically sustainable. This means that sanitation systems in both developed and developing countries should neither pollute ecosystems nor deplete scarce resources. It furthermore, implies that sanitation systems should not lead to degrading of water or land and should where possible solve the existing problems caused by pollution.

2.2 Ecological sanitation strategy

Ecological sanitation strategy has a prime concern for reuse and recycling of nutrients to improve food production as well as protecting health and the environment (Bruijne, 2007). Morgan (2004) defined Ecological sanitation as a system that makes use of human excreta and turns it into something useful, where the available nutrients can be recycled in agriculture to enhance food production, with minimal risk of pollution to the environment and with minimal threat to human health. Warner (2006) viewed Ecological sanitation as a new paradigm in sanitation which is based on an overall view of material's flow as part of an ecologically and economically sustainable waste water management system which is tailored to the needs of the users and to the respective local conditions. Though it does not favour specific technology rather a new philosophy in handling substances that have so far been seen simply as waste water and water- carried waste for disposal. The essence of Ecological sanitation involves treating human excreta as a resource, sanitizing them and then recycling the nutrients contained in the excreta (Esrey *et al*. 1998). In developing countries, Ecological sanitation often refers to a dry system where the urine is separated from the faeces (Hoglund, 2001). Closing the loop enables the recovery of the organic material, macro and micro nutrients, water, and energy contained in household wastewater and organic waste and their

subsequent productive reuse following appropriate treatment - in agriculture, or for other purposes. An essential step in this cycle is the appropriate treatment and handling of the materials throughout the entire process, from collection through to reuse, ensuring a series of barriers are strictly followed so as to reduce the risk of disease transmission to acceptable limits, thus providing comprehensive protection of human health (Warner, 2006).

2.3 Ecological Sanitation Successes

A comprehensive literature review showed that the use of human urine for food production internationally, is an aged and well-known practice e.g. In China, South Africa, Burkina Faso, México, Haiti, Denmark, Zimbabwe, Sweden etc. (Duncker *et al*., 2007; Karak and Bhattacharyya, 2001; Sene, 2013). History also reveals that transport of sewage was introduced early (2500 BC), but only some Asian societies, which did not utilize sewage flushing, redistributed toilet wastes to arable land effectively. Nutrient flow analyses in developed countries indicate a withdrawal of 20 kg N/ha/yr and 3 kg P/ha/yr from arable land because of non-return of organic human wastes (Kirchmann *et al*., 2005). It was also noted that organic amendments through organic farming are an option for solving the environmentally favourable safe agricultural management strategy (Flavel and Murphy, 2006). Several researches had been documented on Ecological sanitation with varying degrees of successes. Although, Karak and Bhattacharyya (2001) pointed out that Kirchmann and Pettersson (1995) were the first to use human urine as fertilizer in scientific experiments. However, it has been used in varying extents for fertilization of different crops in different countries before as an aged cultural practice. The fertilization value of human urine and its use as a crop nutrient source has received greater attention among researchers in recent times (Morgan, 2003; Prajapati and Gajurel, 2003; Jonsson *et al*., 2004; Mnkeni *et al*., 2008). Examples of some recent studies with their references are in Table 1 below;

Table 1: List of some Countries and References of Successful Ecological Sanitation Trial with different crops

Countries	Crops	References
China	Wheat, Corn, Rice and bamboo	Esrey and Andersson (2001),Mang *et al*. (2007).
Finland	Cabbage and Tomato	Heinonen-Tanski et al. (2007), Pradhan *et al.* (2007). Pradhan *et al*. (2009).
Germany	Ryegrass	Winker *et al*. (2009).
India	Mustard and Banana	Jagpal-sigh and Gangasaran-sigh (1993) Sirdevi *et al.* (2009) and Suresh *et al.* (2002).
Japan	Vegetables and Fruits	Matsui (1997).
Mexico	Cabbage, Bird peppers, Celery and Coriander	Strausss and Blumental, 1993) Guadarrama *et al*. (2001) and Esrey and Andersson (2001).
South Africa	Cabbage, Lettuce, Maize, Beetroot, Carrot, Tomato and Spinach	Mnkeni *et al*. (2008), Fatunbi (2009) Kutu *et al* (in press).
Sweden	Barley, Cabbage and Wheat	Kirchmann and Pettersson (1995), Tidaker *et al*. (2007), Rodhe *et al*. (2004) and Ganrot *et al*. (2008).
Switzerland	Different Vegetables	Maura *et al*. (2003).
Tanzania	Spinach	Chaggu *et al.* (2002).
Vietnam	Rice, Sweet potato and corn	Jensen *et al*. (2008).
Zimbabwe	Wheat,vegetables andMaize	Morgan (2003) and Guzha *et al*. (2005).

From Table 1 above, trial conducted in Zimbabwe showed vastly increased yields of different vegetables and maize, grown on sandy soils, as a result of the addition of urine as a liquid fertilizer (Morgan, 2003). These recent study has showed that human urine has a high content of readily available nitrogen, phosphorus and potassium and its fertilizing effect is reported to be similar to that of nitrogen rich chemical fertilizer (Kirchmann and Pettersson, 1995).

2.2.1 Ecological sanitation challenges

So many challenges have been reported to have been faced through implementation of ecological sanitation. For example Scott (1998) reported that in South Africa ventilated improved pit (VIP) toilets have acquired the stigma of being a "poor man's solution" to the sanitation backlog, which has tarnished the image of its technology. In addition, inadequately maintained sewer-systems in urban areas have caused adverse environmental impacts, mostly as a result of leaking or blocked sewers, but sometimes also as a result of overloaded or inadequately operated or maintained treatment works and failed pumping stations. According to Bruijne (2007) Socio-cultural aspects of sanitation include the influence of gender, religion and culture on individuals' attitudes to waste generation and management.

2.2.2 Acceptability of Urine as Organic Fertilizer

Richert *et al*. (2010) stated clearly that urine is a perfect fertilizer for organic production, where synthetic mineral fertilizers are not allowed. However, there are certain barriers to the use of urine in production systems when brand for organic production is used. To his opinion these barriers are expressed for example in regulations by the European Union. The organic agriculture is governed by the European Union regulation (EEG) 2092/91 which applies to all certified European organic agriculture. This regulation regulates among others the inputs allowed in organic agriculture. Human urine is at present not included as a fertilizer in the EU regulation which makes it difficult

for organic farmers in Europe or exporting to a European market to use human urine (Hoglund (2001). The Swedish Organic Agriculture Certifying Organization (KRAV) is the only organization that has made an exemption for one farmer, that is any farmer that has a closed loop system where nutrients are recycled and food delivered in the same community, so far as there is a proximity between the community and the farmer and the risk of contamination or unsustainable practice is minimal (Richert *et al*., 2010). But Hoglund (2001) added that the International Federation of Organic Agriculture Movements (IFOAM) allows urine (and feces) if sanitary requirements are met (IFOAM 2000). Provided that the requirements were established by standardizing organizations.

2.2.3 Ecological sanitation practices in Africa

The report compiled by Buechler and Scott (2006) on wastewater use for urban and peri-urban agriculture indicated that, the percentage of the cities with full water-borne sewerage connections in sub-Saharan African was not significant. Harare, Zimbabwe, is one of the cities in Sub-Saharan Africa with the highest coverage while Lagos, Nigeria, has one of the lowest. In Lagos, Nigeria, Africa's largest city, with a population of 10 million, only 5% of its population is connected to the sewage system and treatment of sewage is below recommended standards (Buechler and Scott, 2006). Only 2% of the cities in sub-Saharan Africa have sewage treatment, and only 30% of these systems are operating satisfactorily. For example, In Addis Ababa, with a population of 2.5 million, the sewage system serves only 35,000 people.

2.3 Human Urine Storage and Uses

Urine is a dilute aqueous solution of metabolic wastes such as urea, salts, and organic compounds. In total the dissolved material amounts to about 5% by weight. Fluid and materials being filtered by the kidneys, destined to become urine, come from the blood or interstitial fluid (Torondel,

2010). Urine is sterile until it reaches the urethra where the epithelial cells lining the urethra are colonized by facultative aerobic gram negative rods and cocci (Egbunwe, 1980). Esrey and Andersson (2011) pointed out that urine has been used as a resource in many parts of the world for centuries. It was used in Europe for household cleaning, softening wool, hardening steel, tanning leather and dying clothes. The Greeks and Romans used it to colour their hair, and African farmers use it for fermenting plants to produce dyes, while the Chinese pharmaceutical industries use it to make blood coagulants. In Mexico unfermented urine is sprayed as a fungicide on farm. Indigenous people in south-eastern Mexico claim that the use of urine as a fungicide on plants was a traditional Mayan practice (Clark, 2003).

According to Morgan (2004) urine has been used as a valuable plant food for centuries in many parts of the world, particularly in the Far East and Africa. It is surprising therefore that nearly all the urine produced in the West and in Africa goes to waste and is lost to agriculture. It contains a lot of nitrogen and also phosphorus and potassium in smaller quantities, nutrients which are very valuable to plant growth. The survival of various microorganisms in urine through time is affected by the storage conditions (schonning, 2001). It is essential that urine be stored in order to achieve proper hygienization, especially if collected from many households or when there is no cropping season. Thus to avoid ammonia losses, it has to be stored in a tightly closed containers. Jerry-cans are the most common way of collecting urine, and a very good way to store it for a short period too. While one cubic metre tanks are quite common in small and medium scale collection systems (Richert *et al*., 2010). Storage is often recommended as the main on-site treatment, although the success in practice is variable (Schonning and Stenstrom, 2004) hence, storage is rather more efficient in killing pathogens in dry, hot climates. The fate of any pathogen entering the urine collection container is important for assessing the hygienic risks associated with the handling and

use of the urine. Studies have been performed with different microorganisms added to the urine and their inactivation followed over time (Höglund, 2001). Karak and Bhattacharyya (2011) stated that storage of human urine is a crucial part before its application in agricultural field. However losses of nitrogen during storage can be minimized by minimizing temperature, and avoiding aeration above the liquid surface in storage containers. However, high pH, high temperature, concentrated form of urine (high N concentration) and long storage periods are favourable for hygienic reasons (Hoglund *et al*., 1998). Vinneras *et al*. (2008) recommended that storage period for human urine as of 6months at 20^0C or higher is safe for unrestricted use with respect to pathogens and viable viruses.

2.4 Nutrient Content of Urine and it's Degradation in Soil

The amount of urine produced by an individual depends on age and amount of fluid intake (Richert *et al*., 2010). However, in areas where meat is more common the quantity of Nitrogen is higher. An individual adult produces 1-1.5 Litres of urine per day in 4-5 times (Karak and Bhattacharyya, 2010) and an average of 500 Litres urine per year (Jonsson *et al*., 2004), while children on the other hand produces about half of an adult (Karak and Bhattacharyya, 2011). Kirchmann and Pettersson (1995) investigated the nutrient content in urine and it was found that the nutrients are in ionic form and their plant availability matches well with chemical fertilizers. According to Karak and Bhattacharyya (2010) one litre of urine contains 11gms nitrogen, 0.8 grams phosphorus and 2 grams potassium. That is a ratio of NPK of about 11:1:2.Thus if 500 litres of urine are produced by each person per year that equals to 5.6 kg nitrogen, 0.4 kg phosphorus and 1.0 kg potassium. Several researches on human urine shows that of the human excreta, urine contains the major part of the daily excretion of nitrogen (N), phosphorous (P) and potassium (K) contributing 88%, 67% and 73%, respectively (Kirchmann and Pettersson, 1995; Schonning, 2001). However,

as mentioned earlier the composition of human urine varies from person to person and from region to region depending on the feeding habit of an individual, the amount of drinking water consumed, physical activities, body size, and environmental factors (Sullivan and Grantham, 1982; Vinneras and Jonsson, 2002). In human urine about 75–90% of N excreted are urea and the remaining are in the form of creatinine, amino acids and uric acid (Lentner, 1981). Most of the nitrogen fractions in urine are taken up by plant and which is same as that of the urea or ammonium fertilizer with nitrogen efficiency approximately 90% of that of mineral fertilizer (Jonsson *et al*., 2004). Schönning (2001) stated that when excreted, the pH of urine is around 6-7. The degradation of urea to ammonium/ammonia raises the pH to around 9 (Equation 1).

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ ……. (1)

In the soil the ammonium is nitrified, releasing two protons (Equations 2 and 3), thus acting as an acid

$NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 1\ H_2O + 2\ H^+$ ……. (2)

$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$ …… (3)

Finally, when taking up the nitrate ion from the soil liquid, the root release a hydroxide ion. In summary, in the urea degradation one hydroxide ion is released, in the nitrification two protons and in the plant uptake one hydroxide ion again. Thus, in total two protons and two hydroxide ions are released, which means that the net effect on the soil pH is small. He further viewed that the nutrient balance and content of the urine reflects well what the crops have removed from the fields and thus the average need of fertilization. The reason for this is that urine contains far more nutrients than the faeces and together urine and faeces contain the same amount of plant nutrients as the food. This means that the nutrient content and balance of the urine is similar to that of the consumed food. Since the nutrients of the food have been removed from the fields, they also show

the amount of nutrients needed to not deplete the field. This is true for all nutrients and thus for the balance between them.

The nutrients in urine are in forms which are readily plant available as have been mentioned earlier, the nitrogen is in the form of urea, which readily degrades to ammonium and nitrate that are both plant available. Concentration of heavy metals in human urine were found to be lower than that of farmyard manure and have less cadmium than artificial P-fertilizers, making them clean fertilizers (Jonsson *et al*., 2005). Moreover, it comprises of trace elements B, Cu, Zn, Mo, Fe, Co and Mn (Rodushkin and Odman, 2001).

2.5 Urine Re-use in Agriculture and it's Benefits

Use of human excreta in agriculture has been in existence for centuries in many countries like China, Mexico, Netherlands, Norway and Germany since 18th century where culture have in many occasions taken middle stage in design and distribution of sanitary systems. In such countries it became popular under the name Ecosan, dewarts and desar, but currently referred to as Urine Diversion Dry Toilets (UDDT) (Odipo 2014). Health risks associated with the use of human urine in plant production are generally low (Richert *et al.*, 2010). Because in a healthy individual the urine is sterile in the bladder, but only when transported out of the body that different types of dermal bacteria are picked up. Freshly excreted urine normally contains <10000 bacteria per ml (Tortoro *et al.*, 1992). But in the case of urinary tract infections, more than 80% of cases are caused by *E. Coli* (Murry *et al.*, 1990). Large number of bacteria may be excreted, however, these have not been reported to be transmitted to other individuals through the environment. Venereal disease causing organisms may occasionally be excreted in urine, but evidence of their continued survival outside the body and its implications is limited (Feachem *et al*., 1983). According to Feachem *et al*., (1983), the pathogens traditionally known to be excreted in urine are *Leptospira interrogans*,

Salmonella typhi and *Salmonella paratyphi* among the bacteria, and *Schistosoma haematobium* are Helminthes while *Microsprodia* is among the Protozoans. The *Cytomegalovirus* (CMV) exist among the viruses (Jawetz *et al*. 1987).

Schonning (2001) made concluding statement that pathogens transmitted through urine are not sufficiently common to constitute a significant public health problem and are thus not considered to constitute a health risk related to the reuse of human urine in temperate climates. An exception in tropical areas is *Schistosoma haematobium*, due to its life cycle, however it implies a low due to inactivation process of urinary excreted pathogens in the environment which reduces their ability for transmission.

According to Karak and Bhattacharyya (2011), the cost of standard compost production and also scarcity and high cost of chemical fertilizers is a limiting factor particularly for economically less sound farmers but still they need to cultivate food to sustain their life. With a better-closed nutrient loop, many more people, including low-income farmers, would be able to produce more food and other plant products by using human urine. Use of human urine as an alternative source of fertilizer in agriculture will not only decreases the fertilizer cost but also limits the pollution effects from unsafe excreta disposal and surplus use of chemical fertilizers and protect surface and groundwater and the air (Heinonen-Tanski and Wijk-Sijbesma, 2005). Farming practices in closely settled peri-urban zone had so far attracted some research attentions. Mortimore (1993) conducted a study of Kano close settled zone between 1964 and 1986, and stated that high population density causes more land to be used for agriculture; therefore rangeland areas are reduced, limiting the availability of animal fodder. Long period of this practice may reduce restoration of soil fertility. Hence in Kano, farmers and herders interact, exchanging fodder for animal manure to restore soil fertility.

It is the balance of nutrients especially the nutrients present in animal manure including human urine over time that determines sustainability.

Urban and Peri-urban Agriculture (UPA) can offer wide-ranging benefits (Pasquini, 2006). It can contribute significantly to the amount of food consumed in the city. Sweet (1999), has it that 15–20% of the world's supply of vegetables and meat is produced in urban areas, and FAO (1999) estimates that 800 million urban dwellers are engaged in UPA, 200 million providing food for markets (FAO, 1999). UPA is practiced for some reasons; for example during crisis management when markets are not working (e.g. in Cuba), and also as a means to overcome cash shortages and for commercial purposes. As well as improving food security and nutrition, and creating employment for the jobless (Lynch *et al.*, 2001), UPA can offer a range of environmental benefits, including improved waste recycling, and improvement in body health including improved physical and psychological health due to increased physical activity as well as additional food vitality (Lock and Van Veenhuizen, 2001).

2.6 Implication of urine re-use in agriculture

Phosphorus and Potassium balances of organic systems indicate that more of these nutrients are removed through harvested products than applied to soil (Kaffka and Koepf 1997; Spiess *et al* 1993; Fagerberg *et al* 1996; Ivarson and Gunnarsson 2001). Farm-gate balances also indicate a greater output than input of nutrients in organic agriculture (Fowler *et al* 1993; Nolte and Werner 1994; Granstedt 1995), although not if sufficient volumes of approved organic manures are purchased (Nyberg and Lindén 2000). For instance, reduced concentrations of plant available P and K were measured in nutrient-rich soils in Norway within five years of conversion to organic practices by Løes and Øgaard (1997) and in Denmark, Askegaard and Eriksen (2000) reported K limited growth of barley and clover ley crops on sandy soils after only a few years of organic

farming. In the United Kingdom, Berry *et al* (2003) examined nine organic farms and found additions of rock phosphate and imported animal feed provided large amounts of P and K but, even so, K budgets were negative on most farms, particularly those without animals. Morgan and SIE (2004) discussed this issue in detail by pointing out that; most vegetable fertilizers for example in Southern Africa contain more phosphorus than nitrogen. Also in an assessment of 10 garden fertilizers available in Zimbabwe, the combined ratios of NPK amount to N = 98 points, P = 174 points and K = 125 points a ratio of very approximately 1:2:1. Compound vegetable top dressing often have a ratio of 2:3:2 for NPK. The Ammonium nitrate is quite often applied separately as a "top dressing" once the plant is established. The recommended fertilizers for maize provide more phosphorus than nitrogen in the ratio 1:2:1 at the planting or seedling stage and then ammonium nitrate at a later stage once the roots have been established and the plant is secure and meaningful vegetative growth will take place. The high phosphorus content of these chemical fertilizers not only reflects the needs of the plant at an early stage of their life, but also that most soils in Africa are very deficient in phosphorus. 70% of natural soils tended by rural farmers in some countries like Zimbabwe possess inadequate phosphorus. It is interesting that studies in China show that the daily output of phosphorus in the faeces is greater than in the urine.

The balanced array of nutrients present in eco-humus is thus ideal for the early growth of plants with more phosphorus in relation to the other major nutrients, compared to urine. Later on urine can be applied as a liquid plant food during the main vegetative period of growth to supply extra nitrogen. Nitrogen loving plants like maize and green leafy vegetables are particularly responsive. Also, according to Hill (1997) an excess of nitrogen can reduce the uptake of vital elements like potassium, which is an essential nutrient for healthy plants. Hill also explains that if you fill the plant transpiration stream with a salt and only a fraction gets used, then other more important

nutrients may get blocked. The uptake of too much phosphorus may block potassium, whilst excess calcium locks up boron (Hill, 1997). Morgan (2004) further explained that it is not uncommon for magnesium to be deficient where chemical fertilizers provide lots of potassium. Therefore the answer to all these problems is to try to accomplish a balance of nutrients in the soil. It is also accepted that unless plants have plenty of humus in the soil, they cannot take up the minerals even if available, especially in drier conditions, a conclusion arrived at by Bromfield (1949) as well as Hill (1997) and many others.

The functions of nitrogen, phosphorus and potassium are interlinked. If large amounts of nitrogen are used, this will cause extra leaf and stem growth, but this growth response will cause the plant to demand extra phosphorus and potassium from the soil. Extra that is to the amount which would have been needed without the nitrogen application. Also nitrogen cannot be efficiently used by the plant unless potassium is there in a proper N/K ratio. Thus deficiencies in phosphorus and potassium show up if too much nitrogen is applied. Nitrogen is a primary growth nutrient, but without the accompaniment of adequate phosphorus and potassium the growth is unhealthy, more liable to pest attack and disease. Potassium in particular is needed to bring about a balance and ensure that the extensive plant structure is formed of healthy and efficient tissues. This imbalance is perhaps not so serious in short lived plants like lettuce (and green vegetable like spinach and rape and covo). But where the plant has to grow for a full season and eventually produce a seed or fruit crop, these derangements caused by unbalanced nitrogen become serious. Apart from the danger of pest attack and disease, the overstressing of the tissue building function leads to delay in the other functions of the plant and the seed formation or fruit ripening stages are held up. According to Hopkins (1945) anybody wishing to demonstrate this by personal experience should see how much is lost by giving one or two tomato plants in a row, applications of soluble nitrogen

in the late (European) summer. Further leaf and shoot formation will occur but the existing fruit will delay their yellowing and reddening until the autumn sunshine has departed. The fruit yield is thus reduced.

Thus a good balance of nutrients is required for the best plant growth, with generally more phosphorus being required at first in relation to the other major nutrients and then more nitrogen and potassium required later. Adequate amounts of potassium are particularly necessary for crops like tomato, potato and also fruit trees. Too much nitrogen can block this vital element. So care is required in the overzealous application of urine.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Study Area

The study area is the Bayero University Kano old campus, located in Gwale local Government of Kano metropolis. Kano State lies approximately between latitudes 10˚ 33'N and 12˚ 23'N and longitudes 7˚ 45'E and 9˚ 29'E, with a population of 11,087 800 based on the 2006 National head count or census (NPC, 2011). It has an estimated land area of 21,276.872 km^2 out of which 1,754,200 hectares for agricultural and 75,000 hectares forest vegetation and grazing land (AIAE, 2007). The urban Kano has a number of peri-urban farms such as 'Kwakwaci, Dan'agundi, Sharada, Ja'en, Kwarin Gogau and Gama Kwari' to mention a few. The farmlands uses domestic wastewater for the cultivation of household vegetables including Spinach (*Amaranthus sp*), Lettuce (*Lactuca sp*), Cabbage (*Brassica sp*), cucumber (*Cucumis sp*) and many others.

3.2 Reason for Selecting the Type of Experimental Toilet Used:

A convenient and appropriate site was selected for the work. In selecting the type of urine diverting toilet constructed, special concern was given to cost, convenience and most common type of toilet use by mass in the experimental area.

3.3 Selection of Experimental site:

A convenient place was also selected for pot experiment, in selecting the site, consideration was given to space for preparation of seedling plots, water availability, sun light and protection against insects, rodents and disease attack.

3.4 Work Plan

The study was organized in to three (3) phases: These included phase I (provision of a make-shift urine toilet), phase II (laboratory determination of concentration levels for chemical substances in urine) and phase III (seed germination and growth monitoring).

3.4.1Phase I: First Field work (Urine Harvest, Collection and Storage):

It includes the construction of a urinal improvised facility (attached for the urine collection from interested subjects) and storage for field experimentation.

3.4.2. The Improvised Urinal Facility for Urine Harvest and Collection

A square shaped land of two square meters was selected and raised by 9 inches height blocks. The selected space was cemented but sloped at one end and attached to a urinal. The urinal was made by cutting a 4 liter gallon vertically and one half was fixed with cement by the end of the sloped part of the space as a urinal. The mouth of the gallon was placed and adjusted as an outlet and attached with 1inch PVC pipe as channel of the urine to the outside. At the outside, 20ltrs jerry-can was selected and 1inch diameter circular space by the right at the top and 5cm away from the handle was perforated using sharp hot metal and 1inch PVC pipe of 10cm length then attached to befit the outlet made and fixed permanently by melting. The PVC pipe was again joined by the other end through an elbow to the union. It was the union that joined through a screw cap ring to the extension of the PVC pipe from the urinal to attach the urine collection facility to the urinal. The facility was placed fixed to the urinal by digging an underground hole of 60 inches deep and 30 by 30 inches by width and breadth and subsequently covered with flat aluminum sheet to avoid anything from tempering with the setting. Hence, five (5) 20ltrs capacity yellow jerry-cans were filled for storage.

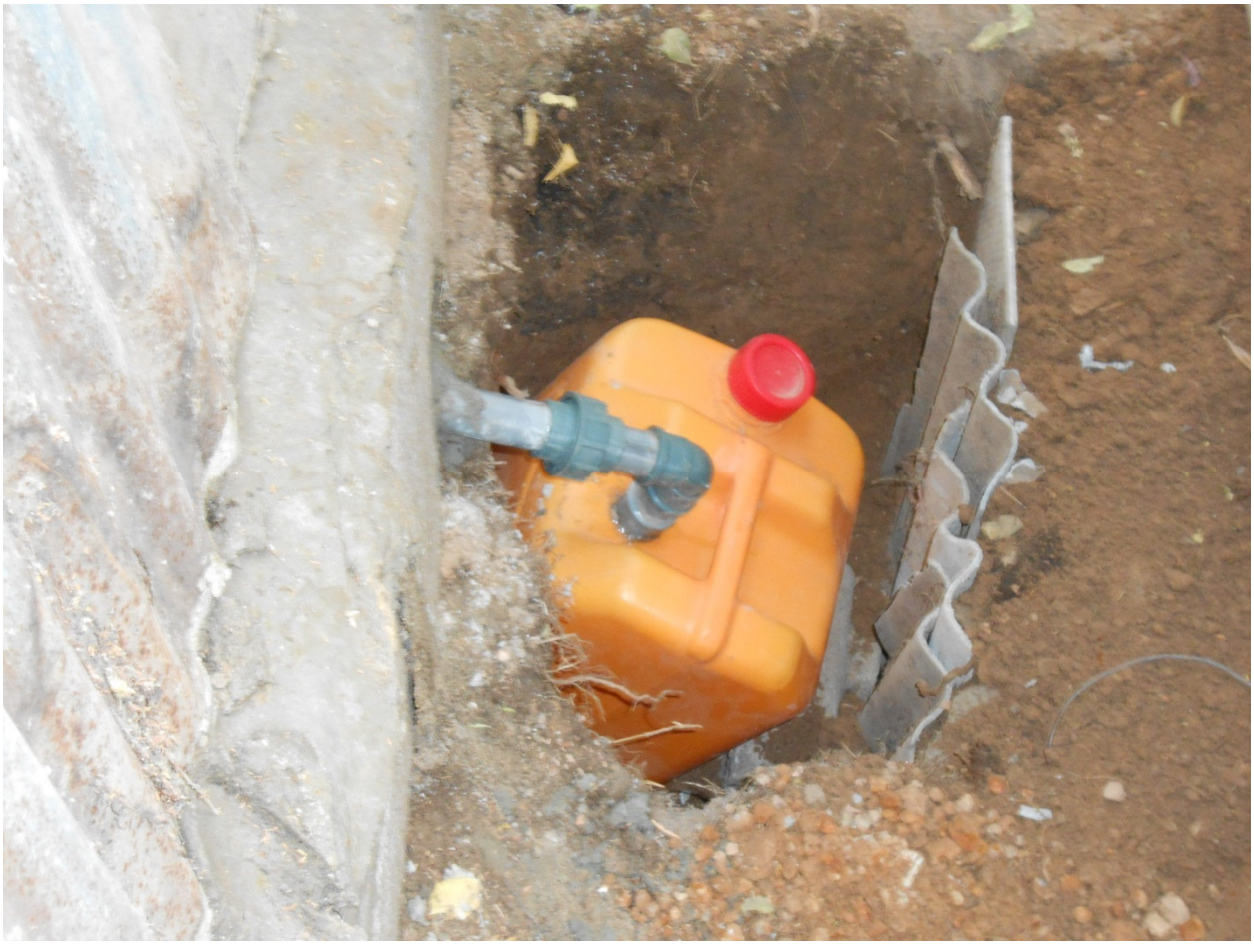

Plate I: The improvised Urine Harvesting Structure

3.4.3 Urine storage

The urine sample collected was stored for maximum of 4 month in tightly capped 20 liters capacity Plastic Jerry-cans in the field as described by Hoglund (2001) and Heinonen Tanski *et al.*, (2007).

3.5 Phase II: Laboratory Determination of Urine Composition: comprised of laboratory determination of pH, Urea, Chloride, Potassium, Uric Acid, Calcium, Bicarbonate, Ammonia, Sodium, Phosphate, and Sulphate within the urine sample.

3.5.1 Determination Chemical Composition of Urine

For the detection quantitatively of various ions/substances contained in urine, procedures and methods employed by other workers were adopted in this work. This methods/procedures included APHA (2005), Tietz; 1976 and 1990; Barnett (1965); Burtis (1996); Henry (1974); Van Slyke and Stadie (1921); Balton and Crouch (1977); Ademori (1996) and Udo *et al*., (2001) respectively.

3.5.2 Determination of pH (APHA, 2005)

The pH of the urine sample was determined using digital pH meter.100 ml of each of the urine samples in a beaker ware used by dipping in to it the pH meter which was switched on and dipped in to distilled water for standardization. The electrode of the pH meter was dipped then into the beaker containing the urine. The pH value was read from the digital screen of the pH meter and the mean of the readings recorded from repeated measures.

3.5.3 Determination of Urea (Balton and Crouch, 1977)

Procedure

Three test tubes were labelled as blank, standard and test. 10µL of Distilled water, 10µL of standard and 10µL sample were pipetted in to three labelled test tubes respectively. 100µL of Reagent 1 (called "R1 buffer" is a combination of Phosphate buffer pH 8.0 (100 mmol/l), Sodium salicylate (80 mmol/l), Sodium nitroprusside (6.0 mmol/l) and EDTA (30.0 mmol/l) was then added in to each tube. These were mixed immediately and incubated at 57ºc for 15min, the absorbance of the test sample and standard was measured against the blank at 578 nm.

Calculation:

$$\text{Concentration of test} = \frac{\text{Absorbance of test} \times \text{concentration of standard}}{\text{Absorbance of standard}}$$

The quantity of Urea Nitrogen in each of the urine sample was determined by multiplying each of the concentration value of urea in the sample by 0.467.

3.5.4 Determination of Chloride (Henry, 1974)

Procedure

Three test tubes were labelled as test, standard and blank. Chloride reagent (1.5 cm^3) was pipetted in to each test tube. Then 0.01 cm^3 of Standard reagent was added in to standard labelled tube followed by the addition of similar quantity of test sample in to 'test' labelled test tube. Contents of all the tubes were mixed and incubated at room temperature for 5 minutes. The absorbance of all cuvettes were read and recorded at 480nm.

Calculation:

$$\text{Concentration of test} = \frac{\text{Absorbance of test} \times \text{concentration of standard}}{\text{Absorbance of standard}}$$

3.5.5 Determination of Potassium (Tietz, 1976)

Procedure

Three test tubes were labelled test, standard and blank. 0.01cm^3 of Potassium reagent (Sodium Tetraphenylboron 2.1 mM, preservatives and thickening agents), 0.01cm^3 of test sample and 0.01cm^3 of distilled water were added each in to respective labelled test tubes, then mixed and incubated at room temperature for 3 minutes. The spectrophotometer was made zero with blank. The absorbance of cuvettes was read at 578nm and recorded.

Calculation

$$\text{Concentration of test} = \frac{\text{Absorbance of test} \times \text{concentration of standard}}{\text{Absorbance of standard}}$$

3.5.6 Determination of Uric Acid (Tietz, 1990)

Procedure

Three test tubes were labelled as blank, standard and test. 1.0ml of Uric acid reagent (made up of Phosphate buffer (100 mmol/L), DCHB (5.0 mmol/L), Potassium hexacyanoferrate (80 µmol/L),

4- amino-antipyrine (0.6 mmol/L), Peroxidase (>3000U/L), Uricase (>500 U/L)) were pipetted in to each test tube, then 20µl of standard reagent was added in to standard labelled test tube and similarly 20µl of test sample were added to test labelled test tube. These were mixed and incubated for 5 minutes at 37℃ . The absorbances of test and standard were measured against reagent blank at 546 nm.

Calculation:

$$\text{Concentration of uric acid in urine} = \frac{\text{Absorbance of test} \times \text{concentration of standard}}{\text{Absorbance of standard}} \times 10$$

3.5.7 Determination of Calcium (Barnett, 1965)

Procedure

Three test tubes were labelled as blank, standard and test. 0.5ml of both reagents 1 (Called R1 Buffer which is 2-Amino-2-methyl-1-propanol (0.3 mol/L) of pH 10.5) & reagent 2 (Called R2 Chromogen which consist of O-cresolphthalein complexone (0.16 mmol/L) and 8-hydroxyquinoline (7.0 mmol/L)) were added in to each of the labelled test tubes. Then 10µL of standard were added in to the test tube labelled 'standard', followed by the addition of similar quantity of test sample in to the 'test' labelled test tube. These were mixed and incubated for 5mins at 20℃ . The absorbances of test and standard were measured against blank at 578nm.

Calculation:

$$\text{Concentration of test} \frac{\text{Absorbance of test} \times \text{concentration of standard}}{\text{Absorbance of standard}} \times 2$$

3.5.8 Determination of Bicarbonate (Van Slyke and Stadie, 1921)

Procedure

Three test tubes were labelled as standard, blank and test. 1ml of CO_2 –reagent were added in to each of the already labelled test tubes and incubated for 3 minutes at 37℃. Then 5µL of H_2O were

added in to 'blank' labelled test tube, followed by addition of 5µL of standard reagent in to 'standard' labelled test tube and similarly addition of 5µL of test sample followed in to 'test' labelled test tube. The content of each test tube was mixed gently by inversion and incubated again for 5mins. The absorbance of all the cuvettes were read at 415nm.

Calculation:

$$\text{Concentration of test} = \frac{\text{Absorbance of test} - \text{Absorbance of blank} \times \text{Concentration of standard}}{\text{Absorbance of standard} - \text{Absorbance of blank}}$$

3.5.9 Determination of Ammonia (Burtis, 1996)

Procedure

Three test tubes were labelled as test, standard and blank. Then 1.0ml of reagent R (Bicine buffer of pH 8.5 (100 mmol/L), α-ketoglutarate (7.5 mmol/L, Sodium Azide (0.05%), GLDH (microbial) 500 Ku/L, NADPH 0.2mmol/L and Sodium Azide (8 mmol/L)) was added in to each of the labelled test tubes. 100µL of standard reagent was added in to 'standard' labelled test tube while 100µL of test sample was added in to 'test' labelled test tube.

The content of each test tube was mixed, and after 30seconds the spectrophotometer's reading was made zero with blank then readings of the cuvettes were read and recorded after exactly 2.5 minutes.

Calculation:

$$\text{Concentration of test} = \frac{\text{Absorbance of test} \times \text{concentration of standard}}{\text{Absorbance of standard}}$$

3.6.0 Determination of Sodium (Tietz, 1976)

Procedure

Filtrate preparation

Three test tubes were labelled as test, blank and standard.

i. 1.0ml of Filtrate reagent (Uranyl Acetate 2.1 mM and Magnesium Acetate 20 mM in ethyl alcohol) was pipetted and added to all test tubes.

ii. 50µL of test sample were also added to test and standard labelled test tubes while same quantity of distilled water to blank marked test tube.

iii. All tubes were shaken vigorously followed by continuous mixing for 3mins.

iv. Tubes were centrifuged at high speed (1500G) for 10mins and the supernatant fluid tested, with much care not to disturb the protein precipitate.

Colour development

a) Test tubes were labelled accordingly as above.

b) 1.0ml of acid reagent (diluted acetic acid) was pipetted to all test tubes.

c) 50µL of supernatant fluid was added to all test tubes also and mixed'

d) 50µL of colour reagent (Potassium Ferrocyanide, non-reactive stabilizers, and Filters) too was added to all test tubes and mixed.

e) Spectrophotometer was made zero reading with distilled water

f) Absorbance readings of all cuvettes at 550nm were recorded.

Calculation:

Concentration of Sodium =

$$\frac{\text{Absorbance of blank} - \text{Absorbance of test}}{\text{Absorption of blank} - \text{Absorption of test}} \times \text{Concentration of standard}$$

3.6.1 Determination of available phosphate (Ademoriti, 1996)

Procedure

i. 5ml of urine sample was pipetted in to a beaker then diluted with 5ml distilled water and subsequent emptying in to a 50-ml Erlenmeyer volumetric flask.

ii. The required acid quantity was added to all the samples to bring the solution pH to 5.0.

iii. 8 ml of reagent b was added, and diluted to 50-ml volume with distilled water, and mixed well.

iv. Standard curve was prepared as follows:

a) 2 ml of each standard (4 ppm) was pipetted, and proceeded as for the samples.

b) The blank was made with only distilled water, and proceeded as for the samples.

v. The absorbance of blank, standards, and samples were read after 10 minutes on the spectrophotometer at 882 nm wavelength.

vi. The calibration curve for standards was prepared, plotting absorbance against the respective P concentration.

vii. The P concentration was read in the unknown samples from the calibration curve.

Calculation:

$$\frac{R \times G \times V.F \times D.F}{A.T}$$

Where R = Absorbance

G = Slope

V.F = Volume of flask

D.F = Dilution Factor

3.6.2 Determination of Sulphate (Udo *et al*., 2001)

Procedure

i. 5mls of the urine sample was pipetted into a 25ml volumetric flask. The distilled water was added to bring the volume to approximately 20mls.

ii. 1ml of the gelatin-$bacl_2$ reagent was added, and the volume was made up with distilled water. The content was mixed thoroughly, and allowed to stand for 30 minutes.

iii. The content was shaken in the flask before pouring in to the cuvettes. The percentage T and optical density (OD) was determined at 420nm within 30mins on spectronic 70 electro-colorimeter.

iv. Sets of standard S solutions containing 0, 25, 50, 75, 100 and 125ug SO_4^- S per 25mls from the working reagent was prepared. Each standard contained 1ml of gelatin-$BaCl_2$ reagent and 10mls of the extracting solution.

Calculation:

$$\frac{R \times G \times V.F \times D.F}{A.T}$$

Where R = Absorbance

G = Slope

V.F = Volume of flask

D.F = Dilution Factor

A.T= Aliquot Taken

3.7 Phase III: Second field work (Pot experiment)

This comprises of preparation of plots for planting and monitoring growth after application of test substances on two selected vegetable species; *Lactuca sativa* (Lettuce) and *Spinacia oleracea* (Spinach).

3.7.1 Experimental Design

The experiment consisted of two variety of vegetable crops: Lettuce (*Lactuca sativa*) and Spinach (*Amaranthus caudatus*), simultaneously tested in two (2) treatments of 4 levels of urine and NPK fertilizer in solution. The treatment combinations were laid out in Randomized completely block design (RCBD) replicated 3 times each making a total of 54 pots.

3.7.2 Seed source

The improved seeds of Lettuce (*Lactuca sativa*) and Spinach (*Amaranthus caudatus*) were obtained from IITA (International Institute for tropical Agriculture).

3.7.3 Seed germination test

There were Thirty (30) seeds each of the test crops counted to be sown. These were placed separately in sterilized (9cm diameter, 1.3cm deep) petri dishes containing 2 layers of 'Whatman' filter paper. The filter papers where moistened with 5 ml of respective urine and NPK fertilizer in solution (25ml, 50ml, 80ml and 100ml) and distilled water was added on control (N_0U_0) and replicated 3 times too. The petri dishes were covered, labelled and kept under laboratory condition and each were observed daily.

3.7.4 Pot preparation

The soil used in the experiment was mixed with humus in the ratio of one part humus seven parts soil that is 1:7 ratio (Sene, 2013). The soil was dried, crushed and bulked together (Abdurrashid, 2007). Soil analysis was conducted prior to planting and the physical properties of the pot soil used include; 7.76% clay, 11.88% silt and 80.48% sand and are texturally classified as loamy sand soil. Then 6kg of the soil was weighed in to each of 54 plastic experimental pots of 12 liters liquid capacity, leaving sufficient space for irrigation. Different quantities based on treatment requirement labelled on pots, for both urine and NPK fertilizer in solution was added and thoroughly mixed with the soil in each pot, then watered to near 80% field capacity moisture content and allowed to equilibrate for 8 hrs before seeding (Mnkeni *et al*., 2008).

3.7.5 Planting and Irrigation

The Pots were watered before and after sowing and ten seeds per pot was planted in to each pot. The seedlings were later thinned to three seedlings per pot 2 weeks after emergence (Umar, 2007).

The daily irrigation with 250mls (Mnkeni *et al.*, 2008) of water per pot was observed immediately after sowing.

3.7.6 Treatment and Mode of Application

The experiment has a total of nine treatments in which dilution percentages in 100mls capacity are: 25%, 50%, 75% and 100% concentration levels of human urine was identified as U_{20}, U_{40}, U_{80} and U_{160} urine treatments in the experiment. While commercial NPK fertilizer in solution was used as source of inorganic nutrients. Liquid (15:4:6 W/V) NPK fertilizer in solution was diluted with water equivalent to 1:100 ratio of liquid NPK to water. Then 25mls, 50mls, 75mls and 100mls of this solution was applied as N_{20}, N_{40}, N_{80} and N_{160} NPK fertilizer in solution treatments. The treatment was applied initially two days before sowing followed by two weeks interval application after sowing for each application. Pot application was made by making small circular furrow by the periphery of the pot making quite sure of avoiding any contact of the plant with the urine, followed by additional watering to flush the urine down after covering the urine with the removed soil (Richert *et al*., 2010).

3.7.7 Crop Management Practice

Cultural practice such as irrigation, weeding and insect control were carried out following recommended practices for each crop.

3.7.8 Plant Growth Monitoring and Data collection

Data collection commenced three weeks after planting (WAP) and subsequently at 4,5,6,7 and 8 WAP. One plant was selected randomly and tagged in each pot to measure the growth parameters: Plant height was measured with measuring tape, Stem girth with micro screw gauge, leaf area with leaf area meter, Chlorophyll content with Chlorophyll meter and number of leaves by counting manually based on Igboro *et al* (2015).

3.8 Growth Parameters

3.8.1 Plant Height

The height of the tagged test crop was measured from the soil level in the pot to the leaf apex of the top most expanded leaf of the tagged plant using meter ruler graduated in centimeter (cm). Readings were recorded, and averages were calculated.

3.8.2 Number of Leaves

Number of healthy and fully expanded leaves per plant was recorded through counting the actual number of leaves per stand of each tagged plant for both crops, and their means were recorded and expressed as number of leaves per plant.

3.8.3 Chlorophyll Content

The Chlorophyll Content of the tagged plant was measured by using portable Chlorophyll meter CL-200 plus (serial number 002176) and the averages of each repeated three readings taken were recorded.

3.8.4 Leaf Area

The leaf area of one of the well expanded leaf of each of the tagged plant was measured by using LI-3000C Portable leaf area meter following the manufacture's manual instruction, and the averages of every repeated three readings taken were recorded.

3.8.5 Harvesting

The plants were harvested by uprooting at 9th week after planting, then fresh weights and dry weight determined respectively (Mnkeni *et al*., 2008).

3.8.6 Fresh weight of Plant

The fresh weights of each of the whole plant were determined using a sensitive scale. Mean values were recorded.

3.8.7 Dry Weights of Plants

Dry weights of each of the test crop per pot was determined by drying the whole plant to a constant weight, then using sensitive scale, the mean weights were measured and recorded

3.9 Statistical Analysis

Statistical analysis was performed using Sigma stat (version 3.5) software. The result were analyzed by two-way analysis of variance (ANOVA) with least significant difference compared, at statistical significant difference $p<0.05$.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Concentrations of various chemical constituents of the harvested urine sample is presented in Table 2. From the results, the urine samples stored for four (4) months were found to have the following concentrations: pH (9.24), Urea (194.9 mg/dl), Chloride (2.96 mg/dl), Potassium (16.24 mg/dl), Uric Acid (2.96 mg/dl), Calcium (4.20 mg/dl), Bicarbonate (23.04mg/dl), Ammonia (0.3165 mg/dl), Sodium (90.63 mg/dl), Phosphate (9.17 mg/dl), and Sulphate (9.25 mg/dl).

4.1.2. The chemical and physical properties of the soil prior to planting is presented in Table 3. From the result; the average temperature of the soil was recorded as 28.900, the pH was 8.900, Electrical conductivity as 1960.000 µS/cm, Ortho Phosphate as 55.880 ppm, Sodium as 0.015 meq, calcium as 3.870 meq, Potassium as 0.180 meq and Total Nitrogen as 1400.000 ppm while Magnesium was not detected.

Table 2: Concentration of Chemical Composition of Harvested Urine per one liter± Sample, 2016

Parameters	Unit	Concentration
pH		9.24±0.1
Water	cm^3	646.33±2.1
Urea	mg/dl	194.9±0.9
Chloride (Cl^-)	mg/dl	2.96±4.3
Potassium (K^+)	mg/dl	16.24±0.3
Uric acid	mg/dl	2.96±0.8
Calcium (Ca^{2+})	mg/dl	4.20±1.7
Bicarbonate (HCO_3^-)	mg/dl	23.04±0.0
Ammonia (NH_3)	mg/dl	0.317±0.2
Sodium (Na^+)	mg/dl	90.63±0.3
Phosphate (PO_4^{2-})	mg/dl	9.17±0.1
Sulphate (SO_4^{2-})	mg/dl	9.25±0.7

Table 3: The chemical and physical properties of the soil prior to planting

Temp	pH	EC(µS/cm)	PO_4(ppm)	Na(meq)	Ca(meq)	K(meq)	Mg(meq)	Total N (ppm)
28.900	8.900	1960.000	55.880	0.015	3.870	0.180	ND	1400.000

4.1.3. The result on the effect of varying concentrations of urine and NPK Fertilizer in solution on the weekly plant height of *Amaranthus caudatus* (Spinach) is presented in Table 4. From the result, significant difference was observed in both samples and within the weekly increase in height (cm) of *Amaranthus caudatus* (Spinach) treated with varying concentrations of urine and NPK fertilizer in solution (25%, 50%, 75% and 100%). At 3rd WAP, Spinach treated with 100% urine and 100% NPK fertilizer in solution were found to be with higher significant difference ($p < 0.05$), followed by 25%, 50% and 75% urine and 25%, 50% and 75% NPK fertilizer in solution and the control treatments. The Spinach left as control produced significantly least height at ($p < 0.05$). At 4th WAP, Spinach treated with 75% urine was significantly different from those treated with 25%, 50% and 100% urine and 25%, 50%, 75% and 100% NPK fertilizer in solution and the control treatments. The least significant difference was also observed in control treatment. At 5th WAP, Spinach treated with 75% urine and 100% fertilizer in solution treatment levels were found to be of greater significant difference from other treatments, followed by 25%, 50% and 100% urine and 75% NPK fertilizer in solution. The least significant difference was also observed in control treatment. At 6th WAP, Spinach treated with 75% urine produced most significant difference at $p<0.05$, while the least significant difference was observed with control treatment. At 7th WAP, Spinach treated with 75%, 100% urine and 75%, 100% NPK fertilizer in solution was found with highest significant difference at $p<0.05$. While the least significant difference was found in the control treatment. At 8th WAP, Spinach treated 75% urine was the most significantly different at $p <0.05$, compared to 25%, 50% and 100% urine treatments and 25%, 50%, 75% and 100% NPK fertilizer in solution and the control. The control as usual produced the least significant difference at $p<0.05$.

Table 4: Mean Plant Height of *Amaranthus caudatus* (Spinach) Treated with varying of Urine and NPK Fertilizer in Solution.

Treatments	Level (%)	3rd WAP	4th WAP	5th WAP	6th WAP	7th WAP	8th WAP	Mean
Urine	25	14.25ab±0.8	23.00bc±1.0	30.33ab±2.5	36.33c±2.5	41.67bc±5.0	61.30b±2.3	34.48
	50	13.33ab±0.6	22.33bc±1.5	31.50ab±8.1	33.67c±2.1	42.67b±4.0	58.30bc±4.7	33.63
	75	14.00ab±1.0	27.67a±0.6	37.67a±2.1	46.33a±0.6	52.67a±2.3	90.30a±6.7	44.77
	100	13.83a±0.3	25.33ab±0.6	32.00ab±1.0	40.33b±2.1	49.33a±3.2	56.00b±0.0	36.14
NPK	25	8.25c±1.3	16.00d±0.7	15.00bc±0.0	26.00d±0.0	35.00c±0.0	41.00c±0.0	23.54
	50	12.73b±0.6	18.17cd±0.3	25.00bc±2.7	31.33cd±1.5	39.67bc±0.6	45.50bc±0.0	28.73
	75	12.67b±0.6	21.25c±1.0	33.00ab±1.0	35.67c±0.6	46.00a±0.0	52.50bc±0.5	33.52
	100	16.00a±1.5	23.67bc±1.0	39.50a±3.5	35.67c±1.2	52.00a±1.0	65.00b±1.8	38.64
Control	0	7.23c±0.6	11.02e±0.0	14.93c±0.6	17.33e±1.5	22.67d±7.5	26.30d±5.5	17.41
Mean		12.48	20.94	28.77	33.63	42.41	55.13	
LSD (0.05)		3.297	3.402	10.255	5.852	7.150	19.261	

Means within each column followed by same letter or none at all are not significantly different at $P < 0.05$.

4.1.4. The result on the effect of varying concentrations of urine and NPK fertilizer in solution on weekly mean plant height of *Lactuca sativa* (Lettuce) is presented in Table 5. From the result, significant difference was not consistent within both samples and within some of the weeks (no significant difference was observed in most of the weekly increase in height (cm)) of *Lactuca sativa* (Lettuce) treated with varying concentrations of urine and NPK fertilizer in solution (25%, 50%, 75% and 100%). At 3rd WAP, no significant difference was found within the varying treatments of urine and NPK fertilizer in solution. At 4th WAP, higher significant difference was present in 25% urine treatment followed closely by 75% urine, 25% 50% and100% NPK fertilizer in solution treatments. The least significant difference was observed in Control treatment. At 5th, 6th and 7th WAP, no significant difference was also detected within the varying urine and NPK fertilizer in solution treatments. At 8th WAP, highest significant difference was obtained in 75% urine treatment. Though 25% and 100% urine treatments recorded statistically similar effect with 100% NPK in solution treatments. As usual, the least significant difference was observed in control treatment.

Table 5: Mean Plant Height of *Lactuca sativa* (Lettuce) Treated with Varying Concentrations of Urine and NPK Fertilizer in solution.

Treatments	Level (%)	3rd WAP	4th WAP	5th WAP	6th WAP	7th WAP	8th WAP	Mean
Urine	25	3.40±0.2	8.03a±0.2	10.5±0.1	17.17±0.0	25.83±0.2	38.00ab±0.6	17.12
	50	3.47±07	4.90c±0.1	9.75±0.3	15.25±0.3	20.00±0.1	28.67b±0.2	13.67
	75	4.00±0.0	5.23bc±0.3	8.13±0.1	15.00±0.2	23.00±0.2	39.70a±0.1	15.84
	100	4.43±1.2	6.33b±0.8	10.33±0.0	16.50±0.1	22.00±0.1	32.00ab±0.7	15.27
NPK	25	3.33±0.5	5.33bc±0.2	10.33±0.2	13.17±0.2	22.00±0.3	21.67bc±0.2	12.64
	50	3.07±0.2	5.00bc±0.1	8.53±0.1	13.78±0.3	19.00±0.1	29.07b±0.2	13.08
	75	3.56±0.1	4.75c±0.2	7.50±0.2	11.25±0.1	18.75±0.2	25.70bc±0.1	11.92
	100	3.90±0.3	5.53bc±0.7	8.25±0.3	12.50±0.7	17.30±0.3	34.00ab±0.3	11.92
Control	0	3.27±0.0	4.40c±0.3	7.30	11.83	14.33	17.86c	9.83
		3.60	5.50	8.96	14.05	20.25	29.63	
LSD (5%)		NS	1.942	NS	NS	NS	10.750	

Means within each column followed by same letter or none at all are not significantly different at $P < 0.05$.

4.1.5. The result on the effect of varying concentrations of urine and NPK Fertilizer in solution on the weekly number of leaves for *Amaranthus caudatus* (Spinach) is presented in Table 6. From the result, significant difference was observed in both samples and within the weekly increase in height (cm) of *Amaranthus caudatus* (Spinach) treated with varying concentrations of urine and NPK fertilizer in solution (25%, 50%, 75% and 100%). At 3rd WAP, Spinach treated with 100% NPK fertilizer in solution recorded greater number of leaves, though 50% NPK in solution showed statistically similar effect with 100% urine treatment. The least significant difference were obtained in control treatment. At 4th WAP, greater number of leaves was found in both 100% urine and 100% NPK fertilizer in solution while the control treatment recorded the least number of leaves. At 5th WAP, 100% NPK in solution recorded highest significant difference seconded by 75% urine and 75% NPK in solution treatments. The least significant difference was as usual in control treatment. At 6th WAP, the 100% NPK in solution treatment recorded the highest number of leaves followed closely by 100% urine treatment while the control treatment produced the least significant difference. At 7th WAP, the 100% NPK in solution recorded greater number of leaves though 75% and 100% urine and also75% NPK in solution treatments recorded statistically similar number of leaves. The least number of leaves was found in control treatment. At 8th WAP, the 75%, 100% urine and 100% NPK in solution treatments produced similar highest significant difference while the control treatment produced the least significant difference.

Table 6: Mean Number of Leaves for *Amaranthus caudatus* (Spinach) Treated with Varying Concentrations of Urine and NPK Fertilizer in solution.

Treatments	Level (%)	3rd WAP	4th WAP	5th WAP	6th WAP	7th WAP	8th WAP	Mean
Urine	25	10.00c±0.7	12.00b±0.1	14.00bc±0.3	16.00cd±0.3	20.00bc±0.1	25.00b±0.6	16.17
	50	11.00bc±0.5	12.00b±0.2	14.00bc±0.6	16.00cd±0.7	22.00b±0.2	26.00b±0.2	16.83
	75	11.00bc±0.2	13.00ab±0.3	15.00b±0.2	18.00b±0.9	24.00ab±0.1	30.00a±0.3	18.50
	100	12.00b±0.1	14.00a±0.2	15.00b±0.1	19.00ab±1.1	24.00ab±0.3	29.00a±0.2	18.83
NPK	25	9.00c±0.3	11.00b±0.3	12.00c±0.1	15.00d±0.3	20.00bc±0.6	24.00b±0.5	16.50
	50	12.00b±0.2	13.00ab±0.1	14.00bc±0.3	16.00cd±0.0	20.00bc±0.5	25.00b±1.2	16.67
	75	13.00ab±0.3	13.00ab±0.3	15.00b±0.9	17.00bc±0.1	23.00ab±0.3	28.00ab±2.4	18.17
	100	14.00a±0.1	14.00a±0.0	19.00a±0.1	20.00a±0.1	25.00a±0.2	30.00a±0.1	20.33
Control	0	9.00c±0.1	10.00d±0.2	11.00c±0.2	15.00d±0.2	18.00c±0.7	21.00c±0.0	14.50
Mean		11.20	12.40	14.30	16.90	21.80	26.40	
LSD (0.05)		1.91	1.26	2.77	1.98	2.77	2.94	

Means within each column followed by same letter or none at all are not significantly different at $P < 0.05$.

4.1.6. The result on the effect of varying concentrations of urine and NPK Fertilizer in solution on the weekly number of leaves for *Lactuca sativa* (Lettuce) is presented in Table 7. From the result, significant difference was observed in both samples and within the weekly increase in number of leaves for *Lactuca sativa* (Lettuce) treated with varying concentrations of urine and NPK fertilizer in solution (25%, 50%, 75% and 100%). At 3rd WAP, Lettuce treated with 25%, 50%, 75%, 100% urine and 50%, 75%, 100% NPK fertilizer in solution treatments recorded similar higher significant difference while 25% NPK in solution and control treatment produced the least significant difference. At 4th WAP, the 25% urine and 50% NPK in solution treatments produced highest significant difference while the least significant difference was observed with control. At 5th WAP, the highest significant difference was observed in 25%, 100% urine and 50%, 100% NPK in fertilizer in solution treatments. While the control treatment was found to show least significant difference. At 6th WAP, the 100% urine produced highest significant difference while the control treatment recorded the least significant difference. At 7th WAP, 100% urine also recorded greater number of leaves followed by 75% urine while the control treatment as usual recorded least number of leaves. At 8th WAP, urine treatment at 75% and 100% produced the most significant difference. The 25% urine and 25% NPK fertilizer in solution produce similar high significant difference while the control treatment confer the least significant difference at $p < 0.05$.

Table 7: Mean Number of Leaves for *Lactuca sativa* (Lettuce) Treated with Varying Concentrations of Urine and NPK Fertilizer in solution.

Treatments	Level (%)	3rd WAP	4th WAP	5th WAP	6th WAP	7th WAP	8th WAP	Mean
Urine	25	5.00a±0.1	7.00a±1.1	8.00a±0.9	11.00b±0.2	13.00b±0.2	18.00b±0.6	9.83
	50	5.00a±0.0	6.00b±1.2	7.00ab±0.8	11.00b±0.1	11.00bc±0.6	17.00bc±0.8	8.83
	75	5.00a±0.2	6.00b±0.0	7.00ab±0.2	14.00ab±0.9	14.00ab±0.1	20.00a±2.3	10.33
	100	5.00a±0.6	6.00b±0.0	8.00a±1.2	15.00a±2.1	16.00a±1.3	21.00a±1.1	11.50
NPK	25	4.00b±0.6	6.00b±0.1	7.00ab±0.3	12.00ab±0.2	13.00b±0.9	18.00b±0.0	9.67
	50	5.00a±0.9	7.00a±1.1	8.00a±0.0	11.00b±0.8	13.00b±0.2	17.00bc±0.9	10.16
	75	5.00a±0.6	6.00b±0.9	6.00b±2.1	9.00b±1.1	12.00b±0.7	16.00bc±0.1	8.83
	100	5.00a±1.1	6.00b±0.8	8.00a±0.9	9.00b±0.6	12.00b±0.0	15.00c±0.9	9.17
Control	0	4.00b±0.2	5.00c±3.2	7.00ab±0.9	8.00b±0.7	9.00c±1.6	10.00d±0.2	7.50
Mean		4.80	6.10	7.30	11.10	12.60	21.10	
LSD (0.05)		0.499	0.763	1.040	3.065	2.378	2.158	

Means within each column followed by same letter or none at all are not significantly different at $P < 0.05$.

4.1.7. The fresh weight of *Amaranthus caudatus* (Spinach) treated with varying concentrations of urine and NPK fertilizer in solution is presented in Table 8. From the result, the total yield measured as total fresh weight (g) and express as yield in Kg/ha per treatment indicated that for both samples, the yield was significantly higher in 75% urine treatment than for 25%, 50%, 100% urine and 25%, 50%, 75%, 100% NPK fertilizer in solution and the control treatments respctively. The least yield was obtained in control treatment at $p < 0.05$.

4.1.8. The fresh weight of *Lactuca sativa* (lettuce) treated with varying concentrations of urine and NPK fertilizer in solution is presented in Table 9. From the result, the total yield obtained for both samples in the experiment measured as fresh weight (g) and expressed as yield in Kg/ha per treatment indicated that the yield was significantly higher in 100% urine treatment level and was seconded by 75% urine treatment although 25%, 50% urine and 25%, 50%, 75%, 100% NPK fertilizer in solution treatments show similar significant difference within themselves. The least yield was obtained in control treatment.

Table 8: Fresh weight of *Amaranthus caudatus* (spinach) Treated with Varying Concentrations of Urine and NPK Fertilizer in Solution.

Treatment	Level (%)	Fresh Weight	Yield (kg/ha)
Urine	25	27.03c±1.8	9010
	50	27.20c±0.9	9067
	75	42.97a±5.5	14323
	100	33.88b±0.7	11293
	25	21.17cd±0.0	7057
NPK	50	23.70cd±0.0	7900
	75	33.40bc±0.9	11133
	100	36.93ab±9.26	12323
Control	0	16.97d±0.9	5657
Mean		29.25	9751
LSD (0.05)		8.41	

Means within each column followed by same letter or none at all are not significantly different at $P < 0.05$.

Table 9: Fresh weight of *Lactuca sativa* (Lettuce) Treated with Varying Concentrations of Urine and NPK Fertilizer in Solution.

Treatment	Level (%)	Fresh Weight	Yield (kg/ha)
Urine	25	13.30b±3.5	4433
	50	13.63b±1.1	4543
	75	19.10ab±0.3	6367
	100	20.87a±1.4	6957
NPK	25	13.16b±1.9	4387
	50	13.37b±0.9	4457
	75	15.93b±0.5	5310
	100	17.27b±0.9	5756
CONTROL	0	10.53c±1.9	3510
Mean		15.24	5080
LSD (0.05)		3.32	

Means within each column followed by same letter or none at all are not significantly different at $P < 0.05$.

4.2 Discussion

As can be observed in Table 2, twelve parameters were determined in the Urine sample. However, the concentration of those parameters varies considerably. The amount of Urea was 194 mg/dl, Sodium (Na^+) 90.63 mg/dl, Bicarbonate (HCO_3^-) 23.04 mg/dl and Potassium (K^+) in order of magnitude. Substances such as Chloride (Cl^-) 2.96 mg/dl, Uric acid 2.69 mg/dl, Ammonia (NH_3) 0.317 mg/dl and Calcium (Ca^{2+}) 4.20 mg/dl were the least in terms of concentration. Compounds such as Phosphate (9.17mg/dl) and Sulphate (9.25mg/dl) are fairly high. The pH of the urine is moderately alkaline or basic. The amount of various substances or compounds in the harvested urine also reflect the physiological states of sampled population. The remarkable concentration of Urea in the urine clearly indicates proteineous content included in the diet such as proteins, lipids and oil to mention but few. The presence of very high content of Urea also in the urine sample after storage is indicating the absence of an enzyme (urease) Karak and Bhattacharya (2011) which are known to degrade Urea to Ammonia during storage hence, the very low content of Ammonia obtained.

The harvested Urine no doubt contained important substances and compounds required by Plants for their metabolic processes.

- Plants in general have different requirement of these substances and compounds.
- The availability of these substances and compounds varies according to place, time, and season and also soil biota.

Where the soil has less amount/concentration of the essential substances and compounds for plant growth, the use or application of addition materials becomes necessary. The use of fertilizers such as organic and inorganic kinds/types is to act as suppliants. The soil nutrient availability and to enhance plant growth and yield as the case may be.

The urine with its high urea content and water in particular with other substances/molecules are essential nutrients for plant growth and development. Concentrated urine discharged in/on to the soil cannot be used by the plant directly and easily, hence, it undergoes both chemical breakdown and transformation/conversion by soil organisms to simpler substances or molecules that are easily absorbable by plant roots. The process is rather complex however, this is a simple explanation of the process.

The dilution of the concentrated urine to 25%, 50%, 75% and 100% was to enable for the reduction of the concentration of the various compounds and also increase water level, other advantages of dilution includes a noticeable odour reduction and a decreased risk of over-application as described by Richert *et al.,* (2010). The parameters detected by urinalysis using either strip or urine analyzer in the Clinical diagnosis is presented in the Table 10. Among the parameters, only Nitrite is relatively important to crop production usually resulted from the breakdown of Urea to Ammonia to Nitrite then finally to Nitrate (Karak and Bhattarya, 2011). In the medical laboratory investigation, the nitrite are detected only in the urine, when Nitrate reducing bacteria specie are present. It is a sign of urinary tract infection caused by bacteria such as Escherichia coli and proteus species which reduces Nitrate in the urine to Nitrite. That is why medical laboratory investigation method was not use to determine the chemical composition of urine sample for plant production.

Table 10: Parameters by Medical Urinalysis using either Strip or Urine Analyzer

Chemical Parameters	**Physical Parameters**
Protein	Color and odor
Glucose	Turbidity
Ketones	Specific gravity
Urobilinogen	pH
Bilirubin	
Blood	
Nitrite	
Leukocytes	

Cheesbrough (2000)

At 25% urine concentration, the plant height of *Amaranthus caudatus* in weeks after planting showed progressive increase in plant height from 3WAP to 7WAP. Similarly, the trend confirmed

with 50% urine concentration. However, the increase in plant height treated with 75% urine concentration was remarkably greater than at 25% and 50% respectively.

As regards to the NPK fertilizer in solution, plant height under 25%, 50% and 75% concentration levels also showed progressive increment. However, increase in height under the two test compounds, that is, Urine and NPK fertilizer in solution, varied across the weeks from 3rd WAP to 7th WAP. The increase in height of Amaranth was significantly higher for urine than for NPK fertilizer in solution under 25% treatment. However, under 50% treatment level, the difference in height of plant (Amaranth) for urine and NPK in solution was small or little. For instance in the 3rd WAP, the increase in plant height was 13.33cm for urine and 12.73cm for NPK in solution. Similarly, under 75% level of treatment, the difference in plant height for urine was slightly higher than that of NPK in solution in the 3rd WAP. However the difference in the increase in height of the treatments of both urine and NPK in solution, across the 7 weeks was not consistent. In the 3rd WAP, plant height was higher for NPK (16.00cm) than for urine (13.83cm). This was also observed in the 5th and 7th weeks. While plant height was only higher for urine in the 4th and 6th weeks. It is also interesting to note that 100% NPK in solution showed remarkable performance for plant height across the weeks of the experiment. Under the control experiment, plant height increased across the weeks only slightly, 7.23cm in 3rd week to 22.67cm at the 7th week. It was apparent that plant growth particularly plant height was enhanced/promoted by both urine and NPK fertilizer in solution. However, based on the treatment levels, 75% urine showed relatively greater effect on plant height than 25% and 50% respectively then followed by 100% concentrated urine. This finding corresponds with opinion of *Richert et al.,* (2010) that, most common dilution ratios of urine to water are 1:3. For NPK fertilizer in solution, the 100% treatment level showed better effect than 25%, 50% and 75% respectively.

Similar dilution of concentrated urine to 25%, 50%, 75% and 100% indicated progressive increase in number of leaves of *Lactuca sativa* from 3WAP to 7WAP. The number of leaves steadily increases from 3WAP to 5WAP followed by sharp progress from 5WAP to 7WAP. The trend is alike in all the urine dilution levels; that is 25%, 50%, 75% and 100% respectively. Regarding to NPK fertilizer in solution, the number of leaves under the different concentration levels (25%, 50%, 75% and 100%) showed significant increment across the weeks. Although there is impressive improvement within the two test compounds, the trend is not exactly the same across the weeks of the experiment. For urine, the increase in number of leaves was regular initially followed by sharp improvement from 5th WAP to 7th WAP while for NPK in solution the progress was gradual throughout the period (3rd WAP to 7th WAP). Nevertheless, under 25% treatment levels for both urine and NPK in solution not much difference has been observed in *Lactuca sativa* across the weeks. For example, at 3rd WAP the number of leaves for urine treatment was 5.00 leaves compared to 4.00 leaves for NPK in solution, also at 6th WAP the number of leaves was 12.00 for urine treatment against 12.00 for NPK in solution in which both examples showed little or no difference. This trend is almost similar for 50% treatment.

For 75% treatment, the pattern of increase in number of leaves of both urine and NPK fertilizer in solution varied. The remarkable increase in number of leaves of *Lactuca sativa* has been apparent within 6WAP to 7WAP in urine treatment although the increment was regular from 3WAP to 5WAP while for NPK in solution the pattern was regular from 3WAP to harvesting period. For instance, at 5WAP the number of leaves was both 6.00 for both urine and NPK fertilizer in solution treatments while at 6WAP urine treatment has recorded 14.00 leaves against 9.00 for NPK in solution treatment. The same trend was observed in 100% urine treatment level of the two tested compounds. For the control experiment, the increase in number of leaves of *Lactuca sativa*

(Lettuce) was not significant across the weeks. For example, at 4th WAP the control was recorded to have 4.00 leaves and at 6th WAP there was an average of 8.00 leaves. It is clear that number of leaves of *Lactuca sativa* (Lettuce) which is a very important leafy vegetable had been improved by both urine and NPK fertilizer in solution. However, within the treatment levels, 100% urine was most effective on number of leaves of *Lactuca sativa* followed closely by 75% as far as urine treatment levels are concern. The 100% NPK fertilizer in solution performed best for NPK fertilizer in solution treatment, it was followed by 25%, 50% and 75% respectively.

Generally, the two tested vegetables; *Amaranthus caudatus* (Spinach) and *Lactuca sativa* (Lettuce) had indicated higher growth (plant height and number of leaves) with human urine treatment than with NPK fertilizer in solution treatments and at each level of concentration. The result has confer more evidence that human urine contains various chemical substances that are equal or even higher than those contained in Urea or Ammonium fertilizers and also confirmed that those chemicals are as effective as those contained in NPK fertilizer in solution or any other commercial fertilizer in enhancing plant growth as emphasized by Kirchmann and Pettersson (1995). Morgan, (2003) also reported similar result for a trial on yield of vegetable treated with human urine in Zimbabwe. In addition, the result collaborates the work of AdeOluwa and Cofie (2012) on yield of *Amaranthus specie* in Ibadan, Nigeria where 100% urine gave 58.17 tone ha^{-1} compared to 34.34 tonnes ha^{-1} of *Amaranthus* under NPK 15:15:15.

CHAPTER FIVE

5.0 Summary, Conclusion and Recommendation

5.1 Summary

In summary, the findings in relation to the research objectives discussed above shows that the design and construction of urine collector for subsequent collection, storage and application of the urine as described by Gail Swithenbank and Richert *et al*., (2010) known as tunnel technique was convenient, relevant and provides a valuable means of improving environmental sanitation that can be adopted in Kano. Also that the urine harnessed and stored was odor free after 3 month of storage, therefore storage contributes to lesser difficulty in handling and distribution during application. The laboratory analysis of urine demonstrated the various chemical composition most of which are essential constituents of plant growth nutrients and their various concentrations were adequate when added on soil to enhance plant growth. In addition, the various levels of treatment of urine on the two plant species; *Amaranthus caudatus* and *Lactuca sativa* revealed positive effect on plant height, number of leaves and yield from 3weeks after planting to harvest at the 9^{th} week after planting. For *Amaranthus caudatus* 75% urine showed better performance while for the number of leaves in *Lactuca sativa*, 100% urine concentration performed better. Generally, for both treatment samples, the 75% urine level of concentration was observed to produce highest yield in both spinach and lettuce followed by 100% NPK fertilizer in solution treatment level. For the number of leaves in Lettuce 75% urine treatment level indicated higher performance and similarly 75% and 100% urine concentration level in Spinach. For the plant height, greatest performance was shown by 75% in both Spinach and Lettuce. Higher yield was observed in 75% urine treatment level in Spinach and 100% urine level of concentration in Lettuce. The comparism

between urine and NPK fertilizer in solution has shown that urine is as effective as NPK fertilizer in solution as demonstrated by this present investigation.

5.2 Conclusion

The re-use of 75% human urine as plant nutrient in vegetable production particularly for Spinach (*Amaranthus caudatus*) and Lettuce (*Lactuca sativa*) cultivation has proved to be efficient and cheap practice.

The experience gained in this study confirmed that harvesting urine is an easy and suitable practice that might contribute immensely to sanitizing the practical area and harvesting urine is an easy, realistic and achievable practice hence, its outcome is essential/important for the attainment of Sustainable Development Goals (SDG) objectives of the United Nations (2015). The practice when fully used serves as a valuable tool for improving sanitation ecologically in places such as the study area of urban Kano where lack of public convenience in our communities/settlement contributes greatly to the poor sanitation states of our urban environment.

The improved sanitation of urine re-use with its economic benefit as indicated by this study would also enhance soil fertility, vegetable production and make our environment cleaner and safer.

5.3 Recommendations

I. There is need to develop urine-diversion toilets for use in public places particularly schools as a model for highly populated public places to ensure safe and effective sanitation.

II. Further examination of the urine for infectious microbes should be conducted to identify communicable pathogens and control them before re-use for crop production.

III. Further trials should be carried out to determine/establish the most effective concentration level for common vegetable plant species for enhanced production that is optimum rate of urine application for vegetables and other various types of crops.

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