USE OF HUMAN URINE AND OTHER SOIL AMENDMENTS IN TOMATO (*lycopersicon esculentum*) AND PEPPER (*capsicum annum*) PRODUCTION

(A CASE STUDY IN THE KWAEBIBIREM DISTRICT)

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL ENVIRONMENTAL SCIENCE DEGREE

JUNE, 2013

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This is to certify that this thesis "**USE OF HUMAN URINE AND OTHER SOIL AMENDMENTS IN TOMATO (***lycopersicon esculentum***) AND PEPPER (***capsicum annum***) PRODUCTION.** (A Case Study in the Kwaebibirem District)" is the result of research undertaken by Annan Martha Adjoa towards the award of the Master of Philosophy (Mphil) degree in Environmental Science in the Institute for Environment and Sanitation Studies (IESS), University of Ghana. All sources have been duly distinguished and appropriately acknowledged.

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DEDICATION

To the Almighty God, to my parents, Mr and Mrs Annan and to all who have contributed in diverse ways towards my education

ACKNOWLEDGEMENT

I would like to express my appreciation and gratitude to all who contributed in diverse ways in making my studies a great academic success.

First and foremost, I am grateful to my supervisors Prof. K. G. Ofosu Budu, Dr S. D. Boateng, Dr Philip Amoah and the foreign discussion partners Josiene Nikiema and Surendra Pradhan whose guidance, assistance, patience and constructive criticism have given me the courage to go on.

Secondly, I wish to express my appreciation to the sponsors of this thesis, International Water Management Institute for providing chemicals and logistics which made it possible for this work to achieve success. My thanks also go to the technicians in Ecolab and the staff of IWMI for their immense support.

Special thanks to my parents, siblings and the entire family for their immense love and support.

I would have made a mistake if I did not acknowledge personalities like Mr Isaac Fenning, Mr Joe Mensah, Mr Kaya, Osofo, Gideon, Tetteh, Solomon, Sampson and all other staff of FOHCREC, Kade.

I also give my special appreciation to Eric Gbenatey Nartey, Elizebeth Aba Annan, Akosua Asare Yeboa, Nana – Oduro Osei Bonsu, Kwabena Danful and Bright Agbomadzi who stuck by me and were there when it become critical.

Kudos guys!

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LIST OF ABBREVIATIONS

^oC	Degree Celsius
EC	Electrical conductivity
G	Grams
Kg	Kilograms
L	Litres
M	Metres
Mg	Milligram
pH	- log of hydrogen ion concentration
%	Percent
NO_3-N	Nitrate nitrogen
NH_4-N	Ammonium nitrogen
NH_4	Ammonia
N	Nitrogen
P	Phosphorus
K	Potassium
Ca	Calcium
Mg	Magnesium
C	Carbon
CO_2	Carbon dioxide
CO_3	Carbonate
MgO	Magnesium oxide
O_2	Oxygen
PO_4	Phosphorus oxide
NO_3	Nitrate
N_2O	Nitrous oxide
$MgSO_4$	Magnesium sulphate
$MgCl_2$	Magnesium Chloride
ANOVA	Analysis Of Varians
LSD	Least Signifiant Difference
CBD	Complete Block Design
EPA	Environmental Protection Agency
ECOLAB	Ecological Laboratory, University of Ghana
FAO	Food and Agriculture Organisation
IWMI	International Water Management Institute
USEPA	United State Environmental Protection
APHA	American Public Health Association
UNESCO	United Nation Education Scientific and Cultural Organisation
WHO	World Heath Organisation

ABSTRACT

Human urine is a valuable plant nutrient resource however; there is very little information on using urine. This research examined the use of human urine as nutrient source as well as biochar and compost as growing media for tomato (cv M2) and pepper (*Capsicum annum* cv bird eye) production. This was studied under greenhouse and field conditions. It further examined the perception and willingness of farmers, marketers' and consumers to grow, sell and consume vegetables fertilized with urine.

The green house experiment was designed using biochar alone and biochar amended with compost (1:1v/v) as growing media. It further evaluated different nutrient sources- urine diluted at the ratio 1: 6, 1: 5, 1: 4 urine/water (urine treatments); 30mg N/L, 50mg N/L and 70mg N/ L (inorganic treatments) and water as a control.. Seedlings were dipped into the nutrient solutions until saturation through capillary action for three weeks. Similarly, a pot experiment was carried out under field conditions using a split plot design. Diluted urine (1:4 urine/water ratio) applied once, twice and thrice a week on five different media treatments were evaluated. The media treatments were; (1) Soil + RHB 1:1; (2) Soil + Compost 1:1; (3) Soil+ Compost+ RHB 1:1:1; (4) Soil + Compost+ RHB 1:1:2 (5) Soil + Compost+ RHB 1:2:1. Applications of inorganic fertilizer and water were used as controls. Vegetative parameters such as chlorophyll content, plant height, dry matter, stem diameter, number of leaves and root to shoot ratio, yield and yield components were monitored.

It was observed that, when biochar was amended with compost, all vegetative parameters increased significantly than biochar alone. For instance, compost amended

media increased tomato plant height and root length by 2.4 fold and 3.3 fold while biochar alone increased by just over 100% and 1.2 folds respectively. In the nutrient sources treatments, it was also observed that the shoot dry weight of tomato transplant produced by DU 1:6 (0.46 mg/plant) was comparable to that produced by In-Fert 1 (0.49 mg/plant) and In-Fert 3 (0.42 mg/plant) treatments.

In the field, the highest yield 961 g/plant and fruit numbers 60 fruits/plant was in plants grown in Soil + Compost+ RHB 1:1:2 fertigated with 0.45 g N/pot. This was 37% and 5.3 fold greater than in the inorganic fertilizer and (water) treatments ($p<0.05$). Generally, corresponding decreases in yield were recorded with high irrigation frequencies. The questionnaire survey revealed that most respondents were not aware of urine as fertilizer. Farmers were willing to use urine if it will improve agriculture. Marketers were not willing to disclose to their clients if the vegetables are fertilized with urine. Some consumers were willing to consume urine fertilized crop if only it was safe to consume. The study concluded that urine combined with compost and biochar is a good source of plant nutrients, especially nitrogen.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Sanitation is an important Millennium Development Goal and the use of urine could represent a possible solution to urban sanitation. Urine is a valuable source of nutrients that has been used since ancient times to enhance the growth of plants, notably leafy vegetables (Jönsson *et al.*, 2004). The nutrients in urine are in ionic form and their plant availability has been found to compare very well with chemical fertilizers (Kirchmann and Pettersson, 1995; Stintzing-Richert *et al.*, 2001). Human urine has been used extensively in crop production in developed countries such as Sweden (Kirchmann & Pettersson, 1995) and United States of America. However, there is little or no information on its use in Ghana. According to Germer (personal communication), 140,000 tonnes of urine and dried faeces per year can realize into 6%, 4% and 2% of NPK consumed in Ghana respectively.

The indiscriminate disposal/discharge of urine and agricultural waste such as rice husk into the environment leads to situations such as surface and ground water pollution, euthrophication, accumulation of salts with harmful impacts on soil health and crop yields, impacts on aquatic life due to over loading of organic matter among others (Hussain *et al.*, 2002). The presence of high nitrate in groundwater causes methemoglobemia (a reduction in blood haemoglobin level) and also stimulates excessive growth of aquatic organism, algal bloom and euthrophication (Silva *et al.*,

2000). A direct link between eutrophication and disease risk has also been suggested by Smith *et al.*, (2006). Excess nutrients in the environment especially water bodies causes increase in invertebrate biomass and altered invertebrate communities (Miltner and Rankin, 1998) of which has been correlated directly with P concentrations (Morin *et al.*, 1998).

One strategy for reducing the quantities of urine and organic solid waste disposed into the environment and polluting the environment is to use these resources, as these materials contain plant nutrients that can be used for vegetable production. Plant biomass such as rice husk can be prepared into biochar and used alone or in combination with compost, as growing medium for raising different vegetable seedlings and other planting materials at the nursery stages. Urine has been successfully used to produce crops such as tomato, maize, cabbage, wheat among others on the field (Mnkeni *et al.*, 2008; Pradhan *et al.*, 2007; Pradhan 2009 and Tidaker *et al.*, 2004). According to Cofie *et al.*, (2011), cabbage yield and above ground matter yield were highest in treatments with urine and poultry litter than NPK and poultry litter. A similar trend was observed by Pradhan *et al.*, (2007) in the cultivation of cabbage. Biochar has also been added to soils due to its unique characteristic of high nutrient retention. These studies have proven that urine and biochar can be used in crop production and will be beneficial and also protect the environment.

Production of vigorous seedlings is a prerequisite for improved vegetable yields (Cantliffe and Karchi, 1992). However the production of seedlings is affected by several factors such as the type of growing media and amount of nutrient that is provided to seedlings during propagation and in the field. Vegetable seedling production in cavity trays requires precise nutrient management (Biernbaum and Versluys, 1998), due to their limited cell volume and high transplant densities. In addition, improved nutrient regimes and management would contribute to efficient high quality seedling development (Tremblay and Senecal, 1988)

Seedlings grown in plug trays have an advantage over those grown on beds as they undergo less root injury during transplanting and mature uniformly. Furthermore, seedlings grown in plugs give higher and early yield than direct seeded plants (Leskovar and Cantliffe, 1993). Furthermore, nutrient and irrigation management in seedlings production are very crucial since the amount of nutrients supplied and type of irrigation system affects the yield and quality of seedling (More, 2006).

Elsewhere, as in Sweden urine is accepted in commercial farming systems, however in Ghana, urine reuse is quite recent thus awareness and adoption maybe low. It is in this view that this study was conducted to reuse urine and biochar to produce vigorous, sturdy, and quality tomato and pepper seedlings that can withstand field environmental challenges. It further evaluated the use of biochar and urine in bird eye pepper production under field conditions and also evaluated the perception of farmers,

consumers and marketers on the willingness to use and use of human urine as an alternative fertilizer.

1.2 Problem Statement

"Ghana's increasing population, changing weather patterns and global food price hikes are squeezing the budget of the less well-off. Although agricultural production has grown at over 5% annually since 2001, this has largely been achieved by bringing new land into cultivation. Yield gaps between Ghana's productivity levels, compared to what is achievable, are far too high" (Gros, 2011). Adopting new technologies such as greenhouse vegetable production will improve agriculture and food security in Ghana. Furthermore, encouraging the use of nutrients contained in urine and organic waste will be a step in the right direction for sustainable crop production.

The current sanitation systems in Ghana are the use of "urinals" or the "flush and discharge" systems. These systems pollute surface water bodies and also contaminate groundwater through seepage (Esrey *et al.*, 1998). The urinals system is quite common in the urban and peri-urban communities in Ghana such as Accra, Kade, and Kumasi, etc. Urinals are structures built directly over or linked to a drainage system, thus discharging the urine directly into the drains. This practice can be considered as a resource or challenge depending on the management system adopted. If the nutrients from these urinals can be rechanneled into food production, sanitation and crop production will be improved.

A study carried out by Cofie *et al.*, (2007) on 14 urinals located within the Central Business District in Accra, Ghana revealed that 7.3m^3 of urine is generated per day. Thus, an estimated 2,200m^3 of urine is generated per year for 14 urinals. From this figure, 6.6 tonnes of plant available N is estimated per year. If these nutrients are not recovered, they leach to contaminate ground water which is a very important resource. Ground water is one of the main sources of potable water for Ghana and most developing countries in general. Globally, ground water sources (Borehole and dug wells) accounted for 30% of drinking water sources (WHO, 2000).

Furthermore, most drainage systems in Ghana are linked to water bodies such as the Korle Lagoon and Chemu Lagoon in Accra. The discharge of urine directly into water bodies without prior treatment causes eutrophication. In a study carried out by Awuah and Fiakuma (2007) on waste management in Ghana, high levels of nutrients were found in fresh water bodies, grey water and beach water. For instance in the Kpeshi and Korle Lagoon, 92.13 and 7.00 mg/L of PO^{3-}_4 – P (mg/L) respectively was recorded. Furthermore, 2.40 and 1.10mg/L of Nitrate (mg/L), 16.30 and 43.95 mg/L Salinity (mg/L) were recorded respectively for Kpeshi and Korle Lagoon. This affects aquatic life, reduces biodiversity (Hussain *et al.*, 2002) and also causes imbalances in plant microbiological communities of water bodies (Smith *et al.*, 1999).

These problems are not only limited to the direct discharge of urine into the environments. In greenhouse production, practices such as fertigation also results in nutrient leaching and in water contamination. This is due to the use of excess

fertilization and irrigation mismanagement leading to contaminated runoff and ground water. One major challenge towards organic greenhouse production is controlling the fertilization in order to obtain sufficient nutrition without risking leaching.

Ghana is an agricultural country and, as such, produces several hundred tonnes of agricultural waste such as rice husk, saw dust, coconut husk, groundnut husk, maize stover, among others. One such way to solve this waste problem is the production and utilization of biochar. The feedstock for biochar production includes essentially all forms of biomass. These materials include rice husk, saw dust, paper, maize/corn cob, empty fruit bunch (EFB) among others. Biochar has been proposed as a sustainable way to improve agriculture and sanitation. Its use leads to three environmental benefits- 1. Improving soils, 2. Reducing environmental pollution associated with improper waste disposal and 3. Mitigation of climate change through carbon sequestration (Lehmann, 2007).

In Ghana, it is estimated that about 4,159,000 tonnes of agricultural crop residues were generated in the country in 2008 (Duku *et al.*, 2011). Assuming that 70% (2,911,300tonnes) of these residues are available and if after the pyrolysis process 35% (Brown, 2009) of the biochar yield is obtained then it can be estimated that 1,455,650 tonnes of biochar could have been produced that year. According to FAO (2009), 33,040,000m^3, 1,305,000m^3 and 317,000m^3 of wood fuel, industrial round wood and sawn wood were consumed in Ghana in 2008. Furthermore, it is estimated that 2,000, 000m3 of municipal solid waste is generated annually in Ghana (Duku *et al.*, 2011).

All these waste products could have been recycled into useful materials especially through biochar production.

Lastly, the adoption of urine as an alternative fertilizer in crop production may be limited by reason that this technology is quite recent, thus, diffusion will be low. Some studies conducted on the use of urine in crop production in Ghana revealed that some farmers, consumers and marketers were willing to consume and use urine as an alternative fertilizer (Cofie *et al.,* 2011). However, technical know-how, health effects and socio-cultural perceptions were some of the challenges preventing the full adoption of urine as an alternative for fertilizer use in Ghana (Cofie *et al.,* 2011).

1.3 General Objective

To improve sanitation and crop production by using nutrients contained in urine and biochar for crop production.

1.4 Specific Objectives

1. To evaluate rice husk biochar and compost as growing media and human urine as nitrogen solution for the raising of tomato and pepper transplants

2. To evaluate human urine as a nutrient source and to determine suitability of biochar and/or compost -amended substrates as growth media for the cultivation of pepper in pots under field conditions.

3. To assess farmers, marketers and consumer's perception, willingness to use and the use of human urine as a fertilizer source for crop production

1.5 Justification

With an annual growth rate of 3.4%, Ghana's population is increasing at a rapid pace. The gap between increasing population rates and waste management is widening. Thus, there is the need to put in greater efforts to develop sustainable and cheaper methods to address the problems of waste management. Urine separation in Ghana using urinals is already established. Improving these systems to collect urine and recycle the nutrient contained in it should be considered as alternative and cheaper management for reducing environmental pollution.

Urine can be the best substitute for inorganic fertilizers. Nutrient contained in urine are in the ionic form and compares well with that of inorganic fertilizer (Kirchmann and Pettersson, 1995). According to Pradhan *et al.*, (2009), urine fertilized tomato plants produced 4.2 times more yield than non-fertilized plants. In addition, urine use is more environmentally friendly and safe even though leaching of excess nutrient is possible if nutrient mismanagement occurs.

In the developed countries, such as USA, seedling production is the primary method of vegetable production using mainly media such as peat, vermiculite and perlite. These materials, especially peat, are faced with depletion since it is a valuable biological habitat. Encouraging transplant production is one way to provide year round

production of diverse vegetables and also to utilise locally produced substrate such as biochar and compost.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Urine

2.1.1 What Is Urine?

Urine is an aqueous solution made up of more than 95 per cent water, with the remaining constituents made up of urea, creatinine, dissolved ions (chloride, sodium, potassium, etc), inorganic and organic compounds or salts (Richert *et al.*,2010). It is a liquid product of the human body that is secreted by the kidneys which contains large amounts of soluble nutrients- macro and micro nutrients (Gensch *et al.*,2011). The nutrient content of urine is affected by the feeding habits; amount of drinking water, physical activities, body size, and environmental factors also affects the nutrient composition of urine (Sullivan and Grantham 1982). These factors differ from region to region, between countries, as well as individuals. Thus, the composition of urine differs from individual to individual, regions to regions and country to country.

2.1.2 Nutrients in urine

Urine contains large quantities of nutrients such as N, P and K, required by plants for growth, development and increased yield. These nutrients are dissolved in urine and are in ionic forms. The availability of these nutrients for plant growth compare favourably with inorganic fertilizer (Kirchmann and Pettersson, 1995). At excretion, the pH of urine is normally around 6 but can vary between 4.5 and 8.2. (Lentner *et al.*, 1981). The pH increases to 9-9.3 after storage (Jönsson *et al.*, 2004). This is due to the

degradation of urea to ammonium and carbon dioxide in the presence of urease (Jönsson *et al.*,2004; Kirchmann and Pettersson, 1995).

urea	water	urease	ammonium	hydroxide	carbonate
$CO(NH_2)_2$ +	$3\ H_2O$	⟶	$2\ NH_4^+$ +	OH^- +	HCO_3^-

The amount of plant nutrients excreted through urine per person and annum ranges between 2.5-4.3 kg N, 0.4-1.0 kg P and 0.9-1.0 kg K (Lentner *et al.*, 1981; Guyton, 1986; Jönsson *et al.*, 2005; Vinnerås *et al.*, 2006). Between 75-90% of the N in urine is in the form of urea and the remaining mainly as ammonium and creatinine. Due to the high N content in urine, the P/N and K/N ratios are slightly lower than that needed by plants (Richert *et al.*, 2010).

2.1.3 Plant availability of nutrients in urine

The urea or ammonium-N in urine compares well with that of urea or ammonium-N in inorganic fertilizers (Kirchmann and Pettersson, 1995). It is estimated that between 90–100% of N in urine is in the form of either urea or ammonium. The P and K form are almost totally (95–100%) in an inorganic form (Kirchmann and Pettersson, 1995) and plant available. Several studies have confirmed the plant availability of nutrients in urine.

According to Pradhan *et al.*, (2007), human urine used as a fertilizer for cabbage production compares equally or better with inorganic fertilizer. Growth, biomass

production and levels of chloride in the cabbage were slightly higher in urine treated plants than in inorganic treated plants. In another study conducted by Heinonem-Tanksi et *al.*, (2007), the yield of cucumber fertilized with urine was similar or slightly better than the yield obtained from those fertilized with inorganic fertilizers.

In a tunnel house experiment, Mnkeni *et al., (*2008) observed that the fertilizer value of human urine (0 to 400 kg N ha^{-1}) for maize and tomato, compared to urea was high. Dry matter yield and leaf tissue Na increased with increased N rate (both as urine or urea). In a study conducted in Arba Minch, Ethiopia, the yield of urine fertilized maize increased seven times that of unfertilized soil (Kassa *et al.*, 2010). The presence of plant available nutrients in urine has given rise to studies on the possibility for nutrient recovery as solids from human urine and the reuse of urine as a liquid fertilizer.

2.1.4 The potential of urine as liquid fertilizer

Urine is a well-balanced nitrogen-rich quick acting liquid fertilizer (Richert *et al.*, 2010). Different crops respond differently to urine application. Pot trials have been conducted with human urine as fertilizer source on cabbage, spinach, maize and tomato production (Mkeni *et al.*, 2006). Diluted human urine (1:3) urine: water was found to be a good source of nutrients, especially nitrogen, for cabbage and spinach production. Maize and tomato responded differently to urine as fertilizer source compared to earlier studies on cabbage and spinach. Maize responded more or less equally to urea and urine. Graded addition of N up to 200kg/ha in the form of urea or urine resulted in significant increase in biomass dry matter yield of maize.

However, above 200 kg N/ha, there was little or no significant increase in yield. A similar increase was observed for tomato. In a study to investigate the nutrient efficiency of urine in comparison with mineral fertilizer and compost in Ghana between 2004 and 2005, it was observed that the yield of the urine and compost treatment were significantly higher than in the control ($p<0.05$) (Germer *et al.*,2006). It was concluded that the fertilization with P and K enriched urine increases the yield of sorghum about 3.5 times. Furthermore, a study carried out by Cofie *et al.*,(2007) on 14 urinals in Accra, Ghana revealed that 7.3m^3 of urine is generated per day. Thus, an estimated 2,200m^3 of urine is generated per year for 14 urinals. From this figure, 6.6 tonnes of plant available N is estimated per year. This can be used as an alternative fertilizer for crop production

2.2 Potential Impact of Urine in the Environment

Urine constitutes only 1% of the total waste water generated. However it contains the largest proportion of plants nutrients found in waste water (Niwagaba, 2007). Reuse of the nutrients contained in urine will reduce environmental pollution.

2.2.1 Public Health Impact

Urine from the bladder is considered sterile (Höglund, 2001) until faecal cross contamination or contamination from the environment. Pathogens transmitted through urine may not constitute a significant public health problem (Höglund, 2001). However, micro pollutants- pharmaceutical compounds have been detected in aquatic environment on several occasions (Pynnöne & Tuhkanen 2012). It is estimated that

around 2/3 of these pharmaceutical residues are excreted with urine (Gensch, 2011). The long term effects of these compounds are still not clearly known. The use of waste water containing urine directly in agriculture may also serve as transmission route for pathogens. There is a possibility that these micro-pollutants would be taken up by plants and enter the human food chain (Richert *et al.*, 2010), especially when applied on a large scale.

2.2.2 Ecological Impact

The sewerage system of the capitals and big cities of West African countries especially Ghana is linked to water bodies such as the Korle Lagoon and Chemu Lagoon in Accra. The discharge of urine directly into water bodies without prior treatment causes euthrophication. In a study carried out by Awuah and Fiakuma (2007) on waste management in Ghana, high levels of nutrients were found in fresh water bodies, grey water and beach water. For instance in the Kpeshi and Korle Lagoons, 92.13 and 7.00 mg/L of PO^{3-}_4 – P (mg/L) respectively was recorded. Furthermore, 2.40 and 1.10mg/L of Nitrate and 16.30 and 43.95 mg/L Salinity were recorded respectively for Kpeshi and Korle Lagoon. This affects aquatic life, reduces biodiversity (Hussain *et al.*, 2002) and also causes imbalances in plant microbiological communities of water bodies. (Smith *et al.*,1999).

2.2.3 Ground Water Impact

The discharge of urine (or waste water in general) leads to the contamination of ground water through leaching of excess nutrients (Nitrogen, Phosphorous and

Potassium) and also the translocation of pathogenic bacteria and viruses to ground water (NRC Report, 1999). A study carried out by Cofie *et al.*, (2007) on 14 urinals in Accra, Ghana revealed that 7.3m^3 of urine is generated per day. Thus, an estimated 2,200m^3 of urine is generated per year for 14 urinals. From this figure, 6.6 tonnes of plant available N is estimated per year. If these nutrients are not recovered, they leach to contaminate ground water, although it is a very important resource. Ground water is one of the main sources of water for both domestic and industrial use in Ghana and most developing countries in general, and need to be protected. Globally, ground water sources (Borehole and dug wells) account for 30% of drinking water sources (WHO, 2000).

2.3 Transplant Production

Plug or cell transplants are seedlings or small vegetatively propagated plants which are raised in individual small cells, called plugs (Jeong, n. d.). The plugs are filled with a cohesive medium, and are eventually transplanted into other growing systems. The use of the plug system is now preferred over the bare root system because raising seedlings takes a relatively long time, large quantities of media needed, spread of diseases and production of transplants of different quality and size (Jeong n. d.). Plug transplants are high in quality, uniform and can be produced all year round. Basic characteristics of growing media that need to be considered include drainage, aeration, and water holding capacity, bulk density, cation exchange capacity, pH, soluble salts and the need for extra fertilization (McCall, 1980).

2.4 Growth Medium for Vegetable Production

Growing media is a key material to produce high quality, container grown plants. There is an increasing need for a regular supply of a uniform growth medium that has the ability to support vigorous plant growth for nursery plants. Peat in container media has been satisfactorily replaced with some organic waste materials including bark and wood fibre, coconut coir and compost. Many different media formulations have been developed from waste materials and successfully introduced to the nursery industries. Such lightweight bio-waste resources, which are more porous than natural soil, are cheaper and more renewable than peat or natural soil (Hernandez Apaolaza *et al.*, 2005). The physical properties of the growing medium are important parameters for successful plant growth, as these are related to the ability to adequately store and supply air and water to the plants. Depending upon the type and rate of organic material, air and water supply capability was decreased (Bugbee *et al.*, 1991), increased (Warren and Fonteno, 1993) or unaffected (Caron *et al.*, 2001).

Nkolongo *et al.* (2000) found that the growing of geranium was either linearly or quadratically decreased as the rate of organic waste increased in the media. Assessments of the physical conditions of the root zone focuses on storage (Air-filled porosity and water holding capacity) characteristics which in many cases have hardly been related to plant response. Information is therefore lacking on exchange properties of the root zone.

Peat moss is the most widely used source of organic matter for growing horticultural crops such as pepper. The demand for peat as a substrate constituent for growing media for the cultivation of horticultural crops has remarkably increased in recent years, thus reducing the availability and increasing cost (Nappi and Barberis, 1993). Composts may serve as qualitatively and economically as competitive alternative sources of organic matter. Composts are useful in supplying crops with macronutrients such as N, P, IC, and S (Barmzini and Del Zan, 1992; Cortelliui *et al.*, 1996; Kuo, S., 1995; Taylor *et al.*, 1978), and also micronutrients such as Cu, Fe, Mn, and Zn (Dixon *et al.*, 1995; Giordano *et al.*, 1975). A study by Chancy *et al.*, (1980) demonstrated that digested biosolids compost could provide sufficient trace elements such as Cu, Fe, Zn, and macronutrients P and K for growth of French marigold *(Tugetes putulu* L.) although not enough nitrogen.

According to Chen *et al.*, (1988) composted cattle manure and composted grape marc contained high nutrient levels, especially P and K which were slowly released during the growing period. Composts are also useful to formulate potting substrates (Gouin, 1985; Link *et al.*, 1983; Tomati *et al.*, 1993). Composts can improve substrate physical properties when they are mixed with peat moss.

2.5 Biochar

Biochar is a stable, carbon-rich form of charcoal that can be applied to agricultural land as part of agronomic or environmental management (Sparkes and Stoutjesdijk,

2011). Interest in biochar has increased recently due to the belief that biochar maybe one such emerging technology to improve agriculture productivity and food security in the world. According to Johannes Lehmann, 'biochar can be used to address some of the most urgent environmental problems of our time—soil degradation, food insecurity, water pollution from agrichemicals and climate change' (Renner, 2007). However, other schools of thought are sceptical about the full potential of biochar as further research is needed to confirm the full potential of biochar (Powlson *et al.*, 2011). Biochar has received this recognition due to the success of Terra Preta soils of the Amazon Basin. Terra preta soils contain residues from human and animal waste, food scraps and other nutritious waste material that were not charred (Krull pers. com. 2011 in Sparkes and Stoutjesdijk, 2011). Some studies have established the potential of biochar to improve soil fertility, water and nutrients retention. However, there is the need for further studies as the full potential of biochar application in agriculture has not been fully exploited.

2.5.1 Biochar properties

2.5.1.1 Stability

Biochar is a highly stable organic carbon which can persist in the environment longer than any other form of organic matter. According to Sombroek *et al.*, *(*2003), biochar has even remained in soils in humid tropical climates such as the Amazon for thousands of years. This is because; biochar resists the rapid rate of mineralization common to organic matter in the humid tropical climates producing a distinct black colour (Lehmann, 2007). Nevertheless, despite this high level of resistance, biochar

will eventually be mineralized to CO_2; otherwise, soil organic matter would be dominated by biochar accumulated over geological time scales (Goldberg, 1985). The recalcitrance of biochar is relative and depends on a number of factors. These factors include the type of biomass used for pyrolysis, the production conditions, soil properties and climatic conditions (Lehmann *et al.,* 2006). Furthermore, there is the need for more studies on biochar due to particulate nature of biochar and the heterogeneous chemical nature of biochar.

- The heterogeneous nature of biochar: depending on carbon properties of the feedstock used pyrolysis conditions and on the formation process (by either condensation of volatiles or by direct charring of plant cells) various forms of carbon maybe obtained (Lehmann, 2007). Therefore, some forms of biochar may mineralize very rapidly relatively than other forms. Thus, an extrapolation from relatively easily mineralisable carbon forms to the entire biochar may therefore lead to erroneous projections (Lehmann, 2007).
- Particulate nature of biochar: Biochar exists as particulates, thus biotic and abiotic decay is initiated on the surface (Lehmann, 2007). Such oxidation is limited to the outer areas of a particle even after so many years (Lehmann, 2007). Therefore the quantification of decomposition of fresh biochar by short-term experiments may therefore lead to an overestimation of the long term decay (Lehmann, 2007). According to Golchin *et al.*, (1994), particulate organic matter is not protected by mineral association and therefore easily mineralised. Conversely, Brodowski *et al.*, (2006) proposes that biochar exists within aggregates which suggest that biochar has physical protection by

minerals in addition to chemical recalcitrance, but there is no substantive evidence of this as yet (Lehmann, 2007).

2.5.1.2 Soil Amendment

Biochar characteristics, i.e. chemical composition, surface chemistry, particle and pore size distribution as well as physical and chemical stabilisation mechanisms of biochar in soils, has a major effect on how the soil functions (Verheijen *et al.*,2009). The application of biochar to the soil has an effect on the soil bulk density, water holding capacity, cation exchange capacity (CEC), pH and nutrient content of the soil. The addition of biochar to soil increases the soil porosity by the nature of its particle size and shape and its porous internal structure (Sparkes and Stoutjesdijk, 2011). This intends affects the surface area of the soil so water is better able to infiltrate.

Furthermore, some studies have shown that addition of biochar to soils increases the CEC of the soil. Once biochar is exposed to oxygen and water, oxidation occurs thus an increase in the net negative charge and hence an increase in the CEC (Joseph *et al.*, 2009). Consequently, Liang *et al., (*2006) suggests that aged biochar have high concentrations of negative charge promoting soil aggregation and increasing nutrient availability to soils. However, Granatstein *et al.,* (2009) observed that CEC did not change significantly as a result of biochar application to soils with a low initial cation exchange capacity. According to the same author, the addition of biochar to the soil affected the pH of the soil. The study noted that, soil pH increased from 7.1 to 8.1 when 39 tonnes per hectare of herbaceous feedstock derived biochar was added to a sandy soil. Furthermore, Chan et al. (2007) conducted a glasshouse pot test using

radish grown in Australian soils and found that adding herbaceous biochar (pH 9.4) at the rate of 100 tonnes per hectare significantly increased soil pH from 4.77 to 5.99, without affecting plant growth. Field trials conducted by Major *et al., (*2010) showed that application of biochar especially with mineral fertilizers or manures increased yields. The Above ground biomass increased by 189% when 23 tonnes per hectare of biochar was added to Columbian soils.

Furthermore, the application of biochar as a soil amendment significantly increased crop yields, even in the absence of nitrogen fertilizer. Corn yields increased approximately 18% and 23% for biochar-A and biochar-B, respectively, compared to the field without any treatment (Zheng *et al.,* 2010).

2.6 Nutrient Solutions

Among factors affecting hydroponic production systems, the nutrient solution is considered to be one of the most important determining factors of crop yield and quality (Trejo-Téllez and Gómez-Merino, 2012). A nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions from soluble salts of essential elements for higher plants (Trejo-Téllez and Gómez-Merino, 2012). A basic nutrient solution should contain nitrogen, phosphorus, potassium, calcium, magnesium sulphur; and be supplemented with micronutrients.

2.6.1 *pH of nutrient solution*

pH is a parameter that measures the acidity or alkalinity of a solution. This value indicates the relationship between the concentration of free ions H+ and OH- present in a solution and ranges between 0 and 14 (Trejo-Téllez and Gómez-Merino, 2012). pH of a nutrient solution affects its composition, elemental speciation and bioavailability. In hydroponic systems, plant productivity is closely related to nutrient uptake and the pH regulation (Marschner, 1995), thus must contain the ions in solution and in chemical forms that can be absorbed by plants (Trejo-Téllez and Gómez-Merino, 2012). pH affects the uptake of N, P, K and other essential nutrients in plant available forms. For a pH range between 2 and 7, NH_3 is completely present as $NH4^+$. Increasing the pH above 7 decreases the concentration of NH_4^+, while the concentration of NH_3 augments (De Rijck & Schrevens, 1999). Tyson *et al., (*2007) observed that the increased ammonia oxidation rate (1.75) compared to nitrite oxidation rate (1.3) at pH 8.5 resulted in accumulation of NO_2^- to levels near those harmful to plants when a study was conducted to determine the nitrification rate response in a perlite trickling biofilter (root growth medium) exposed to hydroponic nutrient solution, varying NO_3- concentrations and two pH levels (6.5 and 8.5). Available P is taken by the plants at a pH of 5. In alkaline and highly acidic solutions, the concentration of P decreases in a significant way (Dyśko *et al.,* 2008). Potassium, calcium and magnesium are however available to plants over a wide range of pH values (2 to 9) (De Rijck & Schrevens, 1998). Iron, copper, zinc, boron and manganese become unavailable at pH higher than 6.5 (Timmons *et al.,* 2002; Tyson, 2007).

2.6.2 *Electrical conductivity of the nutrient solution*

The total ionic concentration of a nutrient solution determines the growth, development and production of plants (Steiner, 1961). The electrical conductivity (EC) is an index of salt concentration that defines the total amount of salts in a solution. Hence, EC of the nutrient solution is a good indicator of the amount of available ions to the plants in the root zone (Nemali & Van Iersel, 2004). The ions associated with EC are Ca_2^+, Mg_2^+, K^+, Na^+, H^+, NO_3^-, SO_4^{2-}, Cl^-, HCO_3^-, OH^- (United States Department of Agriculture (USDA), 2001). The ideal EC is specific for each crop and dependent on environmental conditions (Sonneveld &Voogt, 2009); however, the EC values for hydroponic systems range from 1.5 to 2.5 ds m^{-1}(Trejo-Téllez and Gómez-Merino, 2012). Higher EC hinders nutrient uptake by increasing osmotic pressure, whereas lower EC may severely affect plant health and yield (Samarakoon *et al.*, 2006). The decrease in water uptake is strongly and linearly correlated to EC (Dalton *et al.*, 1997).

2.7 Nitrogen

Most of the Nitrogen (97 – 98%) in the soil is tied up in the organic matter and unavailable to plants. Only 2 – 3% is in the inorganic form of nitrate (NO_3^-) and the ammonium (NH_4^+) forms that is available to plants. During the process of mineralization**,** most of the organic matter is first converted to ammonium (NH_4^+) through nitrification. Most plants absorb majority of their Nitrogen in the nitrate (NO_3^-) form and to a lesser extent the ammonium (NH_4^+) form. Inside the plant, Nitrogen converts to amino acids, the building blocks for proteins. Nitrogen combined with

high concentrations of chlorophyll utilizes the sunlight as an energy source to carryout essential plant functions including nutrient uptake. Chlorophyll is associated with the production of simple sugars from carbon, hydrogen, and oxygen. These sugars along with their conversion products play a role in stimulating plant growth and development along with higher protein content in the grain. Nitrogen deficiency shows up in the yellowing or chlorosis of the plant leaves. Plants will typically be shorter or stunted and grow slower than plants with sufficient nitrogen.

(http://www.nachurs.com/nitrogen.html)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Organisation of Study

The study consisted of three phases;

1. Evaluation of human urine as N source and rice husk biochar, and mixture of rice husk biochar and compost as growing medium in raising tomato and pepper transplants under greenhouse conditions.
2. Evaluation of human urine and different growing media in growing pepper in pots under field conditions and
3. The perception of farmers, marketers and consumers about human urine as N source for vegetable production, the likelihood of using urine in vegetable production, and the perception of marketers and consumers in patronizing urine treated vegetables.

3.2 Study Area Description

Geographical Location of Study Area

The experiment was carried out at the University of Ghana Forest and Horticultural Research Centre (FOHCREC), in Okumaning Kade. The Centre is located in the Kwaebibirem District (6º 05' N; 0º 05'W) (Figure 3.2.1) which is about 175 km from Accra and lies in the Moist Semi - Deciduous vegetation zone in the Eastern Region of Ghana. The Centre is about 150 m above sea level.

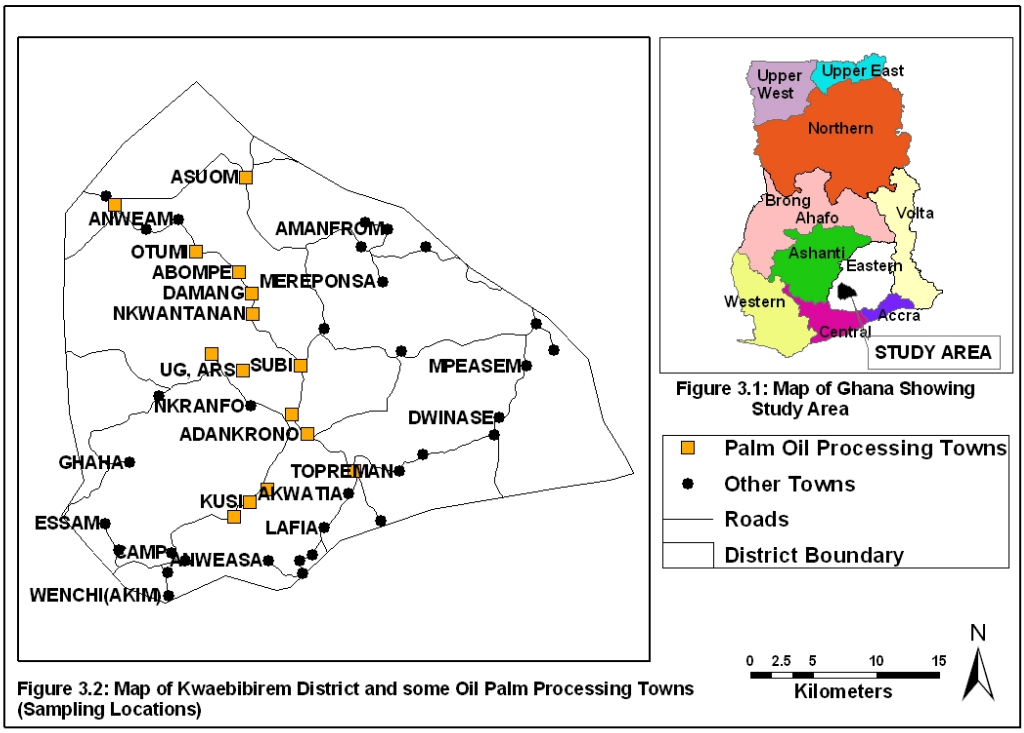

Figure 3.2.1: Map of Kwaebibirem Districts showing the Study Area. *(Source:Adamtey, 2005)*

Political Boundary

Kwaebibirem District is located in the south-western corner of the Eastern Region of Ghana, between latitudes 1˚ O'W and O˚ 35.'E and longitudes 6˚ 22'N and 5˚ 75'S. The district is bounded to the west by the Birim North District, on the east by East Akim Municipal, and, to the South by West Akim Municipal. It is also bounded on the South-West by the Birim South District, on the North East by Atiwa and on the South East by the Suhum Kraboa Coaltar District. Kwaebibirem District has a surface area of about 1,230 km^2 square kilometers (GhanaDistricts.com, 2013).

Relief and Drainage

Birim River is the major river that flows through the district**.** It takes its source from the Atewa range of hills in the Eastern Region of Ghana and follows a course of 175 km to join the river Pra. The Birim basin has an estimated area of 3,875 km^2 with seven important tributaries. It is located between latitude 0º 20'W, 1º 15'W and longitude 5º 45'N, 6º 35'N (Adamtey, 2005)

Geology and Soil

The soils of the area according to Owusu-Bennoah *et al.,* (2000) are generally developed from rocks of the Birrimian system. The well-drained upland soils are generally classified as Acrisols in the FAO-UNESCO Revised Legend (FAO, 1988) and as Utilsols in Soil Taxonomy (Soil Survey Staff, 1998).

Climatic Condition

The region lies within the wet semi-equatorial zone which is characterized by double maxima rainfall in June and October. The first rainy season is from May to June, with the heaviest rainfall occurring in June while the second season is from September to October, with little variations between the districts. Temperatures in the region are high and range between 26^oC in August and 30^oC in March. The relative humidity is high throughout the year and varies between 70 per cent -80 per cent.

Experiment I

3.3 Evaluation of Human Urine as N Source and Rice Husk Biochar as Growing Medium for Tomato and Pepper Transplant Production.

3.3.1 Human urine collection, storage and biochar preparation

3.3.1.1 Human urine Collection and Storage

Urine for the experiment was collected from the Kade Senior High School and Agricultural Research Station Basic School. The urine was collected in October 2012 from both male and female students aged 5 to 19 years and lasted for a period of 3 weeks. Urine was collected weekly using 25 L containers connected to the urinals, transported to the study site and stored in 100 L plastic containers at ambient conditions (20- 28° C). The stored urine was stirred once a week to prevent the development of crystals and precipitation of salts.

3.3.1.2 Characterisation of the Urine

Composite samples of the urine were taken in triplicate after mixing the stored urine thoroughly. These samples were transported in an ice box to the Ecological Laboratory of the University of Ghana. Parameters measured included pH, EC, Total Nitrogen, Available Nitrogen, Total Phosphorus, Available Phosphorus, Total Potassium and Available Potassium. These parameters were determined as described in section 3.5 below.

3.3.1.3 Preparation of Biochar

Biomass (rice husk) used in the preparation of biochar was collected from nearby rice mills in the Kade township and transported to the study site (FOHCREC). A perforated metallic kiln mimicking the metal kiln used in traditional charcoal making was heated for about 30 minutes (Plate 3.3.1). A known quantity of the rice husk biomass was spread around the metal kiln (Plate 3.3.2). This was mixed intermittently until the pyrolysis process was completed. The temperature in the metallic kiln was monitored using a thermocouple.

3.3.1.4 Characterisation of biochar

The physical and chemical properties of the biochar was analyzed using standard methods: pH, EC, Water holding capacity, Bulk density, Total organic carbon, N, P and K following methods described in section 3.6 below.

Temperature of the pyrolysis process was measured using a Thermocouple connected to a multimeter (Plate 3.3.3).

Plate 3.3.1: A photo of a metal kiln and a worker at FOHCREC lighting up fire to heat the kiln before pyrolysis

Plate 3.3.2: A worker at FOHCREC heaping raw materials around the Kiln

Plate 3.3.3: Measuring temperature using a thermocouple connected to a multimeter.

3.3.2 Human urine as an N source for the greenhouse production of tomato and pepper transplant.

3.3.2.1 Greenhouse experiment

The study was carried out in a greenhouse at FOHCREC between January – March, 2013. The temperature in the greenhouse ranged between 28 and 48º C. The completely randomised design with 3 replications was adopted.

Growing media treatments

The growing media treatments were 100% rice husk biochar (RHB) and 50% compost + 50% RHB (v/v). The RHB was obtained as described in section 3.3.1.3 whiles the compost was prepared at FOHCREC. The physical and chemical properties of the growing media was characterised according to standard methods.

Pyramid seed trays of cavity size 85cm^3 were filled with the different media and irrigated with ordinary tap water. The treatments were completely randomized with 3 replications. Three (3) seeds each of tomato and pepper were sown and irrigated with tap water till the seeds had germinated. Germinated seeds were counted on each day after germination from the 4th up to 9th day. The mean days to emergence (MDE) was calculated according to Gerson and Honma (1978). The percentage emerged was calculated with the formula below.

$$\text{MDE} = \frac{\text{(Days to Emergence) (Number Emerged Each Day)}}{\text{Total Number Emerged}} \quad (3.1)$$

$$\text{Percentage emerged (\%)} = \frac{\text{Number of seeds emerged}}{\text{Total number of seeds sown}} \times 100 \quad (3.2)$$

The seedlings were irrigated with tap water until they showed second true leaves. The seedlings were thinned to one plant per cavity. Irrigation with tap water was terminated two days after thinning. The seedlings were then irrigated by dipping (Plate 3.3.4) in the respective nutrient solution treatment; urine and inorganic N fertilizer solutions described below. The media was allowed to absorb the N nutrient solutions by capillary action until moisture saturation and then the trays were removed and

placed on a wooden stand (Plate 3.3.5). Nutrient solutions were replaced regularly and ordinary tap water served as control. The treatment lasted for 21 days.

Plate 3.3.4: Transplants being dipped in plastic container during irrigation

Urine and inorganic N nutrient solution Treatments

The urine treatments were prepared by diluting raw human urine with distilled water at 1: 4, 1: 5 and 1: 6 (urine: distilled water) dilution rates and analysed for their NPK content. The sources of the N, P and K inorganic fertilizers are shown in Table 3.3.1. The inorganic N nutrient solutions were prepared as follows: 30, 50 and 70 mg N/L with each N nutrient solution containing 45mg P/l as TSP and 25 mg K/l. The pH of

all the nutrient solutions were adjusted to between 6.5-6.7 (Sorgona *et al.*, 2011) with NaOH or H_2SO_4.

Table 3.3.1: Composition of the inorganic N nutrient solution

Nutrient	**Sources**	**Percent composition**
N	Ammonium nitrate (NH_4NO_3)	34% N (Yara International, 2013)
P	Triple super phosphate (TSP)	46% P_2O_5 (Better Crops, 1998)
K	Potassium chloride (KCl)	52.45% K (FAO, 2000)

Plate 3.3.5: Tomato transplants on wooden stand 14 days after treatment

Sampling and plant analysis

Tomato and pepper seedlings were sampled (5 plants per treatment/ replicate) every week to measure some selected growth parameters. Leaf chlorophyll content was measured using Apogee chlorophyll meter (Model CCM- 200). Plant height and root length were measured with a measuring ruler and reported in centimeters. Stem diameter was measured at 1 cm above the soil surface with a pair of vernier callipers. The plant samples were oven dried at 68˚C for 48 hours and weighed to obtain dry weights.

Experiment II

3.4 Effect of Growing Media and Human Urine as Nitrogen Source on Growth and Yield of Pepper (*Capsicum annum var. Bird eye*)

3.4.1 Media treatments and their preparation

Five different types of growing media treatments were evaluated. These were prepared from soil, RHB and agric. waste compost (Co). The growing media consisted of different ratios of soil, RHB and compost as presented in Table 3.4.1. The physical and chemical characteristics of the growing media were analyzed as described below;

Table 3.3.1: Different experimental combinations of growing media

Treatment	Composition of growing media	Mixing ratio (v/v)
1	Soil + RHB	1 : 1
2	Soil + Co	1 : 1
3	Soil + Co + RHB	1 : 1 : 1
4	Soil + Co + RHB	1 : 1 : 2
5	Soil + Co + RHB	1 : 2 : 1

RHB = Rice Husk Biochar, Co= Compost

The soil used in this study was sampled from the plough layer (0-15cm) of the Kokofu-Kakum series (Ofosu – Budu, 2013). The soil was air dried, pulverised and sieved through a 5 mm sieve to obtain uniform mixture. Similarly, the Agric. waste compost obtained from FOHCREC was also sieved. Polythene bags were then filled with 10 kg of each growing media treatment.

3.4.2 Urine and inorganic fertilizer treatments

Urine (1 month in storage) was diluted with water at a ratio 1:4 (urine: water) and used as treatment. Other chemicals were added to the urine to supplement the nutrient content to promote growth, as initial analysis showed some deficiency in these elements. Potassium sulphate (1g/L), calcium carbonate (1g/L), TSP (1g/L) and magnesium oxide (0.5g/L) were added to the DU 1:4 to make up for the relatively small quantities of P, K, S, Ca and Mg found in urine. The inorganic N fertilizer nutrient solution treatment was prepared from 5g of NPK (15-15-15), 1g of Urea, 1g of

KCl (muriate of potash), 1g of $CaCO_3$ and 0.5g of MgO and 0.5g of P in 10 L (Hochmuth, 1990). All nutrient solutions were applied at 50mls three times daily to the plants.

N source application rates

The urine treatment was applied at three (3) different rates; once a week (Urine1), twice a week (Urine 2) and thrice a week (Urine 3). The Inorganic fertilizer treatment was only applied twice a week (In-Fert).

3.4.3 Experimental design

The split plot design was adopted with fertigation treatments as main plot and growing media as subplots. (Figure 3.4.1). Each growing media treatment consisted of three polybags. The five fertigation sources were as follows; - inorganic fertilizer (In- Fert), Urine 1, Urine 2 and Urine 3 and a control (water). Plants were spaced at 30cm x 30cm and raised on a wooden platform (Figure 3.4.2). Three replications were adopted.

Soil + Co (1:1)	Soil + Co (1:1)	Soil + Co+ RHB (1:1:2)	Soil + Co+ RHB (1:2:1)	Soil + Co+ RHB (1:1:1)
Soil + Co+ RHB (1:2:1)	Soil + RHB (1:1)	Soil + Co+ RHB (1:1:1)	Soil + Co+ RHB (1:1:2)	Soil + RHB (1:1)
Soil + Co+ RHB (1:1:1)	Soil + Co+ RHB (1:1:2)	Soil + Co (1:1)	Soil + Co+ RHB (1:2:1)	Soil + RHB (1:1)

Figure 3.4.1: Experimental design used in the study- A Split Plot design with N source as Main Plot and growing media as sub-plots

3.4.4 Field Experiment

Three week-old pepper seedlings were transplanted into poly bags containing the media treatments. The transplants were irrigated with tap water for a week to condition the plant to their new environment. The plants were spaced at 30 cm x 30 cm on a wooden platform. Three polybags constituted a growing media treatment. A total of (3 polybags/treatment x 5 growing media x 5 N irrigation x 3 replications) 225 pepper seedlings were transplanted to respective polybags. Fifty mills of each nutrients solution was applied to each plant three times daily. The experiment was terminated 50 days after treatment. Pest and disease control were carried out as and when necessary.

3.4.5 Vegetative measurements

Pepper plants were sampled every two weeks. Parameters monitored included those described in section 3.3.2.1 above. In addition, number of branches, number of flowers and fruit yield (including fruit length, breath, weight and number) was also measured. Total yield /plant were determined by multiplying the mean fruit weight by the total fruit number/plant. The yield per hectare was determined by multiplying the yield/plant by the total number of plants/ha using the spacing of 30 cm x 30 cm.

3.5 Determination of Physical and Chemical Composition of Urine

(i) pH

The pH of the urine samples were measured using a pH meter (Metrohm model 691 pH meter) and procedure stipulated in APHA, AWWA, WEF (1998) was followed. The pH meter was calibrated using pH 4 and pH 7 buffers respectively. Afterwards, the electrode of the meter was dipped into the samples individually and their corresponding pH values recorded. The electrode after measuring a sample was rinsed with distilled water and shaken before dipping into another sample.

(ii) Electrical Conductivity (EC)

Electrical conductivity of the urine samples was determined according to the procedure described by APHA, AWWA, WPCF (1995) using a Metrohm E587 conductivity meter. The instrument was calibrated with standard KCl (0.01M solution), which has a conductivity of 1413µS/cm at 25ºC. The electrode of the conductivity meter was dipped into each sample and the corresponding conductivity value recorded. The electrode after measuring the conductivity of each sample was rinsed with distilled water and shaken before dipping into the next sample.

(iii) Total Nitrogen Determination

Procedure;

The modified method of Folin and Farmer (2009) was used to determine the Total N in the urine. A 50ml conical flask was weighed (a) and an empty test tube was placed in the flask and weighed again (b). Weight of test tube equals the difference between b

and a (b-a). 5mls of urine was measured into the test tube and the weight determined by placing it in the conical flask (c). Weight of urine equals the difference between c and b (c-b).

Density of urine = mass of urine/volume of urine (3.3)

Specific gravity of urine = $\frac{\text{Density of urine}}{\text{Density of water}}$ or $\frac{\text{mass of a volume of urine}}{\text{mass of an equal volume of water}}$ (3.4)

1ml of urine was measured into a test tube and the weight determined as above. 1ml of water was added to the urine and mixed thoroughly. 1ml of conc. H_2SO_4 was added to the test tube followed by 1g of potassium sulphate and 1 drop of 5% copper sulphate and quartz pebble (to prevent bumping). The mixture was boiled for 4-6 minutes until the mixture become colourless. The solution was allowed to cool until digestion mixture was viscous (not allowed to solidify). 6mls of water was added to the mixture in the test tube (a few drops at a time to prevent solidifying of the mixture). The mixture was then emptied into a 100ml bottom flask and water added to the mark.

5mls aliquot of the sample was transferred into a Markham distillation apparatus. 5ml of 40% sodium hydroxide and 100ml of distilled water was added to the sample solution. The distillate was collected in a 2% boric acid indicator until about 50mls of the distillate was collected. The distillate was titrated with 0.01 M HCl.

Calculations:

$$\% \text{ N in urine} = \frac{\text{Titre value} \times 14 \times V \times 100 \times 0.01}{w \times al \times 1000} \quad (3.5)$$

Where; V= final volume of the digestion = 100 ml.

w = dry weight of the sample in grams.

al = aliquot of the solution taken for analysis = 5 ml.

14 = Molar weight of nitrogen.

0.01 = molarity of HCl.

(iv) Ammonium-N (NH_4-N) and Nitrate-N (NO_3-N)

A volume of 10 ml of urine was measured into the distillation flask and about 0.2 g of Magnesium oxide (MgO) was added to the sludge in the flask. The distillation flask was then connected to the distillation apparatus and the distillation process was started. The ammonium-N in the sludge was collected with 5 ml boric acid as described above. Ammonium-N content in the distillate was determined by titrating with 0.01M HCl till colour changed from green to light pink signifying end point of the titration.

After the ammonium-N was distilled from the sludge in the above, the stopper at the side arm of the distilling flask was removed and 0.2g of Devarda's alloy was added. The stopper was then replaced immediately into the neck of the side arm and nitrate-N was distilled into fresh boric acid in a conical flask. The NO_3 is converted to NH_4 and trapped in the conical flask. This ammonium was then estimated by titrating with 0.01M HCl as described above.

Calculation of NH_4-N and NO_3-N,

$$NH_4\text{-N (mg/kg)} = \frac{0.01 \times \text{titre value} \times 18 \times 10^{-3} \times V \times 10^6}{al \times w} \quad (3.6)$$

$$NO_3\text{-N (mg/kg)} = \frac{0.01 \times \text{titre value} \times 18 \times 10^{-3} \times V \times 10^6}{al \times w} \quad (3.7)$$

Where; V = Volume of sample prepared = 40 ml.

al = aliquot of sludge taken = 10ml.

w = dry weight of the sample in grams.

(v) Total Potassium (K)

Ten (10) ml of urine sample was measured into a 500 ml digestion flask and 10 ml of Ternary Solution was added to it. The mixture was heated on the digestion block till a yellow colouration was obtained. After it had cooled, it was transferred into a 100 ml Erlenmeyer round bottom flask and topped up to the mark with distilled water. The concentration of total potassium in the sludge was read by aspirating into Jenway flame photometer (PFP7) that was calibrated at 25 and 50ppm of standard solution.

Calculation of total potassium (K),

$$\%\ K = (\text{flame reading}/1000) \times (V/1000) \times (100/w) \quad (3.8)$$

Where; V = final volume of digestion = 100ml.

w = dry weight of sample.

(vi) Total Phosphorus (P) (Ascorbic acid Method)

Ten (10) ml of the urine sample was measured, digested and made up to the 100 ml mark in an Erlenmeyer as was carried out for Total potassium determination above. Afterwards, 1 ml of the sample was taken into a 50 ml conical flask and 2 drops each of *p*-nitrophenol and ammonia were added followed by 5 ml of ascorbic acid. The colour of the mixture changed to blue and was made up to the mark with distilled water. The total phosphorus concentration was read using PHILIPS PU 8620 UV/VIS/NIR spectrophotometer. The wavelength dial was rotated until the display showed 712 nm. The sample was well shaken and a 1 ml portion of it was poured into the cuvette and read.

Calculation of total phosphorus (P),

$$\% P = (\text{spectrophotometer reading}/ w) \times (V/ al) \times (100/10^6) \qquad (3.9)$$

Where; V = final volume of digestion = 100 ml.

al = aliquot of sample taken.

w = dry weight of sample taken.

3.6 Determination of Physical and Chemical Composition of Growing Media.

(i) pH

The pH was determined by 1:5 sample to water extract method described by USDA and USCC (2001). Five grams (5 g) of the dried media sample was weighed into a 100 ml beaker and 25 g of distilled water was added to the sample and stirred for about 10 minutes. The mixture was allowed to stand for 30 minutes. The pH was then read as described in section 3.5 above.

(ii)Electrical Conductivity (EC)

The EC was also determined by 1:10 sample to water extract method as was carried out for the pH above. The EC was read as described in section 3.5.

(iii) Total Nitrogen (N)

The modified Kjeldahl method as described by Black (1965) was used to determine total N in the media samples. A 0.1g of each of the samples were weighed into 500ml Kjeldahl flask and heated with 5ml of concentrated H_2SO_4 in the presence of selenium catalyst and salts (Na_2 SO_4). The resulting digested mixture was transferred into a 100ml volumetric flask and topped up to the mark. An aliquot of 5 ml was then distilled with excess NaOH and condensed as ammonium hydroxide (NH_4OH) to liberate ammonia. The liberated ammonium was trapped with 5ml boric acid in a conical flask and titrated against 0.01M HCl using mixed indicator (bromocresol green and methyl red) until end point was reached. At the end point, the colour changed from green to reddish pink colour. The volume of HCl used in the titration was recorded.

Calculation of total nitrogen,

$$\% N = \frac{\text{Titre value} \times 14 \times V \times 100 \times 0.01}{w \times al \times 1000} \quad (3.10)$$

Where; V= final volume of the digestion = 100 ml.

w = dry weight of the sample in grams.

al = aliquot of the solution taken for analysis = 5 ml.

14 = Molar weight of nitrogen.

0.01 = molarity of HCl.

(iv) Determination of ammonium nitrogen (NH_4^+-N) and nitrate nitrogen (NO_3- N) in feedstock and co-compost samples

One gram (1g) of air-dried grinded sample that has passed through 2.0 mm sieve was weighed into a 200ml plastic bottle, and 40ml of 2MKCl extracting solution was added. The bottle was covered and the content shaken for one hour. The sample was then centrifuged and filtered through No. 5 Whatman filter paper.

*Measurement of NH_4 – N (*Okalebo *et al.,* 2002*)*

An aliquot of 10ml of the co-compost extract was pipetted into the distillation flask ammonium-N (NH4 –N) was determined as described in section 3.5.

*Measurement of NO_3 – N (*Okalebo *et al.,* 2002*).*

Nitrate- N (NO3-N) was also distilled, following ammonium-N (NH4 –N) distillation as described in section 3.5.

(v) Measurement of total phosphorus (Perchloric acid digestion)

0.1g of the media sample was weighed into a 125ml Erlenmeyer flask which was previously washed with acid and distilled water. 10 ml of Ternary solution was added and digested. After the digested solution had cooled it was filtered completely with Whatman No.42 filter paper, into a 100ml Pyrex volumetric flask and made up to the mark with distilled water. Total P was read as described in section 3.5.

(vi) Determination of available phosphorus (Bray No.1 Method) Extraction

One gram (1g) of air-dried media sample that had passed through a 2mm sieve was weighed into a 100ml conical flask and 7ml of extracting solution added to it. The content of the flask was placed on a shaking machine for 5 minutes and filtered through Whatman No.42 filter paper. Phosphorous was determined calorimetrically as described in section 3.5.

(vii) Measurement of total potassium

0.1g of the media sample was weighed into a conical flask and digested with 10 ml Ternary mixture (20ml of 60% conc. perchloric acid, 500ml conc. nitric acid mixture and 50ml H_2SO_4). The digest was allowed to cool and filtered into 100ml volumetric flask which was top up to the mark. Because of the high concentration of K, 10 ml aliquot of the digest was taken into 100ml volumetric flask and top up with distilled water to the mark. Total K was read as described in section 3.5.

(viii) Total Organic carbon (TOC)

Total organic carbon was determined by principles and procedures described by Walkley and Black (1934). A 0.5g representative sample of the media was weighed in a 250 Erlenmeyer flask. Ten (10) ml of dichromate solution followed by 20 ml of conc. H_2SO_4 was added to the sample. The flask was swirled to make sure the solution was in contact with all the particles of the compost and allowed to stand on an asbestos sheet for 30 minutes. 200 ml of distilled water was added followed by 10 ml of orthophosphoric acid and finally 2 ml of barium diphenylamine sulphonate indicator. The mixture was then titrated with ferrous ammonium sulphate solution until the colour changed to blue then to a green end-point.

Calculations;

$$\% \text{ Carbon} = \frac{\{10.0 - (X\ N\} \times 0.3 \times 1.33}{W} \qquad \text{Eqn (3.11)}$$

Where;

X = ml of ferrous ammonium sulphate required for titration

N = molarity of ferrous ammonium sulphate solution

W = weight of sample taken

10 = ml of dichromate solution used.

(ix) Bulk density

The bulk density of the media is the mass per unit volume expressed as gcm^{-3}. The procedure described by Okalebo *et al.*, (2002) was followed. A 5 cm diameter tin of known weight (W1) and volume (V) was filled with the compost sample. The tin was

dropped about 10 cm above ground several times to ensure that the compost particles filled every available space or volume of the tin. The tin with the sample was weighed again (W2).

Calculations;

$$\text{Bulk density } (gcm^{-3}) = \frac{(W2g - W1g)}{Vcm^3} \qquad \text{Eqn (3.12)}$$

(xii) Water holding capacity

Water holding capacity of the media was determined by procedures described in Vengadaramana and Jashothan (2012). A number of small holes were picked in a base of a tin box. The box was filled with 100 g of air dried and sieved compost/CRH/compost-CRH mixed sample. Water was added to the individual samples till they got saturated. The tin was kept in a slanting position and hanged to a stand with the help of a string. Extra water came out of the perforation at the base. When water drops had stop coming out, the individual sample was removed and weighed immediately. Afterwards the samples were kept in a hot air oven and dried at 105˚C for 48 hours. The samples were cooled in a dessicator and weighed again.

Calculations;

$$\text{Water holding capacity (per gram of media)} = \frac{W2 - W3}{W1} \qquad \text{Eqn (3.13)}$$

Where;

W1 = initial weight of media (100g)

W2 = weight of media after water drained of.

W3 = weight of media after kept in oven at 105˚C for 48 hours.

Experiment III

3.5 Willingness To Use, Use and Perception on the Use of Human Urine as A Fertilizer Source for Crop Production.

A total of 60 respondents were selected randomly for the survey. This included vegetable farmers, marketers and consumers. Thirty (30) vegetable farmers were selected from 3 farming sites (Dzorwulu, Roman Ridge and Korle Bu) in Accra using purposive sampling techniques. Fifteen (15) marketers' and 15 consumers' were randomly selected and interviewed in North Legon, Kaneshie and Labone. These areas were chosen due to their diverse cultural, social and economic characteristics. Three different set of questionnaires were administered; one to the farmers, one to marketers and the other to the consumers (see appendix 1). Questions in the questionnaires were translated into local languages by the investigator as and when it was necessary.

3.7 Statistical Analysis

Treatment effects were subjected to ANOVA analysis using Genstat 9th edition (Release 9.2) statistical package. Treatment means found to be significantly different from each other at $(P < 0.05)$ were separated by the Least Significant Differences (LSD) tests. Data collected from the questionnaire survey were analysed with the use of descriptive statistics such as frequencies and percentages.

CHAPTER FOUR

4.0 RESULTS

4.1 Preparation and Characterisation of Urine, Biochar and Compost

4.1.1 Some chemical characteristics of urine used in the study

Some chemical composition of the urine used for the study is shown in Table 4.1.1. The total nitrogen concentration ranged between (2.66 to 2.68 g/L) and is significantly lower than the reported values of other scientists 10.3 g/L (Cofie *et al.*, 2011) who have earlier conducted studies on urine. The available N form in the urine was mainly ammonium, which formed about 97% of the total N, The pH also ranged between 9.13 and 9.30, which is quite close to the reported value of 9.10 (Semalulu *et al.*, 2012. The Electrical Conductivity (EC) which also ranged between 19.5 and 20.0 dS/cm was very low, compared to the values (3 dS/m) reported by Cofie *et al.*, (2011). Total P and K values that ranged between 4.7 to 5 g/l and 14.7 to 16 g/l respectively were higher than the reported values 0.20 and 0.21g/l for total P and 0.9 to 1.1g/l for total K (Kirrchmann and Pettersson, 1995). The significant amount of plant nutrients contained in the urine thus makes it a valuable nutrient source for vegetable production.

Table 4.1.1: Some chemical characteristics of urine used in the study.

Parameters	Maximum	Minimum	Mean ± STDEV (n=3)
pH	9.30	9.13	9.34 ± 0.23
EC (dS/cm)	20.00	19.50	19.66 ± 0.28
Total Nitrogen (g/l)	2.68	2.66	2.67 ± 0.01
Total Phosphorus (%)	0.50	0.47	0.49 ± 0.01
Total Potassium (%)	1.59	1. 47	1.53 ± 0.05
Ammonium Nitrogen (g/l)	2.62	2.58	2.59 ± 0.02
Nitrate Nitrogen (g/l)	0.04	0.04	0.04 ± 0.00
Available Potassium (g/l)	0.18	0.18	0.18 ± 0.00
Available Phosphorus (%)	0.011	0.012	0.012 ± 0.00

4.1.2 Physical and chemical characteristics of rice husk biochar and compost.

The physical and chemical characteristics of rice husk biochar and compost are presented in Table 4.1.2. The water holding capacity of rice husk biochar in this study was 2.67, while the bulk density was 0.34 g/cm^3. This result falls within the bulk density for rice husk biochar value of 0.15 g/cm (Nakajima, 1986) and 0.84 mg/m^3 (Masulili, 2010). The differences could be due to the temperature used in the preparation of the biochar. The pH of the biochar observed in this study (9.09) is quite close to pH of rice husk biochar 10.7, reported by Sokchea *et al.,* (2013). The total P and K observed for the rice husk biochar (0.61 and 0.48 %) for P and K respectively,

were higher than the reported values of 0.12 and 0.2% (Masulili, 2010). However, the P and K values are within the range of 0.2 to73.0 g P/ kg and 1.0 to 58g K /kg reported by Chan and Xu, (2009). The biochar also contained available N in the form of ammonium-N which can be made available for plant growth.

The N, P and K concentrations of the compost ranged 1.64% for total N, 0.32% for P and 1.11% total K. The macronutrient values observed in this study compare favourably with the reported values for agricultural waste compost (Ofosu-Budu *et al.*, 2010). Similarly, the pH and the EC of the compost are within the range for matured compost normally used in Ghana (Ofosu-Budu *et al.*, 2010; Adamtey, 2010). The very high available-N (ammonium and nitrate-N) contained in the compost, makes it a suitable soil amendment for raising crops and also at the nursery and similar values have been reported earlier (Ofosu-Budu *et al.*, 2010).

Table 4.1.2: Physical and chemical properties of rice husk biochar and compost.

Parameters	Rice husk biochar	Compost
pH	9.09 ± 0.05	7.94± 0.03
EC mS/cm	0.07 ± 0.00	1.73 ±0.06
Water Holding Capacity (per gram)	2.67 ± 0.03	0.97 ± 0.02
Bulk Density(g/cm3)	0.34 ± 0.00	0.95 ± 0.01
Total organic carbon (%)	10.43 ± 3.5	not measured
Total Nitrogen (%)	0.99 ± 0.15	1.64 ± 0.04
Ammonium- N (mg/Kg)	176.40 ± 3.60	212.40 ±2.40
Nitrate-N (mg/Kg)	172.80± 7.2	572.40± 5.20
Total Phosphorus (%)	0.061 ± 0.03	0.32± 0.02
Total Potassium (%)	0.48 ± 0.11	1.11 ± 0.00
Avail. Phosphorus (%)	0.04 ± 0.00	0.10 ± 0.01

4.2 Evaluation of Rice Husk Biochar and Compost as Growing Medium and Human Urine as N Source in Pepper and Tomato Transplant Production.

4.2.1 Physico-chemical characteristics of growing media.

There were significant differences in the physical and chemical properties of the growing media- RHB and CoRHB. Addition of compost to the biochar (CoRHB) affected the physical and chemical properties of the growing media; bulk density, water holding capacity, and also the pH, EC, total N, available N, total P and available P and total K (Table 4.2.1a and 4.2.1b). Electrical conductivity (EC) and bulk density of CoRHB increased significantly with the addition of compost. On the other hand, pH and water holding capacity reduced significantly with the addition of compost. The WHC of the RHB was significantly higher than that of the CoRHB. However, the bulk density and EC of CoRHB, was higher than RHB, but fall within the recommendations set for growing vegetables. The available-N (ammonium-N and nitrate-N) and total P and K in CoRHB was higher and significantly different from that of RHB.

Chemical analysis of the growing media is shown in Table 4.2.1b. Total N, P, K and available N and P increased significantly with the addition of compost to biochar. This consequently improved the physical and chemical characteristic of the compost amended biochar. The result obtained in this study compares favourably with what has been reported in literature and therefore indicates that the media are suitable for raising and growing tomato and pepper plants

Table 4.2.1a: Physical and chemical characteristics of the growing media

Growing Media	pH (1:5 water)	EC (1:10)(dS/cm)	Bulk density (g/cm3)	Water holding capacity (per gram)
CoRHB	8.78 ± 0.03	2.43 ± 0.06	0.56 ± 0.02	1.56 ± 0.08
RHB	9.04 ± 0.05	0.01 ± 0.00	0.34 ± 0.00	2.67 ±0.03
LSD(p<0.05)	0.585	0.092	0.033	0.128

RHB = Rice Husk Biochar, CoRHB = Compost + Rice Husk Biochar (1:1 v/v)

Table 4.2.1b: Some nutrient characteristics of growing media

Growing Media	Total N (%)	NH4-N (mgkg-1)	NO3-N (mgkg-1)	Total P (%)	Avail-P (%)	Total K (%)
CoRHB	1.97± 0.01	191.03 ± 0.03	553.87 ± 0.19	0.37 ± 0.01	0.03 ± 0.00	1.05± 0.01
RHB	0.99 ± 0.01	176.43 ± 1.43	172.57 ± 3.77	0.06 ± 0.01	0.02 ± 0.00	0.48 ± 0.01

RHB = Rice Husk Biochar, CoRHB = Compost + Rice Husk Biochar (1:1v/v)

4.2.2: The pH, EC and nutrient composition of urine and inorganic nutrient solution used for the study.

The chemical composition of the nutrient solution used in the study is presented in Table 4.2.2. The pH of the different urine dilution (DU 1:4, DU 1:5 and DU 1:6) rates did not differ significantly from each other Table 4.2.2. However, the EC of the diluted urine decreased with increasing dilution and ranged between 6.20 and 8.40 dS/cm. The nutrient concentration (total N, P, K and available N and P) of the urine also decreased with increasing dilution, except for nitrate.

Table 4.2.2: pH, EC and nutrient composition of urine and inorganic nutrient solutions

Nitrogen Sources	pH	EC (dS/cm)	Total N (g/l)	NH4-N (g/l)	NO3-N (g/l)	Total P (%)	Total K (%)	Avail P (%)
DU (1:4)	8.90 ±0.10	8.40± 0.03	1.00 ± 0.01	0.66 ± 0.04	0.02 ± 0.00	0.10 ± 0.00	0.29 ± 0.03	0.006 ± 0.00
DU (1:5)	8.92 ±0.12	7.17± 0.13	0.83 ± 0.20	0.46 ± 0.03	0.02 ± 0.00	0.07 ± 0.00	0.19 ± 0.01	0.004± 0.00
DU (1:6)	8.93 ±0.11	6.20± 0.10	0.58 ± 0.07	0.39 ± 0.04	0.02 ± 0.00	0.05 ± 0.00	0.15 ± 0.00	0.004± 0.00
In Fert 1	5.51 ±0.11	0.01± 0.00	0.03± 0.00	0.02 ± 0.00	0.02 ± 0.00	ND	ND	ND
In Fert 2	5.46 ±0.12	0.01± 0.00	0.05± 0.00	0.03 ± 0.00	0.03 ± 0.00	ND	ND	ND
In Fert 3	5.38 ±0.12	0.01± 0.00	0.07 ± 0.00	0.04 ± 0.00	0.04 ± 0.00	ND	ND	ND

(Mean ± STDEV, n=3)
N/D- Not Determined
In-Fert.1 = (30mg N/L), In-Fert 2 = (50mgN/L), In-Fert 3 = (70mgN/L)
DU (1:4) = 1:4 (urine/water) DU (1:5) = 1:5 (urine/water) DU (1:6) = 1:6 (urine/water)

4.2.3 Effect of growing media on number of days for germination and percentage of seeds that germinated for tomato and pepper

The mean number of days to germination was affected by the growing media. The mean number of days for tomato germination was higher in CoRHB (5.70 days) than 3.96 days for RHB and was significantly different. Similarly, the growing media had significant effect on the percentage seed germinated for tomato, and was higher in RHB (94.26 %) than that observed for CoRHB (81.14%) and the difference was significant (Table 4.2.3a).

The mean number of days for pepper seed germination was not affected by the growing media, as there was no significant difference between the mean number of days for CoRHB (13.40) and 13.21 for RHB (Table 4.2.3b). The percentage of seeds that germinated was also affected by the growing medium, as CoRHB recorded 34.5% as against 46.73% for RHB and the difference was significant.

Table 4.2.3a: Effect of growing media on number of days for germination and percentage of seeds that germinated for tomato

Growing Media	Seed germinated (%)	Mean Days to Germination (MDG)
CoRHB	81.14	5.70
RHB	94.26	3.96
LSD ($p<0.05$)	1.725	0.128

RHB = Rice Husk Biochar, CoRHB = Compost + Rice Husk Biochar (1:1v/v)

Table 4.2.3b: Effect of growing media on number of days for germination and percentage of seeds that germinated for pepper

Growing Media	Seed Germinated(%)	Mean Days for Germination (MDG)
CoRHB	34.48	13.40
RHB	46.73	13.21
LSD ($p<0.05$)	0.864	0.254

RHB = Rice Husk Biochar, CoRHB = Compost + Rice Husk Biochar (1:1v/v).

4.2.4 Effect of growing media on the some vegetative properties of tomato and pepper before treatment

The type of growing media significantly affected the growth of tomato and pepper transplants. The plant height, stem diameter, root length, number of true leaves, shoot dry matter and root dry matter of pepper transplants grown in CoRHB was significantly higher than in RHB(Table 4.2.4a.)

Similar observations showing higher values for plant height stem diameter, number of leaves, and shoot dry matter of tomato transplants grown in the CoRHB than RHB were made (Table 4.2.4b). On the other hand, root length, root to shoot ratio and root dry matter were significantly higher in RHB than in CoRHB for tomato transplant. Furthermore, root to shoot ratio of pepper and tomato were higher in RHB than in CoRHB. The plants grown in CoRHB were significantly higher in plant height, stem diameter, root length, number of true leaves, root dry matter, compared those grown in biochar medium.

Table 4.2.4a: Effect of growing media on the some vegetative properties of pepper before treatment

Growing Media	Plant height (cm)	Stem diameter (mm)	Root length (cm)	No. of true leaves	Shoot DM (mg/plant)	Root DM (mg/plant)	Root / Shoot ratio (mg/plant)
CoRHB	8.46	0.16	4.51	4.23	0.10	0.02	0.15
RHB	3.24	0.12	3.62	2.22	0.004	0.007	1.91
LSD *(p<0.05)*	0.490	0.007	0.256	0.297	0.006	0.006	0.277

(n=3). RHB = Rice Husk Biochar, CoRHB = Compost + Rice Husk Biochar (1:1v/v)

Table 4.2.4b: Effect of growing media on the some vegetative properties of tomato before treatment

Growing Media	Plant height (cm)	Stem diameter (mm)	Root length (cm)	No. of true leaves	Shoot DM (mg/plant)	Root DM (mg/plant)	Root / Shoot ratio (mg/plant)
CoRHB	4.70	0.13	3.21	1.46	0.006	0.001	0.26
RHB	4.46	0.13	5.07	1.14	0.005	0.002	0.48
LSD *(p<0.05)*	0.129	0.004	0.177	0.114	0.0007	0.0006	0.140

(n=3) RHB = Rice Husk Biochar, CoRHB = Compost + Rice Husk Biochar (1:1v/v)

4.2.5 Effect of growing media (rice husk biochar and compost amended biochar) on some vegetative properties of tomato and pepper transplants at end of experiment.

Plant height

Plant height of tomato transplant was significantly affected by the growing media and increased progressively during the 21 day period (Table 4.2.5a). At the end of the experimental period, significant difference was observed in the plant height between the final and initial plant heights for the two growing media, as CoRHB recorded 11.3 cm increase as against 4.7 cm for RHB. This represents an increase of 2.4 fold and just over 100% increase over the initial plant heights for the CoRHB and RHB respectively.

Similarly, the plant height of pepper increased progressively during the growing period and was also affected by the growing media. Comparing the final and initial plant heights, it was observed that the CoRHB increased the plant height by 9.2 cm while RHB increased the height by 3.4 cm (Table 4.2.5b) within the experimental period.

Plants grown in CoRHB recorded significantly higher plant heights than in RHB at the end of the experiment (Plate 4.1). At 7 days after treatment, plant height of tomato transplant was 7.61 and 8.07 cm for transplants grown in CoRHB and RHB respectively. After 21 days, the plant height increased to 15.95 and 9.15cm, recording just over 100% increase for CoRHB and 13.4% for RHB during the 14 day period. . Similarly, the plant height for pepper transplants also increased from 14.23 and 5.02

cm in CoRHB and RHB to 17.65 and 6.5 cm respectively, representing an increase of 24% for CoRHB and 29.5% for RHB.

The biochar growth media negatively affected the pepper growth as measured by plant height, dry matter production, chlorophyll content. The leaves of pepper plants grown in the RHB and irrigated with diluted urine showed severe chlorosis similar to NH_4-N toxicity compared to that of CoRHB, although both media received the same diluted urine as N source (Plate 4.2 and 4.3). This result shows that the different media respond differently to the diluted urine and the CoRHB might have buffered the plant against toxicity effects of the urine.

Chlorophyll content

The chlorophyll content of tomato transplant was significantly affected by the growing media. At 7 days after treatment, chlorophyll content of tomato transplant was 8.76 and 4.18 CCI for transplants grown in CoRHB and RHB respectively (Table 4.2.5a). After 21 days, the chlorophyll content increased to 12.69 and 8.30 CCI, recording 45% increase for CoRHB and just over 100 % for RHB during the 14 day period. . Similarly, the plant height for pepper transplants also increased from 8.88 and 6.09 CCI in CoRHB and RHB to 8.40 and 8.08 CCI respectively, representing a decrease of 5.4 % for CoRHB and 24.6% for RHB (Table 4.2.5b). Thus chlorophyll content in RHB was less than in CoRHB during the experiment.

Root Length

Tomato and pepper root length were significantly affected by the growing media. At the end of the experiment, there were significant differences between the initial and final root length of tomato and pepper transplant for both media. Tomato transplants grown in CoRHB and RHB recorded an increase of 10.48 and 6.17 representing an increase of 3.3 and 1.2 folds respectively (Table 4.2.5a). Similarly, pepper transplants also recorded an increase of 6.50 and 6.64 for CoRHB and RHB respectively representing just 100% increase for both media (Table 4.2.5b).

Table 4.2.5a: Effect of growing media on the some vegetative characteristics of tomato transplants after treatment

Days After Treatment	Growing Media	Dry Shoot Mass (mg/plant)	Dry Root Mass (mg/plant)	Chlorophyll Content (CCI)	Plant Height (cm)	Root Length (cm)	Root: Shoot Ratio (mg/plant)
7	CoRHB	0.10	0.05	8.76	7.61	12.35	0.55
	RHB	0.04	0.02	4.18	8.07	9.37	0.61
	LSD *(P< 0.05)*	0.006	0.004	0.364	0.302	0.410	0.109
14	CoRHB	0.30	0.13	11.32	13.28	11.67	0.43
	RHB	0.06	0.03	6.88	7.63	7.32	0.60
	LSD *(P< 0.05)*	0.023	0.017	0.93	0.599	0.342	0.136
21	CoRHB	0.65	0.27	12.69	15.95	13.69	0.41
	RHB	0.14	0.03	8.30	9.15	11.24	0.18
	LSD *(P< 0.05)*	0.014	0.023	0.167	0.148	0.337	0.005

(n=3) RHB = Rice Husk Biochar, CoRHB = Compost + Rice Husk Biochar (1:1v/v)

Table 4.2.5b: Effect of growing media on the vegetative characteristics of pepper transplants after treatment

Days After Treatment	Growing Media	Dry Shoot Mass (mg/plant)	Dry Root Mass (mg/plant)	Chlorophyll Content (CCI)	Plant Height (cm)	Root Length (cm)	Root: Shoot Ratio (mg/plant)
7	CoRHB	0.20	0.46	8.88	14.23	12.06	2.68
	RHB	0.015	0.03	6.09	5.02	10.28	2.53
	LSD *(p<0.05)*	0.013	0.017	0.271	0.232	0.358	0.013
14	CoRHB	0.82	0.33	9.42	17.00	11.88	0.50
	RHB	0.07	0.03	6.66	5.91	9.52	0.55
	LSD *(p<0.05)*	0.008	0.010	0.324	0.258	0.25	0.004
21	CoRHB	0.34	1.16	8. 40	17.65	11.00	5.70
	RHB	0.07	0.14	8.08	6.59	10.26	2.28
	LSD *(p<0.05)*	0.012	0.020	0.102	0.197	0.258	0.038

(n=3) RHB = Rice Husk Biochar, CoRHB = Compost + Rice Husk Biochar (1:1v/v)

Dry shoot weight

The shoot dry weight of tomato transplant was significantly affected by the growing media and increased progressively during the 21 day period (Table 4.2.5a) At the end of the experimental period, significant difference was observed in the shoot dry weight between the final and initial shoot dry weight for the two growing media, as CoRHB recorded 0.64 mg/plant increase as against 0.14 mg/plant for RHB. Similarly, significant difference was observed in the shoot dry weight between the final and initial shoot dry weight of pepper for the two growing media (Table 4.2.5b). CoRHB recorded 0.2 4 mg/plant increase whereas RHB recorded 0.03 mg/plant increase.

Plants grown in CoRHB recorded significantly higher dry shoot weight than in RHB at the end of the experiment. At 7 days after treatment, dry shoot mass of pepper transplant was 2x10 mg/plant and 15x1000 mg/plant for transplants grown in CoRHB and RHB respectively (Table 4.2.5a). After 21 days, the dry shoot weight increased to 3.4 x10 mg/plant and 7x100 mg/plant respectively. Similarly, the dry shoot weight for tomato transplants also increased from 0.10 and 0.04 mg/plant in CoRHB and RHB to 0.65 and 0.14 mg/plant respectively (Table 4.2.5a).

Root to Shoot Ratio

The root to shoot ratio of tomato and pepper transplant was significantly affected by the growing media. Tomato transplants grown in CoRHB recorded an increase of 0.15 mg/plant representing an increase of 57% from the initial root to shoot ratio, whereas RHB recorded a decrease of 0.3 representing a decrease of 63% from the initial root to shoot ratio during the experimental period (Table 4.2.5a). On the other hand, root to shoot ratio of pepper transplant increased progressively during the experimental period. Pepper transplants grown in CoRHB and RHB recorded an increase of 5.55 and 0.37 mg/plant representing an increase of 37% and 19% respectively.

Increases observed in CoRHB were significantly higher than in RHB. RHB had a negative effect on the root to shoot ratio of tomato transplants.

Plate 4.1: Growth of pepper grown in CoRHB and RHB media after 21 days of treatment

4.2.6 Effect of nutrient source on some vegetative parameters of pepper and tomato transplants.

Plant Height

Plant height was significantly affected by the N sources. Generally, plant height of pepper and tomato transplant irrigated with serial dilutions of urine and inorganic N increased progressively during the period. The height of tomato transplant treated with the inorganic N nutrient solution was significantly higher than any of the diluted urine treatments, throughout the experimental period. The height of the diluted urine treatment increased progressively, compared to the control, and DU1:6 was consistently higher than the other diluted urine and the control (water only) treatments. This suggests that the diluted urine contained plant nutrients that promoted the height

growth. Among the diluted urine treatments, the plant height for DU 1:6 was significantly *($p<0.05$)* higher than DU 1:5 and 1:4 (Table 4.2.6a and 4.2.6b).

Chlorophyll Content

The leaf chlorophyll content of tomato transplants increased progressively during the growing period. The In Fert 2 produced the highest leaf chlorophyll content (13.63) at 21 DAT, and was significantly different from the other treatments. On the other hand, the leaf chlorophyll content of tomato produced by DU 1:6 was higher and significantly different from than the other diluted urine treatments, In fert 1, In fert 3 treatments and water only. The chlorophyll content of DU 1:6 was 1.33 fold higher than the water only treatment. Except for the DU 1:6, the chlorophyll content of diluted urine treatments was lower than that produced by the different inorganic N fertilizer solutions.

Shoot dry weight

The shoot dry weight increased progressively during the growing period and the In-fert 2 treatment produced the highest shoot dry weight at 21 DAT, and was significantly different from the other treatments. The shoot dry weight produced by DU 1:6 (0.46 mg/plant) was comparable to that produced by In-fert 1 (0.49 mg/plant) and In-fert 3 (0.42 mg/plant) treatments. The shoot dry weight of DU 1:6 was greater than water only, DU 1:5 and DU 1:4 by 21%, 59% and 84% respectively.

Root length

The root length increased progressively during the growing period, and was significantly affected by the N source. The In-fert 1 treatment produced the longest, while the shortest root length was produced by DU 1:5 treatments at 21 days after treatment (DAT). The root length produced by the diluted urine treatments was significantly lower than that produced by the water only treatment, and the difference was significant. The root length of DU 1:6 was longer than the other diluted urine treatments.

Root: Shoot Ratio

The root to shoot ratio of tomato responded differently to the fertigation treatments. Generally, increasing the N in the inorganic N fertilizer solution increased the root to shoot ratio, and the highest root to shoot ratio was observed in In-fert 3. On the other hand, increasing the urine concentration in the nutrient solution decreased the root to shoot ratio. The DU 1:6 treatment produced the highest root to shoot ratio at 21 DAT among the different diluted urine treatments.

Chlorosis

Chlorosis was observed in both pepper and tomato seedlings (Plate 4.2 and 4.3). Increasing the N content in the urine treatments resulted in chlorosis irrespective of the growing media.

Table 4.2.6a: Effect of nutrient source on some vegetative parameters in tomato plant

Days After Treatment	Nutrient Solution	Dry Shoot Mass (mg/plant)	Dry Root Mass (mg/plant)	Chlorophyll Content (CCI)	Plant Height (cm)	Root Length (cm)	Root: Shoot Ratio (mg/plant)
	DU 1:6	0.09	0.02	8.15	8.48	8.18	0.22
	DU 1:5	0.04	0.03	6.12	7.43	6.57	0.61
	DU 1:4	0.06	0.01	7.72	7.05	7.67	0.31
	In- Fert 1	0.10	0.05	5.85	8.00	12.61	0.55
7	In- Fert 2	0.09	0.06	6.33	8.70	13.58	0.64
	In- Fert 3	0.06	0.03	6.62	8.70	14.12	0.58
	Water	0.03	0.03	4.48	6.50	13.27	1.14
	LSD	0.011	0.008	0.680	0.567	0.767	0.204
	P< 0.05						
	DU 1:6	0.23	0.07	11.18	10.83	7.50	0.37
	DU 1:5	0.14	0.03	8.77	9.30	6.20	0.20
14	DU 1:4	0.15	0.04	9.47	8.24	6.12	0.61
	In- Fert 1	0.24	0.16	8.34	11.70	9.63	0.59
	In- Fert 2	0.22	0.12	11.92	12.36	10.98	0.55
	In- Fert 3	0.17	0.08	8.37	11.92	11.69	0.42
	Water	0.10	0.07	5.68	8.83	14.33	0.85
	LSD	0.043	0.031	1.743	1.120	0.640	0.254
	P< 0.05						
	DU 1:6	0.46	0.09	12.52	12.08	8.78	0.17
	DU 1:5	0.29	0.07	9.78	10.71	6.60	0.15
	DU 1:4	0.25	0.05	9.41	10.25	6.85	0.14
21	In- Fert 1	0.49	0.18	11.33	14.42	18.41	0.27
	In- Fert 2	0.52	0.23	13.63	15.95	14.37	0.40
	In- Fert 3	0.42	0.27	11.39	13.29	16.33	0.58
	Water	0.38	0.18	5.37	11.16	15.92	0.36
	LSD	0.027	0.052	0.312	0.278	0.631	0.009
	P< 0.05						

(n=3)

In-Fert.1 = (30mg N/L), In-Fert 2 = (50mgN/L), In-Fert 3 = (70mgN/L)

DU (1:4) = 1:4 (urine/water) DU (1:5) = 1:5 (urine/water) DU (1:6) = 1:6 (urine/water)

Table 4.2.6b: Effect of nutrient source on some vegetative parameter in pepper plant

Days after treatment	Nutrient Solution	Dry Root Mass (mg/plant)	Dry Shoot Mass (mg/plant)	Chlorophyll Content (CCI)	Plant Height (cm)	Root Length (cm)	Root: Shoot Ratio (mg/plant)
	DU 1:6	0.27	0.08	7.28	9.67	9.27	2.76
	DU 1:5	0.22	0.09	9.15	10.49	7.42	3.48
	DU 1:4	0.22	0.07	6.18	8.66	11.64	2.86
	In-Fert 1	0.21	0.08	6.58	8.93	11.37	2.42
7	In-Fert 2	0.23	0.08	7.03	9.70	9.73	2.95
	In-Fert 3	0.28	0.15	10.00	10.32	14.50	2.68
	Water	0.29	0.23	6.15	9.58	14.25	1.08
	LSD	0.031	0.025	0.508	0.422	0.670	0.012
	P< 0.05						
	DU 1:6	0.48	0.07	4.73	9.73	5.81	0.18
	DU 1:5	0.62	0.22	10.92	13.13	12.79	0.41
	DU 1:4	0.36	0.06	3.44	9.43	5.03	0.31
	In-Fert 1	0.41	0.22	10.46	11.63	13.66	0.57
14	In-Fert 2	0.52	0.10	4.50	10.88	8.84	0.16
	In-Fert 3	0.52	0.20	12.78	13.84	15.74	0.39
	Water	0.22	0.39	9.43	11.52	13.02	1.63
	LSD	0.0167	0.019	0.607	0.482	0.46	0.008
	P< 0.05						
	DU 1:6	0.71	0.07	4.68	10.33	6.52	8.02
	DU 1:5	0.69	0.07	4.57	10.10	6.52	5.49
	DU 1:4	0.42	0.06	4.78	9.33	6.13	5.56
	In-Fert 1	0.67	0.27	10.27	13.11	12.93	2.41
21	In-Fert 2	0.80	0.39	12.07	15.29	13.39	2.18
	In-Fert 3	0.72	0.32	12.55	14.39	14.46	2.13
	Water	0.55	0.27	8.73	12.29	14.46	2.15
	LSD	0.037	0.023	0.191	0.368	0.483	0.071
	P< 0.05						

(n=3)

In-Fert.1 = (30mg N/L), In-Fert 2 = (50mgN/L), In-Fert 3 = (70mgN/L)

DU (1:4) = 1:4 (urine/water) DU (1:5) = 1:5 (urine/water) DU (1:6) = 1:6 (urine/water)

Plate 4.2: Chlorosis in bird eye pepper transplants grown in CoRHB 14 days after treatment

Plate 4.3: Chlorosis in bird eye pepper transplants grown in RHB 14 days after treatment

4.2.7 Interactions effects between growing media and nutrient sources on some vegetative properties of tomato and pepper transplant after treatment

4.2.7.1 Interactions effects between growing media and nutrient sources on some vegetative properties of pepper transplant after treatment

The response of some vegetative plant parts of pepper to growing media and fertilization with N sources differed considerably, and was dependent on specific growing and fertilization regime (Table 4.2.7a). The difference in plant height between tomato plants grown in CoRHB and fertigated with DU 1:6 and DU 1: 4 were significant. However, this was not observed in plants grown in RHB as the difference in plant height grown in RHB and fertigated with DU 1:6 and DU 1: 4 were not significant. Similarly, whereas no significant difference in plant height was observed between plants grown in CoRHB and irrigated with water and In-fert 3, the difference in plant height between pepper plants grown in RHB and fertigated with DU 1:6 and DU 1: 4 was significant.

A growing media and nutrient source interaction were observed for the plant height, chlorophyll content, shoot dry weight, root dry weight and root to shoot dry weight for the pepper transplant. The leaf chlorophyll content of pepper grown in CoRHB and irrigated with water was lower than that of plants fertilized with DU 1:6, DU 1:5 and DU 1:6. However, in the case of plants grown in RHB and irrigated with water, the leaf chlorophyll content was higher than that of DU 1:6, DU 1:5 and DU 1:4.

The shoot dry weight of pepper grown in CoRHB and fertilized with DU 1:6, was significantly different from that fertilized with DU 1:4. However the pepper plants grown in RHB and fertigated with DU 1:6 and DU 1:4 was not significantly different.

There was no significant difference in root length of pepper grown in CoRHB and fertilized with the different inorganic N fertilizer solutions. However significant difference was observed in root length of pepper grown in RHB and fertilized with In-fert 1 and In-fert 3. The difference in the root to shoot ratio of plants grown in CoRHB and fertilized with DU 1:6 and DU 1:4 was not significant. However, the difference between the root to shoot ratio of pepper plants grown in RHB and fertilized with DU 1:6 was significantly different from that of DU: 1:4.

4.2.7.2 Interactions effects between growing media and nutrient sources on some vegetative properties of tomato transplant after treatment

The response of some vegetative plant parts of tomato to growing media and fertilization with N sources differed considerably as was observed for the pepper transplants (Table 4.2.7b). The difference in plant height between tomato plants grown in CoRHB and irrigated with In-Fert 3 and water was not significant. However the difference between tomato plants grown in RHB and fertilized with In-Fert 3 and water was significant. A similar result was observed for the chlorophyll content, as there was no significant difference in the chlorophyll content between tomato plants grown in CoRHB and irrigated with DU 1:6 and DU 1:4. However there was a

significant difference in chlorophyll content of tomato plants grown in RHB and irrigated with DU 1:6 and DU 1:4.

Different responses for root length of tomato were observed for the growing media when irrigated with urine nutrient sources. Root length of plants grown in CoRHB increased progressively whilst those grown in RHB decreased over the sampling period (Fig. 4.1 and 4.2). Furthermore, No significant difference in root length of tomato grown in CoRHB and fertilized with In-Fert 2 and water only was observed. However, the root length grown in RHB and fertilized with In-Fert 2 and water only was significant. Again while the difference in root length of tomato plants grown in RHB and fertilized with DU1:6 and DU 1:5 was not significant, the difference in root length of plants grown in CoRHB and fertilized with DU1:6 and DU 1:5 was significant.

While there was no significant difference in the shoot dry weight of plants grown in CoRHB and fertilized with In-Fert 2 and In-Fert 3, the shoot dry weight of plants grown in RHB and fertilized with In-Fert 2 was higher than that of In-Fert 3 and the difference was significant.

Table 4.2.7a: Interactions effects between growing media and nutrient sources on some vegetative properties of pepper transplant after treatment

Parameter	Growing Media	Urine 1:6	Urine 1:5	Urine 1:4	In-Fert 1	In-Fert 2	In-Fert 3	Water (control)
Plant Height (cm)	CoRHB	16.17	16.03	14.41	18.58	21.97	18.03	18.40
	RHB	4.50	4.17	4.25	7.63	8.67	10.75	6.18
LSD ($p<0.05$)		0.52						
Chlorophyll Content (CCI)	CoRHB	6.13	5.20	5.70	11.13	13.03	13.23	4.33
	RHB	3.23	3.93	3.87	9.40	11.10	11.87	13.13
LSD ($p<0.05$)		0.269						
Root length (cm)	CoRHB	6.70	7.87	7.42	13.45	13.00	13.42	15.18
	RHB	6.33	5.17	4.85	12.41	13.78	15.50	13.75
LSD ($p<0.05$)		0.68						
Dry Shoot Mass (mg/plant)	CoRHB	0.14	0.14	0.07	0.44	0.64	0.47	0.50
	RHB	0.01	0.01	0.04	0.09	0.13	0.18	0.03
LSD ($p<0.05$)		0.032						
Root: Shoot Ratio(mg/plant)	CoRHB	10.04	9.98	10.88	2.58	2.00	2.35	2.05
	RHB	6.00	1.00	0.25	2.23	2.35	1.90	2.25
LSD ($p<0.05$)		0.100						

(n=3)

In-Fert. 1= (30mg N/L), In-Fert 2 = (50mgN/L), In-Fert 3 = (70mgN/L)

DU (1:4) = 1:4 (urine/water) DU (1:5) = 1:5 (urine/water) DU (1:6) = 1:6 (urine/water)

Table 4.2.7b: Interactions effects between growing media and nutrient sources on some vegetative properties of tomato transplant after treatment

Parameter	Growing Media	DU 1:6	DU 1:5	DU 1:4	In-Fert 1	In-Fert 2	In-Fert 3	Water (control)
Plant Height (cm)	CoRHB	15.83	14.50	14.08	18.16	17.98	15.50	15.58
	RHB	8.33	6.91	6.42	10.67	13.91	11.08	6.73
LSD ($p<0.05$)		0.120						
Chlorophyll Content (CCI)	CoRHB	13.50	14.36	13.88	12.67	14.33	10.78	9.27
	RHB	11.53	5.20	4.95	10.00	12.93	12.00	1.48
LSD ($p<0.05$)		0.441						
Root length (cm)	CoRHB	12.57	10.20	10.45	17.22	15.167	14.57	15.67
	RHB	3.25	3.00	4.98	19.60	13.57	18.08	16.17
LSD ($p<0.05$)		0.892						
Dry Shoot Mass (mg/plant)	CoRHB	0.80	0.53	0.48	0.78	0.64	0.64	0.71
	RHB	0.11	0.06	0.02	0.19	0.39	0.20	0.04
LSD ($p<0.05$)		0.038						
Root: Shoot Ratio(mg/plant)	CoRHB	0.21	0.27	0.22	0.45	0.53	0.69	0.48
	RHB	0.12	0.02	0.05	0.10	0.26	0.48	0.24
LSD ($p<0.05$)		0.012						

(n=3)

In-Fert.1 = (30mg N/L), In-Fert 2 = (50mgN/L), In-Fert 3 = (70mgN/L)

DU (1:4) = 1:4 (urine/water) DU (1:5) = 1:5 (urine/water) DU (1:6) = 1:6 (urine/water)

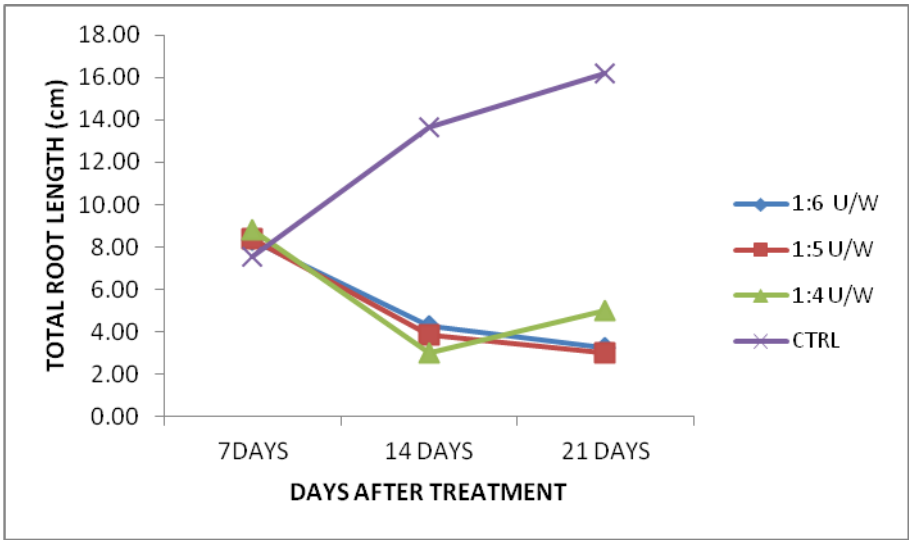

Figure 4.1: Total root length (cm) of tomato transplant grown in RHB as affected by different urine concentrations

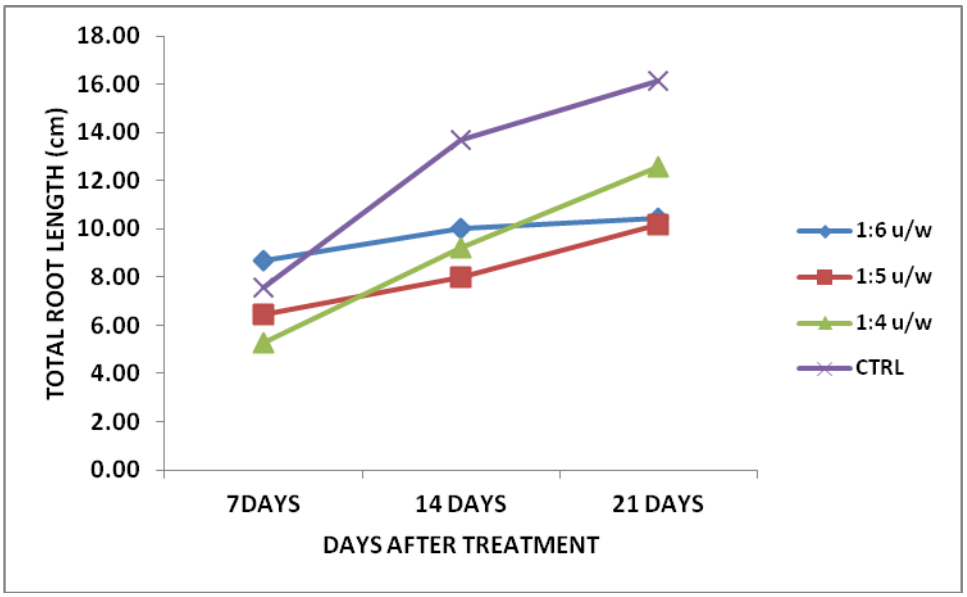

Figure 4.2: Total root length (cm) of tomato transplant grown in CoRHB as affected by different urine fertigation concentration rates

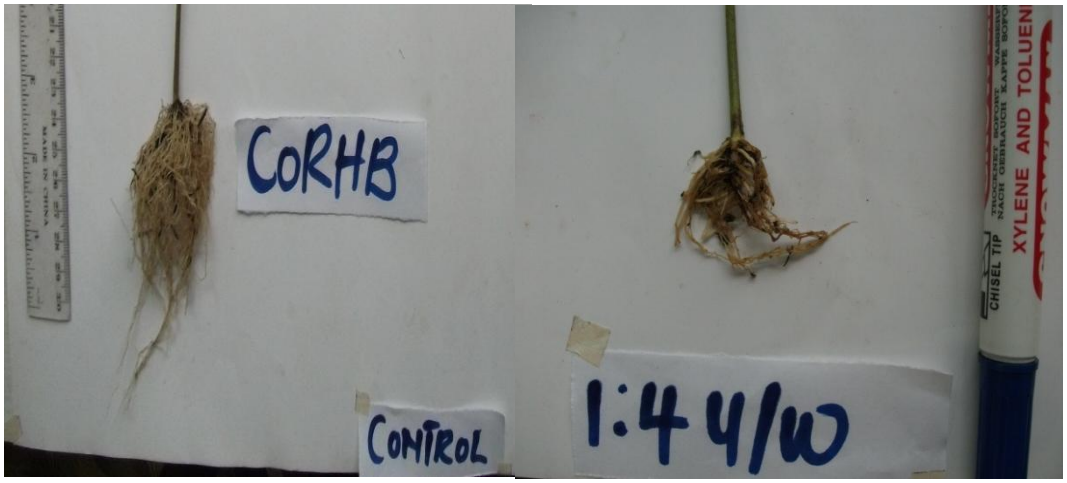

Plate 4.4: Total root length (cm) of tomato transplant grown in CoRHB as affected by different urine fertigation concentration rates

4.3 Evaluation of Compost and Rice Husk Biochar as Growing Media and Human Urine as Nitrogen Source on Growth and Yield Response of Bird Eye Pepper.

4.3.1 Physical and chemical characteristics of growing media before treatment

Physical and chemical parameters of the growing media used in this study are as shown in (Table 4.3.1a and b). Bulk density was highest in media M2 which consisted of one part compost and one part soil (Compost + Soil 1:1v/v) and lowest with media M4 which consisted of one part each of compost and soil and two parts biochar (Soil + Compost + RHB 1:1:2). The relationship was reverse with water holding capacity. M4 recorded the highest value for water holding capacity whilst M2 recorded the lowest. The soil pH was affected by the addition of biochar and compost. Generally, the pH of

the soil increased and was highest in media consisting of one part each of soil, biochar and compost. pH was lowest in media consisting of one part each of biochar and soil. Soil EC also increased only after adding two parts of biochar and two parts of compost to the soil respectively.

Mean values for Total-N was highest in M5 (two parts compost and one part each of soil and biochar) and lowest in M1 (one part each of biochar and soil). NH_4-N and NO_3-N were highest in M4 and M3 (one part each of compost, soil and biochar) respectively (see Table 4.3.1b). The high NO_3-N in M3 maybe as a result of the compost used since after maturity compost contains more NO_3-N than NH_4-N.

Chemical properties of the urine were the same as described in Table 4.3.2. for DU 1:4

Table 4.3.1a: Mean physical properties of growing media before treatment

Parameter	Soil	RHB	Compost	M1	M2	M3	M4	M5
pH (1:5)	5.16± 0.02	9.04 ± 0.05	7.94 ± 0.03	6.55 ± 0.05	8.04 ± 0.03	8.25 ± 0.06	7.88 ± 0.03	7.88 ± 0.06
EC (1:10) mS/cm	0.01 ± 0.00	0.01 ± 0.00	1.73 ± 0.06	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.40 ± 0.00	0.70 ± 0.17
WHC (per gram)	0.38 ± 0.01	2.67 ± 0.03	0.97 ± 0.02	0.63 ± 0.03	0.60 ± 0.02	0.83 ± 0.03	0.92 ± 0.04	0.79 ± 0.00
Bulk Density (g/cm3)	1.55 ± 0.05	0.34 ± 0.00	0.95 ± 0.01	1.10 ± 0.01	1.12 ± 0.02	0.96 ± 0.01	0.91 ± 0.02	0.98 ± 0.02

M1 (Soil + RHB 1:1 v/v), M2 (Soil + Compost 1:1v/v/), M3 (Soil + Compost + RHB 1:1:1 v/v/v), M4 (Soil + Compost + RHB 1:1:2 v/v/v), M5 (Soil + Compost + RHB 1:2:1 v/v/v). RHB- Rice Husk Biochar

Table 4.3.1b: Mean chemical properties of growing media before treatment

Parameters	Soil	RHB	Compost	M1	M2	M3	M4	M5
Total- N (%)	0.81± 0.02	0.99 ± 0.05	1.68 ± 0.04	0.81± 0.00	0.98 ± 0.03	1.08 ± 0.02	1.05 ± 0.05	1.15 ± 0.03
Total- P (%)	0.04 ± 0.01	0.06 ± 0.00	0.32 ± 0.02	0.06 ± 0.01	0.18 ± 0.01	0.27 ± 0.03	0.13 ± 0.00	0.20 ±0.01
Total –K (%)	0.25 ± 0.01	0.48 ± 0.01	1.11 ± 0.00	0.26 ± 0.01	0.48 ± 0.02	0.56 ± 0.02	0.53 ± 0.02	0.68 ± 0.02
NH_4-N ($mgkg^{-1}$)	198.00 ± 2.00	176.39 ± 1.02	212.40 ± 2.40	154.80 ±2.80	190.80 ± 2.40	237.60 ± 1.20	338.40 ± 1.20	205.20 ± 3.60
NO_3-N ($mgkg^{-1}$)	114.50 ± 0.82	172.80 ± 1.60	572.40 ± 5.20	165.58 ± 3.88	315.47 0.23±	342.00 ± 4.00	255.50 ± 2.56	232.30 ± 0.70
Avail. P (%)	0.01± 0.00	0.02 ± 0.00	0.10 ± 0.01	0.01 ± 0.00	0.03 ±0.00	0.03 ±0.01	0.04± 0.00	0.09 ± 0.00

M1 (Soil + RHB 1:1 v/v), M2 (Soil + Compost 1:1v/v/), M3 (Soil + Compost + RHB 1:1:1 v/v/v), M4 (Soil + Compost + RHB 1:1:2 v/v/v), M5 (Soil + Compost + RHB 1:2:1 v/v/v). RHB- Rice Husk Biochar

4.3.2 Effect of nutrient source on some vegetative properties, yield and yield components of bird eye pepper

Chlorophyll Content

The leaf chlorophyll content at flowering was affected by the nutrient source and ranged between 10.42 in water only and 32.70 chlorophyll content index (CCI) in Urine 1(applied once a week) (Table 4.3.2). Increasing the quantity of urine applied to the pepper plant decreased the chlorophyll content, such that the difference between urine applied once and thrice a week was significant. The chlorophyll content of Urine 1 was higher and significantly different from that of inorganic fertilizer N nutrient solution treatment.

Plant Height

The nutrient source affected the plant height at flowering. Urine applied once a week promoted the highest plant height while the lowest was observed at the control. The plant height induced by the Urine 1 was significantly different from the other Urine treatments and the control (Table 4.3.2). .

Fruit Number

The number of fruits per plant was significantly affected by the N source. Fruit number was highest in inorganic treatment and was significantly different from the other treatments (Table 4.3.2). Among the urine treatments, the highest fruit number was observed in plants fertigated with urine applied twice a week, and was significantly different from the other urine treatments and the control. Plants irrigated

with Urine 2(applied twice a week) recorded 2.25 fold increases in fruit number compared with the control (water only) treatment. This represented 95% of the fruit number recorded by the inorganic fertilizer nutrient source.

Fruit weight

Fruit weight was significantly higher in the inorganic treatment (11.44 g) and was significantly different from the other treatments. Among the urine treatments, Urine 1(applied once a week) recorded the heaviest fruit weight and was significantly different from the other urine and the water only treatments.

Yield

The pepper yield was influenced by the nutrient source. The highest pepper yield was produced by the inorganic nutrient treatment, while the lowest yield was observed in the control (water only). The highest pepper yield among the urine treated plants was observed at Urine 1 and represented about 84% of the yield recorded for the inorganic nutrient source treatment. Similarly, the yield of Urine 1 was 2.14 fold greater, while the mean of the urine treatments was just over 2 fold greater than the control. Similarly, the yield at Urine 1 was 4.6% higher than the yield of Urine 3, and the difference was significant. It was observed that when the urine quantity was increased, a corresponding decrease in yield was recorded.

Table 4.3.2: Effect of nutrient source on some vegetative properties, yield and yield components of bird eye pepper.

Nutrient source	Chlorophyll content(CCI)	Plant height(cm)	Fruit number	Fruit weight(g)	Yield(g/plant)
In- Fert	25.78	25.33	41	11.44	521.34
Urine 1	32.70	28.07	36	11.18	436.03
Urine 2	31.67	25.19	39	10.40	431.68
Urine3	31.26	25.79	37	10.34	416.80
Control	10.42	8.60	12	3.45	138.93
LSD($p \leq 0.05$)	0.166	0.131	0.2	0.326	11.791

(n=3)

Urine 1 (applied once a week), Urine 2 (applied twice a week), Urine 3 (applied thrice a week)

4.3.3: Effect of growing media on some vegetative parameters, yield and yield components of bird eye pepper.

Chlorophyll Content

The growth media affected the leaf chlorophyll content taken at flowering. The leaf chlorophyll content ranged between 10.27 (M2, consisting of one part each of soil and compost) and 37.07 (M4, consisting of two parts biochar and one part each of compost and soil) CCI. The chlorophyll content tended to be higher in treatments that contained

higher amounts of biochar (M1,M4) than treatments that contained higher amounts of compost (M2) (Table 4.3.3). The growth media M4 (consisting of one part each of compost and soil and two parts of rice husk biochar) produced the highest leaf chlorophyll content and was significantly higher than in all the other treatments. The lowest leaf chlorophyll content was produced by media M2 (one part each of compost and soil. The chlorophyll content induced by M4 was 2.44 fold richer than the chlorophyll content induced by M2. Increasing biochar content also increased chlorophyll content from 36.81 in M1 (consisting of one part biochar and one part soil) to 42.67 in M4. Furthermore increasing amount of compost in media also increased the chlorophyll content from 12.39 in M2 (consisting of one part compost and one part soil) to 26.19 in M5 (consisting of two parts compost and one part each of soil and biochar). The chlorophyll content seems to be increased when the biochar and compost are mixed together rather than in their individual capacities.

Plant height

The plant height at flowering was affected by the type of growth media and ranged between 13.92 in M2 and 27.32 cm in M4. The difference in the plant height between growth media that contained biochar (M1, M3, M4 and M5) was significantly different from the media that contained soil and compost only as soil amendment. The difference in plant height between M1 which contained the highest amount of biochar was lower than M4 which contained relatively lower amount of biochar. On the other hand, the height at M4 was also higher than the soil and compost only treatment (M2). There seemed to be a synergistic effect on plant height when biochar and compost are

combined in the growing media, as shown by the significant effect on plant height between M4 and M1 or M4 and M2. The synergistic effect is more pronounced when the biochar component is higher than the compost rather than the vice versa, as shown by the significant difference between M4 and M5. In fact, there was a 27% increase in plant height between M4 and M3. This suggests that when the biochar content in the growing media was increased in the presence of compost (M3) relative to M3, the plant height increased, relative to when the content of biochar was relatively lower in the presence of compost. On the other hand, when the percentage of compost was increased in the presence of biochar (M5), the plant height was lower than M4. This suggests that, although there is synergistic effect when the two soil amendments are mixed together, the effect is more significant when the biochar content was higher.

Fruit number

Fruit number was significantly affected by the type of growing media used. Similarly, M4 (consisting of one part each of compost and soil and two parts of rice husk biochar) recorded the highest fruit number (50 fruits / plant) whereas M2 recorded the least number (18 fruits / plant) representing over 100% increase in fruit number. Furthermore, increasing the amount of biochar added also increased fruit number from 31 in M1 (consisting of one part biochar and one part soil) to 50 fruits / plant in M4. Similarly, increasing the amount of compost in the media also increased fruit number from 18 fruits / plant to 42 fruits / plant and M2 and M5 respectively. Equal proportions of biochar, compost and soil also improved the fruit number compared to media consisting of one part soil and one part other amendment.

Fruit weight

The fruit weight also followed a similar trend as observed in fruit number. Fruit weight was significantly higher in M4 and lowest in M2. Furthermore increasing amount of biochar and compost also affected the fruit weight significantly.

Yield

The pepper yield was influenced by the growing media, and the yield ranged between 608.8 g/plant in M4 and 121.05 g/plant in M2 (Table 4.3.3). The highest yield was induced by M4 (consisting of two part biochar) and was 17% and 37% higher than the yield produced by M3 and M5 respectively. Again, the yield of M4 was greater than M2 and M1 by 3.9 fold and 1.5 fold respectively. These results suggest that the relative proportion of the biochar and compost amendments mixed together in the growing media, rather than the composition alone, is most important in promoting yield. The relatively higher percentage of biochar in the presence of compost (M4) seemed to provide the conducive environment in the growing media that gave the highest yield. The highest yield observed in M4 was as a result of improved fruit number and high mean fruit weight.

Table 4.3.3: Effect of growth media on vegetative parameters on yield and yield components of bird eye pepper.

Treatment	Chlorophyll content(CCI)	Plant height(cm)	Fruit number	Fruit weight(g)	Yield(g/plant)
Media					
M1	32.08	24.52	27	7.94	250.63
M2	10.27	13.92	15	6.31	121.05
M3	29.44	26.51	43	10.49	521.06
M4	37.07	27.32	42	12.31	608.83
M5	22.96	20.70	37	9.75	443.22
LSD($p \leq 0.05$)	0.167	0.103	0.4	0.305	10.491

(n=3) Urine 1 (applied once a week), Urine 2 (applied twice a week), Urine 3 (applied thrice a week)

4.3:4: Effect of interactions between growing media and nutrient source on some vegetative parameters, yield and yield components of bird eye pepper

Plant Height

The plant height was also affected by the interaction of the growth media and the nutrient source. Plant height was high when pepper was irrigated with inorganic nutrient solution and grown in media M1 (30.89cm). The height was significantly higher than when the plant was grown in M3 (27.24cm). However, when the growth media M3 was irrigated with Urine 2 (32.85cm) and Urine 3(33.56cm), the plant height was significantly higher than that grown in media M1.

Chlorophyll content

The highest leaf chlorophyll content was recorded in the pepper grown in M1 and fertilized with Urine 1 (46.16), and the lowest was in M2 and fertilized with water only. There were significant interactive effects between the nutrient source and growing media on the leaf chlorophyll content. Whereas the growth media M4 induced the highest chlorophyll content when the pepper was irrigated with In-Fert (inorganic nutrient solution), control, Urine 3 and Urine 2, the growth media M1 and fertigation with Urine 2 interacted to produce the highest chlorophyll content.

Fruit number

The growth media M3 recorded the highest fruit number when the plant was irrigated with Urine 2 and Urine 3 and water only. On the other hand, the highest fruit number was observed in M4 and M5 when the media was irrigated with Urine 1 and In-Fert respectively.

Fruit weight

Similarly, the fruit weight was also induced by specific media and fertigation effects. The heaviest fruit weight was induced in growth media M3 when the plant was irrigated with inorganic nutrient solution. However, the heaviest fruit weight was observed in media M4 when the plant was irrigated with the urine treatments and control (water only).

Yield

The yield of the pepper responded to the different growth media and nutrient sources differently. For example, the yield of pepper grown in the M4 and M3 growth media and fertilized with the inorganic nutrient solution was not significantly different from each other. However the difference in yield between these two growing media when the pepper was fertilized with the different urine treatments was significant. Furthermore, the yield of pepper grown in M3 and fertilized with Urine 3 was significantly higher than that of M4 fertilized with same nutrient solution. However the yield of pepper grown in M4 and fertilized with Urine 2 was significantly higher than the yield of M3 fertilized with the same nutrient solution. Similar observations in the yield differences between M4 and M3 and fertilized with Urine 1 where the yield of M4 was higher than M3 was also observed. The highest pepper yield was recorded in the growth media M4 and fertilized with Urine 1, and this yield was significantly different from the other treatments. Similar differences in the yield components such as fruit number and fruit weight in response to the growth media and fertilized with nutrient solutions were also observed.

Table 4.3.4: Effect of interactions between nutrient source and growing media on some vegetative parameters, yield and yield components of bird eye pepper

N source	Media	Chlorophyll content(CCI)	Plant height(cm)	Fruit number	Fruit weight(g)	Yield(g/plant)
In-Fert	M1	26.44	30.89	23	9.67	225.23
	M2	8.39	12.41	15	6.06	88.81
	M3	25.10	27.24	48	14.55	693.85
	M4	39.33	30.25	56	12.55	698.71
	M5	29.65	25.84	63	14.36	900.10
Urine 1	M1	35.15	31.68	25	7.08	179.45
	M2	20.39	21.75	24	11.37	276.74
	M3	36.09	27.73	43	10.42	448.24
	M4	43.80	33.53	60	15.91	960.59
	M5	28.08	25.66	28	11.12	315.16
Urine 2	M1	46.16	27.15	40	10.05	405.72
	M2	15.38	22.86	22	7.50	162.36
	M3	36.35	32.85	51	11.72	601.44
	M4	43.55	29.45	50	15.53	770.92
	M5	16.90	13.66	30	7.20	217.95
Urine 3	M1	39.49	24.67	34	9.67	332.05
	M2	5.40	9.44	12	4.97	58.00
	M3	37.25	33.56	55	11.83	646.34
	M4	44.00	32.52	35	13.17	460.45
	M5	30.14	28.77	49	12.06	587.18
Control	M1	13.16	8.22	11	3.22	110.68
	M2	1.80	3.15	4	1.66	19.33
	M3	12.42	11.19	18	3.94	215.45
	M4	14.67	10.84	12	4.39	153.48
	M5	10.05	9.59	16	4.02	195.73
LSD($p \leq 0.05$)		0.362	0.234	1.0	0.671	23.271

(n=3) Urine 1 (applied once a week), Urine 2 (applied twice a week), Urine 3 (applied thrice a week) M1 (Soil + RHB 1:1 v/v), M2 (Soil + Compost 1:1v/v/), M3 (Soil + Compost + RHB 1:1:1 v/v/v), M4 (Soil + Compost + RHB 1:1:2 v/v/v), M5 (Soil + Compost + RHB 1:2:1 v/v/v). RHB- Rice Husk Biochar

4.4 Farmer's, Marketer's And Consumer's Perception, Willingness to Use and Use of Human Urine as an Alternative Source for Crop Production.

4.4.1 Farmers

About 77% of the thirty (30) farmers interviewed use chemical fertilisers and 13% do not. Forty seven percent (47%) of farmers have heard of urine as an alternative fertiliser but only 13% of them had actually used it before, whiles 87% of them do not use it at all. Eighteen (18) famers comprising of 60% of the 30 farmers interviewed will be willing to use urine as an alternative fertilizer provided they are educated and trained on how to use it. Furthermore 10% will be willing to use it if the odour and bulkiness of urine can be reduced.

4.4.2 Consumers

About 87% of consumers interviewed were not aware urine is used to fertilize to vegetables. However, 40% of the consumers were willing to consume vegetables fertilized with urine whiles 60% were not willing. Only 33% of them were willing to pay higher prices for urine fertilized vegetables. Ninety percent (90%) of them did not ask what type of fertilizer is used to cultivate the vegetables. Out of the 10% who ask, the willingness of 67% of them to buy vegetables is affected by the type of fertilizer used. A total of 40% of consumers would recommend the use of urine as alternate fertilizer provided the urine is well treated before use

4.4.3 Marketers

Similar to the to consumers, 87% of the marketers were not aware urine is used to cultivate vegetables and so 67% of them were not willing to buy and sell vegetables cultivated with urine. About 93% agreed they would not inform their clients if urine were used to fertilize the crops due to psychological effect and societal influence. Sixty percent (60%) of the marketers interviewed would not recommend the use of urine as fertilizer because it is considered waste, it is not safe and it is not socially acceptable.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Urine Characteristics

The pH value of stored urine observed in this study, 9.30 is within the values reported by Pradhan *et al.,* (2007) (8.6) and (9.1) by Semalulu *et al.,* 2012. During urine storage, urea and urate decomposes which accounts for the high pH value of stored urine (Kirchmann and Pettersson, 1995). The EC for the urine ranged between 19.50 and 20 dS/cm. This result is higher than that recorded by Cofie *et al.,* 2011 and (Mnkeni *et al.,* 2008). The total N recorded in this study was 2.67 gN/l. This value is lower compared to 10.3 gN/l reported by (Cofie *et al.,* 2011), but was close to the value 2.4 gN/l reported by Heinonen-Tanski, *et al.,* (2007) and 2.26 gN/l reported by Semalulu *et al.,* (2012). The low N content in the urine could be due to the relative lower protein and P intake in local diets (Jonsson *et al.,* 2004) of the students, whose urine was used in the study. About 97% of the total nitrogen found in the urine was in the available form (NH_4-N). This confirms earlier reports that between 90–100% of urine N is in the form of either urea or ammonium (Kirchmann and Pettersson, 1995). Total P and K values that ranged between 4.7 to 5 g P/l and 14.7 to 16 g K/l respectively were higher than the reported values 0.20 and 0.21g/l for total P and 0.9 to 1.1g/l for total K (Kirrchmann and Pettersson, 1995). These results suggest that the urine used for this study contained enough available N that could support plant growth.

5.2 Physical and chemical characteristics of rice husk biochar and compost.

The pH of the rice husk biochar observed in this study, 9.09 is quite close to earlier reports by Sokchea *et al.,* (2013) who reported pH of 10.7, but higher than the 7.79 reported by Carter *et al.,* (2013). These differences in the pH could be due to the differences in the temperature used in the biochar preparation. Increasing the temperature during pyrolysis from 310 to 850^{o}C, increased the pH of bargasse biochar from 7.6 to 9.7 (Sohi *et al.,* 2010). The water holding capacity of rice husk biochar in this study was 2.67, while the bulk density was 0.34 mg/cm. This result falls within the bulk density for rice husk biochar value of 0.15 g/cm Nakajima (1986) and 0.84 mg/m3 (Masulili 2010). The differences could be due to the temperature used in the preparation of the biochar. The total P and K observed for the rice husk biochar (0.61 and 0.48 %) for P and K respectively, were higher than the reported values of 0.12 and 0.2% Masulili (2010). However, the P and K values are within the range of 0.2 to73.0 g P/ kg and 1.0 to 58g K /kg reported by Chan and Xu (2009).

The N, P and K concentrations of the compost ranged 1.64% for total N, 0.32% for P and 1.11% total K. These macronutrient values observed in this study compare favorably with the reported values for agricultural waste compost (Ofosu-Budu *et al.,* 2005). Similarly, the pH and the EC of the compost are within the range for matured compost normally used in Ghana (Ofosu-Budu *et al.,* 2005; Adamtey, 2005). The very high available-N (ammonium and nitrate-N) contained in the compost, makes it a suitable soil amendment for raising crops and also at the nursery. Similar values have been reported earlier (Ofosu-Budu *et al.,* 2005). These results obtained from the

biochar and the compost suggests that the growth media could supply nutrients to support the growth of the tomato and pepper transplants.

5.3 Effect of growing media on seed germination and emergence of pepper and tomato transplants

The type of growing media used had an effect on the germination and emergence of pepper and tomato transplants. Germination was faster in RHB than in CoRHB even though percentage emergence was higher in CoRHB. This could be attributed to the differences in the physical and chemical characteristics of the different growth media. The porosity of RHB is high and allows for proper aeration and water retention. This could have affected germination. Furthermore, the addition of compost to the biochar may have inhibited germination due to the high EC content of the compost and possibly the phytotoxicity effects of the compost if not truly matured.

5.4 Evaluation of rice husk biochar and rice husk biochar and compost mixture as growing media for pepper and tomato transplant production.

Generally, CoRHB recorded significant increase in the vegetative parameters monitored in the study. The improved vegetative parameters of tomato and pepper transplants observed in CoRHB could be due to the addition of compost to biochar that supplied nutrients for the growth of the seedlings. The compost and rice husk biochar contained plant nutrients and could have supplied the quantities that the plants needed for growth at that early stage. This observance can be attributed to the physical and chemical characteristics of the media used. Bulk density and water holding capacity were better in RHB than the CoRHB. However, nutrient content in CoRHB was higher

in RHB. Furthermore, the depressive effect of biochar on transplants may be a result of decomposition of biochar during storage or use. This could also induce immobilization of inorganic N (Liang *et al*, 2006) and reduction in ammonification due to adsorption (DeLuca *et al.*, 2006).

Studies have shown that the use of compost alone as potting media have negative effect on plant due to lack of coarse large particles necessary for aeration (Bilderback *et al.*, 2005). According to Nartey (2013) (personal communication), 100% compost used as potting media may not be the best due to the high EC levels, relative high bulk density and reduced water holding capacity of compost. RHB on the other hand have coarser particles which improves aeration especially biochar from wood based feedstock (Sohi *et al.*, 2009). Furthermore, increased number of nitrifying bacteria present in the compost converts N present in the media into nitrate ions which can be taken up by the plants (Morgan, 2003) Increase in yield and dry matter have been observed with the addition of compost to soils (Adamtey 2005; Morgan 2003; Morgan 2005).

5.5 Growth response of tomato and pepper transplants to human urine as N source.

The pH and EC of urine used in this study were high even though EC levels reduced with increasing dilution rate. In this study, plants fertigated with inorganic fertilizer produced higher shoot and root dry matter than the urine treatments. Increasing concentration of urine N resulted in depressive effect on the transplants.

The dry shoot weight, chlorophyll content, plant height and root length of plants which received 0.58g/l (DU 1:6) of urine N, were significantly higher than in plants which received 1.00g/l (DU 1:4) of urine N. Similar findings were observed by Preciado-Rangel *et al.,* (2010). The observed results could be a result of high salinity or ion toxicity (Andriolo *et al.,* 2006) with increasing urine concentration that could have inhibited growth. The total ionic concentration (EC) of a nutrient solution determines the growth, development and production of plants (Steiner, 1961). The ideal EC range for nutrient solutions is between 1.5 to 2.5 dS/m (Samarakoon *et al.,* 2006). However, in this study the EC of nutrients solution was highest in urine with N concentration of 1.00g/l (DU 1:4) with 8.40 dS/cm. This could have caused the retarded growth observed in plants irrigated with higher concentration of N.

Increasing EC of nutrient solutions has been associated with significant decrease in fresh and dry weights of plants (Samarakoon *et al.,* 2006; Miceli *et al.,* 2003; Preciado-Rangel *et al.,* 2010). This may be explained based on the general theories of mineral absorption by plants where some ions are taken up in large quantities and others (especially those present in low quantities) are inhibited (Samarakoon *et al.,*

2006). This imbalance of nutrient absorption may have caused the reduction in plant fresh and dry matter especially with DU 1:4 treatments. The decrease in water uptake is also strongly and linearly correlated to EC (Dalton *et al.*, 1997). This was evident especially in the last week of pepper treatment, where it was observed that absorption of nutrient solution through capillary action was lower than in the previous weeks. Wu *et al.*, (2004) also observed that increasing EC reduced water uptake in different cultivars of tomato but resulted in increase in concentration of total soluble solids and lycopene which are important variable for fruit flavor and quality.

The shoot dry weight of pepper and tomato transplants differed considerably between CoRHB and RHB, when irrigated with water and the different N sources. The increase in the dry weights of plants that received the water only suggests that the plants received nutrients from the media on which they were grown. Furthermore, the significant difference in shoot dry weights between CoRHB and RHB suggest that the CoRHB supplied greater plant nutrients for plant growth. Compost has been reported by several scientists to contain plant nutrients that are released gradually to plants for growth. When mixed with the RHB, there seemed to be a synergistic effect on the growth of the plants.

The increase in growth and dry matter production of the pepper and tomato plants as a result of the supply of the inorganic N and the dilute urine sources, suggest that the urine contained appreciable quantities of N that was available to the plant for growth and dry matter production. Furthermore, the high interactive effect between CoRHB

and the urine solutions, especially DU1:5 suggest complementary effects of the growth media and the urine solution in the growth of the transplants. The relatively lower root dry weight compared to that of the inorganic N solution, suggest that the urine was to some extent toxic to root growth.

Nitrogen (N) is taken up by most plant species in the form of nitrate (NO_3^-) or ammonium (NH_4^+). Plant response to continuous NH_4^+ nutrition is species-dependent. Seedlings are sensitive to high concentrations of NH_4, which causes short and thin stems, reduced fresh and dry weights and a weak root system (Azarmi and Esmaeilpour, 2010). A similar observation was made in this study especially in plants fertigated with 1.00g/l of urine N and also in plants grown in RHB (plate 4.1). In a study by Azarmi and Esmaeilpour, (2010), cucumber plants grown in solution of 75:25 (NO_3^-:$NH_4^{+)}$ had the highest leaf area.

It has also been observed that the use of ammonium as the sole or principal N sources also results in growth and yield reductions (Guo *et al.*, 2002). The current recommendation for soilless culture is that NH_4-N should not exceed 25% of the total-N supply (Sonneveld, 2002). In this study however, NH_4-N is 96.6% of the total-N supply. High concentrations of NH_4 in nutrient solutions leads to NH_4 toxicity which results in effects such as NH_4 induced nutrient deficiency caused by impaired uptake of ions as Ca, K and Mg (Kotsiras *et al.*, 2002; Azarmi and Esmaeilpour, 2010). Ca, K and Mg are immobilized within the roots thus suppressing the uptake leading to impaired growth in plants (Azarmi and Esmaeilpour, 2010; Marschner, 1995).

Furthermore, decreased growth observed in this study maybe as a result of the imbalance in the NH_4: NO_3 ratio. In this study, NH_4: NO_3 ratio was at 98.46: 1.53. A high ratio of NH_4 to NO_3, may lead to the unavailability of NO_3 as an N source and higher demand of carbohydrates channeled for NH_4 assimilation and detoxification (Azarmi and Esmaeilpour, 2010). This observed decrease in the growth of tomato and pepper transplants may also be as a result of reduced water uptake due to high concentration of NH_4 leading to lower water use efficiency and susceptibility of water stress. Therefore, it is recommended that the use of urine as nitrogen source at the seedling or transplant stage, the solution should contain adequate quantities of nitrates.

5.6 Effect of rice husk biochar and compost as growing media and human urine as nutrient source on bird eye pepper

The growth and yields of pepper obtained in this study indicates that urine could be used as a good fertilizer for bird eye pepper and could represent a useful alternative to inorganic fertilizers. It was observed that, urine applied once a week (0.45g N/L) performed better than urine applied twice (0.90 gN/L) and thrice a week (1.35 gN/L), inorganic fertilizer and also the control. Urine 1 recorded 37%, 25%, just over 100% and 5.3 fold increases over inorganic fertilizer, Urine 2, Urine 3 and Control (water).

The observed increases in yields as a result of diluted urine application once or twice per week appeared to be largely related to the ability of the urine to supply nitrogen to the growing plants Mnkeni et al. (2008). This is reflected in the corresponding yield of the urine treated plants to that of the inorganic nutrient solution and control that was applied alongside at every application. The results observed in this study compares

favourably with the earlier reports by other researchers on cabbage, maize, barley, cucumber and tomato (Pradhan *et al.,* 2007; Heinonen-Tanski *et al.,* 2007; Morgan 2003; Guzha *et al.,* 2005; Simmons and Clemens, 2003).

Morgan, (2003) reported that maize yields increased by 5-35 times as a result of urine as the only nutrient source compared to unfertilised control. Pradhan *et al.,* (2009) also reported that urine fertilized plants produced equal amounts of tomato fruits as mineral fertilized plants and 4.2 times more fruits than non-fertilized plants. Nitrogen is required by plants in large quantities and therefore very important to plant growth and development. Nitrogen found in urine is in the ionic form and has been proven to compare well with inorganic fertilizers (Johansson *et al*., 2001; Kirchmann and Pettersson, 1995). This then implies that the nitrogen supplied to the plants irrigated with urine treatments were readily available for their uptake thus transforming into high yields. Furthermore, the addition of other soil amendments such as compost and biochar helps in the uptake of the nutrients in urine. According to Morgan, (2003), the addition of humus to soil increases the number of nitrifying bacteria present in the media which converts the urea and ammonia in urine into nitrate ions which can be taken up by the plants.

From the above, it can be concluded that applying urine twice and thrice a week may be wasteful. In situations where urine availability is a challenged, the use of diluted urine once a week will serve as possible solution.

Significant differences were observed in the vegetative parameters and yield between M2 (consisting of one part each of compost and soil) and M4 (consisting of one part each of soil and compost and two parts of biochar). These differences in the parameters monitored between growth media that contained biochar (M1, M3, M4 and M5) were significant from the media that contained soil and compost only (M2) as soil amendment. The differences in parameter monitored between M1 (one part each of biochar and soil) which contained the highest amount of biochar was lower than M4 which contained relatively lower amount of biochar. On the other hand, these parameter performed better in M4 higher than soil and compost only treatment (M2).

There seemed to be a synergistic effect on these parameters when biochar and compost are combined in the growing media, as shown by the significant effect on plant height between M4 and M1 or M4 and M2. The synergistic effect is more pronounced when the biochar component is higher than the compost rather than the vice versa, as shown by the significant difference between M4 and M5 (consisting of two parts compost and one part each of biochar and soil). In fact, there was a 27% increase in plant height between M4 and M3 (consisting of one part each of biochar, compost and soil). This suggests that when the biochar content in the growing media was increased in the presence of compost relative to M3, the plant height increased. On the other hand, when the percentage of compost was increased in the presence of biochar (M5), the plant height was lower than M4. This suggests that, although there is synergistic effect when the two soil amendments are mixed together, the effect is more significant when the biochar content was higher.

These findings are comparable with results from other researchers (Carter 2013; Zheng *et al.,* 2010; Chan, 2007). A number of factors may account for the relative high increase in M4 over M5, M3 and M1. These factors include; improvement of soil parameters such as soil pH, cation exchange capacity (CEC), water holding capacity, due to the addition of biochar. Researchers have found that improvement of these soil parameters also improved nitrogen use efficiency consequently improving crop productivity (Kimetu *et al.,* 2008) observed a positive yield effects from the addition of biochar and attributed this to the non-nutrient improvement to soil function such as low bulk density, increased water holding capacity and increased aeration. Furthermore, biochar additions have been found to increase the availability of major plant (Glaser *et al.,* 2002; Lehmann *et al.,* 2003). In this study, the improvement of M4 over the other media treatments maybe attributed to a synergy of these factors- available nutrients and improved physical characteristics of soil due to the addition of compost and biochar.

Increase of yields in M4 over M1 may also be related to the accelerated decomposition of soil organic matter due to the addition of biochar Verheijen *et al.*, (2009). This eventually leads to decreased productivity. This may explain why M1, though contained a relatively higher proportion of biochar compared to M4 recorded lower yields. Decreases in yield have also been observed after the addition of biochar. Major *et al.,* (2010), observed a large decrease in overall maize yields in the fourth year.

On the other hand, the addition of compost to the biochar may have decreased the effect of decomposition in M4. According to Kimetu and Lehmann (2010), adding organic matter and biochar together did not result in faster organic matter mineralization rates

The pepper yield was influenced by the growing media. These results suggest that the relative proportion of the biochar and compost amendments mixed together in the growing media, rather than the composition alone, is most important in promoting yield. The relatively higher percentage of biochar in the presence of compost (M4) seemed to provide a conducive environment in the growing media that gave the highest yield.

5.7 Perception, willingness to use and use of human urine as an alternative fertilizer by farmers, consumers and marketers.

The perception analysis revealed that most farmers, marketers and consumers were not aware of urine as an alternative fertilizer for crop production. The interest and willingness of farmers to use urine as a fertilizer is mainly based on the reasons that it will increase productivity and they are educated on its use. 60% and 67% of consumers and marketers interviewed also indicated that they will not sell or consume vegetables grown with urine due to societal influence. However, 40% of the consumers will consume urine fertilized vegetable if only it will not pose any health effect. These results agree to the findings of Cofie *et al.*, 2011 where a study was

conducted to evaluate Perception and willingness of market actors on the use of human urine as a source of fertilizer for vegetables production.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study has shown that urine can be used as an alternative fertilizer in the production of vegetables. This study consisted of three phases, the first phase was to evaluate rice husk biochar and compost amended biochar as growing media and human urine in raising tomato and pepper transplants. From the results, tomato and pepper transplants responded better to urine N concentration of 0.58g/l than to 1g N/L (DU 1:6). Furthermore, tomato and pepper transplants grown in compost amended biochar performed significantly better than in rice husk biochar alone. It can therefore be concluded that, diluted urine at rate 1:6 urine/water and compost amended biochar can be used in raising tomato and pepper transplant.

In the second phase, the study evaluated rice husk biochar, compost and human urine as an N source on some vegetative parameters and yield of bird eye pepper compared to inorganic fertilizer. Amongst the N sources used, inorganic fertilizer recorded the highest yield. However, yields from urine treatments were also comparable. Furthermore, some vegetative parameters such as plant height and chlorophyll content were significantly higher in urine treatment than in inorganic fertilizer.

In the final phase, the perception of farmers, marketers and consumers about human urine as N source for vegetable production, the likelihood of using urine in vegetable

production, and the impression of marketers and consumers in patronizing urine treated vegetables were surveyed. From the results, most respondents did not know about urine reuse in crop production but were willing to use it if; it will improve crop production for farmers and it is safe for consumption with consumers and marketers.

6.2 Recommendation

There is the need for researchers to undertake studies on using urine in composting as N fortifier since urine contains high N content. Furthermore, studies can be undertaken by researchers on the addition of biochar to the composting process as an adsorbent for nutrients.

It was also observed in the greenhouse experiment that there was an imbalance in ammonium and nitrate relationship in urine. It is therefore recommended for researchers to investigate into the dynamics of this relationship. Furthermore farmers and seedling growers interested in the use of urine in crop production will have to adjust this relationship.

Furthermore, extensive studies need to be conducted further on the fertilizer use efficiency (FUE) of urine by agronomist and environmental scientist since urine has the possibility of polluting underground water.

Further studies need to be taken on the nutrient composition of the nutrient solution remained after dipping the trays in it especially nitrate content considering the extent of yellow chlorosis observed in the study

REFERENCES

Adamtey, N. (2005). Evaluation of agricultural and agro-industrial residues for composting for agricultural use in Ghana: A case study in the Kwaebibirim District. *A dissertation submitted to the School of Research and Graduate Studies, Environmental Science Program. University of Ghana, Legon.*

Andriolo, J. L.; Godoi, R. S.; Cogo, C. M.; Bortolotto, O. C.; Luz, G. L. Madaloz, J. C. (2006). Growth and Development of Lettuce Plants at High NH4+:NO3- Ratios in the Nutrient Solution. *Horticultura Brasileira*, Vol.24, No.3, (Jul-Set 2006), pp. 352-355, ISSN 0102-0811.

APHA, AWWA, WEF. (1998). Standard methods for examination of water and wastewater; 20th edition, Washington D.C. pp 5-6.

APHA, AWWA, WPCF. (1995). Standard methods for examination of waste water, 19th edition, New York.

Azarmi, R. and Esmaeilpour, B. (2010). Effect of NO_3 - to NH_4 + ratio on growth, yield and element composition of cucumber (Cucumis sativus L.) *Journal of Food, Agriculture & Environment* Vol.8 (2): 6 0 7 - 6 1 0.

Barmzini, L. and Del Zan, F. (1992). Soil fertility improvement and pollution risks from use of.composts referred to N, P, K, and C balance. *Acta Hort*. 302: 5 1-62.

Better Crops (1998). Production and use of potassium. Vol. 82, No. 3

Biernbaum J. A. and Versluys, B. N. (1998). Water management. *HortTechnology* 8. Online http://google.com/innopac.up.ac.za. Accessed: 23:06:2005

Black, .C.A. (ed) (1965). Methods of soils analysis. *Agronomy* No.9. Part 2 Amer. Soc. Agronomy, Madison, Wisconsin.

Brodowski, S., John, B., Flessa, H., and Amelung, W. (2006). Aggregate occluded black carbon in soil. *Europ J Soil Sci* 57: 539–46.

Brown, R. (2009). Biochar production technology', in Lehmann, J & Joseph, S, Biochar for environmental management: science and technology, Earthscan, United Kingdom: 127–46.

Bugbee, G.J., C.R. Frink and D. Migneault, (1991). Growth of perennials and leaching of heavy metals in media. *Hortic. Sci*., 16: 78-80.

Cantliffe D. J. and Karchi, Z (1992). Performance of crisphead lettuce cultivars on polyethylene mulched , drip irrigated sandy soils in Florida. *Proc. Fla. State Hort. Soc*. 105, 340-342.

Caron, J., More P.H. and Riviere, L.M. (2001). Aeration in growing media containing large particle size. *Acta Hort*., 548: 229-234.

Carter. S., Shackley. S., Sohi. S., Suy . T. B. and Haefele. S. (2013). The Impact of Biochar Application on Soil Properties and Plant Growth of Pot Grown Lettuce (Lactuca sativa) and Cabbage *(Brassica chinensis)*. *Agronomy* 2013 www.mdpi.com/journal/agronomy

Chan, K. Y. and Xu, Z. (2009). Biochar: Nutrient Properties and Their Enhancement. In: Biochar for Environmental Management: Science and Technology (Eds. Lehmann, J. & Joseph, S.), Earthscan.

Chan, K. Y., Van Zwieten, L., Meszaros, I., Downie, A., and Joseph, S. (2007). Agronomic values of greenwaste biochar as a soil amendment. *Australian Journal of Soil Research* 45, 629-634.

Chaney, R. L., Munns,J B., and Cathey, H.M..(1980). Effectiveness of digested sewage sludge compost in supplying nutrients for soilless potting media. *J. Am. SOC. Hort. Sci.* 105: 485-492.

Chen, Y., Inbar, *Y.,* and Hadar, Y. (1988). Composted agricultural wastes as potting media for ornamental plants. *Soil Sci*. 145: 298-303.

Cofie, O. O. and Drechsel, P. (2007) 'Water for food in the cities: The growing paradigm of irrigated (peri)-urban agriculture and its struggle in sub-Saharan Africa', *African Water Journal*, vol 1, no 2, pp23–32

Cofie, O., Amoah, P., Egyir, I., Adamtey, N. and Tettey-lowor F. (2011). Demonstration on the use of urine in urban agriculture. Sustainable Water Management in the City of the Future. *Integrated Project Global Change and Ecosystems*

Cortellini, L., Toderi G., Baldoni, G., and Nassisi, A.. (1996). Effects on the content of organic matter, nitrogen, phosphorus and heavy metals in soil and plants after application of compost and sewage sludge. In: Dalton, F. N., Maggio, A. and Piccinni, G. (1997). Effect of Root Temperature on Plant Response Functions for Tomato: Comparison of Static and Dynamic Salinity Stress Indices. Plant and Soil, Vol. 192, No.2, (May 1997), pp. 307-319, ISSN 0032-079X

De Rijck G. and Schrevens, E. (1998a) Cationic Speciation in Nutrient Solutions as a Function of pH. *Journal of Plant Nutrition*, Vol.21, No.5 pp. 861-870, ISSN. 0190-4167.

De Rijck G. and Schrevens, E. (1999). Anion Speciation in Nutrient Solutions as a Function of pH *Journal of Plant Nutrition*, Vol.22, No.2, pp. 269-279. ISSN 0190-4167.

DeLuca T. H, MacKenzie M. D, Gundale M. J, and Holben W. E. (2006). Wildfire-produced charcoal directly influences nitrogen cycling in ponderosa pine forests. *Soil Sci Soc Am J* 70: 448–53.

Dixon, F. M., Preer, J.T., and Abdi, N. (1995). Metal levels in garden vegetables raised on biosolids amended soil. *Compost Sci. & Util*. 3(2): 55-63.

Duku M. H., Gu, S. and Hagan, E. B. (2011). A comprehensive review of biomass and biofuels potential in Ghana. *Renewable & Sustainable Energy Reviews*; 15(1):404–41.

Dyśko, J., Kaniszewski, S. and Kowalczyk, W. (2008). The Effect of Nutrient Solution pH on Phosphorus Availability in Soilless Culture of Tomato. *Journal of Elementology*, Vol. 13, No.2, (Jun 2008), pp. 189-198, ISSN 1644-2296

Esrey, S.A., Gough, J., Rapaport, D., Sawyer, R., Mayling, S-H., Vargas, J. & Winblad, U., (Eds.) (1998). Ecological Sanitation. Novum Grafiska AB. ISBN 91 586 76 12 0.

FAO (2000). Fertilizers and their use: A pocket guide for extension officers (4th ed). Food and Agriculture organisation of the United Nations international fertilizer industry association, Rome.

FAO (2009). State of the world's forests. Rome, Italy: Food and Agriculture Organisation of the UN, www.fao.org/docrep/012/i0680e/i0680e09.pdf.

Folin, O. & Farmer, J. (2009). A new method for the determination of total nitrogen in urine. Biological Chemistry, 493-501 Dowloaded from www.jbc.org, on October 1, 2012.

Gensch, R., Miso, A., Itchon, Gina. (2011). Urine as Liquid Fertilizer in Agricultural Production in the Philippines A Practical Field Guide. XAVIER UNIVERSITY PRESS ISBN 978-971-9094-11-1 Xavier University

Germer, J., Sauerborn, J. (2006) Exploring the Potentialfor Recycling Nutrients from Waste Water to Enhance Agricultural Productivity - the Example of ValleyView University in Accra, Ghana. Presentation at the Tropentag 2006 - International Research on Food Security, Natural Resource Management and Rural Development. University of Bonn, October 11-13.

Gerson, R. & S. Honma. (1978). Emergence response of the pepper at low soil temperature. Euphytica 27:151-156.

Ghanadistricts.co, (2013). Kwabibirem District. Retrieved from http://kwaebibirem.ghanadistricts.gov.gh/. Accessed on 23rd May, 2013.

Giodano, P. M., Mortvedt, J.T., and Mays, J.T. (1975). Effects of municipal wastes on crop yields and uptake of heavy metals. *J. Environ. Qual*. 4: 393-399.

Glaser, B., Lehmann, J and Zech, W. (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal: A Review. *Biol Fertil Soils*, 35: 219-230.

Glaser, B., Lehmann, J. & Zech, W. (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal - a review. *Biology and Fertility of Soils* 35, 219-230.

Golchin., A., Oades, J.M., Skjemstad, J,O. and Clarke P. (1994). Study of free and occluded particulate organic matter in soils by solid state 13C CP/MAS NMR spectroscopy and scanning electron microscopy. *Austr J Soil Res* 32: 285–309.

Gouin, F. R. (1985). Growth of hardy Chrysanthemums in containers of media amended with composted municipal sewage sludge. *J. Environ. Hort*. 3(2): 53-55.

Granatstein, D., Kruger, C. E., Collins, H., Galinato, S., Garcia-Perez and Yoder, M. J. (2009). Use of biochar from the pyrolysis of waste organic material as a soil amendment: final project report, Centre for Sustaining Agriculture and Natural Resources, Washington hState University, Wenatchee, WA.

Gros T., (2011). Addressing Ghana's agriculture challenges. Retrieved May 8, 2012 http://www.howwemadeitinafrica.com/addressing-ghanas-agriculture-challenges/7663/comment-page-1/

Guzha, E., Nhapi, I. and Rockstrom, J. (2005) An assessment of the effects of human faeces and urine on maize production and water productivity. *Physics and Chemistry of the Earth*, **30**, 840–845.

Heinonen-Tanski, H., Sjöblom, A., Fabritius, H. and Karinen P. (2007). Pure human urine is a good fertiliser for cucumbers. Department of Environmental Sciences, University of Kuopio, P.O. Box 1627,

Hernandez Apaolaza, L., Gasco, A. M., Gasco, J. M. and Guerrero, F. (2005). Reuse of waste materials as growing media for ornamental plants. *Bioresource Technology*, 96, 125 -131.

Hochmuth, G. (1990). Nutrient solution formation for hydroponic (rockwool and NFT) tomatoes in Florida. Univ.FL Coop. Ext. Misc. Pub. SSVEC

Höglund, C. (2001). Evaluation of Microbial Health Risks Associated with the Reuse of Source Separated Human Urine. PhD Thesis, Department of Water and Environmental Microbiology, Swedish Institute of Disease Control, Sweden.

Hussain I., Raschid L., Hanjra M. A., Marikar, F., van der Hoek, W. (2002). Wastewater use in agriculture: Review of impacts and methodological issues in valuing impacts. (With an extended list of bibliographical references). Working Paper 37. Colombo, Sri Lanka: International Water Management Institute

Jeong B. R. (n. d.) The use of plug transplants in Korea- Division of Plant Resources and the Environment, College of Agriculture, Gyeongsang National University, Chinju, Korea 660-701.

Johansson, M., Jönsson, H., Höglund, C., Richert Stintzing, A. and Rodhe, L. (2001) Urine separation–closing the nutrient cycle. Stockholm Water Company. Stockholm, Sweden. Available at: http://www.swedenviro.se/gemensamma_se/documents/ Urinsep_eng.pdf.

Jönsson, H., Richert Stintzing, A., Vinneras, B., & Salomon, E. (2004). Guidelines on the use of urine and faeces in crop production, EcoSanRes Publications Series, Report 2004-2, Sweden..

Joseph, S., Peacocke, C., Lehmann, J and Munroe, P. (2009). Developing a biochar classification and test methods', in Lehmann, J & Joseph, S, Biochar for environmental management: *science and technology*, *Earthscan*, United Kingdom: 107–26.

Kassa, K., Meinzinger, F. and Zewdie, W. (2010) Experiment from the use of urine in Arba Minch, Ethiopia.Sustainable sanitation practice. EcoSan Club.

Kimetu, J. M., Lehmann, J., Ngoze, S. O., Mugendi, D. N., Kinyangi, J. M., Riha, S., Verchot, L., Recha, J. W., and Pell, A. N. (2008). Reversibility of soil productivity decline with organic matter of differing quality along a degradation gradient. *Ecosystems* 11, 726-739.

Kirchmann, H. and Pettersson, S. (1995). Human urine – chemical composition and fertilizer efficiency. *Fertilizer Research* 40:149-154.

Kotsiras, A., Olympios, C. M., Drosopoulos, J. and Passam, H. C. (2002). Effects of nitrogen form and concentration on the distribution of ions within cucumber fruits. *Scientia Horticulturae* 95:175-183.

Krull, E. (2009). Stabilisation of organic carbon in soil through biochar production' in An analysis of greenhouse gas mitigation and carbon sequestration opportunities from rural land use. CSIRO National Research Flagships: Sustainable Agriculture, available at www.csiro.au/files/files/prdz.pdf.

Kuo, S. (1995). Nitrogen and phosphorus availability in groundfish waste and chitin-sludge composts. *Compost Sci. Util.* 3(1): 19-29.

Lehmann J. (2007). Bio-energy in the black concepts and questions. *Front Ecol Environ*; 5(7): 381–387.

Lehmann, J. and Rondon, M. (2006). Bio-Char soil management on highly weathered soils in the humid tropics, in: N. T. Uphoff, et al. (Eds.), Biological Approaches to Sustainable Soil Systems, CRC/Taylor & Francis, Boca Raton FL. pp. 517.

Lehmann, J., da Silva, Jr., J. P., Steiner, C.,Nehls,T., Zech,W. and Glaser, B. (2003) 'Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments', *Plant and Soil*, vol 249, pp343–357

Lehmann, J., Gaunt, J. and Rondon, M., (2006). Bio-char sequestration in terrestrial ecosystems– A review. Mitigation and Adaptation Strategies for Global Change 11(2): 403-427.

Lentner, C., Lentner, C. & Wink, A. (1981). Units of Measurement, Body Fluids, Composition of the Body, Nutrition. Geigy Scientific tables. Ciba-Geigy, Basel, Switzerland.

Leskovar, D.I. and Cantliffe. D.J. (1993). Comparison of plant establishment method, transplant or direct-seeding, on growth and yield of bell pepper. *Journal of the American Society for Horticultural Science* 118:17-22.

Liang, B., Lehmann, J., Solomon, D., Kinyangi, J, Grossman, J, O'Neill, B, Skjemstad, J. O., Thies, J. E., Luizao, F. J., Petersen, J and Neves, E. G. (2006). Black carbon increases cation exchange capacity in soils', *Soil Science Society of America Journal* 70: 1719–30.

Link, C. B., Gouin,F.R., and Shanks, J.B. (1983). Composted sewage sludge and woody ornamental crops. *Acta Hort*. 133: 199-204.

Major, J., Rondon, M., Molina, M., Riha, J.R. and Lehmann, J. (2010). Maize yield and nutrition during 4 years after biocharapplication to a Colombian savanna oxisol. *Plant Soil* (2010) 333:117–128 DOI 10.1007/s11104-010-0327-0

Masulili, A., Hadi W., Utomo Syechfani, M. S. (2010). Rice Husk Biochar for Rice Based Cropping System in Acid Soil 1. The Characteristics of Rice Husk Biochar and Its Influence on the Properties of Acid Sulfate Soils and Rice Growth in West Kalimantan, Indonesia Journal of agricultural science vol 2, No 1

McCall, W. W. (1980). Basic characteristics of media for container-grown plants. College of Tropical Agriculture and Human Resources University of Hawaii. Hawaii Cooperative Extension Service

Miceli, A., Moncada, A and D'Anna, F. (2003). Effect of salt stress in lettuce cultivation. *Acta Horti*, (ISHS). 609:371-375.

Miltner, R.J. and Rankin A.E.T. (1998). Primary nutrients and biotic integrity of rivers and streams. *Freshwater Biology*, 40:145–158

Mkeni, P., Jimenez Cisneros, B., Pasha, M., Austin, L. (2006). Use of Human Excreta from Urine Diversion Toilets in Food Gardens. Agronomical and Health Aspects. Volume 3, Report to the Water Research Commission. WRC Report No 1439/3/06.

Mnkeni, P. N. S., Kutu, F. R. & Muchaonyerwa, P (2008). Evaluation of human urine as a source of nutrients for selected vegetables and maize under tunnel house conditions in the Eastern Cape, South Africa. *Waste Manage. Res*. 2008, 26, 132–139.

More, K. (2006). Response of cabbage (brassica oleracea var capitata) transplant to nitrogen, phosphorus and potassium nutrition. Thesis submitted to Department of plant production and soil science. Faculty of Natural and Agricultural science. University of Pretoria

Morgan, P. (2005). Successful demonstration activities in the use of toilet compost and urine as a source of nutrients for growing crops. Aquamor, Harare.

Morgan, P. (2003). Experiments using urine and humus derived from ecological toilets as a source of nutrients for growing crops. Paper presented at 3rd World Water Forum 16-23 March 2003. Available at: http://aquamor.tripod.com/KYOTO.htm.

Morin A., Bourass, N. and Cattaneo A. (1998). The regulatory of size spectra of algae, protozoa, and invertebrates in streams. NABS Annual Meeting.

Nakajima, (1986). In Milla, O. V. (2010). Effects of Rice Husk Biochar produced under slow pyrolysis on growth of water spinach. International Symposium on environmental behavior and effects of biomass derived charcoal Hangzhou, china Nutrient Solutions for Hydroponic Systems Taiwan.

Nappi. P. and Barberis, R.. (1993). Compost as growing medium: chemical, physical and biological aspects. *Acta Hort*. 342: 249-256.

National Research Council (NRC). (1996). Use of reclaimed water and sludge in food crop production. National Academy Press, Washington, D.C.

Nemali, K. S. and Van Iersel, M. W. (2004). Light Intensity and Fertilizer Concentration: I. Estimating Optimal Fertilizer Concentration from Water-Use Efficiency of Wax Begonia. *HortScience*, Vol.39, No.6, pp. 1287-1292. ISSN 0018-5345

Niwagaba, C. (2007) Human Excreta Treatment Technologies – prerequisites, constraints and performance. Department of Biometry and Engineering Licentiate thesis 005 Uppsala 2007 ISSN 1652-3261

Nkolongo, N.V., Caron, J. Gauthier F. and Yamada, M. (2000). Organic Wastes for Improving Soil Physical Conditions and Enhancing Plant Growth in Container Substrates. In: Nature Farming and Microbial Applications, Hui-lian Xu, James F. Parr and H. Umemura (Eds.). the Haworth Press, Inc., pp: 97-113.

Ofosu –Budu , K. G. (2013). Personal communications. Institute of Agric. Res. College of Agric. and Consumer Sciences.

Ofosu-Budu, G.K., Hogarh, J.N., Fobil, J.N., Quaye, A., Danso, S.K.A. and Carboo, D. (2010) Harmonizing procedures for the evaluation of compost maturity in two compost types in Ghana. *Resources, Conservation and Recycling* 54, 205–209.

Okalebo, J. R., Gathua, K.W. and Woomer, P.J. (2002). *Laboratory methods of soil and plant analysis- A working manual 2nd edition*. TSBF-CIAT and SACRED Africa, Nairobi, Kenya.

Owusu-Bennoah, E., Awadzi, T.W., Boateng, E., Krogh, L., Breuning-Madsen, H. and Borggaard, O.K. (2000).Soil properties of toposequence in the moist semi deciduous forest zone of Ghana. *West African Journal of Applied Ecology* Vol.1:1-10

Powlson, D. S., Gregory, P. J., Whalley, W. R., Quinton, J. N., Hopkins, D. W., Whitmore, A. P., Hirsch, P. R & Goulding, K. W. T (2011). Soil management

in relation to sustainable agriculture and ecosystem services. *Food Policy* 36: S72–87.

Pradhan, K. S., Nerg, A., Sjöblom, A., Holopainen, J., Heinonen-Tanski, H. (2007). Use of Human Urine Fertilizer in Cultivation of Cabbage (Brassica oleracea)––Impacts on Chemical, Microbial, and Flavor Quality *J. Agric. Food Chem.*, 55 (21), 8657- 8663• DOI: 10.1021/jf0717891

Pradhan, S. K., Holopainen, J.K. & Heinonen, T. H. (2009). Stored Human Urine Supplemented with wood ash as fertilizer in tomato *(Solanum lycopersicum)* cultivation and its Impacts on fruit yield and quality. J. Agric. Food Chem 57: 7612-7617.

Preciado-Rangel, P., Torres, A.G., Segura-Castruita, M. A., Fortis-Hernández M., Garcia Hernandez J. L., Rueda-Puente E. O. & Sanchez-Chavez, E. (2010). Evaluation of human urine as a source of nutrients in tomato seedlings production. Faculty of Agriculture and Animal Husbandry (FAZ-UJED) (EORP) University of Sonora. Division of Agricultural Sciences and Management Accountants (ESC) Research Center. Food and Development.

Pynnöne, S. & Tuhkanen, T. (2012). Environmental Impact of Micropollutants Present in Urine 4th International Dry Toilet Conference Department of Chemistry and Bioengineering, Tampere University of Technology

Renner, R. (2007). Rethinking biochar. *Environmental Science and Technology* 41(17): 5932 33.

Richert, A., Gensch, R., Joensson, H., Stenstroem, T. & Dagerskog, L. (2010). Practical Guidance on the Use of Urine in Crop Production*:* EcoSanRes Programme Stockholm Environment Institute Kräftriket 2B, Stockholm, Sweden

Samarakoon, U.C., Weerasinghe, P. A. and Weerakkody, A. P. (2006). Effect of Electrical Conductivity [EC] of the Nutrient Solution on Nutrient Uptake, Growth and Yield of Leaf Lettuce (*Lactuca sativa* L.) in Stationary Culture. *Tropical Agricultural Research*, Vol.18, No. 1, (Jan 2006), pp. 13-21 ISSN 1016.1422.

Semalulu, O., Azuba, M., Makhosi, P. & Lwasa, S. (2012) Potential for Reuse of Human Urine in Peri-Urban Farming, in: A.Bationo (Ed.), Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts, 2011, pp. 651-660. Journal of Agricultural Science and Technology B 2 (2012) 919-933 Earlier title: Journal of Agricultural Science and Technology, ISSN 1939-1250

Silva, J. A., Evensen, C. I., Bowen, R. L., Kirby, R. Tsuji, G. Y. and R. S. Yost (2000). Managing Fertilizer Nutrients to Protect the Environment and Human Health. From: Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture

Simons, J. and Clemens, J. (2003). The use of separated human urine as mineral fertilizers. In: EcoSan – Closing the loop. Proc. of the Second International Symposium on Ecological Sanitation, Incorporating the First IWA Specialist Group Conference on Sustainable Sanitation, 7–11 April 2003, Lubeck, Germany, pp. 595–600.

Simons, J. and Clemens, J. (2004). The use of separated human urine as mineral fertilizer. In C. Werner, V. Avendano, S. Demsat, I. Eicher, L. Hernandez, C. Jung, S. Kraus, I. Lacayo, K. Neupane, A. Rabiega and M. Wafler (eds). Ecosan-Closing the Loop, Proceedings of the 2nd International Symposium on Ecological Sanitation, 7–11 April 2003, Lübeck, Germany, p. 595–600.

Smith, V. H., G. D. Tilman. and Nekola, J. C. (1999). Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems.

Environmental Pollution. Vol. 100, pp. 179-196. <www.elsevier.com/locate/ envpol

Smith, V. H., Joye, S.B. and Howarth R. W. (2006). Eutrophication of freshwater and marine ecosystems. *Limnol. Oceanogr*., 51(1):351–355,.

Sohi, S. P., Krull, E., Lopez-Capel, E. & Bol, R. (2010). Chapter 2–A review of biochar and its use and function in soil. *Advances in Agronomy* 105: 47–82.

Sohi, S., Lopez-Capel, E., Krull, E. & Bol, R. (2009). *Biochar, climate change and soil: A review to guide future research.* CSIRO Land and Water Science Report 05/09.

Soil Survey Staff (1998). Keys to soil Taxonomy. Soil Conservation Service, United States Department of Agriculture. Blacksburg, Virginia, USA, Pocahontas Press, Inc.

Sokchea, H., Borin, K., and Preston, T. R. (2013). Effect of biochar from rice husks (combusted in a downdraft gasifier or a paddy rice dryer) on production of rice fertilized with biodigester effluent or urea. *Livestock Research for Rural Development. Volume 25, Article #4.* Retrieved May 27, 2013, from http://www.lrrd.org/lrrd25/1/sokc25004.html

Sombroek, W., Ruivo, M.L., Fearnside, P.M., Glaser, B. and Lehmann J. (2003). 'Amazonian Dark Earths as carbon stores and sinks', in J. Lehmann, D.C. Kern, B. Glaser and W.I. Woods (eds.), *Amazonian Dark Earths: Origin, Properties, Management*, (pp. 125–139) Dordrecht, Kluwer Academic Publishers.

Sonneveld, C. (2002). Composition of nutrient solutions. In Savvas, D. & Passam, H.C.(eds). Hydroponic production of vegetables and ornamentals. Embryo Publishers Athens, Greece.

Sonneveld, C. and Voogt, W. (2009). Plant Nutrition of Greenhouse Crops, *Springer*, ISBN 9048125316, New York, U. S. A.

Sorgona, A., Abenavoli R. M., Cacco G. and Gelsomino A. (2011). Growth of tomato and zucchini seedlings in orange waste compost media: ph and implication of dose. *Compost Scientic and utilization* Vol 19, No3, 189-196

Sparkes, J and Stoutjesdijk, P (2011), Biochar: implications for agricultural productivity, *ABARES technical report 11.6*, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Steiner, A. A. (1961). A Universal Method for Preparing Nutrient Solutions of a Certain Desired Composition. *Plant and Soil*, Vol.15, No.2, , pp. 134-154, ISBN 0032-079X

Stintzing, A. Richert, Rodhe, L. & Åkerhielm, H. (2001). Human urine as fertiliser of plant nutrients, application technique and environmental effects. Swedish Institute of Agricultural Engineering (JTI): Uppsala, Sweden; JTI-report Lantbruk & Industri 278.

Sullivan, L. P. and Grantham, J. J. (1982). Physiology of the Kidney, 2nd ed.; Lea & Febiger: Philadelphia, PA, p 236.

Taylor, J. M., Sikora,L.J., Tester,C.J.. and Parr, J.F. (1978). Decomposition of sewage sludge compost in soil: 11. Phosphorus and sulfur transfomation. *J. Eviron. Qual.* 2: 84-89

The African Executive (2008). Urine turns pivotal in fighting poverty. Available at Web site http.//www.africanexecutive. com/modulus/magazines/article-print.php?a (Accessed Dec 2012)

Tidåcker, P., Sjöberg, C., Jönsson, H. (2004): The use of sewage fertiliser products on arable land requirements from the farmers' perspective. In: Werner, C., et al.

(editors): "Ecosan - closing the loop" - *Proceedings of the 2nd International Symposium on ecological sanitation*, 7-11 April 2003, Lübeck, Germany, pp.455-462.

Timmons, M. B., Ebeling, J. M., Wheaton, F. W., Summerfelt, S. T. and Vinci, B. J. (2002). Recirculating aquaculture systems. Cayuga Aqua Ventures, ISBN 0-9712646-1-9, Ithaca, NY.

Tomati, U., Galli, E., Buffone E., Rosique, J.C., and Roig, A.. (1993). Composts in floriculture. *Acta Hort*. 342: 175-181.

Trejo-Téllez, L. I., and. Gómez-Merino F. C. (2012). Nutrient Solutions for Hydroponic Systems,Hydr.,ponics - A Standard Methodology for Plant Biological Researches,

Tremblay, N. and Senecal, M. (1988). Nitrogen and potassium in nutrient solution influence seedling growth of four vegetable species. *HortScience* 23, 1018-1020.

Tyson, R. V., Simonne, E. H., Davis, M., Lamb, E. M., White, J. M. & Treadwell, D. D. (2007). Effect of Nutrient Solution, Nitrate-Nitrogen Concentration, and pH on Nitrification Rate in Perlite Medium. *Journal of Plant Nutrition*, Vol.30, No.6, (Jun, 2007), pp. 901-913, ISSN 0190-4167

USDA and USCC (2001). Test Methods for the Examination of Composting and Compost. The United States Department of Agriculture and the United States Composting Council.

USDA. (2001). Soil Quality Test Kit Guide. Natural Resources Conservation Service. Washington, D. C., U. S. A.

Vengadaramana, A.and Jashothan, P.T.J. (2012). Effect of organic fertilizers on the water holding capacity of soil indifferent terrains of Jaffna peninsula in Sri Lanka. J. Nat. Prod. *Plant Resour.*, 2(4): 500 – 503.

Walkley, A. and Black, A.I. (1934). An Examination of the Degtjareff Method for Determining Soil Organic Matter and Proposed Modification of the Chromic Acid Titration Method, *Soil Sci* 37: 29-38

Warren, S.L. and W.C. Fonteno, (1993). Changes in physical and chemical properties of a loamy sand soil when amended with composted poultry litter. *J. Environ. Hort.*, 11: 186-190.

WHO (2000) *Global Water Supply and Sanitation Assessment*. World Health Organization, Geneva.

Wu, M., Buck, J.S. and Kubota, C. (2004). Effect of nutrient solution EC, plant microclimate and clutivars on fruit quality and yield of hydroponic tomatoes (*lycopersicon esculentum*). Controlled Environemnt Agriculture Program (CEAC), Departemnt of Plant Sciences, The University of Arizona, Tucson, AZ, USA.

Wu, M., Buck, J.S. and Kubota, C. (2004). Effect of nutrient solution EC, plant microclimate and clutivars on fruit quality and yield of hydroponic tomatoes (*lycopersicon esculentum*). Controlled Environemnt Agriculture Program (CEAC), Departemnt of Plant Sciences, The University of Arizona, Tucson, AZ, USA. www.yara.com/about/production_sites/production_process_story/production_processes/

Yara International (2013). Yara's various production processes. Retrieved 10 June, *2013* from

Zavalloni, C.; Alberti, G.; Biasiol, S.; Vedove, G.D.; Fornasier, F.; Liu, J.; Peressotti, *A.* (2011). Microbial mineralization of biochar and wheat straw mixture in soil: A short-term study. *Appl. Soil Ecol. 50,* 45–51.

Zheng W., Sharma B. K. and Rajagopalan N. (2010).Using Biochar as a Soil Amendment for Sustainable Agriculture. Illinois Sustainable Technology Center, University of Illinois at Urbana Champaign, Submitted to the Sustainable Agriculture Grant Program, Illinois Department of Agriculture.

APPENDICES

APPENDIX 1: QUESTIONNAIRES

INSTITUTE OF ENVIRONMENT AND SANITATION STUDIES

Questionnaire to ascertain farmer's, marketer's and consumer's perception, willingness to use and use of human urine as a fertilizer source for crop production in Ghana

INTRODUCTION

Urine has large quantities of nutrients contained in it. The release of these nutrients into the environment will lead to pollution of the environment. However these nutrients can be reused in crop production. As part of the partial fulfilment of the requirement for the degree of M. Phil. Environmental Science, I am researching on the reuse of urine in vegetable production in Ghana. It is in view of this that this questionnaire is prepared to help identify problems relating to the perception and willingness to the use of human urine crop production. Your co-operation is therefore highly needed.

Demographic Information

Name …… Age ……..……..…
Sex: (1) Male (2) Female
Occupation……
Marital status: (1) Married (2) Single (3) Divorced (4) Widowed (5) Others……...
Religion (1) Christianity (2) Islamic (3) Traditional (4) Others……..……
Educational Status (1) No Education (2) Primary (3) JHS (4) SHS (5) Diploma and above
Location…….

Farmer's Perception and Willingness to use and Use of urine as an alternative fertilizer

1. Do you use fertilizer on your farm? (1) Yes (2) No (3) Don't Know
2. Which types of fertilizers (1) Organic (2) Inorganic Fertilizer (3) Organic and Inorganic (4) Others.....?
3. Have you heard of urine as an alternative fertilizer? (1) Yes (2) No (3) Don't Know
4. Do you use urine as an alternative fertilizer? (1) Yes (2) No (3) Don't Know. (If No/don't know proceed to question 7)

5. Why do you use urine fertilizer? .....
6. How do you use urine fertilizer? .....
7. Why don't you use urine as a fertilizer? .....
8. Will you be willing to handle urine as an alternative fertilizer? (1) Yes (2) No (3) Don't Know
9. Why.....
10. Do you perceive any risk associated with urine reuse as a fertilizer for crop production? .....
11. Are you aware of any other organic fertilizer apart from urine? (1) Yes (2) No (3) Don't Know
12. Please state.....
13. Which of the following is the main influencing factor in your choice to use urine as a fertilizer (1) Religion (2) Society Hygiene (3) High Nutrient Content (4) Availability of Urine (5) Tribe (6) Others.....
14. Would you patronise an onsite sanitation system where urine is collected separately for crop production. Yes (2) No (3) Don't Know

Marketer's perception and willingness to sell and use urine fertilized vegetables

15. Are you aware that human urine is used to fertilize vegetables? (1) Yes (2) No (3) Don't Know
16. Do you purchase vegetables fertilised with urine (1) Yes (2) No (3) Don't Know
17. Will you be willing to buy vegetables cultivated with urine? (1) Yes (2) No (3) Don't Know
18. Will you be willing to sell vegetables cultivated with urine? (1) Yes (2) No (3) Don't Know
19. Will you be willing to pay higher prices for vegetables fertilised with urine? (1) Yes (2) No (3) Don't Know
20. Will you inform your clients that the vegetables are fertilised with urine? (1) Yes (2) No (3) Don't Know
21. Will you recommend the use of urine as an alternative fertiliser? (1) Yes (2) No (3) Don't Know

22. Why.....

23. Which of the following is the main influencing factor in your choice to use urine as a fertilizer (1) Religion (2) Society (3)Hygiene (4) Public Health (5) Tribe (6) Others.....

24. Would you patronise an onsite sanitation system where urine is collected separately for crop production. Yes (2) No (3) Don't Know

Consumer's perception and willingness to consume urine fertilized vegetables

25. Are you aware that human urine is used to fertilize vegetables? (1) Yes (2) No (3) Don't Know

26. Do you consume vegetables fertilised with urine? (1) Yes (2) No (3) Don't Know

27. Will you be willing to consume vegetables cultivated with urine? (1) Yes (2) No (3) Don't Know

28. Will you be willing to pay higher prices for vegetables fertilised with urine? (1) Yes (2) No (3) Don't Know

29. Will you recommend the use of urine as an alternative fertiliser? (1) Yes (2) No (3) Don't Know

30. Why.....

31. Which of the following is the main influencing factor in your choice to use urine as a fertilizer (1) Religion (2) Society (3) Hygiene (4) Public Health (5) Tribe (6) Others.....?

32. Would you patronise an onsite sanitation system where urine is collected separately for crop production. Yes (2) No (3) Don't Know

33. Any other comment? .....

Selfish

Thank you for your co-operation

APPENDIX 2: Effect of Media and Nutrient Solution Interaction on Root and Other Growth Characteristics of Tomato

Parameters	Media	Nutrient Solutions						
		7 DAYS AFTER TREATMENT						
		1:6 U/W	1:5 U/W	1:4 U/W	30mg N/L	50mg N/L	70mg N/L	CTRL
Dry Root Mass (mg/plant)	CORHB	0.03	0.04	0.02	0.08	0.07	0.05	0.04
	RHB	0.01	0.01	0.01	0.02	0.04	0.02	0.02
	LSD P< 0.05	0.012						
Fresh Root Mass (mg/plant)	CORHB	0.57	0.33	0.49	1.04	0.76	0.76	0.52
	RHB	0.30	0.12	0.07	0.17	0.34	0.31	0.14
	LSD P< 0.05	0.075						
Root Length (cm)	CORHB	10.20	8.63	11.13	13.45	13.58	15.45	13.97
	RHB	6.17	4.50	4.22	11.77	13.58	12.78	12.58
	LSD P< 0.05	1.085						
Root/Shoot Ratio (mg/plant)	CORHB	0.25	0.56	0.18	0.49	0.75	0.50	1.11
	RHB	0.19	0.67	0.44	0.62	0.53	0.67	1.17
	LSD P< 0.05	0.289						
	14 DAYS AFTER TREATMENT							
Dry Root Mass (mg/plant)	CORHB	0.12	0.04	0.06	0.27	0.13	0.13	0.13
	RHB	0.01	0.01	0.01	0.04	0.10	0.02	0.01
	LSD P< 0.05	0.044						
Fresh Root Mass (mg/plant)	CORHB	1.13	0.55	0.83	2.33	1.28	1.60	1.32
	RHB	0.18	0.11	0.05	0.47	0.33	0.43	0.15
	LSD P< 0.05	0.352						
Root Length (cm)	CORHB	10.40	8.57	9.23	11.00	13.70	13.77	15.00
	RHB	4.60	3.83	3.00	8.25	8.27	9.61	13.67
	LSD P< 0.05	0.905						
Root/Shoot Ratio (mg/plant)	CORHB	0.30	0.21	0.22	0.59	0.45	0.54	0.70
	RHB	0.45	0.18	1.00	0.59	0.66	0.30	1.00
	LSD P< 0.05	0.359						
	21 DAYS AFTER TREATMENT							
Dry Root Mass (mg/plant)	CORHB	0.16	0.14	0.11	0.34	0.35	0.44	0.35
	RHB	0.01	0.00	0.00	0.02	0.10	0.10	0.01
	LSD P< 0.05	0.073						
Fresh Root Mass (mg/plant)	CORHB	1.17	1.81	1.25	5.16	4.15	3.76	4.11
	RHB	0.31	0.50	0.06	0.91	2.07	1.37	0.36
	LSD P< 0.05	0.218						
Root Length (cm)	CORHB	12.57	10.20	10.45	17.22	15.17	14.57	15.67
	RHB	3.25	3.00	4.98	19.60	13.57	18.08	16.17
	LSD P< 0.05	0.892						
Root/Shoot Ratio (mg/plant)	CORHB	0.21	0.27	0.22	0.45	0.54	0.69	0.48
	RHB	0.12	0.02	0.05	0.10	0.26	0.48	0.24
	LSD P< 0.05	0.013						

APPENDIX 3: Effect of Media and Nutrient Solution Interaction on Shoot Characteristics of Pepper Transplants

Parameters	Media	Nutrient Solutions						
	7 DAYS AFTER TREATMENT							
		1:6 U/W	1:5 U/W	1:4 U/W	30mg N/L	50mg N/L	70mg N/L	CTRL
Fresh shoot Mass (mg/plant)	CORHB	4.32	2.99	3.35	2.79	3.67	3.86	3.77
	RHB	0.34	0.58	0.31	0.35	0.34	0.61	0.22
	LSD P< 0.05	0.479						
Dry Shoot Mass (mg/plant)	CORHB	0.14	0.15	0.12	0.15	0.14	0.27	0.44
	RHB	0.01	0.02	0.01	0.02	0.01	0.02	0.02
	LSD P< 0.05	0.035						
Chlorophyll Content (CCI)	CORHB	8.43	9.67	8.30	8.77	8.83	9.53	8.63
	RHB	6.13	8.63	4.07	4.40	5.23	10.47	3.67
	LSD P< 0.05	0.718						
Plant Height (cm)	CORHB	14.75	13.18	13.42	12.87	14.98	15.22	15.17
	RHB	4.58	7.80	3.90	5.00	4.42	5.42	4.00
	LSD P< 0.05	0.597						
Leaves (No.)	CORHB	9.17	9.17	3.17	7.00	10.50	11.33	10.00
	RHB	3.50	4.67	3.00	3.83	4.50	4.83	3.17
	LSD P< 0.05	0.885						
Stem Diameter (mm)	CORHB	0.20	0.25	0.24	0.24	0.27	0.27	0.26
	RHB	0.12	0.15	0.12	0.12	0.13	0.14	0.12
	LSD P< 0.05	0.020						
	14 DAYS AFTER TREATMENT							
Fresh shoot Mass (mg/plant)	CORHB	6.06	5.84	5.29	3.96	6.92	5.34	4.41
	RHB	0.37	1.04	0.20	0.77	0.54	1.27	0.39
	LSD P< 0.05	0.25						
Dry Shoot Mass (mg/plant)	CORHB	0.92	1.20	0.69	0.75	0.98	0.88	0.42
	RHB	0.04	0.13	0.02	0.08	0.06	0.16	0.02
	LSD P< 0.05	0.022						
Chlorophyll Content (CCI)	CORHB	6.67	12.63	4.77	10.48	4.37	12.67	14.37
	RHB	2.80	9.20	2.12	10.43	4.63	12.90	4.50
	LSD P< 0.05	0.858						
Plant Height (cm)	CORHB	14.88	15.00	19.50	16.38	16.63	19.50	17.08
	RHB	4.58	3.87	6.77	6.87	5.12	8.18	5.95
	LSD P< 0.05	0.681						
Leaves (No.)	CORHB	15.17	13.83	13.00	9.00	9.00	10.83	10.17

	RHB	3.67	7.00	1.83	6.33	4.50	7.83	3.83
	LSD P< 0.05	0.741						
Stem Diameter (mm)	CORHB	0.28	0.31	0.27	0.27	0.29	0.29	0.34
	RHB	0.135	0.17	0.18	0.15	0.13	0.18	0.13
	LSD P< 0.05	0.020						
	21 DAYS AFTER TREATMENT							
Fresh shoot Mass (mg/plant)	CORHB	13.12	6.66	4.88	5.46	6.25	5.55	4.94
	RHB	0.42	0.61	0.28	1.29	1.68	2.08	0.52
	LSD P< 0.05	0.299						
Dry Shoot Mass (mg/plant)	CORHB	0.14	0.14	0.08	0.45	0.64	0.47	0.50
	RHB	0.01	0.01	0.04	0.09	0.13	0.18	0.03
	LSD P< 0.05	0.033						
Chlorophyll Content (CCI)	CORHB	6.13	5.20	5.70	11.13	13.03	13.23	4.33
	RHB	3.23	3.93	3.87	9.40	11.10	11.87	13.13
	LSD P< 0.05	0.270						
Plant Height (cm)	CORHB	16.17	16.03	14.42	18.58	21.92	18.03	18.40
	RHB	4.50	4.17	4.25	7.63	8.67	10.75	6.18
	LSD P< 0.05	0.520						
Leaves (No.)	CORHB	14.50	13.67	5.67	11.67	13.67	13.33	10.00
	RHB	2.33	3.67	8.67	8.67	11.33	8.33	4.33
	LSD P< 0.05	0.741						
Stem Diameter (mm)	CORHB	0.25	0.32	0.26	0.32	0.32	0.30	0.31
	RHB	0.14	0.14	0.14	0.17	0.20	0.21	0.14
	LSD P< 0.05	0.022						

APPENDIX 4: Effect of Media and Nutrient solution Interaction on root characteristics of pepper transplants

Parameters	Media	Nutrient Solutions						
		7 DAYS AFTER TREATMENT						
		1:6 U/W	1:5 U/W	1:4 U/W	30mg N/L	50mg N/L	70mg N/L	CTRL
Dry Root Mass (mg/plant)	CORHB	0.5167	0.3800	0.4167	0.3967	0.4233	0.5100	0.5600
	RHB	0.0233	0.0633	0.0233	0.0300	0.0300	0.0533	0.0133
	LSD P< 0.05	0.04425						
Fresh Root Mass (mg/plant)	CORHB	1.313	1.710	0.913	1.820	1.140	2.280	3.530
	RHB	0.167	0.337	0.420	0.353	0.167	0.217	0.337
	LSD P< 0.05	0.3066						
Root Length (cm)	CORHB	9.000	12.033	9.033	11.300	8.950	18.150	15.933
	RHB	9.533	11.250	5.800	11.433	10.500	10.850	12.567
	LSD P< 0.05	0.9469						
Root/Shoot Ratio (mg/plant)	CORHB	3.7000	2.6033	3.3967	2.6500	3.2300	1.8667	1.3000
	RHB	1.8267	4.3600	2.3300	2.1800	2.6733	3.5000	0.8500
	LSD P< 0.05	0.03394						
	14 DAYS AFTER TREATMENT							
Dry Root Mass (mg/plant)	CORHB	0.1200	0.3967	0.1133	0.3833	0.1800	0.3300	0.7567
	RHB	0.0100	0.0600	0.0100	0.0500	0.0100	0.0633	0.0300
	LSD P< 0.05	0.02632						
Fresh Root Mass (mg/plant)	CORHB	1.510	4.530	1.273	3.224	1.287	5.100	4.597
	RHB	0.073	0.633	0.047	0.690	0.440	0.737	0.230
	LSD P< 0.05	0.1535						
Root Length (cm)	CORHB	6.867	13.967	6.833	13.550	9.700	15.933	16.283
	RHB	4.750	11.617	3.217	13.767	7.983	15.547	9.750
	LSD P< 0.05	0.6537						
Root/Shoot Ratio (mg/plant)	CORHB	0.1300	0.3600	0.1633	0.5067	0.1867	0.3867	1.7667
	RHB	0.2333	0.4500	0.4467	0.6400	0.1633	0.4000	1.5000
	LSD P< 0.05	0.01154						
	21 DAYS AFTER TREATMENT							
Dry Root Mass (mg/plant)	CORHB	1.3533	1.3633	0.8300	1.1500	1.2800	1.0967	1.0200
	RHB	0.0600	0.0100	0.0100	0.1933	0.3133	0.3333	0.0733
	LSD P< 0.05	0.05257						
Fresh Root Mass (mg/plant)	CORHB	1.517	1.397	0.777	5.020	5.650	4.263	4.933
	RHB	0.070	0.100	0.100	1.093	1.380	1.753	0.350
	LSD P< 0.05	0.1576						
Root Length (cm)	CORHB	6.700	7.867	7.417	13.450	13.000	13.417	15.167
	RHB	6.333	5.167	4.850	12.417	13.783	15.500	13.750
	LSD P< 0.05	0.6837						

Root/Shoot Ratio (mg/plant)	CORHB	10.0400	9.9833	10.8767	2.5867	2.0000	2.3567	2.0500
	RHB	6.0000	1.0000	0.2500	2.2333	2.3567	1.8967	2.2533
	LSD P< 0.05	0.10042						