EVALUATION OF MAIZE AND RICE RESPONSE TO APPLICATION OF URBAN GREEN BIOWASTE COMPOST AT DAKAWA IN MOROGORO REGION

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EXTENDED ABSTRACT

Maize and rice are the primary staple cereal food crops in Tanzania, ranking first and second, respectively. The two crops are also used as cash crops in some parts of the country. Despite their importance as food and cash crops, their yields per unit area are generally very low. Recently yield of maize has been noted to be 1.4 t ha^{-1} while the potential yield is 5 t ha^{-1} and rice yield averages between 0.5-2 t ha^{-1} for upland ecologies and 4.5-6.0 t ha^{-1} for irrigated ecologies compared to the potential yield of 5 t ha^{-1} and 10-11 t ha^{-1} respectively. There are many factors causing such low yields, but soil nutrient depletion ranks high. A study was carried out from August 2018 to June 2019 to assess the response of maize and rice to applied urban green biowaste compost (UGBC). The study included laboratory soil and biowaste compost analysis, pot experiment and field trial.

Results for soil analysis indicated that Dakawa soil is sandy clay loam with a near neutral pH of 7.27, low organic carbon (0.63 %) and very low total N (0.01%). The soil had high levels of extractable phosphorus and sulphur which were 27.81 and 27.93 mg kg^{-1}, respectively. The CEC of the soil was very low with a value of 4.2 $Cmol_c$ kg^{-1}. The levels of Fe, Cu and Mn were 62.7, 1.59, and 30.98 mg kg^{-1}, respectively. These values were above the established critical ranges; this means that the soil had sufficient Fe, Cu and Mn. The level of Zn was 0.9 mg kg^{-1}. This level of Zn was lower than the critical range indicating possible Zn deficiency of the soil. On the other hand, results urban green biowastes compost (UGBC) revealed that UGBC had a high pH of 9.52, very high organic carbon with 17.37 % value. Total N was 1.0 % which was below the established typical composition of N in urban compost. The C:N ratio was 17.37 implying that UGBC was suitable for soil application. The level of P and K in UGBC were 0.43 and 2.15 %, considered sufficient. The concentrations of micronutrients (Zn, Fe, Mn and Cu) were

139, 4956, 387, 8 mg kg^{-1}, respectively which were all below the established critical concentrations in urban biowaste compost. The concentrations of heavy metals (Cr, Ni, As and Pb) in UGBC were 126, 11, 9 and 9 mg kg^{-1}, respectively. These levels of Cr, Ni, As and Pb were below the maximum acceptable limit of these elements in compost set by Japan, Australia and United states. This implies that, these materials qualify for soil application. Based on these findings, the present study concluded that Dakawa soils have pH which is suitable for maize and rice production. The UGBC materials can be used as organic fertilizer subject to fortification with N, Zn, Cu, Fe and Mn nutrients.

Results from pot experiment indicated that use of pelletized urban green biowaste compost (PUGBC) from 0 to 600 mg N kg^{-1} soil increased plant heights from 59.19 to 82.52 cm for maize and from 80.43 to 84.87 cm for rice. Maize dry matter yield increased from 3.8 to 8.77 g pot^{-1} and rice grain weight increased from 14.84 to 26.19 g pot^{-1}. The increase in all cases was statistically significant (P=0.05). However, the highest maize and rice plant heights of 92.61cm and 100.43 cm, respectively and maize dry matter yield of 14.46 g pot^{-1} were recorded in combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil. Maximum number of effective tillers (9.62), number of panicles per plant (9.62), panicle length (21.8 cm), panicle weight (2.982 g) and grains weight per pot (85.17 g) for rice crop were registered in sole application of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil). Results of non-pelletized urban green biowaste compost (NPUGBC) followed the same trend as those of PUGBC for both maize and rice crops. The overall results indicated that use of combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) or 300 mg N (NPUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) improved maize growth and yield parameters. The use of inorganic fertilizer alone (600 mg N (UREA) kg^{-1} soil) improved rice growth parameters and yield. Based on these findings it was recommended that the use of combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) or 300 mg N

(NPUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) is the best option for better maize yield and use of inorganic fertilizer alone (600 mg N (UREA) kg^{-1} soil) is the best option for rice production. However, these results required verification in the field.

Results from field trial indicated that rice crop had a maximum plant height (99.23 cm), number of effective tillers per hill (17.07) and chlorophyll content (51.72) were obtained in a combined fertilization of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} treatment. It was followed by sole application of 150 kg N (UREA) ha^{-1} with values of 96.57 cm, 16.57 and 49.17 for plant height, effective tillers per hill and chlorophyll content, respectively. The significant (P=0.05) lowest values for plant height (88.89 cm), effective tillers per hill (11.67) and chlorophyll content (46.95) were observed in the control (0 kg N ha^{-1}). The significant highest grain yield of 8127 kg ha^{-1} equivalent to 8.13 t ha^{-1} was produced in the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}). This yield was approaching the potential yield of rice (10 to 11 t ha^{-1}) under irrigation ecology in Tanzania. It was followed by 150 kg N (UREA) ha^{-1} treatment (7751 kg) and the third treatment was 150 kg N (UGBC) ha^{-1} (6867 kg). The minimum yield was recorded in the control treatment (5594 kg). The four treatments exhibited significant difference (P=0.05) from each other for grain yield. The same trend of results was observed for maize crop whereby the use of integrated fertilization of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} produced the highest maize grain yield of 8691 kg ha^{-1} equivalent to 8.69 t ha^{-1}. This yield was far above the potential yield of maize (5 t ha^{-1}) in Tanzania. The present study therefore concluded that the integrated use of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} is the best treatment for rice production while the integrated use of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} is the best treatment for maize production. Thus, farmers are recommended to use 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} for best growth performance and high yield of rice and use of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} for best growth performance and high yield of maize.

DECLARATION

I, Ibrahim Kusekwa Mangu Paul, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted for a degree award in any other institution.

Ibrahim Kusekwa Mangu Paul (MSc. Candidate) — Date

The declaration above is confirmed by;

Professor E. M. Marwa (Supervisor) — Date

Professor J. J. Msaky (Supervisor) — Date

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LIST OF SYMBOLS AND ABBREVIATIONS

<	Less than
>	Greater than
%	Percent
AAS	Atomic absorption spectrophotometer
Al	Aluminium
ANOVA	Analysis of variance
As	Arsenic
BNF	Biological nitrogen fixation
C	Carbon
Ca	Calcium
CEC	Cation exchange capacity
Cl	Chlorine
cm	Centimeter
Cmolc kg^{-1}	Centimole cation per kilogram
Cr	Chromium
Cu	Copper
CV	Coefficient of variance
DAE	Day after emergence
DAT	Day after transplanting
DMY	Dry matter yield
DTMA	Drought Tolerance Maize for Africa
DTPA	Diethylenetriamine pentaacetic acid
e.g	For example
EC	Electrical conductivity
ESP	Exchangeable sodium percent

et al	And others
FAO	Food and Agriculture Organization
Fe	Iron
g	Gram
ha	Hectare
HSD	Honestly significant different
ISFM	Integrated soil fertility management
K	Potassium
KCl	Potassium chloride
kg	kilogram
LSD	Least significance difference
m	Metre
m.a.s.l	Metres above sea level
MAFAP	Monitoring African Food and Agricultural Policies
MAFC	Ministry of Agriculture, Food and Cooperative
mcf	Final grain moisture content
mci	Initial grain moisture content
Mg	Magnesium
Mn	Manganese
MOP	Muriate of Potash
MSc	Master of Science
MSW	Municipal solid waste
N	Nitrogen
Na	Sodium
Ni	Nickel
NPUGBC	Non pelletized urban green biowaste compost
ns	Non- significance

OC	Organic carbon
P	Phosphorous
P=0.05	Probability level at 0.05
PASS	Private agricultural sector support
Pb	Lead
pH	Negative logarithm of hydrogen ion concentration
PUGBC	Pelletized urban green biowaste compost
RCBD	Randomized Complete Block Design
S	Sulphur
SSA	Sub Saharan Africa
SUA	Sokoine University of Agriculture
t	Ton
t ha^{-1}	Ton per hectare
TARI	Tanzania Agricultural Research Institute
TSP	Triple super phosphate
TXD	Tanzania cross Dakawa
UGBC	Urban green biowaste compost
USA	United States of America
USDA	United States Department of Agriculture
Viz	Such as
wf	Final grain weight
wi	Initial grain weight
Zn	Zinc

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Importance of maize and rice in Tanzania

Maize and rice are the largest and most preferred food and cash crops in Tanzania. Nearly 90 % of the production of these two cereal crops is done by small-scale farmers, with an average farm size ranging from 0.5 to 2 ha (Mtengeti *et al.*, 2015).

Maize crop is grown in nearly all agro-ecological zones of Tanzania. Tanzania produces mainly white maize, which is considered the most important food crop, covering 45 % of total arable land and generating close to 50 % of rural cash income, an average of 100 USD per maize producing household in 2008 (MAFAP, 2013, Lyimo *et al.*, 2014). Maize constitutes 75 % of the cereals consumed and 31 % of the total food production in the country (Mtengeti *et al.*, 2015). In general, the consumption of maize averages approximately 74.5 kg/ person/year (DTMA, 2014; Mtengeti *et al.*, 2015).

Tanzania is the second-largest rice producer in Eastern, Southern and Central Africa. Rice accounts for 13 % of all cereals produced and is the second most important grain consumed in the country, with per capita consumption of rice increasing from about 14.5 kg/person/year in 1999 to approximately 16.5 kg/person/year in 2010 (Mtengeti *et al.*, 2015).

1.2 Sustainable production of maize and rice in Tanzania

The cultivated areas of maize and rice in Tanzania and overall productivity by the year 2010 were 3 000 000 ha with 1.5 t ha^{-1} yield and 1 000 000 ha with 2.3 t ha^{-1} yield, respectively (MAFC, 2010). This level of productivity could meet the demand of the two crops for 45 million people population of that time. It is however, expected that the human population in the country will increase to 82 million by 2030 and reach 138 million by 2050 (Mtengeti *et al.*, 2015). If it is assumed that there will be no diet changes and that it is projected that undernourishment will be reduced by half by 2030 and eliminated altogether by 2050 (based on the 2010 maize productivity), areas of maize cultivation should be expanded to approximately 6.38 million ha in 2030 and 12 million ha in 2050 (Van Ittersum *et al.*, 2016). If, however, maize productivity is increased to 5 t ha^{-1}, the required land will be 1.98 million ha in 2030 and 3.74 million ha in 2050 (Van Ittersum *et al.*, 2016). Expansion of cropped areas is limited due to increased land-use pressure and is increasingly undesirable as it continues to degrade the environment under the current effects of climate change (Rowahni *et al.*, 2011; Akyoo *et al.*, 2013). The adverse impacts of climate change are already noticeable in the country, with frequent droughts, floods, and temperature increases, along with a dwindling supply of water (Rowahni *et al.*, 2011). For this reason, therefore, intensification of agriculture on smallholder farms which will provide more food for a growing population while conserving dwindling forests, wildlife and water is inevitable. But intensification of agriculture is constrained by a number of factors including soil nutrient depletion, water management, weed and pest management, and the use of improved crop seed varieties (Kassie *et al.*, 2012; Akyoo *et al.*, 2013; Suleiman and Rosentrater, 2015). Among the aforementioned constraints, soil nutrient depletion ranks higher (Kassie *et al.*, 2012), thus, intensification of agriculture requires among others a sustainable soil fertilization program. One of the most appropriate methods of sustaining soil fertility is the use of organic materials as the sole fertilization materials or integrated use of organic materials and inorganic fertilizers (Rashid *et al.*, 2016). Several studies have been conducted on different types of organic materials including animal manure, biosolids and industrial wastes to assess their suitability for crop production. They found manure contained 2.61 to 4.9 % N (Widowati *et al.*, 2012), biosolids contained 1.9 to 3.1 % N (Esperschuetz *et al.*, 2016) while industrial wastes contained 0.9 to 4.7 % N (Rigby and Smith, 2009). Among the three types of biodegradable materials studied above, manure relatively showed big potential of being used in agriculture due to high nitrogen content and is easily degraded. The other two types have been reported to be contaminated with heavy metals, thus requires very much attention on treatment (Rigby and Smith, 2009; Esperschuetz *et al.*, 2016) which is very costly. Despite the potentiality of manure to agriculture, its availability to sustain agricultural production is very limited. Nevertheless, there are other biodegradable materials such as urban green biowastes (UGB) especially green food market biowastes which are day to day increasingly produced from a number of food markets in big cities of Tanzania (Simon, 2008).

1.3 Green biowaste availability and their use in agriculture

Green biowastes (GB) are biodegradable fresh wastes from food markets, gardens, industries and to a lesser extent residential areas (Ghani *et al.*, 2005). They are thought to be valuable resources to farmers in terms of their nutrients and organic matter content. Utilization of biowastes-derived fertilizers increases recycling of waste and reduce the use of inorganic fertilizers which are characterized by their heavy impact on the environment with regard to both pollution and consumption of non-renewable resources (Alliance, 2007). Relying on nutrients from wastes rather than inorganic fertilizers represents a sustainable and economically advantageous approach to meeting crop requirements (Alliance, 2007).

However, organic fertilizers are comparatively low in nutrient content, so large volume is needed to provide enough nutrients for crop growth. The nutrient release rate is too slow to meet crop requirements in a short time; hence some nutrient deficiency may occur. This is due to insufficient quantity of major plant nutrients in organic fertilizer to sustain maximum crop growth. The nutrient composition of compost is highly variable; the cost is high compared to chemical fertilizers. Long-term or heavy application to agricultural soils may result in salt, nutrient or heavy metal accumulation and may adversely affect plant growth, soil organisms, water quality and animal and human health (Chen, 2006).

Biowastes which can be applied to agricultural land include market green biowastes, brewery waste, paper-mill residues, rice mill waste, almond residue, oily food waste, wool and horticultural waste ash (Ghani *et al.,* 2005). It has been reported that Dar es Salaam, one of the biggest cities in Tanzania on average generates between 1040 and 1400 t of green biowaste per day (Simon, 2008). About 83 % of the total biowastes produced are left near the house premises in open pits, streets, markets or storm water drainage channels. All these uncollected wastes cause environmental problems (Simon, 2008). Research into their nutrient content and availability to plant is necessary to support the increased use on farmland and facilitate the continued reduction of biodegradable waste sent to landfill sites. However, there has been relatively little research into the nutrient content of urban green biowaste compost (UGBC) sourced from food markets in spite of the evidences that some of these materials can increase soil nutrient contents and improve crop growth (Rezende *et al.,* 2004).

Biodegradable composts vary significantly in their physical and chemical properties depending on types (e.g. Industrial wastes, manure, biosolids (sewage sludge), biowastes etc.) and sources. These variations imply that to properly use the UGBC in crop production, agricultural practice should adjust to the specific characteristics of each material (Kokkora, 2008). The objective of this study therefore was to assess the effectiveness of UGBC application for increased small-scale rice and maize crop production. Specifically, the study intended:

(i) To characterize the urban green biowastes.

(ii) To characterize the soil of the experimental site at Dakawa for rice and maize production.

(iii) To establish the optimum amount of the UGBC required for rice and maize production through pot experiment.

(iv) To assess the field response of rice and maize crops under application of different rates of UGBC.

(v) To recommend the best use of UGBC for improved maize and rice yields.

1.4 Organization of the dissertation

The dissertation is organized into six chapters: Chapter one presents the general introduction containing a review of importance of maize and rice in Tanzania, sustainable production of maize and rice in Tanzania, green biowaste availability and their use in agriculture and organization of the dissertation. Chapter two presents the literature review containing a review of maize and rice production in Tanzania, nutrient depletion and ways of replenishment. Chapter three addresses the physico-chemical properties of the soils of the study site and the characteristics of the urban green biowaste used in the study. Chapter four addresses the effects of UGBC on maize and rice growth and yield parameters under screen house conditions. Chapter five addresses effects of UGBC on maize and rice growth and yield parameters under field conditions. Chapter six presents the general conclusions and recommendations.

REFERENCES

Akyoo, A. M. Temu, A. E. and Hella, J. P. (2013). Agricultural production risks coping mechanisms and potential for crop insurance in Tanzania. *Time Journal of Agriculture and Veterinary Sciences* 1(1): 11 – 22.

Alliance, G. (2007). The Nutrient Cycle: closing the loop. *Green Alliance, London*.

Chen, J. H. (2006, October). The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility. In *International workshop on sustained management of the soil-rhizosphere system for efficient crop production and fertilizer use* (Vol. 16, p. 20). Land Development Department Bangkok Thailand.

DTMA (2014). Maize in Tanzania: Breakthroughs yet to come. A quarterly bulletin of the drought tolerant maize for Africa project, September 2014. *DT Maize* 3(3): 1-4.

Esperschuetz, J., Anderson, C., Bulman, S., Lense, O., Horswell, J., Dickinson, N. and Robinson, B. H. (2016). Production of biomass crops using biowastes on low-fertility soil: 1. Influence of biowastes on plant and soil quality. *Journal of Environmental Quality* 45(6): 1960-1969.

Ghani, A., Dexter, M., Sarathchandra, U. and Waller, J. (2005). Effects of dairy factory effluent application on nutrient transformation in soil. *New Zealand Journal of Agricultural Research* 48(2): 241-253.

Kassie, G. T., Langyintuo, A., Erenstein, O., Maleni, D., Gwara, S. and Abate, T. (2013). Drought risk and maize production in Southern Africa. *Journal of Asian Scientific Research* 3(10): 956-973.

Kokkora, M. I. (2008). Biowaste and vegetable waste compost application to agriculture. Thesis for Award Degree of Doctorate at Cranfield University, School of Applied Sciences, Natural Resources. 236 pp.

Lyimo, S., Mduruma, Z. and De Groote, H. (2014). The use of improved maize varieties in Tanzania. *African Journal of Agricultural Research* 9(7): 644 – 657.

MAFAP, Monitoring African Food and Agricultural Policies (2013). *Review of Food and Agricultural Policies*. Food and Agriculture Organization, Rome, Italy. 173pp.

MAFC, Ministry of Agriculture, Food and Cooperative (2010) *Overview of crop production in Tanzania,* Government Printer, Dar es Salaam, Tanzania.

Mtengeti, E. J., Brentrup, F., Mtengeti, E., Eik, L. O. and Chambuya, R. (2015). Sustainable intensification of maize and rice in smallholder farming systems under climate change in Tanzania. In; *Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa*. Springer, Cham. pp. 441-465.

Rashid, M. I., Mujawar, L. H., Shahzad, T., Almeelbi, T., Ismail, I. M. and Oves, M. (2016). Bacteria and fungi can contribute to nutrients bioavailability and aggregate formation in degraded soils. *Microbiological Research* 183: 26-41.

Rezende, L. A., Assis, L. C. and Nahas, E. (2004). Carbon, nitrogen and phosphorus mineralization in two soils amended with distillery yeast. *Bioresource Technology* 94(2): 159-167.

Rigby, H. and Smith, S. R. (2009). Agronomic Benefit of Industrial Biowastes Centre for Environmental Control and Waste Management Department of Civil and Environmental Engineering. [http://www3.imperial.ac.uk/ewre] site visited on 05/09/2019.

Rowhani, P., Lobell, D. B., Linderman, M. and Ramankutty, N. (2011). Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology* 151: 449 – 460.

Simon, A. M. (2008). *Analysis of Activities of Community Based Organizations Involved in Solid Waste Management, Investigating Modernized Mixtures Approach: The case of Kinondoni Municipality, Dar es Salaam, Tanzania.* The case of Kinondoni Municipality, Dar es Salaam, Tanzania. M.Sc. thesis, Wageningen University. 77pp.

Suleiman, R. A. and Rosentrater, K. A. (2015). *Current Maize Production, Postharvest Losses and the Risk of Mycotoxins Contamination in Tanzania. An ASABE Meeting Presentation Paper Number: 152189434*. The presentation was done at the 2015 ASABE Annual International Meeting Sponsored by ASABE New Orleans, Louisiana July 26–29, 2015. 127pp.

Van Ittersum, M. K., Van Bussel, L. G. J., Wolf, J., Grassini, P., Van Wart, J., Guilpart, N., Claessens, L., De Groot, H., Wiebe, K., Mason-D'Croz, D., Yang, H., Boogaard, H., Van Oort, P. A. J., Van Loon, M. P., Saito, K. Adimo, O., AdjeiNsiah, S., Agali, A., Bala, A., Chikowo, R., Kaizzi, K., Kouressy, M., Makoi, J. H. J. R., Ouattara, K., Tesfaye, K. and Cassman, K. G. (2016). Can sub-Saharan Africa feed itself? *PNAS* 113(52): 14964-14969.

Widowati, L. R., Sleutel, S., Setyorini, D. and De Neve, S. (2012). Nitrogen mineralisation from amended and unamended intensively managed tropical andisols and inceptisols. *Soil Research* 50(2): 136-144.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Maize and rice production in Tanzania

2.1.1 Maize production in Tanzania

Maize accounts for 31% of the total food production and constitutes more than 75% of the cereal consumption in Tanzania. It is estimated that the annual per capita consumption of maize is 128 kg. According to Suleiman and Rosentrater (2015) nearly 400 g of maize is consumed per day per person in Tanzania. The average national consumption is estimated to be over three million metric tons per year (FAOSTAT, 2014). Maize contributes between 34% and 36 % of the average daily calorie intake (BEFS, 2013). According to FAOSTAT (2014) food balance sheet, 60.8% of the total maize produced in 2013 was used for human consumption. Maize is consumed in a variety of forms; ground maize flour is mixed with water to make thin porridge or stiff porridge ("Ugali"). Green (fresh) maize is boiled or roasted on its cob and served as a snack, as well as popcorn. The primary maize-producing regions in the country include Morogoro, Arusha, Iringa, Manyara, Mbeya, Njombe, Rukwa and Ruvuma (Rowahni *et al.*, 2011).

In the past two decades Tanzania ranked among the top 25 maize producing countries in the world, dropping out of the list only three times 1986, 1997 and 2003. In 2003 there was nearly 3.5 million hectares devoted to maize, later stabilized to 2.5 million hectares. Production is also more or less stable around 3.5 million tons while yields fluctuate between 1 and 1.5 tons per hectare down from an average of nearly 2.5 tons during the first three years of the 21st century (MAFAP, 2013). This yield is very low compared to yield of 12 t ha^{-1} in the United States of America (USA) or 2 to 4 t ha^{-1} in other countries in Africa. Area planted with maize crop increased from 2,570,147 ha in 2005/06 to

3,050,714 ha in the 2009/10 agricultural year with average yields of 1.3 and 1.5 t ha^{-1}, respectively (MAFC, 2010). MAFAP (2013) reported that 65 % of approximately 3 million households in Tanzania grow maize, mainly poor smallholder farmers (average 1.2) who rely on traditional methods of cultivation under a rain-fed regime.

2.1.2 Rice production in Tanzania

Rice is the second most important food and commercial crop after maize; it is among the major sources of employment, income and food security for farming households (Lyatuu *et al.*, 2016). Despite low rice yield levels, the country is the leading producer in eastern and central Africa (Rugumamu, 2014), for southern is the second after Madagascar. In Tanzania, rice is produced in the alluvial lowlands and coastal plains, along bottom valleys of mountains, and in land depressions as well as along river-valley basins. The main producing regions include Mwanza, Morogoro, Mbeya, Shinyanga and Tabora (Lyatuu *et al.,* 2016). On the other hand, Mbeya, Morogoro and Mwanza account for greater than 48 % of national production (Rowahni *et al.*, 2011). Area planted with rice increased from 702 000 ha in 2005/06 to 1 136 287 ha in the 2009/10 agricultural year while the yield increased from 1.5 to 2.3 t ha^{-1} within the same year (MAFC, 2010). About 71 % of the rice grown is produced under rain-fed conditions; irrigated land presents 29 % of the total (Lyatuu *et al.*, 2016).

Historically, rice has been categorized under the staple food crop rather than commercial/cash crop. However, in recent years with the rapid growth of cities and towns propelled by rapid population growth, the country has experienced enormous increase in rice demand (Monela, 2014). With negligible percentages of rice imports, most of rice demanded and consumed by the urban population is sourced from the rural rice producing areas that have stagnating production capacities (Lyatuu *et al.*, 2016). For this reason, rice has consequently been transformed into commercial crop. The country is endowed with more than 2 million hectares of lands suitable for rice production, but not all potential area has been used for rice production (MAFC, 2010). Rice production has been increasing from year to year due to priority that has been given by the government. Rice production is mainly done by small and medium size rice farmers (PASS TRUST, 2013).

2.2 Soil nutrient depletion

The main reason among others for low yields of maize and rice has been reported to be low soil fertility particularly nutrient depletion. The magnitude of nutrient depletion in Africa's agricultural land is enormous. Ove three billion ha of arable land in tropical Africa, only about half a billion ha is free of physical and chemical constraints with 13% having low nutrient content and about 17% having high soil pH (Ugboh and Ulebor, 2011). East African soils for instance have up to 90% N, 50% P and 50% K as limiting nutrients (Bekunda *et al.*, 2002). In general, 55% of African land is desert and can only support nomadic grazing (Eswaran *et al.*, 1997). Over the years, overgrazing, deforestation and over cultivation without efficient nutrient management have contributed to soil nutrient loss in sub-Saharan Africa (Henao and Baanante, 2006). According to Sanchez (2002), an average of 660 kg N, 75 kg P and 450 kg K per ha has been lost in the last 30 years from an estimated 202 million ha of cultivated land in 37 African countries including Tanzania. This is equivalent to 1.4 t of urea ha^{-1}, 375 kg of triple superphosphate (TSP) ha^{-1} or 0.9 t of phosphate rock (PR) ha^{-1} of average composition and 896 kg of potassium chloride (KCl) ha^{-1} during the said period. These figures represent the non-balance between nutrient inputs (in fertilizers, manure, atmospheric deposition, biological nitrogen fixation (BNF) and sedimentation) and nutrient outputs (in harvested products, crop residue removals, leaching, gaseous losses, surface runoff and erosion (Raimi *et al.*, 2017).

Food production has therefore depended on nutrient mining approach, since very small amounts of nutrients are returned through fertilizer application (Raimi *et al.,* 2017). It has been observed that as much as 44 % of N, 42 % of P and 56 % of K taken up were present in crop residues (Raimi *et al.,* 2017). The use of crop residues as sources of nutrients and soil organic matter amendment has long been a major component of many farming systems in Africa. In Tanzania, however, the use of plant residues is low. Presently, most of the crop residues are removed for uses with higher economic value such as animal feed, fuel and building materials (Raimi *et al.*, 2017) and sometimes are burnt in the field. The estimated nutrient loss for NPK yearly was 800 000 t for humid central Africa, 600 000 t for North Africa, 1.5 million t for East Africa and 8 million t in sub-Saharan Africa (Henao and Baanante, 2006). In fact, an estimated US$ 4 billion is lost in Africa annually due to nutrient mining and about US$ 42 billion in income and 6 billion ha of valuable land lost annually due to land degradation and reduction in crop productivity (Raimi *et al.,* 2017).

In sub-Saharan Africa, the yield gap has continually increased, deteriorating to less than 25% of potential attainable yield while the per capita food production has also continued to decrease over the past 40 years (Sanchez, 2002). With the increase in demand for food and social and economic development, the available agricultural land will continue to decrease. Unfortunately, arable land is being damaged by anthropogenic and environmental factors, coupled with the fact that many of the cultivated soils are naturally infertile. Yet, the low nutrient stock will have to be cultivated (Henao and Baanante, 2006). This suggests the need for efficient integrated soil fertility management (ISFM) to improve productivity (Rashid *et al.,* 2016).

2.3 Nutrient replenishment

The major pathways of soil fertility decline on farmlands include the loss of nutrients through erosion, leaching, volatilization, crop uptake and harvest without the complementary replenishment (Quansah, 2010). Soil nutrient replenishment is therefore a prerequisite for halting soil fertility decline. This may be accomplished through the application of inorganic fertilizer, organic fertilizers, biofertilizers or a combination of two or more of these fertilizers. The use of inorganic fertilizer, organic fertilizer or biofertilizer has its advantages and disadvantages in the context of nutrient supply, crop growth and environmental quality (Bitew and Alemayehu, 2017). Thus, their advantages need to be integrated in order to make optimum use of each type of fertilizer and achieve balanced nutrient management for crop growth and yield. Organic and inorganic fertilizers are the major categories of fertilizers used by smallholder farmers (Raimi *et al.*, 2017). Therefore, for the farmers to realize the advantages of these two types of fertilizers, they should use them in combination.

2.3.1 Use of inorganic fertilizers

Increased use of inorganic fertilizer by small-scale farmers in Tanzania has been identified as an option for achieving a higher yield and increasing land productivity. Judicious use of inorganic fertilizer is receiving increased attention today because of growing pressure for agriculture to minimize negative environmental impacts (Mkoma *et al.*, 2015). The amount of inorganic fertilizer used in Tanzania has increased rapidly over the past decade, from an estimated 80,936 tons in 2002 to 348,938.64 tons 2012 (Kamhabwa, 2014). With reference to the national agriculture sample census of 2012, farmers use fertilizer mostly in cereal crops especially in maize and rice production (Vanlauwe *et al.*, 2004; Kamhambwa, 2014). Maize and rice require adequate supply of nutrients particularly nitrogen, phosphorus, potassium and zinc for good growth and high yield. Use of inorganic fertilizer can improve the nutrient balance of soils, which may lead to increases in crop yields. Several studies (Kimaro *et al.*, 2009; Chivenge and Vanlauuwe, 2011) showed a significant increase of grain yield after inorganic fertilizer application. It has however, been reported that use of inorganic fertilizers has different effects on soil health (Bitew and Alemayehu, 2017). The application of inorganic fertilizers cause accumulation of acid such as hydrochloric and sulphuric in soils which in turn creates a damaging effect on soil refers to as soil friability (Bitew and Alemayehu, 2017). The different acids in the soil dissolve the soil crumbs. Soil crumbs result from the combination of humus or decomposed natural material such as dead leaves, with clay. They help to hold together the rock particles. These mineral rich soil crumbs are essential for soil drainage and greatly improve air circulation in the soil. As the chemicals in some of inorganic fertilizers destroy soil crumbs, the result is a highly compacted soil with reduced drainage and air circulation (Tien and Chen, 2012).

2.3.2 Common inorganic fertilizer used and their effects on soil health

Soil health is defined as the capacity of a soil to function, within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality and promote plant and animal health (Kibblewhite *et al.,* 2007). It considers the chemical, physical, biological and ecological properties of soils and the disturbance and ameliorative responses by land managers. Soil health also describes the capacity of soil to meet performance standards relating to nutrient and water storage and supply, biological diversity and function, structural integrity and resistance to degradation (Schreck *et al*., 2008). Nonetheless, it should be emphasized that these functions operate by complex interaction with the abiotic physical and chemical environment of soil. Both natural and agricultural soils are the habitat for many different organisms which collectively contribute to a variety of soil-based goods and services (Heffer and Prud'homme, 2015). However, these soil-based biological processes may become disturbed or improved by different factors such as addition of agricultural inputs, improper land cultivation, and climatic conditions (Sanginga and Woomer, 2009). More specifically, under-use, over-use and adequate use of crop production inputs determine the soil health of an environment (Schreck *et al.,* 2008). Overuse of inorganic fertilizer is among the most important factors which threaten the soil health.

Some of the commonly used inorganic fertilizers are ammonium sulphate [$(NH_4)_2SO_4$], ammonium nitrate (NH_4NO_3), urea (NH_2CONH_2), triple super phosphate [Ca ($H_2PO_4)_2$] and muriate of potassium (KCl). The excessive use of these fertilizers affects soil health as discussed below.

Ammonium sulphate $(NH4)_2SO_4$) is one of the synthetic N fertilizers and contains 21N-0P-0K + 24% S. In the soil, it reacts with water to produce sulphuric acid (H_2SO_4). Sulphuric acid has a pH of less than 1. It is extremely toxic and kills organisms. Hydrogen ions released from the acid replace alkaline elements on the cation exchange sites, depleting the soil of nutrients. The free oxygen created in this reaction oxidizes the organic matter of the soil causes a low level “combustion" (burning) of the organic matter. This is a purely chemical reaction which depletes the organic matter. In calcareous soils (soil with excess calcium) the sulphuric acid reacts with calcium carbonate ($CaCO_3$) to form gypsum ($CaSO_4$ = Calcium sulphate) (Casiday and Frey, 1998). Gypsum is a salt and attracts water to it and away from soil organisms and plant roots. In anaerobic conditions gypsum and water form hydrogen sulfide (H_2S), which is a toxic gas. Gypsum is banned from landfills. Sulphuric acid is a major component of acid rain (Casiday and Frey, 1998).

Ammonium nitrate (NH_4NO_3) contains 34N-0P-0K. In the soil, it breaks down into ammonium (NH_4^+) and nitrate (NO_3^-). The ammonium is consumed by plants and fungi or by denitrifying bacteria which eventually convert it to nitrate (Heenan *et al.,* 1998). The nitrates are consumed by soil organisms, leached or converted to nitrogen gas and volatilized. The free oxygen created through these processes oxidizes the organic matter of the soil and causes a low level of the organic matter. This is a chemical reaction which depletes the organic matter. Some biological soil scientists advocate the use of small amounts of ammonium nitrate under specific circumstances even though it is prohibited for use under organic standards (Heenan *et al.*, 1998; Wheeler and Ward, 1990).

Urea (NH_2CONH_2) contains 46N-0P-0K. The urea is consumed by bacteria which convert it to (excrete) anhydrous ammonia (which is a gas) and carbon dioxide (=$2(NH_3)+CO_2$) (Wheeler and Ward, 1990). Anhydrous ammonia is highly toxic and kills soil organisms. If urea is applied to the soil surface, the gases quickly dissipate. However, in the presence of high air humidity anhydrous ammonia forms gas vapours. These gas vapours are heavier than air and can accumulate in low lying areas. If urea is incorporated into the soil, the ammonia gas reacts with water (H_2O) to produce ammonium hydroxide (NH_4OH), which has a pH of 11.6 (Anderson, 2004). It is highly caustic and causes severe burns. This creates a toxic zone in the immediate vicinity of the applied urea that kills seeds, seedlings and soil dwelling organisms. Within a few days further chemical reactions in the soil release the ammonium ion NH_4^+, which then follows the same path as naturally occurring ammonium, with any excess nitrate created in this way leached into the environment.

Triple super phosphate [$Ca (H_2PO_4)_2$] contains 0N-46P-0K. This is produced by treating phosphate rock (apatite) with either sulphuric acid or phosphoric acid, making it extremely acidifying (Wheeler and Ward, 1990). When applied to the soil it reacts with calcium to form tri-calcium phosphate, which is water insoluble, i.e., requiring microbial action for breakdown. Even in a soil with healthy microbial activity only about 15-20% of this phosphorous is easily available to plants, considerably less in soil which does not have good microbial diversity (Anderson, 2004). The production of each ton of phosphoric acid is accompanied by the production of 4.5 tons of calcium sulphate, also known as phosphogypsum. This is a highly radioactive product and also contains heavy metals and other impurities. Depending on the production process, radioactive substances and heavy metals can be extracted into the fertilizer. The high concentration of radioactive polonium-210 in tobacco is thought to be associated with the use of acid-extracted phosphate fertilizers (Martin, 2000).

Muriate of potash (KCl) contains 0N-0P-60K.This product contains about 60% potassium and 40% chloride. In the soil the chloride combines with nitrates to form chlorine gas. This kills microbes. Applying 0.45 kg of potassium chloride to the soil is equivalent to applying 3.79 litre of clorox bleach. Potassium chloride application typically results in chloride levels as high as 50-200 ppm (Anderson, 2004). Potassium chloride contains very high amounts of potassium, which can result in an unbalanced phosphate: potash ratio. This ratio ideally ranges from 2:1 (most soils) to 4:1 (grasses). Excess potassium in the soil can lead to a calcium deficiency in plants, since plants absorb calcium, magnesium and potassium largely in the ratio in which they are present in the soil. In the soil, excess potassium causes a loss of soil structure (Anderson, 2004) which leads to reduced soil air levels and ultimately reduced root respiration and the production of toxic compounds in plants. Reduced soil air and insufficient calcium individually result in the reduction of soil microbes and the corresponding reduced breakdown of organic matter/nutrient availability to plants. In drilling potassium is used to “close” the soil, because it disintegrates the clay particles (“ages” the clay) and effectively seals the soil (Bitew and Alemayehu, 2017).

2.3.2 Use of organic materials as soil fertilizing materials

2.3.2.1 Waste chemical composition

The use of organic wastes in agricultural fields may increase crop yield and soil quality while reducing pollution and increasing farmer profits (Gong *et al.*, 2019). The effects of waste application on soil fertility depend on waste chemical composition, which is highly variable and linked to its origin (Carmo *et al.,* 2016). The waste production system, storage and management of crop residues and postharvest by-products are other key factors controlling the organic waste chemical composition and its value as an agricultural input. In animal production systems, the composition and amount of feed furnished to animals are other factors that control the waste agronomic value; post-production treatments of composts and sewage sludge and by-products generated in the industry and agro-industries also exert an influence on the waste chemical composition (Melo and Silva, 2008; Silva, 2008). Manures originating from intensive production systems are richer in nutrients than wastes produced by animals raised in extensive pastures or fed with poor nutritional grasses. In comparison to crop residues, pig, quail and chicken manures commonly have higher contents of N, P, K and Ca (Maluf *et al.,* 2018). Animal manures enriched in carbonates or Ca oxides may also benefit crops, through soil acidity correction; however, the intensity of soil acidity neutralization also relies on the initial soil pH and amount of waste added to the soil (Hargreaves *et al.,* 2008; Diacono and Montemurro, 2010).

2.3.2.2 Influence of organic fertilizers on soil fertility

Apart from the amount and chemical composition, the effects of wastes on soil properties are related to many factors. These factors include the nutrient mineralization rate, which is closely linked to chemical, physical and biological waste properties, humification degree and the biotic and abiotic factors in soil regulating the rate of waste decomposition (Abreu Júnior *et al.,* 2005; Pavinato and Rosolem, 2008). The effects of wastes on soil properties are mainly related to the rate of application and the waste chemical composition. Soil organic matter and clay contents are other key factors regulating changes in soil fertility (Müller and Hopper, 2004; Silva, 2008). Generally addition of organic wastes to soils improves soil physical, chemical and biological properties as discussed in the next three sections.

2.3.2.2.1 Effect on soil physical properties

As widely reported in literature, the use of organic amendments increases organic matter in soil (Khaliq and Abbasi, 2015). As a result, it improves soil quality by enhancing soil aggregate stability, water holding capacity and soil porosity (Leroy *et al.*, 2008). Sometimes, organic amendments can affect indirectly soil physical properties. Lucas *et al*. (2014) demonstrated that organic amendments containing high amount of bioavailable carbon derived from cellulose, can promote fungal proliferation and improve soil structure through stabilization of soil aggregates.

2.3.2.2.2 Effect on soil chemical properties

Intensive agriculture, without organic amendments for the restoration of soil organic C stock, negatively affects soil chemical properties resulting into a reduction in soil C content. In turn, it produces deleterious effects on soil microbial biomass, soil enzymatic activities, functional and species diversity, besides a drastic increase in soil salinity (Bonanomi *et al.*, 2011). A large body of empirical studies carried out in different agricultural systems demonstrated that the application of organic amendments in the form of compost is an effective tool to recover soil organic C stock (Zhang *et al.*, 2015).

The C/N ratio is considered an important parameter to predict organic C mineralization rate and dynamical patterns of the nutrient release (Parton *et al.*, 2007; Berg and McClaugherty, 2008). Organic C or N can limit microbial growth when C/N ratio is above the threshold value of about 25-30. Therefore, a crucial step for a sustainable management of soil quality is to identify organic amendments with specific biochemical quality that effectively balance the trade-off between organic C stock recovery and nutrient mineralization. Generally, when organic C enters the soil, the amount retained depends not only on its biochemical quality but also on its interactions with soil mineral components that is, sand, silt, and clay fractions as well as carbonate and organic C content (Clough and Skjemstad, 2000).

The addition of chemical fertilizers generally leads to a rapid mineral N release, while organic amendments induce a slow mineral N release, but extended over time (Claassen and Carey, 2006). Weber *et al.* (2007) reported that the slow mineralization of N in soils under compost amendment improves not only the soil fertility, but also the conditions of organic matter mineralization. In fact, they found an increase of humic acid/fulvic acid ratio in compost amended soil which might be partly due to the original composition of humic substances in the compost, where humic acids always predominate over fulvic acids.

Although compost application could promote nitrification process, if compared with mineral fertilization it reduces N leaching, decreasing the possibility of nitrate groundwater contamination (Montemurro *et al.,* 2007). Numerous researches have been addressed on soil nutrient supply after the application of organic amendments. As a consequence of the application of organic amendments, which increase organic C stock, soil cation exchange capacity (CEC) increases. High values of CEC allow retaining essential nutrient cations making them available for crop productions (Bulluck *et al.*, 2002). In addition, also anions as phosphorus showed an increased solubility subsequent to organic material application (Zaccardelli *et al.,* 2013; Scotti *et al.,* 2015).

2.3.2.2.3 Effect on soil biological properties

Organic amendments, once added to the soil, favour the growth and diversity of microbial communities, highlighting a strong correlation between soil biological fertility and soil organic C content (Chakraborty *et al.*, 2011). In a study conducted for three years, in intensive farm under greenhouse conditions, Morra *et al.* (2010) used different doses of compost (15, 30, and 45 t ha^{-1}) and compost (at dose of 15 t ha^{-1}) combined with mineral N fertilizer to investigate the effects of exogenous organic matter on soil enzymatic activities. They found that soil respiration, fluorescein diacetate hydrolases and phosphomonoesterase activities increased after compost application. The magnitude of the activity increased with compost rate and with cumulative compost amendment. In general, the broad-scale soil biological properties, such as soil respiration, fluorescein diacetate hydrolases and phosphomonoesterase activities were positively affected by compost supply, demonstrating shifts in microbial performances related to C, N and phosphorus cycles in soil (Iovieno *et al.*, 2009). Scotti *et al.* (2015) proposed compost application to soils under intensive farming systems combined with woody scraps to achieve significant changes in biological parameters.

The use of compost can affect soil microbial diversity, as reported by Zaccardelli *et al.* (2013), who showed a clear positive effect on the number of spore-forming bacteria, with an increase directly correlated with the dose of compost. Also, in stressed soil, with high salt content, the use of compost can determine an improvement of biological fertility (Lakhdar *et al.*, 2009). Ouni *et al.* (2013) investigated the effects of composts, produced by MSW and palm wastes, at several doses (0, 50, 100, and 150 t ha^{-1}) on saline soil. They observed an increase of soil organic matter and consequently an improvement of microbial biomass and several enzyme activities, but the results were different in presence of the highest dose of compost (150 t ha^{-1}), where a reduction of some activities was registered. This behaviour could be likely attributed to the potential toxic effect of the trace elements present in this particular compost. Crecchio *et al.* (2004) and Lakhdar *et al.* (2011) tested the use of compost from municipal solid waste (MSW) and sewage sludge to enhance the fertility of degraded soils in the Mediterranean region. A clay loamy soil was amended with 0, 40, and 80 t ha^{-1} of MSW compost or sewage sludge. A significant increase of all the measured activities (arylsulphatase, dehydrogenase, phosphomonoesterase and b-glucosidase) after 70 days at either 40 t ha^{-1} or 80 t ha^{-1} (ranged between 16%-160% and 10%-81%, respectively) was registered.

2.3.2.3 Effects of organic fertilizers on soil health

Organic materials are generally grouped into two main categories namely compostable organics and humic substances. The detailed discussion which links between the properties of various organic inputs and their effects on soil health is provided below.

2.3.2.3.1 Compostable organics

Compostable organics are the organic materials that can be made compost, they include manures, biowastes, sewage sludge, municipal solid wastes, etc. These materials do vary widely in characteristics such as dry matter content, pH, salinity, carbon content, plant nutrient concentrations, non-nutrient elements and microbial types, numbers and activity (Schreck *et al.,* 2008).

Manures and sewage sludge generally have higher salinity than municipal garden wastes and salts can build up in soil with repeated heavy applications (Usman *et al.,* 2004; Hao and Chang, 2003). Sewage sludge (biosolids) often contains heavy metals such as copper, zinc or cadmium, especially where industries contribute to the waste stream. Heavy metals can affect microbial processes more than they affect soil animals or plants growing on the same soils. For example, in a study to assess the effects of metal toxicity in sewage sludge on soil microbe and plants, it was revealed that the nitrogen-fixing rhizobia were far more sensitive to metal toxicity than their host plant clover. This resulted in N deficiency of clover due to ineffective rhizobia in sludge-amended soils (Bitew and Alemayehu, 2017). Sewage sludge and livestock manure may also contain active residues of therapeutic agents used to treat or cure diseases in humans and animals (Hunt, 2016).

Green wastes from farms and gardens are typically lower in nutrient concentrations than manures or sewage sludge and they may contain residues of synthetic compounds such as herbicides, insecticides, fungicides and plant growth regulators (Carmo *et al.,* 2016). Composting degrades some but not all such compounds, depending on the nature of the pesticide and the specific composting conditions. In general terms compost will modify soil organic matter (SOM) levels depending on compost quality and when/where applied. This often leads to increases in organic carbon and total nitrogen in topsoil (Carmo *et al.,* 2016). Equilibrium is achieved after long period of time and this is affected by soil type, climate, by the means of exploitation and the quality/quantity of the compost. Thus, soil pH is generally increased or stabilized. This can save lime inputs in some circumstances (Bitew and Alemayehu, 2017). The cation exchange capacity (CEC) of SOM is higher than that of clay minerals so raising SOM will lift overall soil CEC. In terms of the effects on physical properties compost use can lead to larger and more stable aggregates (Bitew and Alemayehu, 2017).

2.3.2.3.2 Humic substances

Humus in soil has traditionally been separated into humin, humic acid and fulvic acid based on extraction with an alkaline solution and subsequent precipitation after addition of an acid (Bünemann *et al.,* 2006). The fractions typically rank in their resistance to microbial decomposition in the order of humic acid> fulvic acid>humin (Qualls, 2004). Concentrated sources of organic material such as peat, composts and brown coal (oxidized coal, lignite, leonardite) also contain humic substances and are often marketed on the basis of their humic and fulvic acid contents as determined by similar procedures.

Humic substances can stimulate microbial activity directly through provision of carbon substrate, supplementation of nutrients and enhanced nutrient uptake across cell walls. Valdrighi *et al*. (1995) reported that increasing amounts of compost or brown coal-derived humic acid stimulated aerobic bacterial growth but had only slight effects on actinomycetes and no effect on filamentous fungi. Differences in microbial response were related to the molecular weight of the humic acids, with the lower weight fractions, typical of composts, causing greater microbial stimulation than the higher molecular weight fractions extracted from brown coal (Valdrighi *et al.*, 1995). Application of humic substances may induce changes in metabolism, allowing organisms to proliferate on substrates which they could not previously use. Both heterotrophic and autotrophic bacteria can be stimulated by humic acid addition, mostly through the enhanced surfactant-like absorption of mineral nutrients, although heterotrophs also benefit from the direct uptake of organic compounds (Valdrighi *et al.*, 1995; Qualls, 2004).

Field studies vary widely in the applied amounts of humic substances and in outcomes. Chen *et al.* (2004) and Bünemann *et al.* (2006) found no effect of commercial humate applied at 8.2 t ha^{-1} on microbial activity or microbial functional groups (total fungi, actinomycetes, total gram-negative bacteria, fluorescent pseudomonas and P. capsici) in a sandy soil used to grow bell peppers. Similarly, after 5 years of annual applications of 100 L ha^{-1} liquid humic acid to a horticultural soil, Albiach *et al.* (2000) found no effect on microbial biomass or enzyme activity. They ascribed the lack of effect to the low rates recommended by the manufacturer because of high product costs. Municipal solid waste compost and sewage sludge were more affordable and led to significant increases in microbial biomass in the same study (Chen *et al.*, 2004).

2.3.2.4 Adverse effects of organic fertilizers

Adverse effects of wastes on soil fertility attributes are associated with a sharp increase in pH (Mokolobate and Haynes, 2002; Dikinya and Mufwanzala, 2010), which may reach the alkaline range and decrease the availability of some micronutrients. High charges of micronutrients added in soils, especially Zn and Cu, and the addition of K and other chemical elements or pollutants at levels above those considered agronomically safe for agricultural soils are effects that have been reported for some soils successively fertilized with manures (Torri and Corrêa, 2012; Penha *et al.,* 2015). Excessive levels of P in soil and its runoff from sites with intensive poultry activities are other adverse effects observed in fields intensively and continuously fertilized with poultry litter (Harmel *et al.,* 2009). The waste rate definition is a critical issue in organic fertilization and is typically based on the nutrient in the highest concentration, in most cases N, but the water content and N mineralization rate are factors that must be also taken into account (Smith, 2009). When fixing the amount of N added to soils, the input of other nutrients is highly variable and depends on the waste chemical composition and its nutrient charges. Thus, by choosing N as the target nutrient, the application of P and K at higher rates than those required by crops is common, mainly in crop fields where animal manures are successively used for crop fertilization (Bar-Tal *et al.,* 2004). Continuous application of wastes could also increase the soil Ca content (Carmo *et al.,* 2016) causing nutritional imbalances in K, Mg, and N-ammonium supplied to plants.

2.3.3 Integrated use of organic and inorganic fertilizers

There is an increased emphasis on the environmental quality impact due to continuous use of inorganic fertilizers (Laharia *et al.,* 2013). The integrated nutrient management system is an alternative and is characterized by reduced input of inorganic fertilizers and combined use of inorganic fertilizers with organic materials such as animal manures, crop residues, green manure and composts. Management systems that rely on organic inputs as plant nutrient sources have different dynamics of nutrient availability from those involving the use of inorganic fertilizers. For sustainable crop production, integrated use of inorganic and organic fertilizer has proved to be highly beneficial. Several researchers

(Mahmoud *et al.*, 2009; Laharia *et al.*, 2013; Diallo-Diagne *et al.*, 2016) have demonstrated the beneficial effect of combined use of chemical and organic fertilizers to mitigate the deficiency of many secondary and micronutrients in fields that continuously received only N, P and K fertilizers for a few years, without any micronutrient or organic fertilizer. A field experiment was conducted for 7 years continuously to evaluate the influence of combined application of organic and inorganic fertilizers on chemical fertility buildup and nutrient uptake in a mint (*Mentha arvensis*) and mustard (*Brassica juncea*) cropping sequence (Chand *et al.*, 2006). Results indicated that integrated supply of plant nutrients through FYM (farmyard manure) and inorganic fertilizer NPK, along with Sesbania green manuring, played a significant role in sustaining soil fertility and crop productivity. Based on the evaluation of soil quality indicators, the use of organic fertilizers together with inorganic fertilizers, compared to the addition of organic fertilizers alone, had a higher positive effect on microbial biomass and hence soil health (Dutta *et al.*, 2003). Application of organic manure in combination with inorganic fertilizer has been reported to increase absorption of N, P and K in sugarcane leaf tissue in the plant and root crop, compared to inorganic fertilizer alone (Bokhtiar and Sakurai, 2005).

A study was done to compare the change of chemical and biological properties in soils receiving FYM, poultry manure and sugarcane filter cake alone or in combination with inorganic fertilizers for 7 years under a cropping sequence of pearl millet and wheat. Results showed that all treatments except inorganic fertilizer application improved the soil organic C, total N, P and K status. Increase in microbial biomass C and N was observed in soils receiving organic manures only or with the combined application of organic manures and inorganic fertilizers compared to soils receiving inorganic fertilizers (Kaur *et al.*, 2005). The same study showed that balanced fertilization using both organic and inorganic fertilizers is important for maintenance of soil organic matter content and long-term soil productivity in the tropics where soil organic matter content is low. The effects of organic fertilization and combined use of inorganic and organic fertilizer on crop growth and soil fertility depend on the application rates and the nature of fertilizers used. Application of 15 tons FYM ha^{-1} significantly increased soil organic matter and available water holding capacity but decreased the soil bulk density, creating a good soil condition for enhanced growth of the rice crop (Tadesse *et al.,* 2013). Positive balances of soil N and P resulted from combined application of FYM and inorganic N and P sources. Application of 15 tons ha^{-1} FYM and 120 kg N of urea ha^{-1} resulted in 214.8 kg N ha^{-1} positive balance while application of 15 tons FYM ha^{-1} and 100 kg P_2O_5 ha^{-1} resulted in a positive balance of 69.3 kg P_2O_5 ha^{-1} available P. The compost manure + NPK showed a greater potential for increasing plant macronutrients (N, P, K, Ca and Mg) contents (Law-Ogbomo, 2013). The result showed that combined application of Municipal solid waste with NPK performed better than sole application of either Municipal solid waste or NPK fertilizer (Bérard *et al.*, 2004).

REFERENCES

Abreu, C. A. D., van Raij, B., Abreu, M. F. D. and González, A. P. (2005). Routine soil testing to monitor heavy metals and boron. *Scientia Agricola* 62(6): 564-571.

Albiach, R., Canet, R., Pomares, F. and Ingelmo, F. (2000). Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. *Bioresource Technology* 75(1): 43-48.

Anderson, A. B. (2004). The Anatomy of Life and Energy in Agriculture. Acres U.S.A., Metairie, LA. pp114.

Bar-Tal, A., Yermiyahu, U., Beraud, J., Keinan, M., Rosenberg, R., Zohar, D. and Fine, P. (2004). Nitrogen, phosphorus, and potassium uptake by wheat and their distribution in soil following successive, annual compost applications. *Journal of Environmental Quality* 33(5): 1855-1865.

BEFS, Bioenergy and Food Security Projects (2013). Tanzania. BEFS Country Brief.

Bekunda, M., Nkonya, E., Mugendi, D. and Msaky, J. (2002). Soil fertility status, management, and research in East Africa. *East African Journal of Rural Development* 20: 94-112.

Bérard, A., Rimet, F., Capowiez, Y. and Leboulanger, C. (2004). Procedures for determining the pesticide sensitivity of indigenous soil algae: a possible bioindicator of soil contamination? *Archives of Environmental Contamination and Toxicology* 46(1): 24-31.

Berg, B. and McClaugherty, C. (2008). *Plant Litter: Decomposition, Humus Formation and Carbon Sequestration*, 2nd edition, Springer-Verlag, Berlin, Heidelberg. 338pp.

Bitew, Y. and Alemayehu, M. (2017). Impact of crop production inputs on soil health: a review. *Asian Journal Plant Science* 16(3): 109-131.

Bokhtiar, S. M. and Sakurai, K. (2005). Effects of organic manure and chemical fertilizer on soil fertility and productivity of plant and ratoon crops of sugarcane. *Archives of Agronomy and Soil Science* 51(3): 325-334.

Bonanomi, G., D'Ascoli, R., Antignani, V., Capodilupo, M., Cozzolino, L., Marzaioli, R. and Rao, M. A. (2011). Assessing soil quality under intensive cultivation and tree orchards in Southern Italy. *Applied Soil Ecology* 47(3): 184-194.

Bulluck Iii, L. R., Brosius, M., Evanylo, G. K. and Ristaino, J. B. (2002). Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Applied Soil Ecology* 19(2): 147-160.

Bünemann, E. K., Schwenke, G. D. and Van Zwieten, L. (2006). Impact of agricultural inputs on soil organisms-a review. *Soil Research* 44(4): 379-406.

Carmo, D. L. D., Lima, L. B. D., and Silva, C. A. (2016). Soil fertility and electrical conductivity affected by organic waste rates and nutrient inputs. *Revista Brasileira de Ciência do Solo* 40:e0150152

Casiday, R. and Frey, R. (1998). Natural acidity of rainwater. *Washington University, St. Louis, Missouri*.

Chakraborty, A., Chakrabarti, K., Chakraborty, A. and Ghosh, S. (2011). Effect of long-term fertilizers and manure application on microbial biomass and microbial activity of a tropical agricultural soil. *Biology and Fertility of Soils* 47(2): 227-233.

Chand, S., Anwar, M. and Patra, D. D. (2006). Influence of long-term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint-mustard cropping sequence. *Communications in Soil Science and Plant Analysis* 37(1-2): 63-76.

Chen, Y., De Nobili, M., and Aviad, T. (2004). Stimulatory effect of humic substances on plant growth. In 'Soil organic matter in sustainable agriculture'. (Eds F Magdoff, R. R. Weil). pp. 103–130.

Chivenge, P, B., Vanlauwe, B. and Six, J. (2011). Does the combined application of organic and mineral nutrient sources influence maize productivity. A metaanalysis. *Journal of Plant Soil* 342: 1–30.

Claassen, V. P. and Carey, J. L. (2006). Comparison of slow-release nitrogen yield from organic soil amendments and chemical fertilizers and implications for regeneration of disturbed sites. *Land Degradation & Development* 18(2): 119-132.

Clough, A., and Skjemstad, J. O. (2000). Physical and chemical protection of soil organic carbon in three agricultural soils with different contents of calcium carbonate. *Soil Research* 38(5): 1005-1016.

Crecchio, C., Curci, M., Pizzigallo, M. D., Ricciuti, P. and Ruggiero, P. (2004). Effects of municipal solid waste compost amendments on soil enzyme activities and bacterial genetic diversity. *Soil Biology and Biochemistry* 36(10): 1595-1605.

Diacono, M. and Montemurro, F. (2011). Long-term effects of organic amendments on soil fertility. In; *Sustainable Agriculture Volume 2* (pp. 761-786). Springer, Dordrecht.

Diallo-Diagne, N. H., Assigbetse, K., Sall, S., Masse, D., Bonzi, M., Ndoye, I. and Chotte, J. L. (2016). Response of soil microbial properties to long-term application of organic and inorganic amendments in a tropical soil (Saria, Burkina Faso). *Open Journal of Soil Science* 6(02): 21-33.

Dikinya, O., and Mufwanzala, N. (2010). Chicken manure-enhanced soil fertility and productivity: Effects of application rates. *Journal of Soil Science and Environmental Management* 1(3): 46-54.

Dutta, S., Pal, R., Chakeraborty, A. and Chakrabarti, K. (2003). Influence of integrated plant nutrient phosphorus and sugarcane and sugar yields. *Field Crop Research* 77: 43-49.

Eswaran, H., Almaraz, R., van den Berg, E. and Reich, P. (1997). An assessment of the soil resources of Africa in relation to productivity. *Geoderma* 77(1): 1-18.

FAOSTAT (2014). http://faostat.fao.org. site visited on 10/7/2019.

Gong, Q., Chen, P., Shi, R., Gao, Y., Zheng, S. A., Xu, Y., Shao, C. and Zheng, X. (2019). Health Assessment of Trace Metal Concentrations in Organic Fertilizer in Northern China. *International Journal of Environmental Research and Public Health* 16(6): 1031-1052.

Hao, X. and Chang, C. (2003). Does long-term heavy cattle manure application increase salinity of a clay loam soil in semi-arid southern Alberta? *Agriculture, Ecosystems & Environment* 94(1): 89-103.

Hargreaves, J. C., Adl, M. S. and Warman, P. R. (2008). A review of the use of composted municipal solid waste in agriculture. *Agriculture, Ecosystems and Environment* 123(1-3): 1-14.

Harmel, R. D., Smith, D. R., Haney, R. L. and Dozier, M. (2009). Nitrogen and phosphorus runoff from cropland and pasture fields fertilized with poultry litter. *Journal of Soil and Water Conservation* 64(6): 400-412.

Heenan, D. P., McGhie, W. J. and Conyers, M. K. (1998). nd, Soil pH change over time in relation to rotation, N fertiliser, stubble management and tillage. In; *Proceedings of the 9th Australian Agronomy Conference'. Wagga Wagga, NSW.*

Heffer, P. and Prud'homme, M. (2015). Fertilizer outlook 2015–2019. In; *83rd IFA Annual Conference* (Vol. 415). Istanbul (Turkey): International Fertilizer Industry Association (IFA).

Henao. J. and Baanante, C. (2006). Agricultural production and soil nutrient mining in Africa: Implications for resource conservation and policy development*: International Center for Soil Fertility and Agricultural Development,* Alabama, USA: IFDC.

Hunt, J. (2016). Fertilizer facts. *Montana State University Extension Service, Montana State University, Bozeman, MT., USA.*

Iovieno, P., Morra, L., Leone, A., Pagano, L. and Alfani, A. (2009). Effect of organic and mineral fertilizers on soil respiration and enzyme activities of two Mediterranean horticultural soils. *Biology and Fertility of Soils* 45(5): 555-561.

Kamhabwa, F. (2014). *Consumptions of Fertilizers and Fertilizer Use by Crop in Tanzania* . Academic press, New York. 10pp.

Kaur, K., Kapoor, K. K. and Gupta, A. P. (2005). Impact of organic manures with and without mineral fertilizers on soil chemical and biological properties under tropical conditions. *Journal of Plant Nutrition and Soil Science* 168(1): 117-122.

Khaliq, A. and Abbasi, M. K. (2015). Improvements in the physical and chemical characteristics of degraded soils supplemented with organic–inorganic amendments in the Himalayan region of Kashmir, Pakistan. *Catena* 126: 209-219.

Kibblewhite, M. G., Ritz, K. and Swift, M. J. (2007). Soil health in agricultural systems. *Philosophical Transactions of the Royal Society B: Biological Sciences* 363(1492): 685-701.

Kimaro, A. A., Timmer, V. R., Chamshama, S. O. A., Ngaga, Y. N. and Kimaro, D. A. (2009). Competition between maize and pigeonpea in semi-arid Tanzania: Effect on yields and nutrition of crops. *Journal of Agriculture, Ecosystems and Environment* 134: 115–125.

Laharia, G. S., Patil, D. U. and Damre, P. R. (2013). Effect of organic sources on soil fertility, nutrient uptake and yield of soybean. *Crop Research (Hisar)* 45(1/3): 155-159.

Lakhdar, A., Rabhi, M., Ghnaya, T., Montemurro, F., Jedidi, N. and Abdelly, C. (2009). Effectiveness of compost use in salt-affected soil. *Journal of Hazardous Materials* 171(1-3): 29-37.

Lakhdar, A., Scelza, R., Achiba, W.B., Scotti, R., Rao, M.A., Jedidi, N., Abdelly, C. and Gianfreda, L. (2011). Effect of municipal solid waste compost and sewage sludge on enzymatic activities and wheat yield in a clayey-loamy soil. *Soil Science* 176: 15-21.

Law-Ogbomo, K. E. (2013). Nutrient uptake by Abelmuscus esculentus and its effects on changes in soil chemical properties as influenced by residual application of fertilizer. *Journal of Soil Science and Environmental Management* 4(7):132-138.

Leroy, B. L. M., Herath, H. M. S. K., Sleutel, S., De Neve, S., Gabriels, D., Reheul, D. and Moens, M. (2008). The quality of exogenous organic matter: short term effects on soil physical properties and soil organic matter fractions. *Soil Use Management* 24: 139-47.

Lucas, S. T., D'Angelo, E. M. and Williams, M. A. (2014). Improving soil structure by promoting fungal abundance with organic soil amendments. *Applied Soil Ecology* 75: 13-23.

Lyatuu, E. T., Gbete, G. E. W., and Nie, F. (2016). Does the Improvement of Productivity of Maize and Rice Reduce Poverty? Comparison Case Study for Tanzania and Togo. *Journal of Economics and Sustainable Development* 7(2): 25-35.

MAFAP, Monitoring African Food and Agricultural Policies (2013). *Review of Food and Agricultural Policies*. Food and Agriculture Organization, Rome, Italy. 173pp.

MAFC, Ministry of Agriculture, Food and Cooperative (2010). *Overview of Crop Production in Tanzania*, Government Printer, Dar es Salaam, Tanzania.

Mahmoud, E., El-Kader, N. A., Robin, P., Akkal-Corfini, N. and El-Rahman, L. A. (2009). Effects of different organic and inorganic fertilizers on cucumber yield and some soil properties. *World Journal of Agricultural Sciences* 5(4): 408-414.

Maluf, H. J. G. M., Silva, C. A., Morais, E. G. D. and Paula, L. H. D. D. (2018). Is composting a route to solubilize low-grade phosphate rocks and improve map-based composts? *Revista Brasileira de Ciência do Solo* 42: e0170079.

Martin, R. (2000). Radioactive polonium-210 found in tobacco. American Computer Scientists Association Inc.

Mkoma, A. (2015). Response of maize to phosphorus in sole maize and maize-pigeonpea cropping system in semi-arid areas of Tanzania. Dissertation for Award degree of Doctorate at Sokoine University of Agriculture. 68pp.

Mokolobate, M. and Haynes, R. (2002). Comparative liming effect of four organic residues applied to an acid soil. *Biology and Fertility of Soils* 35(2): 79-85.

Monela, A. G. (2014). Access to and adoption of improved seeds by smallholder farmers in Tanzania: cases of maize and rice seeds in Mbeya and Morogoro regions. Dissertation for Award Degree at Sokoine University of Agriculture. 88pp.

Montemurro, F., Maiorana, M., Convertini, G. and Ferri, D. (2007). Alternative sugar beet production using shallow tillage and municipal solid waste fertiliser. *Agronomy for Sustainable Development* 27(2): 129-137.

Morra, L., Pagano, L., Iovieno, P., Baldantoni, D. and Alfani, A. (2010). Soil and vegetable crop response to addition of different levels of municipal waste compost under Mediterranean greenhouse conditions. *Agronomy for Sustainable Development* 30(3): 701-709.

Müller, T. and Höper, H. (2004). Soil organic matter turnover as a function of the soil clay content: consequences for model applications. *Soil Biology and Biochemistry* 36(6): 877-888.

Ouni, Y., Lakhdar, A., Scelza, R., Scotti, R., Abdelly, C., Barhoumi, Z. and Rao, M. A. (2013). Effects of two composts and two grasses on microbial biomass and biological activity in a salt-affected soil. *Ecological Engineering* 60: 363-369.

Parton, W., Silver, W. L., Burke, I. C., Grassens, L., Harmon, M. E., Currie, W. S. and Fasth, B. (2007). Global-scale similarities in nitrogen release patterns during long-term decomposition. *Science* 315(5810): 361-364.

PASS TRUST (2013). Draft Investment Potential for Maize and Rice. A report from Southern Highland Food System Programme. 60pp.

Pavinato, P. S. and Rosolem, C. A. (2008). Disponibilidade de nutrientes no solo-decomposição e liberação de compostos orgânicos de resíduos vegetais. *Revista Brasileira de Ciência do Solo* 32(3): 911-920.

Peacock, A. G., Mullen, M. D., Ringelberg, D. B., Tyler, D. D., Hedrick, D. B., Gale, P. M., and White, D. C. (2001). Soil microbial community responses to dairy manure or ammonium nitrate applications. *Soil Biology and Biochemistry* 33(7-8): 1011-1019.

Penha, H. G. V., Menezes, J. F. S., Silva, C. A., Lopes, G., de Andrade Carvalho, C., Ramos, S. J. and Guilherme, L. R. G. (2015). Nutrient accumulation and availability and crop yields following long-term application of pig slurry in a Brazilian Cerrado soil. *Nutrient Cycling in Agroecosystems* 101(2): 259-269.

Qualls, R. G. (2004). Biodegradability of humic substances and other fractions of decomposing leaf litter. *Soil Science Society of America Journal* 68(5): 1705-1712.

Quansah, G. W. (2010). Effect of Organic and Inorganic Fertilizers and Their Combinations on the Growth and Yield of Maize in the Semi-Deciduous Forest Zone of Ghan. Dissertation for Award Degree at Kwame Nkuruma University of Science and Technology, Kumasi, Ghana. 77pp.

Raimi, A., Adeleke, R., and Roopnarain, A. (2017). Soil fertility challenges and Biofertiliser as a viable alternative for increasing smallholder farmer crop productivity in sub-Saharan Africa, *Cogent Food and Agriculture* 3: 1-9.

Rashid, M. I., Mujawar, L. H., Shahzad, T., Almeelbi, T., Ismail, I. M. and Oves, M. (2016). Bacteria and fungi can contribute to nutrients bioavailability and aggregate formation in degraded soils. *Microbiological Research* 183: 26-41

Rowhani, P., Lobell, D. B., Linderman, M. and Ramankutty, N. (2011). Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology* 151: 449 – 460.

Rugumamu, C. P. (2014). Empowering smallholder rice farmers in Tanzania to increase productivity for promoting food security in Eastern and Southern Africa. *Agriculture & Food Security* 3(1): 7-14.

Sanchez, P. A. (2002). Soil fertility and hunger in Africa. *Science* 295(5562): 2019-2020.

Sanginga, N., and Woomer, P. L. (Eds.). (2009). *Integrated soil fertility management in Africa: principles, practices, and developmental process*. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. 263pp.

Schreck, E., Geret, F., Gontier, L. and Treilhou, M. (2008). Neurotoxic effect and metabolic responses induced by a mixture of six pesticides on the earthworm Aporrectodea caliginosa nocturna. *Chemosphere* 71(10): 1832-1839.

Scotti, R., D'ascoli, R., Gonzalez Caceres, M., Bonanomi, G., Sultana, S., Cozzolino, L., and Rao, M. A. (2015). Combined use of compost and wood scraps to increase carbon stock and improve soil quality in intensive farming systems. *European Journal of Soil Science* 66(3): 463-475.

Silva, C. A. (2008). Uso de resíduos orgânicos na agricultura. *Fundamentos da matéria orgânica do solo: ecossistemas tropicais e subtropicais* 2: 597-624.

Smith, S. R. (2009). A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. *Environment International* 35(1): 142-156.

Suleiman, R. A. and Rosentrater, K. A. (2015). *Current Maize Production, Postharvest Losses and the Risk of Mycotoxins Contamination in Tanzania. An ASABE Meeting Presentation Paper Number: 152189434*. The presentation was done at the 2015 ASABE Annual International Meeting Sponsored by ASABE New Orleans, Louisiana July 26–29, 2015. 127pp.

Tadesse, T., Dechassa, N., Bayu, W. and Gebeyehu, S. (2013). Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem. *American Journal of Plant Sciences* 4(02): 309-316.

Thomas, G. W. (2009). Soil pH and soil acidity. In: *Methods of Soil Analysis Part 3—Chemical Methods: SSSA Book series no. 5. (Edited by Sparks D.L.),* Soil Science of America Inc. 5th Edition. pp. 475-490.

Tien, C. J. and Chen, C. S. (2012). Assessing the toxicity of organophosphorous pesticides to indigenous algae with implication for their ecotoxicological impact to aquatic ecosystems. *Journal of Environmental Science and Health Part B* 47(9): 901-912.

Torri, S. I. and Corrêa, R. S. (2012). Downward movement of potentially toxic elements in biosolids amended soils. *Applied and Environmental Soil Science* 1: 1-7.

Ugboh, O. and Ulebor, J. U. (2011). Application of integrated soil fertility approach in the improvement of soil fertility in semi-arid ecology. *Journal of Agriculture and Social Research* 11(2): 81-86.

Usman, A. R. A., Kuzyakov, Y. and Stahr, K. (2004). Dynamics of organic C mineralization and the mobile fraction of heavy metals in a calcareous soil incubated with organic wastes. *Water, Air, and Soil Pollution* 158(1): 401-418.

Valdrighi, M. M., Pera, A., Scatena, S., Agnolucci, M. and Vallini, G. (1995). Effects of humic acids extracted from mined lignite or composted vegetable residues on plant growth and soil microbial populations. *Compost Science and Utilization* 3(1): 30-38.

Vanlauwe, B. (2004). Integrated soil fertility management research at TSBF: the framework, the principles, and their application. In: Bationo, A. (Ed.), Managing Nutrient content. *Agronomy Journal* 34: 17-25.

Wheeler, P. A. and Ward, R. B. (1990). Non-toxic farming handbook. [agris.fao.org] site visited on 10/7/2019.

Zaccardelli, M., Villecco, D., Celano, G. and Scotti, R. (2013). Soil amendment with seed meals: Short term effects on soil respiration and biochemical properties. *Applied Soil Ecology* 72: 225-231.

Zhang, H., Ding, W., Yu, H. and He, X. (2015). Linking organic carbon accumulation to microbial community dynamics in a sandy loam soil: result of 20 years compost and inorganic fertilizers repeated application experiment. *Biology and Fertility of Soils* 51(2): 137-150.

CHAPTER THREE

3.0 PHYSICO-CHEMICAL PROPERTIES OF DAKAWA SOILS AND URBAN GREEN BIOWASTE COMPOST FROM DAR ES SALAAM TANZANIA

ABSTRACT

Yields of major food crops particularly maize and rice have been low and stagnated in most developing countries including Tanzania. Nutrient depletion due to crop mining and soil erosion has been reported to be among the main factors causing low yield of such crops in Tanzania. A study was carried out between August and September, 2018 to determine the physic-chemical properties of Dakawa soils and to characterize the urban green biowastes compost (UGBC) collected from open markets in Dar es Salaam in order to determine the total chemical composition and the levels of extractable elements which are important for agriculture. The soil samples collected from Dakawa (Morogoro) and the composts made from urban green biowaste collected from open markets in Dar es Salaam were analyzed for their physic-chemical properties and nutrient concentration using established standard scientific procedures. Results indicated that Dakawa soils are sandy clay loam with a neutral pH of 7.27, low organic carbon (0.63 %) and very low total N (0.01%). The soils had high levels of extractable phosphorus and sulphur which were 27.81 and 27.93 mg kg^{-1}, respectively. The soils had medium levels of K^{+1} and Na^{+1} having values of 0.38 and 0.43 $Cmol_c$ kg^{-1}, respectively and low levels of Ca^{+2} and Mg^{+2} having values of 1.64 and 1.11 $Cmol_c$ kg^{-1}, respectively. The CEC of the soil was very low with a value of 4.2 $Cmol_c$ kg^{-1}. The levels of Fe, Cu and Mn were 62.7, 1.59, 30.98 mg kg^{-1}, respectively. These values were above the established critical ranges; this means the soil had sufficient Fe, Cu and Mn. The level of Zn was 0.9 mg kg^{-1}. This level of Zn was lower than the critical range indicating possible Zn deficiency of the soil. The urban green biowastes compost (UGBC) had a high pH of 9.52, very high organic carbon with a value of 17.37 %. Total N was 1.0 % which was below the established typical composition of N in urban composts (1.5-2.0 %). The UGBC had the C:N ratio of 17.37 which was considered to be suitable for soil application. The levels of P and K in UGBC were 0.43 and 2.15 % respectively and were considered as sufficient. The concentrations of micronutrients (Zn, Fe, Mn and Cu) were 139, 4956, 387, 8 mg kg^{-1}, respectively which were all below the established critical concentrations in urban biowaste compost. The concentration of heavy metals in UGBC was 126, 11, 9 and 9 mg kg^{-1}. These levels of Cr, Ni, As and Pb were below the maximum acceptable limit of these elements in compost set by Japan, Australia and United states. This implies that, these materials qualify for soil application. Based on these findings, the present study concluded that Dakawa soils have a pH value which is suitable for maize and rice production. However, because of low organic carbon (OC), low Zn and very low N and CEC, Dakawa soils need N and Zn from external sources. Application of organic materials is also necessary to improve OC and CEC. The UGBC had C:N ratio value which was considered suitable for soil application. However, its total N, Zn, Cu, Fe and Mn were low suggesting the need for fortification of these nutrients to improve the suitability of the material (UGBC) to be used as fertilizer.

Key words: urban green biowastes, crop productivity, yields, sustainable agriculture, soil fertility and soil nutrients.

3.1 Introduction

Low soil nutrients and water availability to crops are among the major constraints to crop productivity in the world (Hengsdijk and Langeveld, 2009). As a result, yields of major food crops particularly maize and rice have been low and stagnated in most developing countries including Tanzania. Observed increase in food production in Tanzania for example has mainly been due to expansion of agricultural land (FAO, 2014), which is not sustainable due to loss of biodiversity and potential land degradation (Cassman *et al.,* 2002; van Ittersum *et al.,* 2013). Thus, sustainable agriculture through soil fertility management to increase food productivity per unit area without degrading the environment is inevitable to attain food security (Union, 2003; Anon, 2004; The Montpellier Panel, 2013).

The quantity and availability of plant nutrient elements in the soil decrease due to removal by harvesting crops, leaching, erosion and inadequate addition of fertilizers (Baggett, 2012). Therefore, assessing present and reserved nutrient status of the soil, understanding its nutrient release pattern and nutrient holding capacity, and knowing the plant and environmental factors that impact nutrient availability are necessary to guide fertilization rates, sources, and method of application of additional nutrient (Pandey *et al.,* 2012).

Several studies have indicated that the crop production systems are very complex in nature, involving many components including biotic (e.g. microbes) and abiotic factors, and thus, for optimal productivity of the systems all of these factors have to be at their optimal levels (Chakraborty *et al.,* 2011). Despite of this fact, majority of farmers have not paid very much attention to the biotic factor. More concentration has been on abiotic factors. This has led to soil degradation and consequently, low crop productivity (Masarirambi *et al.*, 2012). Therefore, the inherent complexity of crop production systems requires integration of many factors to ensure maximum crop yields with the least risk to the environment. One way to take care of the biotic factor in the crop production systems is the deliberate use of composted biowastes as sole fertilizer or complement with inorganic fertilizers. This claim is supported with a number of literatures which have indicated that the current production of biowastes especially in urban areas is very high and that these materials have a potential to be used in agriculture (Zhang *et al.,* 2015). It has also been indicated that high production of biowaste in urban areas pose disposal problem (Reddy and Nandini, 2011). It has also been revealed that scientific and hygienic waste disposal is a serious concern (Qdais and Al-Widyan, 2016) in developing countries like Tanzania. Limited available land for waste processing and disposal has been realized in urban areas where the population density is high and rapidly increasing. About 83 % of 1 400 t of green biowastes generated per day in Dar es Salaam for example is left near the house premises in open pits, streets, markets or storm water drainage channels (Simon, 2008). This big amount of biowastes can be converted into useful fertilizing materials and consequently help to improve soil fertility of the most degraded soils in Tanzania hence improved crop productivity.

Biowastes vary significantly in their physical and chemical properties depending on types (e.g. industrial wastes, manure, biosolids (sewage sludge), biowastes etc.) and sources. Therefore, initial characterization of the biowaste intended for any study is important to determine the chemical composition and quality of the particular biowaste.

Therefore, the objective of this study was to characterize compost made from the urban green biowaste collected from open markets in Dar es Salaam in order to determine the total chemical composition and the levels of elements which are important for agriculture. The study also aimed at determining the physico-chemical properties of soils from Dakawa that was earmarked for use in a pot experiment and field trial.

3.2 Materials and methods

3.2.1 Description of the study area

The soil samples and biowaste compost were collected from Dakawa in Morogoro and Dar es Salaam, respectively. The physico-chemical properties of the soils were determined in the laboratory of Soil Science at Sokoine University of Agriculture (SUA) in Morogoro region. The biowaste compost was analysis at Geological Survey of Tanzania in Dodoma where the total chemical composition and levels of heavy metals of UGBC were determined. SUA is located at latitude 6.8405°S and longitude 37.6533°E at an altitude of 525 m.a.s.l.

3.2.2 Soil sampling, preparation and analysis

Soil samples were collected from the study site at Dakawa. Five spots were selected using zigzag method. From each spot, a sample of at least 60 kg soil was collected from a depth of 0-30 cm using hand hoe and a spade. The samples from each spot were then mixed thoroughly to make a composite bulk sample of 300 kg which was bagged, labeled and transported to SUA for pot experiment. From that bulk sample, a sub-sample of about 3 kg was obtained and replicated three times. Each replicate contained 1 kg soil sample which was bagged and labeled for laboratory determination of selected physico-chemical properties. The soil samples were analyzed for pH, electrical conductivity (EC), organic C, total N, extractable P, Total P exchangeable bases (Ca, K, Mg and Na) and the micronutrients (Cu, Fe, Zn and Mn) using standard scientific procedures as shown in Table 3.1.

Table 3.1: Methods used for determination of chemical and physical properties of the studied soil

Parameter	Method of analysis	References
pH and EC	Soil: water suspension (1:2.5) using glass electrode pH and EC meter, respectively	MacLean (1982)
Soil texture	Bouyoucos Hydrometer method, following by dispersion of soil particle	Day (1965)
Organic carbon	Wet oxidation by Black and Walkley method	Nelson and Sommers (1982)
Total Nitrogen	Micro-Kjeldahl wet digestion-distillation method	Bremner and Mulvaney (1982)
Available P	Olsen method	Olsen *et al.* (1954)
Cation Exchange Capacity (CEC)	Neutral ammonium acetate saturation method (NH4-Ac, pH 7.0) followed by Kjeldahl distillation.	Chapman (1965)
Exchangeable Bases (K^+, Mg^{2+}, Ca^{2+} and Na^+)	1N NH4-Ac (pH 7.0) method	Chapman (1965)
Extractable micronutrients (Fe, Cu, Zn and Mn)	DTPA extraction and determined by atomic absorption spectroscopy (AAS)	Lindsay and Norvel (1978)

3.2.3 Laboratory analysis for total elemental composition of the UGBC

The samples were processed and prepared for laboratory analysis following standard procedures as described by Khan and Webster (1968). Chemical compositions of the urban green biowaste were determined by using X-ray Fluorescence (XRF) method by the use of XRF machine model: PW4030 with Rh tube and spinner (Khan and Webster, 1968). Samples were crushed to reduce the size and then mixed well and ground to pass through 75 microns sieve. The ground samples were put in cup covered with polyesterpetp X-ray film 9430 500 07191 at the bottom and compressed. The samples were then placed into a calibrated XRF machine for analysis. Analysis was done by using Analytical Software at the Geological Survey of Tanzania in Dodoma.

3.3 Results and discussion

3.3.1 Dakawa soils

3.3.1.1 Physical properties of the soil

The physical properties of the studied soil are indicated in Table 3.2. The soil texture was sandy clay loam. This type of soil texture was characterized to be of moderate water infiltration rate and moderate water and nutrient retention capacity. However, soil moisture may be recharged through capillary action from the wetter zones at lower depth or from ground water table during dry season (Adesemuyi, 2014). This type of texture was therefore sub-optimum for maize and rice production. Proper soil management practices are recommended that will insure adequate organic matter buildup to enhance soil water and nutrient retention for improved yields of maize and rice crops.

Table 3.2: Analytical data of selected parameters of the studied soil from Dakawa in Morogoro region

				Macronutrients (%)	(mg kg^{-1})		Exchangeable bases (Cmolc kg^{-1})				
Soil textural class	**pH**	**CE (dS m^{-1})**	**OC (%)**	**N**	**Olsen ext. P**	**S**	**Ca^{+2}**	**Mg^{+2}**	**K^{+}**	**Na^{+}**	**CEC**
Sandy clay loam	7.27	0.11	1.18	0.01	33.59	27.69	1.62	1.11	0.43	0.38	4.2

3.3.1.2 Soil reaction, Electrical Conductivity and Organic Carbon

The Soil reaction (pH), electrical conductivity (EC) and organic carbon (OC) of the studied soil were as indicated in Table 3.2. Soil pH and SOM are the major determinants of micronutrient availability in plants and could contribute to micronutrient elements contents for crop production. The soil pH and OC of soils in the present study were 7.27 and 0.63 % respectively. The pH was considered as near neutral and OC was low based on Landon ratings (Landon, 1991). The soil pH of Dakawa is ideal for good growth and yields of maize and rice crops. This is because most of macro and micro-nutrients are soluble at pH range of 6.5 to 7.5 (Mengel *et al.,* 2001). Low OC of the studied soil is an indication of poor physical, biological and chemical health of the soil which in turn translates to poor soil fertility and productivity (FAO 2017). The low OC of the soils, therefore, suggests the need for application of organic matter for improved maize and rice yields.

The EC of the soils was 0.06 dS m^{-1}. This is considered as non-saline according to Gartley (2011) ratings. Being non-saline, the soils have no limitation to maize and rice crops production if only salinity was to be considered as the limiting factor. Msanya *et al.* (2001) stipulated that soils with EC < 1.7 dS m^{-1} do not result in yield reduction.

3.3.1.3 Total nitrogen, Extractable Phosphorus and Sulphur

The total nitrogen, extractable phosphorous and sulphur of the studied soil were as indicated in Table 3.2. Nitrogen (N) is considered a major limiting factor for maize and rice grain yields. In the present study the total N of the soils was found to be 0.01 % (Table 3.2). This is considered as very low based on Landon ratings (Landon, 1991). The current level of soil N is inadequate for good maize and rice production. Nitrogen is important for the plant metabolism as it is involved in proteins and chlorophyll biosynthesis, being necessary since the early phenological stages of the plant development (Wu *et al.,* 2016). Nitrogen is also involved in several major metabolic pathways of plants biochemistry (Robertson and Vitousek, 2009). Wu *et al.* (2016) demonstrated that, under appropriate levels of other nutrients in the soil, nitrogen provides the greatest increment to maize yield. Andrews *et al.* (2013) also reported that nitrogen is a vital plant nutrient and a major yield determining factor for maize production. Its availability in enough quantity throughout the growing season is essential for optimum growth of maize and rice. Therefore, the studied soils need to be supplemented with N for improved maize and rice production.

The extractable (Olsen method) phosphorus (P) of the soils was 27.81 mg kg^{-1} (Table 3.2). This level of soil extractable P was considered as high according to Landon (1991) and Horneck *et al.* (2011) categorization systems. The high level of extractable P could have been attributed to accumulation of P as a result of continuous application phosphate fertilizer in the studied area. Thus, the studied soils had sufficient phosphorus for maize and rice production.

The concentration of extractable sulphur of the soils was 27.93 mg kg^{-1}. This is considered as high according to Horneck *et al.* (2011) ratings. Currently the soils have sufficient sulphur for maize and rice production as has been pointed out by Horneck *et al.* (2011) that sulphur at a concentration of 20 mg kg^{-1} and above in soil is considered high.

3.3.1.4 Exchangeable bases (K, Ca, Mg and Na) and CEC

The Exchangeable bases (K, Ca, Mg and Na) and cation exchange capacity (CEC) of the studied soil were as indicated in Table 3.2. The exchangeable K in the soil was 0.38 Cmolc kg^{-1}. According to Landon (1991) ratings, this level of K was considered medium for loamy soils. Pillai (2005) reported the level of exchangeable K in soils to range between 0.07 and 0.2 Cmolc kg^{-1}. Thus, the soils of the present study have sufficient K for maize and rice production.

The exchangeable calcium concentration of the experimental site was 1.64 Cmolc kg^{-1}. This was considered as low using Landon ratings (Landon, 1991). These results indicated that the soils in the study area have insufficient Ca for the production of maize and rice. Therefore, external supply of Ca is required for improved maize and rice yields.

Magnesium is an important nutrient for plant growth and development as it activates enzymes that are essential for crop production. The exchangeable magnesium in the soil was 1.11Cmolc kg^{-1}. According to ratings by Landon (1991), this level of Mg was considered as medium. Following these results the soils in the study area has adequate magnesium level for maize and rice crops production. Magnesium activates several enzymes.

The exchangeable Na^{+} in the soils was 0.43 Cmolc kg^{-1}. This value was considered as medium based on Landon ratings (Landon, 1991). Sodium is important in calculating the exchangeable sodium percent (ESP) which is an index to evaluate the level of sodicity in soils. Sodicity is an important factor in evaluating the soil for its suitability in crop production. The ESP is calculated using the equation below.

$$\text{ESP} = \frac{Exchangeable\ Sodiun\ (Cmolc/kg)}{CEC\ (Cmolc/kg)} x\ 100$$

The calculated ESP value was 10.24 % which was considered as slightly sodic according to Msanya *et al.* (2001) ratings. This value of ESP (10.24 %) can cause up to 50% yield reduction of sensitive crops like maize and beans. However, it has minor effect on semi-tolerant crops like rice, sorghum, wheat and sugarcane (Msanya *et al.*, 2001).

The cation exchange capacity (CEC) is an important indicator of soil fertility as it helps to determine the capacity of a soil to hold nutrients and eventually release them for plant uptake (Aprile and Lorandi, 2012). The CEC of the studied soils was 4.2 Cmolc kg^{-1}. This was considered as very low based on Landon categorization (Landon, 1991). Soils with CEC below 15 (cmolc kg^{-1}) are considered to be of low fertility status (Landon, 1991). To improve the CEC of the soils, application of organic materials such as urban green biowaste is necessary.

3.3.1.5 Micronutrients

The levels of micronutrients (Zn, Cu, Mn and Fe) of the studied soil were as indicated in Table 3.3. The soil extractable micronutrients (Mn, Fe, Cu and Zn) were 30.98, 62.7, 1.59

and 0.9 mg kg^{-1}, respectively (Table 3.2). The established critical ranges of Mn, Fe, Cu and Zn are 1.0 to 5.0, 2.5 to 5.0, 0.2 to 0.4 and 0.2 to 2.0 mg kg^{-1} respectively. The values of Mn, Fe and Cu were above the established critical ranges. This means that the studied soils have sufficient amounts of Mn, Fe and Cu for maize and rice production. The level of zinc (Zn) was lower than the established critical range (Oluwatosin and Ogunkunle, 1991; Sims and Johnson, 1991; Tandon, 1995). This is an indication of possible Zn deficiency. Therefore, supplementation of Zn is necessary for high yields of maize and rice crops.

Table 3.3: Analytical data of selected micronutrients of the studied soil from Dakawa in Morogoro region

Nutrient	Value (mg kg^{-1})
Zn	0.9
Cu	1.59
Fe	62.7
Mn	30.98

3.3.2 Urban green biowaste

3.3.2.1 Chemical properties of agricultural importance in urban green biowaste compost

Table 3.4 presents pH, electrical conductivity (EC), organic carbon (OC) and total nitrogen (TN) of the studied urban green biowaste compost.

Table 3.4: Selected chemical properties of agricultural importance in urban green biowaste compost from Dar es Salaam

Parameter	Value
pH (H_2O)	9.52
EC (dS m^{-1})	0.004
OC (%)	17.37
TN (%)	1.00
C:N ratio	17.37

The pH of an organic fertilizer is crucial, because it alters the pH of the soil to which it is applied (Li-Xian *et al.*, 2007; Santillan *et al.*, 2014). The soil root zone, especially the rhizosphere, is the active zone of microbial and root activity (Lagos *et al.*, 2015). The pH of the rhizosphere zone is, therefore, critical in deciding microbial activity (Wang *et al.*, 2016), which in turn regulates the innumerable chemical reactions involved in nutrient transformations and uptake by plant roots. The ideal pH range for active growth and development of plants and microbes is 6.5–7.5 (Wang *et al.*, 2016). The studied UGBC had a pH of 9.52. This pH value obtained is higher than the ideal pH range. This implies that a long-term use of UGBC on soils would possibly lead to development of sodicity if applied in soils with high sodium content.

Electrical conductivity (EC) is a measure of soluble salts. A high salt content is not desirable, because very high concentrations of soluble salts damage plants through specific ion effects and plasmolysis (Turan *et al.*, 2010; Chauhan *et al.*, 2016). Organic fertilizer with EC values less than 3.5 dS m^{-1} are considered safe for soil application (Chen Yiqun *et al.*, 2014). The UGB had EC of 0.004 dS m^{-1} which was considered safe for soil application.

The UGBC had high OC with a value of 17.37 %. Organic carbon is an important parameter with respect to the maturity of the compost/manure as it is used in the C:N ratio computation. The C:N ratio is an important parameter which determines the quality of organic materials for agricultural use. The ideal C:N ratio range for organic fertilizer is 10:1–25:1 (Kumar *et al.*, 2010; Nada, 2015). The studied UGBC had a C:N ratio of 17.37 which was considered suitable for soil application.

3.3.2.2 Macro and micro-nutrient concentration in the urban green biowaste compost

Table 3.5 presents the concentration of selected macro and micro-nutrient in the urban green biowaste compost.

Table 3.5: The XRF analytical results of selected macro and micro-nutrient concentration in the urban green biowaste compost from Dar es Salaam

Nutrients	UGBC	Typical nutrient composition of urban compost (Roy *et al.*, 2006)
Macrontrients	%	%
N	1.00	1.5-2.0
P	0.43	0.44
K	2.15	1.25
Micronutrients	mg kg^{-1}	mg kg^{-1}
Zn	139	705
Fe	4 956	10 000
Mn	387	740
Cu	8	375

3.3.2.2.1 Macronutrients

The levels of macronutrients (N, P and K) of the studied UGBC were as indicated in Table 3.5. The total N was 1.00 %. This amount of N in urban green biowaste compost is low compared to the concentration of N in typical nutrient composition of urban compost. This implies that application of UGBC to soils could not release sufficient amount of N to meet maize and rice requirement. In addition, not all the N present in the UGBC will be released at once, i.e, only 10 % to 15 % of N present in the compost would be mineralized in the first season of application (Hagemann *et al.,* 2016). Thus, fortification of N and some micronutrients (Zn, Cu, Fe and Mn) in biowaste is necessary to improve it suitability for use in crop production. Otherwise its use should be supplemented with inorganic fertilizer to meet crop nutrients requirement.

The concentration of P in the studied UGBC was 0.43 %. This level of P was almost equal to the established typical concentration of P in urban compost (Table 3.5). This means that use of UGBC as fertilizer would release substantial amount of P for maize and rice production.

The concentration of K was 2.15 %. This amount of K in the studied UGBC was almost twice that of established typical concentration of K in urban compost (Table 3.5). This implies that application of UGBC to soils would release sufficient K for maize and rice production.

3.3.2.2.2 Micronutrients

The levels of micronutrients (Zn, Cu, Mn and Fe) of the studied UGBC as indicated in Table 3.5. The concentrations of micronutrients (Zn, Fe, Mn and Cu) were 139, 4956, 387, 8 mg kg^{-1}, respectively. All micronutrient concentrations were found to be lower than that of established typical concentration of micronutrients in urban compost (Table 3.5). Thus, UGBC has insufficient amount of micronutrients suggesting that application of UGBC to soils would require large quantity for it to supply adequate amount of micronutrients for better growth and yield of maize and rice crops. Alternatively, micronutrients should be supplemented in the inorganic form to meet plants requirement.

3.3.2.3 Elements of environmental concern

Table 3.6 presents the total amounts of Chromium (Cr) Nickel (Ni), Arsenic (As), and Lead (Pb) of the studied UGBC. Heavy metals accumulation in soils is now a major concern in agricultural production due to the adverse effects on food safety and marketability, crop growth due to phytotoxicity and environmental health of soil organisms. Metal toxicity has high impact and relevance to plants and consequently it affects the ecosystem, where the plants form an integral component.

Table 3.6: The XRF analytical results of selected elements of environmental concern in the UGB

Element	**Value (mg kg^{-1})**
Cr	126
Ni	11
As	9
Pb	9

The concentration of Cr in UGBC was 126, 11, 9 and 9 mg kg^{-1}. These levels of Cr, Ni, As and Pb were below the maximum acceptable limit of these elements in compost set by Japan, Australia and United states. The results, therefore, indicates that, these materials qualify for soil application.

Table 3.7: Maximum heavy metal concentration acceptable for compost in different countries

Country	Cr	Ni	As mg kg^{-1}	Pb
Japan	500	300	50	100
Australia	400	60	20	200
United states	1200	420	41	300

Source: Gong *et al.* (2019).

3.4 Conclusions and recommendations

3.4.1 Conclusions

Results from the present study have indicated:

- Dakawa soil is sandy clay loam and non-saline with nearly neutral pH, low OC and very low N and CEC and insufficient Ca and Zn.
- Dakawa soils have sufficient P, S, K, Mg, Mn, Fe and Cu.
- Biowastes from Dar es Salaam were found to have very high pH and OC, fairly high K and sufficient P.
- Biowastes had very low N, low Zn, Cu, Fe and Mn.
- Heavy metals (Cr, Ni, Pb and As) in UGBC were found to be below the established maximum acceptable limits of Japan, Australia and United states.

3.4.2 Recommendations

- Dakawa soils need to be applied with organic materials in order to increase organic matter hence increase in OC and CEC.

- Dakawa soils need N and Zn supplementation for improved maize and rice yields.
- When biowaste from Dar es Salaam are used in maize and rice production, they should be supplemented with inorganic fertilizers rich in N and Zn, Cu, Fe and Mn nutrients.
- Another option could be fortification of the biowaste with N and Zn, Cu, Fe and Mn nutrients in order to improve their suitability for agricultural use as fertilizer especially for maize and rice production.

REFERENCES

Adesemuyi, E. A. (2014). Suitability assessment of soils for maize (Zea mays) production in a humid tropical area of South-western Nigeria. *International Journal of Advance Resources* 1(2): 538-546.

Andrews, M., Raven, J. A., and Lea, P. J. (2013). Do plants need nitrate? The mechanisms by which nitrogen form affects plants. *Annals of Applied Biology,* 163(2): 174-199.

Anon, J. E. (2004). Realizing the promise and potentials of African agriculture. *Inter Academy Council*. 267pp.

Aprile, F. and Lorandi, R. (2012). Evaluation of cation exchange capacity (CEC) in tropical soils using four different analytical methods. *Journal of Agricultural Science* 4(6): 278-289.

Baggett, J. (2012). The importance of soil testing. Cornell university cooperative extension of Schenectady County.

Bremner, J. M. and Mulvaney, C. S. (1982). Total nitrogen. In: *Methods of Soil Analysis*. Part 2. Agronomy Monograph 9, American Society of Agronomy, Madison, Wisconsin, USA. pp 1149 -1170.

Cassman, K. G., Dobermann, A. and Walters, D. T. (2002). Agroecosystems, nitrogen-use efficiency, and nitrogen management. *AMBIO: A Journal of the Human Environment* 31(2): 132-141.

Chakraborty, A., Chakrabarti, K., Chakraborty, A. and Ghosh, S. (2011). Effect of long-term fertilizers and manure application on microbial biomass and microbial activity of a tropical agricultural soil. *Biology and Fertility of Soils* 47(2): 227-233.

Chapman, H. D. (1965). Cation-exchange capacity. In: *Methods of Soil Analysis Part 3: Chemical Methods: SSSA Book series no. 5.* (*Edited by Sparks D. L.*), Soil Science of America Inc. 5th Edition. pp. 891-901.

Chauhan, A., Rajput, N., Kumar, D., Kumar, A. and Chaudhry, A. K. (2016). Effect of different salt concentration on seed germination and seedling growth of different varieties of oat (*Avena sativa* L.). *International Journal of Information Resources Review* 3(7): 2627-2632.

Chen, Y., Yu, F., Liang, S., Wang, Z., Liu, Z. and Xiong, Y. (2014). Utilization of solar energy in sewage sludge composting: Fertilizer effect and application. *Waste Management* 34(11): 2014-2021.

Day, P. R. (1965). Particle fractionation and particle size analysis. In: Black, C. A., Evans, D. D, White, J. L., Ensminger, L. E. and Clark F. E. (Eds.). Methods of soil analysis: Physical and mineralogical methods, American Society of Agronomy, Madison, Wisconsin. Pp 545-566.

FAO, Food and Agriculture Organization (2014). Hunger Portal. [http://www.fao.org/ hunger/en/] site visited on 23/06/2019.

FAO, Food and Agriculture Organization (2017). Soil Organic Carbon: the hidden potential. Food and Agriculture Organization of the United Nations Rome, Italy.

Gartley, K. L. (2011). Recommended methods for measuring soluble salts in soils. *Recommended Soil Testing Procedures for the Northeastern United States. Northeastern Regional Publication* 493: 87-94.

Gong, Q., Chen, P., Shi, R., Gao, Y., Zheng, S. A., Xu, Y., Shao, C. and Zheng, X. (2019). Health Assessment of Trace Metal Concentrations in Organic Fertilizer in Northern China. *International Journal of Environmental Research and Public Health* 16(6): 1031-1052.

Hagemann, N., Harter, J., and Behrens, S. (2016). Elucidating the impacts of biochar applications on nitrogen cycling microbial communities. In *Biochar Application* (pp. 163-198). Elsevier.

Hengsdijk, H. and Langeveld, J. W. A. (2009). *Yield trends and yield gap analysis of major crops in the world* (No. 170). Wettelijke Onderzoekstaken Natuur and Milieu.

Horneck, D. A., Sullivan, D. M., Owen, J. S. and Hart, J. M. (2011). Soil test interpretation guide.

Khan, S. U. and Webster, G. R. (1968). Determination of gypsum in solonetzic soils by an x-ray technique. *Analyst* 93(1107): 400-402.

Kumar, M., Ou, Y. L., and Lin, J. G. (2010). Co-composting of green waste and food waste at low C/N ratio. *Waste management* 30(4): 602-609.

Lagos, L., Maruyama, F., Nannipieri, P., Mora, M. L., Ogram, A. and Jorquera, M. A. (2015). Current overview on the study of bacteria in the rhizosphere by modern molecular techniques: a mini review. *Journal of Soil Science and Plant Nutrition* 15(2): 504-523.

Landon, J. R. (1991). Booker Tropical Soil Manual, A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. John Wiley and Sons Publisher, New York. 155pp.

Lindsay, W. L. and Norvell, W. A. (1978). Development of a DTPA Soil Test for Zinc, Iron, Manganese, and Copper In: *Methods of Soil Analysis Part 3: Chemical Methods: SSSA Book series no. 5*. (*Edited by Sparks D. L.*), Soil Science of America Inc. 5th Edition. pp. 421-428.

Li-Xian, Y., Guo-Liang, L., Shi-Hua, T., Gavin, S. and Zhao-Huan, H. (2007). Salinity of animal manure and potential risk of secondary soil salinization through successive manure application. *Science of the Total Environment* 383(1-3): 106-114.

Masarirambi, Z. H., Zong, Z. Q., Li, S. X. and Chen, B. M. (2012). Nitrate accumulation in vegetables and its residual in vegetable fields. *Environmental Science* 23: 79-83.

Mclean, E. O. (1982). Soil pH Lime requirement, In: *method of Soil analysis*, Part 2, Chemical and mineralogical Properties 2nd Ed (Edited by Page A.L Miller, and Keeney, DR) American Society of Agronomy. Madison, Wisconsin. pp.561-573.

Mengel, K., Kirkby, E. A., Kosegarten, H. and Appel, T. (2001). *Principles of Plant Nutrition.* 5th Edition, Kluwer Academic Publishers, Dordrecht, The Netherlands. http://dx.doi.org/10.1007/978-94-010-1009-2.

Msanya, B. M., Kimaro, D. N., Kileo, E. P., Kimbi, G. G. and Munisi, A. I. M. (2001). Land resources inventory and suitability assessment for the production of the major crops in the eastern part of Morogoro Rural District, Tanzania. Soils and Land resources of Morogoro Rural and Urban Districts, Volume 3. Department of Soil Science, Faculty of Agriculture, Sokoine University of Agriculture, Morogoro, Tanzania. 74pp.

Nada, W. M. (2015). Stability and maturity of maize stalks compost as affected by aeration rate, C/N ratio and moisture content. *Journal of Soil Science and Plant Nutrition* 15(3): 751-764.

Nelson, D. W. and Sommers, L. E. (1982). Total carbon, organic carbon, and organic matter. In: *Methods of Soil Analysis Part 3: Chemical Methods: SSSA Book series no. 5.* (*Edited by Sparks D. L.*), Soil Science of America Inc. 5th Edition. pp. 961-1010.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. (1954). *Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate.* USDA circular 939. US Government Printing Office, Washington DC. 89pp.

Oluwatosin, G. A. and Ogunkunle, A. O. (1991). Suitability rating of some soils of the savanna zone of southwestern Nigeria for maize production. *Nigerian Journal of Soil Science* 10: 1-24.

Pandey, S., Thapa, K. B. and Oli, I. B. (2012). Correlations of available phosphorus and potassium with soil pH and organic matter content at different soil reactions categories in soils of Western Development Region, Nepal. *Journal of Chemical, Biological and Physical Sciences* (*JCBPS*) 3(1): 128-136.

Pillai, K. G. (2005). Rice (Oryza sativa L.). World fertilizer use manual. Rice crop Data. In: [www.fertilizer.org/ifa/bublicat/html/pubman/rice.htm] site visited on 23/06/2019.

Qdais, H. A. and Al-Widyan, M. (2016). Evaluating composting and co-composting kinetics of various agro-industrial wastes. *International Journal of Recycling of Organic Waste in Agriculture* 5(3): 273-280.

Reddy, P. S. and Nandini, N. (2011). Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site. *Nature, Environment and Pollution Technology* 10(3): 415-418.

Robertson, G. P. and Vitousek, P. M. (2009). Nitrogen in agriculture: balancing the cost of an essential resource. *Annual Review of Environment and Resources* 34: 97-125.

Roy, R. N., Finck, A., Blair, G. J. and Tandon, H. L. S. (2006). Plant nutrition for food security. *A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin* 16: 368-372.

Santillán, Y. M., Moreno, F. P., Garcia, F. P. and Sandoval, O. A. A. (2014). Effect of the application of manure of cattle on the properties chemistry of soil in Tizayuca, Hidalgo, Mexico. *International Journal of Applied* 4(3): 67-72.

Simon, A. M. (2008). *Analysis of Activities of Community Based Organizations Involved in Solid Waste Management, Investigating Modernized Mixtures Approach: The case of Kinondoni Municipality, Dar es Salaam, Tanzania*. The case of Kinondoni Municipality, Dar es Salaam, Tanzania. M.Sc. thesis, Wageningen University. 77pp.

Simon, F., Mtei, K. M. and Kimanya, M. (2016). Heavy metals contamination in agricultural soil and rice in Tanzania: A Review. *International Journal of Environmental Protection and Policy* 4(1): 16-23.

Sims, J. T., and Johnson, G. V. (1991). Micronutrient soil tests. *Micronutrients in Agriculture*, 2: 427-476.

Tandon, H. L. S. (2005). Methods of Analysis of Soils, Plants, Waters, Fertilisers and Organic Manures. Fertiliser Development and Consultation Organisation. 204-204A Bhanot Corner, 1-2 Pamposh Enclave. New Delhi – 110048, India. 204pp.

The Montpellier Panel (2013). Sustainable Intensification: A New Paradigm for African Agriculture, London Agriculture for Impact 15 Princes Gardens South Kensington Campus Imperial College London SW7 1NA.

Turan, M. A., Elkarim, A. H. A., Taban, N., and Taban, S. (2010). Effect of salt stress on growth and ion distribution and accumulation in shoot and root of maize plant. *African Journal of Agricultural Research* 5(7): 584-588.

Union, A. (2003). Comprehensive Africa agriculture development programme. *Midrand, South Africa: NEPAD*.

Van Ittersum, M. K., Cassman, K. G., Grassini, P., Wolf, J., Tittonell, P. and Hochman, Z. (2013). Yield gap analysis with local to global relevance—a review. *Field Crops Research*, *143*: 4-17.

Wang, J., Xue, C., Song, Y., Wang, L., Huang, Q. and Shen, Q. (2016). Wheat and rice growth stages and fertilization regimes alter soil bacterial community structure, but not diversity. *Frontiers in Microbiology* 7: 1207-1219.

Wu, L., Yuan, S., Huang, L., Sun, F., Zhu, G., Li, G. and Wang, F. (2016). Physiological mechanisms underlying the high-grain yield and high-nitrogen use efficiency of elite rice varieties under a low rate of nitrogen application in China. *Frontiers in Plant Science* 7: 1024-1035.

Zhang, H., Ding, W., Yu, H. and He, X. (2015). Linking organic carbon accumulation to microbial community dynamics in a sandy loam soil: result of 20 years compost and inorganic fertilizers repeated application experiment. *Biology and Fertility of Soils* 51(2): 137-150.

CHAPTER FOUR

4.0 SUSTAINABLE MAIZE AND RICE PRODUCTION USING URBAN GREEN BIOWASTES COMPOST FROM OPEN MARKETS OF DAR ES SALAAM, TANZANIA

ABSTRACT

Maize and rice are the primary staple cereal food crops in Tanzania, ranking first and second, respectively. The two crops are also used as cash crops in some parts of the country. Despite their importance as food and cash crops, their yields per unit area are generally very low. Maize averages 1.4 t ha^{-1} while the potential yield is 5 t ha^{-1} and rice averages 0.5-2 t ha^{-1} for upland ecologies and 4.5-6.0 t ha^{-1} for irrigated ecologies compared to the potential yield of 5 t ha^{-1} and 10-11 t ha^{-1}, respectively. Nutrient depletion among other factors is said to be the major factor contributing to such low yields. A pot experiment was carried out from October 2018 to January 2019 to assess the potential of pelletized urban green biowaste compost (PUGBC) and non-pelletized urban green biowaste compost (NPUGBC) from Dar es Salaam as organic fertiliser for production of maize and rice crops. A split plot design was adopted whereby PUGBC and NPUGBC were used as the main plots and their rates considered as subplots. Each form of biowaste consisted of six rates regarded as subplots in this case. The rates for PUGBC were 0 mg N (PUGBC) kg^{-1} soil, 150 mg N (PUGBC) kg^{-1} soil, 300 mg N (PUGBC) kg^{-1} soil, 600 mg N (PUGBC) kg^{-1} soil, 600 mg N (UREA) kg^{-1} soil and 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil . The same rates were used for NPUGBC. Plant growth and yield parameters were used to evaluate the response of rice and maize to the biowaste compost applied. The use of PUGBC from 0 to 600 mg N kg^{-1} soil increased heights from 59.19 to 82.52 cm for maize and from 80.43 to 84.87 cm for rice. Maize dry matter yield increased from 3.8 to 8.77 g pot^{-1} and rice grain weight pot^{-1} increased from 14.84 to 26.19 g. The increase in all cases was statistically significant (P=0.05). However, the highest maize and rice plant heights of 92.61cm and 100.43 cm, respectively and maize dry matter yield of 14.46 g pot^{-1} were recorded in combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil. Maximum number of effective tillers (9.62), number of panicle per plant (9.62), panicle length (21.8 cm), panicle weight (2.982 g) and grain weight per pot (85.17 g) for rice crop were registered in sole application of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil). Results of NPUGBC followed the same trend as those of PUGB for both maize and rice crops. The overall results indicated that combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) or 300 mg N (NPUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) improved maize growth and yield parameters. The use of inorganic fertilizer alone (600 mg N (UREA) kg^{-1} soil) improved rice growth parameters and yield. Based on the findings of the present study it is recommended that use of combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) or 300 mg N (NPUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) is the best option for better maize yield and use of inorganic fertilizer alone (600 mg N (UREA) kg^{-1} soil) is the best option for rice production. However, these results require verification in the field.

Key words: Maize, Rice, Organic fertilizer, urban green biowaste

4.1 Introduction

Sustainable crop cultivation needs appropriate treatment of nutrient resources and conservation of soil fertility. But depletion of plant nutrients is a main problem to sustain agricultural production and productivity in many countries including Tanzania. Productivity of maize and rice crops in Tanzania has been reported to be very low. Maize yield averages 1.4 t ha^{-1} while the potential yield is 5 t ha^{-1} and rice yields 0.5-2 t ha^{-1} for upland ecologies and 4.5-6.0 t ha^{-1} for irrigated ecologies compared to the potential yield of 5 t ha^{-1} and 10-11 t ha^{-1}, respectively (Luzi-Kihupi *et al.*, 2015). The two crops are the primary staple cereal food crops ranking first and second, respectively in Tanzania (Kahimba *et al.*, 2014; Lyimo *et al.*, 2014). Maize and rice crops are also used as cash crops in regions like Morogoro and Mbeya. The main reason among others for such low productivity is low soil fertility mainly deficiency of nitrogen (Yin *et al.*, 2014).

Soil fertility is defined as the capacity of a soil to supply nutrients in adequate amounts and in proper balance for sustainable biological productivity, maintain environmental quality and promote plant and animal health (Hartemink, 2006; Roba, 2018). One of the most important nutrient input sources into the soil is fertilizer. Fertilizer is any substance, organic or inorganic that supplies plants with the necessary nutrients for plant growth and maximum yield (Alimi, 2007).

Cultivated soils do not usually have sufficient amounts of plant nutrients for high and sustained productivity (Quansah, 2010) due to soil degradation including soil acidification, soil organic matter reduction and decrease in the soil aggregate stability (De Meyer, 2011). In one hand, continuous cultivation without soil nutrients replenishment coupled with total crop residue harvest leads to nutrient depletion, reduced soil organic matter and decrease in soil aggregate stability (De Meyer, 2011; Roba, 2018). On the other hand, continuous cultivation with inorganic fertilizer application, especially N fertilizers leads to soil degradation (Han, 2016; Roba, 2018).

Emerging facts illustrated that combined application of organic and inorganic fertilizers increases the productivity of maize, wheat and rice, (Amujoyegbe *et al.*, 2007; Mahmood *et al.*, 2017; Moe *et al.*, 2017) without negative effect on crop and grain quality (Abedi *et al.*, 2010). It also improves soil fertility through increasing plant residues as compared to the use of organic or inorganic fertilizers separately.

Integrated nutrient management system is an alternative and is characterized by reduced input of inorganic fertilizers and combined use of inorganic fertilizers with organic materials such as green urban biowaste, animal manures, crop residues, green manure and composts (Negassa *et al.*, 2007; Chen, 2008). Combined use of organic and inorganic fertilizers plays a significant role in sustaining soil fertility (Ali *et al.*, 2009; Elkholy *et al.*, 2010; Vanlauwe *et al.*, 2010). The use of organic fertilizers together with inorganic fertilizers has also a higher positive effect on microbial biomass and enhances soil health (Elkholy *et al.*, 2010), improves the use efficiency of recommended inorganic fertilizer and reduces its cost (Ali *et al.*, 2009; Abedi *et al.*, 2010). However, because of the diversity of organic materials in terms of nutrient content and suitability for crop production as a function of type of material, source and handling (Kokkora, 2008) each organic material intended for agricultural use should be characterized and assessed for its suitability for crop production. Several researchers have reported on animal manures, crop residues, green manure and composts as source of nutrients for crop production (Widowati *et al.*, 2012; Negassa *et al.*, 2007; Chen, 2008). Use of these materials in agriculture is limited by their availability (Kayeke *et al.*, 2007). None or very few studies have been conducted to assess the suitability of urban green biowaste for crop production in Tanzania. Urban green biowaste production has been increasing daily in big cities of Tanzania particular Dar es Salaam city. For example, Dar Es Salaam produces between 1040 and 1400 t day^{-1} and about 83 % of these wastes are left near the house premises in open pits, streets, markets or storm water drainage channels (Simon, 2008). This study therefore aimed at evaluating the agronomic potential of urban green biowaste compost from Dar es Salaam as organic fertilizer for maize and rice production.

4.2 Materials and methods

4.2.1 Description of the study area

This study was conducted in a screen house located at SUA, Morogoro (6.8405°S, 37.6533°E), Soil samples used in this experiment were collected from Tanzania Agricultural Research Institute (TARI)-Dakawa, located between (7.42605°S, 37.70272°E) and (7.4267°S, 37.7045°E). The site is situated in Morogoro region at altitude 154 m above sea level. The soils at Dakawa are sandy clay loam classified by Mbaga *et al.* (2017) as Inceptisol (Soil Taxonomy) and Cambisol (World Reference Base). Morogoro region is one of the major rice and maize producing regions in Tanzania. Dakawa ward in Mvomero district is one of the major rice and maize growing areas in Morogoro. Therefore, Dakawa site is considered to have high potential for rice and maize production (Makoi and Mmbaga, 2018).

4.2.2 Materials and methods

Pelletized and non-pelletized urban green biowaste composts (Plate 4.1) were used as organic fertilizer and a source of nitrogen. A split plot design was adopted whereby pelletized and non-pelletized urban green bio-wastes were the main plots. Each type of UGB was applied at rates of 150, 300, and 600 mg N kg^{-1}, soil. 0 mg N kg^{-1} soil and 600 mg N (urea) kg^{-1}soil were used as absolute (zero) and positive controls, respectively.

Another treatment was a combination of inorganic fertilizer (Urea) and UGBC at rates of 300 mg N (Urea) and 300 mg N (UGBC) kg^{-1}soil. These application rates were used as subplots. The experimental units (maize and rice crops in pots) were randomly arranged in blocks and replicated three times. The blocking variable was sunlight gradient in the screen house, which occurred during the mornings and evenings. The pots were randomly arranged in blocks (replicates) to counteract light gradient. Phosphorus (P) as triple super phosphate (TSP) and potassium (K) as muriate of potash (MOP) were applied as basal application rate. Both K and P were applied at a rate of 240 kg ha^{-1}(i.e. 0.95 g MOP and 2.39 g TSP per 4 kg of soil). UGBC, MOP and TSP were applied at planting time. Urea was applied as top dressing in two splits to the plots treated with sole inorganic fertilizer and the one with a combined fertilization. First split (50%) was applied at 15 and 25 days after emergence (DAE) for maize and rice crops, respectively. The second split (50%) was applied at 35 and 50 DAE for maize and rice crops, respectively.

Plate 4.1: Pelletized (A) and non-pelletized (B) urban green biowaste composts

Eight maize (SEEDCO-SC 403 variety) and rice (TXD 306 variety) seeds were sown in eight-litre plastic pots containing 4 kg of 8-mm sieved soil. Potted soil was moistened to field capacity and equilibrated for one day before sowing. Water content was maintained close to field capacity throughout the experiment (45 DAE) for maize crop and for the first 21 days for rice crop before continuously flooding (flooding depth was made not to exceed a maximum of 10 cm above soil surface to allow tillering) up to maturity of the plant. Thinning was done at 15 DAE to remain with two and three seedlings per pot for maize and rice crops, respectively.

4.2.3 Data collection

Plant growth and yield parameters were recorded. Maize plant height (cm), number of green leaves, number of dry leaves, stem girth (cm) and chlorophyll content were measured at 45 DAE. Two maize plants were harvested by cutting at 1 cm above the soil surface at 45 DAE for dry biomass yield measurement. Shoots were washed with distilled water, air dried for 48 hours and then oven dried at 65°C to constant weight and weighed to obtain dry matter yields (DMY). Data collected for rice crop were plant height, number of effective tillers, number of non-effective tillers, number of panicles per plant, panicle length, panicle weight, 100-grain weight and grain weight per pot. Plant height was measured using a tape measure and leaf chlorophyll content was measured using atLEAF Digital chlorophyll meter device. Grain weights were measured by electronic weighing balance and were adjusted to weight at 14% moisture content.

4.2.4 Data analysis

Maize and rice growth and yield parameters were subjected to two-way analysis of variance (ANOVA) using GenStat 15th Edition. Mean separation was done by Tukey's Honestly Significant Difference (HSD) Test (P=0.05). The coefficient of variation (CV) in percentage was recorded.

4.3 Results and discussion

4.3.1 Overall effect of PUGBC and NPUGBC on growth and yield of maize.

Table 4.1 below presents the overall effects of urban green biowaste compost on growth and yield of maize.

Table 4.1: Overall effects of PUGBC and NPUGBC on maize plant growth and dry biomass yield

Type of biowaste	Plant height(cm)	No. of Green leaves per plant	Chlorophyll content	Stem girth (cm)	Dry matter yield (g pot^{-1})
PUGBC	77.69	7	40.51	3.89	8.36
NPUGBC	74.91	7	40.69	3.81	7.75
L.S.D (0.05)	3.032	0.4	1.30	0.79	1.19
Significance	ns	ns	ns	ns	ns

L.S.D = least significance difference, ns = non-significant

Maximum plant height (77.69 cm), stem girth (3.89 cm) and dry matter yield (8.36 g pot^{-1}) were attained in PUGBC while the maximum leaf chlorophyll content (40.69) was produced in NPUGBC. Both PUGBC and NPUGBC produced the same number of green leaves per plant. The difference between application of PUGBC and NPUGBC was insignificant (P=0.05) across all parameters. Insignificant difference between the two forms of biowaste compost could be due to the fact that the same materials were used but in different forms, some were made of pellets for easy application and handling while others were left in non-pellets form. However, the difference observed could be due to additional nutrients present in the clay soil used for binding up the biowastes when making pellets. Generally, use of PUGBC and NPUGBC improved growth and yield of maize significantly (P=0.05) as it is revealed in their different rates applied (Tables 4.2 and 4.3).

4.3.2 The effects of PUGBC on maize growth and dry biomass yield

The effects of PUGBC on maize plant height, stem girth and dry biomass are presented in Table 4.2.

4.3.2.1 Plant height and stem girth

Highest plant height (92.61 cm) and stem girth (4.87 cm) were recorded in the combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} (Plate 4.2). It was followed by sole inorganic fertilizer (600 mg N (Urea) kg^{-1} soil) which produced plants with 83.02 cm height and 4.24 cm stem girth.

Table 4.2: The effects of PUGBC on maize plant height, stem girth and dry biomass yield

Treatment	Plant height (cm)	Stem girth (cm)	Dry matter yield (g pot^{-1})	Chlorophyll content	No. of green leaves	No.of dry leaves,
0 mg N kg^{-1} soil	59.19 a	3.27 a	3.80 a	25.46 a	4.826 a	4.01 c
150 mg N (PUGBC) kg^{-1} soil	67.36 ab	3.44 abc	5.48 ab	30.41 ab	5.51 ab	2.67 abc
300 mg N (PUGBC) kg^{-1} soil	73.11 abc	3.62 abc	6.64 ab	31.42 ab	6.16 abcd	2.34 abc
600 mg N (PUGBC) kg^{-1} soil	82.52 cd	3.64 abc	8.77 ab	49.44 c	7.16 bcde	2.01 a
600 mg N (UREA) kg^{-1} soil	83.02 cd	4.24 cd	9.18 bc	51.36 cd	7.92 cdef	1.34 a
300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	92.61 d	4.87 d	14.46 d	55.48 d	9.49 f	1.34 a
F-Prob.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	6.4	7.4	18.6	4.9	10.3	24.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P=0.05).

Note: *PUGBC = pelletized urban green biowaste compost, CV = coefficient of variations, F-Prob. = F-Probability value*

The shortest plant (59.19 cm) and smallest stem girth (3.27 cm) were obtained in the control which was significantly different (P=0.05) over combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} and sole application of 600 mg N (UREA) kg^{-1} soil and sole application of 600 mg N (PUGBC) kg^{-1} soil for plant height case (Table 4.1). Use of sole inorganic fertilizer (600 mg N (Urea) kg^{-1} soil) and sole application of PUGBC (600 mg N (PUGBC) kg^{-1} soil) produced comparable (P=0.05) plant heights (83.02 cm and 82.52 cm, respectively). The effects of NPUGBC on plant height and stem girth followed the same trend as those of pelletized PUGBC (Table 4.2). The significant influences on plant height and stem girth due to combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil might be due to sufficient macro and micronutrients in these fertilizers and enhanced absorption of nutrients by plants. It might also be due to the enhanced metabolic activities which led to an increase in various plant metabolites responsible for cell division and elongation (Siavoshi *et al.*, 2013). Adamu and Leye (2012) reported that plant height of corn had a high positive correlation with the addition of manure alone or with inorganic fertilizers.

Plate 4.2: Response of maize to different treatments under pot experiment

Measurement of leaf chlorophyll concentration and number of leaves is a basic tool of growth analysis. The two parameters are directly related with both biological and economical yield. In case of any plant, leaves are important organs which have an active role in photosynthesis (Krishnaprabu and Grace, 2017). On the other hand, leaf chlorophyll concentration is often well correlated with plant metabolic activity (e.g., photosynthetic capacity and RuBP carboxylase activity; Fanizza *et al.*, 1991), as well as leaf N concentration. To achieve high yield, maximization of leaf area and leaf chlorophyll concentration are important factors (Krishnaprabu and Grace, 2017). In the present study the greatest leaf chlorophyll content (55.48) and number of green leaves (9.49) were recorded in the treatment combination of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil which was significantly different (P=0.05) over control which produced plants with (4.826) number of green leaves and (25.46) leaf chlorophyll content

(Table 4.1). Sole application of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) and use of PUGBC alone (600 mg N (PUGBC) kg^{-1} soil) produced statistical similar (P=0.05) number of green leaves (7.92 and 7.16 respectively) and leaf chlorophyll content (51.36 and 49.44 respectively) as those of combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil.

4.3.2.2 Number of leaves

The lowest number of dry leaves (1.34) was recorded in the treatment combination of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil and in an exclusive application of 600 mg N (UREA) kg^{-1} soil. It was followed by sole application of PUGBC (600 mg N (PUGBC) kg^{-1} soil) which produced (2.01) number of dry leaves. The highest number of dry leaves (4.01) was recorded in the control treatment which was significantly different (P =0.05) over treatment combination of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil, and exclusive application of 600 mg N (UREA) kg^{-1} soil and the sole application of PUGBC (600 mg N (PUGBC) kg^{-1} soil). The effects of NPUGB on leaf chlorophyll concentration and number of green leaves and number of dry leaves followed the same trend as those of pelletized PUGBC (Table 4.2). The positive effect of the combined fertilization treatment (the 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) on increasing leaf chlorophyll content and number of green leaves compared to inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) and other treatments may be due to the role of PUGBC with inorganic fertilizers in providing the essential nutrient elements necessary for plant growth especially nitrogen which result in the improvement of plant growth and yield parameters (Amanolahi- Baharvand *et al.,* 2014). According to Fageria *et al.* (2010) and Wang *et al.* (2014) nitrogen is one of the most important nutrients essential for the growth of crops and is a major component of chlorophyll and protein which are closely associated with leaf color, crop growth and yield.

4.3.2.3 Dry matter yield

Greatest dry matter yield (14.46 g pot^{-1}) was observed in the combined fertilization of inorganic fertilizer and PUGBC (300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) which was significantly different (P=0.05) over all other treatments including sole application of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil), sole application of PUGBC (600 mg N (PUGBC) kg^{-1} soil) and control with numerical values of 9.18, 8.77 and 3.80 g pot^{-1} respectively. The effects of NPUGBC on dry biomass yield followed the same trend as those of pelletized PUGBC (Table 4.3). The greatest dry matter yield recorded in the combined fertilization of inorganic fertilizer and PUGBC (300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) could have been attributed to highest plant height, greatest number of green leaves, stem girth and chlorophyll content which were recorded in the same treatment. Such growth parameters are positively associated with dry matter accumulation (Latt *et al.*, 2009). Several other researchers have reported similar trend of findings on maize crop in response to combined fertilization of inorganic and organic fertilizers (Afe *et al.*, 2015; Fabunmi and Balogun, 2015).

Table 4. 3: The effects of NPUGBC on maize plant height stem girth and dry biomass yield

Treatment	Plant height (cm)	Stem girth (cm)	Dry matter yield (g pot^{-1})	Chlorophyll content	No. of green leaves	No.of dry leaves,
0 mg N kg^{-1} soil	61.64 a	3.19 a	4.09 a	26.88 a	4.841 a	3.92 bc
150 mg N (NPUGBC) kg^{-1} soil	67.48 ab	3.34 ab	5.37 ab	29.82 ab	5.83 abc	2.33 ab
300 mg N (NPUGBC) kg^{-1} soil	72.81 abc	3.74 abc	7.96 ab	34.55 b	6.84 abcde	2.33 ab
600 mg N (NPUGBC) kg^{-1} soil	77.39 bc	3.79 abc	7.97 ab	47.92 c	7.17 bcde	1.66 a
600 mg N (UREA) kg^{-1} soil	83.34 cd	4.17 bcd	9.49 bc	50.75 cd	8.17 def	1.49 a
300 mg N (NPUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	95.14 d	4.86 d	13.44 cd	53.67 cd	8.84 ef	1.99 a
F-Prob.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	6.4	7.4	18.6	4.9	10.3	24.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P=0.05).

Note: *NPUGBC=Non-pelletized urban green biowaste compost, CV = coefficient of variations, F-Prob. = F-Probability value*

As discussed above, it is clear that the combined fertilization of 300 mg N of PUGBC per kg soil and 300 mg N of urea per kg soil significantly increased plant height, number of green leaves per plant, stem girth, leaf chlorophyll content and dry matter yield. This suggests that combined fertilization of half dose of PUGBC or NPUGBC and urea at rate of 300 kg N kg^{-1} soil would improve growth and yield parameters of maize plant as compared to sole application of full dose of either PUGBC, NPUGBC or urea at a rate of 300 kg N kg^{-1} soil.

4.3.3 Overall effect of PUGBC and NPUGBC on rice plant growth and yield

Table 4.4 presents the overall effects of urban green biowaste on growth and yield of rice.

Table 4.4: Overall effect of PUGBC and NPUGBC on rice plant growth and grain yield

Type of biowastes	Plant height (cm)	Number of effective tillers per plant	Number of non-effective tillers per plant	Number of panicles per plant	Panicle length (cm)	100-Grain Weight (g)	Grain weight per pot (g)	Panicle weight (g)
Pellets	88.83	5.13	1.25	5.15	20.08	2.85	39.41	2.31
Non-pellets	88.80	5.04	1.08	5.06	19.99	2.86	38.24	2.37
L.S.D (0.05)	6.428	0.969	0.668	1.190	0.719	0.059	7.732	0.146
Significance	ns	ns	ns	Ns	ns	ns	ns	ns

L.S.D = least significance difference, ns = non-significant

Maximum plant height (88.83 cm), number of effective tillers (5.13), number of non-effective tillers (1.25), number of panicles per plant (5.15), panicle length (20.08 cm), panicle weight (2.31 g) and grain weight per pot (39.41 g) were attained in PUGB while the maximum 100-grain weight (2.86 g) was produced in NPUGB. The difference between use of PUGBC and NPUGBC was insignificant (P=0.05) across all parameters. Insignificant difference between the two forms of biowaste could be due to the fact that the same materials were used but in different forms as some were made pellets for easy application and handling while others were left in non-pellets form. However, the difference observed could be due to additional nutrients present in the clay soil used for binding up the biowastes when making pellets. Generally, use of PUGBC and NPUGBC improved growth and yield of rice crop significantly (P=0.05) as it is revealed in their different applied rates (Tables 4.5 and 4.6), though PUGBC would be relatively better option.

4.3.4 Rice plant growth and yield response to application of PUGBC

Table 4.4 presents the effect of PUGBC on rice plant height, number of effective tillers per plant, number of non-effective tillers per plant, number of panicles per plant, panicle length, 100-grain weight, grain weight per pot and panicle weight.

4.3.4.1 Plant height

The greatest plant height (100.43 cm) was observed in the treatment combination of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil. It was followed by the use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) which produced plants with 98.65 cm heights. The third treatment in terms of plant height performance was the sole application of 600 mg N (PUGBC) kg^{-1} soil which produced plants heights of 84.87 cm. The shortest plant height (80.43 cm) was recorded in the control which was significantly different (P=0.05) over treatment combination of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil, inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) and the sole application of 600 mg N (PUGBC) kg^{-1} soil. The effect of NPUGBC on rice plant height followed the same trend as those of PUGBC (Table 4.6). The relative increase in plant height in response to integrated use of 300 mg N (PUGBC) kg^{-1} soil and 300 mg N (UREA) kg^{-1} soil over other treatments could be due to enhanced N availability and uptake to the crop plant following the application of inorganic fertilizer in combination with PUGBC.

4.3.4.2 Number of tillers

Tillering is an important trait for grain production and is thereby an important aspect in rice yield. However, the productivity of rice plant is greatly dependent on the number of effective tillers (tillers with panicles bearing at least one filled grain) rather than the total number of tillers. In the present study the greatest number of effective and non-effective tillers per plant (9.62 and 2.21 respectively) was recorded in exclusive application of 600 mg N (UREA) kg^{-1} soil which was significantly different (P=0.05) over the control treatment (2.731 and 0.855). Comparable number of effective tillers per plant (9.62 and 8.065) and non-effective tillers per plant (2.21 and 2.124) was obtained in the treatment with sole applications of 600 mg N (UREA) kg^{-1} soil and in the treatment combination of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil, respectively. Application of exclusive 600 mg N (PUGBC) kg^{-1} soil gave results which were statistically similar (P=0.05) to that of control treatment on number of effective and non-effective tillers per plant. The effect of NPUGBC on number of effective tillers per plant and number of non-effective tillers per plant followed the same trend as those of PUGBC (Table 4.6).

The recorded increase in number of tillers per plant in sole application of inorganic fertilizer compared to other treatments could be due to the enhanced N availability and uptake to the crop plant following an increased N rate which was 600 mg N (UREA) kg^{-1} soil. Nitrogen losses through leaching and volatilization were prevented by using non-perforated pots and continuous flooding throughout the experiment. This might have induced the nitrogen nutrient uptake by the crop plant and led to enhanced metabolic activities increasing production of various plant metabolites responsible for cell division and elongation (Siavoshi *et al.,* 2013).

Table 4.5: The effects of PUGB on rice plant growth and yield parameters

Treatment	Plant height (cm)	Number of effective tillers per plant	Number of non-effective tillers per plant	Number of panicles per plant	Panicle length (cm)	100-Grain Weight (g)	Grain Weight per pot (g)	Panicle weight (g)
0 mg N kg^{-1} soil	80.43 a	2.731 a	0.855 a	2.731 a	18.84 ab	2.811 a	14.84 a	1.861 a
150 mg N (PUGBC) kg^{-1} soil	84.20 ab	2.843 a	0.381 a	2.843 a	19.23 abc	2.817 a	17.39 a	2.039 a
300 mg N (PUGBC) kg^{-1} soil	84.31 ab	3.287 a	0.794 a	3.287 a	19.71 abcd	2.876 a	21.21 a	2.102 a
600 mg N (PUGBC) kg^{-1} soil	84.87 abc	3.954 a	0.635 a	3.954 a	19.90 abcde	2.872 a	26.19 a	2.261ab
600 mg N (UREA) kg^{-1} soil	98.65 bcd	9.620 bc	2.210 b	9.620 b	21.80 e	2.882 a	85.17 b	2.982 c
300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	100.43 cd	8.065 bc	2.124 b	8.176 b	20.71 bcde	2.898 a	68.16 b	2.814 bc
F-Prob.	<.001	<.001	<.001	<.001	<.001	0.318	<.001	<.001
CV (%)	6.0	12.9	25.2	13.1	3.5	2.1	16.8	9.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P=0.05).

Note: *PUGBC = pelletized urban green biowaste compost, CV = coefficient of variations, F-Prob. = F-Probability value*

4.3.4.3 Yield parameters

4.3.4.3.1 Number of panicles, panicle length and panicle weight

The greatest number of panicles per plant (9.62), longest panicle length (21.8 cm) and panicle weight (2.982 g) were obtained in treatment with sole applications of 600 mg N (UREA) kg^{-1} soil which was significantly different (P=0.05) over the control treatment (Table 4.4). Comparable number of panicles per plant (9.62 and 8.176) was recorded in treatment with sole applications of 600 mg N (UREA) kg^{-1} soil and in a treatment combination of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil. The effect of NPUGBC on number of panicles per plant, panicle length and panicle weight followed the same trend as those of PUGBC (Table 4.6). The significant increase in number of panicles per plant and panicle length could be due to the enhanced nutrient availability particularly N to the crop plant uptake following an increased rate of inorganic fertilizer which was 600 mg N (UREA) kg^{-1} soil. Nitrogen loses through leaching and volatilization was also prevented by using non-perforated pots and continuous flooding hence higher number of green leaves that led into higher photo-assimilates and thereby resulted in greater number of panicles per plant and longest panicle length (Siavoshi *et al.,* 2013).

4.3.4.3.2 Grain weight

The heaviest 100-grain weight (2.898 g) was recorded in a treatment combination of 300 mg N (PUGBC) kg^{-1} soil and 300 mg N (UREA) kg^{-1} soil. However, there was no significance difference (P=0.05) between the control and other treatments on 100-grain weight parameter. The effect of NPUGBC on 100-grain weight followed the same trend as those of PUGBC (Table 4.6). Observed increase in 100-grain weight in the integrated use of 300 mg N (PUGBC) kg^{-1} soil and 300 mg N (UREA) kg^{-1} soil compared to sole fertilization of 600 mg N (UREA) kg^{-1} soil and other treatments could be due to the ability of the combined fertilization to check N losses. A combined use of organic and inorganic fertilizers checks nitrogen losses through conserving it by forming organic-mineral complexes and thus ensures continuous N availability to rice plants and greater yields (Joshi *et al.*, 2017).

The greatest grain weight per pot (85.17 g) was recorded in sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil). It was followed by the combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil which produced grain weight of 68.16 g and it was statistically similar (P=0.05) to sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil). The minimum grain weight per pot (14.84 g) was noted in the control which was significantly different (P=0.05) over the sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) and the combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil. The effect of NPUGBC on grain weight per pot followed the same trend as those of PUGBC (Table 4.6). The relative increase in yield of rice in response to inorganic fertilization of 600 mg N (UREA) kg^{-1} soil compared to other treatments could be due to the increased yield parameters viz., number of effective tillers per pot, panicle length, number of panicles per plant and panicle weight which were observed in the pots treated with inorganic fertilizer (600 mg N (UREA) kg^{-1} soil).

As discussed above, it is clear that the sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil significantly increased plant height, number of effective tillers per plant, number of panicles per plant, panicle length, panicle weight and grain weight per pot. This implies that sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil would improve growth parameters and yield of rice plant as compared to other treatments applied.

Table 4.6: The effects of NPGUB on rice plant growth and yield parameters

Treatment	**Plant height (cm)**	**Number of effective tillers per plant**	**Number of non-effective tillers per plant**	**Number of panicles per plant**	**Panicle length (cm)**	**100-Grain Weight (g)**	**Grain Weight per pot (g)**	**Panicle weight (g)**
0 mg N kg^{-1} soil	78.91 a	2.824 a	0.853 a	2.824 a	18.42 a	2.8 a	15.64 a	1.837 a
150 mg N (NPUGBC) kg^{-1} soil	82.91 ab	2.935 a	0.468 a	2.935 a	19.28 abc	2.827 a	18.62 a	2.151 a
300 mg N (NPUGBC) kg^{-1} soil	84.35 ab	3.491 a	0.881 a	3.491 a	19.38 abcd	2.847 a	19.39 a	2.159 a
600 mg N (NPUGBC) kg^{-1} soil	88.13 abcd	3.602 a	0.468 a	3.491 a	20.48 abcde	2.871 a	23.28 a	2.177 ab
600 mg N (UREA) kg^{-1} soil	97.02 bcd	9.824 c	2.315 b	9.824 b	21.46 de	2.877 a	87.25 b	2.911 c
300 mg N (NPUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	101.57 d	7.824 b	2.015 b	8.046 b	21.18 cde	2.934 a	68.78 b	2.824 bc
F-Prob.	<.001	<.001	<.001	<.001	<.001	0.318	<.001	<.001
CV (%)	6.0	12.9	25.2	13.1	3.5	2.1	16.8	9.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P=0.05).

Note: NPUGBC = Non-pelletized urban green biowaste compost, CV = coefficient of variations, F-Prob. = F-Probability value

4.4 Conclusions and recommendations

4.4.1 Conclusions

Results from the present study have indicated that:

- The use of PUGBC or NPUGBC improved growth and yield parameters of both maize and rice crops.
- The use of PUGBC and NPUGBC did not differ significantly across all growth and yield parameters of both maize and rice crops.
- Use of combined fertilization of 300 mg N (PUGBC) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil improved growth and yield parameters of maize plant.
- Sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) improved growth parameters and yield of rice plant.

4.4.2 Recommendations

The study recommended the following:

- PUGBC or NPUGB can be used as soil amendment in maize and rice production. However, PUGBC would be a better option due its added advantages of easy application and handling apart from slight improvement of growth and yield parameters.
- For high maize yield, use of combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil is recommended.
- For high rice yield, use of 600 mg N (UREA) kg^{-1} soil rate of inorganic fertilizer alone is recommended.
- Further study should be conducted under field conditions to verify the findings of this pot experiment.

REFERENCES

Abedi, T., Alemzadeh, A. and Kazemeini, S. A. (2010). Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. *Australian Journal of Crop Science* 4(6): 384-389.

Adamu, S. and Leye, B. O. (2012). Performance of maize (*Zea mays* L.) as influenced by complementary use of organic and inorganic fertilizers. *International Journal of Science and Nature* 3(4): 753-757.

Afe, A. I., Atanda, S., Aduloju, M. O., Ogundare, S. K. and Talabi, A. A. (2015). Response of maize (*Zea mays* L.) to combined application of organic and inorganic (soil and foliar applied) fertilizers. *African Journal of Biotechnology* 14(44): 3006-3010.

Ali, M. E., Islam, M. R. and Jahiruddin, M. (2009). Effect of integrated use of organic manures with chemical fertilizers in the rice-rice cropping system and its impact on soil health. *Bangladesh Journal of Agricultural Research* 34(1): 81-90.

Alimi, T., Ajewole, O. C., Olubode-Awosola, O. O. and Idowu, E. O. (2007). Organic and inorganic fertilizer for vegetable production under tropical conditions. *Journal of Agricultural and Rural Development* 1(6): 120-136.

Amanolahi-Baharvand, Z., Zahedi, H. and Rafiee, M. (2014). Effect of vermicompost and chemical fertilizers on growth parameters of three corn cultivars. *Journal of Applied Science and Agriculture* 9(9): 22-26.

Amujoyegbe, B. J., Opabode, J. T., and Olayinka, A. (2007). Effect of organic and inorganic fertilizer on yield and chlorophyll content of maize (*Zea mays* L.) and sorghum (*Sorghum bicolour* L.) Moench. *African Journal of Biotechnology* 6(16): 1869-1873.

Chen, J. H. (2008). The Combined Use of Chemical and Organic Fertilizers and/or Biofertilizer for Crop Growth and Soil Fertility. Taichung, Taiwan.

De Meyer, A., Poesen, J., Isabirye, M., Deckers, J. and Raes, D. (2011). Soil erosion rates in tropical villages: a case study from Lake Victoria Basin, Uganda. *Catena* 84(3): 89-98.

Elkholy, M., Mahrous, S. E. and El-Tohamy, S. A. (2010). Integrated Effect of Mineral, Compost and Biofertilizers on Soil Fertility and Tested Crops Productivity. *Research Journal of Agriculture and Biological Sciences* 6(4): 453-65.

Fabunmi, T. O. and Balogun, R. O. (2015). Response of maize (Zea mays L.) to green manure from varying populations of cowpea in a derived savannah of Nigeria. *African Journal of Food, Agriculture, Nutrition and Development* 15(3): 10138-10152.

Fageria, N. K., Baligar, V. C. and Jones, C. A. (2010). *Growth and Mineral Nutrition of Field Crops*. CRC Press. 586pp.

Fanizza, G., Ricciardi, L., and Bagnulo, C. (1991). Leaf greenness measurements to evaluate water stressed genotypes in Vitis vinifera. *Euphytica* 55(1): 27-31.

Han, S. H., An, J. Y., Hwang, J., Kim, S. B. and Park, B. B. (2016). The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera Lin.) in a nursery system. *Forest Science and Technology* 12(3): 137-143.

Hartemink, A. E. (2006). Soil fertility decline: definitions and assessment. *Encyclopedia of Soil Science* 2: 1618-1621.

Joshi, H., Joshi, B., Guru, S. and Shankdhar, S. (2017). Consequences of integrated use of organic and inorganic fertilizers on yield and yield elements of rice. *International Journal of Agricultural Science and Research* 7(5): 163-166.

Kahimba, F. C., Kombe, E. E. and Mahoo, H. F. (2014). The Potential of System of Rice Intensification (SRI) to Increase Rice Water Productivity: A case of Mkindo Irrigation Scheme in Morogoro Region, Tanzania. *Tanzania Journal of Agricultural Sciences* 12 (2): 10-19.

Kayeke, J., Sibuga, P. K., Msaky, J. J. and Mbwaga, A. (2007). Green manure and inorganic fertiliser as management strategies for witchweed and upland rice. *African Crop Science Journal* 15(4): 161 – 171.

Kokkora, M. I. (2008). Biowaste and vegetable waste compost application to agriculture. PhD Thesis for Award Degree of Doctorate at Cranfield University School of Applied Sciences National Soil Resources Institute. 77pp.

Krishnaprabu, N. and Grace, T. M. (2017). Effect of nutrient management on growth and yield of traditional red rice land races (*Oryza sativa* L.). *International Journal of Chemical Studies* (*IJCS)* 5(6): 180-186.

Latt, Y. K., Myint, A. K., Yamakawa, T. and Ogata, K. (2009). The effects of green manure (*Sesbania rostrata*) on the growth and yield of rice. *Journal of Faculty of Agriculture, Kyushu University* 54(2): 313-319.

Luzi-Kihupi, A., Kashenge-Killenga, S. and Bonsi, C. (2015). A review of maize, rice, tomato and banana research in Tanzania. *Tanzania Journal of Agricultural Sciences* 14(1): 1-20.

Lyimo, S., Mduruma, Z. and De Groote, H. (2014). The use of improved maize varieties in Tanzania. *African Journal of Agricultural Research* 9(7): 644 – 657.

Mahmood, F., Khan, I., Ashraf, U., Shahzad, T., Hussain, S., Shahid, M., Abid, M. and Ullah, S. (2017). Effects of organic and inorganic manures on maize and their residual impact on soil physico-chemical properties. *Journal of Soil Science and Plant Nutrition* 17(1): 22-32.

Makoi, J. H. and Mmbaga, H. (2018). Soil Fertility Characterization in Mvumi and Mbogo-Komtonga Irrigation Schemes in Kilosa and Mvomero Districts, Morogoro Region, Tanzania. *International Journal of Environment, Agriculture and Biotechnology* 3(3): 1088-1099.

Mbaga, H. R., Mrema, J. P. and Msanya, B. M. (2017). Response of rice to nitrogen and phosphorus applied on typical soils of Dakawa Irrigation Scheme, Morogoro, Tanzania. *Imperial Journal of Interdisciplinary Research (IJIR)* 3(6): 378-384.

Moe, K., Mg, K. W., Win, K. K. and Yamakawa, T. (2017). Combined Effect of Organic Manures and Inorganic Fertilizers on the Growth and Yield of Hybrid Rice (Palethwe-1). *American Journal of Plant Sciences* 8: 1022-1042.

Negassa, W., Getaneh, F., Deressa, A. and Dinsa, B. (2007). Integrated Use of Organic and Inorganic Fertilizers for Maize Production. Witzenhausen, Germany.

Quansah, G. W. (2010). Effect of Organic and Inorganic Fertilizers and Their Combinations on the Growth and Yield of Maize in the Semi-Deciduous Forest Zone of Ghana. Dissertation for Award Degree at Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. 77pp.

Roba, T. B. (2018). Review on: The Effect of Mixing Organic and Inorganic Fertilizer on Productivity and Soil Fertility. *Open Access Library Journal* 5(06): 1-11.

Siavoshi, M., Dastan, S., Yassari, E. and Laware, S. L. (2013). Role of organic fertilizers on morphological and yield parameters in rice (*Oryza sativa* L.). *International Journal of Agronomy and Plant Production* 4(6): 1220-1225.

Simon, A. M. (2008). *Analysis of Activities of Community Based Organizations Involved in Solid Waste Management, Investigating Modernized Mixtures Approach.* The case of Kinondoni Municipality, Dar es Salaam, Tanzania. MSc. thesis, Wageningen University. 77pp.

Vanlauwe, B., Bationo, A., Chianu, J., Giller, K. E., Merckx, R., Mokwunye, U., Ohiokpeh, O., Pypers, P., Tabo, R., Shepherd, K. and Smaling, E. M. A. (2010). Integrated soil fertility management: operational definition and consequences for implementation and dissemination. *Outlook on Agriculture* 39(1): 17-24.

Wang, Y., Wang, D., Shi, P. and Omasa, K. (2014). Estimating rice chlorophyll content and leaf nitrogen concentration with a digital still color camera under natural light. *Plant Methods* 10(1): 36-45.

Widowati, L. R., Sleutel, S., Setyorini, D. and De Neve, S. (2012). Nitrogen mineralisation from amended and unamended intensively managed tropical andisols and inceptisols. *Soil Research* 50(2): 136-144.

Yin, G., Gu, J., Zhang, F., Hao, L. and Cong, P. (2014). Maize Yield Response to Water Supply and Fertilizer Input in a Semi-Arid Environment of Northeast China. *PLoS ONE* 9(1): e86099.

CHAPTER FIVE

5.0 FIELD EVALUATION OF MAIZE AND RICE RESPONSE TO APPLICATION OF URBAN GREEN BIOWASTE COMPOST FROM DAR ES SALAAM AT DAKAWA IN MOROGORO

ABSTRACT

Depletion of soil nutrients is a main problem to sustain agricultural production and productivity in many countries including Tanzania. As a result, maize and rice productivity has been very low in Tanzania. Recently yield of maize has been noted to be 1.4 t ha^{-1} while the potential yield is 5 t ha^{-1} and rice yield averages 0.5-2 for upland ecologies and 4.5-6.0 t ha^{-1} for irrigated ecologies compared to the potential yield of 5t ha^{-1} and 10-11 t ha^{-1} respectively. A field experiment was conducted from January to June, 2019 at TARI- Dakawa to evaluate the agronomic potential of pelletized urban green biowaste (UGBC) collected from open markets in Dar es Salaam as organic fertilizer for maize and rice production at Dakawa in Morogoro region. A randomized complete block design (RCBD) was used for the experiment. The experiment used maize and rice as test crops. Treatments for rice crop were as follows 0 and 150 kg N (UGBC) ha^{-1}); 150 kg N (UREA) ha^{-1} and a combined fertilization of 75 kg N (UREA) ha^{-1} + 75 kg N (UGBC) ha^{-1} while the treatments for maize crop were 0 and 300 kg N (UGBC) ha^{-1}; 300 kg N (UREA) ha^{-1} and a combined fertilization of 150 kg N (UREA) ha^{-1} + 150 kg N (UGBC) ha^{-1}. Thus, a total of four treatments were used for each crop. The treatments were randomized in the experimental units (test crops) and replicated three times. Plant growth and yield parameters were used to evaluate the response of rice and maize to respective treatments. For rice crop, maximum plant height (99.23 cm), number of effective tillers per hill (17.07) and chlorophyll content (51.72) were obtained in a combined fertilization of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}. It was followed by sole application of

150 kg N (UREA) ha^{-1} with values of 96.57 cm, 16.57 and 49.17 for plant height, effective tillers per hill and chlorophyll content, respectively. The significant (P=0.05) lowest values for plant height (88.89 cm), effective tillers per hill (11.67) and chlorophyll content (46.95) were observed in the control (0 kg N ha^{-1}). The significant highest grain yield of 8127 kg ha^{-1} was produced in the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}). This yield was approaching the potential yield of rice (10 to 11 t ha^{-1}) under irrigation ecology in Tanzania. It was followed by 150 kg N (UREA) ha^{-1} treatment (7751 kg) and the third treatment was 150 kg N (UGBC) ha^{-1} (6867 kg). The minimum yield was recorded in the control treatment (5594 kg). The four treatments exhibited significant difference (P=0.05) from each other for grain yield. The same trend of results was observed for maize crop whereby the use of integrated fertilization of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} produced the highest maize grain yield of 8691 kg ha^{-1}. This yield was far above the potential yield of maize (5 t ha^{-1}) in Tanzania. The present study therefore concluded that the integrated use of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} is the best treatment for rice production while the integrated use of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} is the best treatment for maize production. Thus, farmers are recommended to use 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} for best growth performance and high yield of rice and use of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} for best growth performance and high yield of maize.

Key words: Maize, Rice, Organic fertilizer, pelletized urban green biowaste

5.1 Introduction

In Tanzania, maize and rice are the main staple food crops and sometimes are used as cash crops in some regions of the country (Kahimba *et al.*, 2014; Lyimo *et al.*, 2014). Morogoro region for example merely depends on maize and rice as staple food and cash crops (Makoi and Mmbaga, 2018). However, the productivity of these two crops is generally very low. Recently maize productivity has been reported to be 1.4 t ha^{-1} while the potential yield is 5 t ha^{-1}. Rice also has been reported to yield 4.5-6.0 t ha^{-1} for irrigated ecologies compared to the potential yield of 10-11 t ha^{-1} (Luzi-Kihupi *et al.*, 2015). The major factors contributing to the low yield include low soil fertility due to excessive nutrient mining coupled with low use of fertilizers, monocropping, poor agronomic practices, use of unimproved seeds, and poor access to output markets (Ngailo *et al.*, 2013). Nevertheless, there are several ways to increase crop yield per unit area. One of the ways is the proper management of soil fertility, nitrogen management in particular (Fageria, 2014). Ju and Christie (2011) reported that nitrogen is a crucial nutrient that requires careful management in intensive cropping systems because of its diverse beneficial and detrimental effects.

In recent times, farmers have mostly relied on inorganic fertilizers, particularly N fertilizers, to boost their maize and rice yields. This practice has resulted in soil-related problems, such as acidification, loss of organic matter, deterioration of the structure, and reductions in biological activities and fertility (Hati *et al.*, 2008). Several researchers have also reported that inorganic fertilization alone is not a sustainable means of dealing with soil fertility problems (Gala-Bi *et al.*, 2011; Kaho *et al.*, 2011). Thus, there is a need to develop and adopt environmentally friendly alternatives which can supplement or replace inorganic fertilizers. Organic fertilizers are environmentally sustainable and can maintain soil health when used in intensive maize and rice cultivation (Kimuni *et al.*, 2014; Jouquet *et al.,* 2010). They help to conserve the amount and quality of organic matter in the soil, and supply N, P, K, and essential micronutrients (Mulaji, 2011; Ojetayo *et al.,* 2011).

In Tanzania, attempts have been made to study the potential influence of organic materials on crop production. However, many of them have been concentrating on manures and composts whose availability is limited (Kayeke *et al.,* 2007). The emerging increase in urban green biowaste production in Tanzania especially in big cities has not been realized. Dar Es Salaam for example generates up to 1 400 t of urban green biowaste (UGB) per day and about 83 % of these wastes are left near the house premises in open pits, streets, markets or storm water drainage channels (Simon, 2008). None or limited studies have been conducted to assess the potential role of the urban green biowastes from big cities in Tanzania on crop yields. This study therefore aimed at evaluating the agronomic potential of pelletized urban green biowaste compost from Dar es Salaam as organic fertilizer for maize and rice production at Dakawa in Morogoro region.

5.2 Materials and methods

5.2.1 Study area description

This study was conducted from January to June 2019 at Tanzania Agricultural Research Institute (TARI)-DAKAWA located between (7.42605°S, 37.70272°E) and (7.426733°S, 37.7045°E). The site is situated in Morogoro region at altitude 154 m.a.s.l. The soil at Dakawa site is sandy clay loam and was classified by Mbaga *et al.* (2017) as Inceptisol (Soil Taxonomy) and Cambisol (World Reference Base). Morogoro region is one of the major rice and maize producing regions in Tanzania. Dakawa ward in Mvomero district is one of the major rice and maize growing areas in Morogoro. Therefore, Dakawa site is considered to have high potential for rice and maize production (Makoi and Mmbaga, 2018). It was for these reasons that the site was selected to carry out the field study to evaluate the response of maize and rice to the use of urban green biowaste.

5.2.2 Experimental treatments, design and procedures

Pelletized urban green biowaste compost (UGBC) was used as organic fertilizer and a source of nitrogen. Treatments for rice crop were as follows: 0 and 150 kg N (UGBC) ha^{-1}); 150 kg N (UREA) ha^{-1} and a combined fertilization of 75 kg N (UREA) ha^{-1} + 75 kg N (UGBC) ha^{-1}, as recommended for evaluation by the pot experiment in chapter four. Therefore, four treatments in total were used for rice crop. For maize crop the treatments were 0 and 300 kg N (UGBC) ha^{-1}; 300 kg N (UREA) ha^{-1} and a combined fertilization of 150 kg N (UREA) ha^{-1} + 150 kg N (UGBC) ha^{-1}. A total of four treatments were also used for maize crop. A randomized complete block design (RCBD) was used for the experiment. The experimental units were maize and rice crops. The treatments were randomized in the experimental units and replicated three times. The fields were ploughed and harrowed and laid out. Plot sizes were 5 m x 5 m for both maize and rice.

5.2.3 Fertilizer application and field management

Urban green biowaste compost, triple superphosphate (TSP), and muriate of potash (MOP) were incorporated in the soil before planting/transplanting was done. Phosphorus (P) as triple super phosphate (TSP) and potassium (K) as muriate of potash (MOP) were applied at optimal level to enhance correct investigation of the response of maize and rice to N. Both K and P were applied at a rate of 60 kg ha^{-1}(i.e. 300 g MOP and 746.74 g TSP per 5 m^{-2}-plot). UGBC, MOP and TSP were applied at planting/transplanting as basal fertilizer. Four maize seeds (SEEDCO-SC 403 variety) were sown on the 15 cm raised ridges at a spacing of 80 cm x 40 cm. The four seedlings were thinned to two seedlings per hill fifteen days after emergence. Eighteen-day aged two seedlings of rice (TXD 306 variety) were transplanted at a spacing of 20 cm x 20 cm. Continuous flooding was maintained by irrigation when rainfall water was insufficient for rice crop. For maize crop supplementary water was introduced during prolonged dry spells. Weeding using handhoes for maize and hand weeding for rice and pest control were done timely to ensure crops are weed and pest free.

Urea was applied as top dressing in three splits for both maize and rice. First split (40%) was applied at 15 days after emergence (DAE) for maize and 10 days after transplanting (DAT) (initial tillering stage) for rice. The second split (30%) was applied at 30 DAE and 35 DAT (maximum tillering stage) for maize and rice crops, respectively. The third (30 %) was applied at 45 DAE for maize and 60 DAT (panicle initiation stage) for rice.

5.2.4 Yield and agronomic data collection and analysis

Plant growth and yield parameters were recorded. Maize plant height and leaf area were determined at physiological maturity. Other maize parameters were collected after harvest which included cob length, cob weight, cob weight after shelling, number of rows per cob, number of grains per cob, 1000-grain weight and yield.

Leaf area was determined by calculating the product of the total length and breadth at the broadest point of the longest leaf on the plant i.e. Leaf Area = lamina length x maximum width x k (where k is the coefficient with 0.75 value).

Ten cobs were randomly sampled from the cobs harvested in a net 5 m^2 area for determination of cob length, cob weight, cob weight after shelling, number of rows per cob and number of grains per cob. Cob length was measured using ruler; cob weight and cob weight after shelling were measured using a digital balance. Determination of number of rows per cob and number of grains per cob were done by counting. An average was found for each parameter and recorded.

Rice plant height was determined at physiological maturity. Other rice parameters were collected after harvest viz. number of effective tillers per hill and number of non-effective tillers per hill, panicle length, panicle weight, number of grains spikelets per panicle, number of filled grain per panicle, grain weight per panicle, 1 000-grain weight and yield.

Ten hills were randomly harvested for determination of number of effective tillers per hill and number of non-effective tillers per hill within the net 5 m^2 marked for yield harvest. The determination of these two parameters was done by counting the tillers with panicles bearing at least one filled grain which in this case were referred to as effective tillers. Tillers with panicles having no single filled grain were termed as non- effective tillers. An average was found for each parameter and recorded.

Ten panicles were randomly sampled from the panicles harvested in a net 5 m^2 area for determination of panicle length, panicle weight, number of grains per panicle, number of filled grains per panicle and grain weight per panicle. Panicle length was measured using a ruler; panicle weight and grain weight per panicle were measured using a digital balance. Determination of number of grains per panicle and number of filled grains per panicle were done by counting. An average was found for each parameter and recorded.
Leaf chlorophyll content for each maize and rice was measured at flowering stage using atLEAF Digital chlorophyll meter device. The flag leaf and the leaf bearing the ear for rice and maize respectively were used for determination of concentration of chlorophyll in leaf tissues. Ten leaves from different ten plants were selected randomly and measured. The average chlorophyll content of the five plants was recorded as the leaf chlorophyll content of each plot/treatment.

One thousand grains weight was determined by counting 1 000-grains from the grain yield of each plot harvested from a net area of 5 m^2 for both maize and rice and weighed using a digital balance in gram basis. An area of 5 m^2 at the middle of each plot was harvested for yield determination for both rice and maize crops. After threshing for rice and shelling for maize, grains were air dried. Weight measurements were done simultaneously with moisture content determination using electronic balance and digital grain moisture meter.

Weight of grains were then adjusted to 14% moisture content using a formula $Wf = \left(\frac{100-mci}{100-mcf}\right) x\ Wi$, where Wf is the final weight at 14 % moisture content; *mcf* is the final moisture (14 %); *mci* is the initial moisture content and *Wi* is the initial grain weight. This was done also to all parameters involving weights for both rice and maize crops.

Ten leaves for maize and five plants for rice were also sampled from the 5 m^2 area for laboratory determination of nitrogen (N), phosphorus (P) and potassium (K) nutrients concentration in leaf tissues. The leaves were transported to SUA for analysis. They were washed with distilled water, air dried for 48 hours and then oven dried at 65°C to constant weight. Then the samples were ground and ashed ready for analysis.

5.2.5 Statistical data analysis

Data for maize and rice growth and yield parameters were subjected to one-way analysis of variance (ANOVA) using GenStat 15^{th} Edition. Mean separation was done by Tukey's Honestly Significant Difference (HSD) Test at P=0.05. The coefficient of variation (CV) in percentage was recorded.

5.3 Results and discussion

5.3.1 Response of rice crop to various treatments

5.3.1.1 Effect of UGBC on rice growth parameters under field conditions

The results depicted in Table 5.1 showed that plant height, number of effective tillers per hill, number of non-effective tillers per hill and chlorophyll content were all increased significantly (P=0.05) compared to the control.

Table 5.1: Effect of UGBC application on rice growth parameters under field conditions

Treatments	Plant height (cm)	Number of effective tillers per hill	Number of non-effective tillers per hill	Chlorophyll content
0 kg N ha^{-1}	88.89 a	11.67 a	1.13 c	46.95 a
150 kg N (UGBC) ha^{-1}	95.27 b	13.73 b	0.53 b	47.78 a
150 kg N (UREA) ha^{-1}	96.57 bc	16.57 c	0.33 ab	49.17 ab
75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}	99.23 c	17.07 c	0.20 a	51.72 b
F-Prob.	<.001	<.001	<.001	0.022
C.V (%)	1.4	3.7	20.1	2.8

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P=0.05).

Note: *CV = coefficient of variations, F-Prob. = F-Probability value, UGBC = Urban green biowaste compost*

5.3.1.1.1 Plant height

Maximum plant height (99.23 cm) was noted in plants treated with a combined fertilization of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} followed by 150 kg N (UREA) ha^{-1} (96.57 cm) and 150 kg N (UGBC) ha^{-1} (95.27 cm) was the third. All the three treatments were statistically different (P=0.05) over control (88.89 cm). There was no significant difference between the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}) and 150 kg N (UREA) ha^{-1}. The increase in plant height in response to combined application of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} compared to other treatments is probably due to enhanced availability of nutrients, particularly nitrogen. Nutrients availability might have been attributed to improved physico-chemical properties of the soil as a result of UGBC application. Several other researchers reported the same trend of findings when combined application of organic and inorganic fertilizers was used (Siavoshi *et al.,* 2011; Laharia *et al.,* 2013).

5.3.1.1.2 Number of tillers

Tillering is an important trait for grain production and is thereby an important aspect in rice yield. However, the productivity of rice plant is greatly dependent on the number of effective tillers (tillers with panicles bearing at least one filled grain) rather than the total number of tillers. In the present study the highest number of effective tillers per hill (17.07) was observed in plots treated with the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}) followed by 150 kg N (UREA) ha^{-1} (16.57) and 150 kg N (UGBC) ha^{-1} (13.73) was the third. All the three treatments showed statistical difference (P=0.05) over control (11.67). However, the study revealed that the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}) was statistically similar to 150 kg N (UREA) ha^{-1}. The increase in number of effective tillers in a combined fertilization of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} compared to other treatments could be due to the more available nitrogen, which plays a vital role in cell division. Organic sources offer more balanced nutrition to the plants; they also add micronutrients which positively affect number of tiller in plants (Belefant-Miller, 2007). In contrast to number of effective tillers per hill; the highest number of non-effective tillers per hill was recorded in the control treatment (1.13) which was statistically different over other treatments. The lowest number of non-effective tillers per hill (0.2000) was noted in the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}. From this study it was observed that 150 kg N ha^{-1} of urea is not necessary to produce effective tillers, but when 75 kg N (UREA) is supplemented with 75 kg N ha^{-1} organic materials such as UGBC, which also help in providing essential micronutrients to the plants (Belefant-Miller, 2007; Rakshit *et al.*, 2008) produces more effective tillers. Hasanuzzaman *et al.* (2010) and Siavoshi *et al.* (2011) also reported similar trend of results in rice with application of combined inorganic and organic fertilizers.

5.3.1.1.3 Leaf chlorophyll content

The greatest chlorophyll content (51.72) was recorded in the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}, followed by 150 kg N (UREA) ha^{-1} (49.17). However, the two treatments were statistically similar (P=0.05). The two treatments exhibited statistical difference (P=0.05) over control (46.95). However, the 150 kg N (UGBC) ha^{-1} (47.78) treatment showed no significance difference (P=0.05) over the control. The observed significant increase in leaf chlorophyll content in an integrated application of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} compared to application of inorganic alone (150 kg N (UREA) ha^{-1}) and other treatments might have been caused by enhanced availability of N. Fageria *et al.* (2010) and Wang *et al.* (2014) commented that nitrogen is one of the most important nutrients essential for the growth of crops, and is a major component of chlorophyll and protein which are closely associated with leaf color, crop growth status and yield.

As discussed above, it is clear that the combined fertilization of 75 kg N of UGBC per hectare and 75 kg N of urea per hectare significantly increased plant height, number of effective tillers and leaf chlorophyll content. This suggests that combined fertilization of half dose of UGBC and urea at rate of 75 kg N ha^{-1} would improve growth and development of rice plant as compared to sole application of full dose of either UGBC or urea at a rate of 150 kg N ha^{-1}.

5.3.1.2 Effect of UGBC on rice yield parameters under field conditions

The results given in Table 5.2 indicated that panicle length, panicle weight, number of grains per panicle, number of filled grain per panicle, grain weight per panicle, 1 000-grain weight and yield significantly increased (P=0.05) in all treatments over control.

Table 5.2: Effect of UGBC on rice yield parameters under field conditions

Treatments	**Panicle length (cm)**	**Panicle weight (g)**	**Number of grains per panicle**	**Number of filled grain per panicle**	**Grain weight per panicle (g panicle^{-1})**	**1000-grain weight (g)**	**Yield (kg ha^{-1})**
0 kg N ha^{-1}	21.07 a	2.42 a	83.70 a	76.07 a	2.30 a	30.20 a	5594 a
150 kg N (UGBC) ha^{-1}	22.71 b	2.96 b	117.30 b	96.87 b	2.83 b	30.88 ab	6867 b
150 kg N (UREA) ha^{-1}	22.77 b	3.04 b	119.30 b	98.00 b	2.89 bc	31.33 b	7751 c
75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}	23.01 b	3.04 b	119.10 b	99.47 b	2.90 c	31.54 b	8127 d
F-Prob.	0.001	<.001	<.001	<.001	<.001	0.009	<.001
C.V (%)	1.5	3.1	5.2	2.9	0.8	1.0	1.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P=0.05)

Note: *CV = coefficient of variations, F-Prob. = F-Probability value, UGBC = Urban green biowaste compost*

5.3.1.2.1 Panicle length and number of filled grains

Maximum panicle length (23.01 cm) and number of filled grains per panicle (99.47) were observed in plots treated with an integrated application of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}. It was followed by 150 kg N (UREA) ha^{-1} (22.77 cm and 98.00, respectively), the next treatment was 150 kg N (UGBC) ha^{-1} (22.71 cm and 96.87, respectively). All the three treatments were statistically different (P=0.05) over control (21.07 cm and 76.07, respectively). The increase in panicle length and number of filled grains per panicle in the combined fertilization of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} could have been largely attributed to improved soil organic matter, soil physical, chemical and microbial properties with application of UGBC coupled with the inorganic fertilizer applied which ultimately enhanced adequate N supply to plant. Another reason could be better nutrition at grain filling period due to integrated fertilizer management that led to higher filled grain per panicle (Krishnaprabu and Grace, 2017).

5.3.1.2.2 Panicle weight and number of grains

The greatest panicle weight (3.04 g) and number of grains per panicle (119.30) were recorded in the 150 kg N (UREA) ha^{-1} treatment, followed by treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}) (3.04 g and 119.10, respectively) and the third was 150 kg N (UGBC) ha^{-1} (2.96 g and 117.30, respectively). However, the two treatments were statistically similar (P=0.05). The smallest panicle weight (2.42 g) and number of grains per panicle (83.70) was recorded in the control treatment and it was significantly different (P=0.05) compared to other treatments. The significant increase in panicle weight and number of grains per panicle in the plot treated 150 kg N (UREA) ha^{-1} could be due to readily soluble nitrogen in urea which was applied at panicle initiation stage and thereby instantly available to plants. However, increased number of grains and vigorous growth of rice due to high rates of N fertilizer application induce competition for carbohydrate available for grain filling and grain formation (Joshi *et al.*, 2017) as a result fewer number of field grains were recorded in sole inorganic fertilizer application (150 kg N (UREA) ha^{-1}) compared to integrated fertilization (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}).

The treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}) and 150 kg N (UREA) ha^{-1} treatment produced statistical similar results (P=0.05) (Table 5.2) on grain weight per panicle. However, the greatest grain weight per panicle (2.90 g) was recorded in the treatment combination. The minimum grain weight per panicle (2.30 g) was noted in the control which was significantly different (P=0.05) over other treatments. The results also indicated that there was no significant different (P=0.05) between the 150 kg N (UREA) ha^{-1} (2.89 g) and 150 kg N (UGBC) ha^{-1} (2.83 g). Comparable grain weight per panicle from both combined application of organic and inorganic fertilizers (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}) and from sole inorganic fertilizer (150 kg N (UREA) ha^{-1}) is a further indication that the nutrients supplied from the combined application were effective enough (Diallo-Diagne *et al.,* 2016).

5.3.1.2.3 A thousand-grain weight

Maximum 1 000-grain weight (31.54 g) was recorded in the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}), followed by 150 kg N (UREA) ha^{-1} treatment (31.33 g) and the third treatment was 150 kg N (UGBC) ha^{-1} (30.88 g). There was no significant different (P=0.05) among the three treatments. The minimum 1 000-grain weight (30.20 g) was recorded in the control treatment and it was significantly different (P=0.05) over other treatments. Observed increase in 1000-grain weight in the integrated use 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} could be due to the ability of the combined fertilization to check N losses. A combined use of organic and inorganic fertilizers checks nitrogen losses through conserving it by forming organic-mineral complexes and thus ensures continuous N availability to rice plants and greater yields (Joshi *et al.,* 2017).

The significant highest yield of 8127 kg ha^{-1} was produced in the treatment combination (75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}). It was followed by 150 kg N (UREA) ha^{-1} treatment (7751 kg ha^{-1}) and the third treatment was 150 kg N (UGBC) ha^{-1} (6867 kg ha^{-1}) (Plate 5.1). The minimum yield was recorded in the control treatment (5594 kg^{-1}). The four treatments exhibited significant difference (P=0.05) from each other (Table 5.2). Recorded yield of 8127 kg ha^{-1} equivalent to 8.13 t ha^{-1} in the integrated use of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} was approaching the potential yield of rice (10 to 11 t ha^{-1}) under irrigation ecology in Tanzania. The increase in grain yield in the combined fertilization of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1}could be due to the increase in yield attributes (plant height, number of effective tillers hill^{-1}, panicle length, filled grains per panicle, and 1 000-grain weight) which were significantly increased by integrated use of UGBC and inorganic fertilizer at the rate of 75 kg N ha^{-1}. The increase in grain yield components in integrated use of UGBC and inorganic fertilizer also could be due to the fact that more nutrient availability would have improved the nitrogen and other macro- and micro-elements absorption as well as enhancing the production and translocation of the dry matter content from source to sink (Krishnaprabu and Grace, 2017). Several other researchers have also commented that combined application of organic and inorganic fertilizers is the best method and more conducive to increase crop yields and improve soil physical and chemical properties rather than using them individually (Efthimiadou *et al.,* 2010; Jinwei and Lianren, 2011).

From the discussion above, it is clear that the combined fertilization of 75 kg N of UGBC per hectare and 75 kg N of urea per hectare significantly increased panicle length, number of filled grain per panicle, grain weight per panicle, 1 000-grain weight and yield. This suggests that combined fertilization of half dose of UGBC and urea at rate of 75 kg N ha^{-1} would improve yield attributes and yield of rice as compared to sole application of full dose of either UGBC or urea at a rate of 150 kg N ha^{-1}.

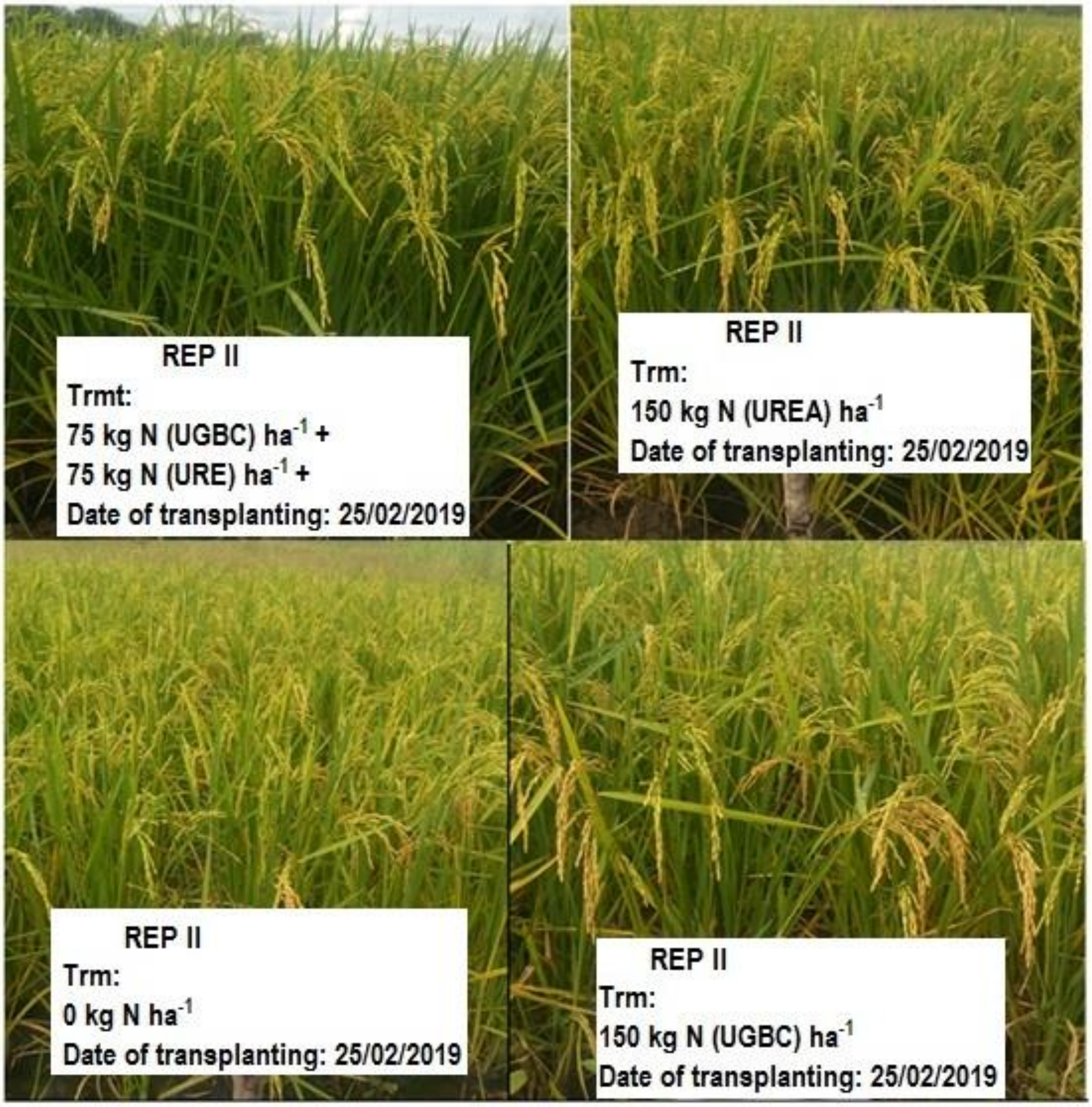

Plate 5.1: Response of rice to different treatments under field conditions

5.3.2 Response of maize crop to treatments

5.3.2.1 Effect of UGBC on maize growth parameters under field conditions

Table 5.3 presents the effect of UGBC on plant height, leaf area and leaf chlorophyll content of maize.

Table 5.3: Effect of UGB on maize growth parameters under field conditions

Treatments	Chlorophyll content	Plant height (cm)	Leaf area (cm^2)
0 kg N ha^{-1}	58.89 a	182.50 a	585.50 a
300 kg N (UGBC) ha^{-1}	62.76 b	189.70 b	640.80 b
300 kg N (UREA) ha^{-1}	62.79 b	190.30 b	673.80 c
150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}	63.58 b	193.00 b	688.40 d
F-Prob.	0.010	<.001	<.001
C.V (%)	1.9	0.7	0.4

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P=0.05)

Note: *CV = coefficient of variations, F-Prob. = F-Probability value, UGBC = Urban green biowaste compost*

Measurement of leaf area and leaf chlorophyll concentration is a basic tool of growth analysis. The two parameters are directly related with both biological and economical yield. In case of any plant, leaves are important organs which have an active role in photosynthesis (Krishnaprabu and Grace, 2017). On the other hand, leaf chlorophyll concentration is often well correlated with plant metabolic activity (e.g., photosynthetic capacity and RuBP carboxylase activity; Fanizza *et al.*, 1991), as well as leaf N concentration. To achieve high yield, maximization of leaf area and leaf chlorophyll concentration are important factors (Krishnaprabu and Grace, 2017). In the present study, maximum leaf chlorophyll content (63.58), plant height (193.0 cm) and leaf area (688.4 cm^2) were obtained in plot applied with combined fertilization of UGBC and inorganic fertilizer (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}). It was followed by sole application of 300 kg N (UREA) ha^{-1} with 62.79, 190.3 cm and 673.8 cm^2 values for leaf chlorophyll content, plant height and leaf area respectively. The third treatment was 300 kg N (UGBC) ha^{-1} having 62.76, 189.7 cm and 640.8 cm^2 values for leaf chlorophyll content, plant height and leaf area respectively. However, the three treatments did not differ significantly (P=0.05) in terms of leaf chlorophyll content, plant height and leaf area (Table 5.2). The minimum leaf chlorophyll content, plant height and leaf area were observed in the control which was significantly different (P=0.05) over other three treatments. The positive effect of the combined fertilization of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} on increasing the plant height, leaf chlorophyll content and leaf area of maize plant compared to other treatments could be due to the role of UGBC with inorganic fertilizers in providing the essential nutrient elements necessary for plant growth especially nitrogen which result in the improvement of plant growth parameters (Amanolahi- Baharvand *et al.,* 2014). Adamu and Leye, 2012; and Uwah *et al.* (2014) reported that plant height and leaf area of corn had a high positive correlation with the addition of manure alone or with inorganic fertilizers. In addition, UGBC has a significant role in improving physical soil properties such as moisture content, bulk density, porosity and aggregation stability (Chakraborty *et al.,* 2010), which in turn improve soil conditions and supported better aeration to the plant roots and absorption of water and nutrients (Manivannan *et al.,* 2009).

As discussed above, it is clear that the combined fertilization of 150 kg N of UGBC per hectare and 150 kg N of urea per hectare significantly increased plant height, number of effective tillers and leaf chlorophyll content. This suggests that combined fertilization of half dose of UGBC and urea at rate of 150 kg N ha^{-1} would improve growth and development of rice plant as compared to sole application of full dose of either UGBC or urea at a rate of 300 kg N ha^{-1}.

5.3.2.2 Effect of UGBC on maize yield parameters under field conditions

Table 5.4 presents the effect of UGBC on cob length, cob weight, cob weight after shelling, number of rows per cob, number of grains per cob, 1 000-grain weight and yield.

Table 5.4: Effect of UGBC application on maize yield parameters under field conditions

Treatments	Cob length (cm)	Cob weight (g)	Weight shelled cob (g)	Number of rows per cob	Number of grains per cob	1000-grain weight (g)	Yield (kg ha^{-1})
0 kg N ha^{-1}	12.40 a	92.80 a	18.66 ab	12.60 a	242.40 a	285.80 a	7799 a
300 kg N (UGBC) ha^{-1}	14.57 b	100.70 b	18.12 ab	13.07 a	287.00 b	300.50 b	8033 ab
300 kg N (UREA) ha^{-1}	19.55 c	104.90 b	21.07 b	13.27 a	288.70 b	307.00 b	8407 bc
150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}	21.13 c	112.70 c	16.09 a	13.40 a	320.60 c	307.90 b	8691 c
F-prob.	<.001	<.001	0.015	0.499	<.001	0.004	0.008
C.V (%)	3.5	2.2	6.7	4.9	1.3	1.6	2.5

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P=0.05).

Note: *CV = coefficient of variations, F-Prob. = F-Probability value, UGBC = Urban green biowaste compost.*

5.3.2.2.1 Cob length

Maximum cob length (21.13 cm) was recorded in the treatment combination (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}) which was significantly different (P=0.05) over 300 kg N (UGBC) ha^{-1} (14.57 cm) and control (12.40 cm). The second longest cob was noted in the 300 kg N (UREA) ha^{-1} (19.55 cm) which was statistically similar (P=0.05) to the treatment combination (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}). The shortest cob length (12.40 cm) was observed in the control. The relative increase in 1 000-grain weight in response to integrated application of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} compared to other treatments could be due to the enhanced N availability and uptake by maize plant as result of UGBC application in combination with inorganic fertilizer. Numerous other researchers also commented that combined application of organic and inorganic fertilizers is the best method and more conducive to increase crop yields and improve soil physical and chemical properties rather than using them individually (Bandyopadhyay *et al.*, 2010 and Jinwei and Lianren, 2011).

5.3.2.2.2 Cob weight and number of grains per cob

The highest cob weight (112.7 g) and number of grain per cob (320.6) were recorded in the treatment combination (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}) which was significantly different (P=0.05) over other treatments. Sole applications of UGBC and urea at 300 kg N ha^{-1} produced statistical similar (P=0.05) cob weight (104.9 g and 100.7 g for 300 kg N (UREA) ha^{-1} and 300 kg N (UGBC) ha^{-1} respectively; and number of grain per cob (288.7 and 287.0 for 300 kg N (UREA) ha^{-1} and 300 kg N (UGBC) ha^{-1} respectively. The significant minimum cob weight (92.8 g) and number of grain per cob (242.4) were recorded in the control treatment. Increase in the cob weight and number of grains per cob with the use of combined fertilization of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}compared to inorganic fertilizers (300 kg N (UREA) ha^{-1}) alone or control could be due to the role of UGBC in improving plant growth and increase the concentration of nutrients in the plant (Uwah *et al.*, 2014) and possibly physical properties of the soil as organic materials are soil conditioners; increased water retention, microbial activities and nutrient retention. Bedada *et al.* (2014) also reported that organic and inorganic fertilizers play an important role in improving corn productivity.

5.3.2.2.3 Weight of the shelled cob

The minimum weight (16.09 g) of the shelled cob was recorded in the treatment combination (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}), while application of urea alone at 300 kg N (UREA) ha^{-1} rate significantly increased (P=0.05) weight of the shelled cob (21.07 g) over other treatments. The minimum weight of shelled cob observed in treatment combination (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}) could imply that most of nitrogen absorbed by a plant was used for grain synthesis rather than cob itself.

5.3.2.2.4 Number of rows per cob

The number of rows per cob was not affected by the applied treatments. However, the relative high number of rows per cob (13.40) was recorded in the treatment combination (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}) while the minimum number of rows per cob (12.60) was noted in the control. The greatest number of rows per cob observed in the combined application of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} could be due to adequate N supply enhanced by application of UGBC. A positive correlation between the addition of organic material alone or in combination with inorganic fertilizer with yield of corn has been reported by other researchers (Adamu and Leye, 2012 and Zhang *et al.*, 2016).

5.3.2.2.5 A thousand grain weight

Maximum 1 000-grain weight (307.9 g) was noted in the treatment combination (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}). It was followed by sole application of 300 kg N (UREA) ha^{-1} (307.0 g). The third treatment was 300 kg N (UGBC) ha^{-1} (300.5 g). However, the three treatments did not differ significantly (P=0.05) with respect to 1 000-grain weight (Table 5.4). The minimum 1 000-grain weight (285.8 g) was observed in the control which was significantly different (P=0.05) over other three treatments. The relative increase in 1 000-grain weight in response to integrated application of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} compared to other treatments could be due to the enhanced N availability and uptake by maize plant as result of UGBC application in combination with inorganic fertilizer. Some researchers have also reported that organic material plays an important role in improving soil permeability to air and water and water stable aggregates (Chakraborty *et al.*, 2010). Thus, application of organic materials UGBC considerably improves soil physical properties and nutrient uptake resulting in greater growth, yield and yield components. This is reflected in the present study by the relative increase in 1000-grain weight in the combined fertilization of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}.

5.3.2.2.6 Grain yield

Maximum yield of 8 691 kg ha^{-1} was recorded in the (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}) treatment combination which was significantly different (P=0.05) over the control (7799 kg ha^{-1}) and 300 kg N (UGBC) ha^{-1} treatment (8 033 kg ha^{-1}). Comparable yields (P=0.05) were recorded between the treatment combination (150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1}) and 300 kg N (UREA) ha^{-1}. The minimum yield was recorded in the control treatment (7 799 kg). Recorded yield of 8 691 kg ha^{-1} equivalent to 8.69 t ha^{-1} in the integrated use of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} was far above the potential yield of maize (5 t ha^{-1}) in Tanzania. The relative increase in yield of maize in response to integrated fertilization of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} compared to application of 300 kg N (UREA) ha^{-1} alone could be due to the increased yield parameters (viz., cob length, cob weight, number of grains per cob and 1 000 -grain weight) as a result of combined fertilization of UGBC and inorganic fertilizer.

From the discussion above, it is clear that the combined fertilization of 150 kg N of UGBC per hectare and 150 kg N of urea per hectare significantly increased cob length, cob weight, number of grains per cob, 1 000-grain weight and yield of maize crop. This suggests that combined fertilization of half dose of UGBC and urea at rate of 75 kg N ha^{-1} would improve yield attributes and yield of maize as compared to sole application of full dose of either UGBC or urea at a rate of 150 kg N ha^{-1}. Similar trend of results was reported by Afe *et al.* (2015) and Fabunmi and Balogun (2015) who applied manure and inorganic fertilizers.

5.4 Conclusions and recommendations

5.4.1 Conclusions

The findings of the present study have revealed that:

- The integrated use of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} significantly increased the growth parameters and produced rice yield (8127 kg ha^{-1} equivalent to 8. 13 t ha^{-1}) which was approaching the potential yield of rice (10 to 11 t ha^{-1}) under irrigation ecology in Tanzania.
- The integrated use of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} significantly increased the growth parameters and grain yield of maize crop. It produced yield of 8691 kg ha^{-1} equivalent to 8.69 t ha^{-1} which is far above the potential yield of maize (5 t ha^{-1}) in Tanzania.

5.4.2 Recommendations

The present study recommended the following:

- Integrated fertilization of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} should be used for improved yield of rice crop.
- Integrated fertilization of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} should be used for improved yield of maize crop.

REFERENCES

Adamu, S. and Leye, B. O. (2012). Performance of maize (Zea mays L.) as influenced by complementary use of organic and inorganic fertilizers. *International Journal of Science and Nature* 3(4): 753-757.

Afe, A. I., Atanda, S., Aduloju, M. O., Ogundare, S. K. and Talabi, A. A. (2015). Response of maize (*Zea mays* L.) to combined application of organic and inorganic (soil and foliar applied) fertilizers. *African Journal of Biotechnology* 14(44): 3006-3010.

Amanolahi-Baharvand, Z., Zahedi, H. and Rafiee, M. (2014). Effect of vermicompost and chemical fertilizers on growth parameters of three corn cultivars. *Journal of Applied Science and Agriculture* 9(9): 22-26.

Bandyopadhyay, K. K., Misra, A. K., Ghosh, P. K. and Hati, K. M. (2010). Effect of integrated use of farmyard manure and chemical fertilizers on soil physical properties and productivity of soybean. *Soil and Tillage Research* 110(1): 115-125.

Bedada, W., Karltun, E., Lemenih, M. and Tolera, M. (2014). Long-term addition of compost and NP fertilizer increases crop yield and improves soil quality in experiments on smallholder farms. *Agriculture, Ecosystems and Environment* 195(3): 193-201.

Belefant-Miller, H. (2007). Poultry litter induces tillering in rice. *Journal of Sustainable Agriculture* 31(1): 151-160.

Chakraborty, D., Garg, R. N., Tomar, R. K., Dwivedi, B. S., Aggarwal, P., Singh, R., Behera, U. K., Thangasamy, A. and Singh, D. (2010). Soil physical quality as influenced by long-term application of fertilizers and manure under maize-wheat system. *Soil Science* 175(3): 128-136.

Diallo-Diagne, N. H., Assigbetse, K., Sall, S., Masse, D., Bonzi, M., Ndoye, I. and Chotte, J. L. (2016). Response of soil microbial properties to long-term application of organic and inorganic amendments in a tropical soil (Saria, Burkina Faso). *Open Journal of Soil Science* 6(02): 21-33

Efthimiadou, A., Bilalis, D., Karkanis, A. and Froud-Williams, B. (2010). Combined organic/inorganic fertilization enhance soil quality and increased yield, photosynthesis and sustainability of sweet maize crop. *Australian Journal of Crop Science* 4(9): 722-729.

Fabunmi, T. O. and Balogun, R. O. (2015). Response of maize (Zea mays L.) to green manure from varying populations of cowpea in a derived savannah of Nigeria. *African Journal of Food, Agriculture, Nutrition and Development* 15(3): 10138-10152.

Fageria, N. K. (2014). *Nitrogen Management in Crop Production*. CRC press. 436pp.

Fageria, N. K., Baligar, V. C. and Jones, C. A. (2010). *Growth and Mineral Nutrition of Field Crops*. CRC Press. 586pp.

Fanizza, G., Ricciardi, L. and Bagnulo, C. (1991). Leaf greenness measurements to evaluate water stressed genotypes in Vitis vinifera. *Euphytica* 55(1): 27-31.

Gala-Bi, T. J., Camara, M., Yao, K. A. and Keli, Z. J. (2011). Profitability of mineral fertilizers on rainfed upland rice cultivation: case of Gagnoa zone in the middle West of Cote d'Ivoire. *Journal of Applied Bioscience* 46: 3153-3162.

Hasanuzzaman, M., Ahamed, K. U., Rahmatullah, M., Akhter, N., Nahar, K. and Rahman, M. L. (2010). Plant growth characters and productivity of wetland rice (*Oryza sativa* L.) as affected by application of different manures. *Emirates Journal of Food and Agriculture* 22(1): 46-58.

Hati, K. M., Swarup, A., Mishra, B., Manna, M. C., Wanjari, R. H., Mandal, K. G. and Misra, A. K. (2008). Impact of long-term application of fertilizer, manure and lime under intensive cropping on physical properties and organic carbon content of an Alfisol. *Geoderma* 148(2): 173-179.

Jinwei, Z. H. A. O., and Lianren, Z. H. O. U. (2011). Combined application of organic and inorganic fertilizers on black soil fertility and maize yield. *Journal of Northeast Agricultural University* (*English edition*) 18(2): 24-29.

Joshi, H., Joshi, B., Guru, S., and Shankdhar, S. (2017). Consequences of integrated use of organic and inorganic fertilizers on yield and yield elements of rice. *International Journal of Agricultural Science and Research* 7(5): 163-166.

Jouquet, P., Plumere, T., Thu, T. D., Rumpel, C., Duc, T. T. and Orange, D. (2010). The rehabilitation of tropical soils using compost and vermicompost is affected by the presence of endogeic earthworms. *Applied Soil Ecology* 46(1): 125-133.

Ju, X. and Christie, P. (2011). Calculation of theoretical nitrogen rate for simple nitrogen recommendations in intensive cropping systems: A case study on the North China Plain. *Field Crops Research* 124(3): 450-458.

Kahimba, F. C., Kombe, E. E. and Mahoo, H. F. (2014). The Potential of System of Rice Intensification (SRI) to Increase Rice Water Productivity: a Case of Mkindo Irrigation Scheme in Morogoro Region, Tanzania. *Tanzania Journal of Agricultural Sciences* 12(2): 10-19.

Kaho, F., Yemefack, M., Feujio-Teguefouet, P. and Tchantchaouang, J. C. (2011). Combined effect of Tithonia diversifolia leaves and inorganic fertilizers on maize grain yield and soil properties of a Central Cameroon acrisol. *Tropicultura* 29(1): 39-45.

Kayeke, J., Sibuga, P. K., Msaky, J. J. and Mbwaga, A. (2007). Green manure and inorganic fertiliser as management strategies for witchweed and upland rice. *African Crop Science Journal* 15(4): 161 – 171.

Kimuni, L. N., Hugues, I. T., Musaya, E. M., Okese, A. E., Lukangila, M. A., Lubobo, A. K. and Longanza, L. B. (2014). Influence of fertilization based on recycled human waste, mineral fertilizers and their combination on the behavior of three varieties of maize (*Zea mays* L.). *Journal of Applied Biosciences* 77(27): 6500-6508.

Krishnaprabu, N. and Grace, T. M. (2017). Effect of nutrient management on growth and yield of traditional red rice land races (*Oryza sativa* L.). *International Journal of Chemical Studies* 5(6): 180-186.

Laharia, G. S., Patil, D. U. and Damre, P. R. (2013). Effect of organic sources on soil fertility, nutrient uptake and yield of soybean. *Crop Research* (*Hisar*) 45(1/3): 155-159.

Luzi-Kihupi, A., Kashenge-Killenga, S., and Bonsi, C. (2015). A review of maize, rice, tomato and banana research in Tanzania. *Tanzania Journal of Agricultural Sciences* 14(1): 1-20.

Lyimo, S., Mduruma, Z. and De Groote, H. (2014). The use of improved maize varieties in Tanzania. *African Journal of Agricultural Research* 9(7): 644 – 657.

Makoi, J. H. and Mmbaga, H. (2018). Soil Fertility Characterization in Mvumi and Mbogo-Komtonga Irrigation Schemes in Kilosa and Mvomero Districts, Morogoro Region, Tanzania. *International Journal of Environment, Agriculture and Biotechnology* 3(3): 1088-1099.

Manivannan, S., Balamurugan, M., Parthasarathi, K., Gunasekaran, G. and Ranganathan, L. S. (2009). Effect of vermicompost on soil fertility and crop productivity-beans (*Phaseolus vulgaris*). *Journal of Environmental Biology* 30(2): 275-281.

Mbaga, H. R., Mrema, J. P. and Msanya, B. M. (2017). Response of rice to nitrogen and phosphorus applied on typical soils of Dakawa Irrigation Scheme, Morogoro, Tanzania. *Imperial Journal of Interdisciplinary Research* 3(6): 378-384.

Mulaji, C. K. (2011). Use of household biowaste composts to improve acid soils fertility of the province of Kinshasa (Democratic Republic of Congo). Doctoral dissertation, Ph. D. Thesis, Universite de Liege, Gembloux Agro-Bio Tech, Gembloux, Belgium. 172pp.

Ngailo, J. A., Mmari, W. N., and Kyando, L. S. (2013). Soil Fertility Survey of Dominant Rice Farming Systems in Southern Highlands Tanzania. Research Internal Meeting (RIM) Southern Highlands Research Institute.

Ojetayo, A. E., Olaniyi, J. O., Akanbi, W. B. and Olabiyi, T. I. (2011). Effect of fertilizer types on nutritional quality of two cabbage varieties before and after storage. *Journal of Applied Biosciences* 48(5): 3322-3330.

Rakshit, A., Sarkar, N. C. and Sen, D. (2008). Influence of organic manures on productivity of two varieties of rice. *Journal of Central European Agriculture* 9(4): 629-633.

Siavoshi, M., Nasiri, A. and Laware, S. L. (2011). Effect of organic fertilizer on growth and yield components in rice (*Oryza sativa* L.). *Journal of Agricultural Science* 3(3): 217-224.

Simon, A. M. (2008). Analysis of Activities of Community Based Organizations Involved in Solid Waste Management, Investigating Modernized Mixtures Approach: The case of Kinondoni Municipality, Dar es Salaam, Tanzania. Unpublished master's dissertation for Award Degree at Wageningen University, Netherlands. 77pp.

Uwah, D. F., Undie, U. L. and John, N. M. (2014). Comparative evaluation of animal manures on soil properties, growth and yield of sweet maize (*Zea mays* L. *saccharata Strut*.). *Journal of Agriculture and Environmental Sciences* 3(2): 315-331.

Wang, Y., Wang, D., Shi, P. and Omasa, K. (2014). Estimating rice chlorophyll content and leaf nitrogen concentration with a digital still color camera under natural light. *Plant Methods* 10(1): 36-45.

Zhang, Y., Li, C., Wang, Y., Hu, Y., Christie, P., Zhang, J. and Li, X. (2016). Maize yield and soil fertility with combined use of compost and inorganic fertilizers on a calcareous soil on the North China Plain. *Soil and Tillage Research* 155: 85-94.

CHAPTRE SIX

6.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The present study has concluded that:

- Dakawa soils are sandy clay loam and non-saline with neutral pH, low OC and very low N and CEC and insufficient Ca and Zn.
- Dakawa soils have sufficient P, S, K, Mg, Mn, Fe and Cu.
- Biowaste composts from Dar es Salaam had very high pH and OC, fairly high K and sufficient P.
- Biowastes had very low N, low Zn, Cu, Fe and Mn.
- Heavy metals (Cr, Ni, Pb and As) in UGBC were found to be below the established maximum acceptable limits of Japan, Australia and United states.
- The use of PUGBC or NPUGBC improved growth and yield parameters of both maize and rice crops.
- The use of PUGBC and NPUGBC did not differ significantly across all growth and yield parameters of both maize and rice crops.
- The integrated use of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} significantly increased the growth parameters and yield parameters of rice. It produced high yield (8 127 kg equivalent to 8. 13 t ha^{-1}) which was approaching the potential yield of rice (10 to 11 t ha^{-1}) under irrigation ecology in Tanzania.
- The integrated use of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} significantly increased the growth parameters and grain yield of maize crop. It produced high yield (8 691 kg equivalent to 8.7 t ha^{-1}) which is far above the potential yield of maize (5 t ha^{-1}) in Tanzania.

6.2 Recommendations

- Dakawa soils need to be applied with organic materials in order to increase organic matter hence increase in OC and CEC.
- Dakawa soils need N and Zn supplementation for improved maize and rice yields.
- When biowaste from Dar es Salaam are used in maize and rice production, they should be supplemented with inorganic fertilizers rich in N and Zn, Cu, Fe and Mn nutrients.
- Another option could be fortification of the biowaste with N and Zn, Cu, Fe and Mn nutrients in order to improve their suitability for agricultural use as fertilizer especially for maize and rice production.
- PUGBC or NPUGBC can be used as soil amendment in maize and rice production. However, PUGBC would be a better option due its added advantages of easy application and handling apart from slight improvement of growth and yield parameters.
- Integrated fertilization of 75 kg N (UGBC) ha^{-1} + 75 kg N (UREA) ha^{-1} should be used for improved yield of rice crop while integrated fertilization of 150 kg N (UGBC) ha^{-1} + 150 kg N (UREA) ha^{-1} should be used for improved yield of maize crop.