NITROGEN RELEASE FROM DECOMPOSED RESIDUES OF HERBACEOUS LEGUMES AND THEIR EFFECT ON MAIZE GROWTH AND YIELD IN LOW NITROGEN SOIL

EMMANUEL AMOS CHILAGANE

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2013

ABSTRACT

This study was conducted at Sokoine University of Agriculture (SUA) located at 6°51′5″S and 37°39′26″E at 525 masl at the site with sandy clay soil pH 5.16 with the overall objective of improving maize productivity through the use of leguminous residues as source of nitrogen (N). Specifically the study aimed at determining the mineralization pattern and total amount of N released from decomposition of legume residues; to assess the effects of legume residues on maize growth and yield and to evaluate the effects of legumes biomass applied on maize yield. The treatments used were control (no legume residue and fertilizer application); application of N (Urea); residues in form of velvets bean (*Mucuna pruriens* L.), dolichos (*Lablab purpureus* L.) and sunhemp (*Crotolaria ochroleuca* G.). Maize variety "Staha" was used as a test crop. Experiments conducted were laboratory mineralization experiment, screen house and field experiments. These experiments were conducted between November 2011 and June 2012. Results showed that sunhemp had the highest N content of 2.77% followed by velvet bean and dolichos with 2.49 and 2.42%, respectively. Total amount of N released over 16 incubation weeks differed significantly ($P \leq 0.05$) with the range of 151.22 μg kg^{-1}. Leguminous biomass production was 15.13, 12.67 and 11.75 t ha^{-1} for velvet bean, dolichos and sunhemp, respectively. Maize grain yield ranged from 1.02 for control to 3.96 t ha^{-1} with Urea application. Sunhemp, velvet bean, and dolichos resulted in 3.69, 3.6 and 3.49 t ha^{-1}, respectively. As the incorporation of leguminous residues resulted into improvement of soil physical characteristics such as texture, bulk density and moisture content, it is recommended for use in mineral low N soils. This application will enhance poor resources farmers to improve maize productivity.

DECLARATION

I, Emmanuel Amos Chilagane, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor concurrently submitted for a degree award in any other institution.

09|10|2013

Emmanuel Amos Chilagane
(MSc. Candidate)

Date

The above declaration is confirmed by;

10/10/2013

Prof. C.L. Rweyemamu
(Supervisor)

Date

9/10/2013

Prof. E. Semu
(Supervisor)

Date

COPYRIGHT

ACKNOWLEDGMENTS

I wish to thank the GOD for his protection and guidance during the whole period of this study.

I would like express my sincere thanks to the Ministry of Agriculture, Food and Cooperative under Department of Research and Development for giving me the opportunity to undertake my MSc studies. More thanks to the Commission of Science and Technology (COSTECH) for financing this study; without this financial assistance this study would not have been possible.

I would like also to express my whole-hearted appreciation to Professor C. L Rweyemamu from Department of Crop Science and Production at Sokoine University of Agriculture and Professor E. Semu from Department of Soil Science at Sokoine University of Agriculture who were my Research Supervisors. Their patient support, advice and scientific guidance made completion this study possible.

Special gratitude is also extended to Mr. A.K. Mbwana and Mr. C. Henry of Sokoine University of Agriculture for their maximum cooperation and assistance during my field activities. Acknowledgments are further extended to all academic staffs at Department of Crop Science and Production including all postgraduate students for their guidance, advice and encouragement in bringing this study to a successful conclusion.

Appreciation is extended to all members of my family and friends for their prayers and support that helped me to finish this work smoothly and successfully. Many God bless you all.

DEDICATION

This work is dedicated to my parents whose constant encouragement and wishes gives me hope, inspiration and strength to pursue this study. May GOD shower his blesses to you all.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF SYMBOLS AND ABBREVIATIONS

%	Percent
μ	Micro- ($x10^{-3}$)
Al	Aluminium
BD	Balk density
BNF	Biological nitrogen fixation
C	Carbon
C:N	Carbon to nitrogen ratio
Ca^+	Calcium ion
CEC	Cation exchange capacity
cm	Centimeter
cmol/kg	centimol per kilogram
CO_2	Carbon dioxide
COSTECH	Commission of Science and Technology
CRD	Completely randomized design
CV	Coefficient of variation
DAP	Days after planting
DM	dry matter
DMRT	Duncan Multiple Range Test
E	East
e.g.	for example
FAO	Food and Agriculture Organisation
FC	Field capacity
Fig	Figure

g	Gram
H_2O	Water
Ha	Hectare
Hr	Hour
i.e.	that is
IITA	International Institute of Tropical Agriculture
K	mineralization constant
K^+	Potassium ion
kg	Kilogram
KJm^{-1}	Kilo Joule per metre square
LA	Leaf area
LAI	Leaf area index
M	Metre
masl	mitre above sea level
MAFC	Ministry of Agriculture, Food and Cooperatives
Max.	Maximum
mg	Milligram
Mg^+	Magnesium ion
Min.	Minimum
mm	millimetre
MPa	Mega Pascal
N	Nitrogen
N_2	Nitrogen gas
N_2O	Nitrite

Na^+	Sodium ion
NH_3	Ammonia
NH_4^+	Ammonium ion
NO	Nitrogen monoxide
NO_3^-	Nitrate
Ns	no significant difference
^oC	degree of Celsius
OC	Organic carbon
OM	Organic matter
P	Phosphorus
P_2O_5	Di-phosphorus pentaoxide
Pa	Pascal
pH	Hydrogen ion concentration
R	correlation coefficient
RCBD	Randomized complete block design
RH	Relative humidity
S	South
s.d	standard deviation
SOM	Soil organic matter
SUA	Sokoine University of Agriculture
T	Tonne
T	Time
TSP	Triple super phosphate
USA	United State of America

WHC	Water holding capacity
WKS	Weeks

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L.) is the staple food crop in Tanzania, and the estimated average consumption is 113 kg per person per year (Magenya *et al.*, 2008). According to the Ministry of Agriculture Food Security and Cooperatives (MAFC, 2012), maize is produced mainly under rain fed agriculture and yield is generally low at an average of about 1.3 t ha^{-1}. The crop is produced over a wide range of altitudes, from near sea level to about 2 400 m above sea level. The main agro-ecological areas that produce maize in Tanzania are the Southern Highlands Zone (44.8 % of all Tanzanian's production), Lake Zone (19.7 %), Northern Zone (11.0 %), Western Zone (9.7 %), Eastern Zone (8.4 %), Central Zone (3.8 %) and Southern Zone (2.6 %) (Nsami *et al.*, 2002).

One of the main problems causing low maize production in Tanzania is low soil fertility. The actual fertility of most soils is decreasing because greater quantities of plant nutrients are being removed than those being added (Tisdale *et al.*, 1985). Inorganic fertilizers and manures, though normally used to rectify soil fertility problems, are expensive, and alternative efforts on the soil fertility management should be adopted for higher and sustainable yields.

As already mentioned, most of the smallholder farmers in Tanzania are experiencing low maize yields. According MAFC (2009), maize production was 3 424 984 tons while the requirement was 4 131 782 tons resulting in a deficit of 706 797 tons.

Therefore, efforts to increase maize yields are needed for insuring food security in the family as well as the nation as a whole.

Continual cropping of maize in the same fields, removal of field crop residues for feed livestock, overgrazing and burning of crop residues in the field to ease ploughing have resulted in deterioration of physical, chemical and biological soil properties. Use of hybrid varieties with higher yielding ability and higher response to inputs call for increased use of fertilizer inputs (FAO, 2005). Therefore, in order for farmers to increase yield, greater effort should be placed on additional soil fertility management technologies. However, most farmers do not have enough capital, knowledge, skills and information about various soil management alternatives. Most farmers in both rural and urban areas of Tanzania are not aware that the use of organic resources such as crop residues can improve physical, chemical and biological condition of the soil.

Organic matter additions to the soil have shown to be critical in improving soil quality and optimizing nutrient and water retention capacities and ultimately crop productivity (Tschakert *et al.*, 2004). It is estimated that herbaceous legumes can accumulate 100 to 200 kg N ha^{-1} in 100 to 150 days in the tropics, with a significant portion of nitrogen (N) derived from biological nitrogen fixation. One of the key limiting nutrient in these soils is nitrogen. The integration of green manure legumes as cover crops into the smallholder farming systems has the potential to enhance the yields of subsequent crops as a result of the N released from the decomposition of the legume residues.

However, the best types of legume residues and the rates of N release from different residues have not yet been established and therefore not well documented. Examples of selected legume residues that may be used in Tanzania include those of velvet bean (*Mucuna pruriens*), dolichos (*Lablab purpureus*) and sunhemp (*Crotalaria ochroleuca*). An understanding of their N mineralization patterns is crucial in the synchronization of N release from residue and its uptake by subsequent crops. This enables good integration of the small quantities of nitrogenous fertilizers used by the farmers along with N released from decomposition of green manure legume cover crop residues, and may offer a strategy to meet the N needs of maize for smallholder farmers. The objectives of this research are as follows;

1.1 Overall Objective

Improving maize productivity through the use of leguminous residue as source of nitrogen.

1.2 Specific Objectives

i. To determine the mineralization pattern and total amount of nitrogen released from decomposition of velvet bean, dolichos and sunhemp.

ii. To access the effect of selected legume residue applied on growth and yield of maize crop.

iii. To evaluate the effect of biomass of selected legumes on maize yield under field condition.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soil Nitrogen

Nitrogen (N) is the nutrient that is needed by crops in larger quantity than others. In Tanzania, N taken out of the soil through maize crop harvest (grain and stover) annually has been estimated to range from 20 to 40 kg ha^{-1} (Smaling *et al.*, 1997). Nitrogen is a major limiting nutrient particularly in cereal production area including Tanzania (Khan *et al.*, 2011; Samki, 1989). This deficit is reflected by crop yield responses to N fertilizer use in different soils of Tanzania (Mowo *et al.*, 1993). Nitrogen levels in soils may differ depending on the proportions of soil particles and the amount of organic matter that the soil contained. Observation made by Odhiambo (2010), showed that the rate of N release as a result of decomposition and its level in a clay soil (62% clay) is low. Further, it was reported that the percentage N contained i0n very fine sand loam soil, clay soil, silt clay soil and silt clay loam were 0.55%, 0.13%,0.079% and 0.094%, respectively (Deenik, 2006).

Nitrogen is present in soils in organic and inorganic forms. There is a wide variation in the types of organic compounds that contain N. Organic compounds can be simple and easily degraded by microorganisms to form amino acids, or large complex molecules such as lignin and waxes that are quite resistant to microbial decay. The most resistant soil organic materials are components found in humus. Inorganic forms of N are nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+) and ammonia (NH_3). Nitrate and ammonium are readily taken up by plants and are beneficial for plant growth while nitrite and ammonia are toxic to plants (Muhammad, 2010; James, 2001).

2.1.1 Sources of soil nitrogen

As described by Muhammad (2010) and James (2001), there are two major sources of N in the soil, namely organic and inorganic N sources. Organic N is contained in organic matter whereas inorganic N is contained in soil solution and on soil exchange sites. Organic nitrogen constitutes between 95 to 99% of soil N but inorganic N accounts for only 1 to 5% (Brady and Weil, 2000). Inorganic N is the form that is taken up and utilized by plants (Gioseffi *et al.*, 2012). Organic N can be transformed to inorganic N and vice versa. Organic matter plays major role as N source because it is a large reservoir of N which is released from biological decomposition of organic matter. Decomposition refers to the conversion or decay of degradable (or chemically unstable) material to simple (or more stable) components or forms.

Nitrogen can also be added in the soil from external sources through industrial fertilizers, organic inputs, biological nitrogen fixation (BNF) and atmospheric N deposition (Brady and Weil, 2000). Organic inputs of N in the soil are through organic matter (OM) technologies including the use of farmyard manure, green manure, plant residues and compost manure. The amount of N added to the soil by these organic inputs depends on the quantity and quality of N that the material contains (Kalumuna, 2005). Atmospheric deposition and farmyard manure has little contribution since it accounts to less than 10 kg N ha^{-1} per year while N content in farmyard manure ranges between 0.58 to 0.74% (Iqbal *et al.*, 2012). Likewise, N content in compost manure varies depending on the chemical composition of the material used during its preparation and its management. The use of cover crop residues and agroforestry are among the technologies that can generate high plant biomass whereby increasing soil N contents through BNF at relative lower labour cost (Kalumuna, 2005).

2.1.2 Soil nitrogen losses

Nitrogen can be lost from the soil in various ways including leaching, denitrification, and nutrient transfer by crop harvest (soil mining) as well as erosion (Brady and Weil, 2000). Nitrogen in form of NO_3^- may be lost through leaching because of its high mobility especially in soil with low water holding capacity and low anion exchange capacity. Gaseous losses of N in form of NO, NO_2, N_2O and N_2 can range from 0 to 69% of the total N applied, and these losses depend much on soil pH, soil moisture as well as soil temperature (Bai *et al.*, 2012). Leaching losses vary between crop systems and crop types depending on root vigour and depth. In West Africa, losses ranging from 0.3 to 0.7 kg ha^{-1} were reported under cereal crops and as high as 25 kg ha^{-1} under groundnuts (Pieri, 1995). Leaching is much greater in course textured soil than on clay soil. In Sweden and Denmark, leaching of 40 kg N ha^{-1}per season was reported under sandy soil (Hansen and Djurhuus, 1997). Studies have shown that erosion losses through sediment transport can account for >95% of N losses. In Minnesota (USA), erosion losses accounting for 50-110 kg N ha^{-1} per year have been reported (Power, 1983). Soil N can also be lost through crop harvests that are not returned to the soil or field.

According to Stoovogel *et al.* (1993) the N loss range from 20 to 40 kg N ha^{-1} per year in Tanzania through crop harvests. Due to these losses and the dynamic nature of N, management of this nutrient needs much attention in order to optimize its availability to a growing crop.

2.1.3 Nitrogen dynamics in the soil

Nitrogen can exist in different forms in the soil depending on the soil condition. Nitrogen changes in the soil with respect to form, amount, time and soil depth are refered to as the N dynamics in the soil. This change is much influenced by soil pH, soil moisture and temperature. Among these factors, soil moisture has more influence on soil N dynamics (Kalumuna, 2005). Soil moisture in rain fed agriculture depends on the amount of rainfall and its distribution, therefore rainfall amount and distribution play a major role on determining N dynamic in the soil.

2.1.4 Nitrogen constraint in crop production

In Sub Sahara Africa, plant nutrients are depleted to a level that adversely affects soil productivity in most soils. It has been reported that depletion of nutrients in this region has great impact on yield reductions of crops by two to four times (Marandu, 2005). According to Stoorvogel *et al.* (1993), N balances were –ve 27 kg N ha^{-1} $year^{-1}$ in Tanzania and –ve 22 kg N ha^{-1} $year^{-1}$ in other Sub Sahara African countries due to N losses. Negative N balances are caused by normal crop management practices used by farmers including continuous cropping without appropriate land management practices to replenish nutrients taken up and harvested with crop. Mineral fertilizers are often applied especially to the cash crops such as tea, sugar cane and coffee.

Regardless of the voucher system that was introduced by the government, but unfavourable crop to fertilizer ratio, ignorance of the farmers and other financial constraints among farmers are factors limiting fertilizer use for food crops (Marandu, 2005). The use of leguminous plants as green manure, in crop rotation, improved fallows, intercropping are some of technologies for correcting the trends of declining soil fertility.

2.2 Concept of Supplemental Organic Materials in Agriculture

Soil organic matter (SOM) maintenance and management is central to the sustainability of soil fertility on smallholder farms in the tropics. Currently, SOM inputs are insufficient to maintain high levels in agricultural soils. Re-introduction of organic materials to smallholder agriculture is needed through a focused combination of new science and traditional agriculture. Several options can be used, including crop rotations, green manures, animal manures, intercropping, relay cropping, and agro-forestry (Marandu, 2005). Most of the promising routes to raise SOM level involve legumes as sole crops or in rotation with cereals, intercropped, fallowed, or used as green manures.

Green manures add up to 200 kg N ha^{-1} to the soil as well as organic matter, which improves physical, chemical and biological properties of soil. Several plant types can be used as green manure, but velvet beans (*Mucuna pruriens* L.), dolichos (*Lablab purpureus* L.) and Sunhemp (*Crotolaria ochroleuca* G.) are popular due to their high extent of N_2 fixation for soil fertility improvement. Sunhemp tends to release N at a constant rate of 0.012 N week^{-1}, dolichos (0.008 N week^{-1}) and velvet beans (0.004 N week^{-1}). This small amount may be of significant benefit to smallholder farmers with limited financial resources to purchase sufficient quantities nitrogenous fertilizers (Odhiambo, 2011), such as those found in Tanzania.

2.2.1 The contribution of herbaceous legumes to soil fertility improvement

The use of herbaceous legumes is very important for soil fertility improvement in infertile soils. Physical, chemical and biological soil fertility can be improved through the use of these legumes. Legumes have ability of fixing atmospheric N_2 and add N to the soil N pool (Carlson and Huss-Danell, 2003) and during decomposition of organic matter, N and other macro and micro elements are released in the soil; hence chemical soil fertility is improved (Kalumuna, 2005). Apart from chemical soil fertility, physical soil fertility, which refers to all physical attributes of the soil that are important for plant growth and development, is also improved. Physical attributes improved include soil structure, bulk density of the soil, soil porosity, water holding capacity and other attributes which provide conducive physical soil environment for plant growth (Marandu, 2005).

According to Avav *et al.* (2009), the canopy of legumes shields the soil from direct raindrops impact hence reduce soil erosion, minimize soil moisture loss and suppress weeds. Soil pH was decreased by 5%, while the organic matter was increased by 38% after incorporation of velvet bean biomass in the soil. The total N was increased up to 50% in velvet bean incorporated soils. Available phosphorus (P) and cation exchange capacity (CEC) of the soil was also increased to 36 and 11% respectively when velvet bean residues were incorporated in the soil (Avav *et al.*, 2009).

2.2.2 Mineralization of N during decomposition of legume residues

Decomposition of residues takes place in two phases, the first phase being rapid, which is controlled by the residue's C: N ratio; the second phase is slower being controlled by lignin and polyphenol contents of the residue (Jama and Nair, 1996). The rate of the first phase of decomposition is accelerated by high contents of soluble N in the residue. The critical level of N below which the rate of decomposition is retarded is 18 to 22 mg N g^{-1} of residue. High lignin and polyphenol contents of the residue reduce the rate of decomposition and hence reduce N net mineralization while enhancing immobilization in the second phase.

2.3 Factors Affecting Decomposition

In tropical systems, the rate of release of minerals in the soil (mineralization rates) are potentially higher because of high soil temperatures during cropping seasons, particularly at the time of incorporation of residues (Muhammad, 2010). Several reviews have summarized the factors affecting crop residue decomposition and came up with three main set of factors: (1) crop residue factors, (2) environmental factors, and (3) residue management factors (Muhammad, 2010; Yadvinder, 2005). The development of an effective crop residue management program depends on the level of understanding of the ways in which these factors influence the decomposition process. It has been reported that organic residue decomposition and SOM dynamics are influenced by the physicochemical environments, e.g. aeration (aerobic/ anaerobic), soil structure, the quality of residues and the types of decomposer community (Yadvinder, 2005).

2.3.1 Crop residues factors

2.3.1.1 Residue particle size

The accessibility of plant residues to soil microbes is of primary importance in their rate of decomposition. The particle size of the residue can provide different degrees of accessibility, which in turn affects residue decomposition rates as well as the mineralization-immobilization process. Generally, small particles decompose faster than large particles, and this is attributed to increased surface area of residues which promote microbial activity by enhancing better soil-residue contact (Marandu, 2005). Angers and Recous (1997) studied the effect of particle size (0.03 to 10 cm) of wheat straw on its decomposition in a silt loam soil. Early decomposition (3 – 17 days) was faster for the small-sized particles (0.06 – 0.1 cm), followed by the large-sized particle (5 and 10 cm). After 102 days, the very fine particles (<0.1 cm) showed the greatest and the intermediate-sized classes (0.5 – 1.0 cm) the lowest amount of C mineralization.

2.3.1.2 Residue chemical composition

It was hypothesised that greater accessibility and availability of N were responsible for the higher rate of decomposition observed for finely ground wheat straw. The effect of residue particle size on C and N mineralization may thus be an interaction between clay content, secondary metabolic products, chemical composition of residues, period of decomposition, and faunal activity (Kumar and Goh, 2000).

2.3.2 Environmental factors

2.3.2.1 Temperature

Environmental conditions can affect residue decomposition rates (Doung, 2009; Yadvinder, 2005). Generally, decomposition rates are faster in tropical areas and decrease as temperature decreases. The minimum and maximum tolerable temperatures for decomposers to survive range from 10.0 ^{0}C to 45.0 ^{0}C and thus support substantial decomposition rates in this range (Cheung, 2008). Singh *et al.* (1995) found that 24.8 – 29.0% and 39.5 – 43.4% of carbon (C) in rice and wheat residues was decomposed in 60 days at 25 ^{0}C and 40 ^{0}C, respectively.

2.3.2.2 Soil moisture

Soil water content can also influence crop residue decomposition and nutrient cycling (Guo *et al.*, 2012). The optimum water potential for residue decomposition lies in soil water potentials between -30 and -100 kPa. Yadvinder (2005) showed that the maximum rate of decomposition of plant residues occurred at 60% of the soil's water holding capacity (WHC). Lower rates of straw decomposition under water logged/ flooded conditions are probably due to limited aeration for sustained aerobic microbial activity. However, Villegas-Pangga *et al.* (2000) reported reductions of 27 – 45% in C evolution from rice straw under anaerobic conditions as compared with those under aerobic systems. These results suggested that under flooded conditions, depletion of O_2 decreased the decomposition rates of straw, but the initial rate of nutrient release was unaffected.

2.3.3 Residues management factors

2.3.3.1 Crop residue placement

Crop residues can be managed differently; e.g. residues may be placed on the surface, mixed into the soil, or confined in mesh bags within the soil. Surface placement reduces the residue - soil contact as compared with incorporation into the soil. This may affect the decomposition dynamics (Yadvinder, 2005) due to decreased soil - residue contact. The soil - residue contact of surface placement residue in the soil is much loose as compared with when the residues are mixed /incorporated in the soil. Good soil - residue contact creates a suitable micro climate for microbial activity (Yadvinder, 2005).

Knowledge of such effects is important when results from different studies are compared and is essential when developing and calibrating decomposition models. It is also important when assessing effects of tillage practices resulting in different degrees of residue-soil contact, e.g. no - till ploughing. The degree of contact between crop residues and the soil matrix, as determined by the method of residue incorporation affect decomposition dynamics under both natural and experimental conditions (Henriksen and Breland, 2002). Evidence from laboratory and field studies has suggested that the rate of the decomposition of plant materials depends on the degree of soil - residues contact (Muhammad *et al.*, 2007).

2.3.3.2 Tillage methods

Residue management practices including tillage practices affect the residue decomposition rates and loss of SOM. The observation made by Lupwayi *et al.*

(2004) revealed that residue decomposition was faster under conventional tillage than under zero tillage in later stages of decomposition. One of the reasons for the faster decomposition under conventional tillage compared with zero tillage is that residues incorporated into the soil has a greater surface area available for microbial degradation than residues left on the soil surface. (Burgess *et al.*, 2002).

2.3.3.3 Depth of incorporation

The depth of residue incorporation has also been shown to affect the decomposition of residues (Hoormanand Rafiq, 2010). Therefore, increasing the depth of residue incorporation resulted in a decrease in breakdown rate due to less biological activity. Likewise, the decomposition rate of rice straw was reduced by 13% by increasing the depth of incorporation of residues from 0 – 10 cm to 20 – 30 cm. In contrast, Breland (1994) found that increasing the depth of incorporation up to 30 cm increased the decomposition rate of residues, due to more favourable moisture regimes in lower layers. Crop residues managed previously can also significantly affect the decomposition of freshly applied crop residues (Yadvinder, 2005).

2.4 Factors Affecting Nitrogen Mineralization

The residue quality, residue placement and soil texture are important determinants of mineralization or immobilization of N during residue decomposition. The extent of mineralization of organic N depends on the N requirements of the soil microbial population, the biochemical composition of the decomposing crop residue, and several soil and environmental factors (Seneviratne, 2000). Crop residue management can affect N mineralisation and stabilization processes, and is a very important factor for efficient utilization of N from fertilizers, crop residues, and soil organic matter. Nitrogen mineralization is a crucial process of nutrient cycling dynamics in the soil–plant system (Kimani *et al.*, 2003).

2.4.1 Crop residue quality

Crop residues of low quality usually have low nutrients; hence decompose slowly in the soil. Among chemical criteria that are used to assess the quality of residues in the prediction of its rate of N release are total N concentration in the crop residues and its carbon to nitrogen ratio (C: N-ratio) (Seneviratne, 2000). Other chemical criteria include the quantity of lignin, polyphenols as well as soluble carbon concentration (Mohant *et al.*, 2010). The C: N ratio of the decomposing residues relative to that of microbial organisms is important in controlling the rate of N release. Microbes usually absorb soil inorganic N ions in the form of ammonium and or nitrate ions and convert them into organic form in their tissues, therefore, leading to a reduction of soil mineral N. This kind of N conversion is termed as nitrogen immobilisation.

When the C:N ratio of crop residues is narrow such as 15:1, microbes readily convert organically bound N into ammonium (NH_4^+) which increases soil mineral N; this process is called N mineralisation (Dar *et al.*, 2012). This ratio is an equilibrium point, and several C: N ratios have been reported as turning points of immobilisation and mineralisation. These include 24:1, 30:1, 25:1 and 20:1. These ratios differ depending on the amount of N, lignin and polyphenols that the residues contained (Marandu, 2005). Total nitrogen in crop residues is the determinant of the rate of residues decomposition. However, C: N ratio is slightly inferior to total N in predicting the rate of residues decomposition. It was observed that the critical value for transition from net immobilisation to net mineralisation is when the N concentration ranges from 1.8 to 2.5 % in the crop residues (Kimani *et al.*, 2003).

Presence of polyphenols in crop residues is another factor that controls decomposition rate. According to Marandu (2005), polyphenols are water soluble compounds which bind proteins, forming complexes, and this reduces the ability of microbes to degrade of crop residues. Trinsoutrot *et al.* (2000) found that polyphenol concentration in residues negatively affects N mineralisation, especially during the first stage of decomposition. However, some observations show that polyphenol: N ratios were a better index of residue N mineralisation than polyphenol alone. Lignin level in residues has also been reported to modify the rate of N release from decomposing residues. Lignin forms complexes with protein in the cell wall of the residues, thus making them to be resistant to microbial degradation. High concentrations of lignin inhibit plant residue decomposition and this is favourable for a soil cover while low concentration of lignin increase residues decomposition rates, more efficient nutrient cycling, and higher corn yields (Carvalho *et al.*, 2011).

2.4.2 Placement of crop residues

Crop residue placement influences N mineralization through an effect on the microclimate of the residue. Slower decomposition rates of surface-placed residues may result in greater potential for immobilizing N for longer periods than in the case of incorporated residues. Residue incorporation under conventional tillage agro-ecosystems leads bacterial-based food webs with fast rates of litter decomposition and nutrient mineralization, while surface applied residues under no-tillage systems support fungal-based food webs that result in slower decomposition and greater nutrient retention (Li *et al.*, 2012). Placement of residues may play an important role in determining availability of soil N to subsequent crops during the N mineralization process.

2.4.3 Soil texture

Soil texture controls the rate of residue decomposition and N mineralization (Najmadeen *et al.*, 2012). It can influence soil aeration/moisture status, affecting the physical distribution of organic materials and hence potential for degradation (Yadvinder, 2005). Hamarashid *et al.* (2010) reported that soil texture represents one of the most important factor that influences the structure of microbial communities, soil pH, CEC, and organic matter content in the soil. Becker *et al.* (1994b) observed that residue N release in clay soil was approximately twice that of sandy soil. Differences in N mineralization rates between soils have an impact on the fertilizer N requirement of the subsequent crop and the potential for N loss due to leaching or denitrification. Decomposition and mineralization of crop residues are however, inhibited under strongly acidic conditions. For example, Khalil *et al.* (2005) indicated that N mineralization increased as soil pH increased. Soil pH is reported to affect the nature and the size of the microbial population, both of which ultimately affect the residue decomposition and N mineralisation (McCauley, 2009).

2.5 Efficiency of Selected Legume Residues on Soil Fertility Improvement

2.5.1 Velvet bean

2.5.1.1 General description and its uses

Velvet bean (*Mucuna pruriens* L.) shown in Fig 1, is an annual plant with long vines that can reach over 15 m in length. When the plant is young, it is almost completely covered with fuzzy hairs, but when older, it is almost completely free of hairs (Dhawan *et al.*, 2011). The leaves are tri-pinnate and ovate shaped. The sides of the leaves are often heavily grooved and the tips are pointy. It bears white or purple flowers, its seed pods are about 10 cm long and are covered in loose orange hairs that cause a severe itch if they come in contact with skin due to protein chemical compounds known as mucunain. In many parts of the world, velvet beans is used as an important forage, fallow and green manure crop and in some few parts can be used as food (Dhawan *et al.*, 2011). It grows better at latitude ranging from 0 to 1900 masl and can tolerate sand poor fertile soils (IITA, 2001).

2.5.1.2 Agricultural value

Since velvet bean is a legume, it fixes N_2 and fertilizes soils. It is a widespread fodder plant in the tropics. The plant was reported to produce a lot of biomass and suppress weeds and root nematodes in Morogoro (Kalumuna, 2005). In Kenya, biomass production of about 4 to 7 Mg ha^{-1} were reported when the plant reached the age of three months, and was reported by Odhiambo (2011) to produce a root biomass ranging from 449 to 808 kg ha^{-1} at the age of four months. Analytical results of velvet bean leaves in east Africa have shown that, the N concentration in leaves ranges between 2.5 to 5.5%, lignin content of 6.04 - 10.94%, phosphorous content of 0.09 - 0.24 and soluble polyphenol between 0.46 and 4.73%. As reported by Marandu (2005) velvet bean plant has a potential of supplying about 35 kg N Mg^{-1} dry matter and it also has low lignin and polyphenol content and narrow C:N ratio(15:1), therefore has high decomposition rate (Marandu, 2005; Dar *et al.*, 2012).

Figure 1: Velvet bean plants 54 DAP

2.5.2 Dolichos

2.5.2.1 Morphological description

Dolichos (*Lablab purpureus* L.) (Fig 2) is a vigorously trailing herbaceous plant. Stems grow upright to 3 - 6 m in length, leaves are trifoliate and leaflets are broad ovate shaped, almost smooth above and short haired underneath. Flowers are white, blue or purple on short pedicels. Pods are 4 - 5 cm long, smooth and beaked by the persistent style containing seeds. It is characterised by fast growth rate with biomass ranges from 3.4 to 7.4 Mg ha^{-1} as reported in Kenya (Gachene *et al.*, 2000). Seed colour of dolichos varieties can range from white/cream to dark brown. Seeds can have a mottled colouring in some domesticated varieties and in all wild material. Have bean shaped seeds which are edible as well as feed for animals. Leaves of dolichos contain approximately 3.04 to 5.77% N, 0.28% P, 4.08 to 7.9% lignin and 1.57 to 3.26% soluble polyphenols (Kalumuna, 2005).

2.5.2.2 Agricultural uses

Lablab is a dual-purpose legume. It is traditionally grown as a crop for human consumption in south and Southeast Asia and eastern Africa including Tanzania. Flowers and immature pods are used as vegetables. It is also used as a fodder legume sown for grazing and conservation in agricultural systems in tropical environments with a summer rainfall. The plant is also used as green manure cover crop and has medicinal effect against human diabetes, high blood pressure and wounds (Marandu, 2005). It can be incorporated into cereal cropping systems as a legume hey to address soil fertility decline and is used as an intercrop species with maize to provide better legume/stover feed quality. As a dual purpose (human food and animal feed) legume, it is sown as a monoculture or in intercrop systems.

Figure 2: Dolichos plants at 54 DAP

2.5.3 Sunhemp

Sunnhemp (*Crotalaria ochroleuca* G.) shown in Fig 3, is a tall, herbaceous, warm-season annual legume with erect fibrous stems. It grows rapidly, competes with weeds and can reach 1 to 3 meters in height. It has been used extensively for soil improvement and green manuring in the tropics. It can tolerate poor, sandy soils and drought, but requires good drainage (Danielle *et al.*, 2007). Sunhemp tolerates moderate acidity, but a soil pH below 5 can limit its growth and becomes fibrous with age, but the plants are succulent for about eight weeks after seeding. It is often planted in midsummer after cool-season vegetables or sweet corn crops are harvested. The plant produces high quantity of biomass and N in 45 to 60 days. It forms a symbiotic relationship with soil bacteria that convert N_2 gas from the atmosphere and transforms N to plant-available forms (Danielle *et al.*, 2007).

Figure 3: Sunhemp plants 65 DAP

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

The present research work was conducted at Sokoine University of Agriculture (SUA), located in Morogoro, Tanzania ($6^0$51'5"S and $37^0$39'26"E) at an altitude of 526 masl at the crop museum in the Department of Crop Science and Production. The site is dominated by sandy loam soil with pH of 5.16 and has bimodal rainfall pattern where short rains (Vuli) start from October to December and long rain (Masika) start from March and end in May (Msanya *et al.*, 2003). The annual rainfall in this area ranges from 750 to 1050 mm with an average of about 900 mm. The annual temperatures in the area vary depending on the season, with average minimum and maximum of 17 and 28 ^{O}C, respectively (Tanzania Meteorological Agency SUA, 2012).

3.2 Soil Sampling and Characterisation for Mineralization Experiment

Soil from the field experimental site was sampled at 0 - 30 cm depth three weeks before planting. Soil samples were obtained randomly in the experimental field using method described by Kimaro (2009) and composite soil was prepared. The composite sample was packed, labelled and taken to the Department of Soil Science Laboratory for both physical and chemical analysis. Fifteen cores with undisturbed soil were also taken to the laboratory for soil bulk density determination. Soil samples for chemical analysis were air dried, ground, sieved through 2 mm sieve and analyzed for pH, total nitrogen (N), extractable P, cation exchange capacity (CEC), exchangeable bases (Ca, Mg, K and Na), extractable micronutrients and organic carbon using the methods shown in Table 1.

Table 1: Soil characterisation for mineralization experiment

Soil characteristics	Method used	Reference
Physical		
Soil texture		
Clay (%)		
Silt (%)	Bouyocous hydrometer-	
Sand (%)	Gee and Bauder(1986).	Landon (1991)
	Core method – Blake (1965).	
Bulk density (g cm^{-3})		Landon (1991)
Soil moisture (%)	Volumetric method	Landon (1991)
Chemical		
pH(H_2O)	pH in water: soil to water suspension (1:2.5) - Thomas (1996).	Landon (1991)
Total N (%)	Micro Kjeldahl method - Bremner (1965)	Landon (1991)
Extr P(mg/kg)	Bray and Krutz 1 method- Olsen and Somners (1982).	Landon (1991)
CEC (cmol$_c$/kg)	Extraction with NH_4-Ac saturation - Summer and Miller (1996).	Landon (1991)
Exch Ca^{2+}(cmol$_c$/kg)	Ammonium Acetate by	
Exch Mg^{2+}(cmol$_c$/kg)	Atomic absorption	
Exch K^{+}(cmol$_c$/kg)	spectrometer-Lindsay	
Exch Na^{+}(cmol$_c$/kg)	and Norvell (1978).	Landon (1991)

3.3 Daily Weather Data

The meteorological data were collected from TMA-SUA (2011/12) and included rainfall amount (mm), temperature for maximum and minimum (^{O}C), solar radiation (MJm^{-1}) and relative humidity (%) all taken on daily basis.

3.4 Field Experiment to Produce the Legume biomass and Treatment Applied

The legumes whose biomass were produced for determining N mineralization pattern were Velvets bean (*Mucuna pruriens* L.), Dolichos (*Lablab purpureus* L.) and Sunhemp (*Crotolaria ochroleuca* G.). The treatments used for assessing the legume residues on maize growth and yield were control (T1) i.e. no fertilizer applied, Nitrogen applied in form of Urea (46%N) fertilizer (T2), Velvets bean residue (2.49%N) (T3), Dolichos residue (2.42%N) (T4) and Sunhemp residue (2.77%N) (T5). The legumes seeds were obtained from the southern highland zone at Agriculture Research Institute – Uyole, Mbeya. The test crop used was maize variety "Staha" obtained from agrochemical shop (Imuka) in Morogoro municipality.

3.5 Determination of Mineralization Pattern and Total amount of Nitrogen Released from Decomposition of Velvet Beans, Dolichos and Sunhemp Residues

3.5.1 Land preparation and crop management

Land preparation was done in October, 2011 to produce fine soil tilth. Land was prepared by use of hand hoe and rake. Irrigation was done using water hose until the soil reached field capacity (FC), and planting was done on 27 October, 2011. Velvet and dolichos bean were planted at the rate of two seeds per hill and the spacing of 75 by 30 cm was used. Each plot contained nine rows and 60 plants per row. The length of each plot was 18 m and the width was 6.75 m, making the plot area to be 121.5 m^2 for each crop. Sunhemp seeds were drilled in rows where the spacing between rows was30 cm, and plots contained 22 rows of 18 m length that resulted into an area of 119 m^2. Total experimental area used in this study was 240.5 m^2. Treatments application was done randomly as described by Gomez and Gomez (1984).

Due to drought conditions that prevailed during the study, the crops were irrigated at the interval of three days after planting up to the second week of December, 2011 after the short rains (Vuli) had started. Weeding was done regularly at the interval of seven days while insects known as elegant grasshoppers (*Zonocerus elegans*) were controlled using insecticide (Profecron) at the rate of 1 litre ha^{-1}. Mechanical method of killing pest using sticks was also applied to further reduce infestation. Mechanical control mentioned was undertaken in the morning (between 0700 - 0900 hr) and in the evening (1700 – 1800 hr) when the insects were more active.

3.5.2 Data collection

3.5.2.1 Plant material characterisation

Above-ground tissues of legumes were harvested from the field when the crops reached flowering stage. The fresh weights (g) of each legume per metre square were recorded and the same materials were taken to the Department of Animal Science and Production Laboratory at SUA for dry weight determination and sample preparation. To determine dry weight, the materials were oven dried at 70 ^{O}C for 48 hr, and dry weights were determined. The materials were ground and sieved through a 0.5mm sieve by labmill grinder No 49 015, packed in plastic bags and labelled accordingly. Total N and organic carbon contents of the samples were determined by the micro kjeldhal method (Bremner, 1996) and the wet oxidation method of Black and Walkley (Nelson and Sommers, 1982), respectively, at Soil Science Laboratory, SUA.

3.5.2.2 Nitrogen mineralization experiment

The N mineralization experiment was carried out as described by Kuo and Sainju (1998). Ground samples of legume residues were added to 2 mm sieved soil at the rate of 10 g residue $kg^{-1}$of sieved soil, on dry weight basis. Then five portions of 250 g of the residue treated soil sample (for each legume) including control (without residue) and standard (with inorganic N) were placed in plastic bottles, and moisture content of these samples were adjusted to 60% of field capacity with distilled water before the soils were incubated at room temperature. The bottles were covered with perforated aluminium (Al) foils and incubated for 16 weeks. Incubation temperature was recorded weekly. The 250 g portions of soil treated with treatments were replicated twice makes the total of 10 bottles, and appropriately labelled to show the treatment contained in each bottle.

The incubated soils were weighed regularly and distilled water was added to bring the soil moisture to its original level (60% of field capacity). At 2, 4, 6, 10 and 16 weeks of decomposition, 20 grams of soil from each bottle were removed and mineral N (in form of NH^+_4, NO^-_3) was determined. Nitrogen mineralization from residues, expressed in percent, was calculated from the difference in cumulative amount of mineral N between residue treatments and control treatment at each sampling time, divided by the initial N in the applied residue material. The rate constant of N mineralization (k) were estimated using the single exponential equation $Y = \exp(-kt)$ (Odhiambo, 2010); where Y is the percentage nitrogen remaining of the residue mixture at time t. The k value was calculated using linear regressions of in Y versus t, where the slope of the linear regression is the k value.

3.6 Assessment of Maize Growth Responses to the Legume Residues Application

The completely randomized design (CRD) was used in the assessment of maize growth response to legume residues applied. Ten litre volume pots were filled with the soil and mixing with the legume residues of known amount of nitrogen, as analysed in Section 3.2. Crop residues were mixed with 10 kg soil in the pots at the ratio of 10 g of residue kg^{-1} of soil while 4 g of urea (46% N) fertilizer was added to pots treated with inorganic N fertilizer (T2). Treatments used in this experiment were similar to those motioned in Section 3.4 of this study. Thus, the experiment contained five treatments replicated three times, hence making a total of 15 pots.

Two maize seeds (variety Staha) were planted in each pot at 5-7 cm depth. Thinning was done at 3 leaf growth stage (two weeks after crop emergence) leaving one plant per pot. Recommended crop management practices were followed throughout crop growth. Irrigation water was regularly applied to bring the soils to 60% field capacity to compensate for evapotranspiration losses (Kanyeka *et al.*, 2007).

3.7 Evaluating the Effect of Legumes Biomass on Maize Yield Components and Yield under Field Conditions

3.7.1 Legume establishment

Land was prepared in October, 2011 using a hand hoe and plots of 3.0 m by 3.75 m were demarcated. A randomized complete block design (RCBD) was used where five treatments were randomly assigned into experimental units and replicated three times to make a total of 15 plots. Irrigation was applied to the plots up to field capacity one day before planting. Velvet bean and dolichos were planted, two seeds per hill at a spacing of 75 by 30 cm. The plots contained 5 rows and 10 plants per row resulting into 11.25 m^2. Sunhemp seeds were drilled in rows where the spacing between rows was 30 cm. The area of the entire experiment was 13.25 by 19 m, making a total area of 252 m^2. Other crop management practices were followed as described in Section 3.5.1.

3.7.2 Incorporation of legume residues into the soil

The legumes were slashed at flowering stage, weighed and incorporated in the soil in their respective plots. Seventy (70) kilogram of each type of residues were incorporated to their respective plots resulting into 328 379 and 183 kg N ha^{-1} for velvet bean, sunhemp and dolichos, respectively. The incorporated residues were left for two weeks for decomposition. Before the legumes were slashed, data pertaining to the legumes were collected. These included days to emergence, crop height (cm) a week before slashing, fresh and dry weight of legume residues in grams per metre squared.

3.7.3 Maize crop management

At the end of the two week incorporation period (for legume decomposition discussed in Section 3.7.2), the experimental units discussed in Section 3.7.1 were used. Plots with and without legume residues were tilled using hand hoes and levelled using rakes then two maize seeds (variety Staha) were sown at a spacing of 75 cm by 30 cm. Triple super phosphate fertilizer (TSP 46% P_2O_5) was applied to all experimental units at the rate of 40 kg P ha^{-1} as recommended and urea (46%N) fertilizer was applied in inorganic N treated experimental units at the rate of 80 kg N

ha^{-1} as described by Kanyeka *et al.* (2007). Thinning was done one week after crop emergence and one plant was left per hill. Other crop management practices that included weeding, irrigation and insect control were performed as described by Kanyeka *et al.* (2007).

3.7.4 Data collection

Data collection included days to initial crop emergence, days to 50% crop emergence, days to 50% tasselling, days to 50% silking, days to 95% crop maturity. Other data collected were plant height (cm), number of leaves plant $^{-1}$, leaf area (cm^2), fresh and dry weights of the crops (g) were also recorded at V 14th (i.e. 14 leaf production) and R1(50% silking) stages. Yield components and grain yield data that recorded were cob length (cm), cob weight (g), seed weight (g) and grain yield (t ha^{-1}). Data collection was from the central rows of each plot.

3.8 Data Analysis

The collected data were analyzed for varience using Co-Stat statistical software, using the following statistical model: $Y_{ij}= \mu+T_i +R_j + \varepsilon_{ij}$; Where: Yij represents the response for the experimental unit, μ is the overall mean, Ti is the treatment effect, Rj is the block effect, and ε_{ij} is the error/residues term (Shieh, 2004). Duncan's New Multiple Range Test (DMRT) was used for means separation at 5% level of significance. Correlation analysis (R) was also done at 5% level of significance for various maize growth and yield variables.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Soil Characteristics at the Experimental Site

The results of characterization of the soil at the experimental site before planting of the legumes are shown in Table 2. The soil particles size distribution (0 - 30 cm depth) was 54% clay, 1% silt and 45% sand, and according to Landon (1991) the soil was classified as sandy clay. The percentage of moisture content of the soil at sampling time was 1.24%, indicating that the soil was very dry at that particular time. The soil had a bulk density (BD) of 1.32 g cm^{-3}, which was rated as medium. Such low value of BD is regarded as having insignificant negative effect on plant root growth and penetration in the soil (Angela and Nina, 2007).

The soil had a pH of 5.16 that is rated as a strongly acidic, but was still within the preferable range for maize production (Belfield and Brown, 2008). The percentage total nitrogen (N) and organic carbon were of medium values of 0.3% and 1.76%, respectively. Extractable P was also found to be medium at 12.5 mg kg^{-1}. The cation exchange capacity (CEC) was 17 cmol$_c$ kg^{-1}; while the exchangeable bases was 4.82 for Ca^{2+}, 4.41 for Mg^{2+}, 1.48 for K^+ and 0.21 for Na^+. According to Landon (1991), the soil had high exchangeable Mg^{2+} and K^+ but low exchangeable Ca^{2+} and Na^+. Overall, the soil was classified as that of medium fertility (Landon 1991) and therefore suitable for maize production (Belfield and Brown, 2008).

Table 2: Soil characteristics at the initiation of the experiment (before legume planting)

Soil characteristic	Values	Rating*
Physical		
Soil texture		
Clay (%)	54	
Silt (%)	1	
Sand (%)	45	Sand clay
Bulk density (g /cm^3)	1.32	Medium
Soil moisture (%)	1.24	Very low
Chemical		
pH(H_2O)	5.16	Strongly acidic
Organic carbon (%)	1.76	Medium
Total N (%)	0.3	Medium
Extractable P(Bray 1,mg/kg)	12.5	Medium
CEC (cmol/kg)	17	Medium
Exchangable Ca^{2+}(cmol$_c$/kg)	4.82	Low
Exchangable Mg^{2+}(cmol$_c$/kg)	4.41	High
Exchangable K^+(cmol$_c$/kg)	1.48	High
Exchangable Na^+(cmol$_c$/kg)	0.21	Low

*Rating for soil characteristics was according to Landon (1991)

4.2 Weather Conditions

4.2.1 Temperature and rainfall

The average weekly weather data collected are shown in Appendix 1, while the average monthly weather data is shown in Table 3. The average minimum and maximum temperature for the whole period of this research ranged from 20.6 to 30.9 ^{O}C. The highest temperature was recorded in February, 2012 where it averaged 33.02 ^{O}C with the month's minimum value being 21.47 ^{O}C. The monthly variation of temperature, rainfall, relative humidity (RH) and solar radiation for the whole research period are presented in Fig 4.

The total amount of rainfall was 692.5 mm from November, 2011 to June, 2012 with poor distribution. The amount of rainfall collected for the whole research period was not enough to raise the maize crop properly (i.e. up to harvesting maturity) as the crop requires 600 to 1 200 mm to perform well (Belfield and Brown, 2008). Therefore, irrigation was done on both crops (legume and maize) to facilitate their proper growth. Whenever there was dry spell, the soil was brought to field capacity as described in Section 3.5.1.

Table 3: Monthly weather data for the whole period of research work

Month	**Temperature Max(^{O}C)**	**Temperature Min(^{O}C)**	**Radiation (MJm^{-2})**	**Rainfall (mm)**	**RH (%)**
November	32.38	21.25	18.96	37.00	72.59
December	31.50	21.50	19.16	191.10	75.47
January	31.34	21.50	35.59	70.30	75.74
February	33.02	21.47	20.83	71.70	69.42
March	31.61	21.35	18.72	49.73	76.06
April	29.91	20.47	15.33	124.90	81.36
May	28.70	19.30	15.10	134.60	82.36
June	28.05	16.96	15.19	22.90	76.53
Average	30.96	20.62	19.89	T* 692.53	76.07

*Total rainfall

Source: Tanzania Meteorological Agency – SUA

4.2.2 Relative humidity and solar radiation

The RH at the research site for the whole research period ranged from 69.42 to 81.36%, with the average of 76.07 % (Table 3). The highest RH was 81.36%, recorded in April and May, 2012. This was probably influenced by the rainfall availability in terms of its amount and distribution for these months as compared with the months of November, 2011 to February, 2012. Solar radiation ranged from 15.19 to 36.59 MJm^{-2} with the average of 19.89 MJm^{-2}.

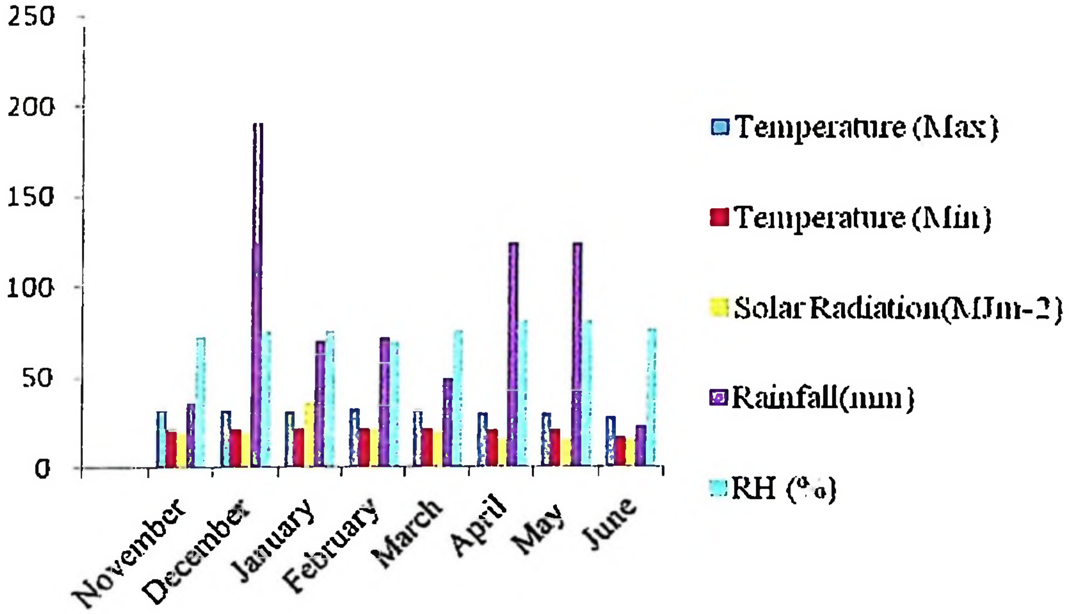


Figure 4: Monthly variation of weather for the whole period of study

4.3 Crops Establishment

4.3.1 Legumes establishment

The average number of days taken for the crops to emerge ranged from 3.3 to 6.3 days (Table 4). There was a significant difference ($P \leq 0.05$) on the days taken for the legume seedling to emerge. Results show that velvet bean was the last to emerge, followed by dolichos and sunhemp with the average of 6.3, 3.7 and 3.3 days, respectively. The differences on the days to emergence might be due to difference in morphological structures and seed sizes that legumes seeds possessed. Velvet bean have hard seed coat and this probably prolonged such initial processes of seed germination as water imbibitions for dilution of stored food, and other subsequent physiological processes. This might have resulted in delayed seed germination process as well as seedling emergence as stated above.

Table 4: Average days taken for the legume seedlings to emerge

Legume	Number of days to emergence
Velvet bean	6.3a*
Dolichos	3.7b
Sunhemp	3.3b
Mean	4.4
Sd±	0.8
F- Statistics	0.02
CV (%)	19.8

*Means in the same column followed by the same letter are not significantly different according to DMRT ($P \leq 0.05$).

A few weeks after the crops had emerged, the soil became dry due to low amount of rainfall and its poor distribution. These conditions persisted for almost two months (November to Desember, 2011). Drought conditions were the main challenge in the management of the legume crops, though some legumes like velvet bean showed some degree of drought tolerance compared with other leguminous crops used and the test cop maize. Due to these condition irrigation had to be applied to the crop which resulted into good crop performance. Insect pests were another challenge in the management of the legumes, with greater infestation observed in dolichos plots while velvet bean and sunhemp showed some degree of resistance to insect infestation as shown in Fig 5.

(a) dolichos (b) velvet bean (c) sumhamp

Figure 5: Legume leaves shows the extent of insect pest infestation

The elegant grasshopper was the major insect pest for legumes in this research. It was effectively controlled mechanically by killing the pest using sticks and chemically by use of insecticide as described in section 3.5.1. Harvesting of legumes and residues incorporation was done in February, 2012 when the legumes reached four months of age as shown in Fig 6.

Figure 6: Experimental site after incorporation of legume

4.3.2 Maize crop establishment

4.3.2.1 Screen house experiment

Maize took an average of 6 days after planting to emerge. The performance of maize crop in this study was not good due to inadequate amount of light in the screen house. The illumination and ventilation in the screen house used for this experiment were not enough to support optimal maize growth. Maize plants became taller with very thin stems that impaired the support system of the plant. This condition leads to crop lodging (Fig 7).

Figure 7: Nonstandard maize growths in screen house experiment due to inadequate light

This situation started one week after crop emergence and hence affected the early maize vegetative growth stages. However, it is worth to note that the amount of light in the screen house was not recorded due to the unavailability of the proper working equipment to use.

4.3.2.2 Field experiment

The average days taken for maize seedlings to emerge ranged from 6 to 7 days after planting. Drought conditions and insect pests were some of the important problems in the management of the maize crop. Irrigation was done up to field capacity to improve moisture in the soil and insecticide (*Shumba dust*) was applied at the rate of 1 kg ha^{-1} to control insect pests. Maize stalk borers (*Buseola fusca* L.) were the major pest affecting the maize crop in this study as shown in (Fig 8). Generally, the performance of maize crop was improved after irrigation and use of insecticide (Fig 9).

Figure 8a **Figure (8b)**

Figure (8a) and (8b): Maize crop leaves affected by stalk borers

Figure 9: General maize performances six weeks after planting

4.4 Legume Biomass Production and its Effects on Soil Properties

4.4.1 Legume biomass production

Biomass produced by the legume plants ranged from 11.75 to 15.13 t DM ha^{-1} (Table 5). There was no significant difference ($P \leq 0.05$) on biomass production among the tested legume crops. However, studies conducted in Kenya and Uganda by Wortmann *et al.* (2000) showed that velvet beans accumulated higher biomass as compared with other legume cover crops. This is because velvet bean crop has high potential to extract water from deeper layers in the soil and this characteristic enables it to survive during long dry period conditions. Biomass produced by dolichos in the present study is 12.67 t ha^{-1} which was higher by 1.77 t of biomass ha^{-1} compared with 10.9 t ha^{-1} reported in Nigeria by Iwuafor and Odunze (2000).

Table 5: Biomass production by selected legumes

Type of legume	Biomass(t/ha)
Velvet beans	15.13 a*
Dolichos	12.67 a
Sunhemp	11.75 a
Mean	13.18
Sd±	5.01
F- Statistics	0.27
CV (%)	16.98

*Means in the same column followed by the same letter are not significantly different according to DMRT at $P \leq 0.05$

It is reported that low and poor distributions of rainfall do interfere with leguminous plant growth and hence reduce biomass production. Although during the present research shortage of rainfall was experienced from November, 2011 to January, 2012, irrigation was undertaken to supplement moisture in the soil. This could be one of the main reason that resulted into higher biomass production with average of 13.2 t ha^{-1}.

4.4.2 Effect of legume residues on particle size distribution and balk density of the soil

The effect of legume residues on the particle size distribution and bulk density of the soil six weeks after residue incorporation are shown in Table 6. The proportions of different soil particles before planting of legumes were 54 % clay, 1 % silt and 45 % sand, but six weeks after incorporation the percentage soil particles where 55 % clay, 2 % silt and 43% sand for velvet beans treated soil, 54% clay, 3 % silt and 43

% sand for dolichos treated soil and 55 % clay, 3 % silt and 42 % sand for sunhemp treated soil. These results show that there is tendency of very slight increase of clay and silt percent while a slight decrease in sand particles when soil is treated with legume residues. However, this may not be long lasting effect. These results are in agreement with those reported by Aviv *et al.* (2009) where they found 3% decrease in the sand fraction in velvet bean incorporated soil. Bulk density of the soil before planting legumes was 1.32 g cm^{-3}. It is reported by Landon (1991) that bulk densities above 1.42 g cm^{-3} hinder the crop root penetration, but the soil under this study had lower bulk density than that stated by London. This indicates that the soil may have no hindrance to root penetration. Six weeks after incorporation of legume residues, the bulk density of the soil decreased from 1.32 to 1.02 g cm^{-3}, 1.04 g cm^{-3} and 1.03 g cm^{-3} for velvet beans, dolichos and sunhemp treated soil, respectively.

According to Ghuman and Sur (2001), the reduction of bulk density of the soil when treated by legume crop residues could be due to increase in the quantity of the lighter fraction and organic matter in the soil and hence mass of the soil per unit volume. They also reported that the surface application of plant residues reduced bulk density of surface soil by 0.05 g cm^{-3} but deeper soil layers are usually not affected. It was also observed by Rezig *et al.* (2012) that the physical properties of the soils, such as saturated and unsaturated hydraulic conductivity, water retention capacity, bulk density, total porosity, pore size distribution, soil resistance to penetration, aggregation, and aggregate stability were all improved in plots amended with organic amendments similar to those applied in this study.

Table 6: Effect of legume residues on physical properties of the soil six week after residues incorporation

Physical Soil characteristics	Before planting legume	T1 Treated soil	T2 Treated soil	T3 Treated soil	T4 Treated soil	T5 Treated soil
Clay (%)	54*	54	54	55	54	55
Silt (%)	1	1	2	2	3	3
Sand (%)	45	45	44	43	43	42
BD (g/cm3)	1.32	1.31	1.28	1.02	1.04	1.03
Moisture (%)	1.24	28	27	34	31	30

*Data not subjected to statistical analysis

4.4.3 Effect of legume residues on soil chemical properties

Total N of soil were significantly affected when the soil was treated with legume residues as shown in Table 7. There was a significant difference ($P \leq 0.05$) on the total N content in the soil at 6 weeks after legume incorporation, the highest value being observed on plots treated velvet bean, with a mean total N of 0.54% compared with the initial value of 0.3% and the control plots value of 0.27% (Table 2). This was followed by sunhemp and dolichos that had a means of 0.53% and 0.51%, respectively. Moreover, plots treated with inorganic fertilizer had a total N of 0.27% which was lower compared with residues treated plots that ranged between 0.51% for dolichos to 0.54% for velvet bean. These results imply that the total N in the soil increases when legume residues are incorporated into the soil, as a result of release of N contained in the residues. Therefore, application of legume residues in low N soil is very important for replenishment of the soil nitrogen.

Table 7: Effect of legume residues on chemical properties of the soil six week . after residues incorporation

Treatments	Total N (%)	CEC(cmol/kg)	OC (%)	Ph
Control	0.27b*	16.8a	1.78a	5.14a
Velvet bean	0.54a	18.1a	2.54a	5.12a
Dolichos	0.51a	17.6a	2.57a	5.12a
Sunhemp	0.53a	17.8a	2.55a	5.13a
Urea (46%N)	0.27b	16.8a	1.72a	5.15a
Mean	0.426	17.42	2.23	5.13
Sd±	0.14	0.59	0.44	0.01
F- Statistics	0.001	0.28	0.54	0.75
CV (%)	11.27	4.8	37.54	16.3

*Means in the same column followed by the same letter are not significantly different according to DMRT at $P \leq 0.05$

The results showed that residues incorporation resulted in no significant difference on the CEC, pH and organic carbon of the soil; though the plots treated with velvet bean had slightly higher CEC, followed by sunhemp and dolichos, with 18.1, 17.8 and 17.6 $\mathrm{cmol_c\,kg^{-1}}$, respectively. The slight increase in CEC of the soil indicates the improvement of the fertility nature of the soil. Organic carbon of the soil also varies. Plots treated with legumes residues had slightly higher organic carbon, which is very important in microbial activity in the soil. Such results have also been documented by Avav *et al.* (2009). The high variation (CV=37.54%) recorded on the OC variable indicated that the soil organic matter in the plots treated with legumes residues had improved compared with those without residues.

4.5 Nitrogen Mineralisation from Incubation Study

4.5.1 Characteristics of the soil and incubated legume residues

Characteristics of the soils used for incubation study are as already presented and discussed in Section 4.1. The characteristics of the legumes residues used are shown in Table 8. The percentage N content of selected residues ranged from 2.42 to 2.77%. Sunhemp had the highest N content of 2.77% followed by velvet bean and dolichos at 2.49 and 2.42%, respectively.

Organic carbon of tested legume residues varied from 38.84 to 44.04%, where velvet bean had the highest value of 44.04% followed by sunhemp and dolichos with 43.73% and 38.84%, respectively. The results in this study are different from those reported by Odhiambo (2010) where it was found to be 2.9, 2.3 and 2.2% N in velvet bean, dolichos and sunhemp residues, respectively.

Table 8: Chemical characteristics of incubated legume residues

	Residues chemical characteristics				
Legume types	**%N**	**%P**	**%K**	**%OC**	**C:N Ration**
Velvet bean	2.49*	0.20	2.15	44.04	17.7:11
Dolichos	2.42	0.17	2.12	38.84	16.08:1
Sunhemp	2.77	0.23	2.14	43.73	15.82:1

*These descriptive statistical data were not subjected to statistical analysis

4.5.2 Nitrogen mineralization pattern from incubation study

The initial N in the soil (i.e. before residues application) was 0.3%N as shown in Table 2. After residues application for each treatment (as described in Section 3.5.3.2), the results in Table 9 indicated that the control treatment (without residue application) had the initial value of 48.45 μg N kg^{-1} soil while the standard treatment (with Urea 46%) had 95.39 μg N kg^{-1} soil. The other treatments were with values of 53.84 (velvet bean), 58.08 (dolichos) and 61.02 (sunhemp). Two weeks after the initiation of the incubation process there was an increase in the soil N which valued 93.07 μg N kg^{-1} soil and there after the increase pattern was at 115.25, 130.92, 125.27 and 118.68 μg N kg^{-1} soil. Similar pattern is shown in Figure 10. The inorganic fertilizer (Urea 46%N) resulted into highest N accumulation followed by sunhemp, dolichos, velvet bean and the control.

Table 9: Nitrogen mineralisation of the applied treatments in μg kg^{-1} soil

Treatment	0wks	2wks	4wks	6wks	10wks	16wks
Control	48.45 e*	54.81 d	60.04 d	64.52 d	66.87 d	65.26 c
Velvet bean	53.84 d	68.43cd	79.50 c	93.74 c	106.73 c	110.46 b
Dolichos	58.08 c	71.35bc	80.73 c	98.07 c	108.64 c	111.42 b
Sunhemp	61.02 b	85.34 b	103.82 b	135.26 b	141.33 b	137.97 ab
Urea(46%N)	95.39 a	185.43a	254.68 a	263.03 a	202.87 a	168.26 a
Mean	63.36	93.07	115.75	130.92	125.27	118.68
Sd±	18.52	52.75	79.19	78.01	50.77	38.10
F- Statistics	0.001	0.001	0.001	0.001	0.001	0.002
CV(%)	2.11	8.19	6.35	9.09	5.43	16.63

*Means in the same column followed by the same letter are not significantly different according to DMRT at $P \leq 0.05$

The pattern of incubation values shown in Figure 7 are also indicated in Appendix 2. The percentage mineral N released from the applied treatment increased with time and reached a peak at 10 wks after onset of incubation for the control and sunhemp, with 27.56 and 56.82%, respectively, while inorganic fertilizer N release peaked at 6wks after onset of incubation. This indicates that inorganic fertilizer has higher and faster N releasing ability over legume residues. This may cause N loss through leaching especially in high rainfall areas with sandy soils and, therefore, the need for split application of inorganic fertilizer is very important. Velvet bean and dolichos had similar trend of N releasing ability which released N at decreasing rate throughout the period of incubation, with the overall percentage increment of 51.26% and 47.87%, respectively, at the end of incubation period.

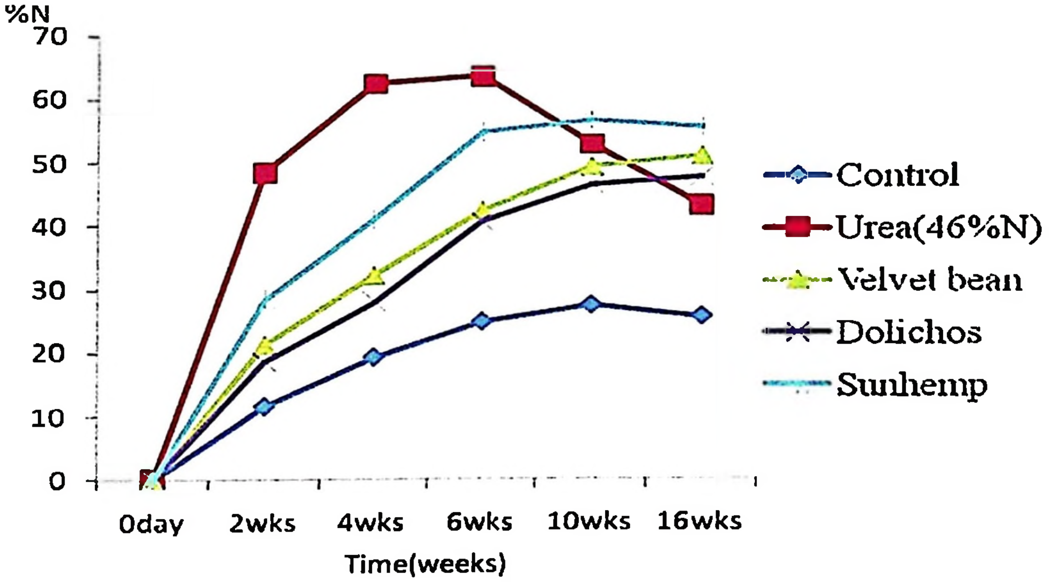
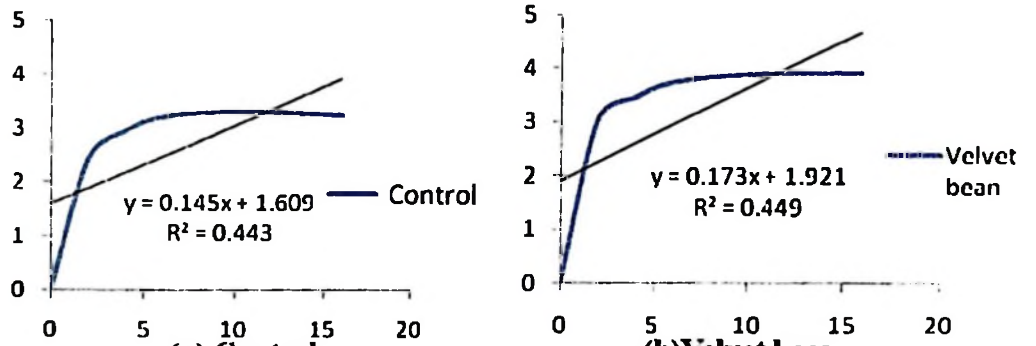


Figure 10: Nitrogen mineralization pattern

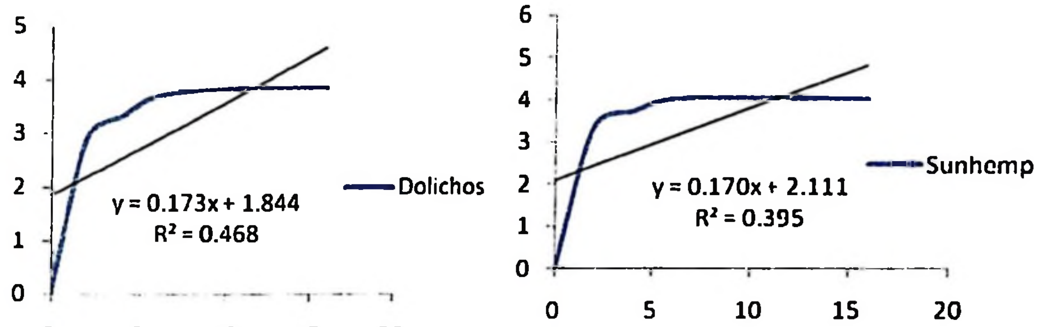
Sunhemp had the highest N releasing ability compared with velvet bean and dolichos. This is due to its higher N content, resulting in the narrowest C: N ratio as shown in Table 8. The mineralisation constant of treatments used for 16 weeks of incubation are presented in Figure 11. Mineralisation rate constant for velvet bean, dolichos and sunhemp were 0.1736, 0.1739 and 0.1702, respectively. Control and inorganic N treated samples tended to have lower mineralization constants of 0.1457 and 0.135, respectively. These values imply that the mineralisation of these legume residues follows similar linear patterns; though they differed in terms of the total amounts of N they released (Table 8). Similar trend of results was observed by Odhiambo (2009) working in Kenya, that sunhemp residue tended to have high N content and mineralization rate but relatively lower mineralization rate constant.

However, at the end of the weeks 16 of incubation period, all the legumes produced substantial amounts of mineral N, which contributed significantly to the N requirement of the maize crop. Maize crop reach tasseling stage approximately 10 - 12 weeks after planting. This is the stage with the maximum demand for N by the crop, and coincided with the maximum amount of N released by the decomposing legume residues, which greatly benefited the maize crop.



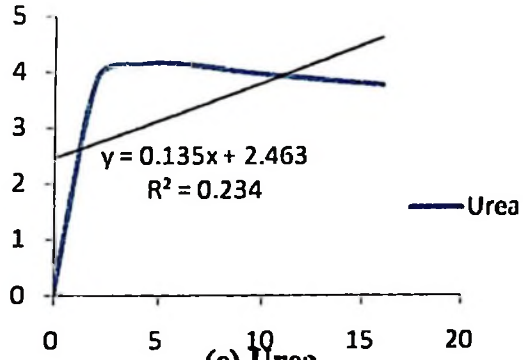
(a) Control

(b)Velvet bean



(c) Dolichos

(d) Sunhemp



(e) Urea

Figure 11: (a-e) Mineralisation rate constant (*k*) for tested treatments

4.6 Effects of Legume Residues of Maize Growth

4.6.1 Effects of legume residues on maize growth stages

Effect of applied residues on maize growth stages are shown in Table 10. Days taken for maize crop to emerge among plots treated with legume residues decreased significantly ($P \leq 0.05$). Maize in the control plots and those applied with inorganic fertilizer (Urea 46%N) took an average of 7 days from planting while those applied with legume residues took an average of 6 to 6.7 days to emerge. These results explain the role of legume residues on the improvement of physical soil properties such as moisture and structure which have great influence on crop emergence as was also reported by Rao *et al.* (2008). When legume residues are incorporated in the soil they improve soil aeration, reduce soil compaction and improve water holding capacity of the soil (Rezig *et al.*, 2012). These factors, when improved, they do facilitate crop emergence.

Table 10: Effect of legume treatments applied on the days to different growth stages of maize crop

Treatment	Emergence	Booting	Tasseling	Silking	Maturity
Control	7.0 a*	43.3 b	45.3 a	53.0 a	110.67a
Velvet bean	6.7 b	45.3 a	46.3 a	52.7 a	110.67a
Dolichos	6.0 b	45.0 a	45.7 a	52.3 a	111.30a
Sunhemp	6.0 b	45.3 a	46.3 a	51.7 a	111.00a
Urea (46%N)	7.0 a	43.3 b	45.3 a	52.3 a	111.60a
Mean	6.54	44.44	45.80	52.40	111.10
Sd	0.50	1.05	0.50	0.49	1.14
F- Statistics	0.002	0.017	0.48	0.81	0.78
CV (%)	3.95	1.692	1.973	2.65	1.03

*Means in the same column followed by the same letter are not significantly different according to DMRT at $P \leq 0.05$

Days taken for maize crop to reach tasseling and silking stage did not differ significantly ($P \leq 0.05$) for plots applied with treatments used. However, plots treated with sunhemp, velvet bean and dolichos took the average days to tassel of 46.3, 46.3 and 45.7, respectively, while the control maize plots and plots with inorganic fertilizer took the average days of 45.3 to tassel. These results imply that the growth stages in maize were influenced by the genetic factors rather than the applied treatments.

4.6.2 Effects of legume residues on plant height, leaf number, LA and LAI

Effects of applied residues on the performance of maize on crop height and leaf number under field condition were observed at 28 DAP. The results show that crop height and leaf number under these treatments do not differ significantly ($P \leq 0.05$) as indicated in Table 11.

Table 11: Effect of legume treatments applied on plant height and leaf number

	At 28 DAP	
Treatment	**Plant height(cm)**	**Number of leaves**
Control	48.89 a*	8.72 a
Velvet bean	50.36 a	8.95 a
Dolichos	47.75 a	8.92 a
Sunhemp	53.41 a	9.14 a
Urea(46%N)	51.67 a	9.31 a
Mean	50.42	9.01
Sd±	2.23	0.23
F- Statistics	0.51	0.74
CV (%)	8.13	6.13

*Means in the same column followed by the same letter are not significantly different according to DMRT at $P \leq 0.05$

Results on the effects of treatments on leaf area (LA) and leaf area index (LAI) under both field and screen house condition are shown in Table 12. At 44 DAP, the results show significant difference ($P \leq 0.05$) on maize leaf area (LA) and leaf area index (LAI) under filed conditions. Maize in plots treated with velvet bean resulted in higher average LA and LAI of 1 961.85 cm^2 and 0.87, respectively, followed by sunhemp that had the value of 1 864.80 cm^2 and 0.83, respectively. On the other hand, sunhemp residues resulted into higher LA and LAI in pot experiment. Results by Kutu (2012) indicated that LAI increased from 1.87 for control to 2.31 under legume – maize intercropping system. Similar observations were reported by Cheruiyot *et al.* (2001) and Dimitrios *et al.* (2012). The low value of LAI averaging 0.76 and 0.79 for field and screen house experiment, respectively, could have been attributed by the variety used in this study and an empirical method used to determine the leaf area. The use of this method in determining the LA resulted into high CV value of 35.9 for LA and 36.1% for LAI.

Table 12: Effect of legume treatments applied on plant height, leaf number, LA and LAI at 44 DAP (Tasseling stage)

	Field experiment		**Pot experiment**	
Treatments	**LA(cm^2)**	**LAI**	**LA(cm^2)**	**LAI**
Control	1658.88 bc*	0.74 bc	1413.80ab	0.63 a
Velvet bean	1961.85 a	0.87 a	1678.90 ab	0.75 a
Dolichos	1651.87 bc	0.73 bc	1897.20 ab	0.84 a
Sunhemph	1475.63 c	0.67 c	2607.40 a	1.16 a
Urea(46%N)	1864.80 ab	0.83 ab	1329.10 b	0.59 a
Mean	1722.61	0.76	1785.30	0.79
Sd±	192.04	0.08	511.3	51.5
F- Statistics	0.006	0.005	0.020	0.18
CV (%)	6.71	6.68	35.90	36.1

*Means in the same column followed by the same letter are not significantly different according to DMRT at $P \leq 0.05$

4.6.3 Effects of legume residues on fresh and dry weight of maize

The values for fresh weight and dry matter production under field and screen house conditions are shown in Table 13. Average fresh weight and dry weight of maize differed significantly at $P \leq 0.05$ due to the treatments. The lowest average value of fresh weight was observed in maize planted on the control plots (plots with neither legume residues nor inorganic fertilizer application). Sunhemp residues resulted in the highest average fresh weight of maize in the field experiment (958.78 g m^{-2}) while urea give the highest (864.7 g m^{-2}) in the screen house experiment.

Table 13: Effect of applied legume residues on fresh (g) and dry weight (g) of maize at tasseling stage (45 DAP)

	Field experiment		Pot experiment	
Treatment	**Fresh weight**	**Dry weight**	**Fresh weight**	**Dry weight**
Control	657.57 b*	63.93 b	442.50 c	52.90 c
Velvet bean	876.03 ab	109.56 a	702.70 b	88.70 ab
Dolichos	800.47 ab	93.59 ab	675.20 b	80.30 b
Sunhemp	958.78 a	108.70 a	815.50 a	97.20 a
Urea(46%N)	927.62 a	95.72 ab	864.70 a	87.90 ab
Mean	844.10	94.30	700.02	81.40
Sd±	120.25	18.47	163.80	17.00
F- Statistics	0.005	0.019	0.001	0.001
CV (%)	14.40	23.40	7.09	7.72

*Means in the same column followed by the same letter are not significantly different according to DMRT at $P \leq 0.05$

These results are also supported those of Dimitrios *et al.* (2012) which indicated that the average fresh and dry weights of maize were higher in the plots treated with legume residues than in plots that were treated with inorganic fertilizers. The relatively high CV value of 23.0% reported on dry weight under field condition could have been influenced by the weather conditions, such as the sporadic rainfall distribution that was observed (Section 4.2.1).

4.6.4 Effects of legume residues on maize yield components and yield

The effects of treatments on maize yield components and yield are shown in Table 14 and Appendix 3.The variety "Staha" had one cob per plant. The average number of rows per cob and seed per row from residue-treated and fertilizer (Urea 46%N) plots were greater than those from control plots (Appendix 3). This probably could be due to higher availability of nutrients in grain formation. Similar results were obtained by Abuzar *et al.* (2011) the highest number of seed per row of 32.33 seeds could possibly be due to enough nutrients and moisture during grain filling stage.

Table 14: Effect of applied legume residues on maize yield components

Treatment	Seed weight (g/100seed)	Seed weight g/plant	Shelling %	Grain yield (g/m^2)	Grain yield (t/ha)
Control	36.23b	25.56c	8.95c	102.22c	1.02 c
Velvet bean	40.63ab	90.00b	24.28ab	349.63b	3.60 b
Dolichos	41.33ab	87.41b	23.35b	360.00b	3.49 b
Sunhemp	43.07ab	92.22b	24.14ab	368.86b	3.69 b
Urea(46%N)	44.33a	98.89a	27.09a	395.56a	3.96 a
Mean	41.11	78.81	21.26	315.25	3.15
Sd±	11.95	7.2	3.7	3.80	1.20
F- Statistics	0.03	0.04	0.001	0.001	0.001
CV (%)	7.69	3.79	7.24	3.8	3.78

* Means in the same column followed by the same letter are not significantly different according to DMRT at $P \leq 0.05$

The average cob weights were highest and significantly different ($P \leq 0.05$) in plot with residues and fertilizers compared with the control. The average seed weight (g

100seeds^{-1}) and seed weight (g plant^{-1}) of maize crop were highest (i.e. 44.33 and 98.89 g, respectively) in plots with inorganic fertilizers and lowest (i.e. 36.23 and 25.56 g, respectively) in the control (Table 14). The average maize seed weight did not differ significantly ($P \leq 0.05$) among the legume residue treatments as it ranged from 40.63 to 43.07 g.

The effects of applied treatments on maize shelling percentage differed significantly ($P \leq 0.05$). Plots treated with urea resulted into the highest shelling percentage (27.09%) while the lowest value (8.95%) was observed on control plots. Plots treated with legume residues resulted in shelling percentages of 24.28, 24.14 and 23.35% for velvet bean, sunhemp and dolichos, respectively.

There was a significant difference ($P \leq 0.05$) in maize yields when the crop was treated with these treatments. The average maize yield was 3.78 t ha^{-1}. The plots treated with urea fertilizer resulted into the highest maize yield of 3.96 t ha^{-1}) while the lowest yield (1.02 t ha^{-1}) was recorded in the control plots. Plots treated with legume residues gave 3.69, 3.60, and 3.49 t ha^{-1} with sunhemp, velvet bean and dolichos residues, respectively.

The good maize performance and yields in treatment urea was probably due to availability of N. The relatively better performance of the residue treated plots to control plots could have been due to N released as a result of continuous decomposition of legume residues. Moreover, presence of legume residues enhanced the improvement of physical soil characteristics, like water availability, which enhanced good maize performance and yields. Improvement of maize yields due to the use of legume residues has been documented elsewhere. In Tanzania, research results by Sibuga *et al.* (2012) in Iringa region showed that maize yields were 3.6 and 3.4 t ha^{-1} when velvet bean and sunhemp biomass were applied. Yield of 4.56 t ha^{-1} was also recorded in Tanga, Tanzania, by Bogale *et al.* (2001) from maize plots previously treated with sunhemp. In Kenya, sunhemp and velvet bean green manure improved maize grain yields by 1.5 t ha^{-1} compared with no incorporation (Ojiem *et al.*, 2000), while in southern Cameroon, the average maize yields greater than 4 t ha^{-1} were realised after a short-term fallow with velvet bean (Odhiambo, 2010). Thus, the importance of legume residues in improving yields is evident.

4.6.5 Simple correlation analysis results on yield and yield components

Simple correlations between grain yield and its contributing components were done as indicated in Table 16. Linear relationships among yield components and grain yield were measured through simple correlation analysis. The most significant and positive correlation was observed between kernel weight with grain yield (R=0.84***). The results show that grain yield was highly and positively correlated with cob length and seed weight (R=0.68** and 0.67**, respectively). Positive correlations were also observed among yield components. There was very high positive correlation between kernel weight and cob length (R=0.82***) while positive correlation (R=5.1*) was observed on seed weight with kernel weight.

The significant values of correlation observed on kernel weight with grain yield and cob length with grain yield indicated that the improvement of kernel length and grain sizes and number of kernels may significantly lead to the increases in maize grain yield. Similar results were obtained by Mohammadi *et al.* (2003) who reported positive and strong correlation between kernal length and grain yield. According to Batool *et al.* (2012), kernel weight, kernel length and 100 seed weight are significantly and positively correlated with grain yield.

Table 15: Simple correlations on yield and yield components

	Yield (ton/ha)	Kernal weight(g)	Cob length(cm)	Dry weight at silking(g)	Seed weight(g/100seed)
Yield (ton/ha)	1				
Kernal weight(g)	0.84***	1			
Cob length(cm)	0.68**	0.82***	1		
Dry weight at silking (g)	0.56*	0.72**	0.64*	1	
Seed weight(g/100seed)	0.67**	0.51*	0.20ns	0.31ns	1

*Significant $P \leq 0.05$

**High significant $P \leq 0.01$

***Very highly significant $P \leq 0.001$

ns- Not significant

n=15, df = n-2

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the information obtained from this research, the following conclusions are made:

(1) Legume residues tested produced significant amounts of mineral nitrogen (N) after 16 weeks of incubation period. Sunhemp residues were the best in N releasing ability and had best mineralization pattern, followed by velvet bean and dolichos. The maximum N demand period in maize plant was at tasseling stage which ranged from 8 to 10 weeks after planting. The amount of N released from residues was higher between 8 and 10 weeks of incubation. These study results indicated that maximum N demand of maize coincided with the maximum N release from legume residues. This greatly benefited maize crop in terms of growth, development and yield.

(2) Among tested legume residues, velvet bean appears to be of the highest efficiency in biomass production followed by dolichos and sunhemp. However, in term of N content, sunhemp residues had highest N content (2.77%) followed by velvet bean (2.49%) and lastly dolichos (2.42%). The use of any of the three legume residues resulted in relatively high potential in increasing maize crop yield. The highest yield was observed from inorganic fertilizer treated plots (3.96 t ha^{-1}) followed by sunhemp (3.69 t ha^{-1}) > velvet bean (3.60 t ha^{-1}) > dolichos (3.49 t ha^{-1}) and finally, the control (1.02 t ha^{-1}). This study indicated that sunhemp, velvet bean and dolichos residues had

similar effects of improving maize yield. These results imply that in case of inadequate amount or lack of inorganic fertilizers such as Urea, the use of the legumes can be applied as substitute. This is especially so for poor resource farmers located in the mineral low N soils such as those at Sokoine University of Agriculture.

5.2 Recommendations

(1) Incorporation of sunhemp, velvet bean and dolichos residues should be encouraged in soils with low mineral N contents so as to improve the fertility status of the soil, especially for poor resource farmers.

(2) It is recommended that legumes should be planted during short rains and incorporated at the beginning of long rains in bimodal rainfall pattern areas. This will enhance poor resource farmers with low purchasing ability of inorganic nitrogenous fertilizers to improve maize productivity.

REFERENCES

Abuzar, M. R., Sadozai, G. U., Baloch, M. S., Baloch, A. A., Shah, I. H., Javaid, T. and Hussain. N. (2011). Effect of plant population densities on yield of maize. *Journal of Animal and Plant Sciences* 21(4): 692-695.

Angela, R. and Nina, L. B. (2007). Using organic amendments to decrease bulk density and increase macroporosity in compacted soils. [http://www.hort.cornell.edu/uhi/research/articles/auf33(2).pdf] site visited on 19/03/2013.

Avav, T., Shave, P. A., Magani, E. I. and Ahom, R. I. (2009). Effects of *Mucuna* biomass and N-fertilizer on *Striga hermonthica* Del. Benth.infestation in maize (*Zea mays* L.). *Journal of Animal and Plant Sciences* 42: 320 – 328.

Bai, E., Houlton, B. and Wang, Y. P. (2012). Isotopic identification of nitrogen hot spots across natural terrestrial ecosystems. *Biogeosciences* 9: 3287–3304.

Becker, M., Ladha, J. K., Simpson, I. C. and Ottow, J. C. G. (1994b). Parameters affecting residue nitrogen mineralization in flooded soils. *Soil Science Society of America Journal* 58: 1666–1671.

Belfield, S. and Brown, C. (2008). Field Crop Manual: Maize. A guide to upland production in Cambodia. [http://aciar.gov.au/files/node/8919/maize%20manual%2072dpi.pdf] site visited on 30/08/2012.

Bogale, T., Assenga, R. H., Mmbaga,T. E., Frisen, D. K., Kikafuda, J. and Ramson, J. (2001). Legume fallows for maize based systems in eastern Africa; Contribution of legumes to enhanced maize productivity and reduce nitrogen requirement. [http://books.google.co.tz/books?id=dRoOfAh6VjAC&pg=PA320&lpg=PA320&dq=germination+and+emergence] site visited on 23/03/2013.

Brady, N. C. and Wail, R. R. (2001). *Element of the Nature and Properties of the Soil*. Prentice- hall.Inc. 559pp.

Breland, T. A. (1994). Enhanced mineralisation and denitrification as a result of heterogenous distribution of clover residues in soil. *Plant and Soil* 166: 1–12.

Burgess, M. S., Mehuys, G. R. and Madramootoo, C. A. (2002). Decomposition of grain-corn residues (*Zea mays* L.): A litterbag study under three tillage systems. *Canadian Journal of Soil Science* 82: 127–138.

Carvalho, M. A., Pereira de Souza, L. L. and Júnior, G. R. (2011). Cover plants with potential use for crop livestock integrated systems in the Cerrado region. *Agropecuária Brasileira Brasília* 46: 1200-1205.

Cheruiyot, E. K., Mumera, L. M., Nakhone, L. N. and Mwonga, S. M. (2001). Rotational effects of grain legumes on maize performance in the rift valley highlands of Kenya. *African Crop Science Journal* 9(4): 667-676.

Cheung, B. N. (2008). Bacterial growth inhibition during composting of food waste: Effects of organic acids. Dissertation for award of the degree of MSc Degree at University of Regina, Saskatchewan. 186pp.

Dar S. R., Thomas, T., Dagar, J. C., Lal, K., Mehboob, S., Bakshi, M. R., Mir, A. H., Mir, H., Kumar, A. and Malik, R. K. (2012). Effect of fertilizer nitrogen and varied C: N ratio of mushroom compost on rice yield and nitrogen forms of soil. *Journal of Food, Agriculture and Environment* 10: 423 - 427.

Danielle, D., Treadwell and Mike, A. (2007). Sunn hemp (Crotalaria juncea L.): A summer cover crop for Florida vegetable producers. [http://edis.ifas.ufl.edu/pdffiles/HS/HS37600.pdf] site visited on 30/08/2012.

Deenik, J. (2006). Nitrogen mineralization potential in important agricultural soils of Hawaii. [http://www.ctahr.hawaii.edu/deenikj/Downloads/SCM-15.pdf] site visited on 13/11/2012.

Dhawan, S. S., Rail, G. K., Darokar, M. P., Lal, R. K., Misra, H. O. and Khanuja, S.P. (2011). Comparative genetic analysis of trichome-less and normal pod genotypes of *Mucuna pruriens* (Fabaceae). [http://www.geneticsmr.com/year2011/vol10-3/pdf/gmr1264.pdf] site visited on 29/08/2012.

Dimitrios, B., Anestis, K., Nikolaos, S., Ilias, T., Aspasia, E., Panagiotis, T. and Ioanna, K. (2012). Maize and legumes root growth and yield as influenced by organic fertilization, under mediterranean environmental conditions. Romanian Agricultural Research. [http://www.incda-fundulea.ro/rar/nr29/rar29.27.pdf] site visited on 27/08/2012.

Doung, T. T. (2009). Dynamic of plant residue decomposition and nutrients release. Dissertation for award of the degree of MSc. Degree at University of Adelaide, Australia. 126pp.

Edmond, M. M. (2004). Agroclimatic characterization of Lesotho for dryland maize production. Dissertation for award of the degree of MSc Degree at University of the Free State, Bloemfontein, RSA, 108pp.

Food and Agriculture Organization for the United National (2005).The importance of soil organic matter. [http://www.fao.org/docrep /009/a0100e/ a0100e.pdfimportance] site visited on 08/04/2013.

Gachene, C. K. K., Palm, C. A. and Mureith, J. G. (2000). Legume cover crops for soil fertility improvement in Eastern Africa Region. The Africa Highlands Initiative Technical report series no. 9. International Centre of Research in Agroforestry and Tropical Soil Biology and Fertility Programme. 23pp.

Gioseffi, E., de Neergaard, A. and Schjoerring, J. K. (2012). Interactions between uptake of amino acids and inorganic nitrogen in wheat plants. *Biogeosciences* 9: 1509–1518.

Gomez, K. A. and Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research*, 2nd edition, John Willey and sons publishers, New York. 680pp.

Guo, X., Drury, C. F., Yang, X., Reynold, D. and Zhang, R. (2012). Impacts of wet–dry cycles and range of constant water contents on carbon mineralization in soils under three cropping treatments. *Soil Science Society of America Journal* 76: 485-493.

Hamarashid, N. H., Othman, M. A., Hussain, A. H. (2010). Effects of soil texture on chemical compositions, microbial populations and carbon mineralization in soil. *Egyptian Journal Experimental Biology* 6(1): 59 – 64.

Henriksen, T. M. and Breland, T. A. (2002). Carbon mineralization, fungal and bacterial growth, and enzyme activities as affected by contact between crop residues and soil. *Biology and Fertility of Soils* 35: 41–48.

Hoorman, J. J. and Islam, R. (2010). *Understanding Soil Microbes and Nutrient Recycling. Cover Crops and Water Quality Soil and Water Specialist.* Extension Educator. Ohio State University. 829pp.

International Institute of Tropical Agriculture (2001). *Increasing Mucuna's Potential as a Food and Feed Crop.* CIEPCA, Cotonou, Benin. 1-5pp.

Iqbal, M. A. G., Khan, A. U., Hassan, M. W., Raza and Amjad, M. (2012). Soil physical health indices, soil organic carbon, nitrate contents and maize growth as influenced by dairy manure and nitrogen rates. *International Journal of Agriculture and Biology* 14: 20–28.

Iwuafor, E. N. O. and Odunze, A. C. (2000). Performance of selected cover crops in an arid zone of Nigeria. In: *Cover Crop for Natural Resources Management in West Africa.* Proceedings of a workshop organized by IITA and CIEPAC (Edited by Carsky) October 1999, Benin, pp 209-213.

Jama, B. A. and Nair, P. K. R. (1996). Decomposition and nitrogen- mineralization pattern of *Leucaena leucocephala* and *Cassia siamea* mulch under tropical semiarid conditions in Kenya. *Plant and Soil* 179: 275-285.

James, J. J. (2001). *Nitrogen in the Soil and Fertilizers*. Published in the SC Turfgrass Foundation News. Ohio. 10pp.

Kalumuna, M. C. (2005). Influence of cover crops on nitrogen availability, soil moisture content and maize yield under sub humid climate of Morogoro, Tanzania. Dissertation for award of the degree of PhD at Sokoine University of Agriculture, Morogoro, Tanzania. 207pp.

Kanyeka, E., Kamala, R. and Kasuga, R. (2007). *Improved Agricultural Technologies Recommended in Tanzania*. 1st edition. Published by the Department of Research and Training, Ministry of Agriculture Food Security and Cooperatives, Dar es salaam, Tanzania. 144pp

Khalil, M. I., Hossaina, M. B. and Schmidhalter, U. (2005). Carbon and nitrogen mineralization in different upland soils of the subtropics treated with organic materials. *Soil Biology and Biochemistry* 37: 1507–1518.

Khan, T. A., Norton, R., Edis, R., Walker, C. and Chen, D. (2011). Comparing, N. and S sources to improve yield and nutrient efficiency in canola cropping systems in south-eastern Australia. 17th Australian Research Assembly on Brassicas (ARAB), Wagga Wagga, Australia. August, 2011. 154pp.

Kimani, S. K., Nandwa, S. M., Mugendi, D. N., Obanyi, S. N., Ojiem, J., Murwira, H. K. and Bationo, A. (2003). Principles of integrated soil fertility management. In: *Soil Fertility Management in Africa*: A regional perspective (Edited by Gichuru, M.P., Bationo,A.,Bekunda, M. A., Goma, H. C., Mafongoya, P. L., Mugendi, D. N., Murwira, H. M., Nandwa, S. M., Nyathi, P. and Swift, M. J.), Academy Science Publishers, Kenya. pp. 51-72.

Kimaro, A. A. (2009). Sequential agroforestry systems for improving fuel wood supply and crop yield in semi-arid Tanzania. Dissertation for Award of PhD Degree at Department of Forestry, University of Toronto. Canada, 29pp.

Kumar, K. and Goh, K. M. (2000). Crop residues and management practices: Effects on soil quality, soil nitrogen dynamics, crop yields, and nitrogen recovery. *Advinces in Agronomy* 68: 197–319.

Kuo, S. and Sainju, U. M. (1998). Nitrogen mineralization and availability of mixed leguminous and non-leguminous cover crop residues in soil. *Biology and Fertility of Soils* 26: 346-353.

Kutu, F. R. (2012). Effect of conservation agriculture management practices on maize productivity and selected soil quality indices under South Africa dryland conditions. *African Journal of Agricultural Research* 7(26): 3839-3846.

Landon, J. R. (1991). *Booker Tropical Soil Manual. A Handbook of Soil Survey and Agricultural Land Evaluation in the Tropical and Subtropical.* Longman, London. 474pp.

Li, Q., Xuelian, B., Lu, C., Zhang, X., Jiang, Y., Liang, W. (2012). Soil microbial food web responses to free-air ozone enrichment can depend on the ozone-tolerance of wheat cultivars. *Soil Biology and Biochemistry* 47: 27-35.

Lupwayi, N. Z., Clayton, G. W., O'Donovan, J. T., Harker, K. N., Turkington, T. K. and Rice, W. A. (2004). Decomposition of crop residues under conventional and zero tillage. *Canadian Journal of Soil Science* 84: 403–410.

Magenya, E. V., Mueke, J. and Omwega, C. (2008). Significance and transmission of maize streak virus disease in Africa and options for management: *African Journal of Biotechnology* 7(25): 4897-4910.

Marandu, A. E. T. (2005). Contribution of cowpea, pigeon pea and green gram to the nitrogen requirement of maize under intercropping and rotation on feral soils in Muheza, Tanzania. Dissertation for award of the degree of PhD at Sokoine University of Agriculture, Morogoro, Tanzania. 218pp.

McCauley, A. (2009). *Soil pH and Organic Matter*. Nutrient Management Module No. 8. Montana State University-Bozeman., USA. 12pp.

Ministry of Agriculture Food Security and Cooperatives Tanzania (2009). Preliminary food crop. forecast. [http://www.kilimo.go.tz/publications/eng/Preliminary%20Food%20Crop%20Forecast%20-%20TANZANIA%20-%202009-2010-Pulic-V1.pdf] site visited 02/01/ 2010.

Ministry of Agriculture Food Security and Cooperatives Tanzania (2012). Preliminary food crop forecast. [http://www.agriculture.go.tz/publications/ english %20docs/AGSTATS-Prel2012-Executive%20Summary-DNFS-Header Subm%20%282%29.pdf] site visited on 14/03/2013.

Mohant, M., Probert, M. E., Sammi, R. K., Dalal, R. C., Subba, R. A. and. Menzies, N. W. (2010). *Modelling N Mineralization from Green Manure and Farmyard Manure from Laboratory Incubation Study.* World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane., Australia. 27pp.

Mowo, J. G., Floor, J., Kaihura, F. B. S. and Magogo, J. P. (1993). *Review of Fertilizer Recommendation in Tanzania.* Soil Fertility Report F6. Mlingano-Tanga, Tanzania. 61pp.

Muhammad, A. R., Asghar, A., Muhammad, A.M. and Mumtaz, H. (2010). Effect of fertilizer levels and plant densities on yield and protein contents of autumn planted maize. *Pakistan Journal of Agricultural Science* 47(3): 201-208.

Muhammad, S., Joergensen, R. G., Mueller, T. and Muhammad, T. S. (2007). Priming mechanism: Soil amended with crop residue. *Pakistan Journal of Botany* 39(4): 1155-1160.

Msanya, B. M., Kaaya, A. K., Araki, S., Otsuka, H. and Nyadzi, G. I. (2003). Pedological characteristics, general fertility and classification of some benchmark soils of Morogoro district, Tanzania. *African Journal of Science and Technology* 4(2): 101-112.

Nkonya, E., Xavery, P., Akonaay, H., Mwangi, W., Anandajayasekeram. P., Verkuijl, H., Martella, D. and Moshi, A. (1998) *Adoption of Maize Production Technologies in Northern Tanzania.* 42pp.

Nsami, E., Pallangyo, B., Mgoo, V. and Omwega, C. O. (2002). Distribution and species composition of cereal stemborers in the eastern zone of Tanzania. *International Journal of Tropical Insect Science* 21: 347-351.

Odhiambo, J. O. (2011). Potential use of green manure legume cover crops in smallholder maize production systems in Limpopo province, South Africa. *African Journal of Agricultural Research* 6: 107-112.

Odhiambo, J. O. (2009). Decomposition and nitrogen release by green manure legume residues in different soil types. *African Journal of Agricultural Research* 5: 090-096.

Ojiem, J. O., Mureithi, J. G., Okwuosa, E. A. (2000). Integrated management of legume green manure, farmyard manure and inorganic nitrogen for soil fertility improvement in western Kenya. In: Mureithi (eds) *Participatory Technology Development for Soil Management by Smallholders in Kenya*. Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research network projects. June 2000, Mombasa, Kenya, pp. 97-102.

Pieri, C. (1995). Long Term Soil Management Experiment in Semi Arid Francophone Africa. In *Soil Management: Experimental Basis for Sustainability and Environmental Quality* (Edited by Lal and Stewart, B.A.). 225-266pp.

Power, J. F. (1983). Soil Management for Efficient Water Use: Soil Fertility. In: *Limitations to Efficient Water Use in Crop Production*. South Segoe Road, Madison, USA. pp. 461-470.

Rao, N., Dong, L., Li, J. and Zhang, H. (2008). Influence of environmental factors on seed germination and seedling emergence of American Sloughgrass (*Beckmanniasy zigachne*). [http://dx.doi.org/10.1614/WS-07-158.1] site visited on 21/4/2013.

Rezig, A. M. R., Elhadi, E. A. and Mubarak, A. R. (2012). Effect of incorporation of some wastes on a wheat-guar rotation system on soil physical and chemical properties. *International Journal of Recycling of Organic Waste in Agriculture* 1: 1-15.

Samki, J. K. (1989). Soil information, classification and land evaluation of soil developed over gnesis, limestone and marine sedments in Mlingano, Tanga region, Tanzania. Dissertation for Award of PhD Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 270pp.

Seneviratne, G. (2000). Litter quality and nitrogen realising in tropic agriculture: a synthesis. *Biology and Fertility of Soils* 31(1): 60-64.

Shieh, G. (2004). The effectiveness of randomized complete block design. *Statistical Neerlandica* 58: 111–124.

Sibuga, K. P., Msaky, J. J., Malima, G., Aloyce, M., Nyallu, L., Mabula, D. and Hepelwa, R. (2012). Legume biomass transfer for enhancing productivity of maize in *Striga* infested farmlands: The case of Iringa district, Tanzania. [www.ruforum.org/system/files/file/Biennual%202012/Sibuga.pdf] site visited on 22/04/2013.

Singh, G. P., Beri, V. and Sidhu, B. S. (1995). Humification of rice and wheat residues in soil. *Journal of Indian Society Soil Science* 43:17–20.

Smaling, E. M. A., Nandwa, S. M. and Jenssen, B. H. (1997). Soil Fertility in Africa is at Stake. In: *Replenishing Soil Fertility in Africa.* (Edited by Brusesh, R. J., Sanchez, P. A. and Calhoun, F.), SSSA Special Publication No. 51. Madison, Wisconsin. pp. 47-61.

Stoorvogel, J. J., Smaling, E. M. A. and Janssen, B. H. (1993). Calculating soil nutrients balances in Africa at different scales, 1 supra-National scale. *Fertilizer Research* 35:227–235.

Tisdale, S. L., Nelson, W. and Beaton, J. D. (1985). *Soil Fertility and Fertilizers,* Fourth edition, Macmillan Publishing Company New York. 754pp.

Trinsoutrot, I., Recous, S., Bentz, B., Lineres, M., Cheneby, D. and Nicolardort, B. (2000). Biochemical quality of crop residues and carbon and nitrogen mineralization kinetics under non limiting nitrogen condition. *Soil Science Society of America Journal* 64: 918-926.

Tschakert, P., Khouma, M., Sene, M. (2004). Biophysical potential for soil carbon sequestration in agricultural systems of the Old Peanut Basin of Senegal. *Journal of Arid Environments* 59: 511-533.

Villegas-Pangga, G., Blair, G. J., and Lefroy, R. (2000). Measurement of decomposition and associated nutrient release from straw (*Oryza sativa* L.) of different rice varieties using a perfusion system. *Plant and Soil* 223: 1–11.

Wortmann, C. S., Mclntyre, B. D. and Kaizzi, C. K. (2000). Annual soil improving legume: Agronomic effectiveness, nutrients uptake, nitrogen fixation and water use. *Field Crops Research* 68: 75 - 83.

Yadvinder, S., Bijay. S. and Timsina, J. (2005). *Crop Residue Management for Nutrient Cycling and Improving soil Productivity in Rice-based Cropping Systems in the Tropics*. Elsevier Inc, Australia. pp. 270-407.

APPENDICES

Appendix 1: Weather data for the whole research period

Month	Week	Max(^{o}C)	Min(^{o}C)	Rainfall(mm)	Mean RH(%)
Nov-2011	1	33.26	21.18	0.00	68.63
	2	31.14	20.70	22.30	77.29
	3	31.91	21.63	5.50	75.71
	4	33.19	21.49	9.20	68.75
Dec-2011	1	32.70	21.36	0.00	70.75
	2	31.69	22.03	71.40	74.86
	3	30.50	21.70	61.30	77.14
	4	31.10	20.91	58.40	79.11
Jan-2012	1	31.00	21.49	7.80	77.00
	2	31.93	22.11	5.00	74.00
	3	31.23	21.09	57.50	78.29
	4	31.20	21.30	0.00	73.67
Feb-2012	1	32.83	21.00	0.00	69.38
	2	33.60	22.46	0.00	66.29
	3	34.36	21.59	35.70	66.43
	4	31.30	20.83	36.00	75.57
Mar-2012	1	31.13	21.34	8.03	75.38
	2	31.30	21.70	39.00	78.86
	3	32.34	21.70	0.00	77.00
	4	31.68	20.64	2.70	73.00
Apr-2012	1	30.88	20.93	44.20	81.88
	2	30.70	20.23	29.50	79.29
	3	29.53	20.33	9.20	81.29
	4	28.55	20.40	42.00	83.00
May-2012	1	28.70	20.60	72.00	86.00
	2	28.40	19.50	38.20	82.00
	3	29.20	19.50	4.50	82.00
	4	28.60	18.00	2.50	79.00
June-2012	1	28.70	18.60	33.60	90.00
	2	28.10	16.20	0.00	88.00
	3	27.70	16.70	7.90	84.00
	4	28.30	17.60	10.40	84.00

Source: Agrometeorological station –SUA.

Appendix 2: Percentage nitrogen mineralized

	0day	2wks	4wks	6wks	10wks	16wks
Control	0	11.61	19.31	24.91	27.56	25.77
Inorganic fert	0	48.56	62.54	63.73	52.98	43.31
Velvet bean	0	21.33	32.28	42.57	49.55	51.26
Dolichos	0	18.59	28.06	40.77	46.54	47.87
Sunhemp	0	28.50	41.22	54.88	56.82	55.77

Appendix 3: Effect of legume residues on maize yield variables

Treatment	Cob length(cm)	No of row/cob	No seeds/row	Cob weight(g)/plant
Control	18.25 b*	14.66 b	28.00 a	286.99 b
Velvet bean	22.67a	15.00ab	30.30 a	371.90 a
Dolichos	21.71a	15.00ab	30.00 a	374.39 a
Sunhemp	22.46 a	15.66ab	30.60 a	383.71 a
Urea (46%N)	20.25 ab	16.00a	30.00 a	365.83 a
Mean	21.07	15.26	29.80	356.56
Sd	8.34	0.35	4.5	17.00
CV (%)	5.37	3.8	7.13	5.31