INFLUENCE OF LEGUME BIOMASS ON SOIL FERTILITY STATUS AND MAIZE PERFORMANCE IN STRIGA INFESTED SOILS OF IRINGA, TANZANIA

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ABSTRACT

The effect of incorporation of legume biomass residues on *Striga* infested soils was evaluated at Mangalali and Kiwere villages in Iringa district, Tanzania. Six legumes: [cow pea (*Vigna unguiculata*), green gram (*Vigna radiata*), mucuna (*Mucuna puriens*), jack beans (*Canavalia ensiformis*), sunhemp (*Crotaliria ochroleuca*) and chick pea (*Cicer arietinum*)] plus two controls (no fertilizer added and one level of fertilizer 80 kg N ha-1 as urea) as nitrogen source were evaluated in randomized complete block design experiment. The legumes and their biomass quantities were incorporated into the soil four weeks prior to planting maize during 2011/12 growing season in the field. Significant differences ($P<0.05$) were recorded for soil chemical properties. Soil pH increased from (6.33 to 6.39) and (4.88 to 5.31) at Mangalali and Kiwere villages, respectively. The highest organic carbon increase was recorded in plots incorporated with cowpea and mucuna with increases of 14% and 5% compared to chickpea (1%) at Mangalali village. At Kiwere village the highest organic carbon increase were recorded in plots incorporated with sun hemp (38%) and cowpea (36%) compared to chickpea (1%). The highest N increase was observed in sun hemp (101.8%) followed by cowpea with an increase of (90.2%) compared to chickpea (12%) at Mangalali village, while at Kiwere village the highest N increases were recorded in sun hemp and cowpea with increases of 553.84% and 541.67%, respectively compared to green gram (169.23%). Mucuna, sun hemp and cowpea also improved soil pH, organic carbon, total nitrogen and available P. Hence there were significant differences ($P<0.05$) among the legumes residues incorpareted on improving soil chemical properties. Maize grain yield after incorporation of legume residues were recorded to be high in cowpea and Urea plots (3.7 t ha^{-1}) > sun hemp (3.5 t ha^{-1}) > mucuna (3.4 t ha^{-1}) > green gram (2.3 t ha^{-1}) > canavalia (2.1 t ha^{-1}) > chick pea and control (1.6 t ha^{-1}). Among legumes, cowpea incorporation was observed to produce higher yield compared to the other studied legumes. The incorporation of cowpea, mucuna and sunhemp legume residues are recommended to be used by poor resource farmers to improve soil fertility, reduce *Striga* infestation and increase maize yield in *Striga* infested areas with low soil fertility.

DECLARATION

I, Rebeca Hepelwa, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has not been submitted or being currently submitted for a degree award in any other institution.

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LIST OF ABBREVIATIONS

a.i	active ingredients
C.V	Coefficient of Variation
CAB	College for Agricultural Banking
CEC	Cation Exchange Capacity
DTPA	Diethylene Triamine Pentaacetic Acid
e.g	for example
FAO	Food and Agriculture Organization
FARMESA	Farm Level Applied Research Methods for east and Southern Africa
FASID	Foundation for Advanced Studies on International Development
HRDA	Human Resource Development Associates
i.e	that is
ICRISAT	International Crops Research Institute for the Semi-Arid Tropic
IDRC	International Development Research Centre
IITA	International Institute of Tropical Agriculture
KARI	Kenya Agricultural Research Institute
LSD	Least Significance Difference
OC	Organic carbon
PANTIL	Programme for Agricultural and Natural Resource Transformation for Improved Livelihoods
pH	power of hydrogen
Ph.D	Doctor of Philosophy

SIDA	Swedish International Cooperation Agency
SUA	Sokoine University of Agriculture
TN	Total nitrogen
UK	United Kingdom
USA	United States of America

CHAPTER ONE

1.0 GENERAL INTRODUCTION

Maize (*Zea mays,* L.) is the main staple cereal food crop in Tanzania. It is the major cereal consumed, with an estimated per capital consumption of 113 kg per year (Hugo *et al.*, 2002). Tanzania is among the top three maize producing countries in sub-Sahara Africa, including South Africa and Zimbabwe. The three countries produce more than 70% of maize in Sub Sahara Africa (Magenya *et al.*, 2008). Maize is a dependable food crop for more than 100 million people in Sub Sahara Africa (Magenya *et al.*, 2008) and is produced mainly under rain fed agriculture over a wide range of altitudes, from near the sea level to about 2400 m above sea level. It is cultivated on an average of two million hectares, which is about 45% of the maize cultivated area in Tanzania with production level of 3 million tons (Mbwaga *et al.*, 2000). The main agro ecological areas that produce maize are the Southern Highlands (44.8 %), Lake Regions (19.7 %), Northern (11.0 %), Western (9.7 %), Eastern (8.4 %), Central (3.8 %) and Southern (2.6 %) zones (Nsami *et al.*, 2002).

Although maize is a major food crop in Tanzania, yield per unit area is still low with an average of 1.2 t ha^{-1} as opposed to the national potential range of 4 – 8 t ha^{-1} (Msaky *et al.*, 2010). Maize production is limited by both abiotic and biotic factors such as low soil fertility, crop pests and low yielding varieties (Msaky *et al.*, 2010).

Among the crop pests, *Striga* is identified as a major biotic problem in maize producing areas because of low soil fertility. *Striga* species, such as *Striga hermonthica* and *Striga asiatica,* affect most of the major cereal crops such as maize, sorghum, millet and rice. *Striga gesnerioides* that attacks minor food crops such as cowpea or groundnut is of less economic importance (Mbwaga *et al.*, 2000). In Tanzania *Striga* occurs in eight out of 21 regions. The affected areas include the Southern plateau, which incorporates some parts of Iringa Rural district (Msaky *et al.*, 2010). AAFT (2009) estimated 179,000 ha of maize fields in Tanzania are infested with *Striga*. Depending on the magnitude of infestation, *Striga* can reduce grain yields of maize between 10% - 100% (Msaky *et al.*, 2010). The weed is considered as an indicator plant of low soil fertility (Ransom, 1996). Unreliable rainfall and declining soil fertility increases the *Striga* infestation problem which increase the risk of reduced maize production in the Southern plateau (Katinila *et al.*, 1998). Currently, there has been a declining trend in maize production in Tanzania. In 2008/09 National maize production for maize was 3.4 million tons with the domestic requirement being 4.1 million tons thus giving a deficit of 0.7 million tons. Total food produced was estimated at 12% below the trend value (MAFC, 2009). This is due to a number of factors that include low soil fertility and *Striga* infestation. Smallholder farmers are aware of the problem of low soil fertility but they rarely use fertilizers due to low purchasing power (Lameck *et al.*, 2003). This results in low production of maize, leading to food insecurity and income reduction among farmers. Increased food production in developing countries will require integrated approaches that focus on increased land productivity. Soil fertility management is one of the major factors that needs to be promoted.

The use of inorganic fertilizers in Tanzania has over years drastically decreased due to poor purchasing power of most smallholder farmers (Lameck *et al.*, 2003). Only 3% of the farmers in Southern plateau have the ability to use inorganic fertilizers. Most of the resource poor farmers cannot afford high prices of inorganic fertilizers (Katinila *et al.*, 1998).

There is, therefore, a great need to promote potential fertilizer alternatives such as the use of crop residues, compost, green manure and farmyard manure (Lekasi *et al.*, 2003). Manures when applied in the soil have many functions that are very important for crop growth and hence high production. Utilization of legume residues as an organic fertilizer can improve and maintain soil quality especially nitrogen, will suppress *Striga* infestation, and ultimately increase crop production. High nitrogen (N) supply can reduce *Striga* infestation by reducing mass flow of nutrient and carbohydrates materials from the host plants to the *Striga*, thereby inhibiting *Striga* parasitism to survive (Vasantraol, 2007).

This study, therefore, was aimed at introducing legume biomass as a source of nitrogen so as to improve soil fertility status and hence enhance suppression of *Striga* occurrence.

1.1 Objectives

1.1.1 General objective

The overall objective of the study was to increase soil fertility status, reduce the *Striga* infestation in *Striga* infested areas and increase maize yield through the use of legume biomass residues as nitrogen source.

1.1.2 Specific objectives

i. To determine the mineralization trend of different types of legume biomass.

ii. To characterize the soils in terms of the initial physical and chemical characteristics.

iii. To assess changes in the fertility status as a result of the use biomass residues as a source of N.

iv. To investigate the effect of different types of legume biomass on maize yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 *Striga* description

Striga (witch weed) is an obligate parasitic plant that attaches to the roots of specific host plants to obtain water, nutrients and carbohydrates (Oswald, 2005). *Striga* is one of the most destructive pathogens in Africa. It affects 40% of Africa's arable savanna region, resulting in up to $13 billion loss annually. About 40 million hectares of crops in sub-Saharan Africa are affected by *Striga* (Mbwaga *et al.*, 2000). *Striga* is found from sea level up to 1600 m above sea level, in production systems with average rainfall ranging from 500 to 2000 mm, and in almost all soil types (Oswald and Ranson, 2001). The seed of the weed is therefore widely spread.

2.2 Ecology

2.2.1 Soils

Soil is an important natural resource, as it constitutes a medium for plant growth. The weed parasite, is frequently found in light soils, and grows well and produces seeds on soils ranging from coarse sands to heavy clays (Hosmani, 1982). Soil type can have direct or indirect effect on *Striga* growth and survival, because it influences soil temperature, diversity of microorganisms and moisture holding capacity. Kayeke *et al.* (2004) reported that heavy soils have low temperature, and cause low *Striga* germination, while light soils have higher temperature leading to higher *Striga* germination. Light soils are highly susceptible to leaching, which can reduce or increase the germination of *Striga*. For example leaching can cause the *Striga* germination stimulant to undergo leaching, hence lower the germination of *Striga*. Moreover light textured soil have low nitrogen concentration due to its high mobility, hence leach easily, causing high germination of *Striga* in the field (Parker and Riches, 1993). Low N content in the soil favours *Striga* germination by making the plant allocate more carbohydrates to storage and in the synthesis of phenolics than to structural development. The phenolics are known to stimulate the germination of *Striga* (Wardlow, 1990). Hence, agricultural land with light soil and low nitrogen levels tend to favour the development of parasitic weeds in dry soils more than in wet soils.

2.2.2 Effect of soil moisture on *Striga*

The parasite weed cannot succeed in very wet soil conditions and in high rainfall areas (Holm *et al.*, 1977). High level of moisture in the soil is not favourable for *Striga* germination. Kayeke *et al.* (2004) observed that germination of *Striga* takes place between 0 MPa to -1.29 MPa. Mohamed and Gejeta (1998) also reported that seeds with moisture content less than 10 per cent at the start of conditioning had germination of more than 93 per cent. As such *Striga* seeds, in order to germinate, need medium wet condition and low nitrogen level. According to Vasantraol (2007) *Striga* seeds in moist, hot environments would rapidly deteriorate and subsequently die. The germination capacity of S*triga* seeds usually declines in moist soils. Therefore, in order to reduce *Striga* infestation soil must be improved to have high water holding capacity.

2.2.3 Effect of temperature on *Striga*

Temperatures ranging from 30 to 35°C in a moist environment are ideal for germination of *Striga* (Parker and Riches, 1993). Temperatures between 20°C and 26°C have been reported to be more favourable for germination of *Striga* seeds (Okonkwo, 1991). Seeds have been shown to survive in frozen soil of temperatures as low as -15°C (Parker and Riches, 1993). Generally therefore, *Striga* seeds can survive in a wide range of temperature.

2.2.4 Reproduction

Flowers of *Striga asiatica* self-pollinate before opening when sticky pollen balls cling to the elongating style. The fruit of *Striga asiatica* is a seed capsule that is ovoid and five sided, with narrow wings at each corner. Capsules can comprise up to 1400 seeds. Seeds are brown, oval and 0.2 mm long. The seed surfaces are striated and overlaid with a reticulate pattern that is visible with magnification (CDFA, 2006). *Striga* produces thousand to half million seeds per plant and the seeds measure 0.4 mm in length and 0.2 mm in breadth, which is too small, hence can spread more easily (Parker, 1984).

2.2.5 Life cycle stages

Wind, water, soil movement, human activities, farm machinery, tools, shoes, and clothing are the main dispersion agents of *Striga* seeds (CDFA, 2006). Seeds need an after ripening period of 6 weeks in warm conditions and to 40 weeks in freezing conditions. Dormant seeds survive freezing condition for at least 49 days and can remain viable under field conditions for up to 14 years or more (Mohamed and Gejeta, 1998). After seed maturation, *Striga* exhibits two main life phases: the independent life phase and the parasitic life phase (Joel *et al.*, 1995).

The independent phase starts with seed conditioning, germination, and end when the parasite finds a host, and attaches to it. This life phase is achieved by the consumption of materials stored in the seed. The parasitic life phase starts after haustorium development. At this stage, the parasite becomes reliant on nutrients produced by the host. Invasive cells of the haustorium penetrate the host root, ultimately forming a physiological bridge between the vascular system of the host and that of the parasite (Daniel, 2000). Afterward, the parasite develops a shoot that emerges from the soil, flowers and sets seeds. The metabolic and developmental phases of root parasites are essential for any attempt taken to develop effective control measures that will specifically prevent the *Striga* infestation, because each developmental stage is very important for the growth and dispersal of these root parasites (Daniel, 2000).

2.2.6 Germination of *Striga*

Germination is more complicated and needs about 1-3 weeks of adaptation period at a suitable temperature regime under moist conditions, followed by a chemical signal from a nearby root of the host plant (Oswald, 2005). The germination of *Striga* has two distinct phases, that is pre-conditioning and stimulation (Parker, 1984). During the pre-conditioning phase, the seeds must be exposed to a regime of adequate moisture and temperature above 20°C for a period of 10-14 days. After adequate pre-conditioning, the seeds require a stimulant for germination. These stimulants comprise purines, coumarin, ethylene and *strigol* (Yoshikawa *et al.*, 1978). Proximity of host root to seed must be within a distance of 10 mm so as to be liable to be stimulated and make contact with host root (Vasantraol, 2007). The germination depends on the distance of the *Striga* seeds from the roots of the host plant which is known to produce the stimulating exudates (Bekker *et al.*, 2003). In these circumstances, seeds germinate within 24 hours. After three weeks of conditioning without a chemical signal, the ability of seeds to germinate decreases and some seeds may pass into a secondary dormancy (Mohamed and Gejeta, 1998). Irregular or light rainfall appears to promote seed germination and plant vigour (Ogborn, 1972). Flowers develop about three weeks after emergence. Viable seeds are produced within 2 weeks after flowering. A minimum of 60 days is required from seed germination to seed production (APHIS, 2000).

2.3 Control methods

Control of *Striga* is difficult to achieve because of its high fecundity (Andrianjaka *et al.*, 2007). Many approaches (physical, chemical, cultural and biological) have been explored against *Striga* such as heavy application of nitrogen fertilizer (Igbinosa *et al.*, 1996), use of trap crops and chemical stimulants to abort seed germination, hoeing and hand pulling, herbicide application (Oswald, 2005), the use of resistant or tolerant crop varieties (Zeyau *et al.*, 2006) and crop rotation (Oswald and Ransom, 2001). These methods are not singularly very effective and most farmers have not accepted these methods to a great extent due to biological and socio economic reasons (Lagoke *et al.*, 1991). The main characteristics that define the effectiveness and adoption potential of *Striga* control methods are: time until *Striga* is reduced to manageable levels in the field, amount of resources required by the farmer to implement the method (whereas resources are not only money, time and labour, but also the extent of training the farmer needs to successfully apply the method), effectiveness to control *Striga* and increase in yield of host-crops and/or farm productivity (Oswald, 2005).

2.3.1 Hand weeding

The method is to interrupt the growth cycle of *Striga*. It is easy to practice and to understand but farmers are reluctant to employ it, due to the following reasons: *Striga* emerges in most host-crops five to six weeks after planting and it takes another three weeks until the plants are big enough to be uprooted (Oswald, 2005). At that time the farmer has already done the 'normal' weeding of the crop, which means coming back to weed *Striga* not only once but several times, because *Striga* continues to emerge until a few weeks before harvest. *Striga* not only absorbs water and nutrients from its host-crop but also exerts a potent phytotoxic effect on the host-crop, which means that although *Striga* is weeded, it has already done considerable damage to the crop (Ransom, 1996).

Due to this reasons, hand weeding is extremely time- consuming because the densities of *Striga* are high. As such, the method of controlling *Striga* remains as an integral part of all *Striga* control approaches (Oswald, 2005).

2.3.2 Seed-dressing of imazapyl resistant maize with the herbicide

A relatively new method in the control of *Striga*. The method is seed-dressing of imazapyl resistant maize with herbicide. This causes *Striga* plants, which attach to the maize roots, to die off immediately. The maize remains *Striga*-free for the first weeks after planting and realizes considerable increase in yield (Kanampiu *et al*., 2002). However, this method also has some serious drawbacks. The resistance to the herbicide is based on a single recessive gene, i.e. that any out-crossing of this maize results in plants that are no longer resistant to *Striga*. Hence, farmers have to buy new seeds every season, which is very unlikely. If this maize crop is widely planted, it will initiate a screening process among millions of *Striga* seeds in infested fields and *Striga* might develop resistance rapidly.

2.3.3 Green manure application as a source of N in the soil

Green manure reduces weed prevalence, both the weed density and weed dry biomass. Kayeke *et al*. (2007) reported that when green manure is added in the farm, reduction in total weed number was 50.5 to 32% whereas reduction in weed dry biomass was 54.6 to 51.4 %. That means green manure has the potential to reduce *Striga* by inducing the germination of *Striga* seed to cause suicidal germination (Parker, 1984). The potential of green manure to stimulate *Striga* seed germination is controlled genetically and environmentally (Odhiambo and Ransom, 1996). When green manure decompose in the soil it release nitrogen, the nitrogen released, tends to increase the osmotic concentration of the host cell sap, leading to reduction of mass flow of materials from the host plants to the weed. this inhibits the *Striga* weed to survive.

2.3.4 Application of N fertilizer as a source of Nitrogen.

Nitrogen is a plant nutrient that is required in larger quantities than other nutrients, especially in cereal crops (Amur, 2003). Soil nitrogen exists in three general forms - organic nitrogen compounds, ammonium (NH_4^+) ions, and nitrate (NO_3^-) ions. The majority of plant-available nitrogen is in the inorganic NH_4^+ and NO_3^- forms (Kalumuna, 2005). Ammonium ions bind to the soil's negatively-charged cation exchange complex (CEC) and behave much like other cations in the soil. Nitrate ions do not bind to the soil solids because they carry negative charges, but exist in dissolved form in the soil water, or precipitated as soluble salts under dry conditions.

It is well established that nitrogen reduces *Striga asiatica* infestation (Ogborn, 1984; Parker, 1984). However, the mechanism by which nitrogen affects *Striga asiatica* is not well known. However several attempts have been made to explain the role of N in the host-parasite relationship (Parker, 1984). Egley (1973) reported that high N supply increased the osmotic concentration of the host cell sap, thus reducing mass flow of materials from the host plants to the weed, ultimately inhibiting *Striga* parasitism. Increasing the supply of available plant nutrients enables the host plant to sustain the infestation more easily than when food reserves in the soil are limiting. Pesch and Piertese (1982) argued that N directly inhibits *Striga* species germination. Ogborn (1984) suggested high N supply may reduce *Striga asiatica* infestation indirectly by reducing light intensity at the soil surface as a result of the denser crop canopy. Also Bebawi (1987) suggested that N fertilization reduced root exudant activity from the host plant, resulting in poor germination of *Striga asiatica.*

At low N content plants allocate less carbohydrate to structural development and more to storage and synthesis of phenolics (Wardlow, 1990). Phenolics are known to stimulate germination of *Striga asiatica* seed. This was reported by Parker (1984) who proposed that the effects of N can be at least explained by its tendency to influence the hosts' partitioning of resources between the roots and shoots. He found that the root to shoot ratio and actual dry weight of the host were increased in favour of roots as a result of infection by *Striga asiatica* when sorghum was grown under varying N-levels. Increased supply of N is thought to enhance reproductive sink activity in maize and under no parasitized conditions the ear becomes the predominant sink after flowering, which limits the amount of photosynthate partitioned to other parts of the plant (Jacobs and Parson, 1992). In the presence of *Striga* species, most of assimilates are re-routed to the parasite which is a stronger sink than the ear and as a result ear formation is adversely affected. Higher levels of N in the soil are therefore expected to rectify this imbalance in favour of the ear because the soil will be able to supply enough nutrients to satisfy both the host and its parasite. Nutrient use efficiency varies from one crop cultivar to another and this provides a guide to an economical means of managing *Striga asiatica*. Nitrogen-mediated resistance of maize to *Striga asiatica* is enhanced by the cultivars that have a better nutrient use efficiency.

2.3.5 Herbicides application

Herbicides have been reported to kill *Striga* when applied on the *Striga* shoots. In Tanzania it is reported that 2, 4-D is effective in reducing *Striga* infestation (Mbwaga, 2000). In the United State of America (USA) the herbicides 2, 4-D and Paraquat have been found to be effective in killing *Striga* (Parker, 1984). In Kenya, application of Imazapyl at 15 g a.i. ha^{-1} gave 70 – 95% suppression of *Striga* development and no capsules appeared at 30 g ha^{-1}. Herbicides also reduce seeds to be returned into the soil.

2.3.6 Legume - Cereal crop rotation

The sequence of growing different crops in successive years and season on the same land is called crop rotation (Radosevich *et al.*, 1997). *Striga* weed species often are associated with particular crops. Therefore when a host, crop is grown on the same field continually for several years, *Striga* population and seed increase due to the same environmental conditions that favour *Striga* survival (Kwacha, 2001). Legume cereal rotation is among the sustainable systems of increasing food production under small scale farming (Dakora, 1997). The potential of most legumes is to increase the soil N through N fixation. Legumes accumulate N during the growing period through the N atmospheric N_2 fixation. Mughogho *et al.* (1992) reported that cowpea contributed the equivalent of 40 – 80 kg N ha^{-1} to maize grown in rotation. The residues of cowpea in rotation increased grain yield by 95%, equivalent to application of inorganic fertilizer at 60 kg of N ha^{-1}. Furthermore, legume rotations reduce witch weed seed bank in the soil due to their trap crop effect. These trap crops have the ability to allow witch weed seeds to germinate, but cannot support for further development hence the seeds die (Kabambe, 2002).

2.4 Crop loss due to *Striga* infestation

In Tanzania Mbwaga *et al.* (2000) reported that *Striga* infestation causes up to 40-90% yield losses in maize field. In the Guinea savanna of Nigeria, Oikeh *et al.* (1996) estimated yield losses ranging from 0 to 46% from the fields. Hence *Striga* can cause the yield losses depending on the extent of its infestation.

CHAPTER THREE

3.0 DETERMINATION OF MINERALIZATION PATTERNS OF BIOMASS TYPES OF DIFFERENT LEGUMES RESIDUES IN LOAMY SANDY SOILS.

Abstract

A laboratory incubation experiment was conducted to determine mineralization patterns of different residues from legumes in loamy sandy soils of Iringa rural district. The main objective was to dertemine N release from different legume residues [Cowpea (*Vigna unguiculata),* greengram *(Vigna radiata),* mucuna *(Mucuna puriens),* jackbeans *(Canavalia ensiformis),* sunhemp *(Crotalaria ochroleuca)* and chickpea *(Cicer arietinum*)] when incorporated into the soil. The soil from Kiwere was acidic with pH of 4.88, very low organic carbon (0.25%) and total N (0.023%), medium extractable P (9.59 mg kg^{-1}) and CEC (12.76 Cmol(+)kg^{-1}). Mangalali soil was slightly acidic in reaction with pH of 6.33, low organic carbon (0.77%), low total N (0.13%), low extractable P (6.29 mg kg^{-1}) and low CEC (9.91Cmol (+) kg^{-1}) indicating low soil fertility status. Legumes C:N ratios was 22.8 for cowpea, 24.59 for green gram, 11.96 for mucuna, 20.95 for canavalia, 12.05 for sunhemp and 18.46 for chickpea. The N release content was high in sunhemp residues (160 mg kg^{-1}), followed by chickpea (151.7 mg kg^{-1}), mucuna (137.5 mg kg^{-1}), green gram (137.3 mg kg^{-1}), canavalia (128.3 mg kg^{-1}) and lowest in cowpea (107.4 mg kg^{-1}) after twelve weeks of incubation. During the incubation period most of the legumes attained their maximum nutrient release between four and eight weeks of incubation. Due to this observed trend of N release, farmers are advised to incorporate the legume residues four weeks before planting so as to benefit from the released N nutrient.

Introduction

Legumes, both domesticated and wild, are used as food by humans and feed for livestock. These legumes are good sources of nutritional protein, fibres and mineral elements. Nitrogen content contained in legume plants is accumulated during the growing period, which is derived from soil N and atmospheric N_2 fixation. Part of the accumulated N is harvested with the grain and part is returned to the soil in form of root excretion, nodule senescence, leaves and plant residues following their decomposition (Sanginga *et al.*, 2001).

Legumes have the ability to fix atmospheric nitrogen and add it to the soil nitrogen pool, thereby improving soil fertility. Legumes also provide abundant organic matter content into the soil through their biomass when incorporated into the soil. This improves soil nutrients resevoir (McRae and Mehuys,1988). Due to these characteristics, legume residues can be used as an alternative source of soil nutrients thereby reducing the cost of inorganic fertilizers and further suppress *Striga* occurence.

The purpose of this study was to examine the pattern of decomposition and N release in different residues of legumes and eventually their contribution to soil N availability. The relationships between legume residue characteristics with the N release were tested to quantify the amount of N released into the soil environment.

Materials and Methods

Soil sampling

Soil samples were obtained from topsoil, 0 cm - 20 cm, in each experimental field (Mangalali and Kiwere villages). Samples were air dried ground and passed through a 2 mm sieve for analysis. Soil particle size distribution was determined using Bouycous hydrometer method as described by Gee and Bauder (1986). Textural class was determined using the textural class triangle. Soil pH, organic carbon, total N, extractable P, cations exchange capacity (CEC) were determined using the procedure as described by Okalebo *et al.* (1993). DTPA extractable micronutrients in soil samples were determined using the procedure described by Lindsay and Norvell (1978).

Incubation Experiment

An incubation experiment was conducted in the Soil Science laboratory at Sokoine University of Agriculture during the period September to December, 2011. Residues from six legumes (cowpea, mucuna, canavalia, sunhemp, green gram and chickpea) which were grown in an experimental field from December, 2010 and harvested in May, 2011, were used for the incubation study.

Characterization of legume biomass residues

The characteristics of the legumes biomass residues that influence nitrogen availability were evaluated. These characteristics were N content, organic carbon and mineralization behaviour. N content was determined by chemical analysis using the Kjeldal method Okalebo *et al.* (1993). Mineralization behaviour was studied in the laboratory under the incubation study.

Mineralization of legume residues through incubation technique

Soil samples from each plot were mixed together to get one representative sample per site. The samples were air dried and sieved through 2 mm sieve to homogenize them and used for the incubation study. Legume residues of cowpea, mucuna, canavalia, sunhemp, chick pea and green gram were ground to the size of < 0.5mm. A sample of 2 g of each legume biomass were mixed with 200 g of soil. The mixture was incubated in a plastic container and moistened to 60% soil moisture (field capacity) and incubated at room temperature of 25°C ± 1°C for 12 weeks. Soil moisture content was maintained at 60% field capacity by intermittent weighing the containers and correcting weight loss by adding distilled water. At each sampling, 20 g of wet soil were extracted with 100 ml 1M KCl and available mineral N (NH_4-N + NO_3-N) was analyzed at 0, 4, 8 and 12 weeks of incubation for the determination of available mineral N (NH_4 + NO_3).

Data Analysis

Gen Stat statistical software was employed to analysis of the collected data. Data for N released from different legumes were analyzed by the analysis of variance (ANOVA) technique to test the differences among treatments. Means were separated by using the Duncan's Multiple Range Test.

Results and Discussion

Characteristics of the experimental soil

The texture of the soil in both sites was loamy sandy. Soil pH at Mangalali was categorized as medium (6.33) and low (4.88) for Kiwere soils. This was based on the categorization by Landon (1991).

Table 3. 1: Some physical and chemical properties of the experimental soils

Soil properties	Sites	
	Kiwere	Mangalali
Clay	11.22	13.83
Silt	1.35	1.97
Sand	87.4	84.19
Textural class	Loamy Sand	Loamy Sand
pH (1:2.5 H_2O)	4.88^{L}	6.33^{S}
Organic Carbon (%)	0.25^{VL}	0.77^{L}
Total Nitrogen (%)	0.023^{VL}	0.13^{L}
Bray-1 Extractable P (mg kg^{-1})	9.59^{L}	6.29^{L}
Extractable S (Cmol(+)kg^{-1})	1.42^{L}	1.04^{L}
CEC (Cmol(+)kg^{-1})	12.76^{M}	9.91^{L}
Exchangeable bases (Cmol(+)kg)		
Ca	2.86^{H}	1.31^{M}
Mg	0.39^{L}	0.74^{H}
K	0.30^{L}	0.26^{M}
Na	0.34^{M}	0.27^{L}
BS (%)	33.00^{L}	26.32^{L}
DTPA Extr. Cu (mg kg^{-1})	0.17^{L}	0.27^{L}
DTPA Extr. Zn (mg kg^{-1})	0.04^{L}	0.83^{M}
DTPA Extr. Fe (mg kg^{-1})	24.03^{H}	19.00^{H}
DTPA Extr. Mn (mg kg^{-1})	100.28^{H}	4.80^{H}

Where: L- Low, M- Medium, H- High, VL- Very high, S- Slightly acidic

Soil organic carbon content was very low (0.25%) and low (0.77%) at Kiwere and Mangalali respectively. Nitrogen levels were also very low 0.023% to low 0.13% at Kiwere and Mangalali, respectively (Table 3.1). This shows that the soils in the two trial sites needed to be supplied with organic matter and nitrogen in order to improve the nitrogen reserve. Bray -1- extractable phosphorus was low (6.29 mg P kg^{-1}) at Kiwere soil and medium (9.59 mg P kg^{-1}) for the Mangalali soil. The levels of sulfur were categorized as low at both sites (1.422 Cmol(+)/kg and 1.042 Cmol(+)/kg) at Kiwere and Mangalali soils, respectively (Baize,1993). The levels of CEC were medium i.e 12.76 Cmol(+)/kg for Kiwere and low 9.91 mg kg^{-1} for Mangalali soil following category proposed by Landon (1991). The levels of exchangeable calcium (Ca) were grouped as medium (2.86 Cmol(+)/kg) and low (1.31Cmol(+)/kg) at Kiwere and Mangalali soil, respectively. Exchangeable Magnesium (Mg) was found to be low (0.30 Cmol(+)/kg) and (0.26 Cmol(+)/kg) at Kiwere and Mangalali soil respectively, while exchangeable potassium (K) was categorized as medium (1.20 Cmol(+) kg^{-1}) and (0.41 Cmol(+) kg^{-1}) at Kiwere and Mangalali soils respectively. Exchangeable sodium (Na) was grouped as medium (0.34 Cmol(+) kg^{-1}) and low 0.27 Cmol(+) kg^{-1}) at Kiwere and Mangalali soils respectively (Table 3.1). The percentage base saturations for Kiwere and Mangalali were 33.00 and 26.32, respectively and these values indicated very low soil fertility status. Extractable zinc was categorized as low (0.04 mg kg^{-1}) and medium (0.83 mg kg^{-1}) at Kiwere and Mangalali respectively. Extractable copper (Cu) was categorized as low (0.17 mg kg^{-1}) and (0.27 mg kg^{-1}) at Kiwere and Mangalali. The exchangeable manganese (Mn) was grouped as high (100.28 mg kg^{-1}) and low (4.80 mg kg^{-1}) at Kiwere and Mangalali soils respectively. Iron (Fe) was found to be grouped high 24.03 mg kg^{-1} and 19 mg kg^{-1} for both sites as categorized by Landon (1991).

These characteristics show that the soils at both sites had low soil fertility status. They cannot provide adequate nutrients for high maize yields. Hence the soils need to be supplied with organic materials such as legume residues, farmyard manure, green manures, and even inorganic fertilizers in order to improve the fertility status of the soils to achieve high crop yields.

Legume Nitrogen release from various legume biomasses under incubation study

The N release in the first four weeks of incubation of legume residues was observed to be high from the soil treated with sunhemp residues (160 mg kg^{-1}), followed by chickpea (141.4 mg g^{-1}), mucuna (115.6 mg kg^{-1}), green gram (90.0 mg kg^{-1}), canavalia residues (87.7 mg kg^{-1}) and lowest was recorded from cowpea residues (81.3 mg kg^{-1}) (Table 3.3). During the eight week of incubation, the highest N release was recorded in sunhemp (155.5 mg kg^{-1}), followed by chickpea (151.7 mg kg^{-1}), mucuna (137.5 mg kg^{-1}), canavalia (128 mg kg^{-1}), green gram (111.7 mg kg^{-1}) and cowpea residues (101 mg kg^{-1}). In the twelve week of incubation the highest N release was recorded in green gram (137.3 mg kg^{-1}) followed by chickpea (126 mg kg^{-1}), canavalia (121.9 mg kg^{-1}), cowpea (107.4 mg kg^{-1}), mucuna (103.7 mg kg^{-1}) and the lowest was recorded in sunhemp residues (103.2 mg kg^{-1}). The highest N release for sunhemp, chickpea and mucuna residues in four and eight weeks was attributed to its narrow C: N ratio (Table. 3.2) which facilitate the mineralization to be high compared to other legume residues such as green gram, canavalia and cowpea residues because they have wide C: N ratio.

Table 3. 2: Chemical characteristics of legume biomass residues

Type of legume residues	Cowpea	Green gram	Mucuna	Canavalia	Sun hemp	Chickpea
OC (%)	46.3	48.2	39.6	55.3	39.9	38.4
Total N	2.03	1.96	3.31	2.64	3.31	2.08
C/N ratio	22.8	24.59	11.96	20.95	12.05	18.46

Sunhemp residues attained the maximum N release 160 mg kg^{-1} in the fourth week of incubation and started to decrease for the rest of incubation period. Chickpea, mucuna and canavalia residues attained the maximum in the eighth week of incubation and decreased thereafter to the end of incubation. Hence there were significant differences ($P<0.05$) in the fourth, eighth and the twelfth week of legume residues incubation.

The significant difference in nitrogen release for different legume residues types were attributed mainly by the C: N ratio of the legume residues. The C:N ratio was 11.96 for mucuna, 12.05 for sunhemp and 18.46 for chick pea , suggesting that they would have high nitrogen decomposition and high mineralization, while the C:N ratio for canavalia was 20.95, cowpea 22.8 and green gram 24.59 (Table.3.2) suggesting that they would have slow decomposition and low N mineralization (Palm *et al*., 2001). Similar results were observed by Jude, (2010) in South Africa who reported that sunhemp mineralized faster than mucuna and lablab due to its narrow C: N ratio. Also Giller and Wilson (1991) reported a general reduction in amounts of N released during decomposition of legume residues was attributed by its C: N ratio of the legume residues. Studying the relationship between N release and C: N ratio, Kalumuna, (2005) reported the net mineralization occurs when the applied residue has C: N ratio < 25. This may be the factor that could also be explained for the variation in the amounts of N released by different legume residues used in this study.

Table 3. 3: **Effect of incubation time on N release from various legumes**

Type of legume	Incubation time (weeks)			
	0	4	8	12
	Amount of N released (mg kg^{-1})			
Control	12.78a	40.2a	38.5	25.6
Cowpea	35.57b	81.3ab	101.1a	107.4ab
Green gram	27.03ab	90.0b	111.7ab	137.3b
Mucuna	28.25b	115.6bc	137.5abc	103.7a
Canavalia	24.79ab	87.7b	128.3abc	121.9ab
Sunhemp	37.84b	160.8d	155.5c	103.2a
Chickpea	29.68b	141.4cd	151.7bc	126.0ab
LSD	14.32	43.22	38.34	28.84
CV (%)	28.7	23.7	18.3	15.6
Grand Mean	28.0	102.4	117.8	103.6
P (0.05)	*	**	***	***

The mean in the same column followed by the similar letter(s) are not statistically different at 5% level of significance.

Conclusion

The results from this study showed that, legume residues release N nutrient after decomposition. Sunhemp (160.8 mg kg^{-1}), chick pea (151.7 mg kg^{-1}) and mucuna residues (137.5 mg kg^{-1}) when incubated released such nutrients and these legume residues can be used as a source of N nutrients to poor resource farmers as viable alternative to inorganic fertilizers. The use of legumes biomass residues have ability to amend and add nutrients into the soils. Poor resource smallholder farmers can use this technology as source of nutrients in the soil so as to improve soil fertility status and increase yield in the family level as well as nation income.

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CHAPTER FOUR

4.0 INFLUENCE OF LEGUME BIOMASS ON SOIL FERTILITY AND MAIZE PERFORMANCE IN *STRIGA* INFESTED SOILS.

Abstract

The role of legume biomass residues in improving fertility status of *Striga* infested soils was evaluated at Mangalali and Kiwere villages in Iringa district, Tanzania. Six legume residues; cowpea (*Vigna unguiculata),* green gram *(Vigna radiata),* mucuna *(Mucuna puriens),* jack beans *(Canavalia ensiformis),* sunhemp *(Crotaliria ochroleuca) and* chick pea *(Cicer arietinum*) were evaluated. In addition, two controls (no fertilizer added and one level of fertilizer at 80 kg N ha^{-1} as urea) were included in a randomized complete block design (RCBD) experiment. The incorporation of legumes significantly ($P < 0.05$) raised soil pH from 6.33 to 6.39 and 4.88 to 5.31; increased soil available P from 6.29 to 18.34 mg kg^{-1} and from 9.59 to 21.14 mg kg^{-1}; total nitrogen from 0.13 to 0.18% and from 0.02 to 0.1% and organic carbon from 0.77 to 0.79% and 0.25 to 0.28% at Mangalali and Kiwere villages respectively. The maize grain yield were significantly ($P<0.05$) higher in cowpea and urea plots (3.7 t ha^{-1}) followed by sunhemp (3.5 t ha^{-1}) and mucuna (3.4 t ha^{-1}) than green gram (2.3 t ha^{-1}), canavalia (2.1 t ha^{-1}), chick pea and control (1.6 t ha^{-1}). This legume residues incorporation technique may be a good alternative technology for resource poor farmers to improve fertility status and increase yield in *Striga* infested soil as a source of nitrogen.

Introduction

Maize is the key staple food crop in Tanzania, However, maize yield per unit area is still low with an average of 1.2 t ha^{-1} as opposed to the national potential yield range of 4 – 8 t ha^{-1}. The current annual production does not meet the total requirements of domestic demand (Msaky *et al*., 2010). Production of the crop is limited by both abiotic and biotic factors such as low soil fertility, pests and low yielding varieties (Msaky *et al*., 2010).

Among the biotic stress, *Striga* weed is identified as a major problem in maize producing areas with low soil fertility. *Striga* species such as *Striga hermonthica* and *Striga asiatica* affect most of the major staple cereal crops such as maize, sorghum, millet and rice. *Striga gesnerioides* which attacks minor food crops such as cowpea or groundnut is of less economic importance (Mbwaga *et al*., 2000). Low soil fertility is one of the factors that promote *Striga* infestation in the field. Most small holder farmers are not using inorganic fertilizers due to high prices and this leads to an increase in nutrient depletion in the soil.

There is therefore a need to promote possible soil fertility management alternatives such as the use of crop residues, compost, green manure and farmyard manure (Lekasi *et al*., 2003).

Using legume biomass residues as a source of fertilizer will improve and maintain soil quality especially nitrogen and suppress *Striga* occurrence, hence increasing crop production.

Materials and Methods

Location and Description of the Study Area

The experiment was conducted in Iringa district at Mangalali and Kiwere villages. Kiwere is located between latitude 7^0 88' 2^0 00' South and longitude $9^0$14' 4^0 00 East. Mangalali is located between latitude 7^0 88' $6^0$00' S and longitude $9^0$15' $5^0$00' E in Iringa district, Iringa region. The area has temperature ranging from 15°C to 25°C and rainfall ranging from 500 to 1600 mm per annum. The site is characterized by a unimodal rainfall pattern with the growing season starting from November to June.

The soils of these areas originate from parent materials that are coarse textured colluvial deposits from the surrounding granitic rock hills. They are deep to very deep, well drained with low water holding capacity, reddish yellow or yellowish red colours, clays with weak to moderate structural development, low pH, low organic matter and low nitrogen (Msaky *et al*, 2010).

Soil sampling for site characterization

Soil samples were obtained from the topsoil, 0 - 20 cm in Mangalali and Kiwere sites. Samples were air dried and grounded to pass through a 2 mm sieve for analysis. Soil particle size distribution was determined using Bouycous hydrometer method as described by Gee and Bauder (1986). Textural class was determined using the textural class triangle. Soil pH, organic carbon, total N, extractable P, extractable sulphur and cations exchange capacity (CEC) were determined using the procedure described by Okalebo *et al.* (1993). extractable micronutrients in soil samples were determined using the procedure described by Lindsay DTPA and Norvell (1978).

Experimental design layout

In year one (2010/2011) six legumes (Cowpea (*Vigna unguiculata*), green gram (*Vigna radiata*), velvet bean (*Mucuna puriens*), jack beans (*Carnavalia ensiformis*), *Crotalaria ochroleuca*) and chick pea (*Cicer arietinum* L.) were planted for biomass production and two maize varieties (Situka and Imazapyl Resistance - maize) were used as test crops. A randomized complete block design (RCBD) with three replications was used. The entire set of eight treatments was laid out in plots of size of 6 m x 4.5 m. The plot to plot and plot to block distances were separated by 1 m paths.

In May 2011 the legumes were harvested and the residue biomass produced were incorporated into the soil in year two (2011/2012) in November 2011, using hand hoes. The amounts of legume biomass incorporated were cowpea (73 kg), green gram (25 kg), mucuna (84 kg), canavalia (16 kg), chick pea (6 kg) and sun hemp (38 kg). After four weeks of incorporation soil samples were taken from each plot for chemical analysis so as to assess the soil fertility improvements.

In December 2011, planting was done using maize variety (Situka) with a spacing of 75cm × 30cm (1 plant per hill) giving a total population of 44444 plants ha^{-1}. Two seeds were sown per hole, and thinned to one plant per hill, seven days after seedling emergence. Phosphate fertilizer was applied at the rate of 40 P_2O_5 kg as Triple Super Phosphate (TSP) at planting per ha^{-1}. Urea fertilizer was applied at the rate of 80 kg N ha^{-1} in split fashion: one third at planting and two thirds top dressed 28 days after planting Di Ammonium Phosphate (DAP). Weeding was done once using a hand hoe and hand pulling. Thiodan (endosulfan 35% emulsifiable concentrate) and gammalin (20% emulsifiable concentrate) insecticides were applied 35 and 54 days after planting (DAP) to control stalk borers (*Buseola fusca*) and termites (*Odontotermis* spp) respectively.

Data collection

Soil samples for chemical analysis were taken four weeks after legume residues incorporation. Five plant samples were taken at booting stage and analyzed for total N uptake for plant. At harvest maize was harvested where, yield components and grain yield were determined including stalk height, stalk weight, grain weight per cob and grain yield.

Data on economic analysis were obtained by considering the price of inputs that prevailed at the time of application and the market price of the commodity were taken in order to determine the cost of cultivation and gross returns, which was used to calculate cost-benefit ratio and net present value of each treatment.

Data Analysis

Gen Stat software was employed for statistical analysis. Data were statistically subjected to analysis of variance (ANOVA) to test the differences among treatments, and means were separated by the Duncan's Multiple Range test.

Results and Discussion

Soil chemical properties and types of legumes biomass

Results on the soil chemical properties after incorporation of legume residues indicated improvement in the soil pH, organic carbon, total nitrogen and available P. Among legumes, the incorporation of green gram and cowpea residues led to an increase in soil pH from 4.48 to 5.65 (26.32%) and from 4.67 to 5.65 (17.27%) comparable to other studied legume residues (Table 4.1 and 4.2) at both villages. Non significant differences ($P<0.05$) were observed among the legume residues incorporated, urea and control (no incorporation), but slightly increased soil pH.

The increase in soil pH at Kiwere could be due to legume residues ability in ameliorating soil acidity by forming organic- Al complexes in soil solution and release low molecular weight organic acids such as malates and oxalates from the decomposing matter. The organic– Al complexes lowers the concentrations of pytotoxic Al^{3+} from the hydrolysis reaction that increase soil pH.

Table 4. 1: Soil chemical properties before legume biomass incorporation

	Mangalali				Kiwere			
	pH (H_2O)	% OC	% N	mg P kg^{-1}	pH (H_2O)	% OC	% N	mg P kg^{-1}
Control	6.38	0.74	0.14	10.46	5.29	0.31	0.021	10.03
Cowpea	6.29	0.68	0.12	3.79	4.67	0.19	0.023	7.03
Green gram	6.29	0.87	0.12	6.25	4.48	0.19	0.026	11.40
Mucuna	6.24	0.71	0.14	8.67	5.08	0.29	0.023	8.15
Canavalia	6.32	0.74	0.10	4.05	4.77	0.28	0.021	7.22
Sun hemp	6.28	0.77	0.14	6.26	5.00	0.22	0.026	13.86
Chickpea	6.35	0.81	0.15	5.12	4.85	0.27	0.021	6.58
Urea	6.44	0.84	0.16	5.76	4.95	0.26	0.023	12.48
Grand Mean	**6.33**	**0.771**	**0.13**	**6.29**	**4.89**	**0.25**	**0.023**	**9.59**
CV (%)	**3.6**	**18.1**	**16.2**	**62.9**	**5.6**	**31.3**	**26.9**	**42.1**
P (0.05)	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

Where; ns- not significance

Table 4. 2: Soil chemical properties after legume biomass residues incorporation

	Mangalali				Kiwere			
	pH (H_2O)	% OC	% N	mg P kg^{-1}	pH (H_2O)	% OC	% N	mg P kg^{-1}
Control	6.4a	0.75	0.11b	12.7a	5.17a	0.29	0.05ab	29.5a
Cowpea	6.4a	0.78	0.23de	17.8a	5.45a	0.25	0.15d	29.8a
Green gram	6.3a	0.88	0.17ab	16.4a	5.65a	0.25	0.07abc	24.8a
Mucuna	6.3a	0.75	0.24e	20.9a	5.18a	0.33	0.18d	13.2a
Canavalia	6.5a	0.76	0.20cd	18.3a	5.15a	0.29	0.09c	21.1a
Sun hemp	6.4a	0.79	0.23de	17.6a	5.32a	0.28	0.17d	17.6a
Chickpea	6.4a	0.82	0.16b	24.2a	5.38a	0.27	0.08bc	17.9a
Urea	6.4a	0.83	0.12a	18.9a	5.14a	0.25	0.08bc	15.3a
Grand Mean	**6.4**	**0.79**	**0.18**	**18.3**	**5.31**	**0.28**	**0.10**	**21.1**
CV (%)	**3.3**	**18.4**	**10.1**	**29.8**	**7**	**30.2**	**21.3**	**26.6**
P (0.05)	**ns**	**ns**	*****	**ns**	**ns**	**ns**	*****	**ns**
LSD	**0.37**	**0.26**	**0.02**	**9.57**	**0.65**	**0.15**	**0.04**	**9.84**

Where; ns - not significant, * ($P< 0.05$) Significant, ** ($P<0.01$) Highly significant, and *** ($P<0.001$) Very highly significant.

The means in the same column followed by the similar letter(s) are not statistically different at 5% level of significance following Duncan's Multiple Range Test.

The results are comparable with those of Kiiya *et al.* (2010) who reported that incorporation of cowpea and lupine residues increased soil pH from 3.6 to 3.9 and 4.2, respectively.

Also incorporation of sunhemp and cowpea residues led to increases in organic carbon from 0.19 to 0.25 and 0.22 to 0.28% being increase of 32% and 27%, respectively at both villages after four weeks of incorporation. The results agree well with the findings of Kamidi *et al.* (2000) who reported increase of organic carbon when mucuna was incorporated in the soil.

Incorporation of legume residues increased mineral N in the soil. Sunhemp residues significantly increased the amount of N from 0.14 to 0.23% followed by cowpea of 0.023 to 0.15% compared to control with an increase of 0.021 to 0.05%. The result confirmed the findings of Agboola (1975) in which incorporation of mucuna in the soil increased N by 20%.

Cowpea and chickpea increased the available P from 7.03 to 29.8 mg kg^{-1} and 5.12 to 24.2 mg kg^{-1} respectively (Table 4.1 and 4.2) compared with those of sunhemp, mucuna, canavalia and green gram at both villages. No significant differences ($P<0.05$) on available P were observed after incorporation of legume residues. However among the legume residues, cowpea and chickpea showed higher increases of available P than the other studied legume residues. The results were similar to the findings reported by Kiiya *et al.* (2010) who reported that incorporation of lupine residues raised available P by 52.8% (20.3 to 31.0 mg kg^{-1}) and garden pea raised available P by 45% from (20.3 to 29.4 mg kg^{-1}). Tisdale *et al.* (1985) reported that the decomposition processes which are stimulated when legume residues are incorporated into the soil increase phosphorus by releasing CO_2 which formed H_2CO_3 in the soil solution, resulting in the dissolution of primary P-containing minerals.

Nitrogen uptake as influenced by legume biomass residues and inorganic fertilizer in the soil

The highest nitrogen uptake was recorded in sunhemp (2.33%) followed by urea (2.31%) while the lowest amount was recorded in control (1.73%) (Table 4.3) at both sites. The results were significantly different ($P<0.05$) for nitrogen (%N) uptake among the legume residues incorporated in the soil in the maize plant at booting stage in both villages. This may be due to the quality and quantity of incorporated residues in the soil before planting maize. Mucuna has 3.31%N and narrow C:N ratio of 11.96 and sunhemp has 3.31%N and C:N ratio narrow 12.05 which quantify them to have high decompostion rate hence release more nitrogen early after has been incorporated into the soil (Palm *et al*., 2001).

Table 4. 3: Nitrogen (% N) uptake by maize plant at booting stage.

Legumes type	Mangalali	Kiwere
Control(no fertilizer added)	1.75a	1.73a
Cowpea	2.16d	2.28cd
Green gram	1.81bc	1.87ab
Mucuna	2.29d	2.14bcd
Canavalia	1.96c	2.01abcd
Sun hemp	2.23d	2.33d
Chickpea	1.77b	1.91abc
Urea (80kg Nha^{-1})	2.29d	2.31d
Grand mean	2.03	2.01
CV (%)	4.7	9.7
P (0.05)	***	**
LSD	0.17	0.35

N.B; ns - not significant, * ($P< 0.05$) Significant, ** ($P<0.01$) Highly significant, and *** ($P< 0.001$)Very highly significant.

The means in the same column followed by the similar letter(s) are not statistically different at 5% level of significance following Duncan's Multiple range Test.

The results are different from those suggested by Tisdale *et al.* (2003) that the critical nutrient range of nitrogen for maize shoots at 45-80 days ranges between 3.4 to 4.5%N.

This difference, probably may be due the competition for nutrients released between maize and witch weed (*Striga asiatica*) (Table. 4. 4) which infested the farm, hence maize failled to absorb enough nutrients to reach the critical nutrient range.

Table 4. 4: *Striga* shoot count in maize fields as influenced by legume residues and urea

Legume types	*Striga* count in m^{-2}	
	Mangalali	Kiwere
Cowpea	2	1
Chickpea	7	5
Green gram	3	4
Mucuna	2	2
Canavalia	4	4
Sunhemp	1	1
Control (no fertilizer added)	7	6
Urea (80 kg N ha^{-1})	2	1
Grand mean	**2.88**	**3.59**
($P<0.05$)	***	***
LSD	**0.80**	**0.99**
CV (%)	**16.4**	**15.8**

Maize yield

The results showed that maize grain yield was high under cowpea residues (3.77 t ha^{-1}) being an increase of 66% followed by urea (3.631 t ha^{-1}) being an increase of 65% and mucuna (3.527 t ha^{-1}) an increase of 64% compared yield of maize under control (no legume residues). Yield of chickpea was low (0.997 t ha^{-1}) an increase of 46% at both villages (Table 4.5). Among legume residues, cowpea, mucuna and sunhemp produced significantly high yield compared with the other legume residues.

There were significant differences ($P<0.05$) in yield of maize with cowpea, mucuna and sunhemp compared the yield of maize with chickpea, green gram and canavalia among the legume residues incorporated. The result are in agreement with the findings of

Whitbread *et al.* (2004) who reported that when mucuna was incorporated into the soil as green manure, 2.3 t ha^{-1} of maize was achieved which was 64% higher than the maize yield from weedy fallow.

Studies conducted in Thohoyandou, Limpopo South Africa by Jude (2011) showed that maize grain yield following legumes incorporation, produced between 19 to 58% more grain yields than control. In Kenya, *C. ochroleuca* and *Mucuna pruriens* as green manure improved maize grain yield by 1.5 t ha^{-1} compared to no incorporation (Ojiem *et al.*, 2000), while in southern Cameroon, Hauser and Nolte (2002) obtained maize yields of 4 t ha^{-1} after a short-term fallow with mucuna.

The results are in agreement with those of Shafi *et al.* (2007) who reported that incorporated legume residues significantly increased grain yield of maize compared with the no legume residues treatment. Similarly, Kouyate *et al.* (2000) reported an increase of grain yield by 37% when crop residues were incorporated as compared with no residues treatment. Therefore incorporation of cowpea, mucuna and sunhemp legume residues are good source of N in *Striga* infested soils. Hence reduce *Striga* occurrence and improve maize yield.

Table 4. 5: Maize yield parameter as influenced by legume residues and Urea

Yield parameters	Stalk weight (gm)				Cob height (cm)				Cob weight (gm)			
Villages	Mangalali		Kiwere		Mangalali		Kiwere		Mangalali		Kiwere	
Treatments	*Striga*	No *Striga*	*Striga*	No *Striga*	*Striga*	*No Striga*	*Striga*	No *Striga*	*Striga*	No *Striga*	*Striga*	No *Striga*
Control	213^{a}	273^{ab}	203.3^{a}	313.3^{a}	10.8^{a}	11.6^{a}	10.00^{a}	12.43^{a}	4.99^{a}	10.51^{a}	12.49^{a}	22.91^{a}
Cowpea	340^{c}	407^{d}	353.3^{b}	453.3^{c}	12.73^{a}	13.13^{a}	14.70^{d}	15.93^{b}	15.66^{b}	15.04^{a}	22.4^{a}	28.90^{a}
Green gram	247^{abc}	287^{abc}	273.3^{ab}	350^{ab}	12.47^{a}	12.8^{a}	12.90^{bcd}	14.87^{b}	8.25a	14.61^{a}	18.30^{a}	19.87^{a}
Mucuna	313^{bc}	393^{cd}	346.7^{b}	413.3^{c}	12.6^{a}	13.13^{a}	14.43^{d}	15.00^{b}	16.72^{b}	14.92^{a}	18.79^{a}	22.58^{a}
Canavalia	240^{ab}	327^{abcd}	283.3^{ab}	346.7^{ab}	11.33^{a}	12.27^{a}	12.23^{bc}	14.40^{ab}	7.81^{a}	13.54^{a}	15.01^{a}	20.91^{a}
Sunhemp	273^{abc}	347^{abcd}	350.0^{b}	420.0^{c}	12.8^{a}	13.40^{a}	14.07^{cd}	15.30^{b}	17.01^{b}	17.88^{a}	18.37^{a}	21.51^{a}
Chickpea	220^{ab}	260^{a}	226.7^{a}	296.7^{a}	10.93^{a}	11.93^{a}	11.13^{ab}	12.70^{a}	6.81^{a}	10.7^{a}	18.61^{a}	23.83^{a}
Urea	300^{abc}	373^{bcd}	356.7^{b}	406.7^{bc}	12.33^{a}	12.67^{a}	14.43^{d}	15.87^{b}	16.73^{b}	14.82^{a}	21.81^{a}	25.97^{a}
Grand mean	268	333	299.2	375.0	12	12.62	12.99	14.56	11.75	14	18.2	23.31
P(0.05)	ns	*	**	***	ns	ns	***	**	***	ns	ns	ns
LSD	87.4	100.9	76.27	59.02	2.488	2.162	1.881	1.934	3.373	7.445	9.01	8.351
CV (%)	18.6	17.3	14.6	9.0	4.7	9.8	8.3	7.6	16.4	30.4	28.2	20.5

N.B; ns - not significant, * ($P< 0.05$) Significant, ** ($P<0.01$) Highly significant, and *** ($P< 0.001$) Very highly significant.

The means in the same column followed by the similar letter(s) are not statistically different at 5% level of significance following Duncan's Multiple range Test.

Table 4. 5 continued. Maize yield parameters and grain yield as influenced by legume residues and Urea

	Grain weight per cob (gm)				Hundred grain weight (gm)				Yield (ton/ha)	
Villages	Mangalali		Kiwere		Mangalali		Kiwere		Mangalali	Kiwere
Treatments	*Striga*	No *Striga*	*Striga*	No *Striga*	*Striga*	No *Striga*	*Striga*	No *Striga*	Yield (t ha^{-1})	Yield (ton/ha)
Control	24.97a	44.69a	61.49a	84.8a	17.9a	23.73a	23.67a	29.43ab	1.148ab	1.953a
Cowpea	78.31b	93.98c	119.06c	144.4c	25.97b	32.27bc	28.70ab	33.87cde	3.568c	3.770c
Green gram	41.24a	73.31b	77.17ab	111.3ab	19.93a	25.83a	28.27ab	32.57bcd	1.936b	2.667b
Mucuna	83.62b	101.48c	98.41bc	122.1bc	25.43b	33.57bc	28.67ab	33.27cde	3.263c	3.527c
Canavalia	39.03a	56.51ab	73.57ab	110.8ab	21.37a	26.13a	26.70ab	28.90a	1.794ab	2.285ab
Sunhemp	85.03b	94.35c	103.01c	131.3bc	25.63b	31.47b	29.47b	36.33e	3.668c	3.486c
Chickpea	34.05a	49.35a	72.95ab	91.3a	18.20a	25.20a	26.30ab	30.73abc	0.997a	2.157ab
Urea	83.65b	100.68c	119.91c	131.9bc	27.10b	35.47c	28.87ab	34.67de	3.442c	3.631c
Grand mean	58.7	76.8	90.7	116.0	22.69	29.21	27.58	32.47	2.477	2.934
P(0.05)	***	***	***	**	***	***	ns	**	***	***
LSD	16.86	17.45	24.60	26.67	3.772	3.456	5.053	3.088	0.7885	0.6019
CV (%)	16.4	2.8	15.5	13.1	9.5	6.8	10.5	5.4	18.2	11.7

N.B; ns - not significant, * ($P < 0.05$) Significant, ** ($P<0.01$) Highly significant, and *** ($P< 0.001$) Very highly significant.

The means in the same column followed by the similar letter(s) are not statistically different at 5% level of significance following Duncan's Multiple range Test

Benefit-cost ratio was observed to be greater than one (>1) in all treatments, which indicates that each treatment can be used by farmers. The benefit cost ratio for cowpea (6.8), green gram (4.6), mucuna (2.6) and urea (2.6) were observed to be higher than that of chickpea (1.9), canavalia (1.7), sunhemp (1.7) and control (1.9). Also net present value was higher in cowpea (4 827 009 Tshs), green gram (2 507 254 Tshs), sunhemp (1 096 588 Tshs), urea (1 038 425 Tshs) and the lowest was in control (351 802 Tshs). The differences were due to high benefit obtained after using cowpea, green gram, mucuna and urea as a source of fertilizer rather than using chickpea, canavalia and control. The results show that the use of legume residues provides more profit than using inorganic fertilizer. This is due to the high cost of production process especially inputs (inorganic fertilizers).

Conclusion

From the results it is concluded that; legume biomass residues can be used as a source of nutrient and soil amendment when incorporated into *Striga* infested soils and has shown the potential to increase maize yield. Furthermore Legume residues are an alternative technology that can be used by resource poor farmers with limited resources to purchase sufficient inorganic N fertilizers to increase yield. When cowpea, sunhemp and mucuna residues were incorporated into the soils infested with *Striga*, maize yields obtained were 3.7, 3.5 and 3.4 t ha^{-1}, respectively. Due to these, use of cowpea, mucuna and sunhemp is highly recommended in Iringa District soils mainly for higher maize yields production. TSP is also a good source of inorganic fertilizer that can be used in this district as it supplies P and Ca.

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CHAPTER FIVE

5.0 GENERAL DISCUSSION

The results of N mineralization among the legumes studied showed that highest total N was released from sun hemp residues (160 mg kg^{-1}) and lowest N from the cowpea residues (107.4 mg kg^{-1}) (Table 3.3 Figure 5.1). This shows that sunhemp has the ability to release more nutrients and faster than the other legumes due to its high N content (3.31%) and low C: N ratio (12.05) (Table 3.2 and appendix 1). Similar results observed by Jude (2010) showed that sunhemp mineralized faster than mucuna and lablab.

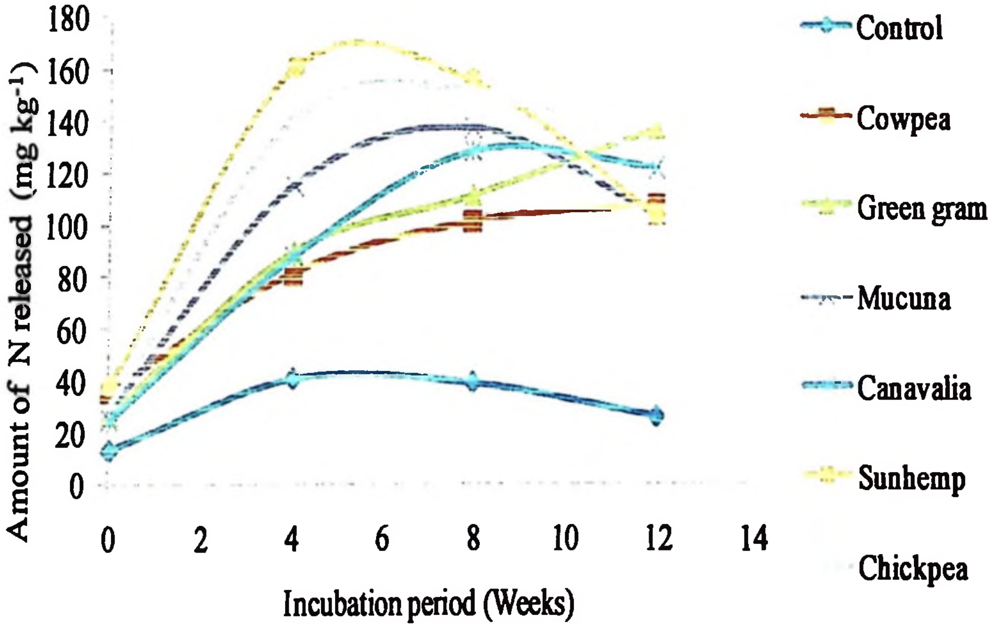

Figure 5. 1: **Trends of N released by different legumes at different incubation periods (weeks).**

In the field, incorporation of legume residues increased mineral N into the soil. Sunhemp residues significantly increased the amount of N from 0.14 to 0.23%, followed by

4.1, 4.2 and appendix 4). These increases are due the high amount of N content in sunhemp residues and its narrow C: N ratio that improves mineralization and release more N content into the soil.

Results on the soil chemical properties after incorporation of legume residues indicated improvement in soil pH, organic carbon, total nitrogen and available P. Non significant differences ($P<0.05$) were observed among the legume residues, Urea and control (no residue treatment added). Among the legumes, the highest soil pH increase was recorded in green gram and cowpea residues with an increase of soil pH from 4.48 to 5.65 (26.32%) and from 4.67 to 5.45 (17%) comparable to other legume residues (Appendix 2) at Kiwere village. The slight pH increase at Mangalali village was observed in canavalia residues from 6.32 to 6.5 (3%) followed by cowpea from 6.29 to 6.4 (2%) and sunhemp from 6.28 to 6.4 (2%).

The increase in soil pH at Kiwere is due to legume residues ability in ameliorate soil acidity by forming organo- Al complexes in soil solution and releasing low molecular weight organic acids such as malates and oxalates from the decomposing matter. The organic– Al complexes lowers the concentrations of pytotoxic Al^{3+} the hydrolysis reaction that increase soil pH. The increases in soil pH helps more nutrients to be available into the soil and hence improving the fertility status of the soil.

No significant differences ($P<0.05$) on available P were observed after incorporation of legume residues. However, cowpea and chickpea showed slightly higher increases of available P than the other legume species. Cowpea and chickpea increased available P from 7.03 to 29.8 mg kg^{-1} and 5.12 to 24.2 mg kg^{-1} respectively (Table 4.1 and 4.2 and appendix 5), compared with those of sunhemp, mucuna, canavalia and green gram. The increase in available P was caused by the increase in the soil pH, that means the P that was fixed by Al and Fe was released into the solution making it available by plant. The results were similar to the findings reported by Kiiya *et al.* (2010) who reported that incorporation of lupine residues raised available P by 52.8% (20.3 to 31.0 mg P kg^{-1}) and garden pea raised available P by 45% from (20.3 to 29.4 mg P kg^{-1}). Tisdale *et al.* (1985) reported that the decomposition processes which are stimulated when legume residues are incorporated into the soil increase phosphorus by releasing CO_2 which formed H_2CO_3 in the soil solution, resulting in the dissolution of primary P-containing minerals.

Maize grain yield obtained after incorporation of legume residues into the soil and urea (80kg N ha^{-1}) application showed no significant differences ($P<0.05$) between sunhemp, cowpea, mucuna and urea but significant differences with green gram, canavalia, chickpea and control. Maize grain yield was high in cowpea residues (3.77 t ha^{-1}) with an increase of 66% followed by urea (3.631 t ha^{-1}) with an increase of 65% and mucuna (3.527 t ha^{-1}) with an increase of 64% compared to that of chickpea (1.0 t ha^{-1}) with an increase of 46% (Table 4.5b and figure 5.2). This is due to its ability to release more N content when incorporated into the soil due to its narrow C: N ratio compared to other legumes.

Variable increases in maize grain yield following incorporation of legumes have been reported in other studies. Tanimu (2007) reported 12.6 - 74.8%, while Kouyate *et al.* (2000) reported 37% increase compared to no other legume residues.

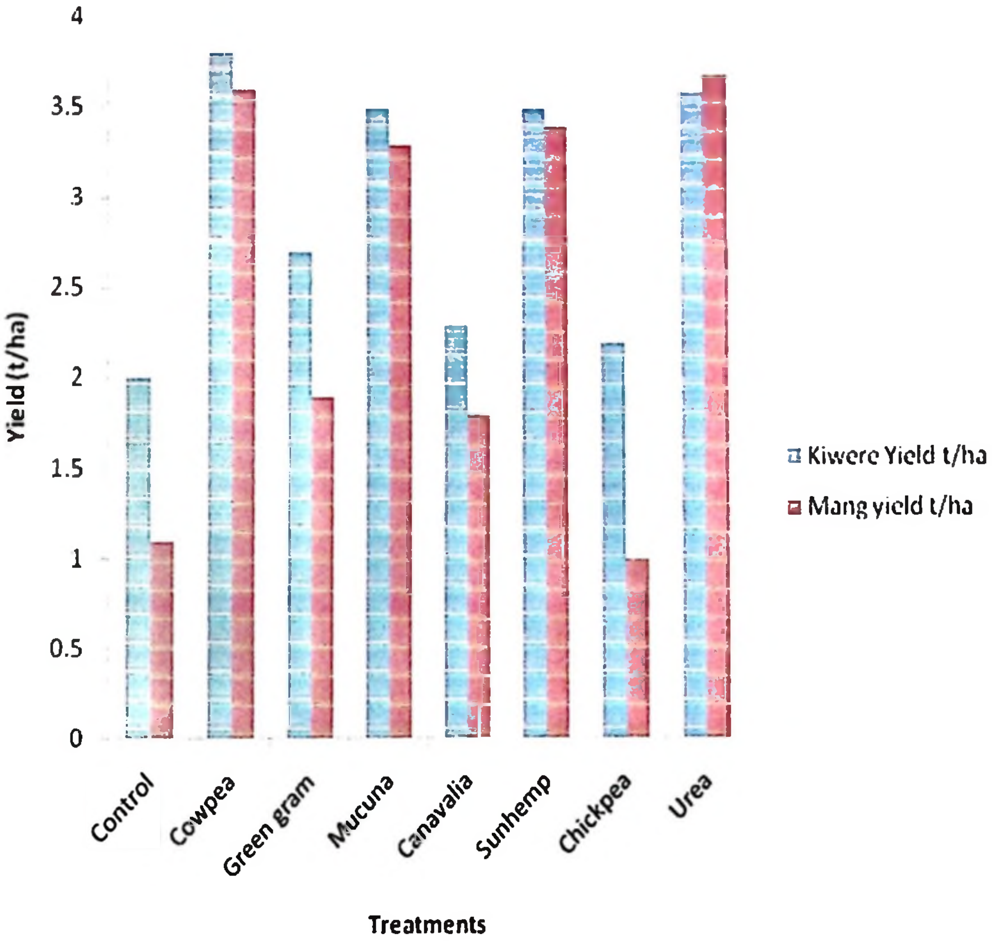

Figure 5. 2: Maize grain yield at Kiwere and Mangalali after legume biomass residues incorporation.

CHAPTER SIX

6.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 General conclusions

From the results it is concluded that:

- Legume biomass residues can be used as a source of nutrient and soil amendment when incorporated into the soil and has shown the potential to control *Striga* and increase maize yields.
- Legume residues are an alternative technology that can be used by resource poor farmers with limited resources to purchase sufficient quantities of inorganic N fertilizers to increase yields.
- Urea, cowpea, sunhemp and mucuna when incorporated into the soils infested with *Striga* increased maize yields to 3.7, 3.7, 3.5 and 3.4 t ha^{-1}, respectively from 1.0 t ha^{-1} of non incorporated legumes residues.

6.2 Recommendation

- Use of cowpea, mucuna and sunhemp can be recommended in Iringa District soils mainly to control *Striga* occurrence and higher maize yields production.
- Use of organic matter can be recommended in Iringa Districts soils so as to increase P availability in the soil solution.

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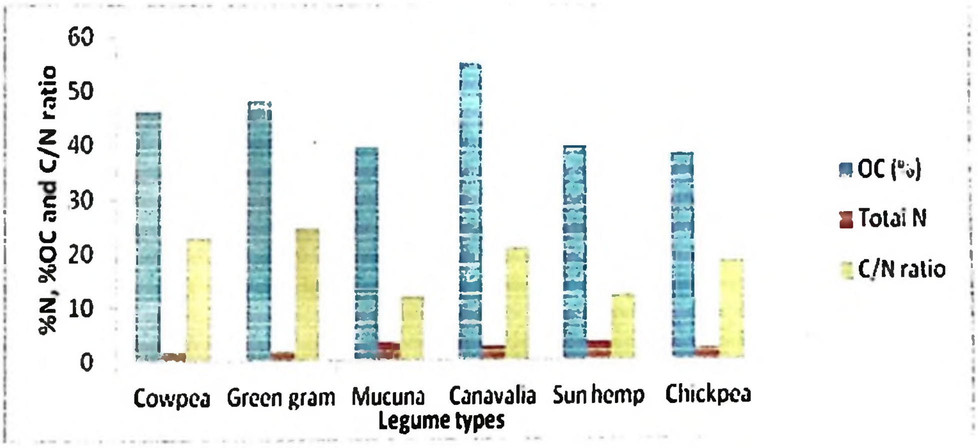
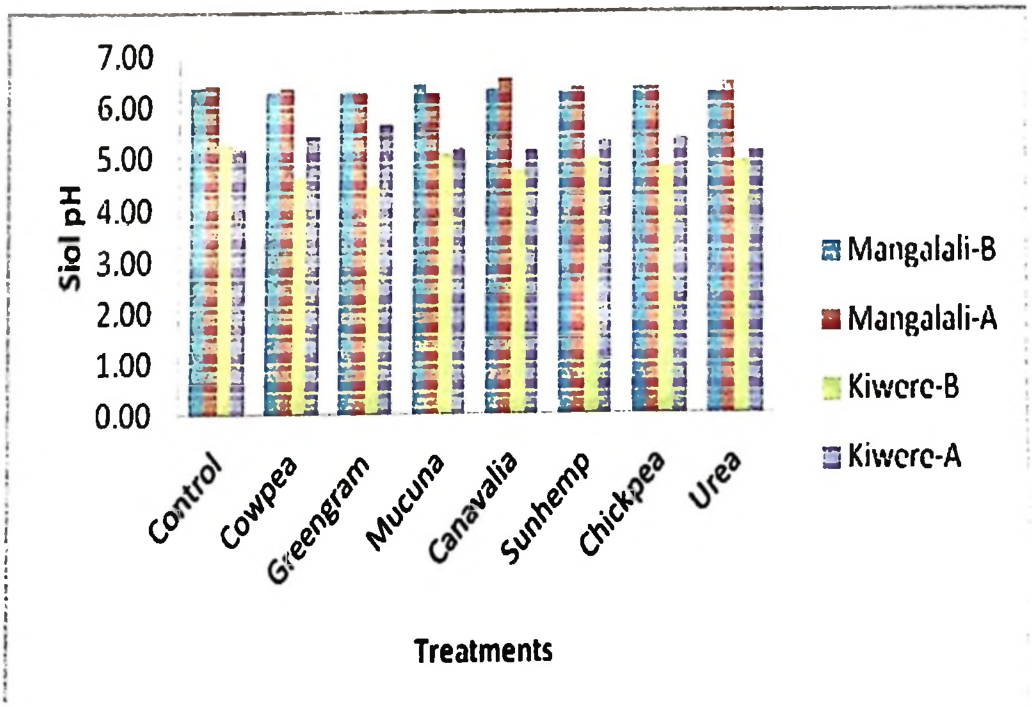
APPENDICES

Appendix 1: **Amount of Total N, OC and C/N ratio in the various legume biomass residues**



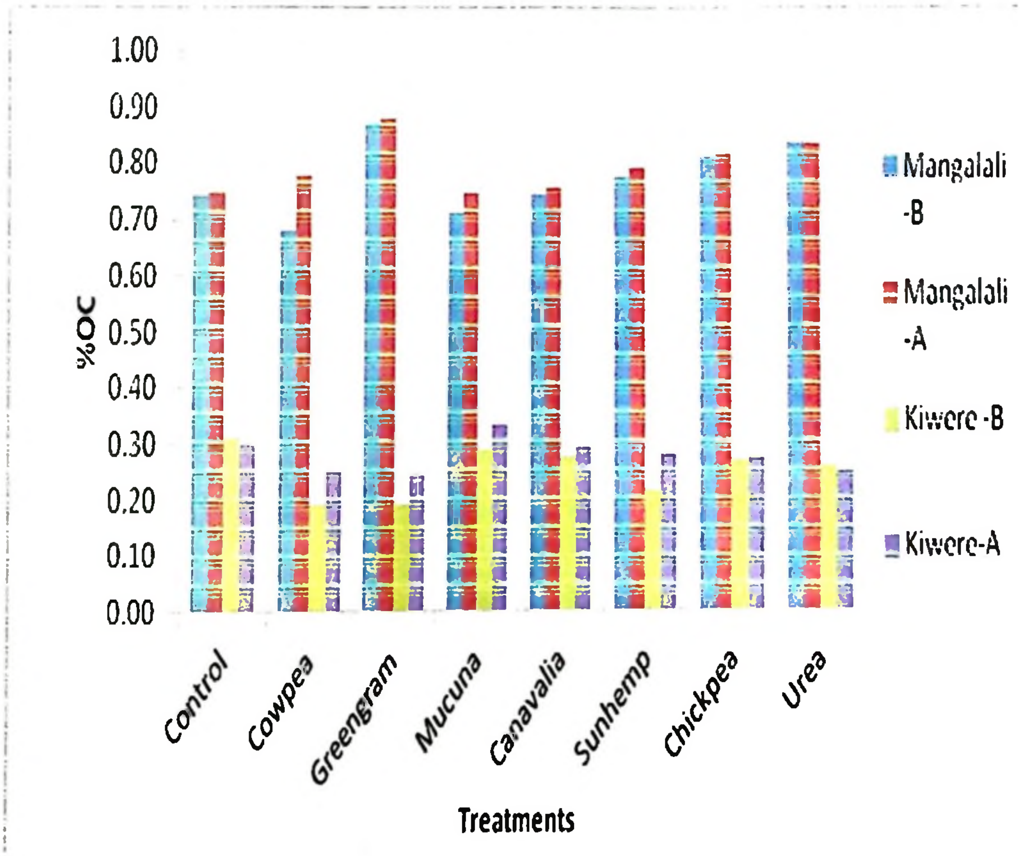
Appendix 2: **Soil pH for Mangalali and Kiwere before and after legumes biomass incorporation.**



A - After incorporation of legume residues

B - Before incorporation of legume residues

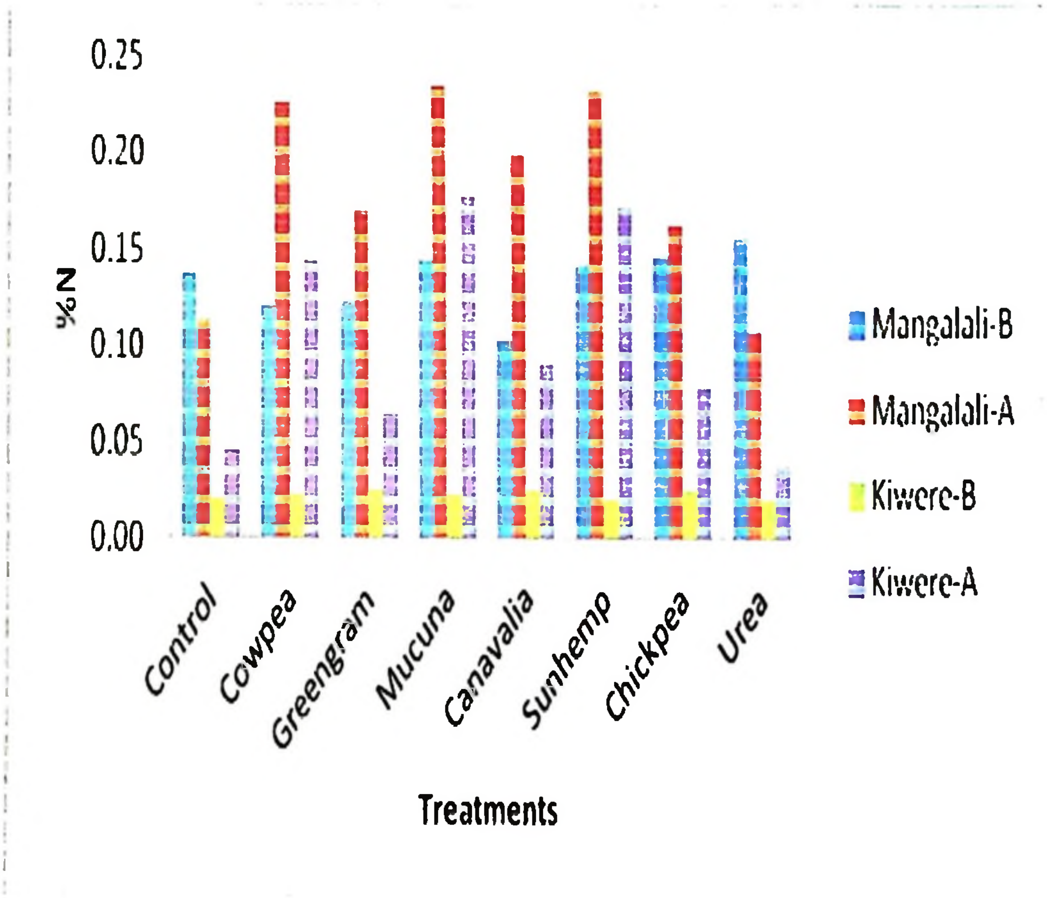
Appendix 3: Soil organic carbon for Mangalali and Kiwere before and after legumes biomass incorporation.



A - After incorporation of legume residues

B - Before incorporation of legume residues

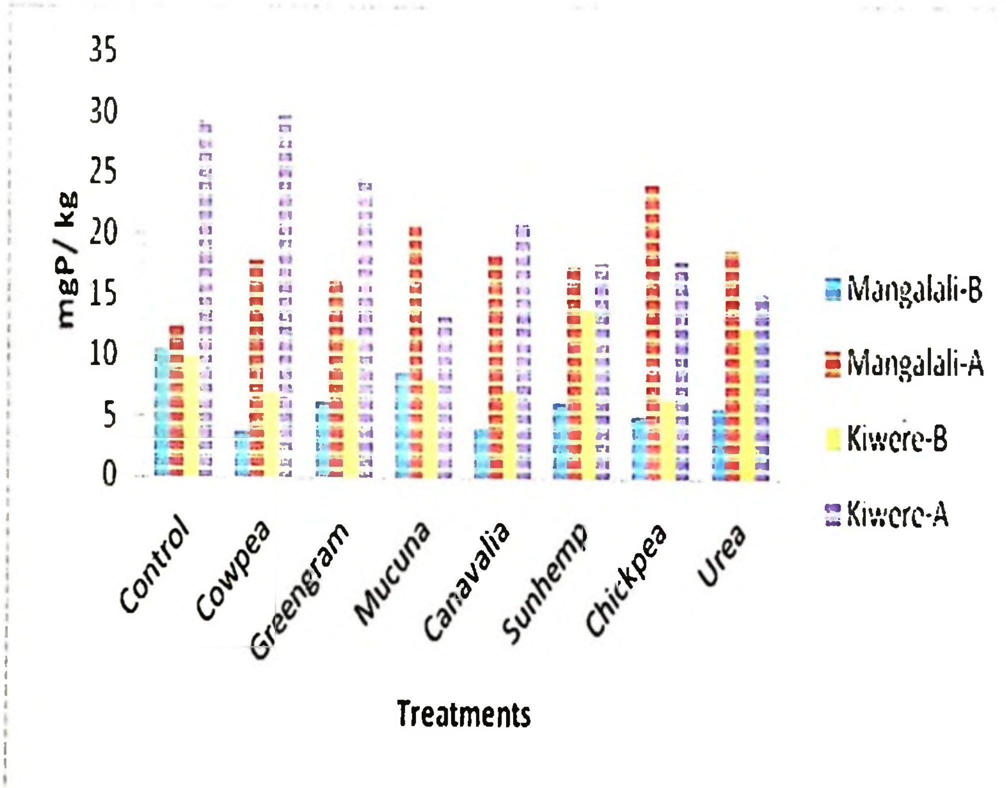
Appendix 4: **Soil %N for Mangalali and Kiwere before and after legumes biomass incorporation.**



A - After incorporation of legume residues

B - Before incorporation of legume residues

Appendix 5: Soil mgP kg^{-1} for Mangalali and Kiwere before and after legumes biomass incorporation.



A - After incorporation of legume residues

B - Before incorporation of legume residues