GROWTH RATE AND BIOMASS ACCUMULATION OF MUCUNA (*Mucuna pruriens*), CENTROSEMA (*Centrosema pubescens*), GLIRICIDIA (*Gliricidia sepium*) *and* LEUCAENA (*Leucaena leucocephala*)

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CERTIFICATION

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DEDICATION

This thesis is dedicated to God Almighty who is the source of my wisdom and knowledge.

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ABSTRACT

Forage legumes have played important roles in crop-livestock systems and in forage research. Research conducted to test the impact of forage legumes on livestock productivity in the sub humid zone of Nigeria is scanty.

This research is aimed at developing a model that can correctly predict the growth rate and also the biomass accumulation of *Mucuna pruriens, Centrosema pubescens, Gliricidia sepium* and *Leucaena leucocephala.*

The experiment was conducted at the screen-house of the Faculty of Agriculture, Federal University, Oye-Ekiti, Ikole campus with Latitude – N 07^0 48.308, Longitude – E 005^0 29.573 and 548.4m above ground level.

The planting was done using completely randomized design (CRD) in 4 rows with 4 replicates of 8 pots of each legume species and a spacing of 1m apart was applied between each bed.

The soil used for this study contained organic matter before planting (39.83%) and after harvesting was (57.72%). The soil used in planting belonged to loam soil category.

The highest growing legume was *Mucuna pruriens* throughout the period of carrying out this experiment. The plant heights of the four legume species were significant ($p<0.05$) from each other.

Leucaena leucocephala had the highest nitrogen content and this was observed in the second cuttings (4^{th} week). Nitrogen was found to decrease linearly as the legumes grow. At $p<0.05$; *Leucaena leucocephala* had more nitrogen content for the study period than, *Gliricidia sepium,*

Centrosema pubescens, and *Mucuna pruriens* at weeks 2 (2.83, 2.28, 1.95, 1.77), 4 (3.05, 2.
1.69, 1.46), 6 (3.04, 2.70, 2.22, 1.77) and 8 (2.51, 2.21, 1.89, 1.53).

The crude protein of the four legume species increased as the legume grew; the highest crude protein was also observed in the second cutting (4th week) due to the nitrogen content and are directly related.

The moisture content varied between the legume species and the times of cuttings; *Leucaena leucocephala* was having the highest moisture content throughout the eight weeks of study compared to *Gliricidia sepium, Centrosema pubecens* and *Mucuna pruriens.*

The crude fibre, crude ash and crude fat of the four legume species, were significantly different ($p<0.05$) from each other. It was noticed that there were fluctuations in the nutrient contents of the legume species due to cutting times.

The growth rate of legumes was observed throughout the course of undertaking this study and the varietal differences were observed with *Mucuna pruriens* the fastest.

The biomass accumulation observed yielded 39.26% - 80.51% while the growth rate of the legume observed was 87.39% - 88.98%.

Keywords: *Mucuna pruriens, Centrosema pubescens, Gliricidia sepium, Leucaena leucocephala*, Growth rate, Biomass, Legume growth model, Nitrogen, Crude protein, Crude Fibre, Crude Fat, Crude Ash, Moisture.

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TABLE OF CONTENTS

TITLE **PAGE**

LIST OF PLATES

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

CHAPTER ONE

1.0 INTRODUCTION

1.1 General project background

A legume is a plant or its fruit or seed in the family Fabaceae (or Leguminosae). Legumes are grown agriculturally, primarily for their grain seed called pulse, for livestock forage and silage, and as soil-enhancing green manure. Fabaceae is the most common family found in tropical rainforests and in dry forests in the America and Africa (Stevens, 2008).

The Fabaceae are mostly herbs but include also shrubs and trees found in both temperate and tropical areas. The leaves are stipulate, nearly always alternate, and range from pinnately or palmately compound to simple (Grubben *et al.*, 2004).

Legumes are notable in that most of them have symbiotic nitrogen-fixing bacteria in structures called root nodules. For that reason, they play a key role in crop rotation.

Legumes are a significant source of protein, dietary fiber, carbohydrates and dietary minerals (David, 2015). Several experiments have shown that pure legume silages and legume-dominated silages can increase milk production compared to that obtained from pure grass silages. It should be pointed out that legumes can be difficult to conserve, however, and special care must be taken to ensure good silage quality and to minimize leaf losses during hay making (Miller *et al.*, 1999). Increasing the concentration of total non-structural carbohydrates (TNC) of legumes will undoubtedly facilitate the production of high-quality silages and increase animal performance. This can be achieved by cutting the plot during the afternoon when sugar content is at its maximum (Akinola, 2008).

Many legumes contain symbiotic bacteria called Rhizobia within root nodules of their root systems. These bacteria have the special ability of fixing nitrogen from atmospheric, molecular nitrogen (N_2) into ammonia (NH_3). The chemical reaction is:

$$N_2 + 8H^+ + 8e^- \rightarrow 2NH_3 + H_2$$

Ammonia is then converted to another form, ammonium (NH_4^+), usable by (some) plants by the following reaction:

$$NH_3 + H^+ \rightarrow NH_4^+$$

This arrangement means that the root nodules are sources of nitrogen for legumes, making them relatively rich in plant proteins (John, 2015).

When a legume plant dies in the field, for example following the harvest, all of its remaining nitrogen, incorporated into amino acids inside the remaining plant parts, is released back into the soil. In the soil, the amino acids are converted to nitrate (NO_3^-), making the nitrogen available to other plants, thereby serving as fertilizer for future crops.

1.1.1 Forage Legume

Over 1500 species of legumes (from about a total of 17 000 legume species worldwide) can be used as feed for livestock, although only about 60 species have been developed and widely used as cultivated forages. Tropical legumes may have originated from tropical forests and natural grasslands and were later adapted to a variety of environments (Williams, 2011).

The wide range of species covers short-lived annuals to long-lived perennial trees and small herbaceous species to large woody species, adapted both to tropical and Mediterranean areas (Mullen, 2010).

Forages legumes are mostly used as cut fodder or grazed pasture. Fodder may be fed directly to livestock or used after conservation as fermented green matter (silage and haylage) or dried for products like hay, pellets or cube concentrates. Pastures may be grazed directly or cut and used in feed rations for livestock (Bogdan, 2011). Forages also have an important role in marginal areas in maintaining the natural resource base through soil stabilization, preventing soil erosion, and contribute to soil fertility through microbial nitrogen fixation and organic matter. Some forage legumes are also used to control leaching of nutrients in soils, as well as rotational crops to control pests and diseases of other crops (Hanson *et al.*, 2010).

The maturity (or stage of growth) of the forage is typically the largest determinant of the crop's nutritive value. As the plant enters the reproductive stages of growth, it develops a higher proportion of fibrous stem material which lowers the overall concentration of digestible energy and protein the animal will receive from the plant.

The length of the grazing period, or time in a paddock, also has a direct effect on pasture intake. An animal's intake decreases the longer it remains in a given paddock. This happens due to plant disappearance as plants are grazed and cattle search for their next bite. The decrease in crude protein content begins roughly two days after the animals have been turned into the paddock. It has been shown that as an animal remains in a paddock, intake and liveweight gains decrease.

1.2 PROBLEM STATEMENT

In Nigeria, inadequate number of forage scientists to conduct necessary research in the various aspects of forage and fodder crops has slowed down development in this area. Most indigenous forage and fodder species are low in yield and nutritive value. Extensive areas of Nigeria's grazing lands are composed of indigenous forage species with their various botanical characteristics. Most of the species grown, until of recent, are of the indigenous or local varieties that often have very low yields. Long periods of cropping, rough topography and frequent bush burning, among other factors, have given rise to mixed tree, shrub and grass vegetation in the savanna zones of the country. Various nutrients and minerals, such as nitrogen, phosphorus, potassium, among others, have also been found to be a key limiting factor in the proper development of our forage and fodder crops, and hence efficient utilization of these crops by our livestock. The importance of various soil minerals in the establishment, growth and utilization of forage species have been documented by a number of workers.

Knowing the correlation between accumulated biomass with relations to legume growth age has been a major problem to pastureland scientists. Knowing the rate at which legume grow in the country has been a major cause of concern for pastureland scientists as they have not been able to correctly predict and adopt a working model that could be used to successfully predict legume growth. This has generated a lot of problems for ruminant farmers as they go extra miles in search of pastures which indirectly limit the economic value of the animals which is also a major cause of inter-tribal fights in Nigeria.

One of the major problems hindering expansion of ruminant production in the country is the un-availability of good quality fodder in sufficient quantity (Sarwar *et al*; 2012). Production of good quality fodder are influenced due to plant species (Kaiser *et al.*, 2002, Mehdi *et al;* 2009), stage of growth and agronomic practices.

Pasture land shortage has been a major constraint affecting the development of ruminant animal production in the country. The land tenure system must be revised in some countries to make it easier for those who really need land to obtain it. The need to instil pride of ownership and willingness to invest in development is crucial because communal grazing is free and therefore unattractive for commercial livestock enterprise. The supply of sufficient manpower/experts, e.g. animal scientists, range managers, and technical staff, is essential to foster rapid improvement in ruminant livestock production. Regulatory control of herd size and distribution to achieve ecological balance and avoid overgrazing needs policy attention. The encouragement of herd owners to move to the sub-humid zone in Nigeria, which is rich in feed resources, is a very slowly developing program.

1.3 JUSTIFICATION

This research work is demand driven and its main purpose is to solve the intra-tribal fights between the Fulani herdsmen and the locals by helping them to identify legume that can grow within a short period of time. This research work will also develop a model that can correctly predict the growth rate and also the biomass accumulation of these legume species. This research is being undertaken because the legume species used are cheap and abundant in Nigeria.

The seeds of the legumes species are readily available in the country. Farmers are usually assisted in procurement of inputs for forage production. These inputs include, forage seed, fertilizer, fencing materials, credit facilities/loans etc. They are either made available directly by government agencies such as the Nigerian Livestock Projects Unit or from other sources. With respect to improved seed for sown pastures, farmers are always encouraged to multiply the seed available in the first growing season so that a greater area could be sown the following season and the remaining seed can be sold to other farmers.

1.4 OBJECTIVES OF THE STUDY

1.4.1 Overall objective

The overall objective is to develop a model that can correctly predict the growth rate and also the biomass accumulation of *Mucuna pruriens, Centrosema pubescens, Gliricidia sepium* and *Leucaena leucocephala*.

1.4.2 Specific objectives

i. Determine the bi-weekly biomass accumulation of *Mucuna pruriens, Centrosema pubescens, Gliricidia sepium* and *Leucaena leucocephala*.

ii. Determine the growth rate of *Mucuna pruriens, Centrosema pubescens, Gliricidia sepium* and *Leucaena leucocephala* 2weeks, 4weeks, 6weeks and 8weeks.

iii. Obtain the varietal differences in each legume growth rates.

iv. Determine the nutrient content of the soil before planting and after harvesting.

v. Determine the nutrient content of the legume at different stages of growth.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Forage

Forage is defined as edible parts of plants, other than separated grain, that can provide feed for animals, or that can be harvested for feeding. Generally, the term refers to such material as pasturage, hay, silage, and green chop, in contrast to less digestible material known as roughage (Leep *et al.*, 2002). In practice, however, the concept is often extended to woody plants producing succulent growth and indeed in the tropics some shrubs and trees are of considerable importance in this respect. Forage crops may be used in pastures or may be cut and carried to the animals that are expected to eat them. Forages have always been an extremely important source of nutrients in livestock rations (Schroeder, 2004).

The most important forage plants are the grasses, which comprise about 75% of the forage consumed in the tropics. A second major group of forages is the legumes. The family Leguminosae is one of the largest of flowering plants with an estimated 700 genera and 14,000 species (Martin, 1993).

2.2 Leguminosae as a good fit

Legumes are second only to the grasses (cereals) in providing food crops for world agriculture. In comparison to cereal grains, the seeds of the legumes are rich in high quality protein, providing man and animals with a highly nutritional food resource (ILDIS, 2006). The leaves and grains are not only used as high-protein diet, but also as high protein fodder for livestock (Sprent, 2001).

The leguminosae (Pule-Meuelenberg & Dakora, 2007) are unique in their ability to form N_2 fixing symbioses (BNF) with members of the Rhizobiaceae (or rhizobia, namely, *Rhizobium*, *Brady rhizobium*, *Sino rhizobium*, *Mesorhizobium*, *Azorhizobium* and *Allorhizobium*). Inside root nodules, these rhizobial bacterial are able to reduce atmospheric N_2 into NH_2 via the GS/GOGAT (glutamine synthetase/glutamate-oxoglutarate aminotransferase) pathway and exchange this nitrogenous solute for photosynthate from the host plant (Dakora, 2003). This mutually beneficial relationship between the Leguminosae and the Rhizobiaceae forms the basis for the ecological importance of legumes in natural and agricultural ecosystem in promoting increased crop yields and livestock production (Pule-Meuelenberg & Dakora, 2007).

2.3 Description of Legume Species

2.3.1 *Mucuna pruriens*

Velvet bean (*Mucuna pruriens* (L.) is a leguminous vine. The plant is an annual, climbing shrub with long vines that can reach over 15 meters in length (US Forest Service, 2011; Wulijarni-Soetjipto *et al.*, 1997). It has a taproot with numerous, 7-10 m long, lateral roots. The stems are slender and slightly pubescent (Wulijarni-Soetjipto *et al.*, 1997). The leaves are generally slightly pubescent, alternate and trifoliolate with rhomboid ovate, 5-15 cm long x 3-12 cm broad, leaflets (US Forest Service, 2011). When the plant is young, it is almost completely covered with fuzzy hairs, shed with age. In young plants, both sides of the leaves are hairy.

2.3.1.1 Floral Characteristics

The flowers are arranged in axillary arrayed panicles, 15 to 32 cm long and each have two many flowers. The accompanying leaves are about 12.5 cm long. The vines come into flowering after 120-125 days of sowing and continue to bear flowers and fruits till 180-200 days. The inflorescence is a drooping axillary raceme that bears many white to dark purple flowers.

2.3.1.2 Pod Characteristics

After flower pollination, velvet bean produces cluster of 10 to 14 pods, and are 1 to 2 cm wide at the time of maturity. The husk is very hairy and they are stout, curved, 4 -12.5 cm long, with between two and seven seeds, covered with greyish-white or orange hairs that may cause irritation to the skin. The chemical compounds responsible for the itch are a protein, called serotinin (US Forest Service, 2011). The velvet bean seeds are variable in colour, ranging from glossy black to white or brownish with black mottling. The seeds are round or flattened, uniform, ellipsoid, 1.0 to 1.9 cm long, 0.8 to 1.3 cm wide and 4 to 6.5 cm thick (FAO, 2011).

2.3.1.3 Distribution

Velvet bean originated from southern Asia and Malaysia and is now widely distributed in the tropics (FAO, 2011). It was introduced to the southern states of the USA in the late 19th century and from there was reintroduced to the tropics in the early part of the 20th century (Eilittä *et al.*, 2003).

2.3.1.4 Climate and Soil

The crop grows in all types of soils, but sandy loam soil with good drainage and pH of 5.50 to 7.50 are preferred. It thrives in sub-tropical to tropical climate with a minimum temperature of 15°C in winter and maximum of 38°C in summer months. The crop is seen growing in varied climate such as coastal humid climate to dry arid climate. Hence the crop is said to be highly acclimatizing and adaptive.

2.3.1.5 Seed Viability

The seeds harvested from the mature fruits are viable for more than two years, recording viability of more than 90%. The germination percentage declines after 2 to 3 years of storage.

2.3.1.6 Land Preparation and Fertilizer Application

The field should be ploughed well to make the soil porous to facilitate germination and sprouting of seeds. Farm yard manure at the rate of 10 to 20 t/ha at the time of land preparation is applied to the field.

2.3.1.7 Time of Planting

It is 180 to 200 days' duration crop and is sown in last week of June prior to onset of rainy season. The germination takes 8 to 10 days and the field is stocked with young growing vines in 9 months' period. These vines need support of bamboo sticks for better growth and higher seed production.

2.3.1.8 Spacing

Results from field experiments have shown that planting at a distance of 1 x 0.75 m/ha or 1.0 x 0.6 m/ha depending upon soil fertility produces 2.5 to 3.0 t/ha of seed on pandal support system.

2.3.1.9 Irrigation

It is given fortnightly irrigation during dry season and one irrigation per month is required in winter during pod picking.

2.3.1.10 Disease and Pest Control

Collar rot during initial stages of seedling growth has been found which can be managed by applications of 2 kg Trichorich (a formulation of trichoderma in neem cake) and 2 kg *Pseudomonas fluorescens* mixed with 500 kg FYM and applied to the root region. Amongst insect pests, the leaf eating hairy caterpillar is found to damage the crop during pre-flowering stage. To control the pest, Neem soap is recommended to be sprayed at the rate of 5 gm/lit.

2.3.1.11 Crop Maturity and Harvesting

The crop matures in about 140 days after sowing. Mature pods are harvested to collect seeds from the pods. At the time of harvesting the pods turn to greyish-brown in colour or from green to dark brown or black, indicating maturity for picking. Normally 3-7 seeds are found in a pod and 5-6 pods per inflorescence are generally available. Pods are harvested by hand (Wulijarni-Soetjipto *et al.*, 1997).

2.3.1.12 Post-harvest Management

The pods thus harvested from the field are dried in the sunlight for 4-7 days; the seeds are further dried in shade to reach approximately 7-8% moisture in the seeds. The seeds are normally stored in gunny bags made of jute and then covered with polythene to protect from absorption of atmospheric moisture.

2.3.1.13 Yield

Seed yield is high between 2.5 to 3.0 t/ha on large scale cultivation. The L-DOPA content from the seed range between 3 to 4%. It yields high L-DOPA (4.5%) and high seed yield; the seed is devoid of stinging hairs. The crop gives reliable yields in dry farming and low soil fertility conditions that do not allow the profitable cultivation of most other food legumes (Buckles *et al.*, 1998). Velvet bean yields range from 10 to 35 t green material/ha and from 250 to 3300 kg seeds/ha depending on the cultivation conditions (Ecocrop, 2011).

2.3.1.14 Processes

Many treatments have been proposed to decrease the content in antinutritional factors of the seeds, such as boiling in water for one hour, autoclaving for 20 minutes, water-soaking for 48 h and then boiling for 30 minutes, or soaking the cracked seeds for 24 h in 4% $Ca(OH)_2$ (Pugalenthi *et al.*, 2005).

2.3.1.15 Cut forage

Velvet bean is a valuable fodder and feed legume. Vines and foliage can be used as pasture, hay or silage for ruminants while pods and seeds can be ground into a meal and fed to both ruminants and monogastrics (Eilittä *et al.*, 2003). Pods with their seeds can be

ground into a rich protein meal and can be fed to all classes of livestock though in limited amounts in monogastrics (Chikagwa-Malunga *et al.*, 2009).

2.3.1.16 Cover crop and soil improver

As a leguminous species velvet bean is reported to improve soil fertility: it provides more than 10 t DM aboveground biomass/ha, and below ground it fixes some 331 kg N/ha, equivalent to 1615 kg ammonium sulfate/ha (Cook *et al.*, 2005; Wulijarni-Soetjipto *et al.*, 1997). Velvet bean is mainly grown as a cover crop and green manure because it can establish very quickly without requiring complete soil preparation (Cook *et al.*, 2005). In intercropping systems including maize and velvet bean, the fast growing legume accumulates nutrient through N fixation and it protects the soil from heavy rains in the wet season. Once slashed into a thick mulch, the velvet bean foliage protects the soil from erosion and prevents weed germination. Velvet bean also has a positive effect on soil moisture (Buckles *et al.*, 1998).

2.3.1.17 Weed and pest control

Velvet bean has an overall beneficial effect on companion crops in intercropping systems due to its pest and disease resistance (FAO, 2011). Velvet bean is one of the most suitable crops for reclaiming land infested with weeds, notably *Cynodon dactylon*, *Cyperus* species, *Saccharum spontaneum* and *Imperata cylindrical* (Wulijarni-Soetjipto *et al.*, 1997).

2.3.2 *Centrosema pubescens*

Centrosema pubescens, common name centro or butterfly pea, is a legume in the family Fabaceae, subfamily Faboideae, and tribe Phaseolae. It is native to Central and South America and cultivated in other tropical areas as forage for livestock (Clements *et al.*, 2008).

2.3.2.1 Description

Vigorous, trailing, twining and climbing perennial herb; in pure stands forms a compact dense cover 40 to 45 cm high in four to eight months from sowing. Very leafy; the slightly hairy stems do not become woody for at least 18 months. Leaves trifoliate; leaflets dark green elliptic or ovate-elliptic, obtuse or shortly obtusely acuminate, about 4 x 3.5 cm, slightly hairy, especially on the lower surface. Stipules long, persistent (Ecocrop, 2009). Each flower has two striate bracteoles. Flowers bright or pale lilac on either side of a median greenish-yellow band with numerous dark violet stripes or blotches. Pod linear with prominent margins 7.5 to 15 cm, long, flat, thick, straight or slightly twisted, acuminate, dark brown when ripe, containing up to 20 seeds: septa between seeds. Seeds shortly oblong to squarish with rounded corners, 4 to 5 x 3 to 4 mm, brownish-black, mottled darker blotches with lighter coloured halo. It has a deep root-system with tap roots and lateral roots (FAO, 2009).

2.3.2.2 Distribution

Centro is native to Central and South America. Now widely grown in the tropics, 50 species occur naturally in South America. It is now widespread in the wet tropics from 22°S to 22°N latitude and up to an altitude of 1600 m (Teitzel *et al.*, 2010). It grows best

on fertile, humid soils. Optimal annual rainfall ranges from 1500 to 1700 mm but centro is known to tolerate 800 mm and a 3 to 4-month dry season. It withstands waterlogging and flooding and is tolerant to shade (up to 80%).

2.3.2.3 Rainfall requirements

Prefers the wet tropics with a rainfall in excess of 1 750 mm or irrigation, but grows in areas receiving 750 mm or more. It does well at Serere, Uganda, which receives 1 325 mm a year with a five-month dry period (Horrell, 1998). Wilson and Lansbury (2000) state that it requires a minimum of 1 000 mm/year of "twin peak" rainfall in Ghana and gives luxuriant growth when rainfall exceeds 1750 mm.

2.3.2.4 Drought tolerance

Deep-rooted and so is fairly drought-tolerant. Dry-season growth slow drops its leaves in a prolonged drought.

2.3.2.5 Soil requirements

Will grow on a wide range of soils, from sandy loams to clays. Will nodulate in soils with a pH as low as 4.0, but optimum pH lies between 4.9 and 5.5.

2.3.2.6 Uses

Centrosema pubescens is widely used as forage and a source of protein to grazing cattle from southern Mexico to Colombia. It is well adapted to tropical conditions and altitudes below 600 m from sea level. *Centrosema pubescens* is grown as a cover crop because it naturally suppresses weeds and is very tolerant to drought. Centro is unable to tolerate cold temperatures, but has very low soil and rainfall requirements. The leaves can also be

used as a cheap source of protein for broiler chickens. It is a good source of calcium and potassium for animals (Guayadeen, 2011).

2.3.2.7 Growing conditions

Centro is propagated by seed, planted directly into the ground or broadcast over a field typically before the rainy season. Centro grows well in soils without fertilizer since it is very adaptable to its environment. For optimal yields it is best to grow centro in wet and humid soils, but it can grow in any soil type from a sandy to clay soil depending on its location. Centro grows best in a soil pH of 4.9–5.5, but will still survive in soils with a pH as low as 4. Ability to spread naturally in a fair to good in a fertile environment.

2.3.2.8 Land preparation for establishment

Will establish quite well in roughly prepared seed beds provided fertility requirements are met. Establishes well in ashes after burning forest. Gives its best performance on a well-prepared seed bed.

2.3.2.9 Sowing methods

In small areas, centro can be established with a small "Planet Junior"-type planter; in larger areas it can be drilled or broadcast. When planting with a "Planet Junior"! It is sown in rows 1 m apart and 50 cm apart in the row (Grof, 1999).

2.3.2.9.1 Sowing depth and cover

The quite large seed can be sown to depths of 2.5 to 5 cm without affecting germination. Should be rolled or lightly covered by harrow after seeding.

2.3.2.9.2. Sowing time and rate

Sow 3.3 to 4.4 kg/ha, drilled in prior to the rainy season. For green manure it can be sown up to 8 kg/ha (Schultze *et al.*, 1990). For broadcasting, increase the seeding rate.

2.3.2.10 Seed treatment before planting

Storage under constant damp conditions depresses total viability and increases hard seed content (Wycherley, 1960). Serpa (1966) showed that germination is hindered by impermeability of the seed coat, which is genetically controlled. The following methods can be used to break dormancy: (a) scarify mechanically; (b) immerse in concentrated sulphuric acid 24 or 36N for seven minutes, then thoroughly wash with water; (c) immerse in hot water at 77°C for 15 min. (Stobbs, 1969) or in boiling water, adding 1/4 cold water, and soak seed overnight (Grundy, 2008); (d) immerse in warm glycerine at 30°C for two hours (Wycherley, 2001); (e) Osram irradiation for 16 hours or more (Wycherley, 2001); (f) warm to 50°C for up to eight hours (Wycherley, 2001).

2.3.3 *Gliricidia sepium*

2.3.3.1 Description

Gliricidia sepium (Jacq.) Kunth ex Walp. is a perennial, medium-sized (2-15 m high) legume tree. It is mostly deciduous during the dry season but is reported to remain evergreen in humid areas. Leaves are imparipinnate; leaflets (5-20) are ovate, 2-7 cm long x 1-3 cm broad. The bright pink to lilac flowers are arranged in clustered racemes. The fruits are dehiscent pods, 10-18 cm long and 2 cm broad, that contain 8 to 10 seeds.

Gliricidia sepium is one of the major tropical forage trees due to its protein-rich forage and high nutritive value. Gliricidia forage can be cut by hand and left on the ground for grazing or carried to paddocks or stalls. It is also possible to make silage from chopped forage, which may be mixed with grasses or maize. Additives, such as molasses, sugar cane or formic acid (0.85%), should be added to provide fermentable carbohydrates (Wiersum *et al.*, 1992).

2.3.3.2 Distribution

Gliricidia sepium is native to the seasonally dry Pacific coast of Central America and is now widespread throughout the tropics within 6°S and 19°N of the equator. It grows well from sea level to an altitude of 1600 m, in areas where the mean temperature ranges from 20°C to 29°C, and annual rainfall is between 900 mm and 1500 mm, with a five-month dry period. It does not withstand frost and night temperatures below 15°C. It is tolerant to waterlogging and to a wide range of poorly fertile soils (Ecocrop, 2009).

2.3.3.3 Forage management

Gliricidia sepium yields 9 to 16 t/ha of DM in fodder plots, similar to *Leucaena leucocephala*, but it is less sensitive to pests and to poor growing conditions. It can be lopped around 7 months after establishment on plants grown from cuttings and 14 months after seedling. Thereafter lopping can be done every 2 to 3 months during the rainy season and every 3 to 4 months during the dry season, provided regrowth reaches 1-2 m high before harvest (Wiersum *et al.*, 1992).

2.3.3.4 Environmental impact

Gliricidia sepium is a legume able to fix N. It produces a lot of litter and the half-life of gliricidia leaves is about 20 days. The plant is thus considered as a good soil improver. Because of its deep roots and quick growth, it is used as a windbreak. It thrives on steep slopes and may be used to reclaim denuded land. *Gliricidia sepium* is also often used as shade for perennials (coffee, tea, cocoa) or as nurse-tree since it produces light shade and reduces soil temperatures (Orwa *et al.*, 2009).

2.3.3.5 Uses

Few non-industrial tree species embody the concept of a multipurpose tree better than *G. sepium.* Throughout both its native and exotic ranges it is used to supply tree products such as fuelwood, construction poles, crop supports, green manure, fodder and bee forage. In addition, it is used in living fences, to stabilise soils and prevent erosion, to shade plantation crops, as an ornamental and in traditional medicine for eczema.

Gliricidia is an important forage crop in cut-and-carry systems in many parts of the tropics including southeast Asia, Sri Lanka and the Caribbean (Falvey, 2002, Chadhokar 1982). In other areas such as West Africa, India and the Philippines, however, its use is severely limited by apparent palatability problems (Trung, 2014). Gliricidia is also little used as forage within its native range in Central America. Its uses have been widely promoted and researched, due largely to its high productivity and quality.

2.3.3.6 Leaf biomass production

Gliricidia resprouts vigorously after lopping and will tolerate repeated cutting. Moreover, its phenology is affected by cutting, with resprouts retaining their leaves in the dry season in the tropics when older shoots are deciduous. Management by lopping thus greatly enhances the value of gliricidia as a dry season forage (Wong and Sharudin, 1999).

The optimum frequency of lopping for leaf production depends on the local climate; clearly trees can be lopped more frequently in the wet than in the dry season. In general, total annual biomass yield increases with less frequent cutting, but as this also increases the wood:leaf ratio the effect of cutting interval on leaf yield is less pronounced (Ivory, 1990). For gliricidia grown in the humid tropics and used only for forage, a cutting interval of 6-12 weeks is usually recommended. On a subtropical site in Australia, however, Gutteridge and MacArthur (1988) obtained higher leaf yields from one harvest per year than from three to six harvests.

2.3.4 *Leucaena leucocephala*

2.3.4.1 Origin

During the 1970s and early 1980s, *Leucaena leucocephala* (Lam.) de Wit (leucaena) was known as the 'miracle tree' because of its worldwide success as a long-lived and highly nutritious forage tree, and its great variety of other uses. As well as forage, leucaena can provide firewood, timber, human food, green manure, and shade and erosion control. It is estimated to cover 2-5 million ha worldwide (Brewbaker and Sorensson, 2000).

Leucaena has its origins in Central America and the Yucatan Peninsula of Mexico where its fodder value was recognised over 400 years ago by the Spanish conquistadores who carried leucaena feed and seed on their galleons to the Philippines to feed their stock (Brewbaker *et al.* 2002). From there it has spread to most countries of the tropical world where leucaena was used as a shade plant for plantation crops. It was introduced into Australia in the late 19th century and it was naturalised in parts of northern Australia (White, 1999).

2.3.4.2 Distribution

Leucaena is native to Guatemala and Mexico. It was introduced to the Philippines and South-East Asia in the 16th century, spread throughout the Asian Pacific region and reached Australia in the late 19th century. It is widespread within 30°N and 30°S and grows well in areas where annual rainfall ranges from 650 to 3000 mm and where day-temperatures are within 25°C and 30°C. It prefers neutral to mildly acid, well drained soils. Leucaena is tolerant of dryer climates (300 mm) and drought periods (up to 6-7 months (Ecoport, 2009; Cook *et al.*, 2005).

2.3.4.3 Description

Leucaena leucocephala is a member of the Fabaceae family and is considered a noxious weed in Florida (MacDonald *et al.* 2008, Wunderlin and Hansen, 2008). The lead tree is commonly found as shrub or small tree in many communities such as disturbed or cleared areas, coastal or forests communities (MacDonald *et al.*, 2008). Soil acidity (up to pH of 4.1) can be tolerated as well as full sun. It is salt tolerant as well as drought tolerant due

to its large roots. Lead tree is known to be able to grow in soils with low fertility, clays, sand, silt and limestone (Langeland *et al.*, 2008).

L. leucocephala is fast growing and has high photosynthetic rates thus allowing it to produce a large biomass which can form dense thickets quickly. It may grow up to 30 tons of dry matter per hectare per year. Additionally, surface roots invade the soil and increase competition for other plants (Langeland *et al.*, 2008). It is typically 12-16 feet tall, but can grow to 33 feet and shade native vegetation (Langeland *et al.*, 2008).

It has a deep taproot and is highly branched. Leaves are bipinnate, bearing numerous leaflets 8 mm to 16 mm long (Cook *et al.*, 2005). The inflorescence is a cream coloured globular shape producing clusters of flat brown pods, 13 to 18 mm long containing 15-30 seeds (MacDonald *et al.*, 2008). Flowering and fruiting occur throughout the year (Ecoport, 2009).

Flowers contain 10 stamens and are located on branch ends in clusters and turn from white or yellow to brown as they mature (MacDonald *et al.*, 2008, Langeland *et al.*, 2008). The actual seeds are also brown, oval, flat, glossy and only a few millimeters long (MacDonald *et al.*, 2008). Seeds are typically dispersed via birds, rodents, and cattle and often germinate after a fire, but are viable for over 10 years (MacDonald *et al.*, 2008, Langeland *et al.*, 2008). The key difference lead tree has from native Florida legumes are the flattened pods and white flower heads. Frosts and fire kill exposed vegetation, but lead tree is able to resprout after a fire (Langeland *et al.*, 2008).

2.3.4.4 Uses

Leucaena leucocephala has a wide variety of uses and it was this multiplicity of roles that led to the worldwide reputation of the species as a 'miracle tree'.

First and foremost, the leaves of leucaena are highly nutritious for ruminants and many excellent animal production data have been published confirming the fodder value of leucaena. Secondly, leucaena can be used in cropping systems. The strips serve as erosion control on steep slopes and as a form of alley cropping in which leucaena foliage is mulched into the soil to enhance yields of inter-row crops.

Leucaena poles are useful for posts, props and frames for various climbing crops (Brewbaker *et al.* 2002). The low seeding varieties are used to provide shade for cacao and coffee and support for climbers such as pepper and vanilla. Leucaena hedges are useful as windbreaks and firebreaks, the latter due to the suppression of understorey grass growth.

2.3.4.5 Temperature

Leucaena is a tropical species requiring warm temperatures (25-30°C day temperatures) for optimum growth (Brewbaker *et al.* 2002). At higher latitudes and at elevated tropical latitudes growth is reduced (Isarasenee *et al.* 2007). Heavy frosts will kill all above ground growth, although the crowns survive and will regrow vigorously in the following summer with multiple branches. Leucaena growth is strongly seasonal in the subtropics with low yields in the cool months and the majority of growth occurring in the summer months (Cooksley *et al.*.2009).

2.3.4.6 Light

Shading reduces the growth of leucaena although this plant has moderate tolerance of reduced light when compared with other tree legumes (Benjamin *et al.* 1999).

2.3.4.7 Rainfall requirements and drought tolerance

Leucaena can be found performing well in a wide range of rainfall environments from 650 to 3,000 mm. However, yields are low in dry environments and are believed to increase linearly from 800 to 1,500 mm, other factors being equal (Brewbaker *et al.* 2002).

Leucaena is very drought tolerant even during establishment. Young seedlings have survived extended periods of dry weather and soil and plant studies have confirmed that leucaena exhibits better drought characteristics than a number of other tree legumes (Swasdiphanich, 2010). Leucaena is a deep-rooted species which can extend its roots 5 m to exploit underground water (Brewbaker *et al.* 2002).

2.3.4.8 Soil type

Leucaena does best on deep, well drained, neutral to calcareous soils. However, it grows on a wide variety of soil types including mildly acid soils (pH > 5.2). It is well adapted to clay soils and requires good levels of phosphorus and calcium for best growth.

2.3.4.9 Establishment

Slow establishment is still considered to be a major limitation to the expanded use of leucaena for grazing in Australia (Lesleighter and Shelton, 2011). Slow seedling growth makes plants vulnerable to weed competition and attack by wildlife. However, leucaena seedlings are not naturally slow growing and have been shown to reach 2 m in height within 14 weeks when growing in a fertile soil well supplied with water and nutrients (Ruaysoongnern *et al.* 2008).

2.3.4.10 Seed treatment

Freshly harvested leucaena often has a high degree of hard seed due to an impermeable waxy coat which must be broken before the seed will imbibe water and germinate. Scarification to break this dormancy usually involves treatment with hot water (boiling water for 4 s) or acid (concentrated sulphuric acid for 5-10 min). Seed must be inoculated before planting with a suitable *Rhizobium* strain.

2.3.4.11 Planting

Leucaena can be planted by seed or 'bare stem' seedlings. Large areas are best planted by seed in rows into fully prepared seed beds or into cultivated strips in existing grasslands. Seeding rates of 1-2 kg/ha at depths of 2-3 cm are usually recommended in rows 3-10 m apart. Sowings are best made early in the growing season but when rainfall is reliable using good weed control measures (cultivation and herbicides) to minimise competition; leucaena seedlings are very susceptible to competition in the root zone (Brewbaker *et al.*

2002). Hand weeding or mechanical cultivation are also effective means of controlling weeds.

2.3.4.12 Forage and fodder

The legume provides an excellent source of high-protein cattle fodder. However, the fodder contains mimosine, (Allison *et al.*, 1990) and a toxic amino acid (Shelton *et al.*, 2015).

2.3.4.13 Green manure and biomass production

Leucaena leucocephala has been considered for biomass production because its reported yield of foliage corresponds to a dried mass of 2,000–20,000 kg/ha/year, and that of wood 30–40 m^3/ha/year, with up to twice those amounts in favorable climates.

It is also efficient in nitrogen fixation, at more than 500 kg/ha/year.It has a very fast growth rate: young trees reach a height of more than 20 ft in two to three years.

2.3.4.14 Potential constraints

Leucaena contains large amounts of mimosine (up to 12% DM in young shoots), a toxic amino acid that is detrimental to non-ruminants (horses, donkeys, pigs and poultry). In ruminants, mimosine is broken down in the rumen to DHP (3,4 and 2,3 dihydroxy-piridine), a goitrogen that is detoxified by rumen bacteria (Hammond, 1995). However, mimosine causes Leucaena to be toxic to cattle if fed in large amounts (more than 30% of the diet) over long periods (Gutteridge *et al.*, 2010). It induces low feed intake, and reduces live-weight gain and reproductive performance. Toxicity symptoms are alopecia,

excessive salivation and enlarged thyroid glands. Mimosine content can also be reduced by soaking in water and drying.

2.3.4.15 Pests and Diseases

Until relatively recently, there were few pests of leucaena because of the insecticidal properties of mimosine (Bray and Woodroffe, 2012). The psyllids or jumping lice are small aphid-like insects adapted to feeding on the young growing shoots of leucaena. Mild infestations cause distortion of leaves whilst heavy infestationsresult in loss of leaves and attack by secondary moulds which feed on the sticky exudate of psyllids (Anon, 2005). A serious disease of seedling leucaena in nurseries is damping-off in moist soils caused by the fungal species *Pythium* or *Rhizoctonia* spp. (Brewbaker *et al.* 2002). This is controlled by good nursery techniques (overwatering promotes the disease) and use of well-drained soil media.

2.4 Legume Growth Rate

Legume models can aid the synthesis and application of knowledge, planning of experiments and forecasting in agricultural systems. Few studies have reviewed the uses and applications of these models for tropical forages. Several empirical models have been developed to predict the growth and biomass accumulation of tropical forages, especially for the faba bean and velvet bean.

Legume models are used to integrate multidisciplinary knowledge, based on processes regarding soil physics and chemistry, plant physiology and genetics, weather and farming management. The effects of these processes can be coded as simple written verbal

description or may be a comprehensive set of equations used in the simulation of a given system (Sinclair and Seligman, 1996) which is used to predict growth, development and yield (Hoogenboom, 2000), even for large scale applications.

Legume modelling has been an effective tool in simulating plant growth, and since the 1980s there have been significant advances, mainly due to the increased demand for accurate predictions in crop management scenarios, as well as in studies on climate change and as a result of advancements in information technology (Jones, 2014).

Model users have followed this progress, which is best expressed by the increase in the number and complexity of models available and on the extension of their applicability (Holzworth *et al.*, 2014).

The objective of this review was to report the main aspects regarding the use of models to predict tropical legume growth and biomass accumulation (often expressed as net accumulation of above-ground dry matter, DM), including a brief historical perspective, major advances achieved, types of models created and adapted, and their applications and limitations (Hoogenboom, 2000).

2.4.1 Classification of models

Wu, Liu, John Baddeley and Christine Watson establish a Models of biological nitrogen fixation of legumes in 2011.

Simulation of growth and development of diverse legume species in APSIM by MJ Robertson, PS Carberry, NI Huth, JE Turpin in 2002.

Use of the Expolinear Growth Model to Analyse the Growth of Faba bean, Peas and Lentils at Three Densities: Predictive Use of the Model by M. D. Dennett and K. H. M. Ishag in 1998.

The EPIC and APSIM models use variations of the first definition to estimate potential N fixation rate. The EPIC model assumes that the total plant N demand is equal to the potential N fixation (Bouniols *et al.*, 1991; Cabelguenne *et al.*, 1999). APSIM defines critical N concentrations for plant tissues and uses these to estimate N demand by maintaining non-stressed N levels in plant tissues and supporting the N demand of new tissues. This N demand is met by either N uptake from soil and/or N fixation (Macduff *et al.*, 1996). The second definition is based on the strong relationship between N fixation and either nodule size/biomass (Weisz *et al.*, 1985; Voisin *et al.*, 2003) or root biomass (Voisin *et al.*, 2007). As the biomass of both nodules and roots are difficult to measure in the field, some studies have used above-groundbiomass to replace nodule/root biomass, based on the relationship between these two variables (Denison *et al.*, 1985; Bell *et al.*, 1994; Yu *et al.*, 2002).

Adaptation of the CROPGRO growth model to velvet bean (Mucuna pruriens)

CROPGRO is a mechanistic, process –oriented model for grain legumes that includes crop development, C balance, crop and soil N balance, and soil water balance subroutines (Boote *et al.*, 1998). Crop development includes processes such as vegetative and reproductive development, which determine life cycle duration, duration of root and leaf growth, onset and duration of reproductive organs such as pods and seeds, and thereby influence dry matter partitioning to plant organs over time. The crop N balance includes

daily soil N uptake, N_2 fixation, mobilization from vegetative tissues, rate of N use for new tissue growth, and rate of N loss in abscised parts.

For each given species, the CROPGRO species file contains knowledge about base temperatures (Tb) and optimum temperatures (Topt) for developmental processes rate of emergence, rate of leaf appearance, and rate of progress toward flowering and maturity and growth processes (photosynthesis, nodule growth, N_2 fixation, leaf expansion, pod addition, seed growth, and N mobilization, etc.) (Scholberg *et al.*, 1997; Boote *et al.*, 1998).

ALAMEDA, a Structural-Functional Model for Faba Bean Crops

ALAMEDA is a functional-structural model of a faba bean (V. faba L.) crop that addresses these issues. An L-system provides the basic conceptual and program structure within which functional relationships can be connected. In this way, it plays a comparable role to physical plant structure that provides the linkage between morphology and physiological processes spatially distributed over plant components (Manschadi *et al.*, 1998).

2.5 Biomass yield of forage legumes

Species growth habits can influence the biomass contribution in a system despite the soil being fertile (Ayisi *et al.* 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site Location and Description

The experiment was conducted at the screen-house of the Faculty of Agriculture, Federal University, Oye-Ekiti, Ikole campus with Latitude - N 07° 48.308, Longitude - E 005° 29.573 and 548.4m above ground level (Garmin 72H, GPS Model). The locality is in the semi-arid tropical region with an annual rainfall of 1778mm.

The research work was conducted during one of the recognized seasons of the year: May (rainy season).

3.2 Soil Description

The soil used in the study was an upland loam soil. Soil samples to 10 cm, taken inMay 2017, showed that the soil was basic (pH 5.60; water method), and high in organic matter (39.83%), N (2.36%), P (117.09 ppm; Bray I extraction method), Zn (72.63 ppm), and Cu (17.35 ppm).

3.3 Layout and Treatments

The planting was done using completely randomized design (CRD) in 4-rows with 4 replicates of 8 pots of each legume species and a spacing of 1m long apart was applied between each bed.

3.4 Source of seeds

Improved legumes (*Mucuna pruriens, Centrosema pubescens, Gliricidia sepium and Leucaena leucocephala*) were planted by seed, which were obtained from National Animal Production Reséarch Institute (NAPRI), Shika - Zaria.

3.5 Viability test and Planting

For a period of 1 week, viability test was conducted on the legume samples seeds inthe laboratory to be sure if there won't be a problem of dormancy on the field withthe test yielding 80% pass rate.

Each Bag used in planting contained 27kg of soil with each bag labelled with M, C, G and L respectively; the soil was taken from the Oil-Palm plantation of the University. Sowing was done by hand drilling the *Mucuna pruriens* seeds on thelabelled Bag, the *Centrosema pubescens*seeds were planted by broadcasting theseeds on each labelled bag, the *Leucaena leucocephala* seeds were planted by hand drilling the seeds on each labeled bag, the *Glyricidia sepium* was also planted by hand-drilling the seeds at 1.5m apart at differentspots on each labelled bag. Planting was done on 22/05/17. On the bags containing eachlegume seeds, manual hand-picking of weeds was done.

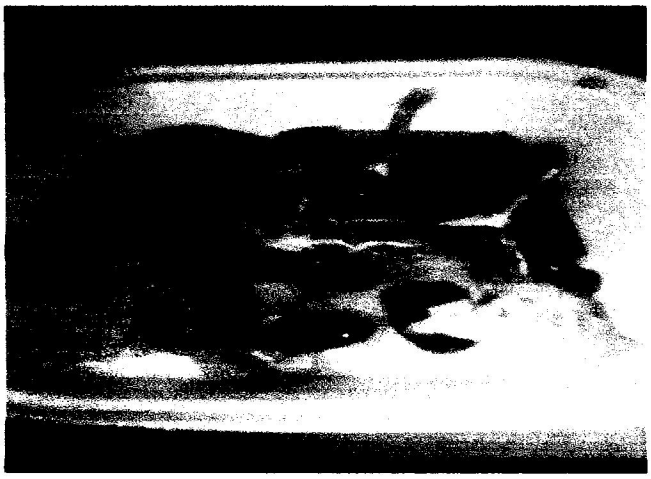

Plate 1: Viability test result for *Mucuna pruriens*

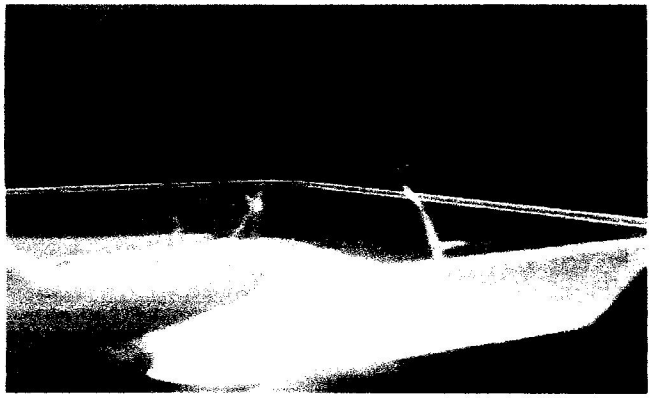

Plate 2: Viability test result for *Centrosema pubescens*

Plate 3: Viability test result for *Gliricidia sepium*

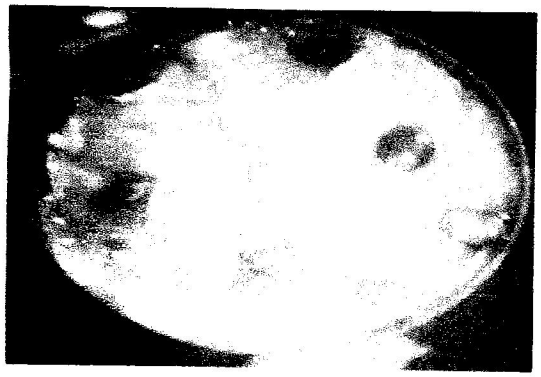

Plate 4: Viability test result for *Leucaena leucocephala*

a b

Plate (5a,b): Arrangement of bags in the screen-house

a b

Plate 6 (a,b): Growing Mucuna (*Mucuna pruriens*)

Plate 7: Growing Centrosema (*Centrosema pubescens*)

Plate 8: Growing Gliricidia (*Gliricidia sepium*)

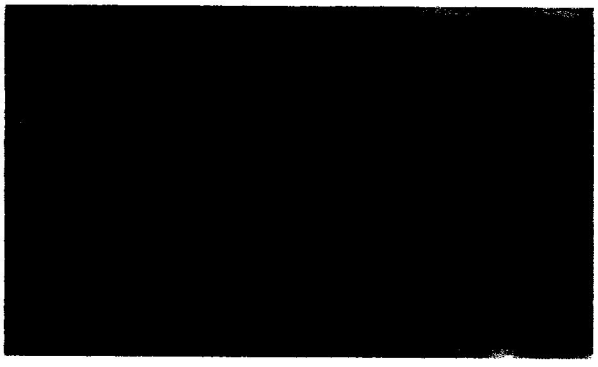

Plate 9: Growing Leucaena (*Leucaena leucocephala*)

3.6 Data collection

3.6.1 Measurements of forage legume characteristics

The growth rate (cm/day) of the legumes was monitored early in the growing season with plant heights (cm), the growth characteristics of the legume were recorded four (4) times in the growing season, i.e. from June 2017 to July 2017, where all plants in a plot were measured. For forage species that grow erect, the highest point was recorded while for prostrate forage species the longest runner was measured. Vegetative materials (leaves, twigs and stems) were collected at bi-weekly intervals during the growing season and were air-dried in a laboratory to 92 – 94 % dry matter for two weeks at room temperature before the dry weight was measured to determine the biomass accumulation (tons/ha).

Biomass yield or biomass accumulation was determined by cutting one randomly selected plant with a pruning shear from each plot at 30 cm height. The fresh weights were recorded and then air-dried at room temperature in a laboratory for two (2) weeks until completely dry (92-94 % DM) and the biomass yield (tons dry weight per hectare) was determined for each plot.

Four cuttings (5th of June, 19th of June, 3rd of July and 17th of July) on each legume species were made in 2017.

3.6.2 Plant Height

Every two weeks, each legume specie height in each treatment was measured using a long meter rule and a tape rule and the values obtained were recorded.

3.6.3 Number of Branches

Every two weeks, the number of branches of each legume specie in each treatment was counted and recorded.

3.6.4 Leaf Length

Every two weeks, each legume specie's leaf length was measured using a metre rule and the values obtained were recorded.

3.6.5 Leaf Width

Every two weeks, each legume specie's leaf width was measured using a metre rule and the values obtained were recorded.

3.7 Chemical Analysis (Soil Attributes before planting)

The soil used in planting was analyzed in the laboratory for the soil pH both in water (H_2O) and it was also analysed for its Organic matter, Organic Carbon, Copper, Calcium, Magnesium, and Phosphorus.

3.7.1 Soil pH in water (1:1 Soil to water ratio)

3.7.1.2 **Apparatus:** Glass-electrode pH meter

3.7.1.3 **Reagents:** Distilled water

3.7.1.4 Procedures

i. 20g of air-dry soil was weighed (passed 2-mm sieve) into a 50 –ml beaker. Add 20ml of distilled water and allow to stand for 30 minutes and stir occasionally with a glass rod.

ii. Insert the electrodes of the pH meter into the partly seetled suspension and measure the pH. The suspension was not stir during measurement. The result was reported as "soil pH in water".

3.7.2 Soil Organic Carbon (using Walkley-Black Method)

3.7.2.1 Apparatus used: Burette, 50ml or 25ml.

3.7.2.2 Reagents

- Potassium dichromate ($K_2Cr_2O_7$) 1N – dissolve 49.04g of $K_2Cr_2O_7$ in distilled water and dilute to 1 litre.
- H_2SO_4 conc.
- O-phosphoric acid (H_3PO_4) conc.
- O-phenanthroline-ferrous complex 0.025 M(Ferroin).
- Barium diphenylamine sulfonate (0.16%) Optional.
- Ferrous sulfate (0.5N) – dissolve 140g of $FeSO_27H_20$ in water; add 15ml conc. H_2SO_4 cool and dilute to 1 liter. Standardize of reagent was carried out each time before using for organic carbon determination by titrating against 10ml 1 N $K_2Cr_2O_7$.

3.7.2.3 Procedure

i. A representative sample was taken and grinds to pass through 0.5mm sieve.

ii. Weigh out the soil samples in duplicate and transfer to 250ml Erlenmeyer flask.

iii. Pipette 10ml of 1N $K_2Cr_2O_7$ solution accurately into each flask and swirl gently disperse the soil.

iv. Add rapidly 20ml conc. H_2SO_4 using an automatic pipette, directing the stream into the suspension. Immediately swirl the flask gently until soil and reagents are mixed, then swirl more vigorously for one minute. Rotate beaker again and allow the flask to stand on a sheet of asbestos for about 30 minutes.

v. Add 100ml of distilled water after standing for 30 minutes.

vi. Add 3-4 drops of indicator and titrate with 0.5N ferrous sulfate solution. As this end point is approached, the solution takes on a greenish cast and then changes to dark green. At this point, add the ferrous sulfate drop by drop until the colour changes sharply from blue to red (maroon colour) in reflected light against a white background.

vii. Make the blank titration in the same manner, but without soil (steps 3,4,5 and 6), to standardize the dichromate.

viii. Then I Calculate the result according to the following formula:

a. % Organic Carbon in soil (air-dry basis) =

$$\frac{(me\ K_2Cr_2O_7 - me\ FeSO_4) \times 0.003 \times 100 \times (f)}{g\ of\ air\text{-}dry\ soil}$$

b. Correction factor, f = 1.33

c. me = Normality of solution x ml of solution used

d. % Organic matter in soil = % Organic Carbon x 1.729.

ix. % Organic Carbon may also be expressed on oven-dry basis after correction for moisture content in air-dry soil.

3.7.3 Determining Soil Exchangeable Ca, Mg, K, Na, Mn

The soil's Ca, Mg and Mn were determined using the Atomic Absorption Spectrophotometer (Perkin-Elmer Spectrophotometer, Model 460) while the K, and Na contents of the soil were determined using a flame photometer (Sherwood, Model 360).

3.7.3.1 Apparatus

- Centrifuge
- 100-ml volumetric flask
- Flame photometer
- Atomic absorption spectrophotometer

3.7.3.2 Reagents

- Acetic acid, glacial abd NH_4OH, conc.
- Ammonium acetate solution, 1N pH 7.0 – add 58ml of glacial acetic acid to about 600ml of distilled water in a 2-liter beaker.

3.7.3.3 Procedure

i. To 5g of sample, add 30ml of 1 N NH_4OAC and shake on a mechanical shaker for 2 hours.

ii. Centrifuge (2,000 rpm for 5 – 10 min). Carefully decant the clear supernatant into a 100 ml volumetric flask.

iii. Add another 30ml of NH_4OAC solution and shake for 30minutes. Centrifuge and transfer the supernatant into the same volumetric flask.

iv. Repeat step 3 and transfer the supernatant into the same volumetric flask.

v. Make up to mark with the NH_4OAC solution.

vi. Determine K, and Na on a flame photometer. Determine Mg, Ca and Mn on an atomic absorption spectrometer.

vii. Effective CEC is thus calculated by the sum of exchangeable bases (Ca, Mg, K, Na) and exchangeable Al and H expressed in meq/100g.

3.7.4 Determination of "Available" P in soils (Olsen's Test)

3.7.4.1 Apparatus

- Bausch & Lomb Spectronic – 70 Electrophotocolorimeter
- Mechanical shaker
- 25 –ml volumetric flask or 35-ml Pyrex test tubes marked for 25 ml.

3.7.4.2 Reagents

- Olsen's extracting solution
  - ✓ Sodium bicarbonate ($NaHCO_3$) solution, 0.5 M
  - ✓ Carbon black. Use carbon black G

3.7.4.3 Procedure

i. Add 2g of soil, 1 teaspoon of carbon black and 40 ml of the extracting solution to a 125 –ml Erlenmeyer flask. Shake the flask for 30 minutes on a mechanical shaker.

ii. Filter the suspension through the Whatman No. 40 paper. Add more carbon black if necessary to obtain a clear filtrate. Shake the flask immediately before pouring the suspension into the funnel. Store the solution for P determination using the colorimetric method as given in a separate section (Ascorbic acid method).

3.7.5 Determining Soil Total Nitrogen

3.7.5.1 Apparatus used

- Complete Tecator Digestor System (unit of 20 tubes).
- Top loading weighing balance.
- Acid dispenser.
- Technicon's Autoanalyzer (AAII).

3.7.5.2 Procedure followed

Soil digestion

i. About 2.00g of air dried soil was passed through 0.5mm sieve into a 250ml digestion tube, after 20.0ml digestion mixture and one Kjeldahl tablet was added to the tube.

ii. The racks were placed in the Tecator Digestor system and later digested at 370°C for about 3 hours. The rack was removed from the digestor and allowed to cool

for 10minutes; then about 100ml of distilled water was added and the tube's contents mixed vigorously.

iii. The tube was allowed to cool and diluted at about 250ml with distilled water. The tube was shaked end-to-end 10 times and when it was clear enough, the liquid was poured into the autoanalyzer sampler cups for Total Nitrogen analysis.

Calculation

$$\% \text{ Total Nitrogen in soil} = \frac{\% \text{ chart reading} \times 0.5 \times 250 \times 100}{2 \times 10^6}$$

3.7.6 Effective CEC and Exchangeable Cations (Ca, Mg, K, Na, Al, H) (Ag-Thiourea Extraction)

3.7.6.1 Apparatus used

- Polyethylene centrifuge tubes 45 ml
- Centrifuge.
- Mechanical shaker, reciprocal
- Atomic absorption spectrophotometer
- Flame photometer
- Burettes 10 or 25 ml
- Magnetic stirrer

3.7.6.2 Reagents

The silver-thiourea (Ag TU) reagent is prepared by first dissolving 30g of anhydrous thiourea in about 500 mlof distillled water in a 2-liter volumetric flask and adding slowly 1 liter of a 0.02M $AgNO_3$ solution (stored in brown bottle) under vigorous stirring. The resulting mixture is then diluted to 2 liters with

deionized water giving a final concentration of 0.01M Ag NO_3 and about 0.2M thiourea. The unbuffered reagent gives a pH value around 5.5. the reagent is stored in a brown bottle.

3.7.6.3 Procedure:

i. Weigh out from 1 to 5g of soil sample, add 30 ml of the silver-thiourea reagent in a centrifuge tube. Shake the content on a reciprocal mechanical shaker for 2 hours.

ii. Centrifuge (2000 rpm or a higher speed for 5-10 minutes.) carefully decant the clear supernatant into a glass vial or a conical flask.

iii. Determine K and Na on a flame photometer. Determine Mg and Ca on an atomic absorption spectrophotometer.

iv. Titrate H and Al in the extract as follows - pipette10 ml of the silver-thiourea extract into a 50-ml conical flask. Add 3 drops of phenolphthalein indicator and titrate the solution with 0.01N NaOH standardized to a permanent pink end-point while stirring the solution with a magnetic stirrer. The amount of base used is equivalent to the total amount of acidity (H + Al) in the volume of aliquot taken.

v. The CEC is calculated by the sum of exchangeable "bases'' (Ca, Mg, K, Na) and exchangeable Al and H expressed in meq/100g soil.

vi. Exchangeable Al in the Ag-thiourea extract can be determined by the aluminium method. The milliequivalents of exchangeable H are obtained by subtracting exchangeable Al from the milliequivalent of the total exchange acidity.

3.8 Determination of the nutritional values of forage legumes

3.8.1 Legume specie attributes

3.8.2 Crude Fibre Content

Crude fibre was determined using the Filter Bag Technology (ANKOM, 2000). This method determines Crude Fibre which is the organic residue remaining after digesting with 0.255N H_2SO_4 and 0.313N NaOH. The compounds removed are predominantly protein, sugar, starch, lipids and portions of both the structural carbohydrates and lignin.

3.8.2.1 Apparatus

- Analytical Balance - capable of weighing 0.1 mg.
- Oven - capable of maintaining a temperature of 102 ± 2°C.
- Electric muffle furnace - with rheostat control and pyrometer that will maintain atemperatureof 600 ± 15°C.
- Digestion instrument - capable of performing the digestion at 100 ± 0.5°C and maintaining a pressure of 10-25psi.
- Filter Bags - constructed from chemically inert and heat resistant filter media, capable of being heat sealed closed and able to retain 25 micron particles whilepermitting solution penetration.
- Heat sealer - sufficient for sealing the filter bags closed to ensure completeclosure (1915, ANKOM Technology).
- Desiccant Pouch - collapsible sealable pouch with desiccant inside that enablesthe removal of air from around the filter bags.
- Marking pen - solvent and acid resistant (F08, ANKOM Technology).

3.8.2.2 Sample Preparation

Samples were grounded in a centrifugal mill with a 2mm screen or cutter type (Wiley) mill with a 1mm screen. Samples ground finer (fibre particles less than 25 microns) may have particle loss through the filter bags that result in lower fibre values (up to 0.5% units).

3.8.2.3 Procedure followed

i. A solvent resistant marker was used to label the filter bags; after they were weighed and the weight of each empty filter bag was recorded (W1).

ii. About 1g of the prepared sample was placed in up to 23 of the bags and the weights were recorded (W2), in running this experiment, one empty bag was placed in the ANKOM machine for the blank bag correction to be determined (C1).

iii. A heat sealer was used to completely seal each filter bag closed within 4mm of the top to encapsulate the sample.

iv. After, fat was extracted from the samples by placing all bags into a 250ml container, then enough petroleum ether was added to cover the bags and the bags were allowed to soak for 10 minutes.

v. After, three bags were placed on each eight bag suspender trays (making it a total of 24 bags); the bags were stacked on the trays with each levelrotated 120 degrees.

Calculation

$$\%\text{Crude Fibre} = \frac{100 \times (W3 - (W1 \times C1))}{W2}$$

Where: W1 = Bag tare weight

W2 = Sample weight

W3 = Weight of Organic Matter (loss of weight on ignition of bag and fibre)

C1 = Ash corrected blank bag factor (running average of loss of weight on ignition of blank bag/original blank bag)

3.8.3 Crude Protein Content

The protein content is determined from the organic Nitrogen content by Kjeldahl method. The various nitrogenous compounds are converted into ammonium sulphate by boiling with concentrated sulphuric acid. The ammonium sulphate formed is decomposed with an alkali (NaOH) and the ammonia liberated is absorbed in excess of standard solution of acid and then back titrated with standard alkali.

3.8.3.1 Apparatus used

- Kjeldahl digestion flask - 500ml.
- Kjeldahl distillation apparatus.
- Conical flask, 250 ml.
- Burette 50 ml.

3.8.3.2 Procedure followed

i. About 1-2g of the sample was weighed and transfeered to a 500ml Kjedahl flask taking care to see that no portion of the sample (s) clings to the neck of the flask.

ii. Then, 0.7gm. of Mercuric oxide, 15gm. Of Potassium sulphate and 40ml of concentrated sulphuric acid were added (Mercuric oxide is added to increase the

rate of organic breakdown during acid digestion.); then, 2-3 glass beads were added with the flask placed in an inclined position on the stand in the digestion chamber for digestion.

iii. The flask was heated gently at low flame until initial frothing ceases and the mixture boiled steadily at a moderate rate, heating was continued for about onehour until the colour of digest changes pale blue, then the digest is cool and about 200ml of water was added.

iv. The flask was connected to a distillation apparatus incorporating an efficient flash head and condenser. The contents of the digestion flask were mixed thoroughly and boiled until 150ml have been distilled into the receiver; 5 drops of methyl red indicator was added and it was titrated with 0.1N NaOH solution and a blank titration was carried out simultaneously.

1 ml of 0 .1 N H_2SO_4 = 0.0014gm N.

Calculation

Calculate protein as = N x 6.25

$$\text{Protein on dry wt. basis} = \frac{\text{Protein content}}{(100 - \text{Moisture content})} \times 100$$

3.8.4 Moisture Content

The moisture content of the grasses was obtained using the oven drying method

3.8.4.1 Apparatus used

i. **Weighing** balance.

ii. **Desiccator.**

iii. **Oven: electric** maintained at 105 ± 10°C

iv. Moisture dishes –Porcelain, silica, glass or Aluminum (7.5 x 2.5 cm)

3.8.4.2 Procedure followed

The empty dish was dried and left in the oven for 3 hours at 105°C and later transferred to a desiccator to cool with the empty dish being weighed (W1). After about 3g of the samples were weighed and placed in the empty dish, the now filled dish was placed in an oven for 3 hours at 105°C. After, the dish was allowed to coolin desiccator with the dish now reweighed (W2).

Calculation

$$\text{Moisture (\%)} = \frac{W1 - W2}{W1} \times 100$$

Where: W1 = weight (g) of sample before drying

W2 = weight (g) of sample after drying

3.8.5 Crude Ash determination

The ash content of the sample (s) was determined using a muffle furnace

3.8.5.1 Apparatus used

- Muffle furnace, equipped with a thermostat, set to 575±25°C.
- Analytical balance, accurate to 0.1 mg.
- Desiccator containing desiccant.
- Ashing crucibles, 50 mL, porcelain, silica, or platinum.
- Porcelain markers, high temperature, or equivalent crucible marking method.
- Ashing burner, ignition source, tongs, and clay triangle with stand.
- Convection drying oven, with temperature control of 105 ± 3°C.

3.8.5.2 Procedure followed

i. Using a porcelain marker, some crucibles were marked, identified and placed in a muffle furnace set at 575 ± 25°C for a minimum of four hours, after the crucibles were removed from the furnace directly into a desiccator with the crucibles weighed to the nearest 0.1mg and this was recorded.

ii. About 2g of the sample was weighed into a crucible with the weight recorded; the samples were then ashed using a muffle furnace set to 575 ± 25°C; using an ashing burner and clay triangle with stand, the crucible was placed over the flame until the smoke disappeared.

iii. Immediately, the crucible was ignited with the samples allowed to burn until no more flame or smoke appeared.

iv. The crucibles were placed in the muffle furnace at 575 ± 25°C for 24 hours; later, the crucibles were removed from the furnace into a desiccator and cooled for 30 minutes, the crucibles were weighed to the nearest 0.1mg.

Calculation

$$\text{ODW} = \frac{\text{weight air dry sample} \times \%\text{Total solids}}{100}$$

$$\%\text{Ash} = \frac{\text{Weight crucible plus ash} - \text{Weight crucible}}{\text{ODW sample}} \times 100$$

Where: ODW = oven dry weight

3.8.6 Crude Fat Determination

The Soxhlet method for determining crude fat content is a lengthy process requiring up to a day for a single analysis. The solvent extraction step alone takes six hours.

3.8.6.1 Procedure followed

i. Crude fat content is determined by extracting the fat from the sample using a solvent, then determining the weight of the fat recovered.

ii. The sample is contained in a porous thimble that allows the solvent to completely cover the sample.

iii. The thimble iscontained in an extraction apparatus that enables the solvent to be recycled over and over again.

iv. This extends the contact time between the solvent and the sample and allows it time to dissolve all of the fat contained in the sample.

v. In order for the solvent to thoroughly penetrate the sample is finely comminuted as possible.

vi. The sample is dried before the solvent extraction step can begin.

vii. The sample was being weighed carefully to avoid loss of moisture by weighing the sample directly into a pre-dried extraction thimble.

viii. For moisture analysis, the dried extraction thimble was preweighed.

ix. After weighing, the sample (in the thimble) was placed in the oven for drying. After drying, the sample was placed directly into the distillation apparatus for extraction.

Calculation

Weight of empty flask (g) = W1

Weight of flask and extracted fat (g) = W2

Weight of sample = S

$$\% \text{ Crude fat} = \frac{(W2 - W1)}{S} \times 100$$

3.8.7 Nitrogen Free Extract Determination

Nitrogen-free extract (NFE) was calculated from NFE (g kg-1 DM) = 1000 – (Moisture content + CP content + CF content + crude fat content + crude ash content).

3.9 Statistical Analysis

3.9.1 Linear Additive Model

$Y_{ijk} = \mu + G_i + C_j + E_{ijk}$

Where;

Y_{ij} = Individual cuttings (effects of j^{th} cutting on the i^{th} legume)

μ = General mean

G_i= Effect of the legume species planted (Growth rate)

C_j= Effect of cuttings (Bi-weekly cuttings)

E_{ijk} = Experimental error

3.9.2 Data Analysis

The data were analyzed using the PROC GLM of SAS (SAS Institute Inc., 2008) with cut time, legume specie. Tukey's Honestly Significant Difference at 5% probability level was used to separate the differences between treatment means.

3.9.3 Model Functions

3.9.3.1 Model Functions for Biomass Accumulation

The equations for biomass accumulation will be derived from the below parameters:

- **CT = PH + NB + LL + LW + α**

Where,

Cutting Time – (CT) is independent

Plant Height – (PH)

Number of Branches – (NB)

Leaf Length – (LL)

Leaf Width – (LW)

} dependent

α is constant and intercept of the model

For Lsp 1,

CT = 2.726 + 0.054PH + 0.524NB + 0.059LL + 0.278LW

Error estimate (ε_t) = 0.377

For Lsp 2,

CT = 0.056 + 0.092PH + 0.096NB + 0.233LL - 0.729LW

Error estimate (ε_t) = 0.242

For Lsp 3,

CT = -0.975 + 0.235PH + 0.411NB + 0.266LL + 0.002LW

Error estimate (ε_t) = 0.627

For Lsp 4,

CT = -0.078 + 0.140PH + 0.481NB + 1.751LL - 3.065LW

Error estimate (ε_t) = 0.627

Note: The positive signs (+) denotes that with an increase in the cutting time, there would be an increase in the biomass accumulation and vice-versa. The negative signs (-) denotes that with an increase in the cutting time, there would be a decrease in the biomass accumulation and vice-versa.

- **$Et = CT + \varepsilon_t$**

Where,

Error estimate – (Et)

Cutting Time – (CT)

Error due to chance (uncontrollable) – ε_t

- **BMA (%) = OMs (%) + Lsp + Et (%)**

Where,

Biomass Accumulation – (BMA)

Organic Matter in the soil – (OMs)

Legume specie – (Lsp)

Mucuna pruriens – (Lsp 1)

Centrosema pubescens – (Lsp 2)

Gliricidia sepium – (Lsp 3)

Leucaena leucocephala – (Lsp 4)

Error estimate – (Et)

3.9.3.2 Model Functions for Legume Growth Rate

Legume growth rate is expressed as Lgr

Viability of species seeds is expressed in terms of percentage as %Spg

Management practices is expressed in percentage as %Mp

Unforeseen interference exigencies is expressed in terms of percentage as Ufe

For successive days:

$$\%L_{gr} = BM_{si} + \%S_{pgi} + BM_{gi} + \%M_{pi} + U_{fei} \text{ ----- (5)}$$

Where,

$$BM_{gi} = L_{gri} - BM_{si} - \%S_{pgi} - \%M_{pi} - U_{fei} \text{ ----- (6)}$$

Equating (4) and (6),

$$\sum_{i=0}^{n}[L_{gri} - BM_{si} - \%S_{pgi} - \%M_{pi} - U_{fei}] = \sum_{i=0}^{n}[BM_{si} + F_i - N_{gi} \pm E_t] \text{ ----- (7)}$$

Where,

$$\%L_{gri} - BM_{si} - \%S_{pgi} - \%M_{pi} - U_{fei} - BM_{si} - F_i - N_{gi} \pm E_t = 0 \text{ ---------- (8)}$$

Where,

$$\%L_{gri} - 2BM_{si} - \%S_{pgi} - \%M_{pi} - U_{fei} - BM_{si} - F_i - N_{gi} \pm E_t = 0 \text{ ----- (9)}$$

Where,

$$- 2(\%BM_{si}) = \%S_{pgi} + \%M_{pi} + U_{fei} + F_i + N_{gi} \pm E_t - \%L_{gri} \text{ ----- (10)}$$

Where,

$$\%BM_{si} = [\%L_{gri} - [\%S_{pgi} + \%M_{pi} + U_{fei} + F_i + N_{gi} \pm E_t]] \text{ ----- (11)}$$

Where growth rate is,

$$\%L_{gri} = 2BM_{si}\% - \%S_{pgi} + \%M_{pi} + U_{fei} + F_i - N_{gi} \pm E_t \text{ ------ (12)}$$

Note:

If there are no unforeseen exigencies, Ufei = 0 and if there are no error recorded, Et =0.

In the case of unforeseen exigencies that affects ¼ of the whole legume specie,

Ufei = ¼ and so on…

The legume growth model will be expressed in percentage.

CHAPTER FOUR

RESULTS

4.0 Soil Physico-chemical Properties

4.1 Soil before planting

Table 1. Soil Physical properties

Physical Properties	Concentration (%)
Sand	89
Silt	4
Clay	7
Total Organic Carbon	18.90
Total Organic Matter	39.83

Table 2. Soil Chemical properties

Chemical Properties	Concentration
Nitrogen (%)	2.36
Phosphorus (%)	117.09
potassium (%)	0.30
Calcium (cmol/kg)	2.12
Magnesium (cmol/kg)	0.81
Sodium (cmol/kg)	0.08
ECEC (cmol/kg)	3.34
pH	5.60

ECEC= Exchaneable cation exchange capacity

Table 3. Soil metallic properties

Metals	Concentration (PPM)
Iron	86.83
Manganese	139.45
Zinc	72.63
Copper	17.35
Chlorine	0.10

4.2 Soil after Harvest

Table 4. Soil Physical properties

Physical properties	Concentration (%)
Sand	76
Silt	9
Clay	15
Total Organic Carbon	33.17
Total Organic Matter	57.72

Table 5. Soil Chemical properties

Chemical properties	Concentration
Nitrogen (%)	8.42
Phosphorus (%)	314.59
Potassium (%)	0.94
Calcium (cmol/kg)	5.26
Magnesium (cmol/kg)	1.91
Sodium (cmol/kg)	0.20
ECEC (cmol/kg)	8.39
pH	6.40

ECEC= Exchaneable cation exchange capacity

Table 6. Soil Metallic properties

Metals	Concentration (PPM)
Fe	225.84
Mn	204.27
Zn	122.16
Cu	42.94
Cl	0.17

4.3 Growth Attributes

Table 7. Growth rate of *Mucuna pruriens, Centrosema pubescens, Gliricidia sepium* and *Leucaena leucocephala*

meters	Plant height (cm)				Number of Branches				Leaf Length (cm)				Leaf Width (cm)			
ng Times (weeks)	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
una pruriens	55.25^{a}	115.50^{a}	158.75^{a}	204.75^{a}	3.50^{a}	6.50^{a}	7.25^{b}	8.50^{b}	9.93^{a}	12.45^{a}	13.73^{a}	14.18^{a}	8.88^{a}	8.13^{a}	7.85^{a}	8.43^{a}
rosema pubescens	10.38^{b}	20.00^{b}	30.38^{b}	51.73^{b}	2.75^{b}	4.50^{b}	9.50^{a}	13.00^{a}	5.23^{b}	12.13^{a}	13.83^{a}	14.45^{a}	0.63^{c}	1.58^{c}	1.45^{c}	1.98^{c}
cidia sepium	5.25^{c}	8.58^{b}	11.93^{c}	18.25^{c}	2.50^{b}	5.00^{b}	6.00^{c}	7.75^{b}	2.83^{c}	4.93^{b}	4.85^{b}	5.45^{b}	2.00^{b}	3.78^{b}	3.63^{b}	4.23^{b}
aena leucocephala	4.45^{c}	8.53^{b}	12.30^{c}	23.83^{c}	2.25^{b}	3.50^{c}	5.25^{c}	8.25^{b}	0.85^{d}	1.25^{c}	1.08^{c}	1.40^{c}	0.21^{c}	0.35^{d}	0.23^{d}	0.45^{d}
SEM	0.49	2.35	1.76	0.96	0.13	0.22	0.29	0.18	0.16	0.22	0.12	0.14	0.1	0.06	0.15	0.13

Means on the same column with different superscript (a, b, c, d) differ significantly ($p < 0.05$). SEM (Standard Error of Mean)

4.3.1 Plant Height

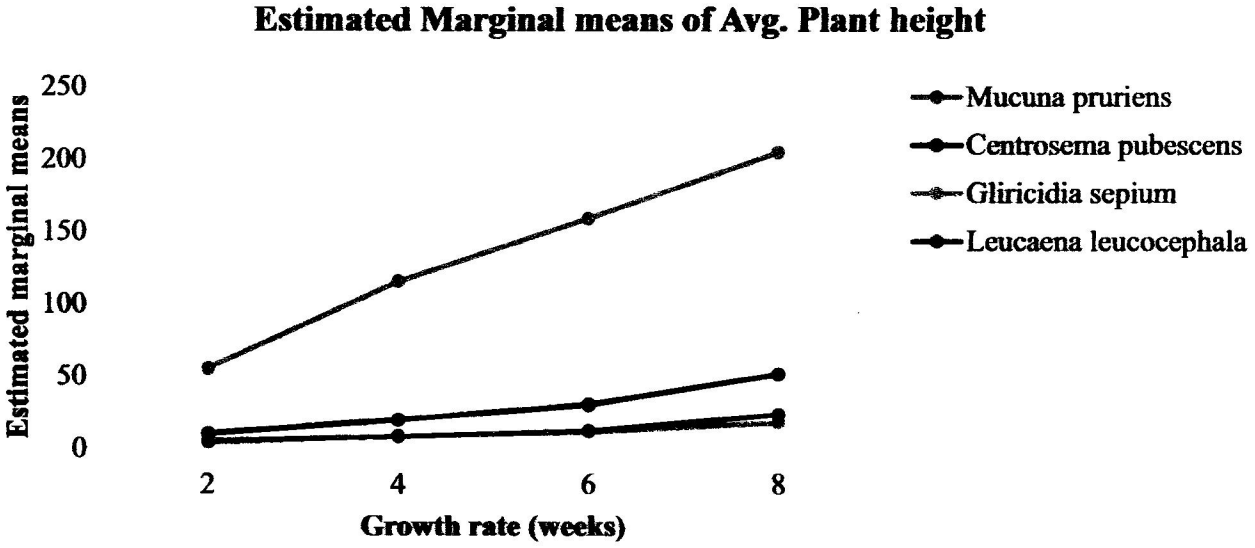

Figure 1. Estimated Marginal means of Average Plant height

3.2 Average Number of Branches

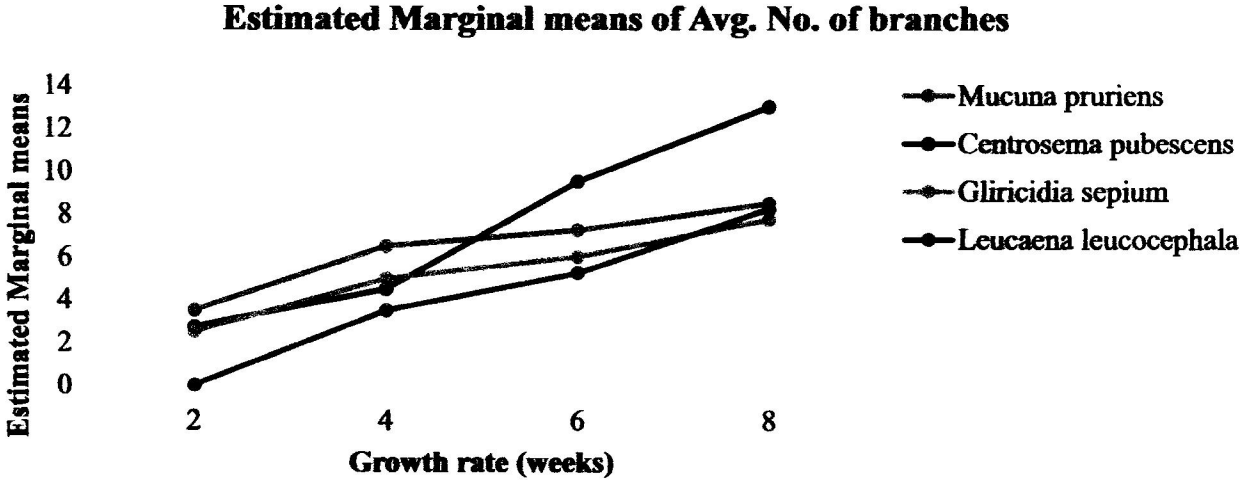

Figure 2. Estimated Marginal means of Average Number of branches

4.3.3 Leaf length

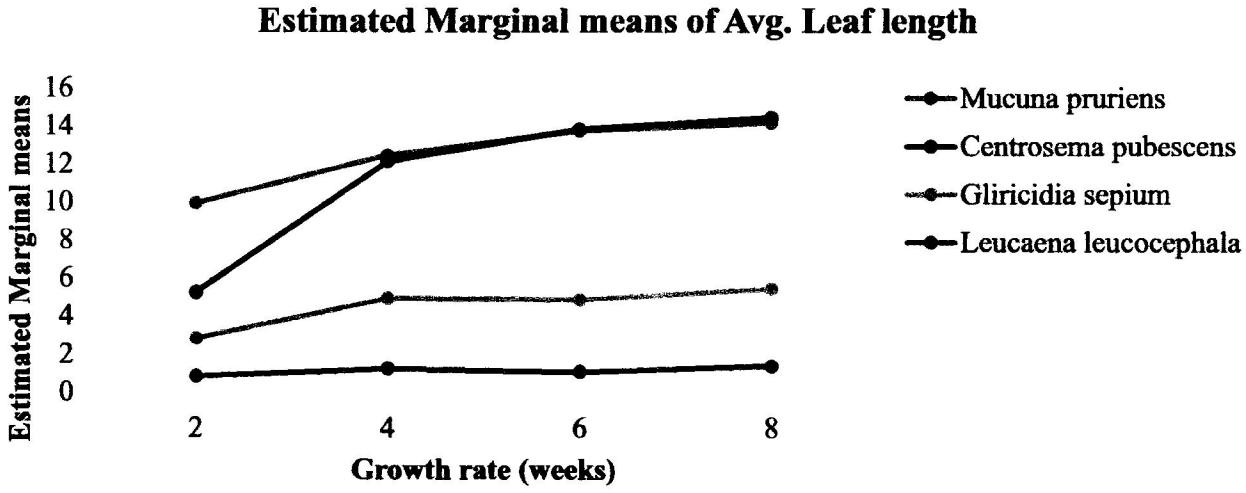

Figure 3. Estimated Marginal means of Average Leaf length

4.3.4 Leaf width

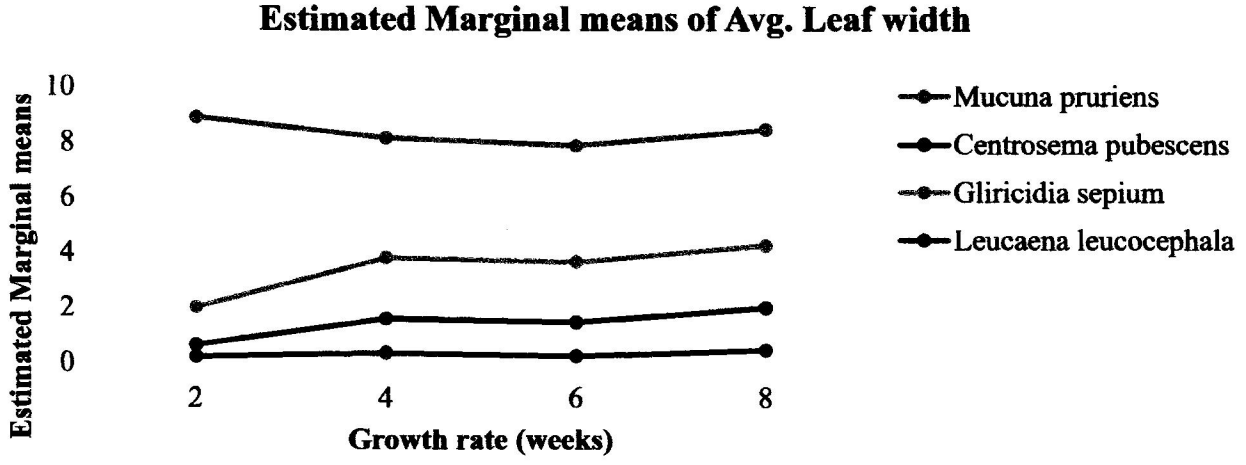

Figure 4. Estimated Marginal means of Average Leaf width

4.4 Forage Quality

Table 8. Proximate composition of Mucuna pruriens, Centrosema pubescens, Gliricidia sepium and Leucaena Leucocephala

eters	Nitrogen				Crude Protein				Moisture Content				Crude Fibre				Crude Ash				Crude Fat			
tting Times eeks)	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
cuna riens	1.77^{c}	1.46^{c}	1.77^{d}	1.53^{d}	11.07^{c}	9.13^{c}	11.05^{d}	9.59^{d}	8.86^{c}	7.31^{c}	8.84^{d}	7.67^{d}	11.39^{c}	9.40^{c}	11.36^{d}	9.86^{d}	4.92^{c}	4.06^{c}	4.91^{d}	4.26^{d}	1.70^{c}	1.40^{c}	1.69^{d}	1.47^{d}
sema ccens	1.95^{c}	1.69^{c}	2.22^{c}	1.89^{c}	12.17^{c}	10.56^{c}	13.83^{c}	11.79^{c}	9.74^{c}	8.45^{c}	11.06^{c}	9.43^{c}	12.52^{c}	10.86^{c}	14.22^{c}	12.13^{c}	5.41^{c}	4.69^{c}	6.15^{c}	5.23^{c}	1.86^{c}	1.62^{c}	2.12^{c}	1.81^{c}
cidia pium	2.28^{b}	2.30^{b}	2.70^{b}	2.21^{b}	14.27^{b}	14.40^{b}	16.85^{b}	13.82^{b}	11.41^{b}	11.52^{b}	13.48^{b}	11.06^{b}	14.67^{b}	14.82^{b}	17.33^{b}	14.22^{b}	6.34^{b}	6.40^{b}	7.49^{b}	6.14^{b}	2.19^{b}	2.21^{b}	2.58^{b}	2.12^{b}
aena hala	2.83^{a}	3.05^{a}	3.04^{a}	2.51^{a}	17.71^{a}	19.09^{a}	19.01^{a}	15.71^{a}	14.17^{a}	15.27^{a}	15.21^{a}	12.57^{a}	18.22^{a}	19.63^{a}	19.55^{a}	16.16^{a}	7.87^{a}	8.48^{a}	8.45^{a}	6.98^{a}	2.71^{a}	2.92^{a}	2.91^{a}	2.41^{a}
SEM	0.04	0.06	0.04	0.04	0.26	0.34	0.25	0.22	0.21	0.28	0.20	0.17	0.27	0.37	0.25	0.22	0.11	0.15	0.11	0.10	0.04	0.05	0.04	0.03

Means on the same column with different superscript (a, b, c, d) differ significantly ($p < 0.05$). SEM (Standard Error of Mean)

4.4.1 Nitrogen content

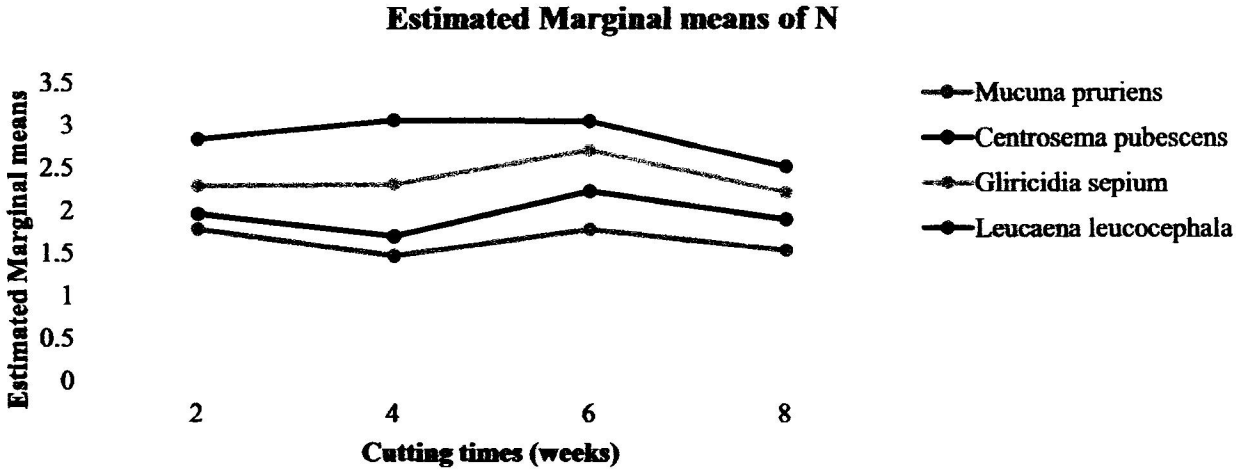

Figure 5. Esimated Marginal means of Nitrogen

4.4.2 Crude Protein content

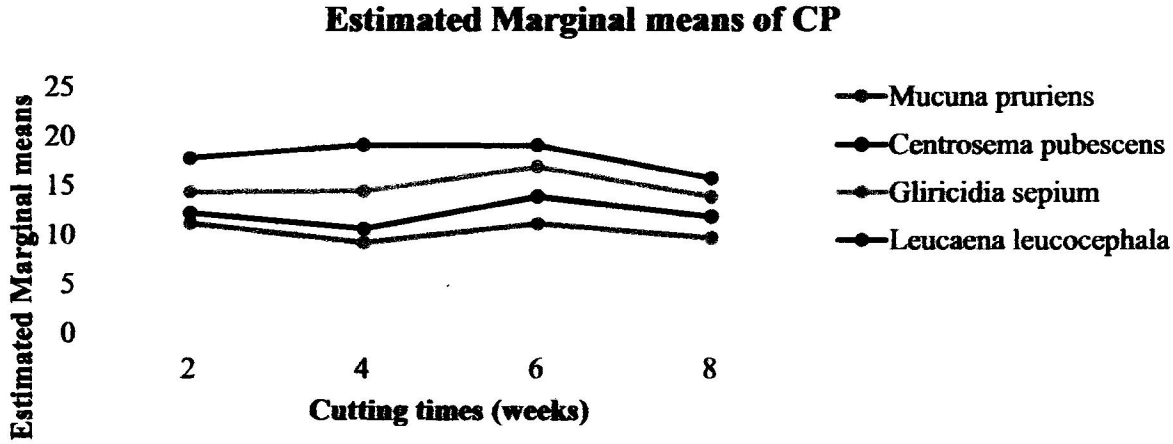

Figure 6. Estimated Marginal means of Crude Protein

4.4.3 Moisture Content

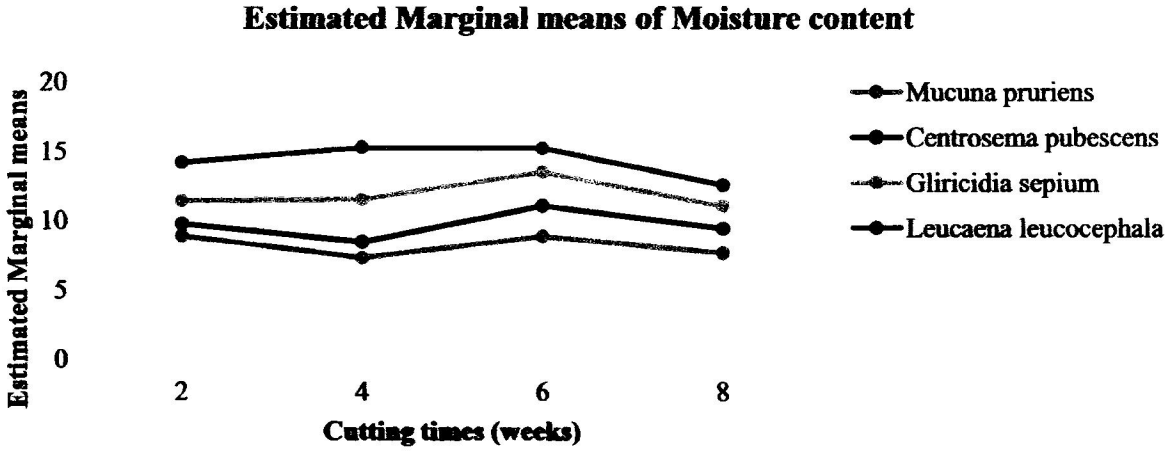

Figure 7. Estimated Marginal Means of Moisture content

4.4.4 Crude Fibre

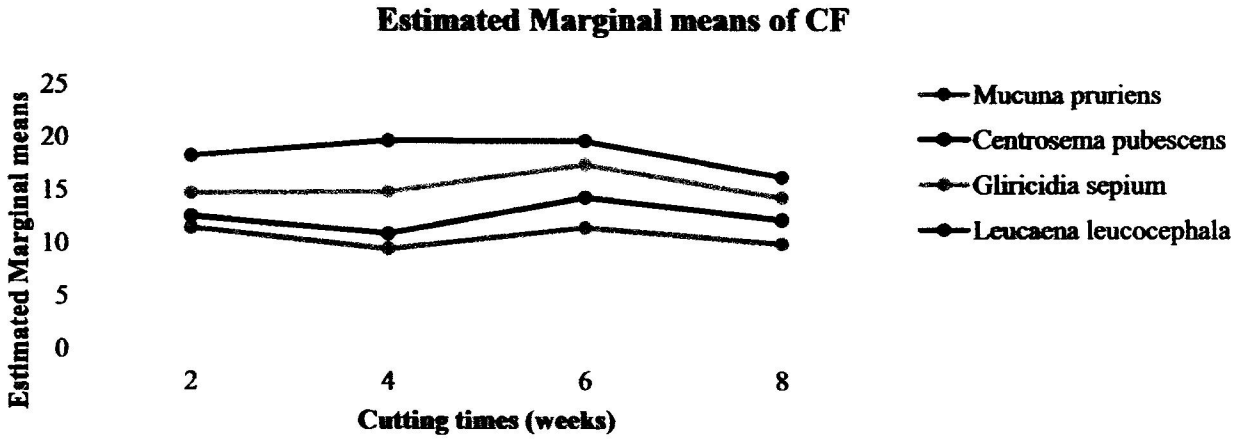

Figure 8. Estimated Marginal means of Crude Fibre

4.4.5 Crude Ash

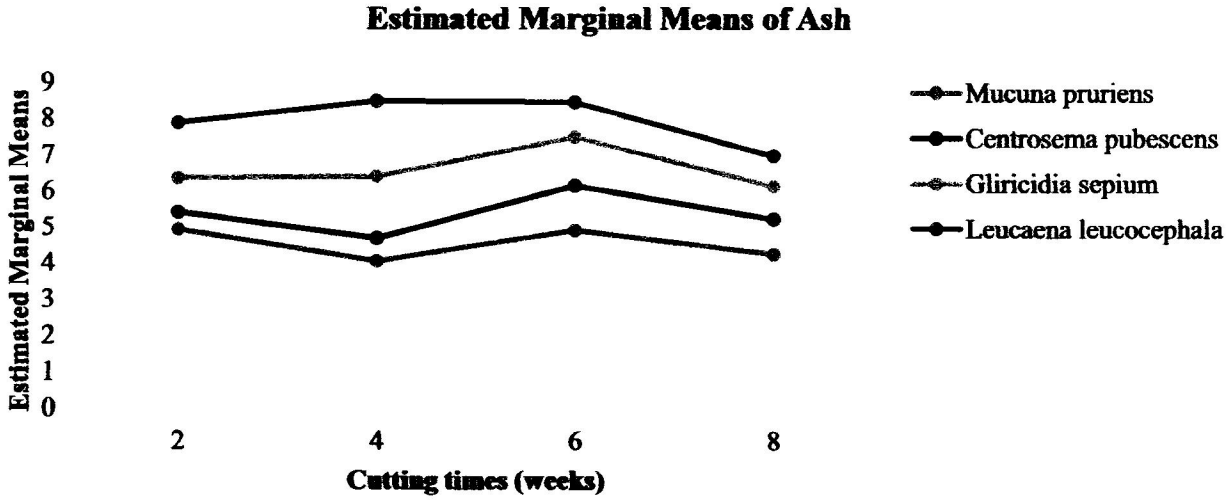

Figure 9. Estimated Marginal means of Crude Ash

4.4.6 Crude Fat

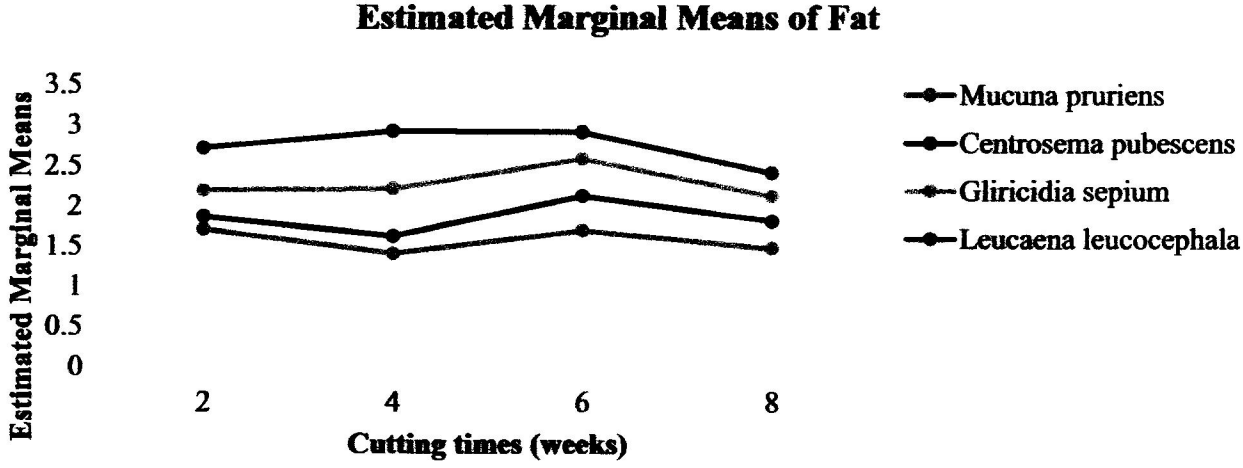

Figure 10. Estimated Marginal means of Crude Fat

Table 9. Bi-weekly Biomass Accumulation and Growth rate of legume species

Legume Species	Bi-weekly Biomass Accumulation (%)				Bi-weekly Growth rate (%)			
	2 weeks	4 weeks	6 weeks	8 weeks	2 weeks	4 weeks	6 weeks	8 weeks
Mucuna pruriens	69.70	74.46	77.19	80.51	88.87	88.98	88.67	88.91
Centrosema pubescens	61.97	63.96	65.89	67.95	88.49	88.75	88.22	88.55
Gliricidia sepium	39.26	41.63	42.81	45.17	88.16	88.14	87.74	88.23
Leucaena leucocephala	40.82	40.82	43.70	46.64	87.61	87.39	87.40	87.93

CHAPTER FIVE

5.0 DISCUSSION

5.1 Physico-chemical properties description

5.1.1 Soil before planting

The physico-chemical properties of soil used for the field study are shown in the Table 1. The surface horizon (0-20cm) of the soil at the experimental site contains 89% sand, 4% silt, 7% clay indicating according to the standard soil classification that it is a Loam soil (USDA, 2014). The particle size distribution results in Table 1 indicated that the fine earth fractions were dominated mainly by sand followed by clay and silt in the soil; the soil contains high appreciable amount of sand and very low amount of clay and silt which presumes that low level of silt may be due to low content of these properties in their parent materials that low clay content observed may indicate the degree of weathering and leaching the soil has undergone.

5.1.2 Exchangeable Nutrients

The soil is moderately low in exchangeable cation exchange capacity (ECEC) (3.34cmol/kg) and high in both organic matter (39.83%) and Organic Carbon (18.89%) implies that the soil is high in biomass as at the time of planting which is favourable to the growth of the four legume species. Furthermore, the CEC parameter particularly measures the ability of soils to allow for easy exchange of cations between soil surface and solution. The relatively low levels of silt, clay, and CEC indicate the potential of high permeability and leachaebility of metals into ground water and runoff.

More so, the low levels of Potassium (0.30%), Mg (0.81cmol/kg), and Na (0.08cmol/kg) falls within the critical low range in soils of Western Nigeria. The high level of N (2.36%) indicates that the soil is high in fertility and will require sustainable little or no soil amendment to ensure fertility and management overtime.

Nitrogen plays key roles in the growth and development of crops. It influences the yields mainly through leaf area expansion, which in turn, increases the amount of solar radiation intercepted, and dry matter production. The pH of the soil (5.60) implies that it is a basic calcareous soil indicating potential bioavailability of heavy metals (Fe, Cu, Na, Zn, Mn).

5.2 Growth Attributes

5.2.1 Plant Height

There was a linear relationship between the cutting times (weeks) and the legume species (Plate 1) as the legumes grow from week 2 to week 8, there was a sharp increase in height observed particularly for *Mucuna pruriens* (204.75) in the eighth week when it outgrew *Centrosema pubescens* (51.73), *Gliricidia sepium* (18.25) and *Leucaena leucocephala* (23.83). The growth of the legume species was due to their adaptability to the environment and their ability to effectively grow under harsh conditions. *Mucuna pruriens* is a fast-growing and high-yielding legume that can weaken within three years (Cook *et al.*, 2005).

At $p \leq 0.05$ (Table 7), *Mucuna pruriens* was significant to *Centrosema pubescens*, *Gliricidia sepium* and *Leucaena leucocephala* at weeks 2 (55.25, 10.38, 5.25, 4.45), 4 (115.50, 20.00, 8.58, 8.53), 6 (158.75, 30.38, 11.93, 12.30), 8 (204.75, 51.73, 18.25, 23.83) respectively; this implies that given the same environmental, soil and climatic

conditions, *Mucuna pruriens* did better than *Centrosema pubescens*, *Gliricidia sepium* and *Leucaena leucocephala.*

There was a significant difference between the cutting times and the legume species; the heights of the legumes increase as the legumes grow (Table 7).

The height is affected by stand density and species composition. The growth rate is controlled by genetic as well as environmental factors such as weather, soil and management factors.

5.2.2 Number of branches

There was significant difference in the number of branches of each legume species at $p < 0.05$ (Table 7) with their cutting times (weeks). At 2 weeks, *Mucuna pruriens* (3.50) has the highest number of branches compared to *Centrosema pubescens* (2.75), *Gliricidia sepium* (2.50) and *Leucaena leucocephala* (2.25). At 4 weeks, the same trend was observed with *Mucuna pruriens* (6.50) having the highest number of branches followed by *Gliricidia sepium* (5.00), *Centrosema pubescens* (4.50), *Leucaena leucocephala* (3.50). At 6 weeks, *Centrosema pubescens* (9.50) had the highest number of branches followed by *Mucuna pruriens* (7.25), *Gliricidia sepium* (6.00), while *Leucaena leucocephala* (5.25) had the least. The same trend was observed at 8 weeks with *Centrosema pubescens* (13.00) having the highest number of branches followed by *Mucuna pruriens* (8.50), *Leucaena leucocephala* (8.25), *Gliricidia sepium* (7.75).

5.3 Forage Quality

5.3.1 Nitrogen

The Nitrogen content was affected by the forage legume species. In table 8. *Leucaena leucocephala* has the highest nitrogen content at week 2 (2.83), 4 (3.05), 6 (3.04) and 8 (2.51) respectively compared to *Mucuna pruriens, Centrosema pubescens* and *Gliricidia sepium*. There was a significant difference between the nitrogen content of the legume species at $p < 0.05$. It shows that *Leucaena leucocephala* is fast growing and has high photosynthetic rates thus allowing it to produce a large biomass which can form dense thickets quickly (MacDonald *et al.*, 2008). It may grow up to 30 tons of dry matter per hectare per year. Additionally, surface roots invade the soil and increase competition for other plants. It has a deep taproot and is highly branched. (Langeland *et al.*, 2008). In *Leucaena leucocephala* nodule senescence and decay occurred within 3 weeeks after each cutting, new ones being formed to continue Nitrogen fixation during regrowth (Guevarra *et al.*, 1999).

5.3.2 Crude Protein

There are significant differences in the crude protein content of the legume species in table 8. *Leucaena leucocephala* has the highest crude protein content followed by *Gliricidia sepium*, *Centrosema pubescens*, and *Mucuna pruriens* at weeks 2 (17.71, 14.27, 12.17, 11.07), 4 (19.09, 14.40, 10.56, 9.13), 6 (19.01, 16.85, 13.83, 11.05), 8 (15.71, 13.82, 11.79, 9.59) respectively. The crude protein content increased from weeks 2 to weeks 4 for all the legumes observed and thereafter decreased with an increased in age at harvest or regrowth interval (Garcia, 2000).

5.3.3 Moisture content

Leucaena leucocephala was having the highest moisture content through out the eight weeks of study compared to *Gliricidia sepium, Centrosema pubecens* and *Mucuna pruriens* at weeks 2 (14.17, 11.41, 9.74, 8.86), 4 (15.27, 11.52, 8.45, 7.31), 6 (15.21, 13.48, 11.66, 8.84) and 8 (12.57, 11.06, 9.43, 7.67) respectively. At weeks 4 *Leucaena leucocephala* has the highest moisture content in table 8. Hariah *et al.*, (1992) reported that lower pruning heights led to high biomass production.

5.3.4 Crude Fibre

At $p < 0.05$, there were significant differences between the different times of cutting (Table 8). At weeks 2 (18.22, 14.67, 12.52, 11.39), 4 (19.63, 14.82, 10.86, 9.40), 6 (9.55, 17.33, 14.22, 11.36) and 8 (16.16, 14.22, 12.13, 9.86) of cutting, *Leucaena leucocephala* had the highest crude fibre content followed by *Gliricidia sepium, Centrosema pubecens* and *Mucuna pruriens*. Studies also demonstrate that the effects of cutting interval on yield and quality vary with the different legume species (Adejumo, 1991). Hariah *et al.*, (1992) reported that lower pruning heights led to high biomass production.

5.3.5 Crude Ash

Ash contain all the important nutritional ingredients especially minerals, both micro and macronutrients, which are very important for the normal physiological functions of the animal's body. Ash content of the legume species, *Leucaena leucocephala, Gliricidia sepium, Centrosema pubescens* and *Mucuna pruriens* were significantly different from each other (Table 8). At Week 4 (*Leucaena leucocephala* (8.48), *Gliricidia sepium*

(6.40), *Centrosema pubescens* (4.69) and *Mucuna pruriens* (4.06) showed comparatively high content of ash with *L. leucocephala* having the highest ash content.

5.3.6 Crude Fat

Fat content of the four legume species, *Leucaena leucocephala, Gliricidia sepium, Centrosema pubescens* and *Mucuna pruriens* were 2.92, 2.21, 1.62, 1.40 at 4weeks with corresponding lower values at weeks 2, 6 and 8 respectively as in Table 8. This implies that, more of fat soluble vitamins were found in *Leucaena leucocephala* than *Gliricidia sepium, Centrosema pubescens* and *Mucuna pruriens.* Cutting interval affect the crude fat content of legume species.

5.4 Model Functions

5.4.1 Model Functions for Biomass Accumulation

The equations for biomass accumulation will be derived from the below parameters:

- $CT = PH + NB + LL + LW + \alpha$

Where,

Cutting Time – (CT) ⟶ Independent variable

Plant Height – (PH)
Number of Branches – (NB)
Leaf Length – (LL)
Leaf Width – (LW)
} dependent

α is constant and intercept of the model

Mucuna pruriens – (Lsp 1)

Centrosema pubescens – (Lsp 2)

Gliricidia sepium – (Lsp 3)

Leucaena leucocephala – (Lsp 4)

For Lsp 1,

CT = 2.726 + 0.054PH + 0.524NB + 0.059LL + 0.278LW

Error estimate (ε_t) = 0.377

For Lsp 2,

CT = 0.056 + 0.092PH + 0.096NB + 0.233LL - 0.729LW

Error estimate (ε_t) = 0.242

For Lsp 3,

CT = -0.975 + 0.235PH + 0.411NB + 0.266LL + 0.002LW

Error estimate (ε_t) = 0.627

For Lsp 4,

CT = -0.078 + 0.140PH + 0.481NB + 1.751LL - 3.065LW

Error estimate (ε_t) = 0.627

Note: The positive signs (+) denotes that with an increase in the cutting time, there would be an increase in the biomass accumulation and vice-versa.

The negative signs (-) denotes that with an increase in the cutting time, there would be a decrease in the biomass accumulation and vice-versa.

$$\mathbf{Et = CT + \varepsilon_t}$$

Where,

Error estimate – (Et)

Cutting Time – (CT)

Error due to chance (uncontrollable) – ε_t

$$\mathbf{BMA = OMS\ (\%) + Lsp + E_t}$$

Where,

Biomass Accumulation – (BMA)

Organic Matter in the soil – (OMs)

Legume specie – (Lsp)

Error estimate – (E_t)

5.4.2 Model Functions for Legume Growth Rate

$$\mathbf{\%L_{gri} = 2BMA_i\% - \%S_{pgi} + \%M_{pi} + U_{fei} + F_i - N_{gi} \pm E_t}$$

Where,

Legume growth rate is expressed as L_{gr}

Viability of species seeds is expressed in terms of percentage as $\%S_{pg}$

Management practices is expressed in percentage as $\%M_p$

Nutrient composition is expressed as N_g

Unforeseen interference exigencies is expressed in terms of percentage as U_{fe}

$U_{fei} = 0$

$E_t = 0$

For the whole study, a growth rate range of 87.39% - 88.98% was observed while the biomass accumulated was observed to be 39.26% - 80.51%

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

During the course of carrying out this research work, the fastest growing legume was *Mucuna pruriens* and it grew faster than *Centrosema pubescens, Gliricidia sepium and Leucaena leucocephala.* The model developed in this research can be used to estimate how faster a legume can grow within the period of eight weeks, given that all other conditions are met (climate and edaphic factor).

6.2 RECOMMENDATION

Since results obtained in this study were for one season and was conducted in the tropics, it is recommended that the experiment be repeated over a number of locations and seasons to confirm these results.

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APPENDIX

A1: Biomass Accumulation of Legume Species

		constant	0.054	PH		0.524	NB		0.059	LL		0.278	LW		CT				BMA
1-	2	2.726	0.054	55.25	2.9835	0.524	3.5	1.834	0.059	9.93	0.58587	0.278	8.88	2.46864	10.59801	0.377	57.720	1	69.695
	4	2.726	0.054	115.5	6.237	0.524	6.5	3.406	0.059	12.45	0.73455	0.278	8.13	2.26014	15.36369	0.377	57.720	1	74.461
	6	2.726	0.054	158.75	8.5725	0.524	7.25	3.799	0.059	13.73	0.81007	0.278	7.85	2.1823	18.08987	0.377	57.720	1	77.187
	8	2.726	0.054	204.75	11.0565	0.524	8.5	4.454	0.059	14.18	0.83662	0.278	8.43	2.34354	21.41666	0.377	57.720	1	80.514
2-	2	0.056	0.092	10.38	0.95496	0.096	2.75	0.264	0.233	5.23	1.21859	-0.729	0.63	-0.45927	2.03428	0.242	57.720	2	61.996
	4	0.056	0.092	20	1.84	0.096	4.5	0.432	0.233	12.13	2.82629	-0.729	1.58	-1.15182	4.00247	0.242	57.720	2	63.964
	6	0.056	0.092	30.38	2.79496	0.096	9.5	0.912	0.233	13.83	3.22239	-0.729	1.45	-1.05705	5.9283	0.242	57.720	2	65.890
	8	0.056	0.092	51.73	4.75916	0.096	13	1.248	0.233	14.45	3.36685	-0.729	1.98	-1.44342	7.98659	0.242	57.720	2	67.949
3-	2	-0.975	0.235	5.25	1.23375	0.411	2.5	1.0275	0.266	2.83	0.75278	0.002	2	0.004	2.04303	0.627	33.587	3	39.257
	4	-0.975	0.235	8.58	2.0163	0.411	5	2.055	0.266	4.93	1.31138	0.002	3.78	0.00756	4.41524	0.627	33.587	3	41.629
	6	-0.975	0.235	11.93	2.80355	0.411	6	2.466	0.266	4.85	1.2901	0.002	3.63	0.00726	5.59191	0.627	33.587	3	42.806
	8	-0.975	0.235	18.25	4.28875	0.411	7.75	3.18525	0.266	5.45	1.4497	0.002	4.23	0.00846	7.95716	0.627	33.587	3	45.171
4-	2	-0.078	0.14	4.45	0.623	0.481	2.25	1.08225	1.751	0.85	1.48835	-3.065	0.21	-0.64365	2.47195	0.756	33.587	4	40.815
	4	-0.078	0.14	8.53	1.1942	0.481	3.5	1.6835	1.751	1.25	2.18875	-3.065	0.35	-1.07275	3.9157	0.756	33.587	4	42.259
	6	-0.078	0.14	12.3	1.722	0.481	5.25	2.52525	1.751	1.08	1.89108	-3.065	0.23	-0.70495	5.35538	0.756	33.587	4	43.699
	8	-0.078	0.14	23.83	3.3362	0.481	8.25	3.96825	1.751	1.4	2.4514	-3.065	0.45	-1.37925	8.2986	0.756	33.587	4	46.642

CT= Cutting Times, PH=Plant Height, NB= Number of Branches, LL= Leaf Length, LW= Leaf Width, Lsp=Legume species, BMA= Biomass Accumulation

A2: Growth Rate of Legume species

	CT	2BMA	Spl	Mp	N	Lgr
Lsp 1-	2	115.44	-100	75	-1.77	88.67
	4	115.44	-100	75	-1.46	88.98
	6	115.44	-100	75	-1.77	88.67
	8	115.44	-100	75	-1.53	88.91
						0
						0
Lsp 2-	2	115.44	-100	75	-1.95	88.49
	4	115.44	-100	75	-1.69	88.75
	6	115.44	-100	75	-2.22	88.22
	8	115.44	-100	75	-1.89	88.55
						0
Lsp 3 -	2	115.44	-100	75	-2.28	88.16
	4	115.44	-100	75	-2.3	88.14
	6	115.44	-100	75	-2.7	87.74
	8	115.44	-100	75	-2.21	88.23
						0
Lsp 4-	2	115.44	-100	75	-2.83	87.61
	4	115.44	-100	75	-3.05	87.39
	6	115.44	-100	75	-3.04	87.4
	8	115.44	-100	75	-2.51	87.93

CT= Cutting Times, BMA= Biomass Accumulation, Spl= Viability of species seeds, Mp= Management practices, N= Nitrogen, Lgr=Legume growth rate, Lsp= Legume species