DECLARATION

I, ORIBAMISE BABATUNDE VICTOR hereby declare that this project "**Growth Rate and Biomass Accumulation of Forage Sorghum (*Sorghum almum*), Congo grass (*Brachiaria ruziziensis*) and Rhodes grass (*Chloris gayana*)**" has been written by me and that it is a record of my own research work. It has not been presented before in any previous application of a degree or any reputable presentation elsewhere. All borrowed ideas have been duly acknowledged.

Tundegaloi

ORIBAMISE B. VICTOR

28/09/16.

Date

CERTIFICATION

This project entitled "**Growth Rate and Biomass Accumulation of Forage Sorghum (*Sorghum almum*), Congo grass (*Brachiaria ruziziensis*) and Rhodes grass (*Chloris gayana*)**" meets the regulations governing the award of degree of Bachelor of Agriculture (B. Agric) of FUOYE (Federal University Oye-Ekiti) and is approved for its contribution to knowledge and literacy presentation.

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DEDICATION

This study is dedicated to my parents, Hon. & Evang (Mrs.) S.O. Oribamise for their continued love over the years. Thanks for everything, Dad and Mum!

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ABSTRACT

Many grasses have played prominent roles in forage research and livestock production in Nigeria. Grasses possess two main photosynthetic pathways: the C_3 pathway that is typical of most plants and a specialized C_4 pathway that minimizes photorespiration and thus increases photosynthetic performance in high-temperature and / or low- CO_2 environments.

Rhodes grass (*Chloris gayana*) is a perennial grass of tropical and subtropical Africa where it remained one of the main C_4 forage grasses.

Forage Sorghum (*Sorghum almum*) originated in Argentina and the latitudinal range of the grass is 25°N to 30°S. It can be found at elevations between sea level and 700m.

Congo grass (*Brachiaria ruziziensis*) has been widely used in crop rotation and crop-livestock integrated systems in the world because of its good adaptation to low fertility soils, high yield potential, and good forage quality.

This research is aimed at developing a model that can correctly predict the growth rate and also the biomass accumulation of *Sorghum almum, Brachiaria ruziziensis* and *Chloris gayana*.

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.

The planting was done using completely randomized design (CRD) in 3-rows with 4 replicates of 8 pots of each grass species and a spacing of 1m long apart was applied between each bed.

The soil used for this study contained a high organic matter before planting (32.81) and after harvesting was completed (18.70). The soil used in planting belonged to the Loam soil category.

The highest growing grass was *Sorghum almum* throughout the period of carrying out this experiment.

The sward heights of the three grass species were not significant from each other.

The highest crude protein content was observed in the first cuttings (2^{nd} week) while *Sorghum almum* had the highest crude protein content. Crude protein was found to decrease linearly as the grasses grow. At $p < 0.05$; *Sorghum almum* had more protein content for the study period than *Chloris gayana* and *Brachiaria ruziziensis* at both weeks 2 (12.11, 7.71 and 4.97), 4 (10.34, 5.77 and 3.52), 6 (8.61, 4.52 and 2.95) and 8 (9.40, 2.57 and 0.84)

The crude fibre content of the three grass species increased as the grasses grew; the highest fibre content was observed in the 8^{th} week of cutting due to encrustation of lignin in them as the grasses matured giving the impression that both the fibre and protein contents of the grasses are inversely related.

The crude Ash content varied between the three grass species and the times of cutting. Ash contains 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.

The moisture content varied between the grass species and the times of cutting; Grass with lowest moisture content could store for a longer time without spoilage.

The Crude fat content decreased significantly from the second week to the eighth week.

The growth rate of the grasses were observed throughout the course of undertaking this study and the varietal differences were observed with *Sorghum almum* the fastest.

The Biomass accumulation observed yielded between 10.11- 21.97% while the growth rate of the grasses observed was 68.81 - 94.98%.

Keywords: *Sorghum almum*, *Brachiaria ruziziensis*, *Chloris gayana*, Growth rate, Biomass, Grass Growth model, Crude protein, Crude Fibre, Crude Ash, Crude Fat, Moisture.

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CHAPTER ONE

INTRODUCTION

1.0 What are tropical grasses?

Many grasses have played prominent roles in forage research and livestock production in Nigeria (Anele *et al.,* 2013). Forage grasses are widespread in the entire world and constitute one of the most important feed sources for grazing animals (Jorge *et al.*, 2005). Grasslands are productive biomes of the Earth; occupying approximately 36% of the Earth's terrestrial surface (Mandar, 2016). These grasses play an important role in the progress of human life and the longevity of the animal husbandry industry in Nigeria. Grasslands currently are producing far less than their production potential. Hence, it has become imperative to recover their grazing potential (Muhammad *et al.,* 2012).

Forage production is gaining more attention in the tropics and the subtropics in both developed and developing countries. New varieties or cultivars of forage and pasture plants have been introduced from areas and countries rich in forage and pasture plant to areas where they are scarce.

Most of the animals in the tropics are greatly dependent on the natural vegetation as their major source of feed for maintenance and production. This attribute is clearly reflected on poor output and performance of animals resulting from poor quality of forages and the problems of over and under grazing. The possible solution is for grassland scientists to know the rate at which each grass variety grows.

It is estimated that existing feed resources are deficient by 29 and 33% for total digestible nutrients and crude protein (CP), respectively (Muhammad *et al.,* 2012). The forage

digestibility is related to chemical composition, particularly of fiber, lignin, and silica contents. Crude fiber mainly consists of cellulose, hemicellulose and lignin. The ether extract is composed of fats, oils, waxes, organic acids, pigments, sterols and vitamins A, D, E and K.

There is a need to determine the growth rate of these grass varieties to enhance forage production to meet animal feeds requirements. Looking at the prevailing degraded condition of grasslands in the country, there is a need for increase in their forage productivity. It is of high importance that high yielding and palatable grass varieties are established in their suitable eco-sites.

1.2 Pathways for C_4 Photosynthesis

Grasses possess two main photosynthetic pathways: the C_3 pathway that is typical of most plants and a specialized C_4 pathway that minimizes photorespiration and thus increases photosynthetic performance in high-temperature and or low- CO_2 environments. C_4 grasses dominate tropical and sub-tropical grasslands and savannas and C_3 dominate the world's cooler temperate grassland regions (Edwards *et al.*, 2010).

The C_4 photosynthetic carbon cycle is an elaborated addition to the C_3 photosynthetic pathway. It evolved as an adaptation to high light intensities, high temperatures, and dryness. Therefore, C_4 plants dominate grassland floras and biomass production in the warmer climates of the tropical and subtropical regions (Edwards *et al.*, 2010). In all plants, CO_2 is fixed by the enzyme Rubisco. It catalyzes the carboxylation of ribulose-1, 5-bisphosphate, leading to two molecules of 3-phosphoglycerate. Instead of CO_2, Rubisco can also add oxygen to ribulose-1, 5-bisphosphate, resulting in one molecule each of 3-

phosphoglycerate and 2-phosphoglycolate. Phosphoglycolate has no known metabolic purpose and in higher concentrations it is toxic for the plant. It therefore has to be processed in a metabolic pathway called photorespiration. Photorespiration is not only energy demanding, but furthermore leads to a net loss of CO_2. Thus the efficiency of photosynthesis can be decreased by 40% under unfavorable conditions including high temperatures and dryness. The unfavorable oxygenase reaction of Rubisco can be explained as a relic of the evolutionary history of this enzyme, which evolved more than 3 billion years ago when atmospheric CO_2 concentrations were high and oxygen concentrations low (Udo and Westhoff, 2011).

The establishment of C_4 photosynthesis includes several biochemical and anatomical modifications that allow plants with this photosynthetic pathway to concentrate CO_2 at the site of Rubisco. Thereby its oxygenase reaction and the following photorespiratory pathway are largely repressed in C_4 plants. In most C_4 plants the CO_2 concentration mechanism is achieved by a division of labor between two distinct, specialized leaf cell types, the mesophyll and the bundle sheath cells, although in some species C_4 photosynthesis functions within individual cells (Edwards *et al.*, 2010).

Since Rubisco can operate under high CO_2 concentrations in the bundle sheath cells, it works more efficiently than in C_3 plants. Consequently C_4 plants need less of this enzyme, which is by far the most abundant protein in leaves of C_3 plants. This leads to a better nitrogen-use efficiency of C_4 compared to C_3 plants, since the rate of photosynthesis per unit nitrogen in the leaf is increased (Sara *et al.*, 2007).

Additionally C_4 plants exhibit better water-use efficiency than C_3 plants. Because of the CO_2 concentration mechanism they can acquire enough CO_2 even when keeping their stomata more closed. Thus water loss by transpiration is reduced.

In the mesophyll cells of C_4 plants CO_2 is converted to bicarbonate by carbonic anhydrase and initially fixed by phosphoenolpyruvate (PEP) carboxylase (PEPC) using PEP as CO_2 acceptor (Sara *et al.*, 2007).

The resulting oxaloacetate is composed of four carbon atoms, which is the basis for the name of this metabolic pathway. Oxaloacetate is rapidly converted to the more stable C_4 acids malate or Asp that diffuse to the bundle sheath cells. Here, CO_2 is released by one of three different decarboxylating enzymes, which define the three basic biochemical subtypes of C_4 photosynthesis, NADP-dependent malic enzyme (NADP-ME), NADdependent ME (NAD-ME), and PEP carboxykinase (PEPCK). The released CO_2 is refixed by Rubisco, which exclusively operates in the bundle sheath cells in C_4 plants. The three-carbon compound resulting from CO_2 release diffuses back to the mesophyll cells where the primary CO_2 acceptor PEP is regenerated by pyruvate orthophosphate dikinase by the consumption of, at the end, two molecules of ATP.

To ensure a direct contact between bundle sheath and mesophyll cells, C_4 plants possess a characteristic leaf anatomy. The bundle sheath cells enclose the vascular bundles and are themselves surrounded by the mesophyll cells. The high vein density in the leaves of C_4 plants leads to a nearly one-to-one ratio of the volumes of mesophyll and bundle sheath tissues. The internal anatomy of a C_4 leaf is often composed of a repeating pattern of vein-bundle sheath-mesophyll-mesophyll-bundle sheath-vein.

Rhodes grass (*Chloris gayana* L. Kunth.) is a summer-growing, stoloniferous perennial, whose runners provide good soils, from infertile sands to fertile brigalow clays. It is difficult to establish and have persistence on heavy cracking clay soils. Rhodes grass is one of the best grasses for rotation land in tropical and subtropical areas, useful for establishment pasture leys. It is suitable for silage and hay liked by all kinds of stock but may causes skin trouble in horses. Its ability to establish rapidly makes it valuable for soil conservation (Reed, 1976).

Forage Sorghum (*Sorghum almum*) originated in Argentina and the latitudinal range of the grass is 25°N to 30°S. It can be found at elevations between sea level and 700 m (Duke, 1983; Olanite *et al.*, 2010). It is a promising forage crop with a high potential for integration into Nigerian livestock production systems. Ease of establishment, drought and salt resistance, rapid growth and reasonable high yields (4000–12000 kg ha^{-1}) indicate it may be a suitable forage crop for silage production during the rainy season while permitting regrowth for hay production or in situ grazing of the standing crop.

Congo grass (*Brachiaria ruziziensis*) has been widely used in crop rotation and crop-livestock integrated systems in the world because of its good adaptation to low fertility soils, high yield potential, and good forage quality (Garcia *et al.*, 2008).

Corral and Fenlon, 1978 estimated grass growth on a 4-week harvest interval with the main focus of the research based on calculating growth rate using a quadratic equation. Corral and Fenlon (1978) observed a remarkable production loss of 23% in the second year mainly due to a slight deficit in the organic manure but they observed that their peak production rate was during their first year; it thus can be concluded that the loss of the soil's organic

matter led to the 23% loss in the second year. Their research was meant majorly to calculate the rate at which their grass species grew; the research was simplistic and mechanical in approach but never gave recognition to the effect the organic matter had in the grasses' growth.

Brereton *et al.*, 1996 developed a model at the Teagasc Research Centre at the Johnson Castle in Wexford, Ireland. The model is driven mainly by empirical relationships, relating growth of the grass as a whole to temperature and light. It is static in approach in that it does not describe growth over time by daily iterations of growth rates, but rather estimates yield at the end of a stipulated time period, given the environmental conditions during the period. It was originally created as a basis for evaluating the farm-scale behavior of grassland systems and the dynamics of grazing management as affected by weather conditions from year to year on farms in Ireland. The model does not and was not intended to; describe the nature of grass growth, as it is not process-based. The Brereton model tried its best to give an estimate of yields at the end of a time period/planting period leaving out the details of the accumulation of biomass in the grassland; it also didn't do enough justice to the Dry Matter (DM) content accumulated by the herbage by each cutting period.

Jouven *et al.*, 2006 during their research developed a dynamic and mechanistic model that is able to simulate the effects of management (type and intensity) on biomass, structure and quality dynamics at the field scale. The Jouven model attempts to combine functional and structural aspects of grass growth. This model was developed in Ireland but focuses mainly on the effects of management of a field has on the growth rate of grass.

1.3 PROBLEM STATEMENT

In Nigeria, knowing the correlation between accumulated biomass with relations to grass growth age has been a major problem to grassland scientists. Knowing the rate at which grass grow in the country has been a major cause of concern for grassland scientists as they have not been able to correctly predict and adopt a working model that could be used to successfully predict grass 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, and also a major cause of inter-tribal fights in Nigeria.

Aganga *et al.,* (2000) stated that feed shortage is the major constraint affecting the development of the animals' industry. This problem of grasslands shortage has contributed mainly to the Fulani herdsmen and locals fights.

According to the World terror list release of November, 2015 (Daily-mail, 2015) placed the Fulani herdsmen as the fourth deadliest terror group in the world with over a thousand deaths. Successfully predicting and adopting a working model for the growth rates of grasses in the country with the accumulation and degradation of biomass in the soil over time will lead to finding a lasting solution to these herdsmen problem and also increasing ruminant production in the country.

1.4 OBJECTIVES

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 *Sorghum almum, Brachiaria ruziziensis* and *Chloris gayana.*

1.4.2 Specific objectives:

i. Determine the bi-weekly biomass accumulation of *Sorghum almum, Brachiaria ruziziensis* and *Chloris gayana.*

ii. Determine the growth rate of *Sorghum almum, Brachiaria ruziziensis* and *Chloris gayana.*

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

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

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

CHAPTER TWO

LITERATURE REVIEW

2.0 GENERAL

Production of livestock in Nigeria faces the most crucial challenges; prices of food for animal origin are very expensive and it's increasing every day and making the reach of poor communities impossible. Feed and fodder are not deficient but also very high priced as well as low in required ingredients and the inevitable results are less number of animals compared with the ever growing population. These phenomena are closely connected with poor health of people and inflation. Social and environmental problems of food producing systems have, thus, multiplied. 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.,* 2002, 2012). Production of good quality fodder are influenced due to plant species (Kaiser and Piltz, 2002, Mehdi *et al.,* 2009), stage of growth and agronomic practices (Rehman and Khan, 2003).

The nutritive value of feed/forage is a measure of proximate composition, digestibility and nature of digested products and there by its ability to maintain or promote growth, milk production, pregnancy or other physiological functions in the animal body. Animal is the best judge for forage quality assessment, which can be determined through palatability, growth rate and milk production. The forage digestibility is related to changes in chemical composition, particularly of fiber, lignin and silica contents and to some extent crude protein.

Grasses are an important component of the Gramineae family. Apart from cereals, many grasses provide forage for livestock, protect the soil from erosion, improve soil structure and hence their retention (Ahmad *et al.,* 2001). The carrying capacity of the highly depleted rangelands of the country could be increased by growing grass species (Parmar *et al.,* 2000).

There is increased interest in grass growth prediction due to the low cost of grazed grass as a feed for ruminants (Barret *et al.,* 2005). In the context of increasing food demand due to the ever increasing global population and the need for economic sustainability of grass based farms, knowing the growth of grass can improve the decision-making process at farm level. Grass growth is determined by the interaction of many environmental and management factors and as such, forecasting grass growth rates is particularly difficult. However, the main determining factors are known to be the prevailing climatic conditions, notably air temperature, light and rainfall (Jouven *et al.,* 2006). In addition, the level of organic matter in form of available or applied Nitrogen is important.

In recent times, grassland scientists have developed mathematical models to predict grass growth rates, generally using meteorological inputs, with a considerable number of published models, originating from the southern hemisphere (Jouven *et al*; 2006) to Northern Europe (Hoglind *et al.,* 2001). In the earliest models used for measuring grass growth, potential growth was determined empirically from the plant's genetic potential or from field measurements.

The knowledge of the growth curves of different versions which are of importance and interest to livestock production is an important tool for research purposes and for taking

the decisions in managing ruminants. Their adequate use can generate and implement programs (Lourdes *et al.,* 2013) helping to identify economical and productive parameters allowing the efficiency and productivity of the livestock sector.

The efficiency of grass growth is determined by the amount of solar radiation interception and its conversion to dry matter (Brereton *et al.,* 1996) which is influenced by the environment and management practice used.

2.1 DESCRIPTION OF GRASS SPECIES

2.1.1 RHODES GRASS

2.1.1.1 General

Rhodes grass (*Chloris gayana* Kunth) is a perennial grass of tropical and subtropical Africa where it remained one of the main C_4 forage grasses. Rhodes grass is a C_4 species widely used as forage in tropical and subtropical areas and known for its ability to withstand dry conditions, soil salinity, and light frost. It belongs to the family *Poaceae* and sub tribe *Chloridoideae.* As a tropical grass with the C_4 type of photosynthesis, like corn and sugarcane, Rhodes grass efficiently uses solar radiation and the available soil moisture to quickly accumulate relatively high amount of biomass.

Rhodes grass can be used as pasture, hay and ley crop. It is also can be used to stabilize disturbed sites. It is found in open grassland, or in grassland with scattered

bush and trees, lake margins or seasonally waterlogged plains up to 2000 m altitude, rarely higher (Bogdan, 1969; Ahmed *et al.,* 2014).

2.1.1.2 Origin and early history

Rhodes grass occurs naturally in most tropical and subtropical parts of Africa, including all of eastern and central Africa, much of southern Africa, and the eastern section of West Africa (Bogdan., 1958, 1969). It is found in open grassland or in grassland with scattered bush or trees, lake margins, or seasonally waterlogged plains up to 2000 m altitude (rarely higher). It is also often preset in fallow ground or abandoned cultivation where it acts as a pioneer species coming in after the initial weedy phase.

Rhodes grass was first cultivated in South Africa, probably in 1895, by Cecil John Rhodes, hence the common name. This was apparently a diploid form, possibly from Zimbabwe, though accounts of its early history vary (Chippendall, 1955). In one story, Rhodes found the grass growing wild on the veld. In another, it was taken to India and later re-introduced by French Moravian missionaries to the Eastern Cape area where Rhodes noticed it flourishing on an adjoining farm. Whatever the origin, it is clear that Cecil Rhodes recognized the economic potential of Rhodes grass and was the first to propagate and distribute it in cultivation. The first published record of its agricultural use, however, was a letter in October 1902 issue of the Cape Agricultural Journal giving advice on the best time, locality, and conditions for planting Rhodes grass (Stent and Melle, 1921).

Rhodes grass was introduced to Australia in about 1902 by soldiers returning from the Boer War (Cameron, 1967). This accession was originally sown in the Hunter Valley of New South Wales (NSW), but quickly spread north, reaching Queensland about 1905. It is now widely sown and naturalized in coastal and sub- coastal districts from northern NSW through to central Queensland and on the Atherton Tableland in north Queensland. Rhodes grass was first imported into the USA in 1903, and most early plantings were from Australian seed (Potts and Hensel, 1947). However, by the 1950s, seed production in Texas was well organized (Wheeler and Hill, 1957). Rhodes grass is now mainly sown in the southern parts of Florida and Texas. Rhodes grass has also been introduced to most other tropical and subtropical countries, and even some warm temperate countries.

2.1.1.3 Taxonomy and morphology

Rhodes grass is placed by taxonomists in the grass subfamily *Chloridoideae*, but recently, phylogenetic opinion precludes further subdivision into the classically recognized tribes and sub-tribes. Morphologically, Rhodes grass is a variable species, best described as a stoloniferous creeping and tufted perennial with erect or ascending stems 0.5 to 2.2m high and glabrous leaf blades 150 to >500mm long by 2 to 20-mm wide. Leaves on the stolons are shorter and arise in groups of two to four from each node. The inflorescence is a digitate or subdigitate panicle with 3 to 20 spikes, each 40- to 150-mm long.

The two-awned spikelets are best developed in the middle of each spike. They are 3- to 5-mm long with two to five overlapping florets along the central rachilla (Chippendall, 1955; Bogdan, 1958, 1966). Florets are laterally compressed,

narrowing at both ends with a hairy point (or callus) at the base and two sharp lobes at (lie top with a rigid awn (1 to 10mm long) arising between the lobes. The lemma of the lowest floret is hinged with hairs forming a 'brush' near the top, with a short prominent nerve (usually hairy) in the middle of each side. Upper florets are glabrous and progressively reduced in coin plexity: they become shorter, more oblong in outline narrowing abruptly towards the top, and have a shorter awn (floret 2) or are awnless. Spikelets end with an undeveloped floret shaped like a minute club.

Rhodes grass caryopses vary in size and shape depending on variety, but are generally spindle-shaped, about 2mm long by 0.5-mm wide, glossy and translucid, and easily detached from the floret (Bogdan, 1966). Because of this, occasional spikelets contain more than one caryopsis.

Rhodes grass ranging from 60 - 160 cm tall, forms strong bunch type stools with runners that rapidly cover the ground surface. It spreads by rhizomes, rooting stolons and seeds. Leaf blades are flat or folded and are 12.5 - 45cm long and 1 - 2cm wide. Inflorescences consists of 6-15 one sided spikes that are clustered at the end of the stem. Spikes are 5 - 10 cm long with numerous spikes that are green when immature turning to copper-brown at maturity.

2.1.1.4 Environmental adaptation

The natural distribution of Rhodes grass through much of Africa, and the extensive sowings and naturalized stands elsewhere demonstrate the wide environmental adaptation of the species as a whole. At the same time, this also reflects the

tremendous range of intra-specific variation, such that different forms can exploit certain environmental niches where others would fail. Where it is well adapted, Rhodes grass normally persists well unless over grazed. A lack of persistence usually reflects more basic problems of adaptation, such as inadequate soil nutrients, low winter temperatures, marginal rainfall, and drought.

Rhodes grass is suitable to tropical and subtropical areas with rainfall ranging from 600 - 1600mm annually when grown on pasture .The crop is grown in a wide range of soils; from clays to sandy loam. It does not do well on very heavy clays. The soil pH range for Rhodes grass is between 5 - 8.3. This pasture crop response well to irrigation and is moderately tolerant of flooding, but is not shade tolerant. It has high salt tolerance ability and can accumulate large amounts of sodium without harm. Rhodes grass responds well to nitrogen fertilizer after a basic pre-plant phosphorus application (Brima, 2007).

2.1.1.5 Rainfall

It is suggested that Rhodes grass is best suited to about 600 to 1200 mm rainfall belt (Cameron, 1967), though the tetraploids have extended this into wetter districts (to 1500 mm average rainfall) where Callide is now the major grass sown in dairy pastures. Experience in South Africa is similar, with the diploid Katambora mainly recommended towards the drier end and the tetraploid Giant towards the wetter end of the range (Dannhauser, 1991; Muir *et al., 2011*). In the drier parts of its native African range, Rhodes grass tends to be restricted to river banks, the margins of flood areas and valley bottoms (van Rensburg, 1948), and has been successfully

cultivated on 'wetter' soils under as little as 450mm rainfall (Dannhauser, 1991; Muir *et al.*, 2011).

2.1.1.6 Temperature

Like other tropical/subtropical grasses, Rhodes grass grows best at high temperatures, as shown by growth chamber studies reporting an optimum of 35°C for photosynthesis (Murata *et al.*, 1965), an almost sixfold increase in DM production of Samford between 20 and 30°C (Ludlow and Wilson, 1970), and a 'plateauing' of relative growth rate for Pioneer above 30/25°C (Sweeney and Hopkinson, 1975).

Data summarized by Bogdan (1969) showed that Rhodes grass was killed by temperatures of about -10°C, which accords with its lack of persistence on the cold South African Highveld (>1400 m above sea level) (Scott, 1955; Fair, 1989; Rethman and de Witt, 1991). Despite this, Rhodes grass has become an important short-term component of pasture sowings on the Highveld, acting as a nurse crop for 1 to 3yr (Rethman, 2000). In controlled environment chambers, Ivory and Whiteman (1978) showed that four diploid accessions (Nzoia, Pioneer, CPI 27211 and CPI 43949) were more resistant to foliar freezing than the tetraploids, Pokot and Samford. Similarly, Loch and Butler (1987) found seed set in Callide (tetraploid) more sensitive to the damaging effects of low night temperatures than in Pioneer. Altitude of origin can have a modifying effect on temperature response. Under their lowest controlled temperature regime (15/10°C), the high altitude tetraploid Masaba (along with the diploids Pioneer and Nzoia) had a higher net

assimilation rate and produced more leaves than Mpwapwa (tetraploid) and a second low altitude ecotype from Serere, Uganda.

2.1.1.7 Soils

Rhodes grass is adapted to a wide range of soil types and conditions. It grows best on fertile loams, ranging from sandy- textured and red volcanic soils to clay loams, but is also reasonably tolerant to less fertile, more poorly drained situations (Cameron, 1967; Bogdan, 1958, 1969; Loch, 1980). Although it will grow once established, Rhodes grass is notoriously difficult to establish on heavy cracking clay soils (Cameron, 1967; Dannhauser, 1991) because of rapid drying of the surface layers causing moisture stress (Leslie, 1965) and poor primary root development of seedlings (Watt and Whalley, l982b; Watt, 1983).

Although it prefers better-drained soils (Bryan and Evans, 1973), Rhodes grass tolerates temporary waterlogging (up to 10-15 d) (Bogdan, 1958, 1969; Dannhauser, 1991; Kretschmer and Wilson, 1995). Plants are killed by deep flooding (>30cm) (Colman and Wilson, 1960) but limited seedling regeneration can occur after flooding (Anderson, 1974).

2.1.1.8 Salinity

Rhodes grass is one of the more salt-tolerant C_4 forage grasses. It occurs naturally on saline sites (Chippendall, 1955; Bogdan, 1969), and numerous authors have commented on its growth and persistence on saline soils or when grown with salty irrigation water. Critical U.S. studies rated Rhodes grass as moderately salt tolerant relative to other pasture plants, though it has been suggested that the tetraploids

Callide and Boma might be less salt tolerant than the diploids (Perez *et al.*, 1999). Rhodes grass germinates under higher salinity levels (Abd El-Rahman and El Monayeri, 1967) and tolerates, high sodium (Na^+) levels better than alternative grasses (Bower and Wadleigh, 1948; Gauch and Wadleigh, 1951; Russell, 1976; Brauer and Wolfson, 1986).

Rhodes grass uses a range of physiological mechanisms to mediate salt toxicity (de Luca *et al.*, 2001). Rhodes grass also accumulates higher Na^+ levels in plant tissues (tops > roots) as the concentration in the growing medium increases (Bower and Wadleigh, 1948; Gauch and Wadleiglh, 1951; Ando *et al.*, 1985), but this is accompanied by progressively reduced plant potassium (K^+) levels (Smith, 1974, 1981). Andrew and Robins (1971) recorded higher Na^+ levels (58% of total cations) in Pioneer Rhodes grass than in eight other C_4 grasses. This, in turn, was balanced by low K^+ levels (20% of total cations) in plant tops.

There is evidence that, at the cellular level, Rhodes grass can compartmentalize saline ions within the vacuole while maintaining cytoplasmic osmotic potential through the accumulation of compatible organic solutes.

2.1.1.9 Other Ecological Factors

As would be expected for a grass from the African savannas, Rhodes grass is tolerant to fire (Skerman and Riveros, 1990), although a heavy fire may thin the stand by killing some of the smaller rooted stolon nodes (Loch, unpublished data, 1975). It is also not shade tolerant (Skerman and Riveros, 1990), as expected from its origin in open woodlands and grasslands.

2.1.1.10 Rhodes grass as forage

Rhodes grass is widely grown on rangeland, irrigated pastures as a pure stand or as a mixture with legumes in irrigated agriculture.

Chloris gayana can be used as a fresh forage or in the form of silage, but utilization as hay and green forage is the major use. According to FAO, (2003) the crop makes quite good hay if cut just as it begins to flowering or a little earlier. Old stand gives low quality hay. Silage has been made successfully in Nigeria, Zambia and Northern Australia, but generally it does not give satisfactory silage.

Gherbin *et al.* (2007), showed that *Chloris gayana* yielded high dry matter in warm-season areas when grown with other species (grasses) and showed values ranging from 16.4 to 21.1ton/ha.

It is found that Rhodes grass resulted in the highest yield from mixture of grasses with butterfly pea and Phillipesara in Sudan. Ehrlich *et al.* (2003) pointed that reducing the frequency and total volume of irrigation resulted in a reduced level of soil water and pasture yields of Rhodes grass.

2.1.1.11 Fertilizer Use

Rhodes grass becomes less persistent as soil fertility declines, and this trend can be exacerbated by overgrazing. Katambora, however, appears better adapted to, and is more persistent on, low fertility soils than other cultivars (Cook, 1978; Skerman and Riveros, 1990).

2.1.1.12 Insect Pests

Rhodes grass can be damaged at times by a number of different insects, none of which presents major problems.

Typically, these pests also affect other grasses to a greater or lesser extent. Rhodes grass scale (*Antonina graminis*) warrants further mentioning because it was of specific concern in the USA prior to the introduction of effective predators during the 1950s. Biological control is the most effective long-term solution, and has been achieved in different U.S. states and in different countries with at least two separate parasitoids (*Anagvrus antoninae, Neodusmetia sangwani*), which differ in their environmental adaptation.

2.1.1.13 Diseases

Numerous fungal, bacterial, and viral diseases are reported to infect Rhodes grass, either naturally or through laboratory inoculation, though few cause significant economic damage. Largely through attrition of susceptible ecotypes (e.g., Nzoia), the current commercial cultivars are relatively resistant to fungal diseases, which generally infect either leaves or grain and seedheads. Grain and head diseases tend to have more restricted distributions, but can cause substantial losses of grain particularly in wet years (Bogdan, 1969). The main virus disease of Rhodes grass is *chloris striate mosaic virus* (CSMV). The causal agent of CSMV is a geminivirus reported only from Australia where Rhodes grass is also infected by the less easily transmitted paspalum striate mosaic virus. Symptoms of maize streak virus, the major African geminivirus, have also been observed on Rhodes grass in Zimbabwe.

2.1.2 FORAGE SORGHUM

2.1.2.1 General

Forage Sorghum (*Sorghum almum*) originated in Argentina and the latitudinal range of the grass is 25°N to 30°S. It can be found at elevations between sea level and 700m (Duke, 1983; Olanite *et al.,* 2010). It is a promising forage crop with a high potential for integration into Nigerian livestock production systems. Ease of establishment, drought and salt resistance, rapid growth and reasonable high yields (4000–12000 kg ha^{-1}) indicate it may be a suitable forage crop for silage production during the rainy season while permitting regrowth for hay production or in situ grazing of the standing crop.

Sorghum almum can reach a height of 4.5 m with its short rhizomes reaching as deep as 50 cm. It can withstand heavy grazing but not heavy trampling. *Sorghum almum* did not feature in the early evaluations of grasses, at least in southwest Nigeria. Meanwhile, preliminary studies in Northern Nigeria (Muhammad, 1993; Muhammad *et al.,* 1997) indicated that the grass is promising in terms of drought tolerance and dry-matter yield. Muhammad *et al.* (1997) also stated that Forage Sorghum is a C_4 grass.

Elsewhere, the response of the grass to nitrogen (N) fertilizer for dry-matter yield and nutritive quality was also recorded (Narayanam and Dabadghao, 1977). Forage species that show encouraging performances in the northern part of Nigeria may

not necessarily do well in the south because of vast differences in climatic and soil factors.

2.1.2.2 Common names

Columbus grass (Australia), five-year sorghum, Sorgo Negro, Sudan Negro (Argentina).

2.1.2.3 Description

A more robust species than *S. halepense* (q.v.), sometimes reaching 4.5 m in height. It is a short- term perennial. The most satisfactory method of distinguishing between the two is by the articulation of the pedicelled spikelet. In *S. almum* the spikelet breaks off with the uppermost portion of the pedicel at maturity; in *S. halepense* there is a clean abscission at the base of the spikelet. *S. almum* usually produces short rhizomes, more or less pointing upwards, which are not as extensive or aggressive as those of *S. halepense*, but reach a depth of 50 cm (Chippendall, 1955; Pritchard, 1964).

2.1.2.4 Distribution

It originated in Argentina as a probable hybrid between *Sorghum halepense* and a member of the series *Arundinacea*. It has now been introduced into several tropical countries.

2.1.2.5 Rainfall requirements

It is usually grown within the annual rainfall range of 460-760 mm, but may be grown under irrigation, or in areas with up to 1900 mm annual rainfall (Russell & Webb, 1976).

2.1.2.6 Drought tolerance

It is more tolerant to drought than maize, Sudan grass and Johnson grass, and has survived in areas receiving 200 mm of annual rainfall.

2.1.2.7 Soil requirements

It prefers a soil of high fertility, from light loams to heavy clays, with a pH range from 5 to 8.5.

2.1.2.8 Response to fire

It is rarely necessary to burn, but an established crop would survive a quick fire.

2.1.2.9 Diseases

Susceptible to leaf diseases (*Helminthosporium turcicum*, blight, and *Puccinia purpureum*, rust).

2.1.2.10 Pests

It can be attacked periodically by grasshoppers, army-worms and wild predators.

2.1.3 CONGO GRASS

2.1.3.1 General

Congo grass (*Brachiaria ruziziensis*) has been widely used in crop rotation and crop-livestock integrated systems in the world because of its good adaptation to low fertility soils, high yield potential, and good forage quality (Garcia *et al.*, 2008). This grass may have a positive effect on soil P availability, resulting from the influence of organic acids on P sorption, since it can exude citrate or oxalate under low pH conditions (Louw-Gaume *et al.*, 2010) and decrease the maximum

adsorption capacity of P in the soil (Janegitz *et al.*, 2013). In addition, the activities of root acid phosphatases and phytases of Congo grass were higher under conditions of low P supply (Merlin *et al.*, 2009). *Brachiaria ruziziensis* belongs to the Poaceae family, Panicoideae subfamily and the Paniceae tribe. A tufted grass, Congo grass is a creeping perennial that has short rhizomes which form a dense leafy cover over the ground. Stems of the plant arise from many-noded creeping shoots and short rhizomes and then when fully grown reach a height of 1.5 m when flowering. The leaves of this grass are soft but hairy, with an average width of 15mm, length of 25mm and a seed weight of 250,000/kg. The seeds should be drilled into a well prepared seed bed, sowing in rows that are spaced 60 cm apart and it can be grazed upon as soon as it is ready.

2.1.3.2 Origin and early history

Congo grass is a tropical forage native to Africa, found in regions such as the Ruzizi Valley, in the Democratic Republic of the Congo and Burundi. Germplasm of this species was originally obtained from Rwanda, multiplied in Kenya in the early 1960s, and then spread to continental Africa and Madagascar.

From Madagascar, it was sent to Australia (Keller-Grein *et al.*, 1996). Reports mention its first introduction in Brazil also in the 1960s, probably after its release in Australia as cultivar Kennedy, by the Queensland Herbage Plant Liaison Committee, in 1966 (Keller-Grein *et al.*, 1996).

Early reports of germplasm collections of Congo grass date back to the 1950s, led by the National Agricultural Research Station in Kitale, Kenya (Keller-Grein *et al.*, 1996). A second initiative took place in eastern Africa, in 1984 and 1985.

It was supported by the International Board for Plant Genetic Resources (IBPGR, now Bioversity International), and the International Livestock Centre for Africa (ILCA, which took part on the foundation of the International Livestock Research Institute, ILRI). These accessions were deposited in the germplasm collection of the International Center for Tropical Agriculture (CIAT) and, in 1987, were brought to Brazil for agronomic evaluations performed by the Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária, Embrapa), for their use as forage In the new agricultural frontier of the Brazilian Cerrados.

2.1.3.3 Other names

The species is known under various common names depending on the countries in which it is grown. These include: Kennedy Ruzi grass (Australia) - Kennedy is now regarded as the Australian cultivar name (D. Loch, personal communication 1999), Congo Signal grass (Africa), prostrate Signal grass (Kenya), and Ruzi grass (Thailand). The names "Congo grass" and *Brachiaria ruziziensis* are used in this study.

2.1.3.4 Taxonomy and morphology

Congo grass is a short-lived perennial grass (Husson *et al.*, 2008). It is tufted, creeping (semi-prostrate) and rhizomatous. It roots from the nodes and forms a dense leafy cover (Cook *et al.*, 2005; Urio *et al.*, 1988). Congo grass has a dense

system of bunched, quickly growing roots that can go as deep as 1.8 m (Husson *et al.*, 2008). Culms grow from the nodes of the rhizomes and may reach 1.5 m high when flowering (Cook *et al.*, 2005). The leaves are soft but hairy on both sides, lanceolate in shape and up to 25 cm long x 1-1.5 cm broad, light-green in colour. Inflorescence consists of 3-9 relatively long racemes (4-10 cm), bearing spikelets in 1 or 2 rows on one side of a broad, flattened and winged rachis (Cook *et al.*, 2005). The spikelets are hairy, 5 mm long. The weight of 1000 grains is about 4 g (Husson *et al.*, 2008). Congo grass is very similar to signal grass (*Brachiaria decumbens*) and is often mistaken for it (Cook *et al.*, 2005). Genetic material from Congo grass has been used to hybridize with *Brachiaria brizantha* and yielded a series of cultivars known as Mulato (Argel *et al.*, 2007; Argel *et al.*, 2005).

Five stages of morphological changes in the apex, and the visible changes occurring during reproductive development of Congo grass have been reported by Wongsuwan *et al.*, 1997. The inflorescence consists of dense and spike-like racemes. The spikelets are all sessile and close together, the rachis of the racemes winged, broad and over 3 mm wide. The lower glume is under half the length of the spikelet which is hairy (Haker and Napper, 1960). Congo grass has softer leaves than *Brachiaria brizantha* (Schum) Stapf and Hubbard (Deinum and Dirven, 1976).

2.1.3.5 Rainfall

Rattay. (1973) reported that Congo grass grows successfully at an altitude range of 1000 - 2000m above sea level in Kenya and up to 1200m in Panama. It is most productive under an average annual rainfall of about 1000mm and can endure hot

dry spells (Skerman and Riveros, 1990), and hence is described as drought resistant. It will not, however, withstand flooding or frost.

2.1.3.6 Temperature

Being a tropical species, the main season of growth of Congo grass is during the rainy season in the so-called summer or warmer period of the year, with an optimum temperature of 33°C day and 28°C night (Deinum and Dirven, 1972). Plant growth is stimulated by increasing temperature which leads to lower protein content and lower digestibility of organic matter in leaves and stems. Temperature also has a direct negative effect on stem digestibility, apart from its effect on stem development (Deinum and Dirven, 1976). Lower temperatures, as found by Ludlow (1976), adversely affect the growth rate of this species.

Dirven *et al.*, (1979) found that first head emergence occurred later in a $12^{1/2}$ hour treatment than in two shorter photoperiods (9 and $10^{1/4}$ hours).Moreover, they found that the shorter the day-length the greater the number of heading tillers produced, and accordingly they concluded that *B. ruziziensis* was a quantitative short-day plant.

2.1.3.7 Soils

Congo grass requires light to loam soils of moderately high fertility (pH 5.0–6.8) and cannot tolerate strongly acid conditions.

2.1.3.8 Light

Congo grass has moderate shade tolerance and is grown under coconut plantations.

2.1.3.9 Defoliation

It can stand moderately heavy grazing and requires high levels of fertilizing to persist under frequent cutting.

2.1.3.10 Fire

Congo grass will recover after a fire, but burning is not recommended.

2.1.3.11 Congo grass as forage

Congo grass is very palatable and suitable not only as a green forage for dairy cattle (Sanchez and Soto, 1998) but also as hay (Rensburg, 1969) and silage (Risopoulos, 1966).

2.1.3.12 Fertilizer Use

It will tolerate acid soils and also responds well to nitrogen, either from fertilizer or legumes, but has a higher requirement than Guinea grass (Mellor *et al.*, 1973b).

On the Adamawa plateau of the Cameroons, Pamo and Pieper (1989) showed that nitrogen fertilization in combination with phosphorus and potassium increased the productivity of Congo grass and recommended that a fertilizer rate of between 60-90 kg nitrogen/ha be applied after each cutting, with a single application of 100 kg triple superphosphate and potassium sulphate/ha at the beginning of each rainy season. This response was obtained under a 30 day cutting frequency. In field trials in Ribeirao Preto, Sao Paulo, Brazil, Andrade *et al.*, 1996 reported nitrogen increased dry matter and crude protein yields of *B. ruziziensis* by 319% and 598 %, respectively, and also significantly increased forage concentrations of S, Zn and Cu, while effects of potassium were not significant.

Dry matter production of Congo grass can vary considerably, depending on rainfall, fertility conditions and management. In Tanzania, dry matter yields of 21159 kg/ha have been recorded (Naveh and Anderson, 1967), and at South Johnstone, North Queensland, Grof and Harding (1970) recorded dry matter yields of 19500 kg/ha under a six week cutting intervals and following an input of 220 kgN/ha/year. In Sri Lanka dry matter yields of 16807, 22031 and 25585 kg/ha/year were obtained with nitrogen applications of 112, 224 and 336 kgN/ha respectively (Appadurai, 1975).

2.1.3.13 Seed dormancy

Seed dormancy is generally high in freshly harvested seed, because of an impermeable seed coat (Davidson, 1966; McLean and Grof, 1968), for removing the hull or cutting at the base of the spikelet stimulates germination (Renard and Capelle, 1976). Davidson (1966) found that only 20% of fresh seed germinated and after 12 months in storage germination was increased to 40%. Seed dormancy can be broken by treating the seed with concentrated sulphuric acid for 15 minutes (Banad, 1969) which can increase germination from 17 to 40% (McLean and Grof, 1968), or by mechanical scarification (Jones, 1973a).

2.1.3.14 Insect Pests and Diseases

Congo grass is severely attacked by spittlebug (*Aeneolamia* spp., *Deois* spp. and *Zulia* spp.) in tropical Africa. Leaf is attacked by foliar blight (*Rhizoctonia solani*) in tropical Africa. Seed heads are attacked by a fungus (*Sphacelia* spp.) in Zaire.

2.2 GRASS GROWTH MODEL

Grass growth 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 genera *Cynodon*, *Paspalum*, *Panicum* and *Brachiaria*. Their application, however, is often location or region specific. The adaptation of mechanistic models to accurately predict biomass accumulation in tropical grasses is still limited. Recent advances have been made on the plot-scale and farm-scale process-based models ALMANAC, CROPGRO Perennial Forage and agricultural production systems simulator (APSIM), with promising results. In addition, global-scale process-based models, such as the Century Agroecosystem Model and the Orchidee Grassland Management Model, have been tested for tropical grassland areas. A greater number of region-specific calibrations of empirical models can enhance their use, and improved databases and model parameterizations for a wide range of tropical grasses will enable the continuous improvement of mechanistic models.

Grass growth models can be valuable tools to evaluate long-term effects of environmental variations (e.g. weather patterns and soil characteristics) and management on plant responses, but they must be tested and calibrated for new regions before their application can be extrapolated to predict crop responses accurately. Models can summarize a great deal of information, facilitate knowledge application and be used in defining agricultural policies, agro-climatic zoning,

climate change studies and production planning. Grass growth 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 which is used to predict growth, development and yield, even for large scale applications. Thus, models can aid in the organization, interpretation and application of current scientific knowledge, identifying research priorities in areas where current knowledge is insufficient and favoring the appearance of new ideas.

Grass growth 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. 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.

In general, the greatest limitation for developing and improving grass growth models is the limited availability of information and knowledge about the physical and physiological processes involved, the responses of the system to be simulated, and data availability. Despite their importance and dissemination, grass models are still little used in most tropical areas, and few studies have reviewed or evaluated the application of models created or adapted for tropical forages. This is partially explained by the lack of understanding of their capabilities and limitations, lack of

experience in calibrating, evaluating and using models, and a general lack of model credibility in tropical areas.

2.2.1 Classification of models

Corral and Fenlon (1978) estimated grass growth on a 4-week harvest interval with the main focus of the research based on calculating growth rate using a quadratic equation. Corral and Fenlon (1978) observed a remarkable production loss of 23% in the second year mainly due to a slight deficit in the organic manure but they observed that their peak production rate was during their first year; it thus can be concluded that the loss of the soil's organic matter led to the 23% loss in the second year. Their research was meant majorly to calculate the rate at which their grass species grew; the research was simplistic and mechanical in approach but never gave recognition to the effect the organic matter had in the grasses' growth.

Brereton *et al.* (1996) developed a model at the Teagasc Research Centre at the Johnson Castle in Wexford, Ireland. The model is driven mainly by empirical relationships, relating growth of the grass as a whole to temperature and light. It is static in approach in that it does not describe growth over time by daily iterations of growth rates, but rather estimates yield at the end of a stipulated time period, given the environmental conditions during the period. It was originally created as a basis for evaluating the farm-scale behavior of grassland systems and the dynamics of grazing management as affected by weather conditions from year to year on farms in Ireland. The model does not and was not intended to; describe the nature of grass growth, as it is not process-based. The Brereton model tried its best to give an estimate of yields at the end of a time period/planting period leaving out the

details of the accumulation of biomass in the grassland; it also didn't do enough justice to the Dry Matter (DM) content accumulated by the herbage by each cutting period.

Jouven *et al.* (2006) during their research developed a dynamic and mechanistic model that is able to simulate the effects of management (type and intensity) on biomass, structure and quality dynamics at the field scale. The Jouven model attempts to combine functional and structural aspects of grass growth. This model was developed in Ireland but focuses mainly on the effects of management of a field has on the growth rate of grass.

2.3 MODEL FUNCTIONS

2.3.1 Model functions for biomass accumulation

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

Single soil type - (Ss)

The same 50g of fertilizer will be added - (F_q)

The organic component of the soil will be analyzed - (O_s)

The inorganic component of the soil will also be analyzed - (I_s)

The organic component of cut grass (after analysis) - (G_o)

The inorganic component of cut grass (after analysis) – (I_o)

The nutrient composition is expressed as N_g

Error recorded is expressed as E_t

Where,

Biomass of the soil expressed in BM, kg/pot (BM_S) = $I_s + O_s$ ------- (1)

Where,

Biomass of the grass expressed in BM, kg DM/pot (BM_G) = $G_o + I_o$ (2)

Where,

$BM_G = BM_S + F_q - N_g \pm E_t$ ----- (3)

Where,

The biomass accumulation for i days will be expressed as:

$BM_{Gi} = \sum_{t=0}^{n} [BM_{si} + F_i - N_{gi} \pm E_t]$ ------ (4)

The age of the biomass in each cut grass species is calculated daily as expressed above.

2.3.2 Model functions for grass growth rate

Grass growth rate is expressed as G_{gr}

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

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

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

For successive days:

$\%G_{gr} = BM_{si} + \%S_{pgi} + B_{Mgi} + \%M_{pi} + U_{fei}$ ---- (5)

Where,

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

Equating (4) and (6),

$\sum \frac{n}{i=0}[G_{gri} - BM_{si} - \%S_{pgi} - \%M_{pi} - U_{fei}] = \sum \frac{n}{i=0}[BM_{si} + F_i - N_{gi} \pm E_t]$ -- (7) Where,

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

Where,

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

Where,

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

Where,

$\%BM_{si} = \frac{1}{2}[\%G_{gri} - [\%S_{pgi} + \%M_{pi} + U_{fei} + F_i + N_{gi} \pm E_t]]$ ----- (11)

Where growth rate is,

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

Note:

If there are no unforeseen exigencies, $U_{fei} = 0$ and if there are no error recorded, $E_t = 0$.

In the case of unforeseen exigencies that affects $\frac{1}{3}$ of the whole grass variety,

$U_{fei} = \frac{1}{3}$ and so on…

The grass growth model will be expressed in percentage.

CHAPTER THREE

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: February (hot, dry season).

3.2 Soil Description

The soil used in the study was an upland loam soil. Soil samples to 10 cm, taken in February 2016, showed that the soil was basic (pH 8.17; water method), and high in organic matter (32.62%), Nitrogen (5.19%), Phosphorus (535.53 ppm; Bray I extraction method), Zinc (93.35 ppm), and Copper (9.93 ppm).

3.3 Layout and treatments

The planting was done using completely randomized design (CRD) in 3-rows with 4 replicates of 8 pots of each grass species and a spacing of 1m long apart was applied between each bed.

3.4 Viability test and Planting

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

Each Bag used in planting contained 27kg of soil with each bag labelled with SA, BR, and CG respectively; the soil was taken from the oil-Palm plantation of the University. Sowing was done by broadcasting the *Chloris gayana* seeds on the labelled Bag, the *Brachiaria ruziziensis* seeds were planted by hand-drilling three seeds at 1.5m apart at three different spots on each labelled bag, the *Sorghum almum* grass was also planted by hand-drilling three seeds at 1.5m apart at three different spots on each labelled bag. Planting was done on 2/2/16. The bags containing each grass seeds were irrigated every three days; there was application of NPK 15:15:15 fertilizer on each grass specie. Manual hand-picking of weeds was done.

Plate 1. Viability test result for *Sorghum almum*

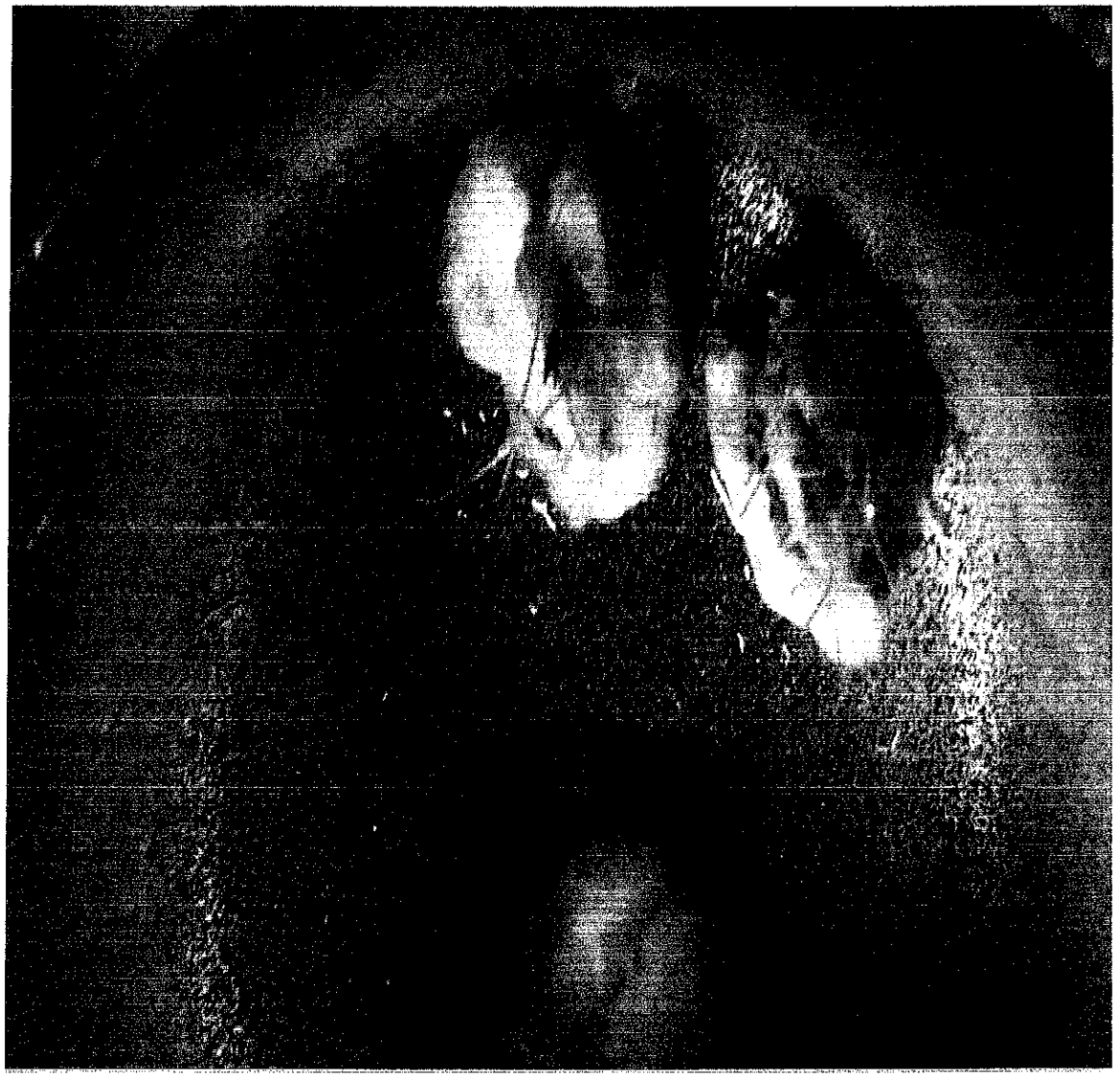

Plate 2. Viability test result for *Brachiairia ruziziensis*

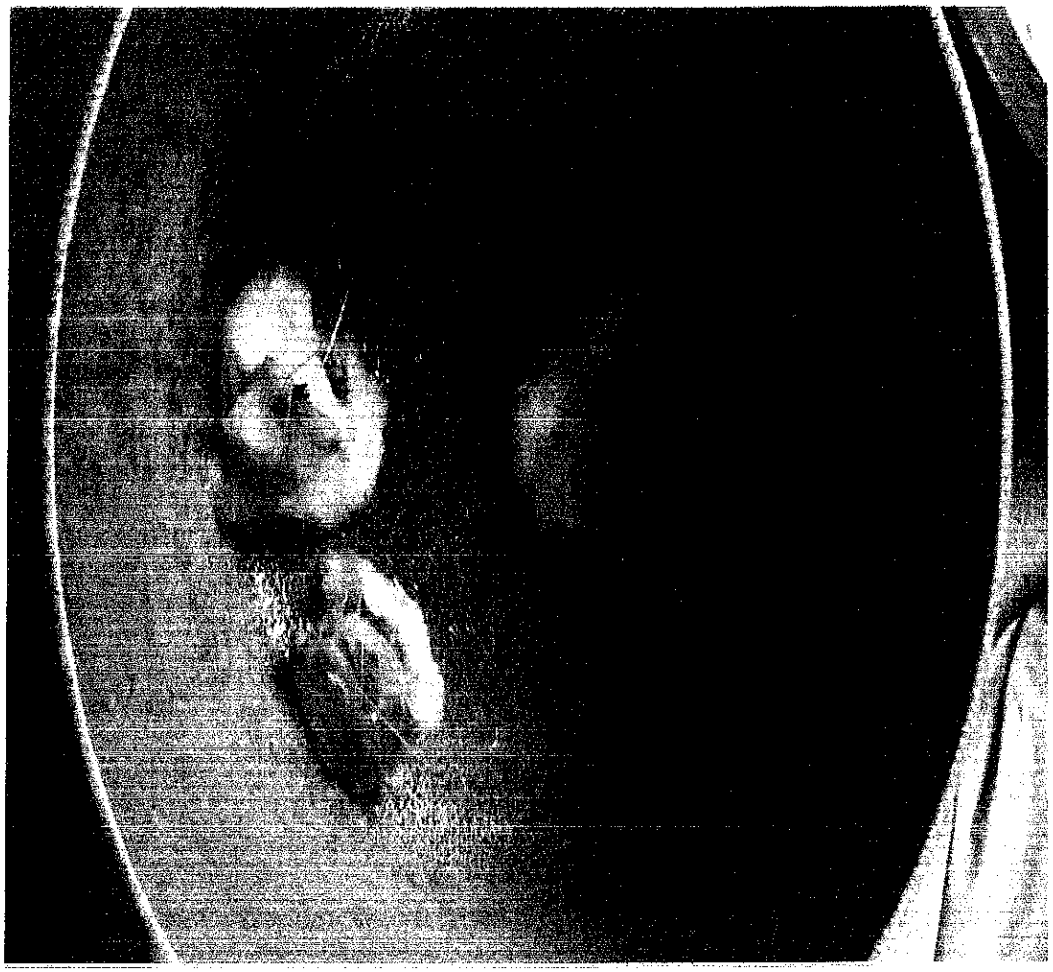

Plate 3. *Viability test result for* Chloris gayana

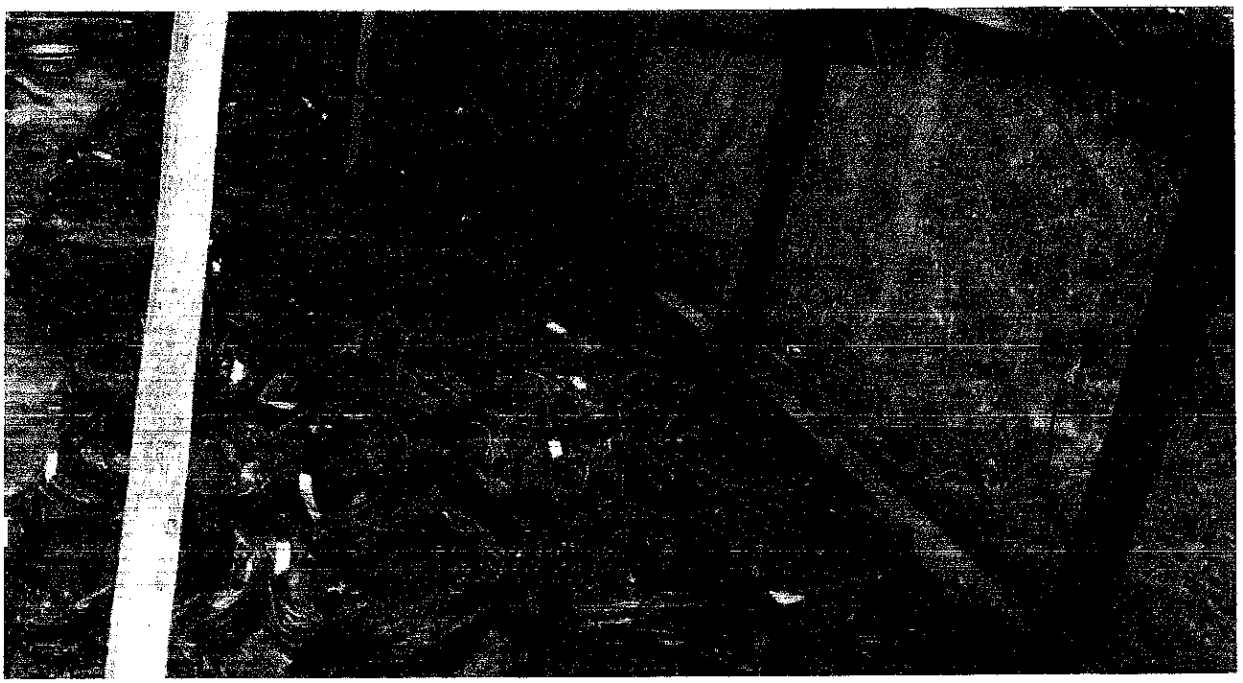

Plate 4. Arrangement of bags in the Screen-house.

Plate 5. A growing grass (*Sorghum almum*)

Plate 6. A growing grass (*Brachiaria ruziziensis*)

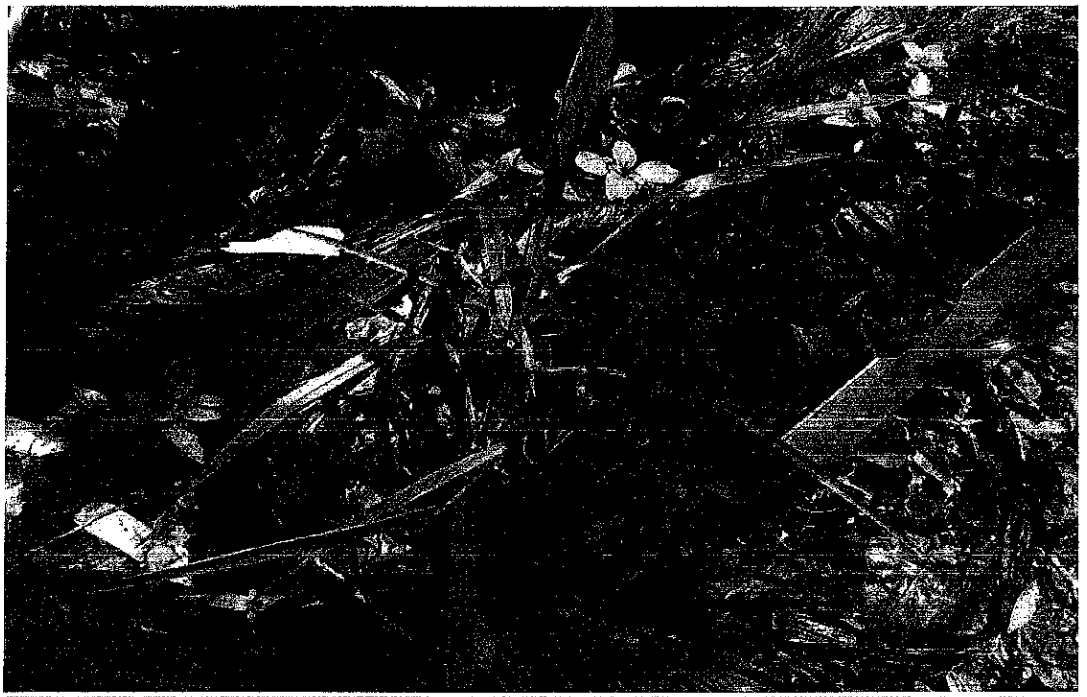

Plate 7. A growing grass (*Chloris gayana*)

3.5 DATA COLLECTION

3.5.1 Plant Height

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

3.5.2 Number of Stalks

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

3.5.3 Sward Height

Every two weeks, each grass specie's sward height was measured using a short metre rule and the values obtained were recorded.

3.6 CHEMICAL ANALYSIS

3.6.1 Soil Attributes

3.6.1.1 Soil before planting

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

3.6.1.2 Soil pH (in water)

10cm of the soil was collected and extracted into the extraction cup after oven drying and determining the moisture content. The extraction cups were allowed to stand for 25 minutes after stirring well; the pH value was read

on the pH meter standardized with buffer solution of pH 4.0 and 7.0 (IITA, 1982).

3.6.1.3 Soil Organic Carbon

3.6.1.3.1 Apparatus used

i. Conical flasks (250ml).

ii. Pipettes (5, 10, 15, 20,25ml).

iii. Custom Laboratory dispensers (10ml, 100ml).

iv. Automatic pipettors (20ml).

v. 50ml vials with wooden stands.

vi. Brinkman Probe Colorimeter.

vii. Weighing balance.

3.6.1.3.2 Procedure Followed

The soil organic carbon was determined by the Walkley Black Modified Method (1976); after air drying the soil, about 1.000g of the air dried soil was weighed into a special weighing boat, after the soil was transfer to a clean and dry 250ml conical flask; blanks and carbon standards were prepared using a pipette 2ml of working standards 0, 2.5, 5.0, 7.5, 10.0 and 12.5mg org c/mol into six different 250ml size conical flasks. Each flask then contained 0.0, 5.0, 10.0, 15.0, 20.0, and 25.0 organic carbon which is equivalent to 0.0,, 0.5, 1.0, 1.5, 2.0 and 2.5% organic carbon; 10.0ml of 1N $k_2Cr_2O_7$ was dispensed accurately into each flask using the custom

laboratory dispenser, after the flasks were swirled gently so that the soil is wetted and dispersed.

An automatic pipettor was used to dispense 20ml of concentrated H_2SO_4 into the soil suspension and it was swirled vigorously for one minute; this was done in a fume hood. The soil was allowed to stand in the conical flask for 30 minutes, after 100ml of distilled water was added using a custom laboratory dispenser; small portions of the solutions was filtered using a No. 2 Whatman filter paper into 50 vials. The vials were later read on a Brinkman probe colorimeter (Baker, 1976) using a 4cm probe and 650nm filter with the blank set at 100%Transmittance.

3.6.1.4 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).

3.6.1.4.1 Apparatus used

i. Atomic Absorption Spectrophotometer (Ca-Mg-Mn).
ii. Flame Photometer (K-Na).
iii. Mechanical stirrer (1550 rpm).
iv. Set of extraction cups.
v. Dispenser (30ml).

vi. Filter paper No. 540 (9cm).

vii. Weighing balance

3.6.1.4.2 **Procedure followed**

About 5.0g of soil was weighed and transferred to an extraction cup; after, about 30ml of 1N NH_4OA_C was added using a custom laboratory dispenser, and then the soil was stirred for 15minutes on a mechanical stirrer (1550 rpm).

The soil suspension was allowed to stand for 15 minutes and later filtered using a Whatman No. 540.

Using the Atomic Absorption Spectrophotmeter, Ca, Mg and Mn was read while the flame photometer was used to read for both Na and K, respectively.

3.6.1.5 Determining Soil Total Nitrogen

3.6.1.5.1 **Apparatus used**

i. Complete Tecator Digestor System (unit of 20 tubes).

ii. Top loading weighing balance.

iii. Acid dispensor.

iv. Technicon's Autoanalyzer (AAII).

3.6.1.5.2.1 Procedure followed

3.6.1.5.2.2 Soil digestion

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. 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. 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.

3.6.1.5.2.3 Calculation

$$\% \text{ Total Nitrogen in soil} = \frac{\% \text{ chart reading x } 0.5 \text{ x } 250 \text{ x } 100}{2 \text{ x } 106}$$

3.6.2 GRASS SPECIE ATTRIBUTES

3.6.2.1 Crude Fibre Content

Crude fibre was determined using the Filter bag Technology (ANKOM, 2000) (ANKOM Technology, Macedon, NY). 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.

3.6.2.1.1 Apparatus used

i. Analytical Balance—capable of weighing 0.1 mg.

ii. Oven—capable of maintaining a temperature of 102 ± 2°C.

iii. Electric muffle furnace—with rheostat control and pyrometer that will maintain a temperature of 600 ± 15°C.

iv. Digestion instrument—capable of performing the digestion at 100 ± 0.5°C and maintaining a pressure of 10-25psi. The instrument must be capable of creating a similar flow around each sample to ensure uniformity of extraction (ANKOM 2000 with 65rpm agitation, ANKOM Technology).

v. Filter Bags—constructed from chemically inert and heat resistant filter media, capable of being heat sealed closed and able to retain 25 micron particles while permitting solution penetration.

vi. Heat sealer—sufficient for sealing the filter bags closed to ensure complete closure (1915, ANKOM Technology).

vii. Desiccant Pouch—collapsible sealable pouch with desiccant inside that enables the removal of air from around the filter bags.

viii. Marking pen—solvent and acid resistant (F08, ANKOM Technology).

3.6.2.1.2 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).

3.6.2.1.3 Procedure followed

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). 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). A heat sealer was used to completely seal each filter bag closed within 4mm of the top to encapsulate the sample. 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. 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 level rotated 120 degrees.

3.6.2.1.4 Calculation

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

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).

3.6.3.1 Crude Protein Content

The protein content was 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.

3.6.3.1.1 Apparatus used

i. Kjeldahl digestion flask - 500ml.

ii. Kjeldahl distillation apparatus.

iii. Conical flask, 250 ml.

iv. Burette 50 ml.

3.6.3.1.1.1 Procedure followed

1g of the sample was weighed and transferred to a 500ml Kjedahl flask taking care to see that no portion of the sample (s) clings to the neck of the flask. 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. 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 one hour until the colour of digest changes pale blue, then the digest is cool and about 200ml of water was added. 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 H2 SO4 = 0.0014gm N.

3.6.3.1.1.3 Calculation

Calculate protein as = N x 6.25

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

3.6.4 Moisture Content

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

3.6.4.1 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 x2.5 cm.)

3.6.4.1.1 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 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 cool in desiccator with the dish now reweighed (W2).

3.6.4.1.2 Calculation

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

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

W2 = weight (g) of sample after drying

3.6.5 Crude Ash determination

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

3.6.5.1 Apparatus used

i. Muffle furnace, equipped with a thermostat, set to 575±25°C.

ii. Analytical balance, accurate to 0.1 mg.

iii. Desiccator containing desiccant.

iv. Ashing crucibles, 50 mL, porcelain, silica, or platinum.

v. Porcelain markers, high temperature, or equivalent crucible marking method.

vi. Ashing burner, ignition source, tongs, and clay triangle with stand.

vii. Convection drying oven, with temperature control of 105 ± 3°C.

3.6.5.1.1 Procedure followed

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

3.6.5.1.2 Calculation

$$\text{ODW} = \frac{Weight\ (air\ dry\ sample)\ X\ \%Total\ Solids}{100}$$

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

Where: ODW = oven dry weight

3.6.6 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.

3.6.6.1 Procedure followed

Crude fat content is determined by extracting the fat from the sample using a solvent, then determining the weight of the fat recovered. The sample is contained in a porous thimble that allows the solvent to completely cover the sample. The thimble is contained in an extraction apparatus that enables the solvent to be recycled over and over again. 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. In order for the solvent to thoroughly penetrate the sample it is necessary for the sample to be as finely comminuted as possible. Before the solvent extraction step can begin the sample must be dried. Often a moisture analysis is required as well as a fat analysis and this can be achieved by accurately weighting the sample after drying and before

extraction, as well as before drying. If a moisture analysis is not required the sample need only be weighed before drying and again after solvent extraction. In either case the sample must be weighed accurately on an analytical balance at each stage of the analysis. When the sample is being weighed it is important not to lose any part of it including any moisture that may weep from the sample during weighting. Loss of this moisture can be avoided by weighing the sample directly into a pre-dried extraction thimble or alternatively on to a pre-dried filter paper. If a moisture analysis is required, the dried extraction thimble or filter paper also has to be pre-weighed. After weighing, the sample (in the thimble or filter paper) can be placed in the oven for drying. After drying, the sample can be placed directly into the distillation apparatus for extraction.

3.6.6.2 Calculation

Weight of empty flask (g) = W1

Weight of flask and extracted fat (g) = W2

Weight of sample = S

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

3.6.7 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).

3.7 STATISTICAL ANALYSIS

3.7.1 LINEAR ADDITIVE MODEL

$$Yij = \mu+Gi+Cj+Eij$$

Where,

Yij = Individual cuttings (effects of jth cutting on the ith grass)

μ = General mean

Gi= Effect of the grass specie planted (Growing rate)

Cj= Effect of cuttings (Bi-weekly cuttings)

Eij= Experimental error

3.7.2 DATA ANALYSIS

The data were analyzed using the PROC GLM of SAS (SAS Institute Inc., 2008) with cut time, grass specie. The Duncan's Multiple Range Test at 5% probability level was used to separate the differences between treatment means.

CHAPTER FOUR

RESULTS

4.0 SOIL PHYSICO-CHEMICAL PROPERTIES

4.1 Soil before planting

Table 1. Soil Physical properties

Physical Properties	Concentration (%)
Sand	74
Silt	7
Clay	19
Total Organic Carbon	18.97
Total Organic Matter	32.81

Table 2. Soil chemical properties contd

Chemical properties	**Concentration**
Nitrogen (%)	5.02
Phosphorus (%)	0.96
Potassium (%)	55.71
Calcium (cmol/kg)	3.65
Magnesium (cmol/kg)	1.13
Sodium (cmol/kg)	0.08
ECEC (cmol/kg)	2.63
pH	8.10

ECEC= exchangeable cation exchange capacity

Table 3. Soil metallic properties contd

Metals	**Concentration (PPM)**
Iron	206.65
Manganese	126.95
Zinc	95.25
Copper	9.96
Chlorine	0.17
Aluminum	0.017

4.2 Soil after harvest

Table 4. Soil Physical properties

Physical properties	**Concentration (%)**
Sand	70
Silt	8
Clay	22
Total Organic Carbon	9.50
Total Organic Matter	18.70

Table 5. Soil Chemical properties contd

Chemical properties	**Concentration**
Nitrogen (%)	4.54
Phosphorus (%)	0.61
Potassium (%)	34.17
Calcium (cmol/kg)	2.60
Magnesium (cmol/kg)	0.80
Sodium (cmol/kg)	0.04
ECEC (cmol/kg)	2.63
pH	6.20

ECEC= exchangeable cation exchange capacity

Table 6. Soil Metallic properties contd

Metals	**Concentration (PPM)**
Iron	99.88
Manganese	92.60
Zinc	66.93
Copper	7.90
Chlorine	0.10
Aluminum	0.014

4.3 GROWTH ATTRIBUTES

Table 7. Growth rate of *Sorghum almum, Chloris gayana* and *Brachiaria ruziziensis*

PARAMETERS	**Height (cm)**				**Number of stalks**				**Sward height (cm)**			
Cutting Times	2	4	6	8	2	4	6	8	2	4	6	8
Sorghum almum	18.20^{a}	27.98^{a}	41.10^{a}	89.46^{a}	1.75^{c}	1.59^{c}	2.15^{a}	2.23^{a}	3.01^{c}	3.18^{a}	5.01^{a}	6.01^{a}
Brachiaria ruziziensis	14.34^{b}	18.71^{b}	24.85^{c}	47.00^{b}	1.84^{a}	1.78^{a}	1.72^{b}	1.98^{b}	3.68^{a}	2.76^{c}	3.91^{b}	4.10^{c}
Chloris gayana	12.26^{c}	18.70^{b}	29.67^{b}	39.66^{c}	1.80^{b}	1.68^{b}	1.70^{b}	1.84^{c}	3.30^{b}	2.86^{b}	3.49^{c}	4.43^{b}
SEM	1.14	1.94	4.45	8.05	0.01	0.01	0.01	0.01	0.27	0.12	0.26	0.31

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

4.3.1 Grass height

AvgGrassheight

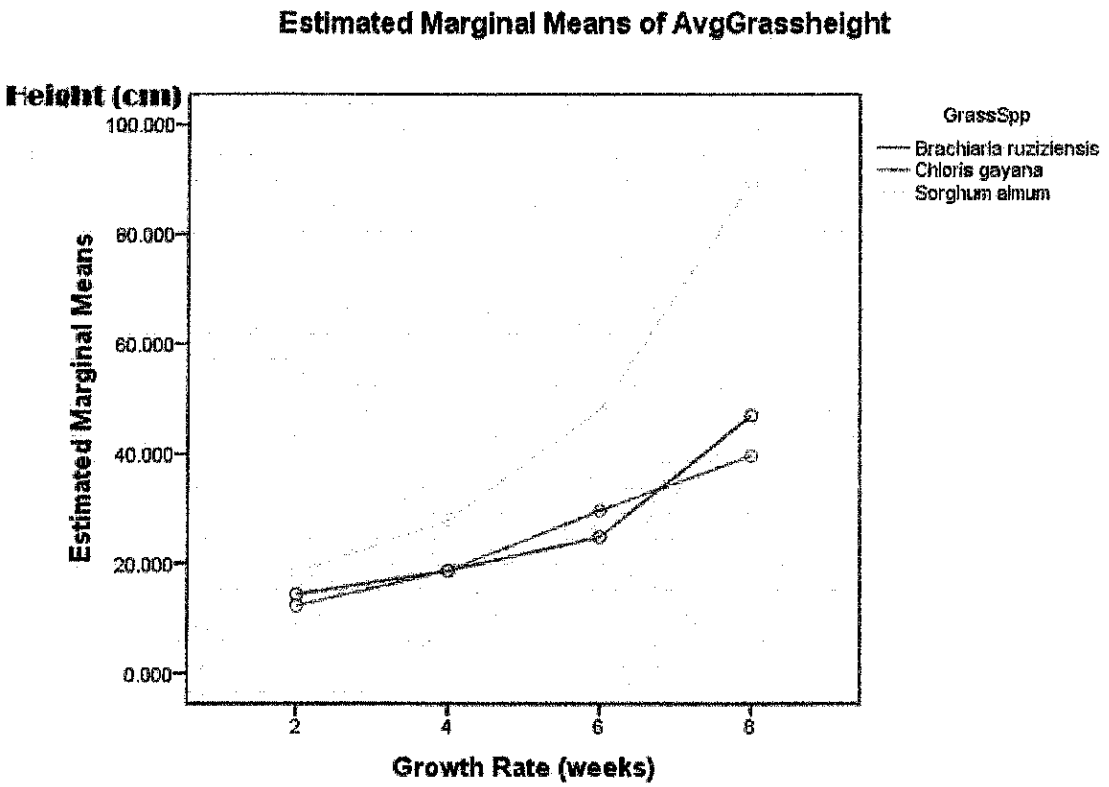

Figure 1. Estimated Marginal means of Average Grass height

4.3.2 Average Sward Height

AvgSwardHeight

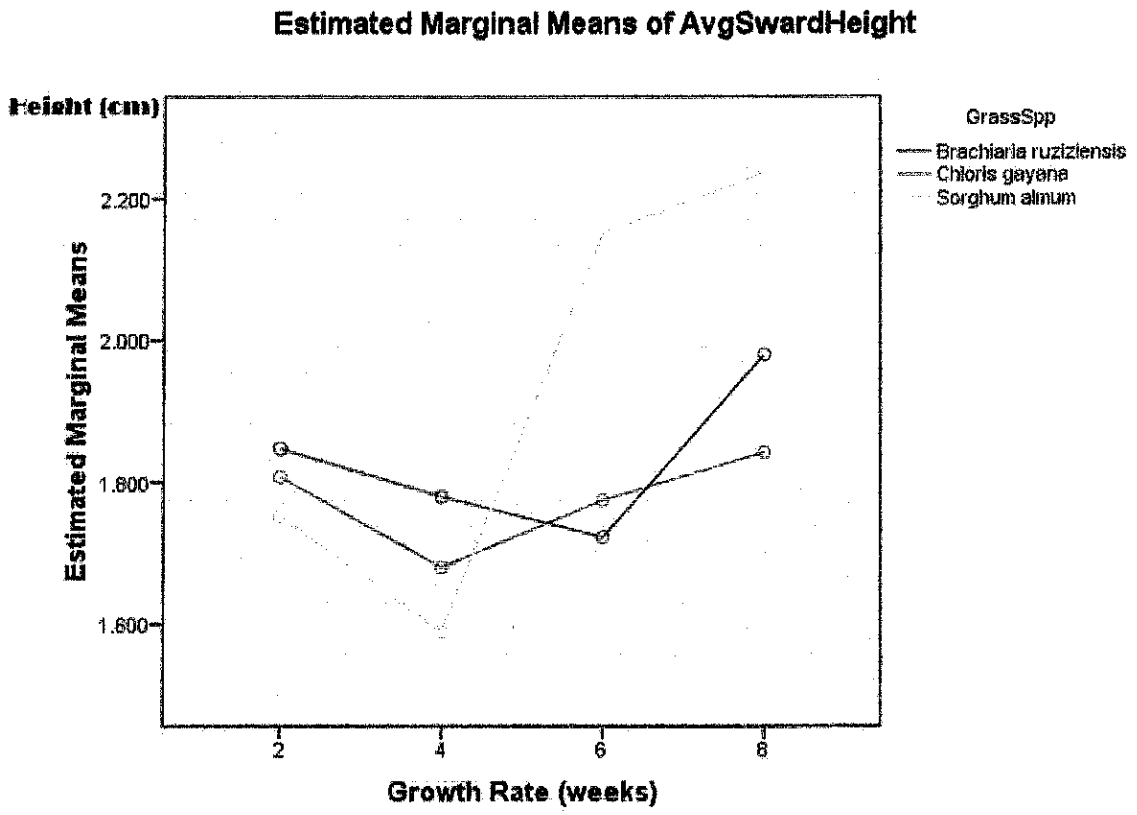

Figure 2. Estimated Marginal means of Average Sward height

4.4 FORAGE QUALITY

Table 8. Proximate composition of *Sorghum almum, Chloris gayana* and *Brachiaria ruziziensis*

PARAMETERS	**Crude Fibre**				**Crude Protein**				**Moisture Content**				**Crude Ash**				**Crude Fat**			
Cutting Times (weeks)	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
Sorghum almum	17.10^{b}	26.47^{a}	28.39^{a}	31.83^{a}	12.11^{a}	10.34^{a}	8.61^{a}	9.40^{a}	9.35^{a}	7.70^{a}	7.03^{a}	7.57^{a}	6.82^{a}	9.61^{a}	10.18^{a}	11.21^{a}	3.49^{a}	3.08^{a}	2.69^{a}	2.87^{a}
Brachiaria ruziziensis	15.45^{c}	19.69^{c}	21.29^{c}	23.20^{c}	4.97^{c}	3.52^{c}	2.95^{c}	0.84^{c}	8.05^{c}	5.25^{c}	4.96^{c}	5.14^{c}	6.33^{c}	7.57^{c}	8.07^{c}	8.64^{c}	1.86^{c}	1.53^{c}	1.40^{c}	0.92^{c}
Chloris gayana	17.93^{a}	23.11^{b}	23.05^{b}	26.67^{b}	7.71^{b}	5.77^{b}	4.52^{b}	2.57^{b}	8.94^{b}	6.36^{b}	5.76^{b}	6.25^{b}	7.07^{b}	8.61^{b}	8.59^{b}	9.67^{b}	2.48^{b}	2.04^{b}	1.76^{b}	1.33^{b}
SEM	0.06	0.06	0.06	0.06	0.18	0.18	0.18	0.18	0.09	0.09	0.09	0.09	0.11	0.11	0.11	0.11	0.14	0.14	0.14	0.14

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

4.4.1 Crude Protein

CP

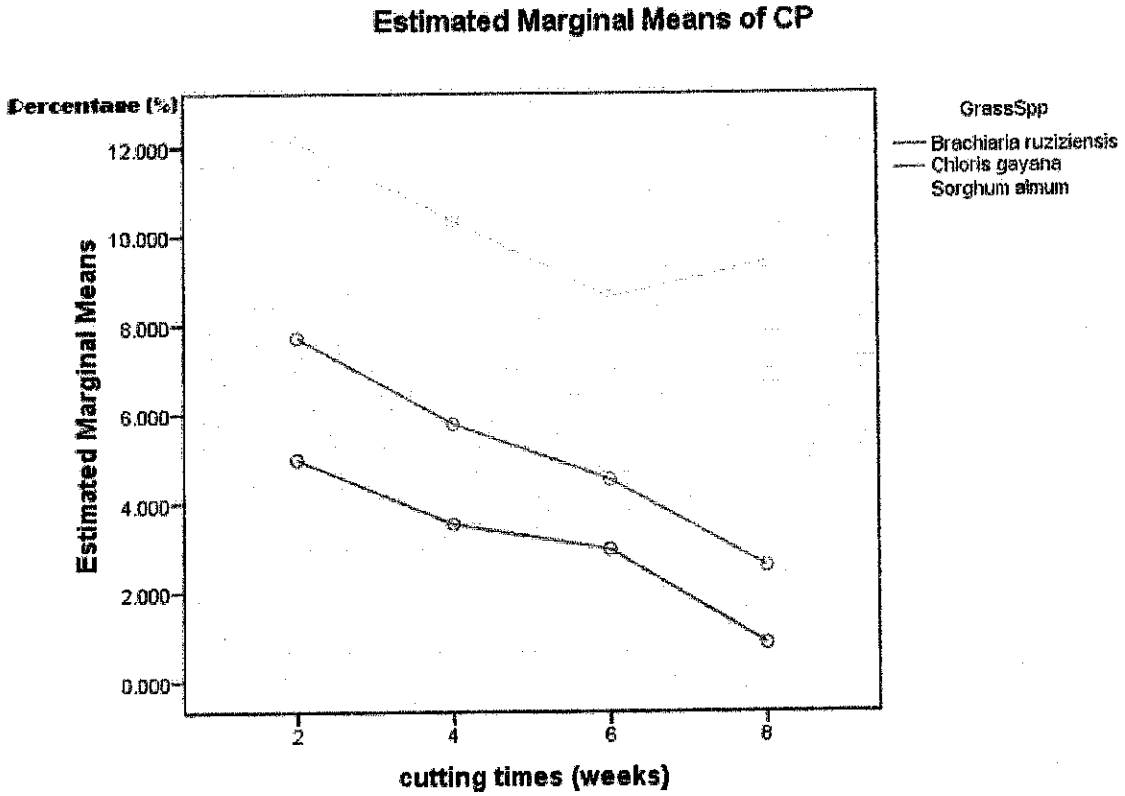

Figure 3. Estimated Marginal means of Crude Protein

4.4.2 Crude Fibre

CF

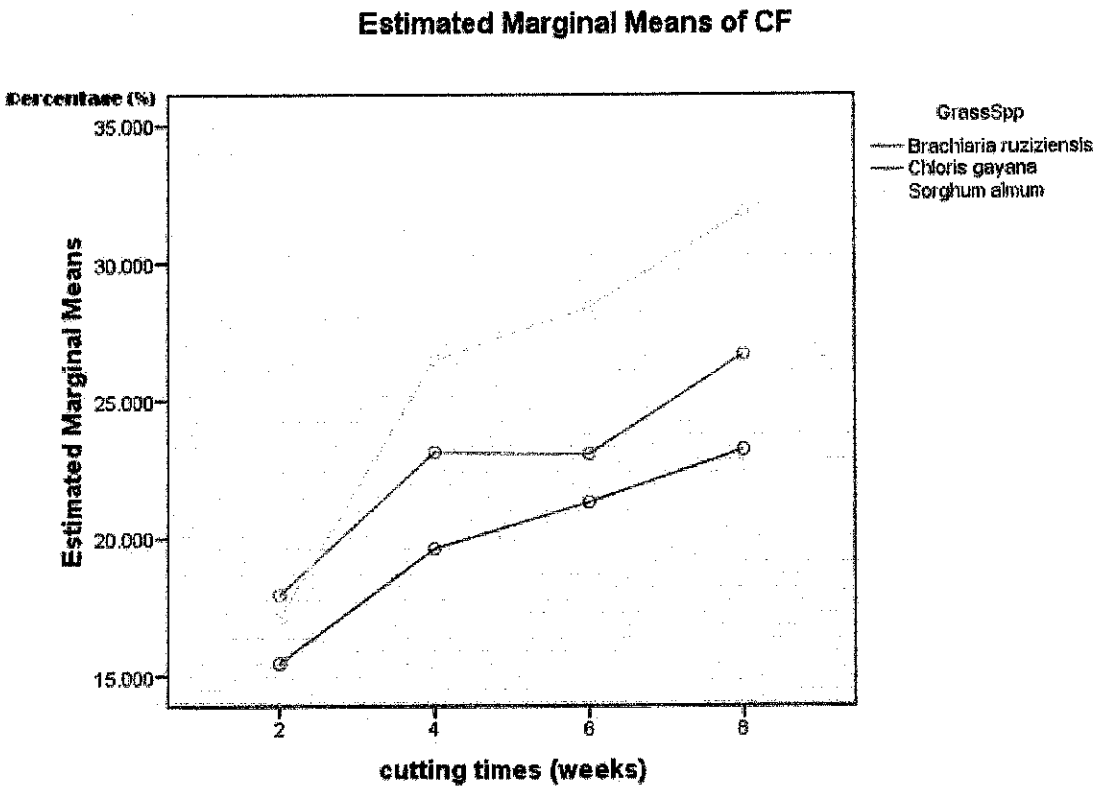

Figure 4. Estimated Marginal means of Crude Fibre

4.4.3 Crude Ash

Ash

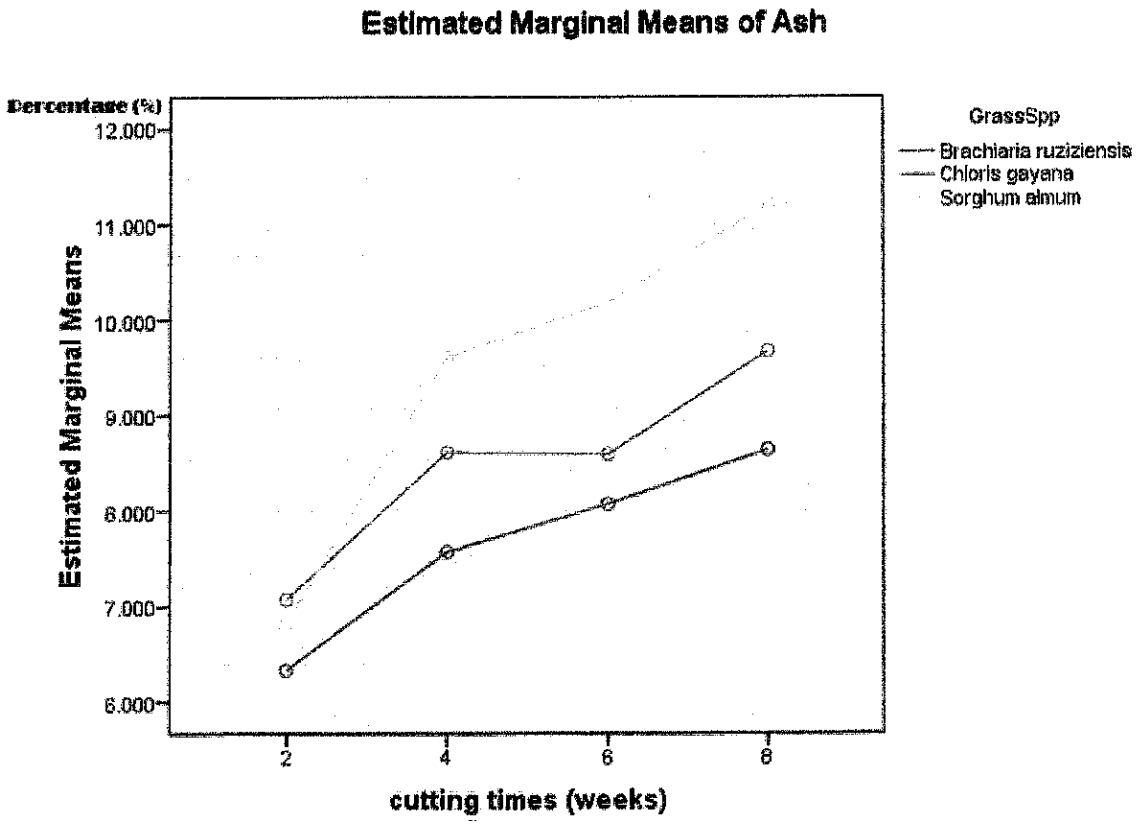

Figure 5. Estimated Marginal means of Crude Ash

4.4.4 Crude Fat

fat

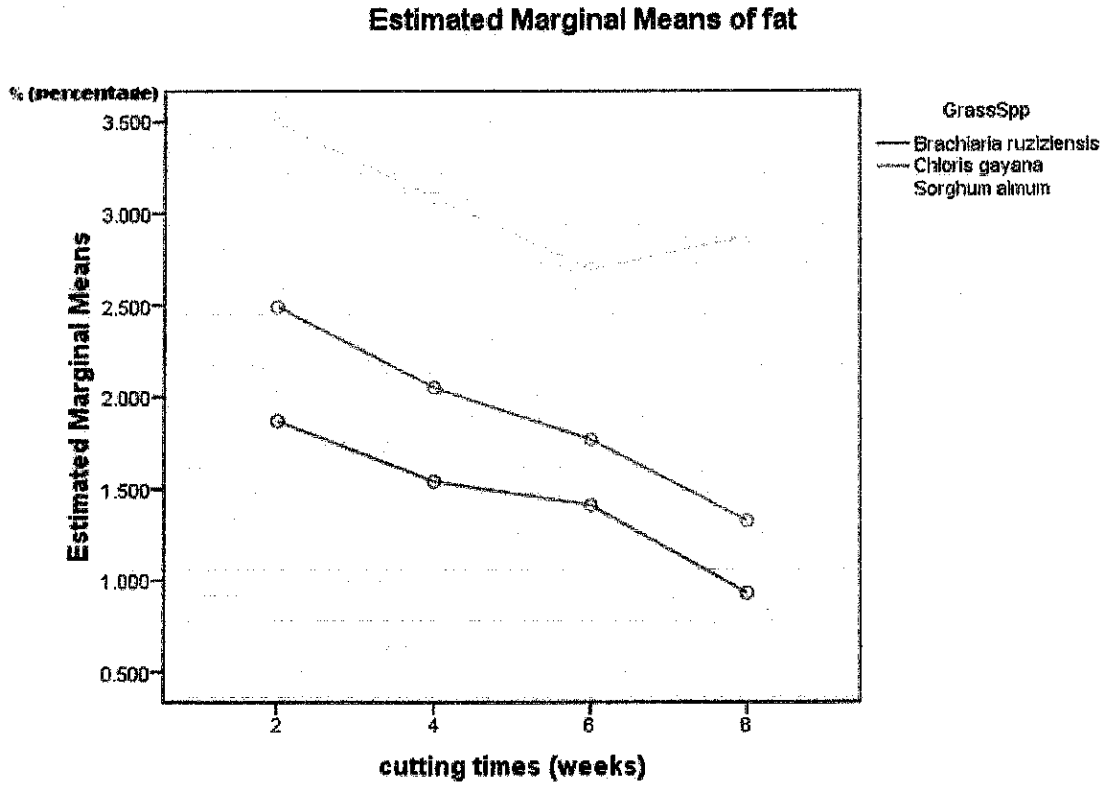

Figure 6. Estimated Marginal means of Crude Fat

4.4.5 Moisture Content

moisture

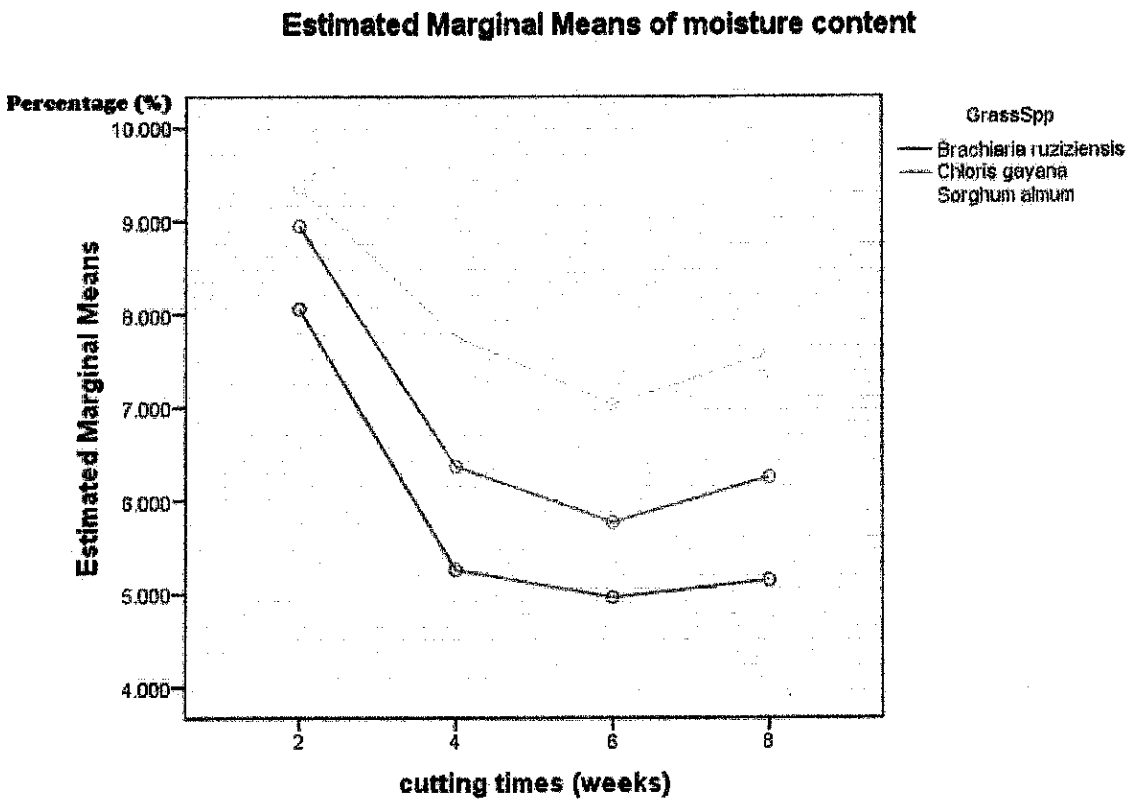

Figure 7. Estimated Marginal means of Moisture Content

CHAPTER 5

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 74% sand, 7% silt, 19% 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 that the soil has undergone.

5.1.2 Exchangeable Nutrients

The soil is moderately low in exchangeable cation exchange capacity (ECEC) (4.77cmol/kg) and high in both organic matter (32.81%) and Organic Carbon (18.97) implies that the soil is high in biomass as at the time of planting which is favourable to the growth of the three grass 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 (0.96%), Magnesium (1.13cmol/kg), and Sodium (0.08cmol/kg) falls within the critical low range in soils of Western Nigeria (Fasina *et al.,* 2015). The high level of Nitrogen (5.02%) 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 (8.1) implies that it is a basic calcareous soil indicating potential bioavailability of heavy metals (Fe, Cu, Na, Zn, Mn). The soil pH plays a major function in the adsorption of heavy metals as it directly controls the solubility and hydrolysis of metal hydroxides, carbonates and phosphates. It also influences ion -pair formation, solubility of organic matter, as well as surface charges of Fe, Mn and Al oxides, organic matter and clay edges.

5.2 Growth Attributes

5.2.1 Grass Height

There was a linear relationship between the Cutting times (weeks) and the grass species (Figure 1) as the grasses grow from week 2 to week 8, there was a sharp increase in height observed particularly for *S.almum* (41.10) in the sixth week when it outgrew both *B.ruziziensis* (24.85) and *C.gayana* (29.67). The growth of the grass

species was due to their adaptability to the environment and their ability to effectively grow under harsh conditions. The fertilizer added also contributed to the enhancement of the soil by supporting the growth of the grasses throughout the period of carrying out this study. *Sorghum almum* is a fast-growing and high-yielding grass that can weaken within three years (Cook *et al.*, 2005)

At $p < 0.05$ (Table 7), *Sorghum almum* is significant to both *Brachairia ruziziensis* and *C.gayana* at weeks 2 (18.20, 14.34, and 12.26), 4 (27.98, 18.71, and 18.70), 6 (41.10, 24.85 and 29.67) and 8 (89.46, 47.00 and 39.66) respectively; this implies that given the same environmental, soil and climatic conditions, *Sorghum almum* did better than both *Brachiaria ruziziensis* and *Chloris gayana.*

There was a significant difference between the Cutting times (weeks) and the grass species; the heights of the grasses increase as the grasses grow (Table 7).

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

5.2.2 Sward Height

There were significant difference between the sward height of the grass species at $p < 0.05$ (Table 7) and also for the Cutting times (weeks), there were significant difference at week 2 for *Sorghum almum* (3.01), *Chloris gayana* (3.30) and *Brachiaria ruizizensis* (3.68), respectively. At week 4, there was another major significance between the sward heights for *Sorghum almum* (3.18), *Brachiaria ruziziensis* (2.76) and *Chloris gayana* (2.86). At week 6, *Sorghum almum* had the

highest sward height (5.01) followed by *Brachiaria ruziziensis* (3.91) and *Chloris gayana* (3.49), respectively. At the 8th week, there was a slight change in the sward heights for both *Brachiaria ruziziensis* (4.10) and *Chloris gayana* (4.43) with *Sorghum almum* being the grass variety with the highest sward height for this week of cutting (6.01).

In some species, biomass has been assessed measuring sward height. Pasture can be estimated using the sward heights; forage yield can be approximated from sward height with reasonable accuracy if precautions are taken.

5.3 Forage Quality

5.3.1 Crude Protein

As expected crude protein percentage declined markedly as the grasses grow (Figure 3). Crude protein was found to decrease linearly as the grasses grew.

At $p < 0.05$ (Table 8); *S.almum* has more protein content for the study period than *C.gayana* and *B.ruziziensis* at both weeks 2 (12.11, 7.71 and 4.97), 4 (10.34, 5.77 and 3.52), 6 (8.61, 4.52 and 2.95) and 8 (9.40, 2.57 and 0.84) respectively; it shows that *Sorghum almum* has the ability to preserve and conserve protein than the others. For the period of study, it is a known fact that as the grasses grow, their crude protein percentage decreases drastically (Table 8).

Crude protein content tends to decline as forages mature due to accumulation of stems and deposition of lignin in leaves and stems (Adesogan *et al.*, 2006). Arthington and Brown (2003) reported that increasing pasture regrowth interval from 4 to 10 weeks resulted in decreased CP and digestibility.

Additionally, forage regrowth in the dry seasons may have lower quality due to increased lignin deposition associated with high temperatures. (Adesogan *et al.*, 2006).

The protein content of the grasses declined as the plant aged. The reason for this could be attributed to the rapid growth rate of tropical grass and the rapid build-up of crude fibre and the encrustation of lignin in them as the grasses matured noting that fibre and protein contents of the grasses are inversely related. This suggestion is similar to the report of Johnson *et al.* (1968) who indicated that crude protein contents of forage decreased as the forage matured from 3 – 10 weeks of growth.

Frequent defoliation may have negative effects on plant persistence. Stem base, rhizome, stolon, and root mass are generally depleted under conditions of frequent and severe defoliation (Chambliss, 1999; 2000; and 2006). According to Youngner (1972), root growth is generally reduced by defoliation as results of the reduction of photo-synthetically active tissue and shortage of carbohydrates for root growth.

5.3.2 Crude Fibre

There was a positive correlation relationship between the growth rate and fibre content of the three grass species (Figure 4). The fibre content of the three grasses increased due to the encrustation of lignin in them as the grasses matured giving the impression that both the fibre and protein contents of the grasses are inversely related; as the grasses grew, the protein contents decreased and the fibre contents increased. High cutting frequency reduces growth and development, whereas long intervals between harvests lead to accumulation of fibre and reduction in quality (Tessema *et al.*, 2010).

At $p < 0.05$, there were significant differences between the different times of cutting (Table 8), at the 8th week of cutting (*Sorghum almum:* 31.83, *Chloris gayana*: 26.67 and *Brachiaria ruziziensis*: 23.20), the grasses have increased lignin in their stems and leaves compared to the 2nd week of cutting (*Chloris gayana*: 17.93, *Sorghum almum*: 17.10 and *Brachiaria ruziziensis*: 15.45). This is because the grasses has high structural cell wall carbohydrates that increase rapidly with maturity causing decline in CP concentration and digestibility (Van Soest., 1994). Studies also demonstrate that the effects of cutting interval on yield and quality vary with the different grass species (Cuomo *et al.*, 1996; Khairani *et al.*, 2013), management practices and environmental conditions (Chaparro *et al.*, 1996).

5.3.3 Crude Ash

Ash is also very important from biochemical point of view. 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 grass species, *Sorghum almum*, *Brachiaria ruziziensis,* and *Chloris gayana* were significantly different from each other. (Table 8). Weeks 8 (*Sorghum almum* (11.21), *Brachiaria ruziziensis* (8.64), and *Chloris gayana* (9.67)) and 6 (*Sorghum almum* (10.18), *Brachiaria ruziziensis* (8.07), and *Chloris gayana* (8.59)) showed comparatively high contents of ash, indicating that when the grasses are cut late, they tend to include a high level of crude ash content and may be rich sources of nutritionally important elements.

5.3.4 Moisture Content

Moisture in grasses is a good source of water and is necessary as it is considered that around 20% of the total water consumption of animal must come from feed moisture. *Sorghum almum* was having the highest moisture content throughout the eight weeks of study (12.11, 10.34, 8.61 and 9.40) while *Brachiaria ruziziensis* (4.97, 3.52, 2.95 and 0.84) having the lowest moisture contents on dry basis (Table 8). The average moisture content holding capacities were found to be dependent on the grass specie and the environment.

Looking at the Cutting times (weeks) moisture content on dry basis (Table 8)

Grass with the lowest moisture content could store for a longer time without spoilage.

5.3.5 Crude Fat

Fat promotes the absorption of fat soluble vitamins hence it is very important in diets. Fat content of the three grass species, *Sorghum almum*, *Brachiaria ruziziensis,* and *Chloris gayana* were 3.49, 1.86, and 2.48 (week 2) respectively (Table 8) implying that more of fat soluble vitamins were found in *Sorghum almum* than *Brachiaria ruziziensis* and *Chloris gayana.* The fat content decreased significantly from the second week to the eight week (Figure 7).

5.4 MODEL FUNCTIONS

5.4.1 Model functions for Biomass Accumulation

$$BM_{Gi} = \sum_{i=0}^{n} [BM_{si} + F_i - N_{gi} \pm E_t]$$

Where,

Single soil type - (Ss)

The same 50g of fertilizer will be added - (F)

The nutrient composition is expressed as N_g

Error recorded is expressed as E_t

The organic component of the soil analyzed - (O_s)

The inorganic component of the soil analyzed - (I_s)

The organic component of cut grass (after analysis) - (G_o)

The inorganic component of cut grass (after analysis) – (I_o)

Biomass of the soil expressed in BM, kg/pot (BM_S) = $I_s + O_s$

Solution

5.4.1.1 Biomass Accumulation before Planting

$BM_{Gi} = \sum_{i=0}^{n} [BM_{si} + F_i - N_{gi} \pm E_t]$

$BM_S = 32.81\%$ (organic Matter)

$F = 50\%$

N_g = 5.02% (Nitrogen) + 0.96% (Potassium) + 3.65% (Calcium) + 1.13% (Magnesium) + 0.08% (Sodium) = 10.84%

$E_t = 0$

$BM_{Gi} = 32.81 - 10.84 + 0$

$BM_{Gi} = 21.97\%$

5.4.1.2 Biomass Accumulation after Harvesting

$BM_{Gi} = \sum_{i=0}^{n} [BM_{si} + F_i - N_{gi} \pm E_t]$

$BM_S = 18.70\%$ (organic Matter)

$F = 50\%$

N_g = 4.54% (Nitrogen) + 0.61% (Potassium) + 2.60% (Calcium) + 0.80% (Magnesium) + 0.04% (Sodium) = 8.59%

$E_t = 0$

$BM_{Gi} = 18.70 - 8.59 + 0$

$BM_{Gi} = 10.11\%$

5.4.2 Model functions for Grass growth rate

5.4.2.1 Grass Growth Rate For Before Harvest

$\%G_{gri} = 2BM_{si}\% - \%S_{pgi} + \%M_{pi} + U_{fei} + F_i - N_{gi} \pm E_t$

Where,

Grass growth rate is expressed as G_{gr}

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

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

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

$U_{fei} = 0$

$E_t = 0$

$2BM_S = 32.81\% + 32.81\% = 65.62$

$S_{pg} = 80\%$

$M_p = 70\%$

$F = 50\%$

$N_g = 10.84\%$

$\%G_{gri} = 65.82 - 80 + 70 + 0 + 50 - 10.84 + 0$

$\%G_{gri} = 94.98\%$

5.4.2.2 Grass Growth Rate For After Harvest

$\%G_{gri} = 2BM_{si}\% - \%S_{pgi} + \%M_{pi} + U_{fei} + F_i - N_{gi} \pm E_t$

Where,

Grass growth rate is expressed as G_{gr}

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

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

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

$U_{fei} = 0$

$E_t = 0$

$2BM_S = 18.70\% + 18.70\% = 37.40$

$S_{pg} = 80\%$

$M_p = 70\%$

$F = 50\%$

$N_g = 8.59\%$

$\%G_{gri} = 37.40 - 80 + 70 + 0 + 50 - 8.59 + 0$

$\%G_{gri} = 68.81\%$

For the whole study, a growth rate range of 68.81% - 94.98% was observed while the biomass accumulated was observed to be 10.11% - 21.97%.

CHAPTER SIX

6.0 CONCLUSION

During the course of carrying out this research work, the fastest growing grass was *Sorghum almum* and it can grow faster than *Brachiaria ruziziensis* and *Chloris gayana.* The model developed in this research can be used to estimate how faster a grass can grow given that all other conditions are met (Climatic and edaphic).

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