GROWTH RATE AND BIOMASS ACCUMULATION IN FORAGE MAIZE (*Zea mays*), FORAGE MILLET (*Echinochloa utilis*), ELEPHANT GRASS (*Pennisetum pupereum*) and GAMBA GRASS (*Andropogon gayanus*)

BY

MAKINWA OLUSEGUN MAYOWA

ASC/12/0459

A PROJECT SUBMITTED TO
THE FACULTY OF AGRICULTURE, DEPARTMENT OF ANIMAL PRODUCTION AND HEALTH, FEDRAL UNIVERSITY OYE-EKITI, EKITI STATE, NIGERIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF AGRICULTURE (B. Agric.) IN ANIMAL PRODUCTION AND HEALTH

FEDERAL UNIVERSITY OYE-EKITI, EKITI STATE,

NIGERIA.

November, 2017

DECLARATION

I, MAKINWA OLUSEGUN MAYOWA, hereby declare that this thesis **"Growth Rate and Biomass Accumulation in Forage Maize (*Zea mays*), Forage Millet (*Echinochloa utilis*), Elephant Grass (*Pennisetum pupereum*) And Gamba Grass (*Andropogon gayanus*)"** has been written by me and that it is a record of my own research work. It has not been presented before any previous application of a degree or any reputable presentation anywhere else. All borrowed ideas have been duly acknowledged

MAKINWA O. MAYOWA

06/12/2017
Date

CERTIFICATION

This is to certify that this thesis titled **"Growth Rate and Biomass Accumulation in Forage Maize (*Zea mays*), Forage Millet (*Echinochloa utilis*), Elephant Grass (*Pennisetum pupereum*) And Gamba Grass (*Andropogon gayanus*)"** was carried out and submitted by **MAKINWA, Olusegun Mayowa** with Matric Nunber: **ASC/12/0459** and has satisfied the regulations governing the award of the degree of Bachelor of Agriculture (B. Agric) Animal production and health in the Department of Animal production and health, Federal University, Oye-Ekiti, Ekiti State and is approved for its contribution to knowledge and literacy presentation.

PROF. A.A. AGANGA
(PROJECT SUPERVISOR)

14-12-2017
Date

DR. A.H. EKEOCHA
(PROJECT SUPERVISOR)

14/12/17
Date

DR. A.H. EKEOCHA
HEAD OF DEPARTMENT

14/12/17
Date

DEDICATION

This report is first dedicated to my parents Mr. and Mrs. Makinwa and my brothers (Samuel, Oreoluwa and Ikeoluwa Makinwa) for their love, support encouragement and of course for financing this project.

I would also like to dedicate the project to the memories I have of my five year stay here in Federal University, Oye-Ekiti. With special emphases on those memories of my final year when I met someone special, I hope these memories last a lifetime.

ACKNOWLEDGEMENT

All thanks to Almighty God for his protection, provision and guidance during my project work. I appreciate my parents, Mr. & Mrs. MAKINWA and my siblings, for their love towards me during this period.

I would like to specially appreciate my supervisors Professor (Mrs.) A. A. Aganga and Dr. A. H. Ekeocha for their roles during the course of these project and the host of lecturers in the department who also played motherly and fatherly roles in ensuring that this work was a success.

Special appreciation goes to Dr. O. A. Babatunde and the H.O.D. Department of Mathematics for their meaningful contributions in this project work.

I would specially appreciate Oribamise Victor, a true definition of a friend; who though being busy during the course of this experiment, took his time to put me through the details of this projects. I would also appreciate my friends Pelumi, Victor, Itelorun, Funmilayo, and Mercy who helped me out during the project. Also I would appreciate Okiki whose room I used for the air drying of harvested samples.

Finally I would appreciate someone special, Miss Oluwadamilola; who was instrumental to the completion of this project with sweet words of advice and encouragements which helped me not to give up during the course of the work. I would also appreciate course mates (the fantastic seven wonderful girls in my class). You girls are simply the best!

ABSTRACT

To have higher profits and sustained production of livestock it is important to understand the biomass accumulation and growth rate of the forages the animals feed on. This project work looked into the growth and biomass accumulation of forage maize (*Zea mays*), forage millet (*Echinochloa utilis*), elephant grass (*Pennisetum purpereum*) and gamba grass (*Andropogon gayanus*).

The experiment was conducted at a location within Federal University Oye-Ekit, Ekiti State, Nigeria with Latitude - N 07° 48.308, Longitude - E 005° 29.573 and 548.4m above ground level with an annual rainfall of 1778mm. The planting was done using completely randomized design (CRD) in 4-rows with 4 replicates. The soil used for this study contained a high organic matter before planting (49.96%) and after harvesting was completed (33.59%). The soil used in planting belonged to the Loam soil category. The highest growing grass in terms of plant height and sward height was *Penninsetum purpereum* throughout the period of carrying out this experiment.

Zea mays had the largest leave width (5.44cm at 8weeks) as well as the highest number of leaves during the experiment. At the end of 8weeks; *Zea mays* had the highest biomass accumulation of 114%, *Echinochloa utilis* had a biomass accumulation of 51.31%. *Andropogon gayanus* had a biomass accumulation of 45.53%, *Pennisetum purpereum* had a biomass accumulation of 44.32%.

Samples from the last cuttings (8th week) had the highest crude protein content (11.88% in *Andropogon gayanus*) although there was no significant differences between the crude protein levels of the different species statistically **($p \leq 0.05$)**. Crude protein was found to increase nearly linearly as the grasses grew. The crude fibre content of the three grass species was observed to undulate as the grasses grew although there was no significant

difference between the species. The highest fibre content was observed in the 6th week (13.58% in *Zea mays* of cutting due to encrustation of lignin in them as the grasses matured. The crude Ash content did not vary between the four grass species statistically **($p \leq 0.05$).** Although the highest crude ash content was recorded in the 6th week (5.80% in *Andropogon gayanus*). The crude fibre, moisture content and the fat content all followed the same irregular patterns and there was no significant differences between their percentage compositions in all the plant samples.

Keywords: *Zea mays, Echinochloa utilis, Pennisetum purpureum, Andropogon gayanus,* Growth rate model, Biomass accumulation model, proximate composition.

Word Count: 398

TABLE OF CONTENTS

LIST OF PLATES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ZM- *Zea mays*

EU- *Echinochloa utilis*

PP-, *Pennisetum purpureum,*

AG- *Andropogon gayanus*

CP-Crude protein

CF-Crude fibre

MC-Moisture content

PH-Plant Height

SH-Sward height

AvgNL- Average number of leaves

BMA-Biomass Accumulation

CT-Cutting time

CHAPTER ONE
INTRODUCTION

Nutrition remains very imperative to the survival as well as livelihood of any living thing be it plants or animals. Green plants can source for their own foods on their own with the use of inorganic materials and are therefore called ***autotrophs*** while animals have to rely on the plants directly or indirectly to get their food and are called ***heterotrophs***. Animals that rely on plants directly and totally as food are called herbivores and they include ruminants and pseudo-ruminants; examples include cattle, sheep, goats etc. These animals consume plant material in form of forage (a general term that refers to grasses, plants or plant parts that are consumed by animals). To have higher profits and sustained production of these it is important to understand these forages. This project work looks into the growth and biomass accumulation of forage maize (*Zea mays*), forage millet (*Echinochloa utilis*), elephant grass (*Pennisetum purpereum*) and gamba grass (*Andropogon gayanus*).

1.1 What are Tropical Grasses?

Grass is a common name for any plant in a large family ***Poaceae*** *(*formerly ***Gramineae)*** of flowering plants that is economically and ecologically the most important in the world. These plants are usually with hollow jointed stems and long narrow, usually green leaves and tiny flowers arranged in spikes. Grasses include important food plants for humans such as wheat, oats, barley, rice, rye, corn, millet, and sorghum as well as sugar cane and some non-food plants such as bamboo, gamba grass, guinea grass etc. that serve as important feed stuff for animals. The grass family contains about 635 genera and 9000 species, making it the fourth largest family after the legume, orchid, and composite families. (Pardee, 2008)

Grasses are almost uniform in basic vegetative structure, and have several features characteristic in common. The main roots are usually fibrous; secondary roots, called

adventitious roots, often arise from the nodes (joints) of the stems, as in the prop roots of corn. The stems are usually herbaceous (lawn grasses) or hollow (bamboo), but exceptions occur, such as the pithy stems of corn and the woody stems of some bamboo. (Pardee, 2008)

The leaves, which are borne at the nodes along the stem, are in two rows and consist of two parts: the sheath and the blade. The sheath, a distinctive feature of the grasses, circles around the stem and gives support to the area just above each node. Interestingly, unlike most plants, in which stems increase in length from the tip, grasses increase by growth all along the stem above each node.

Another distinctive feature of grasses is the ligule, a short hairy or membranous projection, at the point where the leaf sheath joins the leaf blade. The function of the ligule is still unknown, but it may keep moisture from entering the region between the stem and the sheath. (Crosby, 2008)

The leaf blade is typically long and narrow, with parallel veins, but differences may occur across species in shape and size. The leaf blade has a meristematic area, which is located at its base above the place where the blade joins the sheath. Meristematic cells are cells that are undifferentiated and are usually found in plant parts where growth is expected to occur. Growth occurs in this area rather than at the leaf tip, as in most plants. Therefore, even if the upper end of the leaf is cut off, the blade can continue to grow. This feature, together with the presence of meristem tissue in the stems and the fact that grasses branch near the ground, enables grasses to withstand the rigors of many natural and artificial environments in areas where other plants cannot grow. The usefulness of grasses as pasture plants is also derived from these features, because grasses continue to grow after grazing. In addition, grasses can withstand burning, grazing, and trampling and now dominate large areas where such events occur.

The flowers of grasses are usually individually inconspicuous, but they are often aggregated into large, sometimes showy clusters (inflorescences). For example, in the corn plant, the young ears are clusters of the female flowers, and the tassels are clusters of the male flowers. Most grasses are pollinated by wind, so that their flowers are highly reduced and very simple, as are most wind-pollinated flowers (Pardee, 2008).

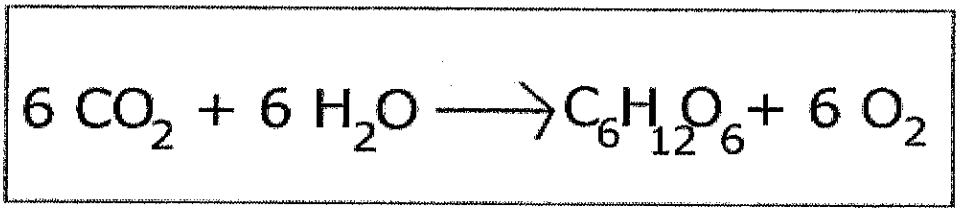
Although their basic parts are simple and few, great variation exists among grasses in details of the structure of spikelet's and their aggregation into flower clusters. This, together with details of overall structure and less easily observed characteristics of anatomy, cytology, and chemistry, accounts for the tremendous number of species of grasses.

Asides being important sources of food to man, grasses are also the primary source of food for domestic and wild grazing animals, which feed on pastures and grasslands and which are fed hay and silage harvested from them. The total land area devoted to these kinds of croplands is greater than the land area for all other kinds of croplands combined (Pardee, 2008). Many grasses have played prominent roles in forage research and livestock production in Nigeria (Anele *et al*; 2013). Forage-crop farming serves as the basis for much of the world's livestock industries. Forage crops are mowed, dried, and stored as hay; chopped and stored wet as silage; or fed directly to cattle as pasture or as freshly chopped forage. In tropical and subtropical regions, most livestock consume forages as pasture. In temperate zones, forages are commonly stored as hay or silage for winter use (Pardee, 2008).

Grasslands are productive ecological zones of the Earth that occupy approximately 36% of the Earth's non aquatic surface (Mandar, 2016). The Federal Ministry of Environment of Nigeria (FMEN, 2001) 1993 estimate of irrigated land is 9 570 km^2 and arable land about 35 %; 15 % pasture; 10 % forest reserve; 10 % for settlements and the remaining 30 % considered uncultivable for one reason or the other. These grasses are very

important in the feeding of livestock which is needed for the livelihood of man. Grasslands currently are producing far less than their production potential. Hence, it has become imperative to recover their grazing potential (Muhammad *et al;* 2012). One way to monitor and improve on the grazing potential of these grasses is to understand their rate of growth and biomass accumulation.

Biomass accumulation simply put refers to the amount of living matter that can be produced by a plant. Growth on the other hand refers to increase in size or progressive development that is usually irreversible. For growth or bioaccumulation to occur in grasses at any point, a very important process (photosynthesis) must occur. Photosynthesis is a biochemical process in which green plants produce necessary sugars needed for growth and normal physiological wellbeing by breaking up the carbon dioxide absorbed from the atmosphere through their pores with light energy that is trapped by chlorophyll and combining it with molecules of water.



Equation for photosynthesis which is regarded the most important reaction in nature.

The perennial grasses can be classified as either C3 or C4 plants depending on the different pathways that plants use to capture carbon dioxide during photosynthesis. C3 plants are cool season plants that have an optimum temperature range of between 18°C to about 20°C. C3 plants extract carbon from carbon dioxide and fix it directly by the enzyme ribulose bi-phosphate carboxylase (RUBPcase) in the chloroplast. The reaction between carbon dioxide and ribulose bi-phosphate, a phosphorylated 5-carbon sugar forms two molecules of a 3-carbon acid. This 3-carbon acid is called 3-phosphoglyceric acid and explains why the

plants using this reaction are called C3 plants. C3 plants have an advantage over the C4 plants in that they contain a higher percentage of crude protein; however they have a limitation of reduced efficiency with increasing temperatures. Growth usually occurs between 4°C and 8°C which would continue to decline with increasing temperatures for C3 grasses species. During the warm seasons, growth is reduced and dormancy is induced by high temperatures and low precipitation.

C3 plants can be annual or perennial. Annual C3 plants include wheat, rye, and oats. Perennial C3 plants include orchard grass, fescues, and perennial ryegrass. The breakdown of C3 plants in the rumen of the Bovine is often faster than C4 grasses because of the thin cell walls and leaf tissues and is therefore often higher in forage quality.

C4 plants are often called tropical or warm season plants. They reduce carbon dioxide captured during photosynthesis to useable components by first converting carbon dioxide to oxaloacetate, a 4-carbon acid. This is the reason these plants are referred to as C4 plants. Photosynthesis then continues in much the same way as C3 plants. This type of photosynthesis in highly efficient and little fixed CO_2 is lost through photorespiration.

C4 plants are more efficient at gathering carbon dioxide and utilizing nitrogen from the atmosphere and in the soil. They also use less water to make dry matter. C4 plants grow best at 32—35°C. They begin to grow when the soil temperature is 15—20°C. Forage of C4 species is generally lower in protein than C3 plants but the protein is more efficiently used by animals.

C4 plants can be annual or perennial. Annual C4 plants include corn, sorghum, millet, rice, etc. Perennial C4 plants include maize, millet, bermuda grass, switch grass, gamba grass,

guinea grass, Rhodes grass etc. C4 plants perform better with rising temperatures and low CO_2 conditions minimizing photo-respiration. (Taylor *et al.*, 2012)

Maize (*Zea mays)* is a tropical annual crop. The starch, energy and intake characteristics of maize silage together with its high dry matter yield potential, makes it a good feed for ruminant and pseudo-ruminant animals. (Morgan *et al*; 2015).Medium-textured soils are best for maize.

Forage Millet, (*Echinochloa utilis*) is a robust multi-stem annual tropical grass that can grow as high as 1.5-3.0m with a stem diameter of 10-20mm. Forage millet is salt tolerant and usually requires a moderate to high soil fertility without water logging. With no limitations of water and nutrients, forage millet can produce up to7–10 t DM/ha. (Pasture genetics.com, 2016)

1.2 Problem Statement

As at the end of 2016, the World Bank and the United States census bureau had the population of Nigeria to be about 186million people (2.55% of the total world population) with an estimated annual growth of 2.6%. It is worthy to note that according to the CIA world fact book; 43.8% of this population is composed of children between the ages of 0and 14. According to the United Nations it is projected that the rate at which the country's population is increasing exponentially; the population might reach 391 million by 2050 making it the 4th most populous country in the world by then. The implications of these figures are simple, for the country to support such a high demand for animal protein by 2050 especially for the teaming population of young children; a proper and more definitive approach should be directed to the production of livestock. That however, may look like a long shot into the future as the country is currently experiencing grassland shortage at the moment. Aganga *et al* in 2000 reported that grasslands shortage has been a major constraint affecting the

development of ruminant animal production in the country. Ajuwon in 2004; Fasona and Omojola in 2005 also reported that the farmer-herdsmen conflict in Nigeria has remained the most preponderant resource-use conflict in Nigeria. All this is not far-fetched from the fact that pasture and range management has received the least professional attention over the years as compared to other areas of agriculture (Adegbola *et al*, 1966). 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 (Oribamise, 2016). To be able to meet the figures and projections of 2050 and put an end to the Fulani herdsmen crisis looming in the country; there is a need to start pasture reserves across the country. To have this, it would be imperative to have grass growth and bioaccumulation models that would serve as a guide for pasture farmers to know which pasture plants to grow and which to avoid with reasons.

1.3 Justification

This project is justified by the availability and easy access to the grasses used for the project. It is further justified in that, an understanding of the growth and biomass accumulation of forage grasses is an imperative and paramount planning tool in a highly demanding market for forage based animal product like we have in Nigeria. Considering future perspectives where forage-based animal-production systems are likely to be increasingly challenged from technical and environmental standpoints, with increasing demand for animal products, and the need for fine-tuning production procedures and processes becoming routine, forage models may gain in importance and become common elements and useful tools in forage-based livestock production (Andrade, *et al.*, 2015). This

project work looks to have at the end; a model that can accurately predict the growth and bioaccumulation of grasses.

1.4 Objectives

1.4.1 Overall Objectives

- The overall objective is to develop a model that can correctly predict the growth rate and also the biomass accumulation of the four grass species.

1.4.2 Specific Objectives:

- Determine the bi-weekly biomass accumulation of each grass species.
- Determine the growth rate of each grass species.
- Obtain the varietal differences in each grass growth rates.
- Determine the nutrient content of the soil before planting and after harvesting.
- Determine the nutrient content of the grass at different stages of growth.
- To understand the effect of cutting on the nutrient composition of the various grass species.
- To at the end of the experiment recommend the best grass species for grazing based on growth rate, biomass accumulation and nutrient composition.

CHAPTER TWO
LITERATURE REVIEW

2.1 General

Ruminant animal production is predominantly grass based, proportion of grazed grass in the diet of dairy cows is typically approximately 60% in most developed countries like Ireland as compared with 100% grazed grass diet in developing countries of Africa like Nigeria. It is important to stress that the supply of such grasses in quantity and quality directly affects the quality and quantity of meat and other closely related products like milk, hides, skin, wool etc. The quality of such forage however is determined by the chemical composition, palatability and digestibility of which the animal is the best judge of all three parameters. The chemical composition describes the quantities of carbohydrates (soluble, fibre and lignin), crude protein, minerals present in the forage which gives an idea of how nutritious the forage are to the animal. The palatability describes the taste and level of acceptance of the forage to the animal, this is important because even if the forage is very nutritious, if the animal does not accept it based on its instincts; it remains useless. Digestibility describes the how much of the forage that can be broken down by the animal's digestive system and can be converted to flesh. Kaiser and Piltz, 2002, Mehdi *et al in* 2009 explained that quality of fodder depends plant species, while Rehman and Khan in 2003 added that stage of growth and agronomic practices also have important effects in the quality of fodder.

For a plant to experience a physical increase in size, a range of important basic conditions must be met, these including: air, water, and nutrients. Air is needed for respiration and photosynthesis, water is needed for the transportation or nutrients as well as other important biochemical functions in the plant, nutrients are chemical substances that are needed in the plants for proper physiology of the plant systems. Elements that define or

determine the growth of a plant include: light interception, light use efficiency, dry matter production & loss, duration of growth, dry matter partitioning.

With increasing biomass, plant diversity often declines and, when biomass remains high for extended periods, these declines are thought to be persistent. Accumulated plant material also contributes to the regulation of many ecosystem functions such as nutrient cycling, population dynamics and animal habitat suitability. (Morgan, 2014)

A Crop Simulation Model (CSM) is a simulation model that helps estimate crop growth, development, bioaccumulation and yield as a function of weather conditions, soil conditions, and choice of crop management practices. (Wikipedia, 2017)

Crop 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 (Wu *et al.*, 1996). 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 (Andrade, et al., 2015). Crop models are used to integrate multidisciplinary knowledge, based on processes regarding soil physics and chemistry, plant physiology and genetics, weather and farming management. The effects of these processes can be coded as simple written verbal description or may be a comprehensive set of equations used in the simulation of a given system (Sinclair and Seligman, 1996) which is used to predict growth, development and yield (Hoogenboom, 2000), even for largescale applications (Rosenzweig *et al.*, 2013). 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 favouring the appearance of new ideas.

As in industrial and engineering systems, there is a need to quantitatively study and analyse the many constituents of complex natural biological systems as well as agro-ecosystems via research-based mechanistic modelling (Mabrouk, 2010). This objective is normally addressed by developing mathematically built descriptions of multilevel biological processes to provide biologists a means to integrate quantitatively experimental research findings that might lead to a better understanding of the whole systems and their interactions with surrounding environments. Aided with the power of computational capacities associated with computer technology then available, pioneering cropping systems simulations took place in the second half of the 20th century by several research groups across continents (Mabrouk, 2010).

Crop 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 (Dourado-Neto *et al.*, 1998). Despite their immense importance as a tool in animal production, growth models are still finding a foot in tropical developing countries like Nigeria. Marin and Jones in 2014 reports that 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 this areas.

Across the various scientific disciplines, models range from very simple, with only one linear equation, to extremely complex, with thousands of equations (Hoogenboom, 2000). Ideally, models to predict crop growth and yield should be sufficiently simple to be readily understood and used, and yet include sufficient detail to allow for application under a wide range of conditions (Dourado-Neto *et al.*, 1998c).

Models have different classifications, they can be static or dynamic, discrete or continuous, deterministic or stochastic, and mechanistic or empirical (Andrade, et al., 2015). A model can be classified as dynamic if it shows the changes in variables over time while a static model is one that does not show changes in variables over time. A mode is considered a continuous model, if it has time recorded as an actual value (e.g. 2.24 h), whereas in the discrete models, time is determined by integer values (e.g. 2 h). Both discrete and continuous models are dynamic models because they show the changes in variable with time. Stochastic models include a random factor or probability distributions, while the deterministic models do not (Teh, 2006). Models to simulate crop yield are generally dynamic and deterministic models: they represent how a system responds over time without an associated probability distribution (Thornley and Johnson, 1990). There are different types of crop models; and they are broadly classified under three groups: the mechanistic crop models; the empirical/statistical crop models and the functional crop models. The model to be adapted is not to be selected by convenience, instead the model to be adapted is selected based on the objective of the simulation and the information available.

Mechanistic crop models consider the knowledge of physical, chemical and biological processes that govern the phenomena under study (Andrade, et al., 2015). These attempt to use fundamental mechanisms of plant and soil processes to simulate specific outcomes. Sometimes they are considered explanatory because they express a cause–effect relationship between the variables (Teh, 2006). Empirical models are also called correlative or statistical models (Dourado-Neto *et al.*, 1998b), offering little or nothing to the understanding of the cause–effect processes involved, and are designed to obtain the correlation between crop production with one or more variables such as temperature, radiation, water availability and

nutrients, especially nitrogen. The empirical models are currently the most widely studied and used under tropical conditions (Overman *et al.*, 1990; Tonato *et al.*, 2010; Cruz *et al.*, 2011).

2.2 Description of Grass Species

2.2.1 Maize (*Zea mays*)

Maize was first domesticated in modern day Mexico about 10,000 years ago (Wang *et al.*, 1999, Rebourg *et al.*, 2003) and is a tropical crop. As a tropical crop it grows best in warm climates with a longer growing season than that experienced in much of the UK, furthermore it benefits from being grown in sheltered locations with little wind (Phipps and Wilkinson, 1985).

2.2.1.1 Temperature Requirements

Maize drilling usually takes place in the second half of April and first half of May being chiefly governed by soil temperature. Maize Seeds germinate at 8-10^{0}C and so drilling should take place once minimum soil temperature reaches a consistent 8^{0}C over a period of 7 consecutive days (Draper, 2013). Over a complete growing season a maize crop needs a set amount of solar energy in order to develop from germination through to harvest (Phipps *et al.*, 1974).

2.2.1.2 Soil type and topography

Maize is able to be grown on a wide variety of soil types. As much as this is true, the soil type will influence other factors like; drilling dates and the ability to harvest the crop successfully to a greater extent than combinable arable crops. As a crop planted at the onset of the rainy season requiring temperatures of at least 8^{0}C for germination; it is important to note that dark soils and soils with light textures warm up much more quickly than heavier and wetter soils (Phipps and Wilkinson, 1985). Maize will grow successfully on soils with a pH in the range of 6 to 8 (Bunting, 1978).

Furthermore soil type has a significant effects on moisture content and subsequent plant development. Light soils tend to retain less moisture than heavy soils which may be problematic during drought conditions. Heavier soils are more prone to water logging which can delay planting and make rainy season harvesting more difficult (Draper, 2005). Groffman *et al.*, 1996 observed that soil type has a marked effect on microbial content established within the rhizosphere due to differences in soil texture, pH and drainage which in turn impacts on the nutrient availability to plant roots. Nitrogen fixing microbe populations such as *A. brasilense* are positively correlated with soils containing Na, Mg, Ca, higher proportions of silt and a more neutral pH, whilst are negatively correlated to sand content, N, C and P (Latour *et al.*,1996, Chiarini *et al.*,1998). Therefore it can be deduced that better quality soils will have positive impacts on the maize crop performance due to better nutrient availability to roots from microorganisms that are found in such soils.

2.2.1.3 Moisture

Maize seeds and seedlings just like most plants require a reasonable amount of moisture to enable germination and ongoing development. Maize drilling should be done according to the level of soil moisture available if rapid germination is to follow (Draper, 2003). Typical drilling depth for maize seed is from 4-8cm, depending on soil type (deeper on light soils), maize will not germinate in dry soil so ensuring good seed to soil contact with enough moisture is essential (Morgan, 2013). Maize drilled at a deeper depth will take longer to germinate and establish, due to the lower soil temperatures than shallower drilled crops, however seeds sown too shallow are quite vulnerable to predation from birds which can lead to significant losses (Morgan, 2013).

2.2.1.4 Altitude

As altitude increases air pressure decreases and consequently temperature drops. This long established scientific theory is known as the lapse rate and the temperature drop is roughly 0.65^{0}C per 100m gain in height dependent on time of day and humidity (Agriculture and Horticulture Development Board, 2014) . Altitude linked cooling can be problematic when waiting for soil temperatures to reach 8^{0}C in order to begin drilling, the higher the altitude the slower the soil will be to warm up, consequently drilling will be delayed and the growing season shortened. This cooling effect linked to increasing altitude limits, in most circumstances, maize growing to fields below 305 m (1000 feet). When sowing maize at or around this upper margin, site selection is particularly important with sheltered free draining soils providing the best opportunity for successful crop harvest with little or no soil related problems. It is likely that due to on-going climatic change the altitude at which maize can be grown will be higher than it is currently (Agriculture and Horticulture Development Board, 2014).

2.2.2 Forage Millet *(Echinochloa utilis)*

Forage millet (*Echinochloa utilis),* is a tropical annual Pearl millet, allogamous (cross-pollinated) diploid cereal, belonging to the ***Poaceae*** family, subfamily ***Panicoideae***, tribe ***Paniceae***, sub tribe ***Panicinae***, section ***Penicillaria*** and genus ***Pennisetum***. The entire plant is fed to animals as hay or silage while the seeds are for human and animal consumption. It is a bunch grass growing 4–8 ft. tall, on smooth ½–1 inch diameter stems, with upright side shoots (tillers). Compared to sorghum, it will produce more tillers and has a woodier stem (Kajuna, 2001). The inflorescence (4–20 in) is a terminal spike, resembling that of cattail. Seeds are cylindrical, typically white, or yellow, but there are varieties with colors ranging from brown to purple. Leaf blades are long and pointed.

2.2.2.1 Origin and Distribution

Pearl millet originated in central tropical Africa and is widely distributed in the drier tropics and India. It was introduced into the western state in the 1850s and became established as minor forage in the Southeast and Gulf Coast states. The plant was probably domesticated as a food crop some 4 000 to 5 000 years ago along the southern margins of the central highlands of the Sahara. It has since become widely distributed across the semiarid tropics of Africa and Asia. (RSA Deparment of Agriculture, Fisheries and Forestry, 2011)

The geographical origin and the center of domestication of pearl millet are situated in western Africa. The plant was subsequently introduced into India, where the earliest archaeological records date back to 2000 B.C. (Hanna, 1987; Rai *et al.*, 1997; Gari, 2002; Oumar *et al.,* 2008). Records exist for cultivation of pearl millet in the United States in the 1850s, and the crop was introduced into Brazil in the 1960s.

2.2.2.2 Temperature

Pearl millet is usually a short-day plant, but some varieties are day length neutral (RSA Deparment of Agriculture, Fisheries and Forestry, 2011). Temperature is very important factor that determines germination in forage millet. This is because the plant is a C4 plant and therefore requires higher soil temperatures of between 18°C and 30 °C for germination and emergence to occur. Under this temperature and other favourable conditions, it is expected that emergence should occurs in 2 to 4 days.

Rainfall

Forage millet, although drought resistant; requires evenly distributed rainfall during the growing season for optimal productivity. The South-African department of agriculture, fisheries and forestry in 2011 stated that the crop is grown where rainfall ranges from 200 to 1 500 mm and that the lowest rainfall areas rely mainly on early-maturing cultivars. Too much rain at flowering can also cause a crop failure.

2.2.2.3 Soil requirements

Forage millet tolerates a wide range of soils although it is important to grow it on a good soil for optimum productivity. A light, well-drained loamy soil is just perfect for the forage millet. However, if such soils that are available are those that are not as good, forage millet will still be productive as the crop tolerates poor, infertile soil better than the other crops. However the crop performs poorly in clay soils and cannot tolerate waterlogging. It is tolerant of subsoils that are acidic (even those as low as pH 4–5) and high in aluminium content (RSA Deparment of Agriculture, Fisheries and Forestry, 2011).

2.2.2.4 Soil preparation

Pearl millet is propagated by seed on well-drained soils. Seedbeds should be weed free. Deep till or in-row subsoil sandy textured soils are used to disrupt any hard pans. No-till or conservation-tillage plantings can be successful and are desirable on highly erodible land or clayey soils. This will reduce soil erosion and enhance stand establishment owing to better seed depth control in firmer soils and control of emerged weeds prior to planting. If no-tilling in the spring, deep tillage ahead of the winter cover crop in the fall is preferred. However, reconstitution of the hard pan in

sandy soils can occur, particularly if good rainfall occurs during the winter. (RSA Deparment of Agriculture, Fisheries and Forestry, 2011)

2.2.2.5 Planting

Optimum planting time for forage millet according to the South-African department of agriculture, fisheries and forestry is between early October and November, and this according to them is dependent on the intended use. Soil temperatures should be at least 18 °C. Planting in cooler soils can cause problems with reduced emergence and greater competition from weeds. Plant densities should be similar or slightly higher (100 000 to 175 000 plants/ha) than for sorghum (RSA Deparment of Agriculture, Fisheries and Forestry, 2011). Seed should be planted into a firm, mellow, moist seedbed. According to the South African department of agriculture fisheries and forestry, shallow planting is recommended to obtain good seed-to-soil contact, this is because the seeds of forage millet are very small. Planting at very higher depths might lead to a situation where the seed is planted in regions of lower temperatures or a situation where the soil and the seed are not in proper contact and in some other instances it leads to delayed emergence time.

2.2.3 Gamba Grass (*Andropogon gayanus*)

Gamba grass is a tall perennial grass with short rhizomes, forming tussocks up to 1 m diameter. Seed heads of ungrazed gamba grass can grow to 4 m (Cook, B.G., et al., 2005). Leaves (up to 1 m long) green, becoming bluish under moisture stress, with a strong white midrib; hairy on both surfaces, particularly when young; leaf sheath up to 20 cm long, hairy at base; leaves may appear to have petioles as the leaf blade is reduced almost to the midrib above the ligule (Cook, B.G., et al., 2005). The seed head is borne on tall strong culms; inflorescence consists of paired racemes 4-9 cm long, bearing about 17 spikelet pairs; spikelets are sessile and have a long (-30 mm) conspicuous awn. Gamba grass has three types

of roots - most are fibrous roots close to the surface that probably produce the vigorous early growth; thick cord roots which store starch and anchor the tussock ; and vertical roots that can extract water at depth during the dry season (Cook, B.G., et al., 2005). The root system spreads up to 1 m from the tussock, close to the soil surface. Fibrous roots close to the soil surface absorb water from the surface of the soil and probably contribute to its early, vigorous regrowth. Cord roots are thick, store starch and anchor the tussock. Vertical roots are able to extract water well into the dry season. This root system enables gamba grass to tolerate prolonged dry periods and to respond vigorously to early rains (Bowden 1964).

The plant grows actively in the wet season and flowers in April. Seeds develop from May to June and set in July and August (The State of Queensland, Depar tment of Agriculture and Fisheries, 2016). Plants can produce up to 244 000 seeds/plants each year with 65% viability (The State of Queensland, Depar tment of Agriculture and Fisheries, 2016). The seeds are light and easily dispersed by the wind, although 90% fall within 5 m of the parent plant (The State of Queensland, Depar tment of Agriculture and Fisheries, 2016).

2.2.3.1 Origin and Distribution

Gamba grass has a broad natural distribution in Africa. The native range of gamba grass extends across the tropical and subtropical savannas of Africa, from Senegal on the west coast to Sudan in the east, south to Mozambique, Botswana and South Africa (Csurhes & Hannan-Jones, 2016). Like savannas elsewhere, extended dry seasons are a feature of much of this region (Csurhes & Hannan-Jones, 2016). Gamba grass grows most vigorously below an altitude of 980 m and seldom forms a significant part of the vegetation above an altitude of 1970 m, though var. squamulatus has been collected in the Sudan at 2300 m (Bowden 1964). Almost all

known locations of gamba grass lie between the 400 mm and 1500 mm annual rainfall isohyets (Bowden 1964). Within its native range, several varieties of gamba grass exist and each occupies a slightly different habitat type (Bowden 1963, 1964).

2.2.3.2 Habitat and Climate

While gamba grass can grow in areas with 400–3000 mm annual rainfall, and a strong dry season of up to 9 months, it prefers more than 750 mm per annum with 3–7 months of dry season (Cook *et al.* 2005). Gamba grass will grow with rainfall up to 2000 mm per annum provided there is a strong dry season.

Best growth is in lowlands of the tropics and warmer subtropics (15–20°S latitude), as growth is restricted where mean minimum temperature of the coldest month is below 4.4°C (Bowden 1964; Cook *et al.* 2005). The leaves are killed by frost. Optimal flowering occurs at 25°C (Cook *et al.* 2005).

Gamba grass is generally considered to require full sunlight, but can grow under light shading or cloudy conditions (Cook *et al.* 2005). Gamba grass varieties seem adapted to a wide range of soils (sands to clays, neutral to strongly acid (pH 4–7.5), infertile to fertile), but generally grow best on loams of moderate fertility (Cook *et al.* 2005). Some varieties of gamba grass can withstand short-term flooding and waterlogging, but most have poor tolerance (Cook *et al.* 2005. Gamba grass is reported to tolerate soils high in aluminium (greater than 80% saturation) through exclusion of the element, but not salinity. Gamba grass has a relatively low requirement for phosphorus for successful growth (Jones 1979). Altitude range is about 1 000m to 2 000 m above sea level but it grows best at 1000m above sea level (Skerman & Riveros, 1990).

2.2.3.3 Planting

A clean, firm seed-bed is required for planting gamba grass. Cleaned and de-bearded seed is drilled in shallow rows or broadcast and rolled. It can be planted also from root-stocks (splits), the best being mature woody stumps (Skerman & Riveros, 1990). Seeds can be sown at a planting depth of between 1cm and 2.5 cm below the surface of the soil. Planting time is at the beginning of the rainy season at a planting rate of 5 kg/ha (35-70 kg/ha uncleaned).

Dry-matter yield increased during the wet season from June to October in Nigeria, reaching a maximum of about 3 800 kg/ha in October, declining then until February

2.2.3.4 Response to Defoliation

At Fashola Livestock Farm, Nigeria, *A. gayanus* required intervals of more than six weeks between cuttings, and a cutting height of about 4 cm to maintain productivity and a good stand (Ahlgren *et al.*, 1959). It cannot stand heavy grazing until it is well established, but requires high stocking rates to maintain reasonable height.

2.2.3.5. Grazing Management

The International Center for Tropical Agriculture (*CIAT)* in 1978 reported that gamba grass should be utilized when young, as once flowering stems appear it becomes harsh and of little nutritional value. Burning during the dry season is universal. However, it is important to maintain some residual dry matter and leaf area after grazing in such erect grasses (CIAT, 1978).

2.2.3.6 Response to Fire

It tolerates fire and in Ghana and elsewhere it is burnt every year. Early dry-season burning promotes its growth, whereas late burning promotes the unpalatable Loudetia acuminata (Ramsey & Rose-Innes, 1963).

2.2.3.7 Dry-matter and green-matter yields

Adegbola (1964) recorded 14 800 kg DM/ha per year at Agege (Lagos), Nigeria. In India 3 300 kg/ha fresh grass was obtained. Hendy (1975) obtained a production of 40 000 kg DM/ha per year at the Livestock Research Station, Tanga, United Republic of Tanzania, from a fertilizer application of 44 kg P2O5, 30 kg K2O and 50 kg N/ha per year. A selection of A. gayanus, No. 621 from Shika, Nigeria, yielded 4 000 kg DM/ha at Quilichao, Colombia without fertilizer nitrogen but with adequate phosphorus (CIAT, 1978). Cutting in early October gave best balance of bulk and quality (Haggar, 1970).

2.2.3.7 Suitability for Hay and Silage

It has been conserved as silage and hay, but its low nutritive value (Ademosun, 1973) does not justify the work involved (Miller, Rains & Thorpe, 1964). It is coarse and of l8 ow nutritive value after maturity, with only 1.5 percent crude protein (Miller, Rains & Thorpe, 1964). No toxicity has been reported by (Everist 1974). In Nigeria, natural grassland containing 60 percent of A. gayanus resulted in a weight gain of 0.31 kg per day when grazed by N'Dama and Keteku cattle, but when consumed as silage the weight gain was 0.11 kg/ day (Adegbola, Onayinka & Eweje, 1968). It is palatable when young and cattle will eat it up to flowering. Palatability ranking was *A. gayanus* > *Panicum coloratum* > *P. maximum* > *Pennisetum purpureum* (Bowden, 1963)

2.2.4 Elephant Grass *(Pennisetum purpureum)*

Elephant or elefante grass, Napier grass, gigante (Costa Rica), mfufu (Africa) is a robust perennial grass with a vigorous root system, sometimes with underground horizontal

stems called stolons with a creeping rhizome. The hollow stems are usually about 180-360 cm high, which are branched upwards. Leaf-sheaths glabrous or with tubercle-based hairs; leaf-blades 20-40 mm wide, margins thickened and shiny. Inflorescence a bristly false spike up to 30 cm long, dense, usually yellow-brown in colour, more rarely purplish (Chippendall, 1955).

Pennisetum purpureum is a monocot C4 perennial grass in the Poaceae family (Aminah, A. , Wong, C. C., & Eng, P. K, 1997). It is tall and forms in robust bamboo-like clumps (Farell, Simons, & Hillocks, 2002). It is a heterozygous plant, but seeds rarely fully form; more often it reproduces vegetatively through stolons which are horizontal shoots above the soil that extend from the parent plant to offspring (Farell, Simons, & Hillocks, 2002). This species has high biomass production, at about 40 tons/ha/year (Khan, Z. R., Midega, C. A. , Wadhams, L. J., Pickett, J. A., & Mumuni, A, 2007) and can be harvested 4-6 times per year (Farell, Simons, & Hillocks, 2002). Additionally it requires low water and nutrient inputs. (Strezov, Evans , & Hayman, C., 2008)

Napier can be propagated through seeds, however as seed production is inconsistent, collection is difficult (Farell, Simons, & Hillocks, 2002). Alternatively, it can be planted through stem cuttings of the stolons. The cuttings can be planted by inserting them along furrows 75 cm apart, both along and between rows. (Aminah, A. , Wong, C. C., & Eng, P. K, 1997)

2.2.4.1 Origin and Distribution

Elephant grass originated from sub-Saharan tropical Africa (Clayton *et al.*, 2013). It has been introduced as forage into most tropical and subtropical regions worldwide. It was introduced into the USA in 1913, in the 1950s into Central and South America and the West Indies, and in the 1960s into Australia. It is commonly

naturalized and sometimes becomes invasive (CABI, 2014). Elephant grass in mainly found from 10 °N to 20 °S. It is often regarded as a weed in crops, along roadsides, waterways, wetlands, floodplain, swamps, forest edges, disturbed areas and wastelands (CABI, 2014; Francis, 2004).

2.2.4.2 Habitat and Climate

Elephant grass can withstand drought conditions and is a pioneer species in arid lands such as the Galapagos Islands (CABI, 2014). Elephant grows from sea level up to an altitude of 2000 m (Francis, 2004). It does well in places where temperatures range from 25 °C to 40 °C (FAO, 2015) and where annual rainfall is over 1500 mm. It stops growing below 15 °C and is sensitive to frost, though it can regrow from the stolons if the soil is not frozen (Duke, 1983). Elephant grass is tolerant of drought and will grow in areas where the rainfall range is 200-4000 mm (Skerman & Riveros, 1990). Elephant grass is not tolerant of flooding and prefers well-drained soils. With poor drainage, it is best grown on raised beds (Göhl, 1982). It does better on rich, deep soils, such as friable loams, but can grow on poorly drained clays, with a fairly heavy texture, or excessively drained sandy soils with a pH ranging from 4.5 to 8.2 (FAO, 2015; Cook *et al.*, 2005; Duke, 1983). Elephant grass is a full sunlight species that can still produce under partial shade but does not withstand complete shade under a dense tree canopy (Francis, 2004). It grows best in deep, fertile soils through which its roots can forage although deep, friable loams are preferable (Skerman & Riveros, 1990).

2.2.4.3 Planting

Full land preparation with ploughing and subsequent disc-harrowing and drilling will repay the cost of establishment of this perennial grass (Skerman & Riveros, 1990). Either root cuttings or stem pieces with at least three nodes are planted in the drills (Skerman & Riveros,

1990). When planting stem pieces, two nodes should be covered with soil, the third being exposed. One hectare of grass will provide propagating material for 15-25 hectares (Skerman & Riveros, 1990). Planting rooted elephant grass pieces directly into an Imperata sward during the rainy season in the Philippines has had some success (Farinas, 1970). Plant in furrows about 15 cm deep and cover with about 7.5 cm of soil initially, gradually filling as the plant grows (Skerman & Riveros, 1990). Elephant grass is planted at the beginning of the wet season, at about 2 000 kg/ha of stem material.

2.2.4.4 Response to Defoliation

Elephant grass will stand heavy grazing and provides a great bulk of feed (Harrison & Snook, 1971), especially if fertilized and irrigated. It is suited to rapid rotational grazing, which must not be severe enough to hinder regrowth (Ware-Austin, 1963). Only the leaves are eaten when the grass is near maturity. A height of 5 cm is best for cutting (Vicente-Chandler *et al.*, 1974).

2.2.4.5 Grazing Management

Elephant grass is commonly used in a cut-and-carry system, feeding it in stalls, or it is made into silage. For grazing, it should be heavily stocked to maintain it in a lush vegetative form. The mature leaves are razor sharp and sometimes provide a problem for grazing cattle. The coarse stems produce new shoots and leaves called "lala" in Hawaii; the grass is best grazed when the new growth consists of five new leaves and associated stem growth. A stem plus "lala" takes a year to grow (Younge & Ripperton, 1960). Odhiambo (1974) showed no drop in nutritive value at Kitale, Kenya, in analyses taken at seven to 12 weeks. Grazing at six- to nine-week intervals at a height of about 90 cm gives good utilization. Nitrogen can be applied after each grazing or cutting in high-rainfall areas. Any coarse, leafless stems should be mowed.

2.2.4.6 Response to Fire

Elephant grass will burn if dry enough, and produce new growth afterwards, but it is seldom dry enough to burn in its normal environment.

2.2.4.7 Dry-Matter and Green-Matter Yields

Elephant grass gives heavy yields and Vicente- Chandler, Silva and Figarella (1959) established a world record production of 84 800 kg DM/year when it was fertilized with 897 kg N/ha per year and cut every 90 days under natural rainfall of some 2 000 mm per year. Other recorded yields are 35 500 kg DM/ha per year over three years in Tobago (Walmsley, Sargeant & Dookeran, 1978), 32 400 kg DM and 3 400 kg crude protein per hectare per year when cut every 56 days at CIAT, Colombia (Moore & Bushman, 1978), 20 800 kg DM/ha per year in Nigeria (Adegbola, 1964) and 40 000-50 000 kg green matter per hectare when cut each 35-40 days at the Tulio Ospina Station, Colombia (Crowder, Chaverra & Lotero, 1970).

2.2.4.8 Suitability for Hay and Silage

It makes good hay if cut when young but is too coarse if cut late in its annual growth cycle. It is more usually made into silage of high quality without additives. Silage losses have been 9 percent in India (Mahadevan & Venkatakrishnan, 1957) and 17 percent in Puerto Rico (Vicente- Chandler *et al.,* 1953). In Taiwan, elephant grass is widely used for the production of dehydrated grass pellets.used as a supplementary stock feed (Manidool, personal communication).

2.2.4.9 Value as a Stand-over or Deferred Feed

If the grass is allowed to reach maturity before the last wet-season cut, it gives better dry-season use. On the Atherton Tableland, Queensland, it is used for dry-season feed by rolling at the end of winter, as it can make some winter growth during this period (Quinlan & Edgley, 1975).

2.2.4.10Toxicity

García-Rivera and Morris (1955) recorded 2.48 percent of oxalates in the dry matter of elephant grass and 2.5 percent in the Merker variety but no toxicity was experienced. Ndyanabo (1974) recorded 3.1 percent total oxalates but again no toxicity.

CHAPTER THREE

METHODS AND METHODOLOGY

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 between the months of July and August 2017 (rainy season).

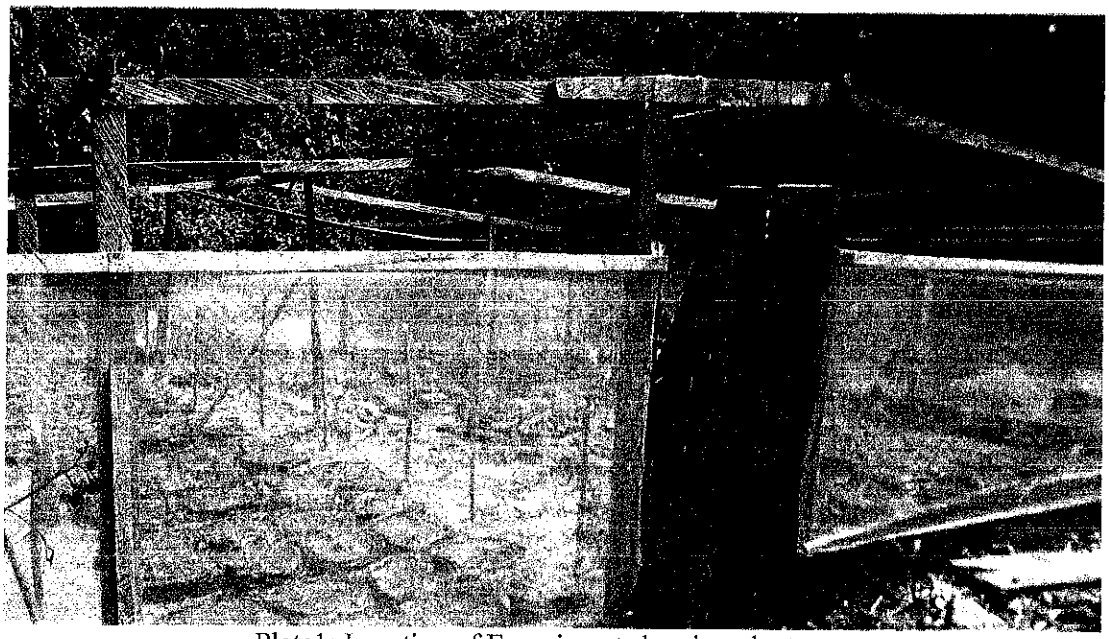


Plate1: Location of Experiment showing plant pots

3.2 Layout and Treatments

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

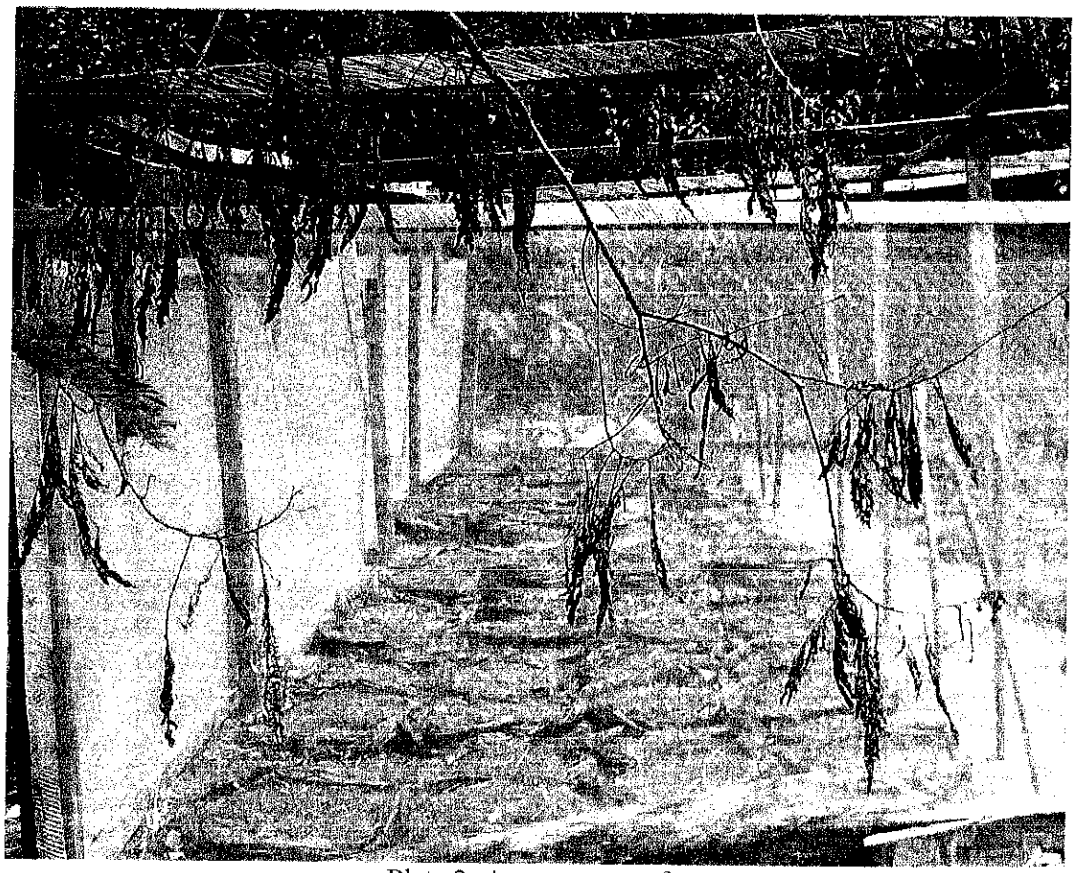


Plate 2: Arrangement of pots

3.3 Viability Test

For a period of one week prior to planting, viability tests were carried out on the seeds of the four species of grasses to be planted. The viability test was to calculate the percentage of viable seeds in the total amount of seeds to be used for planting which will serve as a guide for planting on the field. For the forage maize, forage millet and the gamba grass, Petri dishes with tissue papers placed at the base were obtained. Water was then added to the tissue

papers after which ten seeds selected at random were kept on the tissue. Germination was then monitored from the petri-dish. The scientific principle behind this method is that for germination to occur; a seed must be subjected to water, air and a certain amount of heat. After a period of two days, the plumule was observed emerging from the seeds after which the radicle was observed; germination percentage for both maize (*Zea mays*) and millet (*Echinochloa utilis*) were 100%, however for the gamba grass the germination percentage was not as high, as a germination percentage of 60% was recorded. The implication of this is that: for the maize and millet seeds sampled, in every 10 seeds to be planted, there would be 10 stands; all things being equal; however for the gamba grass, all things being equal, I expect only about 6 seeds to germinate in every 10 seeds to be planted. The results for the gamba grass is not so good and can only be used for experimental purposes as of this one.

Elephant grass reproduces sexually just like millet and maize however unlike maize and millet, the seeds of elephant grass are very small which explains the fact that they do not germinate well and might require longer period of time to germinate compared to other grass species, thus it is reproduced using rhizomes. Therefore with all these in mind, a viability test for elephant grass cannot be conducted as like it has been said earlier. Ten rhizomes of elephant grass were planted in polythene bags with constant supply of water as at when need. The bag was observed for a period of six days within which 70% germination was observed. This result means that for every ten rhizomes planted 7 are going to be viable all things being equal, which is considerably okay.

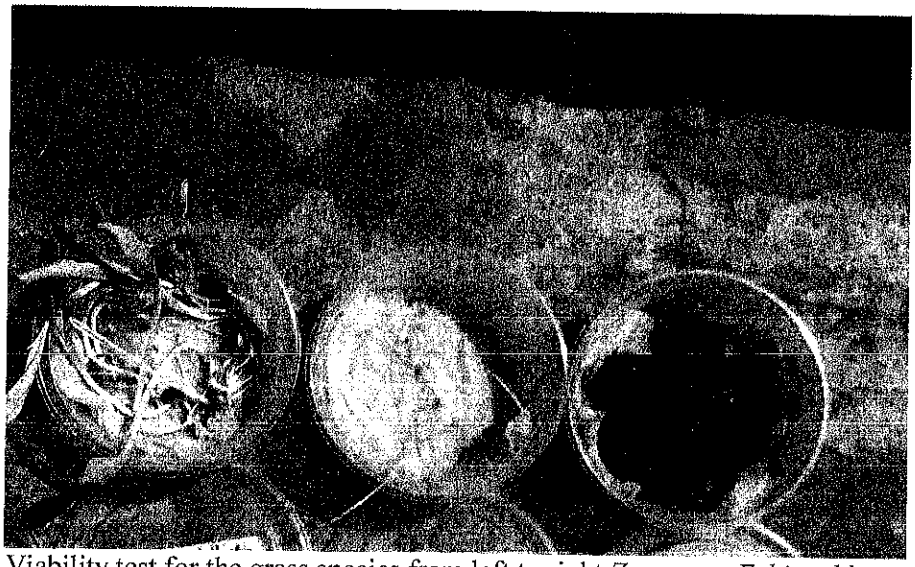


Plate 3: Viability test for the grass species from left to right *Zea mays, Echinochloa utilis and Andropogon gayanus*

Plate4: Viability test for *Pennisetum purpereum*

3.4 Data Collection

3.4.1 Plant Height

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

3.4.2 Number of Leaves

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

3.4.3 Sward Height

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

3.4.4 Leaf Width

The leave width was measured bi-weekly was measured using a short meter rule and the values obtained were recorded.

3.5 Chemical Analysis

3.5.1 Soil Attributes

The soil used in planting was analyzed in the laboratory before and after planting 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.

3.5.1.1 Soil pH (in water)

10ml 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).

3.5.1.2 Soil Organic Carbon

Apparatus used: Burette, 50ml or 25ml.

Reagents:

- Potassium dichromate ($K_2Cr_2O_7$) 1N – dissolve 49.04g of $K_2Cr_2O_7$ in distilled water and dilute to 1 litre.
- H_2SO_4 conc. If chloride (Cl) is present in the soil add Ag_2SO_4 to the acid at the rate of 15g per litre.
- O-phosphoric acid (H_3PO_4) conc.

- O-phenanthroline-ferrous complex 0.025 M (Ferroin). When ferroin indicator is not available it can be prepared as follows – dissolve 14.85g of O-phenanthroline monohydrate and 6.95g of $FeSO_47H_2O$ in water dilute to 1 liter.
- Barium diphenylamine sulfonate (0.16%) Optional. can be used in place of O-phenanthroline-ferrous complex.
- Ferrous sulfate (0.5N) – dissolves 140g of $FeSO_27H_20$ in water; add 15ml conc. H_2SO_4 cool and dilute to 1 litre. Standardize this reagent daily, or each time before using for organic carbon determination by titrating against 10ml 1 N $K_2Cr_2O_7$.

Procedure:

The soil organic carbon present was estimated using the using Walkley-Black Method (1987). A representative soil sample was collected and grinded to pass through 0.5mm sieve. The soil samples were weighed in duplicates and transferred to 250ml Erlenmeyer flask. 10ml of 1M $K_2Cr_2O_7$ solution was pipetted accurately into each flask and swirled gently to disperse the soil. 20ml of concentrated H_2SO_4 was added rapidly using an automatic pipette, directing the stream into the suspension. The flask was gently swirled until soil and reagents were mixed, then it was swirled more vigorously for one minute. The beaker was rotated again to allow the flask stand on a sheet of asbestos for about 30 minutes. 100ml of distilled water was added after standing for 30 minutes. About 3 drops of indicator was added and the mixture was titrated with 0.5N ferrous sulfate solution. As the end point is approached, the solution takes on a greenish cast and then changes to dark green. At this point, ferrous sulphate was added drop by drop until the colour changed sharply from blue to red (maroon

colour) in reflected light against a white background. I then calculated the result according to the following formula:

$$\%\ \text{Organic Carbon in soil (air dry basis)} = \frac{(\text{me } K_2Cr_2O_7 - \text{me } FeSO_4) \times 0.003 \times 100 \times (f)}{\text{mass of air dry soil}}$$

Correction factor, f = 1.33
me = Normality of solution x ml of solution used
% Organic matter in soil = % Organic Carbon x 1.729.
% Organic Carbon may also be expressed on oven – dry basis after correction for moisture content in air – dry soil.

3.5.1.3 Determining Available" P in soil (Olsen's Test)

Apparatus:

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

Reagents:

- Olsen's extracting solution

Sodium bicarbonate ($NaHCO_3$) solution, 0.5 M:- adjust the pH of this solution to 8.5 with 1 M NaOH. Add mineral oil to avoid exposure of the solution to the air. Prepare a fresh solution before use if it has been standing over one month in a glass container. Store the solution in a polyethylene container for periods longer than month.

- Carbon black. Use carbon black G (Fisher Scientific Company, Cat. No. C-179).

Procedure:

2g of soil, 1 teaspoon of carbon black and 40 ml of the extracting solution were added to a 125 –ml Erlenmeyer flask. Flask was shaken for 30 minutes on a mechanical shaker. The suspension was filtered through the Whatman No. 40 paper. The flask was shaken immediately before pouring the suspension into the funnel. The solution was stored for P determination using the colorimetric method as would be discussed later.

3.5.1.4 Determining Soil Total Nitrogen

Apparatus used

1. Complete Tecator Digester System (unit of 20 tubes).

2. Top loading weighing balance.

3. Acid dispenser.

4. Technicon's Autoanalyzer (AAII).

Procedure followed

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 370oC 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.

Calculation

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

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

Apparatus used:

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

Reagents:

The silver-thiourea (Ag TU) reagent is prepared by first dissolving 30g of anhydrous thiourea in about 500 ml of distilled water in a 2-liter volumetric flask and adding slowly 1 litre of a 0.02M $AgNO_3$ solution (stored in brown bottle) under vigorous stirring. The resulting mixture is then diluted to 2 litres with deionized water giving a final concentration of 0.01M Ag NO_3 and about 0.2M thiourea. The unbuffered reagent gives a pH value around 5.5. Store the reagent in a brown bottle.

Procedure:

1 to 5g of soil sample was weighed and 30 ml of the silver-thiourea reagent is added in a centrifuge tube. The content is the shaken on a reciprocal mechanical shaker for 2 hours. Centrifuge (2000 rpm or a higher speed for 5-10 minutes.) The clear supernatant are then carefully decanted into a glass vial or a conical flask. Potassium (K) and Sodium contents were determined using a flame photometer. Magnesium (Mg) and Calcium (Ca) composition were determined using atomic absorption spectrophotometer.

10 ml of the silver-thiourea extract was pipetted into a 50-ml conical flask. 3 drops of phenolphthalein indicator was added and the solution was titrated with 0.01N NaOH standardized to a permanent pink end-point while stirring the solution with a magnetic stirrer. The amount of base used is equivalent to the total amount of acidity (H + Al) in the volume of aliquot taken. The CEC is calculated by the sum of exchangeable "bases" (Ca, Mg, K, Na) and exchangeable Al and H expressed in meq/100g soil.

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

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 H2SO4 and 0.313N NaOH. The compounds removed are predominantly protein, sugar, starch, lipids and portions of both the structural carbohydrates and lignin.

Apparatus

1. Analytical Balance—capable of weighing 0.1 mg.

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

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

4. 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).

5. 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.

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

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

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

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).

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.

Calculation

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

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)

3.6.2.2 Crude Protein Content

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

Apparatus used

1. Kjeldahl digestion flask - 500ml.
2. Kjeldahl distillation apparatus.
3. Conical flask, 250 ml.
4. Burette 50 ml.

Procedure followed

About 1-2g 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.

$1\ ml\ of\ 0.1\ N\ H2SO4 = 0.0014gm\ N.$

Calculation

$Calculate\ protein\ as = N\ x\ 6.25$

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

Moisture Content

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

Apparatus used

1. Weighing balance.
2. Desiccator.
3. Oven: electric maintained at 105 ± 10oC
4. Moisture dishes –Porcelain, silica, glass or Aluminium (7.5 x2.5 cm.)

Procedure followed

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

Calculation

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

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

$W2 = weight\ (g)\ of\ sample\ after\ drying$

3.6.2.3 Crude Ash determination

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

Apparatus used

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

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

Calculation

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

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

$Where: ODW = oven\ dry\ weight$

3.6.2.4 Crude Fat Determination

The Soxhlet method (1879) 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.

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 reweighed. 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.

Calculation

$$Weight\ of\ empty\ flask\ (g) = W1$$

$$Weight\ of\ flask\ and\ extracted\ fat\ (g) = W2$$

$$Weight\ of\ sample = S$$

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

Nitrogen Free Extract Determination

Nitrogen-free extract (NFE) was calculated using the formula:

$$NFE\ (g\ kg-1\ DM) = 1000 - (Moisture\ content + CP\ content + CF\ content + crude\ fat\ content + crude\ ash\ content$$

3.6 Model Functions

3.6.1 Model for Biomass Accumulation

The equation for bio-mass accumulation (BMA) was derived using the following parameters:

1. GS: Grass species
2. CT: Cutting time
3. SL: Sward length
4. LW: leaf width
5. AVGnL: Average number of leaves
6. OM's: Soil organic matter

$$\boxed{BMA = OM's + GS + E_t}$$

where E_t is error due to time and can be minimized by taking note of the CT

CT is indepent while PH, SL, LW and AVGnL are all dependent on CT

$E_t = CT + \varepsilon_t$
ε_t *is uncomtrollable and it is the error due to chance*
$CT = PH + SL + LW + AVGnL + \alpha$ *; where* α *is a constant or intercept*

For Gs1
$CT = -5.026 - 0.061PH + 0.97SL + 0.157LW + 0.644AVGnL;$
$\varepsilon_t(Error\ of\ Estimate\ for\ Gs1) = 0.270$

For Gs2
$CT = -2.7 + 0.07PH + 0.062SL + 0.694LW + 0.304AVGnL;$
$\varepsilon_t(Error\ of\ Estimate\ for\ Gs2) = 0.326$

For Gs3
$CT = -4.556 + 0.069PH + 0.003SL + 0.258LW + 0.005AVGnL;$
$\varepsilon_t(Error\ of\ Estimate\ for\ Gs3) = 0.406$

For Gs4
$CT = -2.63 + 0.21PH + 0.056SL + 0.294LW + 0.384AVGnL;$
$\varepsilon_t(Error\ of\ Estimate\ for\ Gs4 = 0.193$

3.6.2 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}

BM_s is the soil organic matter content in %

N_g is the % nitrogen content

For successive days:

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

3.7 Statistical Analysis

3.7.1 Linear Additive Model

$$Y_{ij} = \mu + G_i - C_j + E_{ij}$$

Where

Y_{ij} = Individual cuttings (effects of jth cutting on the ith grass

μ = General mean

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

C_j= Effect of cuttings (Bi-weekly cuttings)

E_{ij}= Experimental error

3.7.2 Data Analysis

The data were analysed using the PROC GLM of SAS (SAS Institute Inc., 2008) with cut time, grass specie, as fixed effects. The Turkey's honestly significantly different Test at 5% probability level was used to separate the differences between treatment means.

CHAPTER FOUR

RESULTS

4.1 Soil Physico-Chemical Properties

4.1.1 Soil before Planting of Grass Species

Table 1: Soil Physical Properties before planting of grass species

Physical properties	Concentration (%)
Sand	89
Silt	4
Clay	7
Total organic carbon	28.71
% Organic matter	50.00

Table 2: Soil Chemical Properties before planting of grass species

Chemical Properties	Concentration
N%	2.96
K(cmol/kg)	0.30
Na(cmol/kg)	0.08
Ca (cmol/kg)	2.46
Mg(cmol/kg)	0.80
ECEC	3.67
pH	6.6
Fe (PPM)	178.91
Cu (PPM)	26.01
Cl (PPM)	0.13
Zn (PPM)	89.82
Mn (PPM)	126.35

4.1.2 Soil after Harvesting of Grass Species

Table 3: Soil Physical Properties after Harvesting of grass species

Physical properties	Concentration (%)
Sand	73
Silt	11
Clay	16
Total organic carbon	19.30
% Organic matter	33.59

Table 4: Soil Chemical Properties after Harvesting of grass species

Chemical Properties	Concentration
N%	1.99
K(cmol/kg)	0.37
Na(cmol/kg)	0.10
Ca (cmol/kg)	4.01
Mg(cmol/kg)	1.00
ECEC	5.51
pH	5.5
Fe (PPM)	93.22
Cu (PPM)	16.83
Cl (PPM)	0.10
Zn (PPM)	71.73
Mn (PPM)	106.23

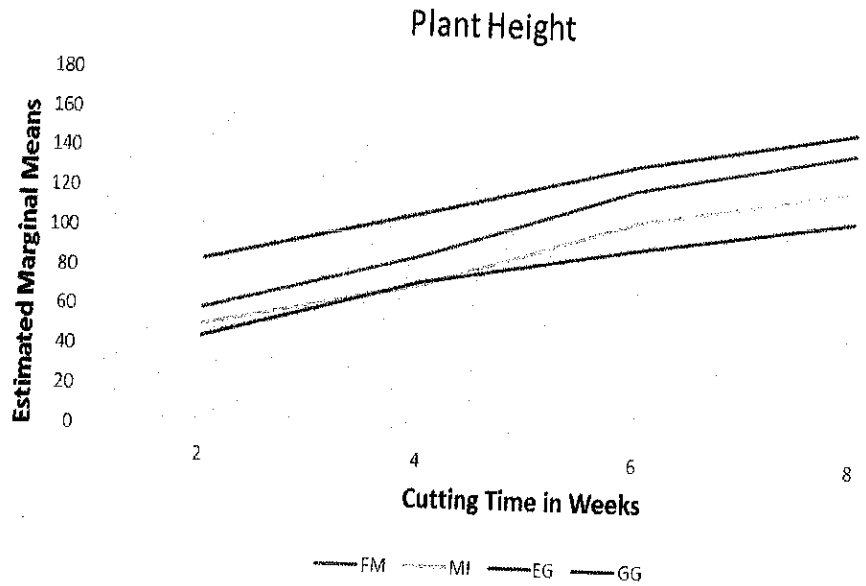
4.2 Growth Attributes

Table 5: Growth attributes of *Zea mays*, *Echinochloa utilis*, *Pennisetum pupureum* and *Andropogon gayanus*

Parameters	Plant Height (cm)				Sward Height (cm)				Leave Width				Average Number of leaves			
Cutting Times (weeks)	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
Zea mays	59.79^{b}	88.51^{b}	124.80^{b}	145.37^{a}	43.78^{b}	64.21^{b}	76.42^{b}	89.85^{b}	2.52^{a}	3.72^{a}	4.66^{a}	5.44^{a}	5.13^{a}	5.60^{a}	7.87^{a}	8.67^{a}
Echinochloa utilis	51.01^{c}	73.54^{c}	108.33^{c}	126.64^{b}	37.83^{c}	57.00^{c}	65.73^{c}	75.93^{c}	0.67^{b}	1.51^{d}	2.76^{d}	3.56^{c}	4.94^{a}	5.00^{a}	7.03^{b}	7.81^{b}
Pennisetum purpureum	84.34^{a}	109.89^{a}	136.83^{a}	155.69^{a}	55.76^{a}	84.17^{a}	103.51^{a}	117.43^{a}	2.08^{a}	2.88^{b}	4.28^{b}	4.51^{b}	4.13^{b}	4.26^{b}	5.15^{d}	5.88^{c}
Andropogon gayanus	45.60^{c}	75.638^{c}	94.35^{d}	111.37^{c}	30.91^{d}	50.96^{c}	64.24^{c}	80.26^{c}	1.24^{b}	1.90^{c}	3.19^{c}	4.61^{b}	3.88^{b}	4.46^{b}	5.61^{c}	6.08^{c}
SEM	1.02	1.22	0.76	1.55	0.47	1.13	0.52	0.81	0.11	0.04	0.04	0.06	0.11	0.04	0.04	0.06

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

4.2.1 Plant Height



FM-Forage maize

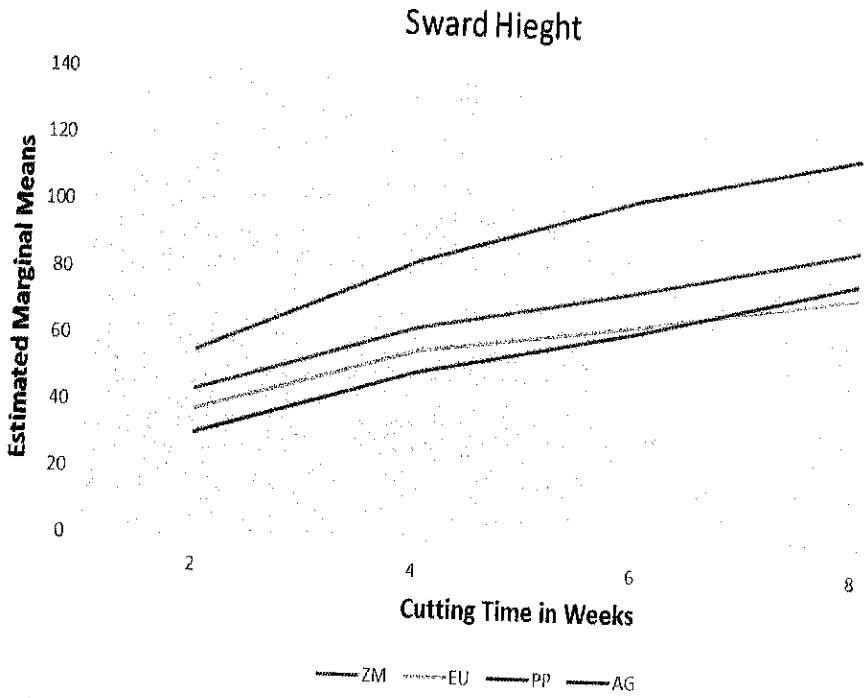
MI- Forge Millet

EG-Elephant Grass

GG-Gamba grass

Figure 1: Estimated Marginal Means of Bi weekly Plant Height

4.2.2 Sward Height



ZM-*Zea mays*

EU: *Echinochloa utilis*

PP: *Pennisetum pupureum*

AG-*Andropogon gayanus*

Figure 2: Estimated Marginal Means of Bi weekly Sward Height

4.2.3 Leave Width

ZM-*Zea mays*

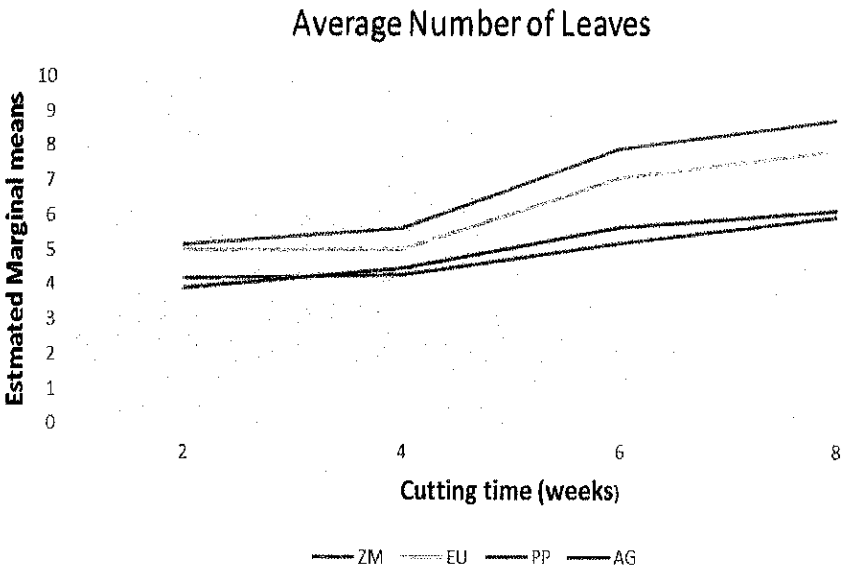
EU: *Echinochloa utilis*

PP: *Pennisetum pupureum*

AG-*Andropogon gayanus*

Figure 3: Estimated Marginal Means of Bi weekly Leave Width

4.2.4 Average Number of Leaves



ZM-*Zea mays*

EU: *Echinochloa utilis*

PP: *Pennisetum pupureum*

AG-*Andropogon gayanus*

Figure 4: Estimated Marginal Means of Bi weekly Average Number of Leaves

4.3 Forage Quality

Table 6: Proximate Composition of *Zea mays*, *Echinochloa utilis*, *Pennisetum pupureum* and *Andropogon gayanus*

Parameters	Crude Protein (CP)				Ash				Moisture content				Crude Fat				Crude fibre			
Cutting Times (weeks)	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
Zea mays	3.31	7.31	8.81	11.19	4.38	4.86	5.87	4.97	7.88	8.75	10.56	8.95	1.51	1.68	2.02	1.71	10.13	11.25	13.58	11.51
Echinochloa utilis	3.56	6.69	8.75	10.75	4.77	4.46	5.83	4.80	8.58	8.02	10.49	8.63	1.64	1.54	2.01	1.65	11.03	10.32	13.49	11.10
Pennisetum pupureum	3.81	6.94	8.63	10.38	5.12	4.62	5.77	4.60	9.22	8.31	10.44	8.28	1.77	1.59	1.99	1.58	11.86	10.68	13.35	10.64
Andropogon gayanus	3.69	7.31	8.69	11.88	4.93	4.86	5.80	5.27	8.88	8.74	10.38	9.48	1.70	1.67	2.00	1.82	11.42	11.25	13.42	12.19
SEM	0.02	0.02	0.02	0.06	0.09	0.08	0.08	0.17	0.25	0.14	0.15	0.30	0.05	0.03	0.09	0.06	0.38	0.18	0.19	0.39

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

4.3.1 Crude Protein (%)

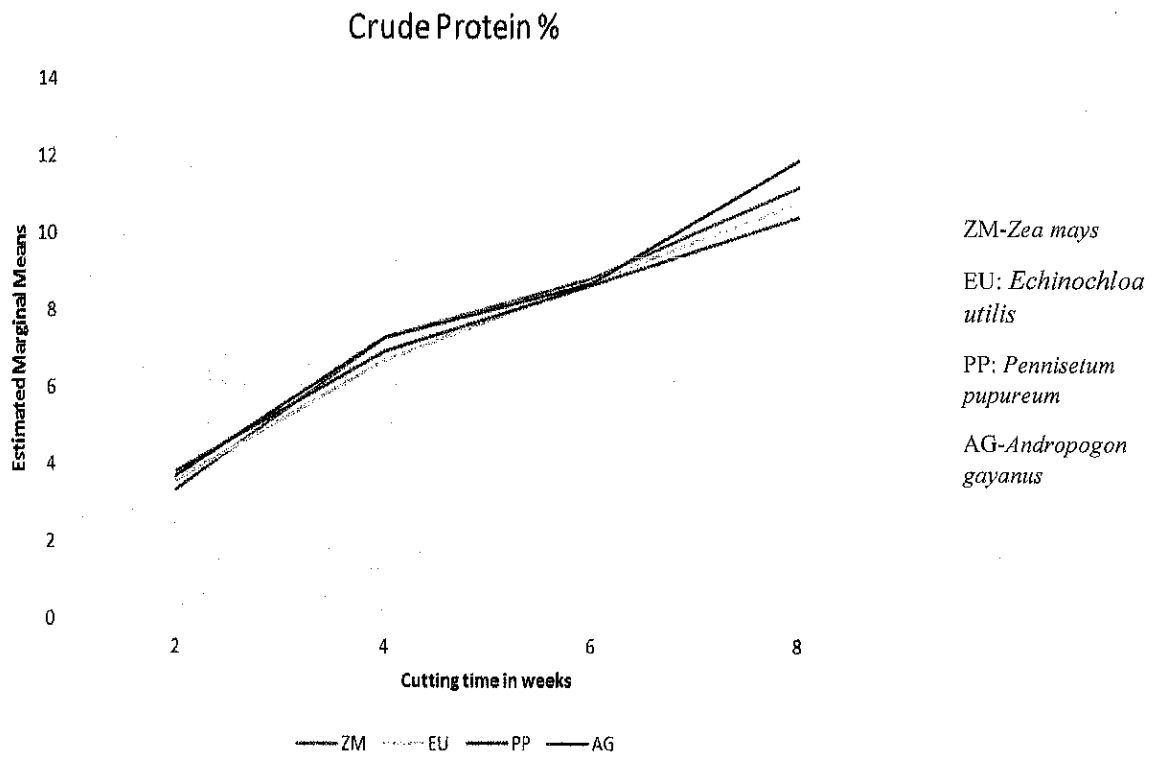


Figure 5: Estimated Marginal Means of Bi-weekly Crude Protein

4.3.2 Ash Content (%)

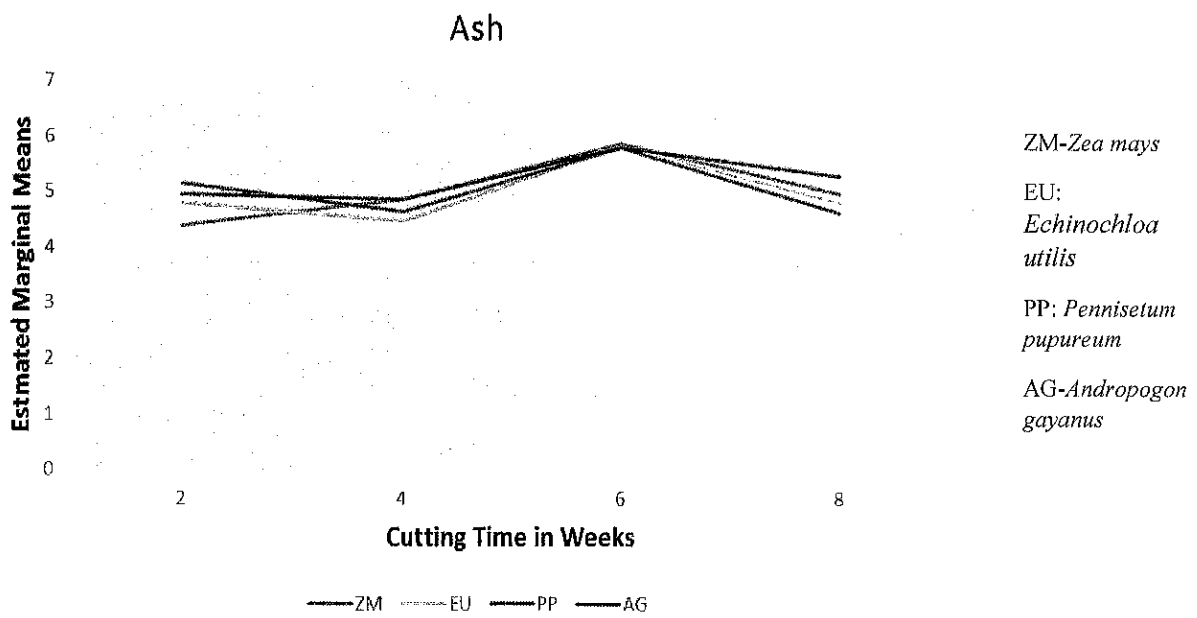
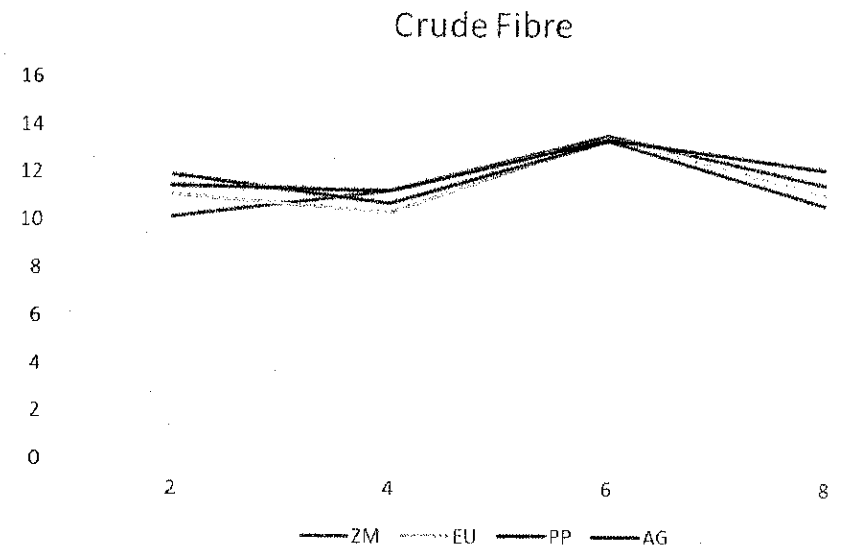


Figure 6: Estimated Marginal Means of Bi weekly Ash Content

4.3.3 Crude Fibre (%)



ZM-*Zea mays*

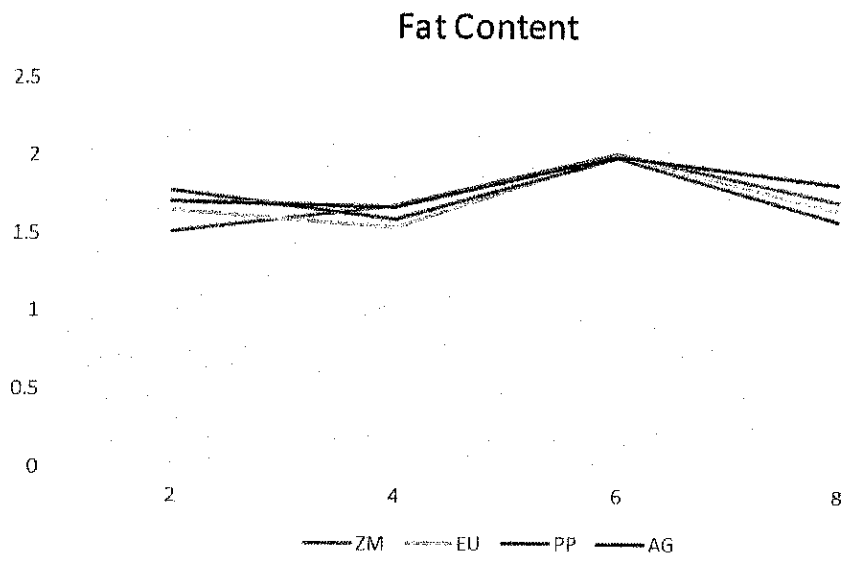
EU: *Echinochloa utilis*

PP: *Pennisetum pupureum*

AG-*Andropogon gayanus*

Figure 7: Estimated Marginal Means of Bi weekly Crude Fibre Content

4.3.4 % Fat



ZM-*Zea mays*

EU: *Echinochloa utilis*

PP: *Pennisetum pupureum*

AG-*Andropogon gayanus*

Figure 8: Estimated Marginal Means of Bi weekly Fat Content

4.3.5 Moisture Content

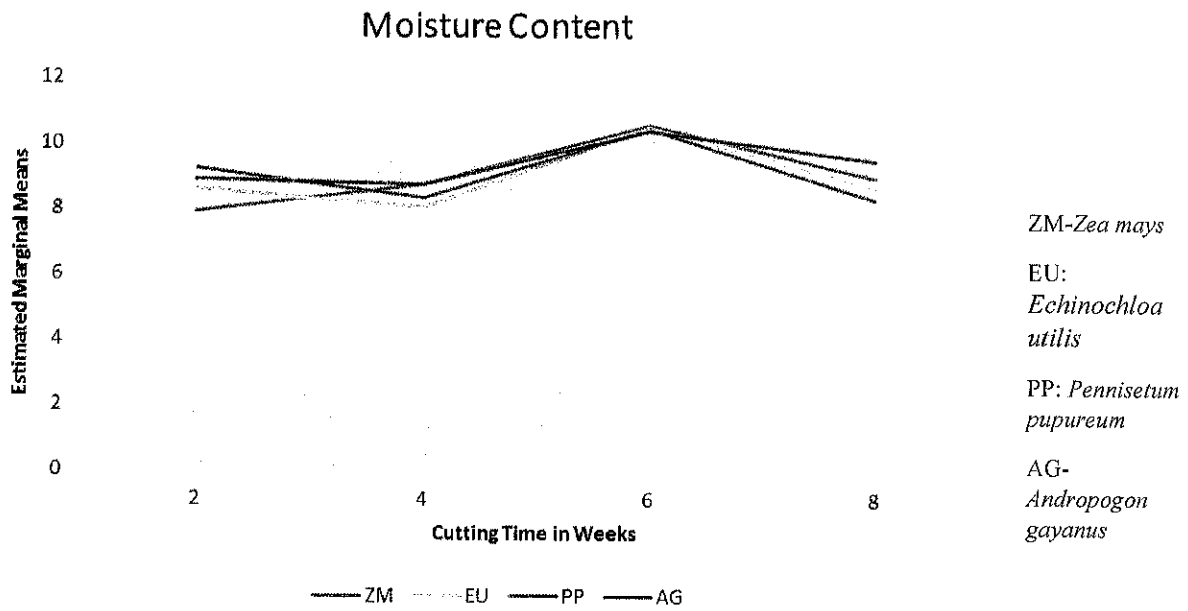


Figure 9: Estimated Marginal Means of Bi-weekly Moisture Content

4.4 Biomass Accumulation and Growth Rate

Table 7: Biomass accumulation and growth rate of *Zea mays, Echinochloa utilis, Pennisetum pupureum and Andropogon gayanus*

	Biweekly Biomass Accumulation (%)				Biweekly Growth rate (%)			
Grass Species	2 weeks	4 weeks	6 weeks	8 weeks	2 weeks	4 weeks	6 weeks	8 weeks
Zea mays	72.14	92.65	102.00	114.43	41.65	41.01	40.77	40.39
Echinochloa utilis	40.77	44.14	48.60	51.31	41.61	41.11	40.78	40.46
Pennisetum purpureum	38.58	40.63	42.91	44.32	81.57	81.07	80.80	80.52
Andropogon gayanus	48.12	55.97	61.46	66.53	71.59	71.01	70.79	70.28

CHAPTER FIVE
DISCUSSIONS

5.1 Physico-Chemical Properties Description

5.1.1 Soil before Planting

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

5.1.2 Soil after Harvest

The physico-chemical properties of soil after harvest is shown in the Table 2. The surface horizon (0-20cm) of the soil at the experimental site contains 73% sand, 11% silt, 16% clay indicating according to the standard soil classification that it is a Loam soil (USDA, 2014). The changes in the soil texture especially relating to the reduction in sand particles could be due to absorption of sand in form of silica by the plants as a defence mechanism against plant eating predators. There was a reduction in the organic matter content of the soil after harvest and this could be explained that it was used up during the production of biomass in the grasses.

5.2 Growth Attributes

5.2.1 Plant Height

The results show that of all four grasses planted; Elephant grass had the highest plant height which was statically different **(at $p \leq 0.05$)** from the other three throughout the course of the experiment, followed by forage maize which was also stood out during the course of the experiment. Although Forage millet and gamba grass did not show any statistical difference at two weeks, even until the fourth week of planting; forage millet later outgrew gamba grass and came third in the 8th week. The growth of the species could be attributed to their adaptability to the environment and their ability to effectively grow under harsh conditions. Elephant grass is regarded as one of the highest yielding tropical grasses. It is a very versatile species that can be grown under a wide range of conditions and systems: dry or wet conditions, smallholder or larger scale agriculture. It is a valuable forage and very popular throughout the tropics, notably in cut-and-carry systems (Food and Agriculture Organisation (FAO), Rome, Italy, 2015). The plant height for the various grass species 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

The results show that of all four grasses planted; Elephant grass had the highest sward height which was statically different **(at $p \leq 0.05$)** from the other three throughout the course of the experiment, followed by forage maize which was also stood out during the course of the experiment. Forage millet showed had sward heights that were statistically different from gamba grass at two weeks, even though they did not show any more statistical differences afterwards. The differences in the sward heights can easily be explained by the same causes of difference in the plant height such as genetic causes, soil organic components, fertilizer application etc. This is because the sward height is directly linked with contributing to the

plant's total height. All ingestive behaviour variables except bite area (i.e. bite weight, rate, depth, and volume) were significantly related to sward height irrespective of forage species, and sward height always had a greater effect than bulk density. Bite area had no significant functional relationship with either sward height or bulk density.

(Realini , Hodgson, Morris , & Purchas, 1999) suggested that maintaining a sward height of 10 cm offers advantages in terms of individual animal output and output per hectare compared with grazing at 5 cm, and that compensatory growth does not seem to be an important phenomenon in heavy (over 500 kg live weight) finishing steers.

5.2.3 Average Number of Leaves

The number of leaves varied significantly (at $p \leq 0.05$), with *Zea mays* having the highest average number of leaves per week (table 5). Since animals feed mainly on the leaves of forage plants, the average number of leaves is important because it directly influences the amount of dry matter available for consumption for the animal from each plant. The number of leaves is also important because it accounts for photosynthesis for the plant which directly impacts growth. The differences in the number of leaves as observed during the course of this project work can be attributed to the nutrient available to each plant, interspecies differences, genetic makeup of individual plants and the availability or amount and or quality of sunlight received by the plants.

5.3. Forage Quality

5.3.1 Crude Protein (CP)

The crude protein content of the four grass species did not differ statistically **(at $p \leq 0.05$)**. However, the crude protein content was observed to increase nearly linearly as the grasses grew Samples from the last cuttings (8th week) had the highest crude protein content (11.88% in *Andropogon gayanus*). The increase in the crude protein with time could be attributed to the high level of Nitrogen in the soil. The high proximate (CP, fat, and ash) composition of the forage species observed during the rainy season in the present work, may

be due to high concentration of such minerals which are precursors to the proximate formation in the rainy season than in dry season. Minerals activate enzymes and are essential co-factors of metabolic reactions. They also function as carrier of protein (George et al., 2005). For instance, nitrogen is required for protein synthesis, formation of chlorophyll and nucleic acids whereas calcium, potassium and magnesium are components of ash.

5.3.2 Crude ash

The crude Ash content did not vary between the four grass species statistically (at $p \leq 0.05$). Although the highest crude ash content was recorded in the 6th week (5.80% *in Andropogon gayanus*). Ash content represents 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 irregular patterns of the crude ash as seen in the results can be explained in that the grasses absorbed some sand from the soil in form silicon. This was reported by Alice Klein in 2017 in an article titled "Plants have evolved a taste for sand that deters hungry insects" on New Scienctist.com. According to Klein, this absorption of sand from the soil could be seen as an evolutionary defence mechanism against plant consuming predators. This could easily explain the masked reduction in the levels of sand present in the soil at the end of the experiment. The high proximate (CP, fat, and ash) composition of the forage species observed during the rainy season in the present work, may be due to high concentration of such minerals which are precursors to the proximate formation in the rainy season than in dry season. Minerals activate enzymes and are essential co-factors of metabolic reactions. They also function as carrier of protein (George et al., 2005). For instance, nitrogen is required for protein synthesis, formation of chlorophyll and nucleic acids whereas calcium, potassium and magnesium are components of ash.

5.3.3 Crude Fibre

The crude fibre content of the grasses showed an irregular pattern of rise and fall during the experiment in which the patterns where similar to that of moisture content

although the crude fibre content across the grass species did not differ statistically, at $p \leq 0.05$ throughout the course of the experiment. The fibre content of the three grasses increased due to the encrustation of lignin in them as the grasses matured. 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).

The highest crude fibre level was recorded in the 6th week 13.58 in *Zea mays* although it dropped a little to this pattern could be attributed to the changes in season during the period of the experiment(august break) which could have resulted in differences in available water levels in the soil in those periods. 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).

5.3.4 Fat Content

Fat promotes the absorption of fat soluble vitamins hence it is very important in diets. Fat content in Zea mays, *Echinochloa utilis*, *Pennisetum purpureum* and *Andropogon gayanus* did not differ statistically (**at $p \leq 0.05$**). The implication of this result is that an analysis into the relative content of fat soluble vitamins in the four species of grasses would most probably yield no statistical difference. This could be attributed to similarities in the genetic makeup of the plants or the uniformity of the soil used for the experiment.

5.3.3 Moisture content

The moisture content did not vary between the grass species statistically (at $p \leq 0.05$). Although the highest moisture content was observed in the 6th week (10.56 in *Zea mays*) as it further dropped in the 8th week (table 6). Grass with lowest moisture content could store for a longer time without spoilage. Also the moisture content affects the amount of dry matter available to the animals for consumption. With higher levels of moisture, there would be

lesser levels of dry matter which would imply that the animals could eat a lot of forage to fill up their stomach but may not meet their nutrient requirement levels.

Generally, Onyeonagu *et al;* 2013, reported that masked differences in proximate composition can be observed in grasses harvested under different seasonal variations. Eze 2010 also explained that the relative composition of forages is function of various factors that interact with one another to produce varied results. High proximate composition of the grass species observed maybe due to the high concentration of such mineral which are precursors to the proximate formation (Onyeonagu et al; 2013).

5.4 Biomass Accumulation and Growth Rate

The results from the biomass accumulation saw *Pennisetum purpureum* having a low biomass accumulation yield (44.32%) as compared with the highest *Zea mays* (114.43%) at 8weeks. *Pennisetum purpureum* also had the highest growth rate 81.57% followed by *Andropogon gayanus* (71.59%) at 2 weeks. The biomass yield increased with the number of weeks while the growth rate reduced with the number of weeks. This implies that the grasses grew rapidly as they were planted and their growth declined as they aged. Using the values obtained, one could get a prediction for the future by easily plotting a graph or using a trend analysis to understand what the growth rate or biomass accumulation would look like for the four species.

CHAPTER SIX
CONCLUSION

The highest growing grass during the course of the experiment was *Pennisetum purpureum* although it had a low biomass accumulation yield (40.34%) as compared with *Zea mays* (114%). *Pennisetum purpureum* also had the highest growth rate 80%. The model developed in the course of this research work can easily predict growth rate and biomass accumulation of the four grass species. Since results obtained in this study were for one season and was conducted in the tropics, it is recommended that the experiment be repeated over a number of locations and seasons to confirm these results.

6.1 Recommendations

Based on these results, I would recommend *Pennisetum purpureum* and *Zea mays* ahead of other grass species used in the course of this research. I would also recommend that the biomass accumulation and growth rate models be made into computer software to allow for easy computation by farmers. Such software should be easy to operate and should allow for interpretation so that pasture farmers can make easy decisions as regards what they are to plant.

6.2 Suggestions for Further Research

- The biomass accumulation of this grasses could further be examined with legume intercrop.
- The digestibility of the grass samples could be further examined using animals, so as to have more accurate recommendations as regarding which of the grasses should be grown.

REFERENCES

Adegbola, A.A. (1964). Forage crop research and development in Nigeria. *Nigerian Agricultural Journal*, 1: 34-39.

Adegbola, A.A., Onayinka, E.A.O. (1976). A review of range management problems in the southern Guinea and derived savanna zones of Nigeria. *Tropical Grassland*, 10: 41-51.

Adegbola, A.A., Onayinka, E.A.O. & Eweje, J.K. (1968). The management and improvement of natural grassland in Nigeria. *Nigerian Agricultural Journal*, 5: 4-6.

Ademosun, A.A. (1973). A review of research on the evaluation of herbage crops and natural grasslands in Nigeria. *Tropical Grassland*, 7: 285-296.

Agriculture and Horticulture Development Board. (2014). *Growing and feeding forage maize – a review*. Reading: University of Reading.

Aganga, A.A., Adogla-Bessa T., Omphile, U.J., and Tshireletso, K. (2000). Significance of browses in the nutrition of Tswana goats. *Archivos Zootechnia. 49: 469-480.*

Aminah, A. , Wong, C. C., & Eng, P. K. (1997). *Techniques for rapid vegetative multiplication for pasture species and commercial production.* Rome: Regional Forage Development, FAO.

Aminah, A., Wong , C. C., & Eng , P. K. (1997). *Techniques for rapid vegetative multiplication for pasture species and commercial production.* Regional Forage Development, FAO, Rome.

Andrade, A. S., Santos, P. M., Pezzopane, J. R., de Araujo, L. C., Pedreira, B. C., Marin, F. R., & Lara, M. A. (2015). Simulating tropical forage growth and biomass accumulation: an overview of model development. *Grass and Forage Science*.

Anele, U.Y., Jolaosho, O.A., Arigbede, O.M., Olanite. J.A. and Onifade, O.S. (2013). Effects of growth habits of grasses on weed population and dry matter yield in grass-legume swards. *Archivos de Zootechnia; vol. 62, Num. 237, p.87.*

AOAC. 976.05 (2005), *Protein (crude) in animal feed and pet food, Final action 1977.*Codex- adopted AOAC Method, Revised March 1996.

AOAC (Association of official Agricultural Chemists). (1990*). Official methods of analysis*, 15th ed. 2200 Wilson Boulevard Arlington Virginia, USA. Pp. 69–88.

AOAC. (2010). Association of official analytical chemists. Official methods of analysis. Arlington. Virginia. USA. 19th edition.

Bowden, B.N. (1964). Studies on *Andropogon gayanus* Kunth. 3. An outline of its biology. *J. Ecol.*, 52: 255-271.

Chippendall, L. K. A. (1955). *A guide to the identification of grasses in South Africa. p. 1-527. In d. meredith (ed).* The grasses and pastures of South Africa. Central news agency, Cape Town South Africa.

Chippendall, L.K.A. (1955). A guide to the identification of grasses in South Africa. *In* Meredith, D., ed. *The grasses and pastures of South Africa.* Parov (Cape Province), South Africa, Central Newsagency.

CIAT. (1978). *Ann. Rept.* Cali, Colombia.

Cook, B.G., Pengelly, B.C., , Brown, S.D., Donnelly J.L., Eagles, D.A., Franco, M.A., Schultze-Kraft, R. (2005). *Andropogon gayanus.* Retrieved September 9, 2017, from Tropical Forages: an interactive selection tool., CSIRO, DPI&F(Qld), CIAT and ILRI, Brisbane, Australia.: http://www.tropicalforages.info/key/Forages/Media/Html/Andropogon_gayanus.htm

Crosby C.F. (2008). Grasses. In *Microsoft® Encarta® 2009 [DVD].* Redmond WA: Microsoft Corporation. Retrieved from Microsoft® Encarta® 2009 [DVD].

Csurhes , S., & Hannan-Jones, M. (2016). *Gamba grass; Andropogon gayanus.* Queensland: The State of Queensland, Depar tment of Agriculture and Fisheries.

Duke, J.A. (1983). *Handbook of legumes of world economic importance.* NY, USA: Plenum press.

Everist, S.L. (1974). *Poisonous plants of Australia.* Sydney, Angus and Robertson.

Eze SM (2010). *The effect of season on the chemical composition of some forage grasses and legumes found in Nsukka derived savannah zone of Nigeria. B. Agric project report.* Department of Crop Science University of Nigeria, Nsukka. P. 60.

Farell, G., Simons, S. A., & Hillocks, R. J. (2002). Pest Diseases and Weeds of Napier Grass, Pennisetum Purpureum. *International Journal of Pest Management, 48*(1), 39-48.

Farinas, E.C. (1970). Pasture legumes and grasses and other forage plants at the National Forage Park, Philippines (1958-1968). *Proc. 11th Int. Grassl. Congr.*, Surfers Paradise, Australia, 224-226.

Fasina, A.S., Raji, A., Oluwatosin, G.A., Omoju, O.J., and Oluwadare, D.A. Properties, Genesis, Classification, Capability and Sustainable Management of Soils from South-Western Nigeria. 2015. *International Journal of Soil Science 10 (3): 142-152, 2015 ISSN 1816-4978 / DOI: 10.3923/ijss.2015.142.152.*

Fasona, M. J. and Omojola, A. S. (2005). *"Climate Change, Human Security and Communal Clashes in Nigeria."* Paper at International Workshop in Human Security and Climate change, Holmen Fjord Hotel, Oslo Oct. 21-23, 2005 Retrieved January 26, 2017, from HYPERLINK "http://www.intechopen.com/" www.intechopen.com .

FMEN (Federal Ministry of Environment of Nigeria) (2001). National Action Programme to combat desertification. http://www.uncd.int/actionprogrammes/Africa/national/2001/Nigeria-eng.pdf

Food and Agriculture Organisation (FAO), Rome, Italy. (2015). *Grassland Index.* . Retrieved November 1, 2017, from A searchable catalogue of grass and forage legumes: http://www.fao.org/ag/AGP/AGPC/doc/GBASE/commonnames/commonsearch.htm

George MF, Lin CH, Lerch RN, Garrett HE (2005). Incorporating Forage Grasses in Riparian Buffers for Bioremediation of Atrazine Isoxaflutole and Nitrate in Missouri. *Agroforest. Syst. 63:87-95.*

Jones, R.J. (1973). Some seed problems associated with the use of tropical pasture species and methods of overcoming them. Int. Training Course on Seed Improvement and Certification. Canberra, Dept. Foreign Affairs.

Keller-Grein, G., Maass, B.L., and Hanson, J. (1996). Natural variation in Brachiaria and existing germplasm collections. In J.W. Miles (ed.) Brachiaria: *Biology, Agronomy, and Improvement. CIAT & EMBRAPA p. 16-42.*

Khairani, L., Ishii, Y., Idota, S., Utamy, R.F., and Nishiwaki, A. (2013).Variation in growth attributes, dry matter yield and quality among 6 genotypes of Napier grass used for biomass in year of establishment in Southern Kyushu, Japan. *Asian Journal of Agricultural Research 7:15–25. DOI: 10.3923/ajar.2013.15.25.*

Khan, Z. R., Midega, C. A. , Wadhams, L. J., Pickett, J. A., & Mumuni, A. (2007). Evaluation of Napier grass (Pennisetum purpureum) varieties for use as trap plants for the management of African stemborer (Busseola fusca) in a push-pull strategy. *Entomologia Experimentalis et Applicata, 124,* 201-211.

Klein, A. (2017, March 15). *Plants have evolved a taste for sand that deters hungry insects.* Retrieved November 15, 2017, from New Scientist.com: https://www.newscientist.com/article/2124690-plants-have-evolved-a-taste-for-sand-that-deters-hungry-insects/

Mandar, N.R. (2016). Floristic diversity and effect of anthropogenic activities on human dominated grasslands in subtropical regions of peninsular India. *Tropical grasslands – Forrajes Tropicales, volume 4, 8 18.*

Miller, T.B., Rains, A.B. & Thorpe, R.J. (1964). The nutritive value and agronomic aspects of some fodders in the northern Africa. *J. Brit. Grassl. Soc.*, 19: 77-81.

Morgan, J. (2014). Biomass accumulation in grasslands and why it matters in south-east Australia. *'Grass half full or grass half empty? Valuing native grassy landscapes'* (p. 1). Bundoora: Friends of Grasslands Inc.

Muhammad, A.U., Arshad, U., Maqsood, A., Amir, S.R., Muhammad, R. and Amjad, A. (2012). Assessment of promising exotic forage grasses at Faisalabad, *Pakistan Pakistan Journal of Agric. Science, vol. 49(2), 339-343.*

Onyeonagu, C. C.; Eze, S. M. (2012). Proximate composition of some forage grasses and legumes as influenced by season harvest *African Journal of research vol. 8(29), 339-343.*

Oribamise, B.V. (2017). *Growth rate and biomass accumulation of in Rhodes grass (ChlorIis gayana), Congo grass (Bracharia ruzizensis) and Forage sorghum (Sorghum almum). B. Agric project report.* Department of Animal Science Federal University Oye-Ekiti, Ekiti State, Nigeria. P. 60.

Pardee, W. D. (2008). Crop Farming. In *Microsoft® Encarta® 2009 [DVD].* Redmond WA: Microsoft Corporation. Retrieved from Microsoft® Encarta® 2009 [DVD].

Pasture genetics. (2016). Forage Millet. Retrieved January 26, 2017, from www.pasture genetics.com

Realini , C. E., Hodgson, J., Morris , S. T., & Purchas, R. W. (1999). Effect of sward surface height on herbage intake and performance of finishing beef cattle. *New Zealand Journal of Agricultural Research,, II*(42), 155-164.

RSA Deparment of Agriculture, Fisheries and Forestry. (2011). *Pearl millet; Production Guidelines.* Johanesburg: Department of Agriculture, Forestry and Fisheries.

SAS. (2008). *Statistical Analysis System.* USA

Skerman, P. J., & Riveros, F. (1990). *Tropical Grasses.* Rome: Food and Agricuture Organisation (FAO).

Strezov, V., Evans , T. J., & Hayman, C. (2008). Thermal conversion of elephant grass Pennisetum purpureum Schum) to bio-gas, bio-oil and charcoal. *Bioresources Technology, 99*, 8394-8399.

The State of Queensland, Depar tment of Agriculture and Fisheries. (2016). *Gamba grass; Andropogon gayanus.* Queensland: The State of Queensland, Depar tment of Agriculture and Fisheries

Tessema, Z.K., Mihret, J. and Solomon, M. 2010. Effect of defoliation frequency and cutting height on growth, dry-matter yield and nutritive value of Napier grass (Pennisetum purpureum (L.) Schumach). Grass and Forage Science 65:421–430. DOI: 10.1111/j.1365-2494.2010.00761.x.

World Population prospects (2017), ESA.UN.org. United Nations Department of economic and social affairs, Population Division. Retrieved from www.wikipedia.com, 10 August, 2017

Nigeria: people, (2012); *CIA* The World Fact-book

APPENDIX

Appendix 1: Growth rate computations for the four grass species

	Soil Organic Matter BM_s (%)	Viability of Species S_{pg} (%)	Management Practices M_P (%)	Unforeseen Circumstances U_{fe}	Fertlizer Application F (%)	Bi-weekly Nitrogen content of species N_g (%)	Error due to time E_t	Growth rate G_{gr} (%)
Zea mays	67.18	-100	75	0	0	-0.53	0	41.65
	67.18	-100	75	0	0	-1.17	0	41.01
	67.18	-100	75	0	0	-1.41	0	40.77
	67.18	-100	75	0	0	-1.79	0	40.39
Echinochloa utilis	67.18	-100	75	0	0	-0.57	0	41.61
	67.18	-100	75	0	0	-1.07	0	41.11
	67.18	-100	75	0	0	-1.4	0	40.78
	67.18	-100	75	0	0	-1.72	0	40.46
Pennisetum purpureum	67.18	-60	75	0	0	-0.61	0	81.57
	67.18	-60	75	0	0	-1.11	0	81.07
	67.18	-60	75	0	0	-1.38	0	80.8
	67.18	-60	75	0	0	-1.66	0	80.52
Andropogon gayanus	67.18	-70	75	0	0	-0.59	0	71.59
	67.18	-70	75	0	0	-1.17	0	71.01
	67.18	-70	75	0	0	-1.39	0	70.79
	67.18	-70	75	0	0	-1.9	0	70.28

Appendix 2: Biomass accumulation computations for the four grass species

Constant	-0.06	PH		Constant	SL		0.157	LW		Constant	AVGnL		CT	Et	OM	Grass Species	BMA
-5.026	-0.06	59.79	-3.59	0.97	43.78	42.47	0.157	2.52	0.40	0.644	5.13	3.30372	37.55256	0.27	33.587	1	72.4
-5.026	-0.06	88.51	-5.31	0.97	64.21	64.21	0.157	3.72	0.58	0.644	5.6	3.6064	58.06384	0.27	33.587	1	92.9
-5.026	-0.06	124.8	-7.49	0.97	76.42	74.13	0.157	4.66	0.73	0.644	7.87	5.06828	67.4133	0.27	33.587	1	102.2
-5.026	-0.06	145.37	-8.72	0.97	89.85	87.15	0.157	5.44	0.85	0.644	8.67	5.58348	79.84386	0.27	33.587	1	114.7
-2.7	0.07	51.01	3.57	0.062	37.83	2.35	0.694	0.67	0.46	0.304	4.94	1.50176	5.1829	0.326	33.587	2	41.0
-2.7	0.07	73.54	5.15	0.062	57	3.53	0.694	1.51	1.05	0.304	5	1.52	8.54974	0.326	33.587	2	44.4
-2.7	0.07	108.33	7.58	0.062	65.73	4.08	0.694	2.76	1.92	0.304	7.03	2.13712	13.01092	0.326	33.587	2	48.9
-2.7	0.07	126.64	8.86	0.062	75.93	4.71	0.694	3.56	2.47	0.304	7.81	2.37424	15.71734	0.326	33.587	2	51.6
-4.556	0.069	84.34	5.82	0.003	55.76	0.17	0.258	2.08	0.54	0.005	4.13	0.02065	1.98803	0.406	33.587	3	38.9
-4.556	0.069	109.89	7.58	0.003	84.17	0.25	0.258	2.88	0.74	0.005	4.26	0.0213	4.04326	0.406	33.587	3	41.0
-4.556	0.069	136.83	9.44	0.003	103.51	0.31	0.258	4.28	1.10	0.005	5.15	0.02575	6.32579	0.406	33.587	3	43.3
-4.556	0.069	155.69	10.74	0.003	117.43	0.35	0.258	4.51	1.16	0.005	5.88	0.0294	7.73188	0.406	33.587	3	44.7
-2.63	0.21	45.6	9.58	0.056	30.91	1.73	0.294	1.24	0.36	0.384	3.88	1.48992	10.53144	0.193	33.587	4	48.3
-2.63	0.21	75.63	15.88	0.056	50.96	2.85	0.294	1.9	0.56	0.384	4.46	1.71264	18.3773	0.193	33.587	4	56.1
-2.63	0.21	94.35	19.81	0.056	64.24	3.60	0.294	3.19	0.94	0.384	5.61	2.15424	23.87304	0.193	33.587	4	61.6
-2.63	0.21	111.37	23.39	0.056	80.26	4.49456	0.294	4.61	1.36	0.384	6.08	2.33472	28.94232	0.193	33.587	4	66.7

Grass Species 1: *Zea mays*

Grass species 2: *Echinochloa utilis*,

Grass species 3: *Pennisetum purpereum*

Grass species 4: *Andropogon gayanus*