AN EVALUATION OF BRACHIARIA GRASS CULTIVARS PRODUCTIVITY IN SEMI ARID KENYA

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(MSc LIVESTOCK PRODUCTION SYSTEMS)

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DECLARATION AND RECOMMENDATION

I Susan Akinyi Nguku declare that the work contained in this thesis is my original work and has not been presented in part or as a whole for any academic award in any other university.

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Recommendation by supervisors

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DEDICATION

This work is one of the greatest achievements of my life and I dedicate it to the following:

My husband Obadiah Nguku Kimanzi and sons Emmanuel, Joshua and Bethuel for the encouragement they gave me.

My parents Fredrick and Emma Oguta for their lifelong support and goodwill.

May God bless you all.

ABSTRACT

The scarce and low nutritive livestock forage resource base in semi arid Kenya limits livestock production in these regions. The major factor contributing to this situation is inadequate and erratic rainfall patterns accompanied by long dry spells often culminating into drought. To exploit the full potential of the ASALs for livestock production there is need to expand the forage resource base through introduction of climate smart forage species. This study was carried out to evaluate the growth of *Brachiaria* grass cultivars, seasonal herbage yield and quality in semi arid regions of Eastern Kenya. It was conducted at Kenya Agricultural Research Institute, (now Kenya Agricultural and Livestock Research Organisation) Katumani, Machakos. *Brachiaria* cultivars namely *B. decumbens* cv. Basilisk, *Brachiaria* hybrid Mulato II, four *Brachiaria brizantha* cultivars Marandu, Xaraes, BRS Piata, MG4 and two *Brachiaria humidicola* cultivars Humidicola and Llanero were assessed in their performance with reference to establishment rates ,dry matter yields, chemical and nutritive composition. Rhodes grass (*Chloris gayana* KAT R3) and Napier grass (*P. pupureum* cv. Kakamega I) were included as controls. In the first experiment germination percentages of the cultivars under controlled conditions in the laboratory over a period of 14 days were established alongside seedling vigour. The experimental set up involved soaking seed in concentrated sulphuric acid (> 95%) for 10 minutes and another set of the same seed in water only as controls. The second experiment involved two phases namely field establishment phase and production phase. Field establishment of the cultivars was carried out in a randomized complete block design with four replications. Plant production parameters and attributes which include plant numbers, heights, spread, plant tiller number and plant cover were monitored up to 16 weeks post seedling emergence. A standardization cut was carried out on all the plots at the end of this period and dry matter yields determined. The production phase involved measuring of the same plant attributes and chemical analysis of forage samples harvested at 6, 8 and 12 weeks regrowths after standardization.

Treatment of the seeds with Concentrated sulphuric acid (> 95%) had no significant effect ($p>0.05$) on germination percentage. Cultivars Marandu, MG4 and *Brachiaria* hybrid Mulato II had similar germination percentage and were superior to the rest of the cultivars. *Brachiaria brizantha* cultivars Marandu, MG4 and Piata demonstrated superior seedling vigour. All the growth parameters measured varied significantly ($p<0.05$) among the grass cultivars during the establishment phase. *Chloris gayana* KATR3 recorded the highest plant numbers (48 plants /m^2) and Napier grass the highest plant height (103.8cm), plot cover (94.9%) and average dry matter yields (5430kg /ha). Llanero recorded highest plant spread (146.9 cm) and tiller recruitment (31/plant). At the production phase nutritive value and chemical composition of the cultivars varied significantly ($p<0.05$). Piata recorded highest dry matter yields (8,867kg/ha), IVDMD (52.3%) at week 12 harvest interval. The metabolizable energy of the grasses declined with maturity and at the week 12, there was no significant difference among the cultivars for

this variable. Mean crude protein content of the grasses decreased by 4.8% during the harvest intervals and only MG4, Mulato II and Xaraes were able to meet minimum CP requirement for rumen microbial function during this period. There was a general decrease in ash and phosphorus content and increase in calcium content of the cultivars during the harvest intervals. Mulato II maintained high ash content (15%) ash content during this period. Phosphorus content was low. Mulato II, MG4 and Marandu recorded higher phosphorus content than the rest of the cultivars ranging from 0.81% at week 6 to 0.096% at week 12 harvest interval. *Chloris gayana* KATR3 recorded highest NDF (72.5-73.8%), ADF (45.6-50.2%) and ADL (5.2-6.5%) content throughout the production phase.

From the study, *Brachiaria* grasses cultivars Marandu, MG4 and Mulato II establish well in terms of germination percentages and seedling vigour. Llanero is excellent in plant spread and this attribute can be used to protect soil from erosion alongside being used as forage. MG4, Mulato II and Xaraes are able to supply quality feed for longer periods than the rest of the cultivars. In general the *Brachiaria* grass species have potential to supply feed in the semi arid regions of Eastern Kenya and can cushion livestock from feed stress in the prolonged dry seasons. It is recommended that the experiment be conducted for a longer period of time to quantify their production in both dry and wet periods. Further research is needed to assess the effect of feeding these grass cultivars on animal performance.

ACRONYMS AND ABBREVIATIONS

ADF	**Acid Detergent fibre**
AD	**Acid Detergent**
ADL	**Acid Determined Lignin**
ASAL	**Arid and Semi Arid Lands**
BecA	**Biosciences eastern and central Africa**
CAN	**Calcium Ammonium Nitrate**
CEC	**Cation Exchange Capacity**
CIAT	**International Centre for Tropical Agriculture**
CNCT	**National Council of science and technology**
CP	**Crude Protein**
Cv	**Cultivar**
DM	**Dry Matter**
DoMD	**Dry organic Matter Digestibilty**
EMBRAPA	**Empressa Brasileira de Pesquisa Agropecuária Centro Nacional de Pesquisa de Gado decorate**
FAO	**Food and Agriculture Organisation**
ILRI	**International livestock research Institute**
IPEAN	**Intituto de Pesquisa Agropecuãria do Norte**
IVDMD	***In vitro* Dry Matter Digestibility**
IVOMD	***In vitro* Organic Matter Digestibilty**
KALRO	**Kenya Agricultural and Livestock Research Organisation**
KARI	**Kenya Agricultural Research Institute**
LWG	**Live Weight Gain**
ME	**Metabolizable Energy**
NDF	**Neutral detergent fibre**

NPK	**Nitrogen Phosphorus Potassium**
OMD	**Organic Matter Digestibility**
Sida	**Swedish International Development Agency**
TSP	**Tri- Super Phosphate**
UNPD	**United Nations Population Division**
USD	**United States Dollars**

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Chapter 1

1 INTRODUCTION

1.1 Background information

Livestock is considered a key asset for rural households worldwide and a primary livelihood resource for rural communities. About 752 million of the world's poor keep livestock to produce food, generate cash income, manage risks and build up assets (FAO, 2012). Livestock "widens and sustains three major pathways out of poverty, namely securing the assets of the poor, improving smallholder and pastoral productivity and increasing market participation by the poor" (ILRI, 2007). In developing countries, the livestock sector is evolving in response to rapidly increasing demand for livestock products whereas in developed countries, demand for livestock products is stagnating, while many production systems are increasing their efficiency and environmental sustainability (Thornton , 2010).

The world's livestock, particularly ruminants in pastoral and extensive mixed systems in many developing countries, suffer from permanent or seasonal nutritional stress. Inadequate feed supply, both in quantity and quality is an endemic problem in these systems. According to Orodho (2007) this affects all livestock feeding systems including cut and carry, tethered or free grazing systems. Most of these livestock are kept in the arid and semi arid (ASAL) regions in the tropics which are characterized with high moisture deficits and variable as well as erratic rainfall. Agro-pastoralism and pastoralism are the main economic activities in these areas and majority of the people derive their livelihoods from them. In beef production systems, over-stocking leads to over-grazing and land degradation especially in communal pastures. Mganga et al (2010) reports that the ASALs of Kenya have undergone increasingly land use pressure resulting in land degradation. This manifests in forms of impoverishment and depletion of vegetative cover, loss of biological and economic productivity, wind and water erosion, salinization and deterioration of physical, chemical and biological soil properties. He further reports that in the semi arid lands of Kenya, grass reseeding technology has been used to combat land degradation with the use of locally adapted perennial grass species. This however, has not been successful due to low rainfall, destruction by the grazing animals, pests and rodents, flush floods, poor sowing time, poor seed quality, lack of enough seed and weeds.

In most African countries, Kenya inclusive climate related impacts have compounded and affected livestock production. Prolonged droughts have left many livestock keepers poorer and unsure of reliable livestock feed source. According to Gullet et al (2011), effects of drought manifest through stress migrations in pastoral communities, dwindling of water resources at a faster rate than normal, Seasonal conflicts over water resources which begin earlier than usual, significant decline in school enrolment and increasing livestock sales at very low prices. Gullet et al (2011) further reports that in 2005/6 the drought conditions ravaged the Northern frontier and North Eastern provinces of Kenya, affecting a total population of 4,000,000 people, with an estimated loss of 50-60 percent of livestock (sheep and goats, camels and cattle). The drought was followed by mild El-Nino conditions which caused flooding and, as a result, an outbreak of the Rift Valley Fever (RVF) mainly in pastoral areas. In his report, at least 150 people were confirmed dead in Kenya from RVF in addition to 100,000 livestock deaths recorded in the Horn of Africa. Animal movement quarantine and a ban on animal slaughter crippled the livestock markets in the country, with the effects rolling back to pastoral areas where farmers resigned to fate as they watched their livestock herds die (Gullet et al, 2011). Gullet further reports that the economic cost of the RVF outbreak to the livestock farmers was estimated at USD 7.6 Million while the loss to the national economy was estimated at USD 26 Million. A drought experienced in 2008/9 affected approximately 10 million people; a third of the country's population with massive losses in livestock occurring in the Northern Frontier (Gullet et al, 2011). The government's supported off take, meant to cushion the communities from the drought's effect came in too late and animals wasted away from lack of access to pasture and fodder (Gullet et al, 2011). Drought in 2004-2006 affected approximately 5 million people and in between these droughts, the country was affected by postelection violence in 2007 and floods in 2006 and 2009/10 (Gullet et al, 2011).

The major limitation of livestock production is the lack of suitable fodder crops that can produce green forage year round (Leeuw et al, 1992).This situation becomes severe in the areas constrained by low rainfall and acidic soils. There is therefore need to evaluate suitable forage species or cultivars to address the feed shortage challenge. Considering the production of improved *Brachiaria* grass and its adaptation to the various geographical areas, the grass may be able to address the lack of year round supply of fodder in the areas of low rainfall and acidic soils. This will also allow the farmers to select the best varieties adapted to their respective areas while helping to increase profit from cattle production (Rivas and Holmann, 2005). The genus *Brachiaria* includes about 100 species which occur in the tropical and subtropical regions of both eastern and western hemispheres but mostly in Africa (Renvoize et al, 1996). Seven perennial species of African origin *B arrecta*, *B. brizantha*, *B. decumbens*, *B. dictyoneura*, *B. humidicola*, *B. mutica* and *B.ruziziensis* have been used as fodder plants, particularly in tropical America (Argel and Keller-Grein, 1996). The forage potential of these grasses was realized in 1950's in restricted niches in tropical Australia but their major impact was realized in the 70's when a handful of cultivars derived directly from naturally occurring germplasm was widely sown in Tropical America. The limited commercial use of *Brachiaria* in Africa is because other forages are more appropriate to the prevailing livestock production systems (Ndikumana and de Leeuw, 1996). *Brachiaria* is now the most widely used tropical grass genus especially in Central and South America and in Brazil alone it occupies over 80million hectares (Pizzaro et al, 1996). The *Brachiaria* seed industry in Brazil has grown to meet the large internal demand and an expanding export market placing it in competition, in monetary value with major cereal crops (Santos Filho, 1996). All existing *Brachiaria* cultivars, based directly on introduced wild germplasm, have agronomic limitations (Keller-Grein et al, 1996). According to do Valle and Savidan (1996), applied breeding of *Brachiaria* is now an established activity with major programs in both Brazil and Columbia. The authors further report that molecular markers and tissue culture techniques provide tools to increase the effectiveness of genetic improvement of *Brachiaria*. Principles established for forage improvement are based primarily on the recognition of three factors; first importance of genetic variation; second, the reproduction system of the species and third, the nutritional requirements of livestock. Current breeding schemes for *Brachiaria* seek to exploit apomixis whereby the development of simple mechanisms to control expression of apomixis would be a tremendous advance for breeding *Brachiaria* (Miles and do Valle, 1996).

It is in the basis of the fore going that this study was designed to evaluate the productivity of *Brachiaria* grass species; *Brachiaria brizantha* cv. Marandu, *Brachiaria brizantha* cv. Xaraes, *Brachiaria brizantha* cv. BRS Piatã, *Brachiaria brizantha* cv. MG4, *Brachiaria decumbens* cv. Basilisk, *Brachiaria humidicola* cv. Humidicola, *Brachiaria humidicola* cv. *Llanero*, *Brachiaria* hybrid cv. Mulato II in the Arid and Semi arid regions of Kenya. Specifically, investigation of their establishment rates, productivity and nutritive quality relative to other species grown in the area namely, Rhodes grass (*C. gayana*) and Napier grass was undertaken.

1.2 Problem statement and Justification.

Livestock systems occupy about 30 per cent of the planet's ice-free terrestrial surface area (Steinfeld et al, 2006). In tropical agricultural systems, livestock used for meat and dairy production are in greater or lesser numbers and may be associated with or be an integral part of agriculture (Williamson. and Payne, 1978). Human population in 2050 is estimated to be 9.15 billion, with a range of 7.96–10.46 billion (UNPD, 2008). Most of the increase is projected to take place in developing countries. Demand for livestock products are increasing in developing countries due to increasing population, increase in per capita income and urbanization (Thornton, 2010). Keeping livestock is also an important risk reduction strategy for vulnerable communities, and livestock are important providers of nutrients and traction for growing crops in smallholder systems.

A major setback, however, to this sector is unstable and often fluctuating feed resource base due to changing climatic scenarios. According to Muchina and Warden (2009) current dry seasons have been characterized by extended periods of drought conditions that results in high mortality rates of livestock. This has necessitated pasture improvement efforts including identification of high yielding, drought tolerant and nutritious fodder species initiated through national research institutions (Orodho, 2006). Efforts have been made to promote indigenous species that are perceived to have evolved under the harsh climatic conditions of the ASALs in southern and central-northern rangelands of Kenya. These include grasses like *Cenchrus ciliaris*, *Eragrostis superba*, *Enteropogon macrostachyus*, and *Chloris roxburghiana* (Gitunu et al, 2003). These grasses' nutritional and yield status decline with changing climatic conditions in the year and are not able to supply the nutritional requirements of livestock throughout the year prompting supplementation which is not always possible for resource poor farmers. To meet feed shortage challenge more adopted indigenous feed resources need to be screened, improved and introduced in the livestock production systems.

Studies on *Brachiaria* grass species indigenous to Africa and have been developed elsewhere is an opportunity as well as a challenge to research more on the grass species and consider reintroducing it back home. According to Miles et al (1996) *Brachiaria* grasses a native of eastern Africa, are extensively grown as livestock forage in South America and East Asia, and is believed to occupy about 80 million hectares in South America alone. Besides their use as livestock feed, they are known to contribute significantly to carbon sequestration, ecological restoration and soil erosion control, and play an important role in reducing greenhouse gases and nutrient losses from soils. *Brachiaria* grasses if reintroduced back to East Africa may be a boost toward the forage resource base for livestock propelling the industry further through pasture seed multiplication and bulking. This would enable resource poor farmers to benefit through increased incomes from seed and stock, and contribute to the GDP contributed by Agriculture through the livestock sector.

This feasibility study aims at reintroducing *Brachiaria* back home. It is also meant to assess its productivity relative to other grown grass species like Rhodes grass and Napier in ASAL regions. Napier has been encountering disease and pest attacks that are rendering it vulnerable (Orodho, 2006). The fundamental question is whether the effort towards reintroducing it is worthwhile, or are the farmers better-off with the local species they are currently growing. Another question to address is whether farmers are going to find an alternative to Napier grass, it being currently under threat to disease and pest attack.

1.3 Hypotheses

1. There is no significant (H_0) difference between the germination rates of *Brachiaria* grass cultivars and *Chloris gayana* seeds.

2. There is no significant (H_0) difference in establishment and growth rate of *Brachiaria* grass cultivars, *Chloris gayana* and *Pennisetum pupureum* (Napier grass)

3. There is no significant (H_0) difference in dry matter yields, chemical composition and nutritive value of *Brachiaria* grass cultivars, *Chloris gayana* and Napier grass

1.4 OVERALL OBJECTIVE

The overall objective of this study is to evaluate production of various Brachiaria grass cultivars in Semi arid region of Eastern Kenya relative to other cultivated grasses like Chloris gayana and Napier grass.

1.4.1 SPECIFIC OBJECTIVES

The specific objectives to this study were to:

i. Ascertain germination and seedling vigour of eight *Brachiaria* grass cultivars.
ii. Investigate plant establishment and growth of eight *Brachiaria* grass cultivars.
iii. Assess yield and herbage quality of the *Brachiaria* grass cultivars under three cutting frequencies.

Chapter 2

2 LITERATURE REVIEW

2.1 Introduction.

More than 80% of Kenya is classified as arid and semi-arid (Mutunga, 1999). These areas are characterized by low rainfall, high ambient temperature and poor quality feed resources. According to Kinyamairo and Ekaya (2001), the ASALs support at least 50% of the livestock population and more than 25% of Kenya's human population, forming an important avenue for rural development. ASALs provide the bulk of the beef consumed in the country.

Feeding constitutes a substantial proportion of the cost components of a production system. Attention should therefore be given to ensuring a sufficient supply of feed resources of adequate quality (Gueye, 2002). Beef production is pasture-based therefore sufficient feed supply can be achieved through utilization of available natural pastures (Preston, 1992). These can be preserved in the form of standing hay or hay for use during the drought period. The main drawback to production systems in these regions is inadequate and low quality forages during the dry spell. The introduction of forage species that are able to provide high and quality food source will alleviate the losses incurred by livestock keepers in terms of animal and animal products. *Brachiaria* grasses which are a native of Eastern Africa are extensively grown as livestock forage in South America and East Asia. Miles et al (1996) cites, “the grasses are also known to contribute significantly to year round forage supply, carbon sequestration, ecological restoration and soil erosion control. They play an important role in reducing greenhouse gases and nutrient losses from soils.”

Studies to evaluate the performance of forage species have been carried out. Bulle et al (2011) and Ogillo (2010) used biomass yield, seed yield, and forage quality in their studies to evaluate forage performance. Bulle et al (2011) conducted a comparative evaluation study of *C. gayana*, *E. superba* and *C. ciliaris* in Marsabit County, Northern Kenya. Ogillo (2010) evaluated the performance of *C. ciliaris*, *C. roxburghiana*, *E. superba* and *E. macrostachyus* under different micro-catchments in Kibwezi, Southern Kenya. Manske (1998) reports that tolerance to frequent defoliations is critical for native warm-season grasses managed for forage and wildlife habitat. When defoliation is done appropriately, with minimal losses of or damages to growing points and at intervals that allow sufficient time for regrowth, timely harvesting may increase total forage yield and quality by recovering nutrients in mature leaves before their translocation to reproductive and/or storage tissues.

2.2 The impact of Climate Change on livestock and livestock products

Effects of climate change on livestock are widespread. These are mostly anticipated in grazing systems because of their dependence on climatic conditions, their natural resource base and their limited adaptation opportunities (Aydinalp and Cresser, 2008). Climatic impacts are expected to be more severe in arid and semi arid grazing systems at low latitudes where higher temperatures and lower rainfall are expected to reduce yields on rangelands and increase land degradation (Thornton, 2010). Current weather projections for East Africa indicate that climate will become warmer with different levels of increase in temperature. The rise in temperature will increase evaporation and cause loss of soil moisture hence increasing the plant moisture requirements (Waithaka et al, 2013). Models show the coolest future climates, averaging changes over the entire region of 1.3°C and 1.5° and that precipitation will either increase or remain the same on average across the region with some models predicting over 100mm increase in rainfall per year for over half of East Africa by 2050 (Waithaka et al, 2013). According to Thornton (2010) direct impacts of climate change on livestock production systems include productivity losses (physiological stress) due to temperature increase and change in water availability. Indirect impacts include alteration in fodder quality and quantity, change in host-pathogen interaction resulting in an increased incidence of emerging diseases, increased resource prices (e.g. feed, water, energy and cost of animal housing e.g. cooling systems for non grazing systems). Climate smart livestock related interventions include resource use efficiency, sowing of improved pastures and better pasture management (Thornton and Herrero, 2010). By introducing climate smart *Brachiaria* the socio-economic impacts of hybrids of *Brachiaria* that can suppress nitrification would be immense in terms of increased feed resources in the tropics. This will lead to more efficient use of purchased inputs, more efficient use of land resources, increased integration of crops and livestock in agricultural systems, and mitigation of climate change through reduced atmospheric buildup of green house gases.

2.3 Role of grasses in Livestock Production

Grass is one of the most important sources of nutrients for domesticated ruminants during a large part of the year (Taweel et al, 2005). Herrera (2004)) argued that pasture turn out to be an appropriate source of food for ruminants, mainly in countries of tropical climate. This is due to the high number of species that can be used, possibility of cultivating them throughout the year, capacity of ruminant using fibrous foods, does not compete as food for humans and tends to be a cheap economical source. Grasses are more easily accessible, better in taste and quicker in digestion than shrubs and trees (Quraishi, 1999). Nutritive quality of forage has been defined as the product of the voluntary intake, digestibility and efficiency of nutrients that are used by the animal (Reid, 1994). The digestibility of the different grass species could be distinctly different, and is also influenced by area of origin, including temperature, light intensity, total rainfall, soil type, fertilization level, and by stage of maturity and preservation method (Huhtanen et al, 2006; Jančík et al, 2009). This is especially evident in the rate and extent of ruminal degradation of neutral detergent fibre (NDF) (Hoffman et al, 1993). Lignin concentration affects mainly the availability of cell wall polysaccharides (Van Soest, 1994). Cellulose, which along with lignin forms acid detergent fibre (ADF), reduces the digestion rate and extent of digestion which are related to the lignin content. Hemicellulose (presenting NDF along with cellulose and lignin) is closely associated with lignin, and the digestibility of hemicellulose is directly related to that of cellulose and inversely related to lignification (Van Soest, 1994). Crude protein (CP) is one of the key nutrients in feeds. The typical dry cow needs 7.5% CP, and a lactating cow needs 11% CP of the daily food intake. Minerals are necessary both for the growth and development of plants as well as for the growth, maintenance and productivity of grazing animals in the range areas. The mineral composition of range plants depends upon various environmental factors such as geographic aspects, climate, soil minerals, grazing stress, seasonal changes and the ability of plant to get minerals from soil (Ganskopp and Bohnert, 2003; Khan et al, 2006). It has been concluded that minerals deficiency results in poor animal health, productivity and reproductive faults even if sufficient green fodder is present (Tiffany et al., 2000). Ganskopp and Bohnert (2003) observed that mineral composition of grasses changed seasonally, especially in dry climate. In productivity of grazing livestock, both the excess and deficiency of minerals are the major constraints. Calcium (Ca) and

Phosphorus (P) are important major minerals. A dry cow requires 0.25% Ca and 0.16% P, while a lactating cow needs 0.31% Ca and 0.21% P. It is also important that the ratio between Ca and P is 1.5:1 (e.g. 0.3% Ca and 0.2% P) to 4:1 (e.g. 1% Ca and 0.25% P) (McDowelI, 1976). When P level in the forage is higher than Ca, producers should seek a high calcium mineral supplement. Otherwise a standard mineral supplement should take care of Ca and P needs. Bell (2006) reports that digestibility is a useful measure of quality for the following reasons: It is directly and positively related to the energy content of the pasture. Energy is needed by animals for body functions. Energy in feed is assessed in megajoules of metabolisable energy per kilogram of dry matter (MJ ME/kg DM). Digestibility is positively related to protein content. When digestibility is high, protein content will also be high. However, there is variation in protein content between pasture species. For example, clovers are generally higher in protein than grasses at a similar stage of growth and that it directly relates to the speed of digestion and therefore the movement of feed through the animal. In general, pastures with higher levels of digestibility will be digested more rapidly, allowing for higher intake and consequently higher levels of animal production.

Grasses are the most dominant plants in most forage based enterprises throughout the world. They provide energy and nutrients for animal growth and maintenance. Their leaves are more palatable than stems and re-growths more nutritious than old tissues (Briske, 1991). Cattle and sheep feed on grass which form their major diet and are able to convert the vegetative matter into products such as milk and meat. There are many genera of grasses and numerous species ranging from short leafy grasses to tall coarse fibrous grasses. During the early stages of growth at the onset of the rains, the plants put out soft leaves which are very rich in protein and sugar. At this stage the contents within the cellulose cell wall are readily available to the animal (Barett and Larkin, 1974). As the grass plant matures, the leaves reach their full size and contain less digestible protein and the carbohydrates which in turn are less available to the animal. Grasses are most negatively affected when grazed during their reproductive period and least affected during dormancy. According to Briske (1986), plant species do not grow or respond to grazing as isolated individuals, but rather as members of a population and community. Individual grass plants consist of an assemblage of phytomers and tillers. Grass populations reflect the number of plants per unit area and the number of tillers per plant.

Grassland communities are further composed of an aggregation of populations variously arranged in terms of abundance and space (Briske, 1986).The first, and most direct, mechanism by which grazing alters competitive interactions involves the differential utilization of populations within the community in response to the relative display of avoidance mechanisms. Species grazed severely are placed at a disadvantage when competing with associated species grazed less severely (Briske, 1986). The ability of plants to respond to defoliation is not only determined by an inherent suite of morphological and physiological characteristics, but also by competitive pressure from associated species (Caldwell, 1984). During the rains, with proper stocking rate, the pasture will be in excess of cattle consumption. The excess pasture can be conserved in the form of hay and grass silage.

2.4 History of pasture improvement in Kenya.

East Africa is recognized as the Centre of origin and distribution of 8-10 of the most economically tropical and sub-tropical grasses, contributing 20-25% of sown pasture (Hartley and Williams, 1956). Research on grass in Kenya started in 1927 when a botanical survey of the entire country was carried out.The country was thereafter classified into eight regions based on natural vegetation types (Orodho, 2007). According to Orodho (2007), this was to form the basis of agricultural and pasture development. High rainfall areas were recommended for intensive farming with suitable pasture species, while the low rainfall regions from medium to low altitudes were recommended for extensive farming and rangeland management. Since 1951, rapid progress has been made in forage collection and introduction of pastures grasses and legumes. The 1970's had pasture research emphasis on ley grasses and accumulation of germplasm. In late 70's and early 80's emphasis on research was based on the needs of the small holder farmer. From 1974-1987 Kenya/FAO project on forage collection and evaluation collected 202 grass accessions and 164 legume accessions from different parts of the country. The project went on to produce forage materials from abroad with two main objectives of introducing forage exotic crops and re-introducing forage crops which originally came from Kenya and had been improved elsewhere resulting in superior types. These forage materials were tested and evaluated in various ecological zones of Kenya and the promising ones recommended in those regions. It is worth noting that these grasses have gone some way in improving livestock production but their seasonal availability, agronomic factors and animal production potential output may not be sustainable.

Opportunities for improvement of pasture resources include increasing diversity through germplasm introductions. The introduction of climate smart *Brachiaria* spp can enhance production year round and increase the available forage resource base.

2.5 Some common grasses found in the Semi arid lands

Grasses commonly found growing in the semi arid lands include Buffel grass (*Cenchrus ciliaries),* Rhodes grass (*Chloris gayana*), *Panicum Maximum*, Masai love grass (*Eragrostis superba*), Horse tail (*Chloris roxbhurgiana*), *Entropogon machrostachys* and Napier grass. In this study, grasses that have been selected to serve as control experiments are Napier and Rhodes grass. Napier has been selected because it is the main fodder grass used by dairy farmers but is currently threatened by disease and pest that might wipe it out. Interventions would include growing a developed disease resistant strain or introduction of other forage grasses that can serve as an alternative to it. *Chloris gayana* has been selected in this study because of its lower loss of dry leaves compared to *Cenchrus ciliaries* and *Panicum maximum* (Cook et al, 2005). It also effectively suppresses woody regrowth provided trees and shrubs are not well established prior to planting the grass.

2.5.1 Cenchrus ciliaris

Buffel grass also known as African fox tail grass (*Cenchrus ciliaris L.)* is a drought tolerant tufted or spreading perennial grass widely naturalised in sub-humid and semi-arid tropics and subtropics (Cook et al, 2005). Cook et al (2005) further state that the grass is invasive in arid and semi-arid environments and is declared noxious in some areas (northern America, Hawaii and Mexico). It is an aggressive grass by virtue of its extensive root system, competing with associated species for nutrients and water. It is generally established from seed but can also be established vegetatively from root splits. Fresh seed often has high level of dormancy but germination rate can be improved with storage of 6-18 months after harvest or by separating caryopses. *Cenchrus* is slow to establish and grazing may need to be delayed 4-6 months after sowing, and up to 9-12 months, depending on establishment conditions. It is allelopathic and inhibits germination and growth of other plants. Stands become unproductive with time as nitrogen is tied in the root systems Cook et al (2005). Since quality declines rapidly with age, *Cenchrus ciliaries* should be cut or grazed at least every 8 weeks. Dry matter crude protein values range between 6-16% but in old grass this can be as low as 4%. *Cenchrus ciliaris* pastures were found to yield 4.80 to 9.08 t/ha dry matter with the application of 168 kg N/ha each year over a six-year period at Narayan, Queensland (Henzell, 1976-77) In India, a yield of 2 010 kg DM/ha was obtained by cutting at 60-day intervals (Shankarnarayan et al 1977). Pastures can carry up to 1 steer/ha depending on rainfall and soil fertility. Cattle gains of 180-200kg/head/yr at 2ha/beast on fertile soils under good growing conditions have been obtained (Cook et al, 2005). Oxalate levels can cause 'big head' (Osteodystrophia fibrosa) in horses, and oxalate poisoning in young or hungry sheep. However, with soluble oxalate levels of 1-2% in the DM, there is rarely a problem with mature ruminants (Cook et al, 2005).

2.5.2 Chloris gayana

Rhodes grass (*Chloris gayana)* is a tufted perennial, usually stoloniferous with foliage from 0.5-1.2m with fertile tillers, 0.9 -2m tall (Loch and Harvey, 1999). Rhodes grass can be propagated vegetatively or through seed. According to Loch et al (2004), a more rapid cover is obtained by planting seed usually at sowing rates of 0.5-1 kg/ha. Seed of the diploids has little or no post-harvest dormancy, while seed of the tetraploids may not reach maximum germination for 3-6 months (sometimes up to 18 months) after harvest (Cook et al,2005). Being light and fluffy, seeds might prove difficult to sow therefore seeds for broadcasting is mixed with sawdust and dust and for drilling pelleted. Seed germinates in 1-7 days, and seedlings develop rapidly (Cook et al, 2005). Since feeding value declines rapidly with onset of flowering, it is important to maintain the stand in a leafy condition by fairly regular defoliation. Crude protein levels vary with age of material and level of available nitrogen in the soil and may range from 17% on a dry matter basis in very young leaves to 3% in old leaves. Loch et al (2004) further states that phosphorus levels in DM may vary with age of material and available phosphorus in the soil ranging between 0.1- 0.4% depending on age of material. *In Vitro* Dry Matter Digestibility (IVDMD) varies from 40-80% and dry matter yields range from about 2-25ton/ha; depending on variety, soil fertility, environmental conditions and cutting frequency. Yields of second year of establishment may double but this also depends on management and environmental conditions. Bogdan (1969) reports that in Kenya, live-weight gains in cattle were 382 kg/ha in the first year of Rhodes grass growth, 228 kg/ha in the second, and 167 kg/ha in the third. In Zimbabwe, Rhodes grass fertilized with 220 kg/ha superphosphate + 440 kg/ha ammonium sulphate supported five steers per hectare for four months of peak growth in summer while they gained 117 kg/head, or 234 kg/ha. When only 220 kg/ha of sulphate of ammonia was used, the stocking rate had to be reduced to 2.5 steers/ha for the same level of live-weight gain (Cook et al, 2005). No record of toxicity has been reported in *Chloris gayana*.

2.5.3 Enteropogon macrostachyus

The common name for *Enteropogon macrostachyus* is bush rye in Kenya and Mopane grass in Zimbabwe. It grows as a tufted annual or perennial of about 30-100cm height (Pratt and Gwynne, 1977). This species occurs naturally in grasslands and rocky outcrops in ASALs of tropical Africa from 300-1600m above sea level. It is abundant between Sultan Hamud and Voi, Kenya (Bogdan and Pratt, 1967); and on Kongwa ranch, Tanzania (vanRensburg, 1969). The grass is a very high seed-producer and seed can be collected rapidly by cutting the seed-heads or stripping the heads by hand (Machogu, 2013). It germinates readily and grows vigorously. Comparative studies on biomass yields have been carried out for *C. ciliaries, E. macrostachyus* and *E. superba in* Kitui district where yields of 4908.5, 3734 and 2434.5 kg/ha for *E. macrostachyus*, *C. ciliaris* and *E. superba*, were obtained respectively (Opiyo, 2007). The forage is highly palatable with 9-12% CP content (Machogu, 2013).

2.5.4 Cynodon dactylon

The common names for *Cynodon dactylon* are Couch grass or Bermuda grass. The grass is a creeping grass whose roots form a dense mat wherever the nodes touch the ground (FAO, 2012). It is a hardy, long lived perennial grass and one of the most used seasonal forages in the world (Hacker et al, 1998). It reproduces through seeds, runners and rhizomes and one plant can cover an area of about 2.5m^2 in just 150 days after germinating. According to Cook et al (2005), no seed dormancy has been reported. The grass is very competitive especially in fertile soils and only aggressive legumes are capable of forming an association with it. It responds well to improved fertility (Labri et al, 1990). Seedlings usually root down quickly and grow vigorously once established. Cook et al (2005) reports that crude protein varies with age of plant and level of fertilization i.e., 3-20% depending on age and fertility. It can spread over 2 m/month during the growing season, a single plant forming a dense sward up to 25 m across in 2.5 years. *In vitro* dry matter digestibility (IVDMD) varies from 40-69% depending on genotype. Annual dry matter yields are generally of the order 5-15t/ha (FAO, 2012). Average daily gains of 0.3-0.9kg have been achieved in un supplemented steers grazing intensively Bermuda grass pastures (Cruz, et al, 2009). Weight gains for cattle vary from 200-300 kg/hd/yr or over 700g/hd/day when moderate rates of fertilizer are applied with a stocking rate of about 2or more beasts /ha (Harlan and Wet, 1969). Strains show considerable variation with respect to seed set and in general seed production is relatively low ranging from 100-350kg/ha (Harlan and Wet, 1969). Cook et al (2005) reports that some varieties have the potential to produce high levels of prussic or hydrocyanic acid (HCN), especially when high levels of nitrogen are applied. However, instances of prussic acid poisoning in cattle grazing *C. dactylon* are rare and although levels of total oxalate of >1% of the DM have been recorded there is no experience of detrimental effects on grazing cattle.

2.5.5 Eragrostis superba

Common names for the grass include; Saw tooth love grass (South Africa); Wilmann love grass (USA); Masai love grass (Kenya). *Eragrostis superba* occurs naturally in South Africa and northwards through East Africa to Sudan. It is very common in various vegetation types, mainly grassland and savanna types throughout its distribution range. *Eragrostis superba* is a perennial, densely tufted grass that can grow up to1m tall. It does well in sandy soils but also occurs on clay loams and clays. It has been reported to have high tolerance to salinity and alkalinity (Ryan et al, 1975). The grass has high ability to spread naturally and has high seed production (Millington. and Winkworth, 1970). It is fairly palatable because of the rather hard stems (Hatch et al, 1984) and can make good hay. Although it is drought resistant, its nutritional value declines late in the season, and the grass becomes less palatable as it gets harder. A dry matter of more than 24 000 kg/ha per year under an eight-week cutting interval was obtained by Strickland (1973) at Samford, Queensland. *Eragrostis superba* has about 12 % crude protein in the dry matter at an early-flowering stage with 30-35 percent crude fibre (Bogdan and Pratt, 1967). No toxicity has been reported.

2.5.6 Pennisetum purpureum

Napier grass, *Pennisetum purpureum,* also known as Elephant grass is a perennial grass grown widely in East Africa as a fodder crop. The grass is propagated vegetatively because seed have low genetic stability and viability (Humphreys,1994). Its natural habitat is damp grasslands, forest margins and river beds. Napier grass plays a very important role as the major livestock feed in small holder dairy production systems in Kenya (Orodho, 2006). Orodho (2006) further reports that it is the main fodder crop in Central Kenya and is fed to livestock by cut and carry. Mature plants normally reach up to 4m heights and may have up to 20 nodes (Henderson and Preston, 1977). Napier grass has been the most promising and high yielding fodder among dairy farmers in Kenya (Anindo and Potter, 1994) giving dry matter yields that surpass most tropical grasses (Humphreys, 1994). In Kenya, the average dry matter yields vary between 10 and 40 t DM ha^{-1} yr^{-1} depending on soil fertility, climate, and management (Schreuder et al, 1993). Napier grass on average contains 20% DM, 7 to 10% CP, 70% NDF and 45% ADF (Gwayumba et al, 2002 ; Islam et al, 2003). Serious problems of disease outbreaks are emerging and threaten to wipe out Napier grass in East Africa (Orodho, 2006). These include Napier grass stunt disease associated with Phytoplasma belonging to the 16SrXI (*Candidatus* Phytoplasma oryzae) group (Jones et al, 2004). Orodho (2006) declares that the impact is that small holder dairy in Western Kenya has been seriously threatened by the disease. According to Orodho (2006), farmers in Western Kenya noticed that the disease is much more severe and prevalent in poorly managed fields. Most of the Napier grass varieties grown in the area are susceptible to the disease which usually becomes visible in re-growth after cutting or grazing. Affected shoots become pale yellow green in colour and seriously dwarfed. Often the whole stool is affected with complete loss in yield and eventual death. Many smallholders have lost up to 100 percent of their Napier crop and are forced to de-stock or sell off their entire herd because of lack of feed (Jones et al, 2004).

Another disease is Head Smut Disease caused by the fungus *Ustilago kamerunensis* and has a devastating impact on Napier grass (Orodho, 2006). Orodho (2006), further states that it turns vigorous, impenetrable clumps of valuable livestock feed into thin shrivelled stems.The infected stems harden and shoot to premature flowering, becoming thin and fibrous rather than normal thick and juicy. Emerging plant stems then become smaller and the total dry matter of the affected crop is drastically reduced. After 2-3 cuttings, the entire stool dries. The result is a catastrophic decline in biomass which leads to falling milk production . In Central Kenya where this impact is strongly felt, some farmers had to sell their dairy cows while others were left with the alternative of grazing their dairy cattle on sparse communal pastures along the road side, a practice that exposes them to increased risks from East Coast Fever (Orodho, 2006).

2.6 *Brachiaria* grasses

2.6.1 History of Brachiaria

The genus *Brachiaria* and its species originated from Africa but found their way to the sub tropical and tropical regions of Australia and South America (Parsons, 1972). In Brazil, introduction of *Brachiaria spp* stems 500 years back when *B. mutica* was introduced through African slaves. The new forage grasses were favoured by stock owners due to their persistence under grazing and higher nutrient value compared to indigenous grasses. *Brachiaria* species are common constituents of the natural vegetation in East Africa. According to Ndikumana and De Leeuw (1996) sown pastures still play no role in livestock production in East Africa except in small holder dairies in the highlands. Within these areas cut and carry or extensive grazed pasture is more often practised. Miles et al (1996) states that the forage potential of these grasses was first recognized about 40 years ago in restricted niches in tropical Australia.The major impact of the genus was however, realized between 1976-1981 when a handful of germplasm was sown in Tropical America and numerous cultivars have been developed to date.

2.6.2 Regional experience with Brachiaria

2.6.2.1 Sub-Saharan Africa

In Sub- Saharan Africa the centre of diversity of the genus *Brachiaria* is in Eastern Africa (Renvoize et al, 1996). According to Ndikumana and de Leeuw (1996), the most common and extensively evaluated *Brachiaria* species as cultivated pastures are *B. brizantha*, *B. ruziziensis, B. decumbens* and *B.mutica*. In recent years *B. humidicola* and *B. Platynota* have also received increased attention. The first four species produce high yields, show excellent response to fertilizer, are persistent and remain green long into the dry season. Although in Africa, data on nutritive value are incomplete, they indicate that forage from *Brachiaria* is highly palatable to stock, leading to high intake, whether fed fresh or grazed *in situ* (Ndikumana, 1985). Ndikumana and de Leeuw (1996) further report that *Brachiaria* performs poorly at altitudes above 1,800m because low temperature depresses growth. *Brachiaria* for pasture improvement began in the 1950's in Kenya, Nigeria, Uganda, Tanzania and Zaire. Establishment rates from splits averaged 76% and 60% from cuttings, in 1955 at Yangambi, Congo (now Zaire) according to Institut National Pour l'étude Agronomique Du Congo Belge (INEAC) (Ndikumana and de Leeuw, 1996). Experiments conducted by Capelle in 1974 demonstrated that removal of upper and lower glumes from spikelets induced quick vigorous germination of *B. ruziziensis* seeds (INEAC 1955,cited in Ndikumana ,1985). Under favourable conditions *B. ruziziensis* yields up to 140kg/ha of seed with the maximum yield in the second year after establishment (Ndikumana and de Leeuw, 1996). At Kitale in kenya, *B. ruziziensis* flowered 21 weeks after sowing, while regrowth headed as early as 3 weeks after cutting (Boonman, 1971). *B. ruziziensis* was among the most persistent forages in heavily grazed pastures during dry season (Ndikumana , 1985) but did not persist where dry season exceeded 7 months (Boudet, 1962). *B. brizantha* gave cumulative yields of 6t/ha DM in Sangalkam, Senegal (<500mm rainfall) and was more drought tolerant than *Andropogon gayanus* which yielded 5t/ha (Boyer, 1986). According to Ndikumana and de Leeuw (1996), in Madagascar *B. decumbens and B. brizantha* remained green during dry season when other forage grasses become yellow and highly lignified. Further, data from Burundi, Madagascar, Nigeria and Tanzania suggest that few grass species are more persistent than *B. brizantha*. In Madagascar *B. brizantha* invaded adjacent grazing areas and persisted under frequent grazing and severe trampling (Granier and Lahore, 1966) and in Tanzania swards of these species persisted for 20 years despite frequent harvesting (Urio et al, 1988). At Azariah (Nigeria), Miller and Blair-rains (1963) assessed the nutritive value of several fodders including *B. brizantha* fed to local sheep and Zebu cattle. Sheep fed *B. brizantha* at full- bloom stage consumed 0.89kg/day of DM, containing 4% CP, 31% CF, with 56.6% digestible organic matter and 0.8% digestible CP. Daily weight gains of 0.59kg per head were recorded for cattle grazing *B. decumbens* pastures at a stocking rate of 6.8 head/ha during 126 days in the rainy season were reported at the same location. The nutritive value was low as the forage was harvested at an advanced stage of maturity. At Makerere, University, Uganda, Soneji et al (1971) used Corriedale sheep to determine *in vivo* digestibilty of three forage species at different stages of growth. Intake and digestibility of *B. ruziziensis* were higher than those of *C. gayana* and *Setaria sphacelata* at late growth stages. Optimal intake of digestible nutrients probably occurs when pasture utilization of *B. ruziziensis* coincides with the late head stage or early bloom stage of growth (Ndikumana and de Leeuw, 1996).

2.6.2.2 American humid Low lands

In the tropical America humid lowlands, *Brachiaria* species have become important components of sown pasture with *Brachiaria* cultivars; *B.decumbens* cv. Basilisk, *B.brizantha* cv. Marandu, *B.dictyoneura* cv.Llanero and *B.humidicola* cv. humidicola being the most evaluated (Argel and Keller-Grein, 1996). According to Argel and Keller- Grein (1996) cultivar Basilisk is the most commonly used in the region because it adapts well to a wide range of soils in the region and is easy to manage. However, it is easily attacked by the Spittle Bug and is associated with photosensitization in cattle (Beatriz Riet-Correa et al, 2011). Cultivar Marandu requires medium to high fertility soils, is resistant to spittle Bugs but does not tolerate waterlogged sites (Argel and Keller- Grein, 1996). Argel and Keller- Grein (1996) further state that cultivars Llanero and Humidicola are adapted to low and medium fertility soils but have low nutritional quality and that soil compaction, spittle bug infestation and runoff of soil nutrients are factors associated with *Brachiaria* pasture degradation in the humid tropics.

2.6.2.3 Asia, Pacific and Australia

In Asia, the South Pacific and Australia, *Brachiaria* species occupy about 300,000 hectares (Stur et al, 1996). *Brachiaria mutica* is practically naturalized in every country in the region having been introduced in Asia more than100 years ago. In Asia and the south Pacific, pasture grasses are grown widely in the humid and sub humid tropics. In Australia *Brachiaria* grasses occupy more than half of the area of improved pastures. Stur et al (1996) report that three species are important in Australia namely; *B. decumbens, B. mutica* and *B. humidicola* which are planted primarily for fattening and breeding beef cattle but are not popular for dairying.

These species are also used for seed and hay production and are often grown in rotation with annual crops.

2.7 The Biology and Agronomy of *Brachiaria*

Brachiaria are C_4 grasses some of which are annual and others perennial.They belong to the poacea family. *Brachiaria* species are adapted to a wide range of soil types, from Oxisols and Ultisols (low-fertility acid soils) to Alfisoils and Mollisols (high-fertility neutral soils) and perform much better on acid soils than other grasses such as panicum species (Rao et al, 1993). Several *B. brizantha* accessions are high leaf producers with better seasonal distribution of production and fast dense regrowth after defoliation (Valle et al, 1993). All *Brachiaria* species may be propagated both vegetatively and from seed. Vegetative propagation is simple, but, except in very small-scale farming, impracticable (Hopkinson et al, 1996). The erect, semi erect and stoloniferous growth habit in *Brachiaria* is strongly associated with good production and adaptation. *Brachiaria* species show rapid regrowth and good persistence under heavy or frequent defoliation (Rika et al, 1991). *Brachiaria* species have proved to show some shade tolerance being planted under plantation crops like coconuts and rubber in the South East Asia and pacific Islands (Stur et al, 1996). *Brachiaria* species are very aggressive making them difficult to grow in long term associations with legumes (Thomas and Grof, 1986). Few exceptions however exist eg. the legume *Arachis pintoi* is now well known to be compatible with *Brachiara* species (Fischer and Cruz, 1994). Usually few weeds invade *Brachiaria*, unless it is grossly mismanaged through overgrazing. Flooding has a profound and differential effect on species survival. In relatively well drained areas *B. decumbens* dominates; intermittently areas have *B. humidicola* dominating and where water stands more than a few weeks non survives (Argel and Keller-Grein,1996). Cytological behaviour, mode of reproduction and its inheritance, and cross compatibilty of different species has been studied. The two of major agronomic importance - *B. decumbens* and *B. brizantha*- are tetraploid (2n=4x=36) and apomictic (embryos are produced without fusion of male and female gametes) (do Valle and Savidan, 1996) According to Vendramini et al (2011), the growing interest in *Brachiaria* grasses prompted an urgent need to develop new 6 cultivars with outstanding agronomic characteristics, greater range of adaptation, greater biomass production and nutritional quality, and resistance to Rhizoctonia (a disease-causing fungus) and spittle bug species. Mulato II is the result of three generations of crosses and screening conducted by the International Center for Tropical Agriculture (CIAT) in Colombia, including original crosses between *Brachiaria* ruziziensis R. Germ. & Evrard clone 44-6 (sexual tetraploid) x *Brachiaria decumbens* Stapf cv. Basilisk (apomictic tetraploid) (Vendramini et al, 2011). Sexual progenies of this first cross were exposed to open pollination to generate a second generation of hybrids. From the second generation of hybrids, a sexual genotype was selected for its superior agronomic characteristics and was again crossed, producing Mulato II. Subsequent progenies of this clone confirmed their apomictic reproduction, and results with molecular markers (microsatellites) showed that Mulato II has alleles that are present in the sexual mother *B. ruziziensis*, in *B. decumbens* cv. Basilisk, and in other *B. brizantha* accessions, including cv. Marandu (Vendramini et al, 2011). Do Valle and Savidan, 1996 further reported that with the considerable genetic resources now available, the breeding of Brachiaria can be a low- risk and highly profitable enterprise that will have a major impact on animal production in the tropics.

2.8 Poisonous aspects of *Brachiaria*

Brachiaria have been known to cause hepatogenous photosensitization in livestock (Riet-Correa et al, 2011).The poisoning is due to lithogenic steroidal saponins, protodioscin being the main saponin found in different species (Brum et al, 2009). According to Riet-Correa et al (2011) *Brachiaria* poisoning has been reported among sheep, cattle and goats with sheep being more susceptible than cattle. He further states that there exist differences in susceptibility between animals of the same species and this difference has been suggested to be genetic. Sheep raised on *Brachiaria* pastures are less susceptible to poisoning than sheep grazing them for the first time having been raised on other pasture species (Castro et al, 2009). In Brazil most outbreaks of poisoning are caused by *B. decumbens* (Souza et al, 2010), whereas outbreaks caused by *B. brizantha* are less frequent (Brum et al, 2007). Control measures include removing cattle from toxic pastures, keeping animals in the shade and providing food and water. Future preventive measures could incude selection of resilient or resistant animals and cultivars with low saponin content (Riet-Correa et al, 2011).

2.9 *Brachiaria* in Intergrated crop livestock production systems.

Brachiaria as a forage grass has been used in crop pasture intergrated systems where the the grass seed is oversown on maize crop planted earlier favouring the production of high quality forage in the off season (Maia et al , 2014). The accompanying advantages include reduced degradation of pastures, improved chemical, biological and physical properties of the soil and yield potential of grain forage and silage (Silva et al, 2010). This technique stands as being part of the technologies used to boost Brazilian agribusiness (Almeida et al, 2012). The advantages of using the *Brachiaria* genus in the intergrated systems is that, the species have abundant roots which contribute to the collection of water, soil aggregation and aeration (Kluthcouski et al, 2004). Most studies on crop, livestock intergration evaluate the use of *Brachiaria brizantha* cv. Marandu, *Brachiaria decumbens* and *Brachiaria ruziziensis* (Pariz et al, 2010). Maia et al (2014) reports that intercropping corn with *Brachiaria* species favors the production of high quality forage in the offseason, and the cultivars of *Brachiaria brizantha* and *Brachiaria decumbens* show higher production of dry matter. Cultivars of *Brachiaria brizantha* (Marandu palisadegrass, Xaraes palisadegrass and Piata palisadegrass) are the most suitable for presenting food of better quality, compared with *Brachiaria brizantha* cv. MG4, *Brachiaria decumbens* and *Brachiaria ruziziensis*.

2.10 Nutritional quality and Animal performance from *Brachiaria* pasture

Brachiaria forages have good adaptability, tolerance and resistance to biotic factors. When fertilized with nitrogen and well managed they have high forage quality (Lascano and Euclides, 1996) and show high dry matter production making them capable of meeting nutritional requirements of animals especially in the dry season (Brighenti et al, 2008). *Brachiaria* species have high digestibility although this may vary among and within species. Variation is caused mainly by different levels of crude protein possibly associated with inhibition of nitrification (Lascano and Euclides, 1996). The *Brachiaria* grasses when grown with compatible legumes like *Arachis pintoi* lead to improved animal production and pasture performance as shown by Lascano and Euclides (1996). Animals fed on signal or other *Brachiaria* grasses may sometimes fall sick or show hepatogenous photosensitization probably due to plant metabolites, mainly steroidal saponins (Lascano and Euclides, 1996). *Brachiaria decumbens* cv. Basilisk (Signal grass) is the most widely planted. The above authors continue to say that its quality has been measured in many cutting experiments and feeding trials together with other well known grass species. Values of IVDMD in signal grass have ranged from 60% to 70% in immature forage, and from 50% to 60% in mature forage, which is higher than the average (55%) for tropical forage grasses. The CP range between 9–20% depending on soil fertility and management, but can decline rapidly with age of leaf, from 10% at 30 days to 5% at 90 days as reported by Cook et al (2005). The authors have further said that DM yields can be very high under heavy fertiliser application, with yields of 10t/ha/yr DM commonly recorded. Production however, reduces dramatically in the dry season and will cease in winter in subtropical environments. In the humid environment of South Johnstone, Australia live weight gain/ha/year on unfertilized signal grass was 50% higher than that recorded earlier at the same location with unfertilized common *P. maximum* (Grof. and Harding, 1970), whereas on fertilized signal grass, LWG was almost 1000 kg/ha (Harding and Grof, 1978). In a drier environment (Cape York Peninsula, Australia), signal grass in association with legumes, produced more LWG in heavily stocked pastures than a common *P. maximum* association (Winter et al, 1977). In southeastern Queensland, Australia, signal grass fertilized with N and the improved *P. maximum* cv. Hamil produced similar LWG at both medium and high stocking rates (Whiteman et al, 1985). However, in Campo Grande, Brazil, animal gains on unfertilized signal grass were 20% to 30% lower than on improved *P. maximum* cultivars (Lascano and Euclides 1996). The nutritional value of *B. humidicola* is good (5–17% CP) considering the low fertility of the soils in which it is often grown (Cook et al, 2005). In the Colombian savannah, 6-week old foliage in a 54-accession collection had 5.2–8.5% CP content in the rainy season and 3.3–9.3% in the dry season; IVDMD was 59–66% and 51–67%, respectively. Its digestibility (48–75%) declines quickly if not grazed according to Cook et al (2005). The above authors further report that DM production is strongly influenced by soil fertility and ranges from 7–34 t/ha/year. The above authors also report that in Fiji, unfertilised *humidicola* grass produced an annual DM yield of 11 t/ha DM, whereas DM increased to 34 t/ha with the application of 452 kg/ha N and in humid-tropical Vanuatu, annual yield declined from 28 t/ha DM, to 17 t/ha DM as fertility declined. Annual DM yields of 7 t/ha and 5–9 t/ha were reported from Paraguay and Brazil, respectively. In Colombian savannas, LWGs of 80 kg/head/yr and 240 kg/ha/yr from pure swards increased to 134 kg/head and 402 kg/ha/yr when grown with Arachis pintoi. Pure stands, grazed at 2 head/ha gave LWGs of 0.56 kg/head/day and 406 kg/ha/yr in humid tropics of Ecuador and that in Panama, pure stands grazed at 4 head/ha, gave LWGs of 0.32 kg/head/day and 501 kg/ha/yr while with *Pueraria phaseoloides*, the corresponding LWGs were 0.38 kg/head/day and 585 kg/ha/yr. *Brachiaria brizantha* is very palatable and has a good leaf/stem ratio. Its nutritive value is dependent on the basic fertility of the soil, fertiliser application and age of regrowth as reported by Cook et al (2005). In the same region, IVDMD of regrowth declined from 75% at 2 weeks to 55% at 12 weeks. *Brachiaria brizantha* is very productive and can support high stocking rates with good persistence under continuous or rotational grazing. Dry matter yields range from 8–20 t/ha/yr (Cook et al, 2005). In a grazing trial in Sri Lanka, Fernando (1961) obtained a live-weight gain of 464 kg/ha from grass alone, 647 kg/ha from a *Pueraria phaseoloides*/*Brachiaria brizantha* sward and 631 kg/ha from a *Centrosema pubescens*/*B. brizantha* mixture over a 260-day season. Cultivar Mulato (*Brachiaria brizantha* x *B. ruziziensis* artificial hybrids) is reported to be highly palatable to grazing animals. In the same research Cook et al (2005) reported that *Brachiaria* hybrid Mulato II produces 10–25% more DM than *B. brizantha* or *B. decumbens* and that in Tabasco, Mexico, yields of up to 25 t/ha DM have been reported. Similarly it is reported that for 90 day and 168 day regrowth in Colombia, CP was 13.1% and 10.6%, respectively, and IVDMD 70.0% and 70.6%, respectively. Individual cattle LWGs of up to 0.9 kg/head/day were reported following short periods of grazing in Honduras (Cook et al, 2005).

2.11 Major plant attributes of some important *Brachiaria* species.

Table 1 below outlines a summary of both positive and negative attributes of some species of *Brachiaria* whose cultivars are the subject of this study. It is important to take note of the fact that Mulato II is the result of three generations of crosses and screening conducted by the International Centre for Tropical Agriculture (CIAT) in Colombia.It is a three way hybrid between (B. ruziziensis, B. decumbens and B. brizantha) (Cook et al, 2005).

Table 1: Major plant attributes of important *Brachiaria* species.

Species	Positive attributes	Negative attributes
B. decumbens	High productivity under intensive use, tolerance to low fertility, good performance under shade, good quality forage	Susceptibility to spittle bug, low adaptation to poorly drained soils, toxin production (sporidesmin) production, susceptibility to foliar blight
B. brizantha	High productivity, spittle bug tolerance, responsiveness to fertilizer application, drought resistance, ability to spread and suppress weeds, ability to grow in shade , good quality forage	Low adaptation to poorly drained soils, need for moderately fertile soils, susceptibility to foliar blight
B. humidicola	Strongly stoloniferous habit with ability to root at stolon nodes, adaptation to low fertility soils, ability to cover ground rapidly and compete with weeds, adaptation to poorly drained soils, low p and Ca requirements, some spittlebug tolerance	Low seed production at low altitudes, low dry matter digestibility, low N and Ca concentration in forage, susceptibility to rust infection
B. ruziziensis	Fast growth early in wet season, compatibility with legumes, high seed production potential, ease of establishment, good quality forage	Need for well drained fertile soils, susceptibility to spittle bug and foliar blight, low competitiveness with weeds

(**Source: Rao et al, 1996**)

CHAPTER 3

3 MATERIALS AND METHODS

3.1 Description of Site

The study was conducted at the Kenya Agriculture Research Institute (now Kenya Agriculture and Livestock Research Organization) Katumani, Machakos, Kenya (1^0 58´S, 37^0 28´E). The site elevation is 1600m above sea level and the mean temperature is 19.6^0C (Njarui et al, 2003). The mean annual rainfall is 717mm, with a bimodal pattern, the long rains (LR) occurring from March-May and the short rains (SR) from October- December with two dry seasons (June-September; January- February). During the time of the experiment, the total rainfall recorded for the two rainy seasons was 677.1mm and average temperature ranged between 15.1^0C -25.6^0C. The soils of the site are Luvisols, low in nitrogen and phosphorus with a pH of 6.5 (Aore and Gitahi, 1991).

3.2 Land preparation

Land was cleared, tractor ploughed and harrowed to a fine tilth before laying out plots and planting. Soil samples were taken diagonally in the experimental area at 10m intervals at 30cm depth. Of these, 3 sub samples were labeled; Soil sample A, Soil sample B and Soil sample C respectively and taken for initial characterization for determination of NPK, CEC, pH and minor elements (mainly Mg and Mn). Rainfall and temperature was recorded throughout the experimental period.

3.3 Experimental Design and Treatment

3.3.1. Seed germination tests.

The germination of the grass seeds of the *Brachiaria* cultivars (*B. brizantha* cv. Marandu, *B. brizantha* cv. Xaraes, *B. brizantha* cv. Piata, *B. brizantha* cv. MG4, *B. decumbens* cv. Basilisk, *B. humidicola* cv. Llanero, *B. humidicola* cv. Humidicola, *Brachiaria* hybrid cv. Mulato II) and *Chloris gayana* was examined under controlled conditions in a growth chamber as described by Rao et al (2006). The seeds were drawn randomly from storage bags and soaked in sulphuric acid (>95%) for ten minutes after which they were rinsed in running distilled water. The rinsed seed were then divided into 3 replicates with 100 seeds per replicate for each cultivar and spread uniformly on top of Whitman filter paper placed in dry and sterilized 90mm petri dishes. The filter paper was then moistened with distilled water and covered with snugly fitting lids to prevent excessive moisture loss. Care was also taken to ensure that none of the seeds were in contact to each other. A permanent marker was used to label the containers with the type of seed being tested and the replication number. The same procedure was used for another set of seeds only that they were not soaked in acid hence serving as a control. In total

54 petri dishes were placed in the growth chamber such that three replicates of each grass seed were acid treated and three were not. The seeds were kept at alternating temperatures of 30^0C for 8 hours and 20^0C for 16 hours daily and seed germination was monitored for 14days. Each day, the petri dishes would be removed from the growth chamber to record the number of seed of each cultivar that had germinated. The germinated seeds were then removed from the petri dishes after which the petri dishes were randomly returned to the growth chamber. The petri dishes were kept moist with distilled water throughout this period. Seed germination is defined as the resumption of growth of the embryo and emergence or protrusion of the radicle from the covering structures (Rao et al, 2006), therefore a protusion of the radical from the seed was counted as a sign of germination and the seedling removed from the Petri-dish. The initial ten germinated seeds of each cultivar were selected to monitor seedling vigour. This was done by measuring the seedling length every 3 days from day seven after seed germination. Percent germination was calculated using the formula:

$$\% \text{ Seed germination} = \frac{\text{No. of seeds germinated}}{\text{Seeds per petri-dish}} \times 100$$

3. 3. 2 Field establishment, growth, production and nutritive quality of the grasses.

This experiment involved two phases namely establishment and productive phase and was run within the period of October, 2013 to end of June, 2014 covering two rainy seasons (short rains Oct-Dec, 2013 and long rains March to May2014). Data is however, included for rainfall and temperature figures for January to December 2012. The same *Brachiaria* grass cultivars were tested for field establishment, dry matter yields, chemical composition and nutritive value. *Chloris gayana* cv KAT R3 and Napier grass were included as controls. The experimental design was a randomized complete block design with 4 replications. Individual plot sizes were 4m x 5m with a 1m path between plots and 1m path between the blocks. The grass species were randomly allocated to the plots.

3.3.3 Field establishment and growth phase

The seeds were drilled in furrows of about 2cm deep on a well prepared seedbed at an inter row spacing of 0.5m, giving 10 rows in each plot. Triple super phosphate (TSP, 46 % P) fertilizer was applied to the soil prior to sowing of the seed at the rate of 50.8kg P/ha in the planting rows. Sowing was done manually by placing the seeds in the furrows and covering them with a thin layer of soil. The grass seed was sown at rates of 5kg/ha. For Napier grass 3 splits were planted at intervals of 1m apart in holes dug 15cm deep after adding TSP at the rates of 50.8kg P/ha .The trials were kept weed free throughout the experiment by hand weeding and slashing inter row spaces to reduce weed competition within the replications.

Standardization cuts were carried out in the sixteenth week at the onset of the long rains and thereafter the plots top dressed with CAN at rates of 100kg N/Ha.

3.3.3.1 Data collection

Plant attributes (Plant height, plant counts, tiller numbers, plot cover and plant spread) were recorded at week 4, 8, 12 and 16 after seedling germination. A standard cut was done at week sixteen at the onset of the long rains (April-May) and dry matter yields established.

Plant counts: Number of plants was determined by counting plants in a 1m x 1m fixed quadrat placed over two rows.

Plot cover: Percentage plot cover was established by using a quadrat of 1m x1m subdivided into 25 squares of 0.2m x0.2m as described by Njarui and Wandera (2004). Plant cover in each of the squares was estimated and the number of squares fully covered with grass used to calculate percent coverage as follows:-

$$\% \text{ Plant cover} = \frac{\text{No. of squares fully covered}}{25} \times 100$$

The percent canopy cover of Napier grass was determined using the dot method as described by Sarrantonio (1991). This involved use of a sisal twine of 5 m long, marked in several dots at every 15 cm interval with ink. The string was then stretched in opposite diagonals (twice) across the plots and the number of dots that lay over or under the plant parts were counted. The percent cover was calculated using the equation below:

$$\frac{\text{Total dots over or under plant species (Fd + Sd)}}{\text{Total possible dots in plot (Fd + Sd))}} \times 100 = \% \text{ cover}$$

Where: Fd stand for first diagonal and Sd for the second diagonal.

Plant spread: For spread, the diameter was measured from one edge to the other of each of the 4 tagged plants. This was done using a metre ruler.

Plant height: Plant height was measured on the primary shoot from the soil surface to the base of the top-most leaf using a metre rule as described by Rayburn et al (2007). This was done on the same four plants tagged.

Number of tillers: The number of tillers for the same 4 tagged plants was counted and recorded. Total tiller number per tuft on each measurement occasion was defined as the sum of total tiller number at previous measurement and number of tillers formed after previous measurement.

Standardization: The onset of the long rains (March-May, 2014) marked the end of establishment phase at16 weeks after seedling emergence. After recording plant counts, plant cover, plant height, tiller numbers and plant spread, the grasses were cut to a stubble height of 5cm in a randomly selected area of $4m^2$ within the plots as described by Tarawali et al (1995). A fresh weight of all the harvested material was recorded after which sub samples of these were weighed and recorded. The sub samples were dried in an oven for 72 hours at temperatures of 65^0C after which the dry sample weights were recorded. The oven-dry weights were used to calculate dry matter (DM) yield per plot which was then extrapolated to dry matter yields in kg/ha at the end of establishment and growth phase. These oven dried samples included the leaves and stems harvested at 5cm stubble height.

3.3.4 Production phase

Plant numbers, plant cover, plant spread, tiller numbers and plant height were recorded at week 6, 8 and 12 of re-growths after standardization as described for the establishment phase. After recording these measurements, the forages were evaluated under successive cuts (week 6,8 and 12) by collecting samples from $2m^2$ quadrats, randomly placed within each plot and harvested at stubble 5cm height of after cutting. Unlike the other grasses data for Napier was collected only at week 8 and harvesting done in an area of $4m^2$.The dried samples were then ground with a hammer mill and sieved using 1mm sieves and stored in labeled plastic bags for chemical analysis.

3.3.4.1 Data Collection

During the production phase, data collection and interval harvests were carried out in a split plot arrangement as shown in Fig1.

***Plant morphological characteristics*.** Plant counts, plant cover, plant spread, plant tiller numbers and plant height) were recorded using the same procedures as at during the establishment phase.

Dry matter yields. Fresh weights and subsample weights of the forages were taken. The sub samples were dried at 65^oC for 72 hours and weighed as described during the end of establishment phase and dry matter yields extrapolated for the phase.

Forage quality analysis. Materials that were harvested for above ground biomass yield at week 6, 8 and 12 were sub- sampled for feed quality assessment and chemical analysis. These samples were oven dried at 65^oC for 72 hours and then ground through a 1mm Wiley mill in preparation for the proximate analyses method (AOAC, 1990) and the Van Soest and Robertson (1980) feed analysis. Chemical analyses were carried out at the KALRO Muguga animal nutrition laboratory. Chemical analyses were performed to determine the, crude protein (CP), *In vitro* dry matter digestibility (IVDMD) (Tilley and Terry, 1963), Ash, Crude fibre (neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL)) (Van Soest and Robertson, 1980).

Crude protein .Crude protein was analyzed using Kjeldahl nitrogen determination (AOAC, 1995)

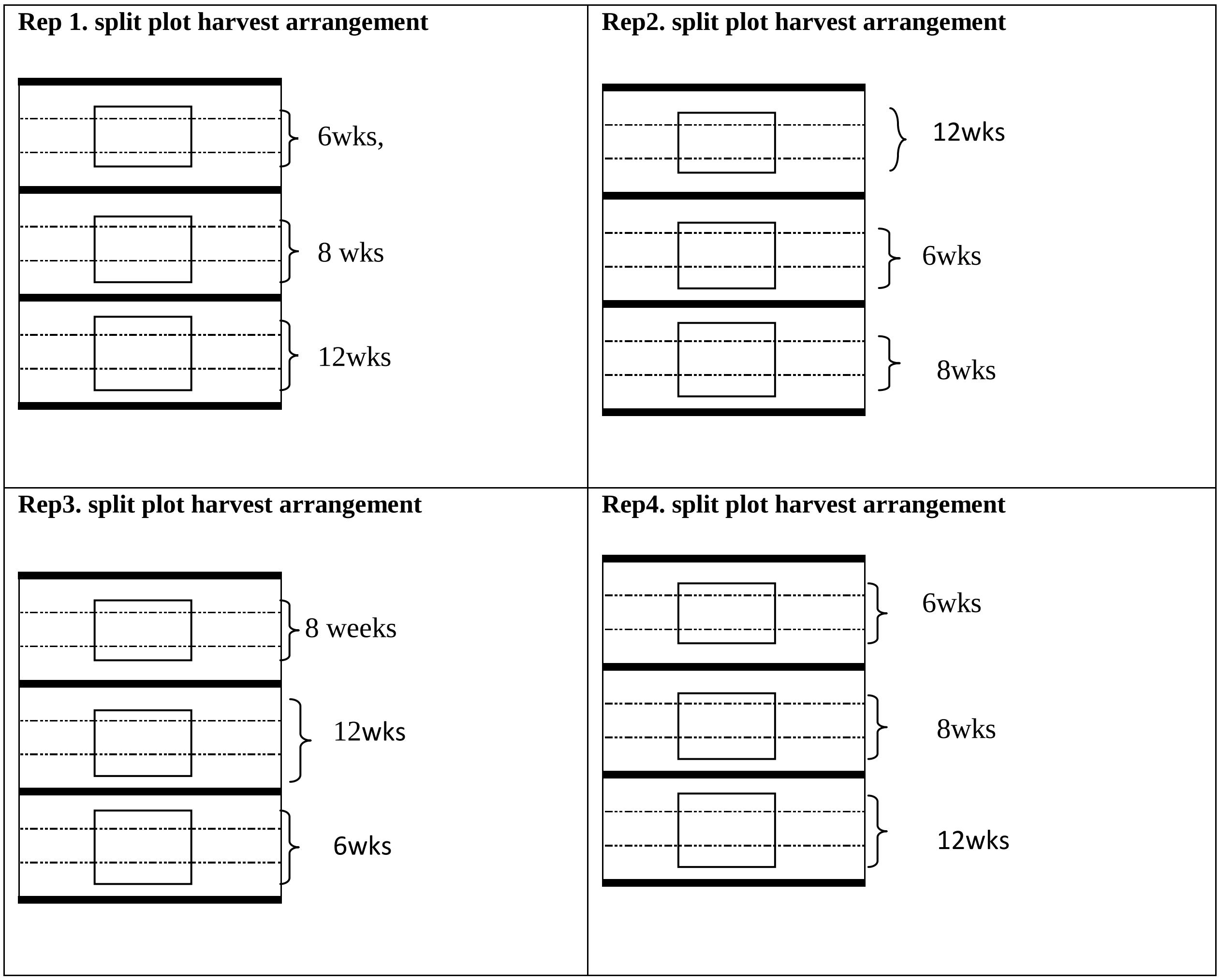

Fig 1: Data collection and harvest at week 6, 8 and 12 of regrowths after standardization

Key

Rows of planted grass

Border rows (also planted)

Quadrat

Crude protein was estimated as:

CP= 6.25 x %N   where CP is crude protein and N is nitrogen.

***Crude fibre*.** Fibre analysis was done using the Ankom fibre method which is a modification of the Van Soest System (1967) of forage analysis. The Ankom fibre analyzer utilizes a series of extractions to determine the fibre content of a plant sample. Each sample of the extractions are done in the order of NDF (%), ADF (%) and then ADL (%).

In vitro dry matter digestibility. For determination of *in vitro* dry matter digestibility (IVDMD), the two stage technique for *in vitro* digestion of forage crops (Tilley and Terry, 1963) was used. This was adapted to the artificial rumen, developed by ANKON®, using the instrument "Daisy incubator" of Ankom Technology (in vitro true digestibility- IVDMD).The ruminal fluid was obtained from one rumen cannulated steer with an average weight of 550 kg kept on Rhodes (*C.gayana*) pasture and hay.

Ash. Ground dried samples were ignited in a furnace at 600^0C for 2hours to oxidize all organic matter. Ash was then determined by weighing the resulting inorganic residue (AOAC, 1990).

Calcium and Phosphorus. Minerals were analyzed in a Thermo ICAP 6300 Inductively Coupled Plasma (ICP) Radial Spectrometer (Thermo Fisher Scientific, Inc., Waltham, MA 02454, USA).

***Metabolizable energy ME*.** Metabolizable energy was estimated on the basis of the equation described by García-Trujillo and Cáceres (1984) as follows:-

ME = 37.28 OMD% -148.9
ME = metabolizable energy
OMD= organic matter digestibilty.

3.3.5 Statistical analyses.

Data on agronomic parameters and quality of forage samples were subjected to ANOVA based on the model designed for a randomised complete block design (RCBD) according to Gomez and Gomez (1984).To compare significant differences in response variables, ANOVA analysis was done using SAS package (SAS Institute Inc., 2001). Duncan's Multiple Range Test was carried out for subsequent comparison of means as described by Steel and Torrie (1980).

CHAPTER 4

4.0 RESULTS

4.1Climatic Data

Rainfall data (Fig.2) for the site during the period January 2012–June 2014 have been presented for 5 seasons: long rains (March–May), short rains (October–December), short dry season (January–February) and long dry season (June–September). Rainfall data for the long rains in 2014 is given for 3 months, March– May which was recorded toward the end of the experimental period. Rainfall during the long rains was above the short-term average (STA) in March 2013 and 2014 and May 2012. April 2012 and 2013 also recorded rains above the Short Term Average (STA). The short rains were quite variable being slightly above the Short-term average in November 2012, slightly below Short Term average in 2013 and above Short Term Average in December 2013. Rainfall experienced in February 2014 which is usually a time of dry spell was a boost to the grasses establishment. Temperatures in almost all months were similar to the medium term average temperature (Fig.3).

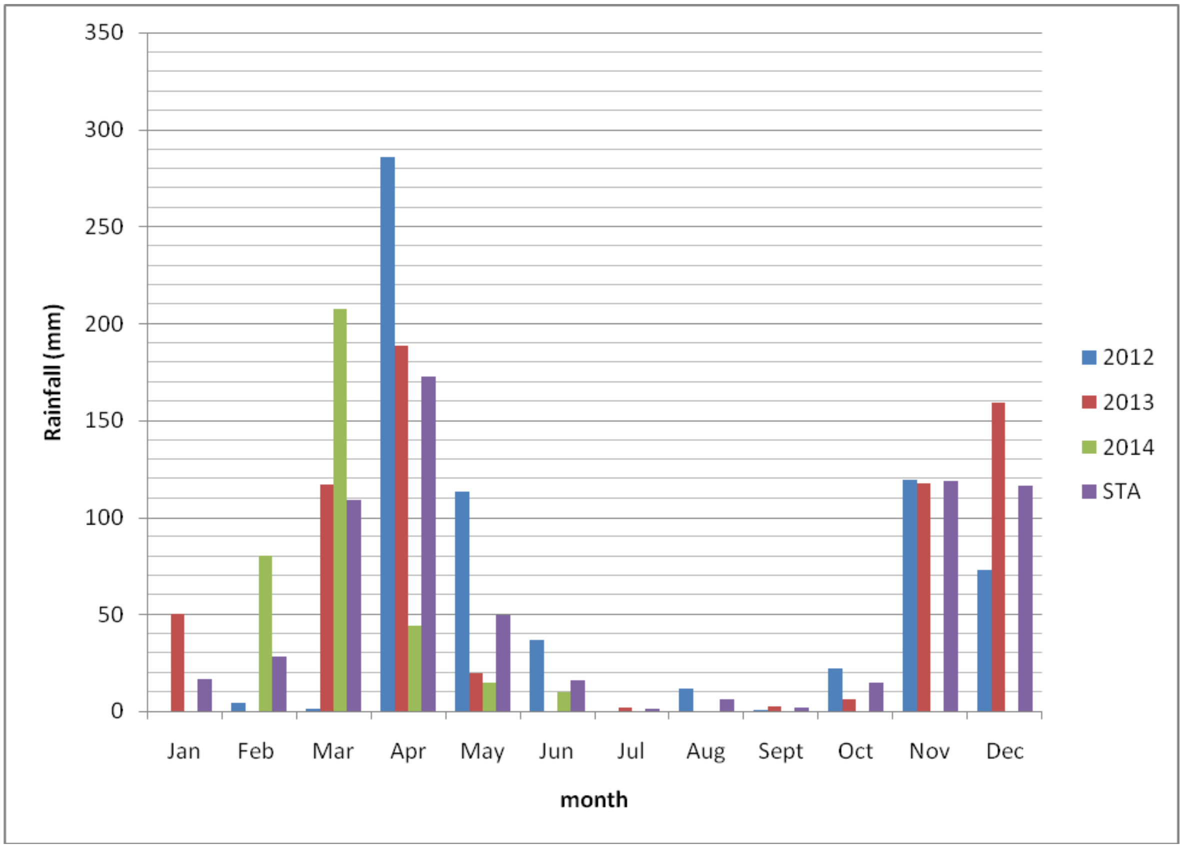

Fig 2: Monthly rainfall recorded data at experimental site from year 2012 to June, 2014. (Source: KALRO, Katumani)

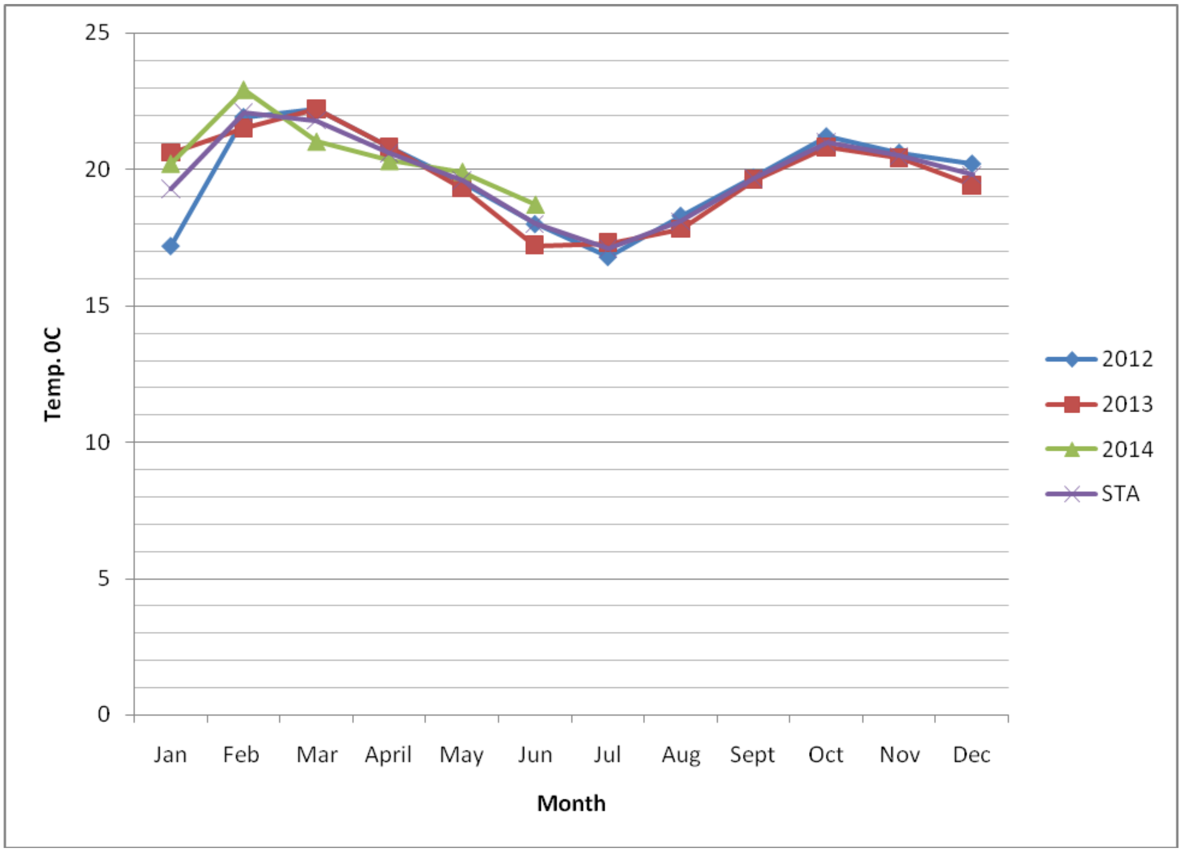

Fig 3: Mean monthly temperature at experimental site from year 2012-June 2014. (Source: KALRO, Katumani)

4.2 Soil sampling results

The soil analysis result is given in Table 2 below. Soil reaction (pH) was found to be satisfactory for plants' growth ranging between 5.81-5.9. Nitrogen, phosphorus and zinc were deficient.

Table 2: Soil samples analysis results for the experimental site

Soil Analytical Data						
Field	**Soil sample A**		**Soil sample B**		**Soil sample C**	
Lab. No/2013	9825		9826		9827	
Fertility results	Value	Class	Value	Class	Value	Class
Soil pH	5.90	Medium acid	5.81	Medium acid	5.83	Medium acid
Total Nitrogen %	0.13	Low	0.15	Low	0.11	Low
Org. Carbon %	1.28	Low	1.43	Low	1.08	Low
Phosphorus ppm	15	Low	15	Low	15	Low
Potassium me%	0.92	Adequate	0.64	Adequate	0.56	Adequate
Calcium me%	3.9	Adequate	3.1	Adequate	3.1	Adequate
Magnesium me%	5.20	High	4.55	High	4.09	High
Manganese me%	0.22	Adequate	0.19	Adequate	0.21	Adequate
Copper ppm	3.34	Adequate	3.38	Adequate	3.89	Adequate
Iron ppm	17.6	Adequate	18.4	Adequate	17.8	Adequate
Zinc ppm	2.22	Low	2.62	Low	1.31	Low
Sodium me%	0.18	Adequate	0.14	Adequate	0.12	Adequate

4.3 Seed germination

The mean germination percentages based on treatments are shown in Table 3 below. Seed treated with acid resulted in mean percentage germination of 34.4% compared to 39.5% with water only. Seed treatment had no significant effect on germination percentage ($p>0.05$). For both water and acid, the best variety in terms of germination percentage was Marandu with 76.3% germinating within the 14 day period of investigation. MG4 emerged the poorest in acid treatment with a germination percentage of 0.33% but second best in germination with water only treatment. Basilisk and *C. gayana* KAT R3 germinated poorly in the water alone treatment with percentages of 12.7% each. Cultivar MG4 (0.33%) recorded lowest germination in acid treatment.

Table 3: The effect of water and concentrated sulphuric acid (>95%) on percent germination of seed cultivars

Cultivar	Treatment		Performance ranking	
	Acid and water	**Water only**	**Acid and water**	**Water only**
Marandu	76.3 [a]	76.3 [a]	1	1
MG4	0.33[f]	67.3 [a]	9	2
Mulato II	70.7[ab]	66.7 [a]	2	3
Xarares	55.7[bc]	56.7 [b]	3	4
Piata	47.7[c]	31.0 [c]	4	5
Humidicola	23.0[d]	16.7 [d]	5	6
Llanero	20.3[ed]	15.7 [d]	6	7
Basilisk	13.7[edf]	12.7 [d]	7	8
C. gayana	2.0[ef]	12.7 [d]	8	8
Mean	34.4[a]	39.5[a]		
SE	±2.02	±1.08		

Column means for cultivars with the same superscript are not significantly different ($p<0.05$). Treatment means are also not significantly ($p>0.05$) different.

Fig. 4 shows seed germination among the grasses during a14 day period. On day two 36% of MG4 and 21% Marandu seed had already germinated. By day ten, 50% of seed of cultivars Marandu, MG4, mulato II and Xaraes had germinated. Seed germination for the other cultivars never reached 50%.The plateaus observed on the germination curves were the period during which no further germination was observed. These figures are based on the water only treatment. Marandu recorded the highest germination percentage at 76% followed by MG4 at 67%. *Chloris gayana* KatR3 recorded the lowest germination percentage at 10% by day 14.

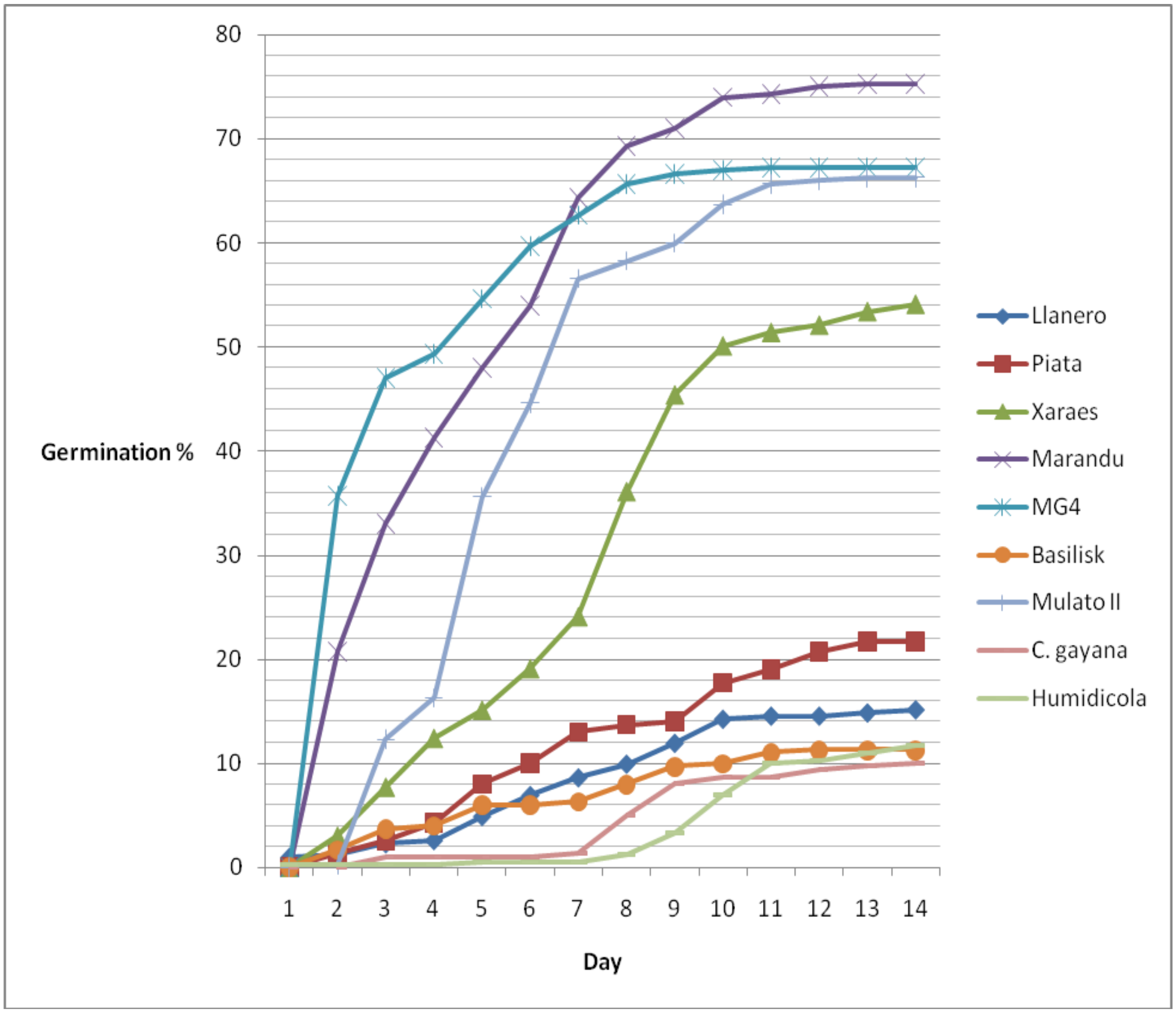

Fig 4: Daily percentage seed germination of the grass cultivars under controlled laboratory conditions (30^0C, 8 hrs; 20^0C, 16hrs) in the study area.

Seedling vigour was assessed in terms of progressive seedling length. Table 4 shows the seedling vigour of the grass seedlings with time. Seedling vigour was monitored immediately after seedling germination. Marandu exhibited the highest seedling vigour and at day 21 seedling length was11.9cm whereas *C. gayana* KAT R3 had the lowest (3.4cm) on the same date. By day 21 most of the seedlings had yellowed and were stunted.

Table 4: Mean seedling length of grass cultivars in a 21 day period

	Average Seedling length in cm								
	Marandu	**MG4**	**Mulato II**	**Xaraes**	**Piata**	**Humidicola**	**Llanero**	**Basilisk**	**C.gayana**
Day 7	4.4	4.9	2.6	3.3	2.0	1.7	1.7	4.5	1.1
Day 10	9.8	9.4	4.9	7.8	4.9	3.7	1.9	4.9	1.5
Day 13	10.8	10.7	5.9	9.3	8.0	6.1	2.0	7.0	1.9
Day 17	11.9	11.0	7.3	9.3	9.8	6.7	3.2	7.5	2.3
Day 21	11.9	11.0	7.6	10.2	11.3	6.6	3.4	10.0	2.3
Ranking	1	3	6	4	2	7	8	5	9

4.4 Field establishment

Although 9 cultivars were sown, data for *B. humidicola* cv. Humidicola was not recorded due to failure of the grass to establish. Therefore the results reported are for 8 cultivars and Napier grass.

4.4.1 Establishment phase parameters

Population: Establishment rates for the cultivars are shown in Table 5 below. Plant population means for the cultivars were significantly ($p<0.05$) different during the establishment phase. At week 16, *Chloris gayana* cv Kat R3 recorded highest plant numbers at 48.5plants/m^2. MG4 (27.3 plants/m^2), Mulato II (23.8 plants/m^2), Marandu (20.8plants/m^2) and Basilisk (24 plants/m^2) recorded similar plant population. Plant population for Xaraes (12 plants/m^2), Piata (8.3 plants/m^2) and Llanero (16 plants/m^2) recorded lower but similar ($p>0.05$) plant population.

Table 5: Mean plant population (plants/ m^2) during Establishment phase

Cultivar	Week4	Week 8	Week 12	Week 16
Llanero	14^{bac}	17^{ced}	17^{cbd}	16^{cbd}
MG4	22.3^{a}	27.3^{b}	27.3^{b}	27.3^{b}
Marandu	16.5^{ba}	20.8^{cbd}	21.8^{cb}	20.8^{cb}
Piata	7.3^{c}	8.3^{fe}	8.3^{ed}	8.3^{ed}
Xaraes	10.5^{bc}	11.8^{fed}	12^{ced}	12^{ced}
Mulato11	19.5^{ba}	23.8^{cb}	23.8^{b}	23.8^{b}
Basilisk	18^{ba}	19.5^{cbd}	24.0^{b}	24.0^{b}
Kat R3	22.5^{a}	48.5^{a}	48.5^{a}	48.5^{a}
Napier		4^{f}	4^{e}	4^{e}
Mean	16.3	20.1	20.7	20.5
SE	±1.0	±1.0	±1.2	±1.2

Column means with similar superscripts are not significantly different (p<0.05)

Plant spread: Table 6 shows the mean values for spread for the cultivars. Plant spread for the cultivars increased during the establishment phase. At week 4, mean values for spread were similar (p>0.05) for all cultivars except for Marandu. At week 8, mean values of spread for the cultivars was similar (p>0.05) but for Llanero which also had highest (49.4cm) spread. At week 12, mean values of spread for Llanero, Mulato II and Napier were significantly different (p<0.05) while spread for the rest of the cultivars were similarFrom week 12 to end of establishment, Mulato II recorded lower spread than the other cultivars. *Brachiaria brizantha* cultivars MG4 (58.6cm), Piata (56.4cm), Xaraes (47.4cm) and Marandu (49.7cm) showed similar (p>0.05) spread at the end of this phase. Generally *B. decumbens* cv. Basilisk performed better (60.4cm) than all the *B. Brizantha* cultivars even though it's mean spread was not significantly (p>0.05) different from MG4 (58.6cm). Napier (72.2cm) and *C.gayana* cv KatR3 (60cm) showed impressive spread at the end of this phase. Llanero outperformed all the other cultivars by week 16.

Table 6: Mean plant spread (cm) during establishment phase

Cultivar	Week4	Week 8	Week 12	Week 16
Llanero	3.6^{b}	49.4^{a}	107.7^{a}	146.9^{a}
MG4	4.8^{b}	16.3^{b}	38.1^{cb}	58.6^{cb}
Marandu	10.0^{a}	12.1^{b}	29.2^{cb}	49.7^{cd}
Piata	3.0^{b}	10.0^{b}	31.2^{cb}	56.4^{c}
Xaraes	3.6^{b}	12.1^{b}	29.4^{cb}	47.4^{cd}
Mulato11	2.3^{b}	9.8^{b}	24.5^{c}	40.7^{d}
Basilisk	3.2^{b}	10.1^{b}	36.6^{cb}	60.4^{cb}
Kat R3	2.3^{b}	13.5^{b}	34.7^{cb}	60.0^{cb}
Napier		16.3^{b}	47.1^{b}	72.2^{b}
Mean	4.1	16.6	42.1	65.8
SE	±0.6	±0.8	±2.1	±1.5

Column means with the same superscript are not significantly different (p<0.05).

Plant cover: Table 7 shows the plot cover for the grasses during the establishment phase. Plot cover generally increased for all the cultivars and cover means were significantly different for the cultivars (p<0.05) during this phase. Napier had the highest plot cover at 84.9% followed by Llanero (81%) at the end of establishment phase. Of the *B. brizantha* cultivars Marandu (74%) and MG4(74%) had higher(p<0.05) plot cover compared to Xaraes(62%) and Piata (49%). Only Piata had less than 50% plant cover at the end of the establishment period. *Chloris gayana* cv KAT R3 (69%) had similar (p>0.05) plant cover to all the cultivars but higher than Piata (49%).

Table 7: Mean Plant cover (%) during establishment.

Cultivar	Week4	Week 8	Week 12	Week 16
Llanero	8^{bc}	25.0^{bac}	71.5^{a}	81^{ba}
MG4	13^{a}	32.0^{ba}	51.3^{ba}	74^{ba}
Marandu	10^{ba}	19.0^{bac}	47.0^{bc}	74^{ba}
Piata	5^{bc}	16.0^{c}	34.0^{bc}	49^{c}
Xaraes	8^{bc}	25.0^{bac}	39.0^{bc}	62^{bc}
Mulato11	8^{bc}	18.0^{bc}	45.0^{bc}	70^{ba}
Basilisk	13^{a}	33.0^{a}	31.0^{bc}	71^{ba}
Kat R3	9^{b}	13.0^{c}	44.0^{bc}	69^{ba}
Napier		15.8^{c}	24.5^{c}	84.9^{a}
Mean	9.3	21.9	43.0	70.5
SE	±0.4	±1.5	±2.6	±2.0

Column means with the same superscript are not significantly different (p<0.05)

Plant tiller number: Tiller number increased progressively for all cultivars and their values were significantly different (p<0.05) for the cultivars as shown in Table 8. At week 4, MG4, Basilisk and Marandu had similar tiller numbers while Basilisk, Llanero, Xaraes, Mulato II and *C.gayana* cv Kat R3 also recorded similar tiller numbers(p>0.05). Piata had the lowest tiller numbers (2tillers/ plant). At the end of establishment phase at 16 weeks, Llanero recorded highest tiller numbers (30.5tillers/plant) that however was not significantly different (p>0.05) from MG4 (24.5tillers/plant), Piata (25.5tillers/plant), Xaraes (25.5tillers/plant), Mulato II (23.8tillers/plant) and Basilisk (20.5tillers/plant). At week 16 there were not significant (p>0.05) differences between mean tiller numbers for Napier, *C. gayana* cv Kat R3, Basilisk and Marandu. Among *B. brizantha* cultivars MG4 (24.5tillers/plant), Piata (25.5 tillers/plant), and Xaraes (25.5 tillers/plant) proved superior (p<0.05) to Marandu (16.8tillers/plant). The *Brachiaria* spp showed higher tiller recruitment (16.8-30.5 tillers /plant) than both *C. gayana* cv KAT R3 (17.8 tillers/plant) and Napier (10.6 tillers/plant) at the end of this phase

Table 8: Mean plant tiller number during establishment.

Week	Week4	Week 8	Week 12	Week 16
Llanero	3.5^{b}	9.5^{ba}	16.5^{ba}	30.5^{a}
MG4	4.8^{a}	12.3^{a}	16.8^{a}	24.5^{ba}
Marandu	4.8^{a}	8.0^{bc}	11.8^{bc}	16.8^{bc}
Piata	2.0^{c}	5.5^{c}	12.8^{bac}	25.5^{ba}
Xaraes	3.3^{b}	9.3^{ba}	14.3^{ba}	25.5^{ba}
Mulato11	3.2^{b}	8.5^{bc}	14.8^{ba}	23.8^{ba}
Basilisk	4.0^{ba}	7.8^{bc}	12.3^{bac}	20.5^{bac}
Kat R3	3.4^{b}	6.8^{bc}	11.8^{bc}	17.8^{bc}
Napier		8.0^{bc}	8.3^{c}	10.6^{c}
Mean	3.6	8.4	13.2	21.7
SE	±0.1	±0.4	±0.5	±1.2

Column means with the same superscript are not significantly different (p<0.05).

Plant height**:** Table 9 shows the mean plant heights for the cultivars during the establishment period. Mean heights for the different cultivars were significantly different (p<0.05) throughout the establishment phase. At the end of the establishment phase, Napier recorded the highest mean plant height (103.8cm) and Llanero lowest at 6cm. Among the *Brachiaria* cultivars MG4 (63.4cm) recorded higher plant height and that was significantly lower than Napier (103.8cm), but not significantly different from *C. gayana* cv Kat R3 (52.8cm).

Table 9: Mean Height (cm) of plants during establishment

Cultivar	Week4	Week 8	Week 12	Week 16
Llanero	2.3^{c}	3.3^{b}	3.9^{d}	6.0^{f}
MG4	5^{a}	4.5^{b}	37.3^{b}	63.4^{b}
Marandu	4^{ba}	3.4^{b}	10.2^{dc}	20.4^{de}
Piata	2.9^{bc}	3.3^{b}	14.6^{c}	29.8^{dc}
Xaraes	3.9^{ba}	4.3^{b}	12.6^{dc}	24.9^{dce}
Mulato11	2.1^{c}	3.0^{b}	7.9^{dc}	14.3^{fe}
Basilisk	4.6^{a}	3.7^{b}	12.8^{c}	34.9^{c}
Kat R3	2^{c}	2.3^{b}	7.3^{dc}	52.8^{b}
Napier		44.4^{a}	67.3^{a}	103.8^{a}
Mean	3.3	8.0	19.3	38.9
SE	±0.1	±0.4	±0.9	±1.4

Column means with the same superscript are not significantly different (p<0.05).

Dry matter yields at the end of establishment Phase. Figure 5 shows the dry matter yields of the cultivars at the end of the establishment phase. Dry matter yield in week 16 represented primary production. Napier (5430KgDM/ha), MG4 (4583.4 Kg DM/Ha) and Mulato II (4050.2 Kg DM/Ha) showed similar yields (p<0.05). *Chloris gayana* cv Kat R3 (2740.5 Kg DM/Ha), Piata (3305.7 Kg DM/Ha), Basilisk (3191.3 Kg DM/Ha), Marandu (2595.7Kg DM/Ha), Xaraes (2334.4 Kg DM/Ha) and Llanero (2282 Kg DM/Ha) had similar yields (p>0.05). The lowest yield at week 16 was recorded for Llanero while Napier recorded the highest dry matter yield.

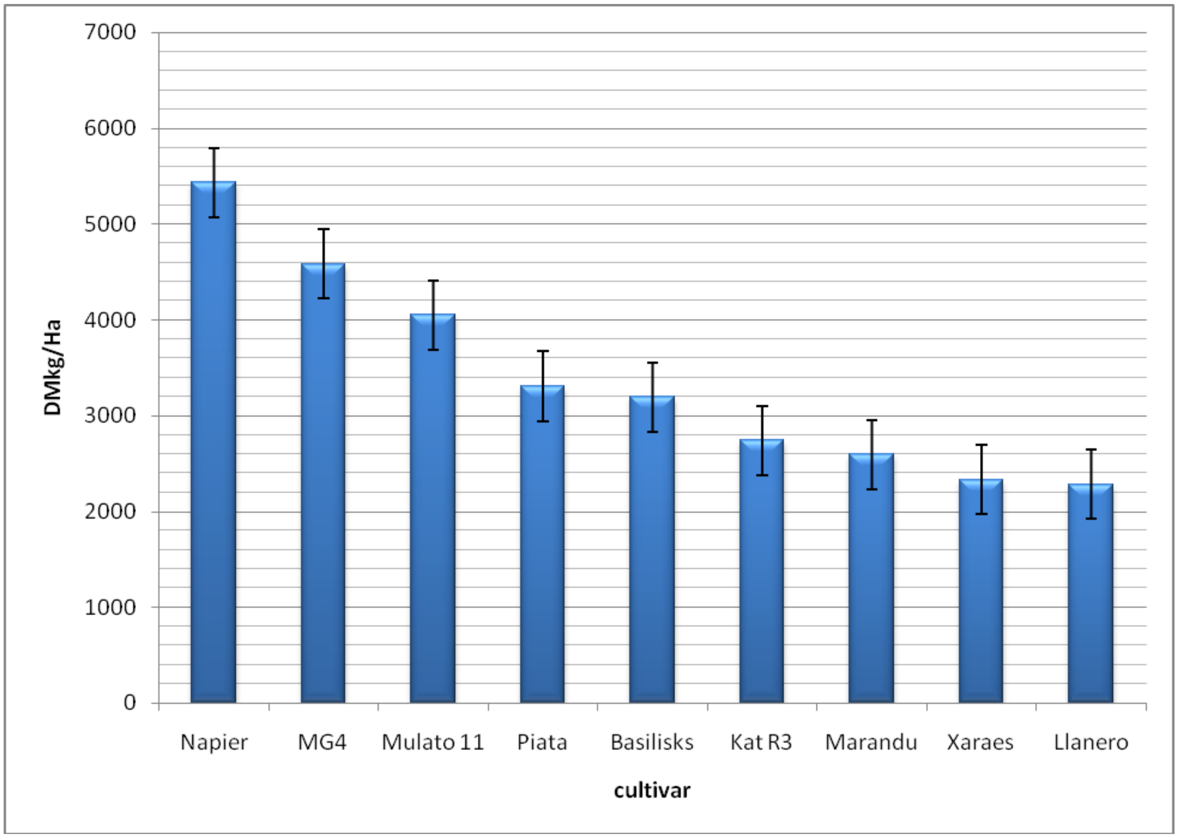

Fig: 5 Dry matter yields for the cultivars in Kg/ha at the end of establishment period

4.4.2 Production phase parameters

During the production phase data for Napier grass was collected only once at week 8 harvest interval. This was to simulate the recommended harvest interval of 6-8weeks cutting intervals after initial establishment for Napier grass.

Plant population. Mean plant population for the cultivars increased during the production phase as shown in Table 10. *Chloris gayana* cv Kat R3 maintained highest plant population numbers (61-165plants/m) whereas Xaraes maintained lowest plant population figures (18-26 plants/m^2) during this phase. During week12 of this phase, MG4, Basilisk, Marandu and Llanero had similar plant numbers ($p>0.05$). *Brachiaria brizantha* cultivars Piata and Xaraes had similar plant population but lower than that for Marandu and MG4.

Table 10: Mean plant population (numbers/m^2) during production phase

Cultivar	Week 6	Week 8	Week 12
MG4	32^{cb}	51^{b}	45^{cb}
KAT R 3	61^{a}	142^{a}	165^{a}
Basilisk	38^{b}	49^{b}	44^{cb}
Piata	31^{cb}	32^{cbd}	30^{cd}
Xaraes	18^{c}	16^{cd}	26^{d}
Marandu	34^{b}	44^{b}	41^{cbd}
Mulato II	28^{cb}	38^{cb}	37^{cd}
Llanero	39^{b}	53^{b}	57^{b}
Napier	-	8^{d}	-
Mean	35	48	56
SE	±2	±3	±2

Column means with similar superscripts are not significantly different ($p<0.05$).

Plant height. Table 11 shows mean plant heights for the cultivars recorded during the production phase. Napier recorded highest plant height at week8. *Chloris gayana* cv Kat R3 recorded highest height at week 6 and 12 (74.1cm and 113.2cm respectively) and Llanero lowest (8.8 and12.6cm respectively) throughout this phase. Of the *B. brizantha* cultivars, MG4 recorded the highest height (75.6cm) which was similar ($p>0.05$) to Basilisk (80.1cm) at week 12. Piata, Xaraes, Marandu, Mulato II and Llanero also recorded similar height ($p>0.05$) at week 12.

Table 11: Mean plant heights (cm) during production phase

Cultivar	Week 6	Week 8	Week 12
MG4	18.2[b]	24.0[c]	75.6[b]
KAT R 3	74.1[a]	77.2[b]	113.2[a]
Basilisk	11.9[c]	26.7[c]	80.1[b]
Piata	13.6[cb]	24.4[c]	34.8[c]
Xaraes	15[cb]	24.5[c]	26.1[dc]
Marandu	11.1[c]	19.2[c]	23.1[dc]
Mulato II	10.6[c]	14.2[c]	28.2[dc]
Llanero	8.8[c]	7.1[c]	12.6[d]
Napier	-	103.1[a]	-
Mean	20.4	35.6	49.2
SE	±0.7	±2.9	±2.2

Column means with similar superscripts are not significant different ($p<0.05$).

Plant spread. Mean plant spread for all the cultivars increased during production phase as shown in Table 12 below. Llanero recorded highest plant spread (95.9-116.2cm) and KatR3 lowest (22.1cm-36.7cm) during this phase. At week 8, Napier came second to Llanero and recorded 75.4cm spread. At week 12 all the *B. brizantha* cultivars, Basilisk and Mulato II showed similar spread ($p>0.05$). MG4 showed lowest (49.1cm) spread of the *Brachiaria* cultivars.

Table 12: Mean plant spread (cm) during production phase

Cultivar	Week 6	Week 8	Week 12
MG4	70.2^{b}	37.9^{c}	49.1^{b}
KAT R 3	22.1^{d}	14.7^{d}	36.7^{c}
Basilisk	46.3^{cb}	46.3^{c}	67.6^{b}
Piata	50.4^{b}	44.1^{c}	68.3^{b}
Xaraes	39.5^{cb}	47.1^{c}	60.8^{b}
Marandu	32.0^{cd}	41.0^{c}	55.3^{b}
Mulato II	37.9^{cb}	35.4^{c}	54.4^{b}
Llanero	95.9^{a}	88.4^{a}	116.2^{a}
Napier	-	75.4^{b}	-
Mean	46.6	47.9	66.2
SE	±1.6	±1.4	±2.0

Column means with similar superscripts are not significantly different ($p<0.05$).

Plant cover: Mean plant cover increased for all the cultivars during the production phase. There was no significant difference ($p>0.05$) among the cultivars for plant cover as shown in Table 13 below at week 12, although Mg4 recorded highest plant cover of 100%.

Table 13: Mean plant cover (%) during production phase

Cultivar	Week 6	Week 8	Week 12
MG4	92.5[a]	95[ba]	100[a]
KAT R 3	79[a]	75[b]	96[a]
Basilisk	77.5[a]	98.5[a]	99.5[a]
Piata	82[a]	93[ba]	98[a]
Xaraes	82.5[a]	87[ba]	98[a]
Marandu	85[a]	99.5[a]	99.5[a]
Mulato II	90.5[a]	99[a]	99.5[a]
Llanero	90.3[a]	97[a]	98[a]
Napier	-	91.5[ba]	-
Mean	84.9	92.8	98.6
SE	±1.7	±2.2	±0.4

Column means with similar superscripts are not significantly different ($p<0.05$).

Plant tiller number: Mean tiller numbers for the cultivars decreased as the production phase progressed as shown in Table 14 below. At week 6, MG4 showed highest (86 tillers/plant) but similar ($p>0.05$) values to Basilisk, Xaraes and Mulato II. For all the cultivars, tiller number decreased at week 12 though values for MG4 had decreased during week 6-8 (86-37 tillers/plant). Xaraes showed highest tiller mean number at 61tillers/plant even though tiller numbers value for this cultivar was similar to Basilisk, Piata and Mulato II. At week 8, Napier had similar ($p>0.05$) tiller numbers with Mulato II, Marandu, Piata, katR3 and MG4. *Chloris gayana* cv Kat R3 had lowest tiller number at week12.

Table 14: Mean plant tiller numbers during production phase

Cultivar	Week 6	Week 8	Week 12
MG4	86[a]	46[bc]	37[b]
KAT R 3	21[c]	14[d]	17[c]
Basilisk	67[ba]	74[a]	56[a]
Piata	52[b]	52[bac]	47[ba]
Xaraes	66[ba]	74[a]	61[a]
Marandu	46[b]	44[bc]	36[b]
Mulato II	68[ba]	52[bac]	51[ba]
Llanero	50[b]	62[ba]	39[b]
Napier	-	35[dc]	-
Mean	57	50	43
SE	±3	±2	±2

Column means with similar superscripts are not significantly different ($p<0.05$).

Dry matter yields. Mean dry matter yields for the cultivars increased at week 6-8 as shown in Table 15. There was a significant difference ($p<0.05$) between dry matter yields for all the cultivars at week 6, 8 and 12. *Chloris gayana* cv KAT R3 had highest (3606.7 kg/ha) but similar ($p>0.05$) dry matter yields with MG4, Piata and Xaraes at week 6 whereas Llanero had lowest (2137.7 kg/ha) dry matter yields compared to all the other cultivars. At week 8, Xaraes recorded highest (7077kg/ha) dry matter yields compared to all the other cultivars but Llanero had the lowest (4477kg/ha) yield at that time. At week 12, Piata was leading in dry matter yields (8867kg/Ha) though having similar production with Mulato II, Marandu, Xaraes, Basilisk, *C. gayana* cv KAT R3 and MG4. At the end of this phase the lowest yields were obtained from Llanero (3515kgDm/Ha) followed by Marandu.

Table15: Dry matter yields (kg/Ha) for cultivars during production phase.

Cultivar	Week 6	Week 8	Week 12
MG4	3055.4^{ba}	5850^{ba}	8015^{a}
KAT R 3	3606.7^{a}	6100^{ba}	7401^{ba}
Basilisk	2359.9^{b}	5952^{ba}	6677^{ba}
Piata	3046.1^{ba}	6487^{ba}	8867^{a}
Xaraes	2681.2^{ba}	7077^{a}	6842^{ba}
Marandu	2249.2^{b}	5449^{ba}	5360^{ba}
Mulato II	2276.2^{b}	4941^{ba}	8626^{a}
Llanero	2137.7^{b}	4477^{b}	3515^{b}
Napier	-	5544^{ba}	-
Mean	2676.5	6380.3	6912.8
SE	±111.1	±287.8	±475.4

Column means with similar superscripts are not significantly different ($p<0.05$).

Plates 1 to 9 show photos of all the cultivars taken during week six of regrowths after the standardization cuts. The photos were taken on 7th May, 2014. Standardization cuts were done on 26th March 2014.

Plate 1: ***Brachiaria brizantha*** **cv Piata**

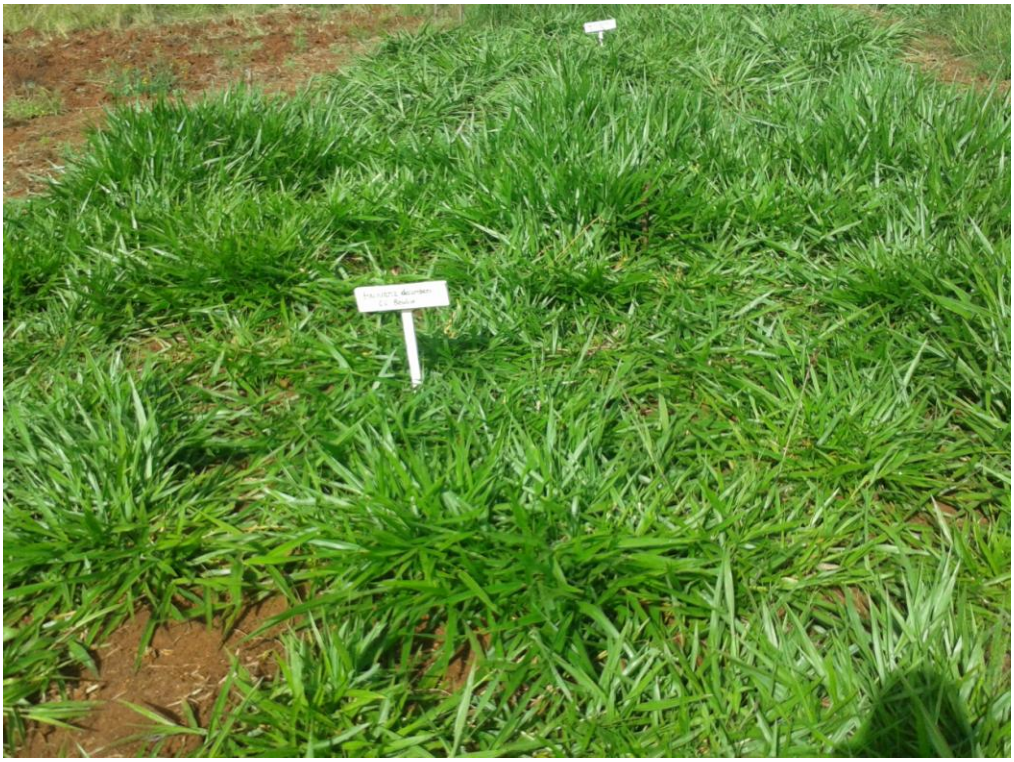

Plate 2: ***Brachiaria decumbens*** **cv Basilisk**

Plate 3: ***Brachiaria*** **hybrid cv Mulato II**

Plate 4 : ***Chloris gayana*** **cv KAT R3**

Plate 5: ***Pennisetum Pupureum*** **cv Kakamega I**

Plate 6: ***Brachiaria brizantha*** **cv Xaraes**

Plate 7: ***Brachiaria brizantha*** **cv Marandu**

Plate 8: ***Brachiaria humidicola*** **cv Llanero**

Plate 9: ***Brachiaria brizantha*** **cv MG4**

4.4.3 Chemical composition

Ash, calcium and phosphorus: There was a significant (p<0.05) difference among the grass cultivars for ash at week 6, 8 and 12 as shown in Table 16 below. The ash content decreased during the production phase with Mulato II recording highest values during week 6 (15%) and week 8 (15%). At week 12, Marandu recorded highest (12%) but similar (p>0.05) ash content to Mulato II, Llanero and Xaraes. Throughout this phase *C. gayana* cv Kat R3 maintained lower (9.5-8.3%DM) ash content. The other cultivars recorded similar values for ash from week 6-8. Mean calcium and phosphorus values were significantly different (p<0.05) among the cultivars during the harvest intervals. *Chloris gayana* cv Kat R3 recorded highest and increasing content of calcium (0.158%, 0.347% and 0.357%) but lowest phosphorus content which increased at week 8 and decreased again at week 12 (0.054%, 0.078% and 0.048%) during Week6 to 8. Only at week 6 were C. gayana cv. Kat R3 calcium content similar (p>0.05) to other cultivars (in this case Mulato II and Marandu). The *B. brizantha* cultivars showed higher calcium (0.104-0.267%DM) content than the other *Brachiaria* cultivars (with an exception of *Brachiaria* hybrid Mulato II) as the production phase progressed. At week 6, Mulato II and MG4 recorded higher but similar (p<0.05) phosphorus content to Marandu. (0.081% DM) but at week 12 Marandu had higher phosphorus content (0.096%DM). This value was similar to values recorded for Mulato II and MG4.

Table 16: Mean ash, calcium and phosphorus (%DM) of the cultivars at three cutting frequencies during the production phase.

Cultivar	Week 6			Week 8			Week 12		
	Ash	Ca	P	Ash	Ca	P	Ash	Ca	P
Mulato II	15.0[a]	0.14[bac]	0.087[a]	15.0[a]	0.133[ed]	0.075[c]	11.4[ba]	0.277[b]	0.091[ba]
MG4	13.3[bc]	0.117[bc]	0.087[a]	12.5[bc]	0.218[cb]	0.136[a]	9.6[dc]	0.168[dc]	0.082[bac]
Marandu	14.6[ba]	0.154[ba]	0.081[a]	13.9[ba]	0.085[e]	0.08[c]	12.0[a]	0.267[b]	0.096[a]
Xaraes	12.6[c]	0.104[dc]	0.068[b]	12.6[bc]	0.267[b]	0.109[b]	10.6[bac]	0.178[dc]	0.072[bdc]
Piata	13.1[bc]	0.123[bc]	0.065[cb]	11.4[c]	0.237[b]	0.096[cb]	10.2[bc]	0.139[de]	0.056[ed]
Llanero	12.3[c]	0.069[d]	0.065[cb]	11.4[c]	0.168[cd]	0.098[cb]	11.1[ba]	0.099[e]	0.074[bdc]
Basilisk	13.1[bc]	0.108[c]	0.63[cb]	12.1[bc]	0.106[ed]	0.05[d]	8.5[d]	0.198[c]	0.064[edc]
KatR3	9.5[d]	0.158[a]	0.054[c]	8.6[d]	0.347[a]	0.078[c]	8.3[d]	0.357[a]	0.048[ed]
Napier	-	-	-	15.2[a]	0.110[ed]	0.50[d]	-	-	-
Mean	13.0	0.123	0.071	12.5	0.186	0.085	10.2	0.211	0.073
SE	±0.2	±0.042	±0.001		±0.007	±0.002	±0.2	±0.005	±0.002

Column means with the same superscripts are not significantly (*p*<0.05) different.

Crude protein: Crude protein (CP) values for the cultivars as shown in Table17 were significantly (p<0.05) different during all the harvest intervals. The values for all the cultivars were initially high (Mean CP 11.1%) but decreased during harvest intervals week 8 and week12. At week 6 harvest interval, Mulato II recorded highest CP (12.8 %) but this value was similar (p>0.05) to those for Marandu (11.9 %), Xaraes (11.1 %), Piata (11.5%) and MG4 (11.5 %). *Chloris gayana* cv KAT R3 (9.7%) and Basilisk (9.8%) had lower CP values though similar to MG4 (11.5%), Piata (11.5 %), Xaraes (11.1 %) and Llanero (10.7 %). Mulato II was again highest (10.7 %) in CP at week 8 but recorded similar (p>0.05) values to Xaraes (9.6 %), and Llanero (9.5 %). *Chloris gayana* cv KAT R3 and Napier had the lowest CP value at week 8 harvest interval. This value was similar (p>0.05) to values for MG4 (8 %) and Basilisk (8 %). At week 12 harvest interval, Xaraes (8 %) recorded higher CP than the rest of the cultivars although this value was not significantly different from the values for MG4 (7 %), Mulato II (7 %) and Llanero (6.6 %).There was a general decrease in CP with maturity of the cultivars.

Table 17: Mean Crude Protein Content (CP %) of the cultivars at three cutting frequencies during the production phase.

Cultivar	Week 6	Week 8	Week 12
MG4	11.5^{bac}	8.0^{dc}	7.0^{ba}
KAT R 3	9.7^{c}	6.9^{d}	4.4^{d}
Basilisk	9.8^{c}	8.0^{dc}	4.9^{dc}
Piata	11.5^{bac}	8.7^{bc}	6.1^{bc}
Xaraes	11.1^{bac}	9.6^{ba}	8.0^{a}
Marandu	11.9^{ba}	9.2^{bc}	6.2^{bc}
Mulato II	12.8^{a}	10.7^{a}	7.0^{ba}
Llanero	10.7^{bc}	9.5^{ba}	6.6^{ba}
Napier	-	7.6^{d}	-
Mean	11.1	8.7	6.3
SE	±0.2	±0.1	±0.2

Column means with similar superscripts are not significantly ($p<0.05$) different

The NDF content of the grasses is shown in Table 18. Mean NDF content was significantly different ($p< 0.05$) for the cultivars during all the harvest intervals (week6 to week 12). *Chloris gayana* cv. Kat R3 recorded higher NDF values during all the harvest intervals. At 6 weeks cutting interval MG4, Basilisk, Piata, Marandu and Llanero recorded similar (p>0.05) NDF values. At week 12, Basilisk was second (71.3%) to *C. gayana* cv Kat R3 (73.8%) in NDF content and mean NDF values for MG4, Piata, Llanero and Xaraes were similar (p>0.05). Mulato II recorded lowest values for NDF at all the harvest intervals. Napier recorded similar (p> 0.05) NDF values to Basilisk, Piata, Xaraes and Marandu during week 8 harvest interval. Among the *Brachiaria* cultivars, Basilisk recorded the highest NDF content (73.8%) and Mulato II lowest value at the 12 week harvesting interval. Napier was cut only once at week 8and had similar NDF values with Basilisk, Piata, Xaraes, Marandu and Llanero.

Table 18: Mean NDF (%) Content of the cultivars at three cutting frequencies

Cultivar	Week 6	Week 8	Week 12
MG4	60.6[c]	64.7[c]	69.1[c]
KAT R3	72.5[a]	72.3[a]	73.8[a]
Basilisk	63.9[cb]	68.1[b]	71.3[b]
Piata	63.6[cb]	67.0[cb]	69.0[c]
Xaraes	64.7[b]	65.2[cb]	67.5[c]
Marandu	60.3[c]	65.6[cb]	65.6[d]
Mulato II	56.1[d]	60.6[d]	63.3[e]
Llanero	63.4[cb]	66.6[cb]	68.7[c]
Napier	-	68.2[b]	-
Mean	63.1	66.5	68.5
SE	±0.4	±0.3	±0.2

Column means with similar superscripts are not significantly (*p*<0.05) different

Table 19 shows the content of ADF for the cultivars at the 3 harvest intervals during the production phase. ADF content increased with age for all the cultivars and mean values showed a significant difference (p<0.05) among cultivars. *Chloris gayana* cv Kat R3 showed the highest value for ADF at all cutting intervals (45.6-50.2%). At the week 8 harvest interval, values for *C. gayana* cv KAT R3 were similar (p>0.05) to Napier (45.1%). MG4 (42.9%), Basilisk (42.4%), Piata (41.4%), Xaraes (39.9%) and Llanero (40.4%) had similar (p>0.05) values for ADF at the week 12 harvest interval.

Table 19: Mean ADF (%) Content of the cultivars at 3 cutting frequencies during production phase.

Cultivar	Week 6	Week 8	Week 12
MG4	36.1[ed]	38.8[cd]	42.9[b]
KAT R3	45.6[a]	48.5[a]	50.2[a]
Basilisk	38.6[cbd]	42.2[bc]	42.4[b]
Piata	37.1[ced]	40.8[bcd]	41.1[cb]
Xaraes	39.2[cb]	35.4[d]	39.9[cbd]
Marandu	35.3[fe]	38.6[cd]	38.0[cd]
Mulato II	32.8[f]	36.9[cd]	37.5[d]
Llanero	40.0[b]	40.9[bcd]	40.4[cbd]
Napier	-	45.1[ba]	-
Mean	38.1	40.8	41.5
SE	±0.3	±0.6	±0.4

Column means with similar superscripts are not significantly (p<0.05) different.

Acid detergent Lignin (ADL) content for cultivars increased with age and their mean values showed significant (p<0.05) differences among cultivars during the harvest intervals as shown in Table 20. *Chloris gayana* cv KAT R3 recorded higher values of ADL (5.2-6.5%) alongside Llanero (5.3-4.4%) during all the harvest intervals. MG4, Piata and Marandu recorded similar (p>0.05) ADL content at all the harvest intervals. At the week 12 cutting interval all the cultivars recorded similar (p>0.05) mean values for ADL. At week 8 Napier showed similar ADL to all the other cultivars except for *C. gayana* cv KAT R3. At week 12 harvest interval, Mulato II recorded highest (6.4%) ADL content while Marandu (3.6%) had the lowest.

Table 20: Mean ADL (%) Content of the cultivars at 3 cutting frequencies during production phase.

Cultivar	**Week 6**	**Week 8**	**Week 12**
MG4	3.1[b]	3.3[cb]	4.4[a]
KAT R 3	5.2[a]	6.6[a]	6.5[a]
Basilisk	3.6[ba]	3.4[cb]	4.9[a]
Piata	2.9[b]	2.9[c]	4.0[a]
Xaraes	3.9[ba]	2.3[c]	5.2[a]
Marandu	3.2[b]	2.3[c]	3.6[a]
Mulato II	4.4[ba]	2.6[c]	6.4[a]
Llanero	5.3[a]	4.4[b]	4.4[a]
Napier	**-**	3.2[cb]	-
Mean	3.9	3.4	4.9
SE	±0.2	±0.1	±0.3

Column means with similar superscripts are not significantly (p<0.05) different.

4.4.4 Digestibility and Energy content

Table 21 shows the percent *in vitro dry* matter digestibility for the cultivars at the harvest intervals during the production phase. *In vitro* dry matter digestibility (IVDMD) decreased during the harvest intervals. At week 6, similar (p>0.05) and higher (52.4-57.5%) IVDMD values were obtained for MG4, Piata, Xaraes, Marandu, Mulato II and Llanero. *Chloris gayana* cv KAT R3 (48.7%) ranked second after these 5cultivars and showed similar (p>0.05) values to Piata and Llanero. At week 8 harvest interval, Napier showed similar IVDMD values to Mulato II, Marandu, Xaraes, Piata, Basilisk, *C. gayana* cv KAT R3 and MG4. At week 12 harvest interval, all the cultivars except Marandu had similar (p>0.05) IVDMD values. Piata recorded highest IVDMD (52.3%) at week12 and Marandu lowest (28.8 %).

Table 21: Mean *In vitro dry* matter digestibilty (%) of cultivars at 3 cutting frequencies during the production phase.

Cultivar	Week 6	Week 8	Week 12
MG4	57.5[a]	54.4[ba]	43.6[a]
KAT R 3	48.7[b]	47.5[bc]	46.4[a]
Basilisk	37.2[c]	53.8[ba]	50.1[a]
Piata	53.2[ba]	54.0[ba]	52.3[a]
Xaraes	59.1[a]	54.1[ba]	45.8[a]
Marandu	57.0[a]	52.0[ba]	28.8[b]
Mulato II	57.4[a]	57.5[a]	51.4[a]
Llanero	52.5[ba]	42.7[c]	45.5[a]
Napier	**-**	52.8[ba]	-
Mean	52.8	52.1	45.1
SE	±0.7	±0.9	±1.6

Column means with similar superscripts are not significantly ($p<0.05$) different

Organic matter digestibility (OMD) for all the cultivars decreased during the harvest intervals in the production phase as shown in Table 22. At week 6 harvest interval, Basilisk showed lower OMD (37.5%) and *Chloris gayana* cv KAT R3 recorded second lowest (50.3%) but similar ($p>0.05$) values to Llanero (54.2%). Napier (54.8%) showed similar ($p>0.05$) OMD values to all the other cultivars apart from Llanero at week 8 harvest interval. At week 12 harvest interval, only Marandu differed from the other grasses ($p<0.05$) exhibiting the lowest OMD values at 46%.

Table 22: Mean OMD (%) of the cultivars at 3 cutting frequencies during production phase.

Cultivar	Week 6	Week 8	Week 12
MG4	59.2^{ba}	50.5^{ba}	46.4^{a}
KAT R 3	50.3^{c}	56.9^{a}	47.4^{a}
Basilisk	37.5^{d}	56.1^{a}	52.3^{a}
Piata	55.8^{bac}	55.4^{a}	54.6^{a}
Xaraes	61.1^{a}	56.1^{a}	48.3^{a}
Marandu	58.3^{ba}	54.3^{a}	46.0^{b}
Mulato II	57.4^{ba}	58.6^{a}	53.3^{a}
Llanero	54.2^{bc}	45.3^{b}	48.7^{a}
Napier	-	54.8^{a}	-
Mean	54.2	54.2	47.6
SE	±0.7	±0.9	±1.2

Column means with similar superscripts are not significantly (*p*<0.05) different.

Table 23 shows the results for dry organic matter digestibility (DoMD) based on samples of the cultivars during the production phase. Generally DoMD decreased for all the cultivars from week 6 to 12 harvest intervals. Initially at week6 cutting interval Xaraes had the highest (5.2g/kg DM) DoMD though the value was not significantly (p>0.05) different from values obtained for MG4 (5.0g/Kg DM), Piata (4.6g/Kg DM), Marandu (4.9g/Kg DM), Mulato II (4.9g/kg Dm), and Llanero (4.6g/Kg DM). Basilisk (3.2g/kg DM) and *C.gayana* cv KAT R3 (4.4g/kg DM) had lower DoMD even though values for *C.gayana* were similar (p>0.05) to those for MG4, Piata, Marandu, Mulato II, and Llanero. Napier recorded similar (p>0.05) values to all cultivars at week 8 harvest interval. At week12 harvest interval, Marandu recorded lowest DoMD at 2.6g/kg DM which value was similar (p>0.05) to those obtained for all the cultivars apart from Basilisk (4.4 g/kg DM), Piata (4.6 g/kg DM) and Mulato II (4.6 g/kg DM).

Table 23: Mean Dry organic matter digestibility (DoMD in g/Kg DM) for the cultivars at 3 cutting frequencies during production phase.

Cultivar	Week 6	Week 8	Week 12
MG4	5.0^{ba}	4.2^{ba}	4.0^{ba}
KAT R 3	4.4^{b}	4.8^{a}	4.1^{ba}
Basilisk	3.2^{c}	4.7^{ba}	4.4^{a}
Piata	4.6^{ba}	4.8^{a}	4.6^{a}
Xaraes	5.2^{a}	4.8^{a}	4.1^{ba}
Marandu	4.9^{ba}	4.6^{ba}	2.6^{b}
Mulato II	4.9^{ba}	4.9^{a}	4.6^{a}
Llanero	4.6^{ba}	3.9^{b}	4.1^{ba}
Napier	-	4.5^{ba}	-
Mean	4.6	4.6	4.1
SE	±0.1	±0.1	±0.2

Column means with similar superscripts are not significantly ($p<0.05$) different.

Generally metabolizable energy decreased at harvest intervals (week 6 to week12) for the cultivars as shown in Table 24 below. At week6 harvest interval, Xaraes recorded highest metabolisable energy at 7.04 MJ/Kg DM which value was similar to those of MG4(6.9 MJ/kg DM), Piata (6.6 MJ/kg DM), Marandu (7.0 MJ/kg DM) and Mulato II (7.0 MJ/kg DM) . Basilisk recorded lower values during this interval at (5.3MJ/Kg DM). At week 8 harvest interval, Napier had similar (p>0.05) ME values to all the cultivars except for Llanero. At week 12 harvest intervals, Marandu had the lowest ME value (4.6 MJ/Kg DM).All the other cultivars had similar (p>0.05) ME values ranging between 5.7-6.4MJ/Kg DM).

Table 24: Mean metabolizable energy (MJ/kg DM) of the cultivars at 3 cutting frequencies during production phase.

Cultivar	Week 6	Week 8	Week 12
MG4	6.9[ba]	6.1[bc]	5.7[a]
C. gayana	6.1[c]	6.5[ba]	5.9[a]
Basilisk	5.3[d]	6.6[ba]	6.2[a]
Piata	6.6[ba]	6.6[ba]	6.4[a]
Xaraes	7.04[a]	6.7[ba]	5.9[a]
Marandu	7.0[ba]	6.5[ba]	4.6[b]
Mulato II	7.01[ba]	7.0[a]	6.4[a]
Llanero	6.5[bc]	5.7[c]	5.9[a]
Napier	-	6.7[ba]	-
Mean	6.6	6.5	5.9
SE	±0.1	±0.1	±0.1

Column means with similar superscripts are not significantly (p<0.05) different.

CHAPTER 5

5.0 DISCUSSION

5.1 Experimental site soil characteristics

Soil sampling results indicate that the soil in the experimental site are medium acid with a pH range of 5.81- 5.90. According to Rao et al (1996), most commercial *Brachiaria* species are adapted to low fertility acid soils in the tropics and that the relative importance of different soil nutrients in growth and productivity depends on the physiological adaptation of the species. The authors further report that some of the attributes that enable them adapt include the ability to maintain root growth at the expense of shoot growth; acquire and use both nitrate and ammonium forms of nitrogen; acquire nitrogen through associative fixation; acquire phosphorus through extensive root systems and association with vessicular-arbuscular mycorrhizae; and acquire calcium through extensively branched roots with large numbers of root tips. Phosphorus content was low at 15ppm confirming Marschner's (1991), report that in acid soils, some minerals like phosphorus are deficient. According to (Sanchez and Salinas, 1981), phosphorus is the major nutrient limiting the growth and productivity of *Brachiaria* pastures in acid soils. Rao et al (1996) reports that deficiency of essential nutrients like N, P, and Ca can be alleviated by the identification of ecotypes of *Brachiaria* species that are adapted to these infertile soils and can make the most use of applied nutrients.

5.2 Germination

This study shows that *Brachiaria* species show different levels of seed germination. The differences observed among the grass cultivars may be explained by the intrinsic properties of the grass seeds such as dormancy and tegumental hardness (Opiyo et al, 2007). Treatment of seed through scarification by concentrated sulphuric acid (>95%) did not have a significant effect on seed germination. As the seeds were not freshly harvested it is agreeable that long storage of up to 6-12 months after harvesting could have contributed to breakage of dormancy for the cultivars (Cook et al, 2005). This could explain the reason acid scarification treatment had no significant ($p>0.05$) effect on seed germination relative to plain water. Seed dormancy occurs in all groups of domesticated tropical pasture grasses, but is most conspicuosly in those closely related genera of the Paniceae including *Brachiaria* whose caryopses are enclosed within a hard , tight husk (Hopkinson et al, 1996). Both husk and embryo dormancy are particularly strongly developed in *Brachiaria* and are imposed physically by the seed coverings and physiologically by embryo dormancy (Hopkinson et al, 1996). Physical dormancy is overcome in testing by removing or sometimes breaching the husk (Renard and Capelle, 1976). Acid scarification is the commonest method of breaching the husk, both in routine testing and in treatments for sowing (Mclean and Grof, 1968). Embryo dormancy presents greater difficulties but diminishes progressively with age. Basing germination on treatment figures will lead to a biased conclusion as it has been demonstrated in this study that with just water alone ranking was as follows; Marandu> MG4 >Mulato II >Xaraes> Piata> Humidicola> Llanero >Basilisk> KAT R3 whereas treatment with acid had the sequence as follows; Marandu >Mulato II> Xaraes> Piata> Humidicola> Llanero >Basilisk >MG4. Mulato II ranked 3^{rd} and 2^{nd} position respectively for both treatments. According to Vendramini et al (2011) commercial Mulato II seed has good vigour when placed in a moist firm seed bed and has been shown to germinate in 5-10 days. The results with water treatment therefore give a true reflection of the performance of the cultivars. Besides, under normal circumstances farmers will have no acid to scarify the seed. Studies by Loch et al (2004) indicate that *Chloris gayana* seed seem not to suffer seed viability difficulties and have been found to germinate in 1-7 days and that seedling development takes place rapidly which is contrary to what was found in this experiment of low germination percentage (10%) by the 14^{th} day.

All the *B. brizantha* cultivars exhibited high seedling vigour. Davidson (1966) concurs that *B. brizantha* cultivars exhibit excellent seedling vigour and CIAT(1978) reports good seedling vigour for *B.humidicola*.

5.2 Establishment Phase

5.2.1 Plant population

Plant population is a function of seed germination rate, seedling establishment and survival. *Chloris gayana* cv KAT R3 recorded high plant numbers (49plants/m^2) compared to the other cultivars at the end of establishment phase despite recording low germination percentage (12.7%). Sowing rates for all the seed was 5kg/Ha of seed. The 5kg of seed for each of the cultivars will have different proportions of seed in terms of numbers and *C.gayana* is likely to have the greatest number of seed (7 250 000 to 9 500 000 per kg of seed) (Cook et al, 2005). This explains the higher plant counts for *C.gayana* cv KAT R3 as compared to the other cultivars. Differences in plant population can also be attributed to species differences in seed germination rates, seedling establishment and survival. Seed proportion of *C.gayana* has been shown to have a significant effect on agronomic traits (Yisehak, 2008). Higher plant populations for *Brachiaria brizantha* cultivars MG4 and Marandu, can be explained by their higher germination percentages and accompanying seedling vigour. Similar studies carried out by Opiyo (2007) and Mganga (2009) showed that local species with high plant densities like *E. macrostachyus* have been shown to have higher seed viability which has been attributted to their fast seed germination and establishment. Despite low plant numbers in some cultivars, all cultivars except Humidicola which did not establish persisted for the duration of the study.

5.2.2 Plant spread.

Spread for the cultivars increased greatly toward the end of establishment phase from week 12 to 16. Spread can mainly be attributed to individual growth habits of the cultivars. *B. humidicola* is a strongly stoloniferous and rhizomatous perennial grass, forming a dense ground cover and *B. decumbens* has good ground cover, aggressive growth and decumbent habit as reported by Cook et al (2005). Napier being a fodder crop and gigantic nature would naturally outdo the other grasses when it comes to spread. Cook et al (2005) further reports that the ability of *C. gayana* to spread is because it produces stolons which creep over the ground and developing roots at the nodes and that Marandu is said to have some allelopathic effect which even reduces seedling recruitment of its own seed. This was also observed in the study.

5.2.3 Plant height.

Plant height can be attributed to the morphological and physiological differences among the cultivars. *Brachiaria humidicola* cv. Llanero's decumbent habit explains why it is the shortest at the end of the establishment phase. The vertical growth habit of Napier, MG4 and *C. gayana* cv KAT R3 explain why they are tallest at the end of the establishment phase. Opiyo (2007), Mganga (2009) and Ogillo (2010) report that, pasture species which grow fast and tall are more efficient in use of resources and therefore, are more competitive. Such species eventually shade out the other species if planted in mixed stands thereby, suppressing their growth. MG4 and Napier were taller than the other plants and also produced high dry matter yields at the end of the establishment phase. This concurs with Tessema et al's (2003) findings that increasing foliage height in Napier grass increased biomass yield. Studies carried out by Yisehak (2008) on *C. gayana* planted with sweet clover in mixed seed proportions revealed that Rhodes grass plants grown in mixtures with sweet clover were taller than those grown in a pure stand, since plants in the mixed stand produced fewer tillers and so devoted their nutrient reserve for the growth of the main culm. In this study there exists a positive correlation ($r= 0.52579$; ($p<0.05$)) between dry matter yields and plant height.

5.2.4 Plant cover

In this study, all cultivars except piata attained over 50% plant cover at the end of the establishment phase. The high plant cover for both *B. brizantha* and *B. decumbens* cultivars is because of their growth habits. *B. brizantha* is more tufted in terms of growth habit and *B.decumbens* more decumbent and these allow the species to form a denser cover (Cook et al, 2005). Mulato II on the other hand produces vigorous cylindrical stems, some with a semi-prostrate habit capable of forming roots at the nodes when they come into contact with the soil hence enhancing soil cover (Vendramini et al, 2011). Llanero has a strongly stoloniferous growth habit and this causes it to have good ground cover (Cook et al, 2005). Napier on the other hand is a tall, tufted, rhizomatous perennial, very coarse and robust, in dense clumps. Its giant nature naturally makes it occupy a larger area relative to the other grasses hence the higher plot cover (Bogdan, 1977). *Chloris gayana* is a tufted perennial that also has a stoloniferous growth habit making it have a high plot cover. It produces stolons which creep over the ground, rooting at the nodes, and also produces abundant seed to give rise to new plants (Cook et al, 2005).

5.2.5 Plant tiller numbers

Tillers increase the chance of survival and the available forage resource of grasses (Laidlaw, 2005). Nelson and Zarrough (1981) report that tiller numbers are an indicator of resource use efficiency by different grass species and that the weight of a plant's tillers will determine its productivity. Llanero, MG4, MulatoII, Piata, Basilisk and Xaraes had higher tillering ability than the rest of the cultivars. The distinct variation in tiller densities of the cultivars implies that these five cultivars would recover faster after defoliation. Marandu appears to have some form of allelopathic effect which even reduces seedling recruitment of its own seed (Cook et al, 2005) hence the comparatively lower tiller recruitment relative to the other *B. brizantha* cultivars. Tillering in Llanero can be attributed to its growth habit (Cook et al, 2005). According to Halim et al, (2013) taller varieties of Napier tend to have fewer tillers but produce higher DM yields compared with shorter varieties which recruit higher tiller numbers and have higher nutritive values. Hiernaux et al (1994) found that plant tillering early in the life of the stand compensated for low plant density that resulted from drought or intense grazing.

5.2.6 Dry matter yields.

There were differences in dry matter yields among the grasses which can be attributed to their genotypic and phenotypic differences. Napier out yielded the other grasses confirming studies by Humphreys (1994) and Skerman and Riveros (1990) of its potential for high dry matter yields relative to other tropical grasses. Marandu demonstrated highest germination percentage and seedling vigour but had lower yields compared to Napier, MG4, Mulato II, Piata, Basilisk and *C.gayana* cv KAT R3. This was contrary to findings by Rao et al (1998) of rapid establishment of Marandu and high DM production due to rapid uptake of nutrients. He however explains that in acidic soils the results may not be the same unless fertilizer is applied. Marandu also being allelopathic to the point of inhibiting seedling recruitment of its own (Cook et al, 2005) will not favour its own herbage yield hence low DM yields Mulato II was second to MG4 among the *Brachiaria* grass cultivar in dry matter yields. Dry matter yields for Mulato II can be largely attributed to its large size leaves (15-2" long) and thick stems (1-1.5" width) (Guiot and Meléndez, 2003). Herbage yield of Napier grass may be affected by the harvesting day after planting. Generally, as grass ages, herbage yield is increased due to the rapid increase in the tissues of the plant (Minson, 1990).

5.3 Production phase

5.3.1 Morphological plant characteristics

Plant population: Mean plant population increased for the cultivars during the harvest intervals. *Chloris gayana* cv KATR3 maintained highest plant population figures (61-165 plants/m^2) whereas Xaraes maintained lowest plant population figures (18-26 plants/m^2). *Chloris gayana's* natural ability to produce stolons which form roots and eventually new plants at the nodes explains the high plant population (Skerman and Riveros, 1990).

Plant spread: Llanero recorded highest plant spread (95.9-116.2cm) and KATR3 lowest at 22.1cm-36.7cm during this phase. The ability of the grasses to spread is probably due to individual physiological and genotypic characteristics.

Plant cover: All the grasses had similar ($p>0.05$) plant cover in all the harvest intervals. Mean plant cover increased (84.9-98%) for the grasses which can be attributed to accumulation of herbage mass as the plants mature. High percentage plant cover can also be attributed to superior competition by the grass species against the weeds. According to Asiegbu and Onyeonagu (2008), long cutting intervals produced better competitive ability in the desired pasture species over the weed species. This could account for the better plot cover by the desired species than the weeds.

Plant height: Napier recorded highest plant height at week 8 while *C. gayana* cv KAT R3 recorded higher height at week 6 and 12 (74.1cm, 113.2cm) and Llanero lowest (8.8-12.6cm) throughout this phase. Frequency of cutting will have an effect of plant height and also greatly influence biomass yields. Da Silva et al (2000) and Braga et al (2009) reported that long rest periods increase the possibilities for a plant community to replenish the reserves needed to restore the canopy. If, however, intervals are too long, allowing for the canopy to intercept almost all the incident light, stem elongation is triggered, changing the dynamics of forage accumulation and often resulting in ever-increasing post-graze stubble mass, especially in tropical grass species. Studies conducted by Alvaro Rincón (2011) reveal that cuts made at lower heights negatively affected the forage production of grasses tested and resulted in a decrease in ground cover, especially in the *B. brizantha* cv. Toledo.

Plant tiller number: Mean tiller numbers for the cultivars decreased as the production phase progressed. General decrease of tiller number can be attributed to progressing dry season that causes older tillers to die out. *Chloris gayana* has excellent natural ability to spread. It produces stolons which creep over the ground, rooting at the nodes. New plants arise through vegetative propagation. This explains the big increase in plant population, plant spread and plant cover for this species (Cook et al, 2005).

Dry matter yields: The dry matter content in the diet of an animal is important because its increase leads to the increase of energy. According to Meissner (2000), the deficit of energy in the animals' diet leads to low production in livestock. The grasses that have high DM content are likely to boost energy in forage for cattle. Dry matter yields increased for all the grass species during all the harvest intervals. *Chloris gayana* cv Kat R3 ranked fourth in dry matter yields at the end of the production phase. The high DM yields of the *Chloris gayana* can be attributed among other factors, to well-established root system that enabled the grass to extract growth resources from the soil (Yisehak, 2008). According to Skerman and Riveros (1990) and Skerman et al (1988), Rhodes grass stands a good deal of defoliation, but in Israel, Dovrat and Cohen (1970) showed that in irrigated and fertilized fields, dry-matter production was some 50 percent higher at 28-day cutting intervals than at 14-day intervals. The decrease in nutritive value is higher before the first cut compared to subsequent cuts, likely because of the early flowering habit of the species (Mbwile and Udén, 1997). Studies conducted by Luis et al (2001) on yield and plant morphology of Rhodes grass at six maturities revealed that cutting age affects yield and that optimal interval for cutting to get good DM yields is 30 to 40 days.

Despite recording a lower height at week12 harvest interval, Piata had the highest DM yields which can be attributed to its genetic variability (Chiari et al, 2008). Researchers have shown that in plots under cutting the Piata palisade grass produced an average of 9.5 tons per hectare of dry weight, with 57% leaves, 30% yield obtained in the dry season (Embrapa, 2008). In addition to the production and nutritional qualities, Torres et al (2008) reported that Piatã grass is indicated for use in crop-livestock integration system, due to the slower initial growth, compared with Marandu palisade grass and Xaraes palisade grass and high growth after harvest of annual crops. These characteristics make the cultivar BRS Piata palisade grass an excellent alternative for reducing large areas characterized by monocultures of Marandu palisade grass, currently existing in all states of the Midwest and Southeast regions of Brazil.

5.3.2 Chemical and nutritive composition.

Ash and minerals: Calcium (Ca) and phosphorus (P) are important minerals in the diet of animals because they are involved in the growth of bones (Miles and Manson , 2000). These minerals are rarely deficient in forages. The grasses showed a trend of increasing calcium and decreasing phosphorus content with increasing age. Calcium and phosphorus plant content showed a negative correlation at all harvest stages in the growth phase. Mean values for ash and phosphorus content decreased as the production phase progressed whereas the mean values for Calcium content increased during this time. Evaluated minerals showed the pattern of tropical grasses to reduce phosphorus and increase calcium with the increase in age of the grasses (Vazquez and Torres, 2006). These nutrients in forage vary according to many factors such as forage species and climate (Baron and Belanger, 2007). Tergas and Blue (1971) reported that the reduction in the proportion of stem with the increase of age, influences the decrease in mineral content (P, K, Mg). A late stage pregnant cow requires 11% of CP, 0.37% of Ca and 0.26% of P daily (Meissner et al, 2000). Among the grasses only *C. gayana* is able to meet the calcium content of 0.37% for late stage pregnant cows. None of the grasses attained the 0.26% P required by a late pregnancy cow and therefore there is need for supplementation with suitable mineral supplements in the animal's diet. Mtengeti (unpublished data) reported that *Brachiaria* spp have a fairly high mineral content. Studying mineral status of some pasture species at Morogoro in Tanzania, Urio et al (2006) reported high magnesium content of *B. brizantha* as compared to other pasture species studied.

Crude protein.

Higher CP content was observed at week 6 harvest interval than in week 8 and week 12 for all the grasses during the production phase. For all the grasses the levels of CP in the harvested forage exceeded the minimum of 7.5% suggested as necessary for optimum rumen function by Van Soest (1994) during the week 6 harvest interval but dropped during the week 8 and 12 harvest interval. At the third harvest interval all the grasses achieved lower CP content than this. This trend in CP content has been reported by other studies by Kidunda et al (1990); Seyoum et al (1998) and Tessema et al (2002) and is mainly attributable to dilution of the CP contents of the forage crops by the rapid accumulation of cell wall carbohydrates at the latter stages of growth (Van Soest 1994). Comparative studies were developed by Euclides et al (2009) who evaluated the nutritional values of Marandu palisade grass, Xaraes palisade grass and Piata palisade grass and showed that regardless of the experimental year, the CP were higher during the rainy season. Crude protein content declined in the dry season but levels remained above the critical level quoted by Van Soest (1994) for the satisfactory development of ruminal cellulolytic bacteria (7.0%).Vega et al (2006) stated that other factors like maturity of the grass can be the source of declining CP.

The *Brachiaria brizantha* cultivars had high (11.1-11.9%) and similar CP content with Mulato II (12.8%) at the six week harvest interval which can be partly attributed to the Nitrogen application of fertilizer at rates of 5.8 Kg N /Ha after standardization cuts were done on the plots. CP content for these cultivars ranged between 6.1 to 11.9% during the production phase. Studies carried out by Mtengeti and Lwoga (1989) reported the effects of 3 cutting intervals (20, 40, 60 days) and four rates of N application (0, 100, 200 or 400kg N/ha) on the yield and CP content of *B. brizantha* at Morogoro Tanzania. Cumulative DM yield increased with increasing N rates and less frequent cutting. Crude protein content of the herbage declined with longer cutting intervals, but increased from 6.9% to 12.9% when N was increased from 0 to 400kg/ha. Crude protein yield increased with increasing cutting interval up to the 40-day interval. It was concluded that at Morogoro, Tanzania *B. brizantha* should be harvested at about 6-week intervals to strike a balance between herbage yield and quality. Values for Napier

(7.6%) which was cut once during this phase were slightly above 7.5% as recommended by Van Soest (1994).

In all harvest intervals, Mulato II recorded high CP levels that ranged between 7-12.8% which is almost within the range reported by Vendramini et al (2010) of 10-14% crude protein in Thailand on poor soils and 12-17 % crude protein on better soils in Florida, USA.

Values for CP for Basilisk ranged between 9.8% (week 6 harvest interval) and 4.9% (week 12 harvest interval).These were lower than those found by Evitayani et al (2005) in the tropical region of Indonesia for *Brachiaria decumbens* collected in the natural grassland of Sumatra during the wet and dry seasons at CP content of 12.8 and 8.7%, respectively.

NDF, ADF and ADL: Fibre fractions are important as they describe those forage components that have low solubility in a specific solvent system and are relatively less digestible than starch (Tavirimirwa et al, 2012). The trend in ADF content due to days at cutting was similar with NDF and ADL and significantly increased ($P < 0.05$) with advance in maturity confirming the results of similar studies by Zinash Sileshi et al (1995) and Seyoum et al (1997). NDF is relevant to improvement of forage nutritional value and can be an important parameter in defining forage quality. More fibrous pasture is associated to longer ruminal retention and limits the intake rate. A high NDF that is above 72% will cause low intake of forage (Lima et al, 2002) and as NDF percentages increase, dry-matter intake generally will decrease (Schroeder, 2012).

For all grasses used in the study, the value of NDF was high during the third cut and varied between 63.3-73.8% . This can be attributed to the low development of the grasses in the dry period and to forage maturation (Pontes et al, 2007). The value of NDF for *Chloris gayana* at the third cut was above 72% during all the harvest intervals and this can cause low intake (Lima et al, 2002).

ADF is the value that refers to the cell wall portions of the forage that are made up of cellulose and lignin. These values are important because they relate to the ability of an animal to digest the forage. The digestibility of foods is related to the fiber because the indigestible portion has a proportion of ADF, and the higher the value of ADF the lower the food digestibility (Costa et al, 2005). Nussio et al (1998) reported that forage with ADF content around 40%, or more, shows low intake and digestibility. Studies conducted by Maia et al (2014) indicated that intercropping annual crops with forages is a good option for providing quality food at critical periods of drought, as from the corn harvest; there is recovery of emergence of new tillers, providing yield and forage with good digestibility. Forages grown in integrated systems with corn were still able to attain below 40% ADF at the fourth harvest. *Chloris gayana* (Kat R3) maintained higher values for ADF during all the harvest intervals.

ADL content for all the cultivars increased with harvest interval and was in conformity with other reports by Kidunda et al (1990), Tessema et al (2002) and McDonald et al (2002) that showed that ADL content increases with the advance in harvesting days of forage crops. Brown et al (1984) reported that the soil fertility could also influence grass lignin concentration. *Chloris gayana* cv KAT R3 recorded higher ADL (5.2-6.5%) content in all the harvest intervals although at week 12 cutting interval, values for ADL for all the cultivars were similar ($p>0.05$). Mean ADL values for the grasses ranged between 3.9-4.9% which is within the range reported by Sultan et al (2007) that the lignin contents of marginal land grasses at early bloom varied between 2.8% to 4.6%. At mature stage lignin contents ranged between 3.4 to 5.7%.

In Vitro Dry Matter Digestibility (IVDMD).

Decreasing values of IVDMD may possibly be explained by the advancing physiological maturity, due to the seasonality of forage production which increases the cell wall components and reduces digestibility. The age at cutting of forage crops also has an influence on *in vitro* digestibility, which is a function of the chemical constituents of forages (Coward-Lord J et al, 1974). IVDMD values of the grasses ranged between 43.6-57.5% that is lower than the range reported by De Gues (1977) that the digestibility of cultivated tropical grasses lie between 50 and 65%, and of temperate grasses between 65 and 80%. Piata, Basilisk and Mulato II had higher digestibility compared to the other grasses at harvest interval week12. Values of IVDMD in signal grass, *B. decumbens* has been found to range between 60% to 70% in immature forage, and from 50% to 60% in mature forage - higher than the average (55%) for tropical forage grasses found by Minson (1990).

The IVDMD values for the *C. gayana* give the range studied by Skerman and Riveros (1990) of 40 to 60% for sole Rhodes grass. Young Rhodes grass of 4 weeks of re growth or less was found to have a high *in vitro* Organic Matter digestibility of 70-80 % by Mbwile and Udén (1997) and Mero and Udén (1997). This decreased to 50% after 10 weeks of re growth. In Kenya and Tanzania, *in vivo* OM digestibility and intake of Rhodes grass by dairy cows or heifers decreased with increasing maturity after the first cut (Mbwile and Udén, 1997b).

Studies conducted by Fabio et al (2002) on degradability of napier grass at different growth stages revealed that there was a decrease in *in vitro* Dry Matter Digestibilty of Napier as maturity progressed. The above authors further reported that the progress in the Napier grass maturity stage affects directly the stem and leaf degradabilities. This is more accentuated for stems due to the more intense cellular wall lignification.

Basilisk recorded digestibility values ranging between 37.2% (at week6 harvest interval) to 50.1% (at week 12 harvest interval) which is almost in the range of 42.7 and 50.3%, obtained by Carvalho et al (2005). He however reports that the *Brachiaria decumbens* in his experiment was subject to the shadow of a leguminous tree.

Organic matter digestibilty: Mean organic matter digestibility for the grasses decreased ranging between 54.2-47.6 % during the harvest intervals. Organic matter digestibility values for *C. gayana* during this phase decreased from 50.3-47.4%. Similar studies carried out by Mbwile et al (1997) in Tanzania revealed that *in vivo* OM digestibility decreased from 76% at 6 weeks of regrowth to 60% at 12 weeks of regrowth in cows fed fresh Rhodes grass. Other studies carried out by Abate et al (1981) in Kenya reported that intake of Rhodes grass decreased with maturity in grazing growing Friesian and Ayshire heifers. However, after the second cut, the effect of the stage of maturity on intake and *in vivo* digestibility was less important as these parameters remained high even with mature forage (Mbwile et al., 1997).

Metabolizable energy. Mean metabolisable energy during the production phase decreased from 6.6-5.9 MJ/kg DM. The highest metabolisable energy values obtained in this experiment were for Xaraes, Marandu and Mulato II of 7.0 MJ/kg DM for the grasses. In relation to the metabolizable energy CNCT (1975) suggested that pasture and forage with values exceeding 8.37 MJ/kg DM are considered of good quality. Metabolizable energy content decreases with the age of the plant and this value is closely related to the digestibility of organic matter.

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

The grass cultivars depended solely on the short and long rains with no irrigation water added. The soil reaction was satisfactory for plant growth and the success of the grasses in establishing can be attributed to several shoot and root attributes which include ability to change the partitioning of fixed carbon to favour root growth, to acquire N through associative fixation, to acquire P through extensive root systems and mycorrhizal association, and to acquire Ca through highly branched root systems. *Brachiaria* species show superior germination percentage with *Brachiaria brizantha* cultivars MG4, Marandu , Xaraes and *B.* hybrid Mulato II achieving 50% germination. Seedling vigour exhibited by *B. brizantha* cultivars and *B. decumbens* is also superior to the rest of the cultivars. *Chloris gayana* maintained high plant population throughout the study and Napier height making them superior to the rest of the grasses in these attributes. The *Brachiaria* species performed better in plant attributes like spread (Llanero), plant cover (MG4, Xaraes, Llanero) and tiller recruitment (MG4 and Xaraes). After initial establishment the *Brachiaria* grass cultivars demonstrated higher dry matter yields with Mulato II, MG4 and Piata producing above 8000Kg DM/Ha. Piata recording highest dry matter yields of 8867Kg DM/Ha.The nutritive quality of all the grasses deteroriated with age, resulting in a decrease in Crude protein, phosphorus, dry matter digestibility and Metabolisable energy, and high NDF, ADF and ADL content. The *Brachiaria* grasses maintained superiority in ash (Mulato II, Marandu), phosphorus (Mulato II, MG4 and Marandu), Dry matter digestibilty (MG4, Mulato II), Crude protein (Mulato II and Xaraes), NDF(Mulato II), ADF(Mulato II) and ADL (MG4, Piata and Xaraes) content. There were no significant differences in ADL values at week 12 harvest interval. MG4 and Mulato II were the only grasses able to meet CP requirements for microbial rumen function throughout all the harvest stages at the production phase.

For effective germination it is recommended that freshly harvested seed should be stored for not less than 6 months. Dry matter and nutritive quality are a function of soil fertility, fertilizer application and age of regrowth. Nitrogenous and phosphate fertilizer application to the soil and good management can lead to high forage quality and high dry matter production improving the capability of the grasses to meet nutritional requirements of animals especially in the dry season. The feed quality reported in this study is only laboratory analysis, therefore studies on feeding trials by livestock on the grass cultivars will be necessary to compare their preference and marginal output (body weight/ milk yield). Additionally, feeding trials and chemical analyses need to be conducted to authenticate whether the nutritional value of the forage species mirror their laboratory analyses. Research can also be carried to identify genotypes with greater soil nutrient acquisition and forage quality.

CHAPTER 7

7.0 REFERENCES

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CHAPTER 8

8.0 APPENDIX

8.1 Analysis of variance tables for the plant morphological characteristics and nutritive content of the grass cultivars

8.1.1 Analysis of variance tables for germination

Table 25: Analysis of variance for germination percentage

Source	DF	SS	MS	F	Pr > F
Model	11	30179.51852	2743.59259	11.51	<.0001
Error	42	10012.40741	238.39065		
Corrected total	53	40191.92593			

R-Square	Coeff Var	Root MSE	percent germination Mean
0.750885	41.77128	15.43990	36.96296

Source	DF	ANOVA SS	MS	F	Pr > F
Block	2	169.59259	84.79630	0.36	0.7028
Cultivar	8	29657.25926	3707.15741	15.55	<.0001
Treatment	1	352.66667	352.66667	1.48	0.2307

8.1.2: Analysis of variance tables for week Sixteenth (establishment phase)

Table 26: Analysis of variance for Population

Source	DF	SS	MS	F	Pr > F
Model	11	5610.888889	510.080808	9.95	<.0001
Error	24	1230.111111	51.254630		
Corrected total	35	6841.000000			

R-Square	Coeff Var	Root MSE	pop Mean
0.820185	34.92309	7.159234	20.50000

Source	DF	ANOVA SS	MS	F	Pr > F
Block	3	141.888889	47.296296	0.92	0.4448
Cultivar	8	5469.000000	683.625000	13.34	<.0001

Table 27: Analysis of variance for Spread

Source	DF	SS	MS	F	Pr > F
Model	11	32847.94401	2986.17673	37.04	<.0001
Error	24	1934.69618	80.61234		
Corrected total	35	34782.64019			

R-Square	Coeff Var	Root MSE	sprd Mean
0.944378	13.64317	8.978438	65.80903

Source	DF	ANOVA SS	MS	F	Pr > F
Block	3	671.98741	223.99580	2.78	0.0630
Cultivar	8	32175.95660	4021.99457	49.89	<.0001

Table 28: Analysis of variance for plant cover

Source	DF	SS	MS	F	Pr > F
Model	11	5290.914767	480.992252	3.22	0.0080
Error	24	3585.860356	149.410848		
Corrected total	35	8876.775122			

R-Square	Coeff Var	Root MSE	cover Mean
0.596040	17.32651	12.22337	70.54722

Source	DF	ANOVA SS	MS	F	Pr > F
Block	3	1770.672544	590.224181	3.95	0.0201
Cultivar	8	3520.242222	440.030278	2.95	0.0192

Table 29: Analysis of variance for plant tiller number

Source	DF	SS	MS	F	Pr > F
Model	11	1537.993056	139.817551	2.62	0.0235
Error	24	1281.194444	53.383102		
Corrected total	35	2819.187500			

R-Square	Coeff Var	Root MSE	tiller Mean
0.545545	33.65700	7.306374	21.70833

Source	DF	ANOVA SS	MS	F	Pr > F
Block	3	407.743056	135.914352	2.55	0.0798
Cultivar	8	1130.250000	141.281250	2.65	0.0310

Table 30: Analysis of variance plant height

Source	DF	SS	MS	F	Pr > F
Model	11	29430.92840	2675.53895	37.47	<.0001
Error	24	1713.76847	71.40702		
Corrected total	35	31144.69688			

R-Square	Coeff Var	Root MSE	height Mean
0.944974	21.71607	8.450267	38.91250

Source	DF	ANOVA SS	MS	F	Pr > F
Block	3	136.22965	45.40988	0.64	0.5992
Cultivar	8	29294.69875	3661.83734	51.28	<.0001

Table 31: Analysis of variance for dry matter yields

Source	DF	SS	MS	F	Pr > F
Model	11	49756100.75	4523281.89	3.44	0.0055
Error	24	31560701.33	1315029.22		
Corrected total	35	81316802.08			

R-Square	Coeff Var	Root MSE	dm Mean
0.611880	33.82274	1146.747	3390.462

Source	DF	ANOVA SS	MS	F	Pr > F
Block	3	11888030.34	3962676.78	3.01	0.0498
Cultivar	8	37868070.41	4733508.80	3.60	0.0070

8.1.3 Analysis of variance tables for Week 12 of Production phase

Table 32: Analysis of variance for Ash

Source	DF	SS	MS	F	Pr > F
Model	9	40.29007083	4.47667454	6.88	0.0008
Error	14	9.10502500	0.65035893		
Corrected total	23	49.39509583			

R-Square	Coeff Var	Root MSE	Ash Mean
0.815669	7.891206	0.806448	10.21958

Source	DF	TYPE I SS	MS	F	Pr > F
Week	0	0.00000000	-	-	
Block	3	2.71430833	1.35715417	2.09	0.1610
Cultivar	7	37.57576250	5.36796607	8.25	0.0005

Source	DF	TYPE III SS	MS	F	Pr > F
Week	0	0.00000000	-	-	
Block	3	2.71430833	1.35715417	2.09	0.1610
Cultivar	7	37.57576250	5.36796607	8.25	0.0005

Table 33: Analysis of variance for NDF

Source	DF	SS	MS	F	Pr > F
Model	9	239.8678958	26.6519884	18.52	<.0001
Error	14	20.1472667	1.4390905		
Corrected total	23	260.0151625			

R-Square	Coeff Var	Root MSE	NDF Mean
0.922515	1.750345	1.199621	68.53625

Source	DF	TYPE I SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	21.9900000	10.9950000	7.64	0.0057
Cultivar	7	217.8778958	31.1254137	21.63	<.0001

Source	DF	TYPE III SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	21.9900000	10.9950000	7.64	0.0057
Cultivar	7	217.8778958	31.1254137	21.63	<.0001

Table 34: Analysis of variance for ADF

Source	DF	SS	MS	F	Pr > F
Model	9	360.5635542	40.0626171	12.88	<.0001
Error	14	43.5618417	3.1115601		
Corrected total	23	404.1253958			

R-Square	Coeff Var	Root MSE	ADF Mean
0.892207	4.245863	1.763961	41.54542

Source	DF	TYPE I SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	25.6237583	12.8118792	4.12	0.0392
Cultivar	7	334.9397958	47.8485423	15.38	<.0001

Source	DF	Type III SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	25.6237583	12.8118792	4.12	0.0392
Cultivar	7	334.9397958	47.8485423	15.38	<.0001

Table 35: Analysis of variance for IVDMD

Source	DF	SS	MS	F	Pr > F
Model	9	1136.572681	126.285853	2.24	0.0967
Error	12	676.423955	56.368663		
Corrected total	21	1812.996636			

R-Square Coeff Var Root MSE IVDMD Mean

0.626903 16.63718 7.507907 45.12727

Source	DF	TYPE I SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	48.570306	24.285153	0.43	0.6596
Cultivar	7	1088.002375	155.428911	2.76	0.0590

Source	DF	Type III SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	25.923411	12.961706	0.23	0.7980
Cultivar	7	1088.002375	155.428911	2.76	0.0590

Table 36: Analysis of variance for OMD

Source	DF	SS	MS	F	Pr > F
Model	9	1241.817158	137.979684	3.59	0.0161
Error	14	537.485375	38.391812		
Corrected total	23	1779.302533			

R-Square Coeff Var Root MSE DMD Mean

0.697924 13.01750 6.196113 47.59833

Source	DF	Type I SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	16.177758	8.088879	0.21	0.8125
Cultivar	7	1225.639400	175.091343	4.56	0.0077

Source	DF	Type III SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	16.177758	8.088879	0.21	0.8125
Cultivar	7	1225.639400	175.091343	4.56	0.0077

Table 37: Analysis of variance for DoMD

Source	DF	SS	MS	F	Pr > F
Model	9	8.35585772	0.92842864	1.43	0.2756
Error	12	7.77800137	0.64816678		
Corrected total	21	16.13385909			

R-Square Coeff Var Root MSE DoMD Mean

0.517908 19.87203 0.805088 4.051364

Source	DF	Type I SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	0.52362338	0.26181169	0.40	0.6764
Cultivar	7	7.83223435	1.11889062	1.73	0.1937

Source	DF	Type III SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	0.32116530	0.16058265	0.25	0.7845
Cultivar	7	7.83223435	1.11889062	1.73	0.1937

Table 38: Analysis of variance for metabolisable energy

Source	DF	SS	MS	F	Pr > F
Model	9	6.48954754	0.72106084	2.21	0.1009
Error	12	3.92228523	0.32685710		
Corrected total	21	10.41183277			

R-Square Coeff Var Root MSE ME Mean

0.623286 9.760076 0.571714 5.857682

Source	DF	TYPE I SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	0.27275420	0.13637710	0.42	0.6681
Cultivar	7	6.21679334	0.88811333	2.72	0.0616

Source	DF	Type III SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	0.13416277	0.06708138	0.21	0.8173
Cultivar	7	6.21679334	0.88811333	2.72	0.0616

Table 39: Analysis of variance for ADL

Source	DF	SS	MS	F	Pr > F
Model	9	35.75737862	3.97304207	1.91	1.399
Error	3	27.03430833	2.07956218		
Corrected total	22	62.79168696			

R-Square	Coeff Var	Root MSE	ADL Mean
0.569460	29.65363	1.442069	4.863043

Source	DF	TYPE I SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	15.65556553	7.82778276	3.76	0.0513
Cultivar	7	20.10181310	2.87168759	1.38	0.2918

Source	DF	Type III SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	14.22647500	7.11323750	3.42	0.0640
Cultivar	7	20.10181310	2.87168759	1.38	0.2918

Table 40 Analysis of variance for CP

Source	DF	SS	MS	F	Pr > F
Model	9	30.53323400	3.39258156	4.76	0.0048
Error	14	9.97921894	0.71280135		
Corrected total	23	40.51245295			

R-Square	Coeff Var	Root MSE	CP Mean
0.753675	13.43730	0.844276	6.283076

Source	DF	Anova SS	MS	F	Pr > F
Week	0	0.00000000	-	-	-
Block	2	2.45096719	1.22548359	1.72	0.2149
Cultivar	7	28.08226681	4.01175240	5.63	0.0030